CONNECTICUT SITING COUNCIL APPLICATION

FOR THE

Greater Hartford–Central Connecticut Reliability Project

BY

THE CONNECTICUT LIGHT AND POWER COMPANY

DOING BUSINESS AS EVERSOURCE ENERGY

VOLUME 2:
SUPPORTING ENVIRONMENTAL, CULTURAL, ELECTRIC AND MAGNETIC FIELD, AND PLANNING STUDIES

JUNE 2017

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VOLUME 2:
SUPPORTING ENVIRONMENTAL, CULTURAL, ELECTRIC AND MAGNETIC FIELD, AND PLANNING STUDIES

Exhibit 2.A Natural Resources Supporting Information

Wetlands and Watercourses Report (AECOM, May 2017). Including the appendix:

Vernal Pool Assessment Report (AECOM, May 2017)

Exhibit 2.B Cultural Resources Supporting Information

2.B.1 *Phase IB Cultural Resources Reconnaissance Survey of the Greater Hartford Central Connecticut Reliability Project Corridor in Newington, Connecticut* (Heritage Consultants, LLC, April 2017). Including the appendix:

Cultural Resources Review Report Addendum (Heritage Consultants, LLC, November 4, 2016)

2.B.2 *Cultural Resources Review of the Project Region Associated with the Greater Hartford Connecticut Reliability Project* (Heritage Consultants, LLC, May 19, 2015)

Exhibit 2.C Electric and Magnetic Field Supporting Information

2.C.1 *Electric and Magnetic Fields Best Management Practices for the Construction of Electric Transmission Lines in Connecticut* (Connecticut Siting Council, February 20, 2014)

2.C.2 *Research on Extremely Low Frequency Electric and Magnetic Fields and Health* (Exponent, August 1, 2012 – August 31, 2016)

2.C.3 *Tabulated Calculations of Electric and Magnetic Fields*

Exhibit 2.D Planning Documentation

2.D.1 *Analysis of the Feasibility and Practicality of Non-Transmission Alternatives (NTAs) to the Greater Hartford/Central Connecticut Reliability Project (GHCCRP)* (London Economics International LLC, August 31, 2015)

2.D.2 *Transmission Planning Technical Guide* (ISO-NE, December 2014)

2.D.3 *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment* (ISO-NE, May 2014), Redacted to secure Confidential Energy Infrastructure Information (CEII)

2.D.4 *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Solutions Study* (ISO-NE, February 2015), Redacted to secure Confidential Energy Infrastructure Information (CEII)

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Exhibit 2.A Natural Resources Supporting Information

Wetlands and Watercourses Report (AECOM, May 2017). Including the appendix:

Vernal Pool Assessment Report (AECOM, May 2017)

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Greater Hartford-Central Connecticut Reliability Project

WETLANDS AND WATERCOURSES REPORT

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May 2017

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1.0 Introduction

The Connecticut Light and Power Company doing business as Eversource Energy (Eversource or the Company), is proposing an electric transmission system reliability project in the Greater Hartford - Central Connecticut area. Eversource proposes to construct and operate a new 115-kilovolt (kV) transmission line, to perform associated upgrades to two existing Eversource substations (Newington and Southwest Hartford), and to modify a 0.01-mile section of an existing overhead 115-kV transmission line that connects to Newington Substation (upgrades referred to as the Newington Tap or the Newington Tap Modifications).

The new 115-kV electric transmission line would extend for approximately 3.7 miles between Eversource's existing Newington Substation in the Town of Newington, through the Town of West Hartford, to Eversource's existing Southwest Hartford Substation in the City of Hartford (see Project Locus Figure 1-1). The proposed 3.7-mile transmission line would link the two substations, which are presently not electrically connected (see Figure 1-2). To connect the new 115-kV line to the transmission grid, Eversource proposes to expand and make related improvements to both substations.

These proposed electric transmission system improvements, referred to as the Greater Hartford – Central Connecticut Reliability Project (GHCCRP or Project) are required to bring the electric supply system in the Greater Hartford Sub-area into compliance with applicable national and regional electric reliability standards and criteria, and to fulfill a need to improve the capability of the transmission system to move power across Connecticut from east-to-west when the system is under stress.

To identify a preferred route and configuration for the new 115-kV line, Eversource conducted studies of various alternatives within a defined Project Study Area (refer to Figure 1-1). As a result of these analyses, Eversource identified a preferred route (i.e., the Proposed Route) that would follow various existing linear rights-of-way (ROWs), including an Eversource distribution line ROW, local and state road ROWs, and an Amtrak railroad ROW (refer to Figure 1-2).

Along this Proposed Route, Eversource plans a hybrid configuration for the new 115-kV line, consisting of approximately 1.3 miles of underground cross-linked polyethylene (XLPE) cable and approximately 2.4 miles of overhead transmission line. The overhead line segment would be located within Amtrak's ROW (which is occupied by two Amtrak rail lines as well as the Connecticut Department of Transportation's CT*fastrak* busway), whereas the underground segments would be aligned primarily within Eversource's ROW and would cross public road ROWs and private parking lots.

As noted above, Eversource also examined potential alternative routes and variations to the Proposed Route. These alternate route alignments are discussed in the following documents:

- The Connecticut Siting Council (CSC) *Application* Volume 1 materials accompanying this Wetlands and Watercourses report includes additional detail on the route variations and alternatives to the current Proposed Route (underground and overhead alignment);
- The Municipal Consultation Filing, which was submitted in December 2015 to the municipalities of Newington, West Hartford, and Hartford, Connecticut included detail on an earlier Proposed Route, as well as alternatives and variations to this route. The previous Proposed Route was configured in an all-underground fashion and extended primarily through paved public road ROWs in these municipalities. As determined during the siting and municipal consultation process, the all underground route is no longer preferred because

the current Proposed Route (with hybrid underground/overhead configuration) offers significant cost savings. The current Proposed Route would result in minimal environmental and social impacts.

As part of the route selection process, Eversource commissioned AECOM to perform water resource investigations. Wetlands and watercourses along potential routes in the Project area were identified during desktop investigations and were further investigated, where access was available, during field reviews. In-field investigations were completed for wetland and water resources that were accessible from public roads and those located on Eversource lands and on select public parcels. This report provides a summary of wetland and watercourse inventories conducted for the Project.

Wetland and watercourse delineations were conducted by AECOM to identify both federal and Connecticut jurisdictional water resources. Desktop analyses (e.g., using Connecticut Environmental Conditions Online viewers[1], CT DEEP and other online Geographic Information Systems data), as well as on-site field delineations[2] were employed to determine wetland and watercourse boundaries in accordance with applicable regulations.

Water resources along the Proposed Route and at Eversource's Newington and Southwest Hartford substations were identified and delineated by AECOM during field investigations conducted in May 2015, January 2016, and August 2016[3]. Vernal pool investigations were conducted in March, April and May 2017; however, no vernal pools were confirmed in the survey area along the Proposed Route[4].

A discussion of applicable federal and state wetland protection regulations is presented in Section 2. A description of wetland and watercourse delineation methodologies is presented in Section 3. Survey results, including tables of the field-identified wetlands and watercourses, are located in Section 4. The delineated wetlands in the Project vicinity are illustrated on the aerial-photography based maps included in Volume 3 of the accompanying CSC *Application*.

Project wetland data forms are provided in Appendix A to this report and a photo log is included in Appendix B. Appendix C includes the resumes of key AECOM personnel involved with delineation and vernal pool assessment activities. Methodologies and results relative to vernal pool surveys are discussed separately in the attached *Vernal Pool Assessment* report, which is included in Appendix D.

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1 http://www.cteco.uconn.edu/

2 Specific field investigations of the Proposed Route within the Amtrak ROW have not yet been performed because Eversource is currently in the process of finalizing a license agreement with Amtrak. However, the Amtrak ROW segment along which the Proposed Route would be aligned is located in a highly urbanized area and, as such, was observed from adjacent roads and other publicly-accessible areas. Publically available GIS resources and desktop resources (i.e. Google Earth) were used to review the nature of this area. These observations indicate that the Amtrak ROW encompasses primarily upland areas that have been highly disturbed by historical development. Field investigations of the Amtrak ROW segment of the Proposed Route will be performed after Eversource obtains a license agreement from Amtrak.

3 The 2015 surveys focused on Eversource's substation properties and the all-underground transmission line route that was initially considered for the new 115-kV line. Subsequent surveys focused on the current Proposed Route and its variations as depicted in Figure 3-1.

4 AECOM biologists conducted vernal pool investigations along the Proposed Route (including the substation parcels and the underground route segment) in spring 2017. The investigation areas included depressions that were previously identified as potential vernal pool locations. A vernal pool assessment report is presented in Appendix D.

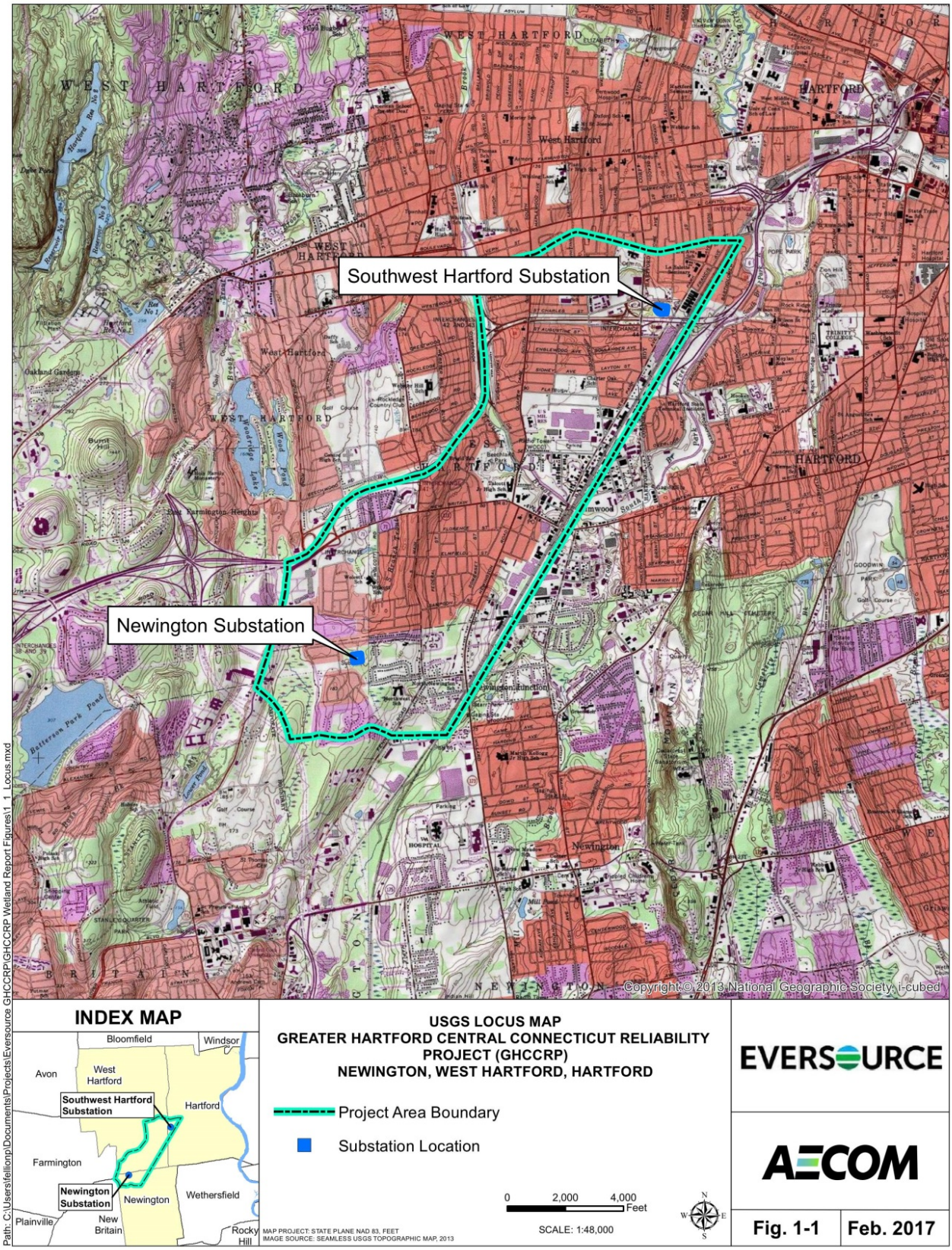


Figure 1-1: USGS Locus Map

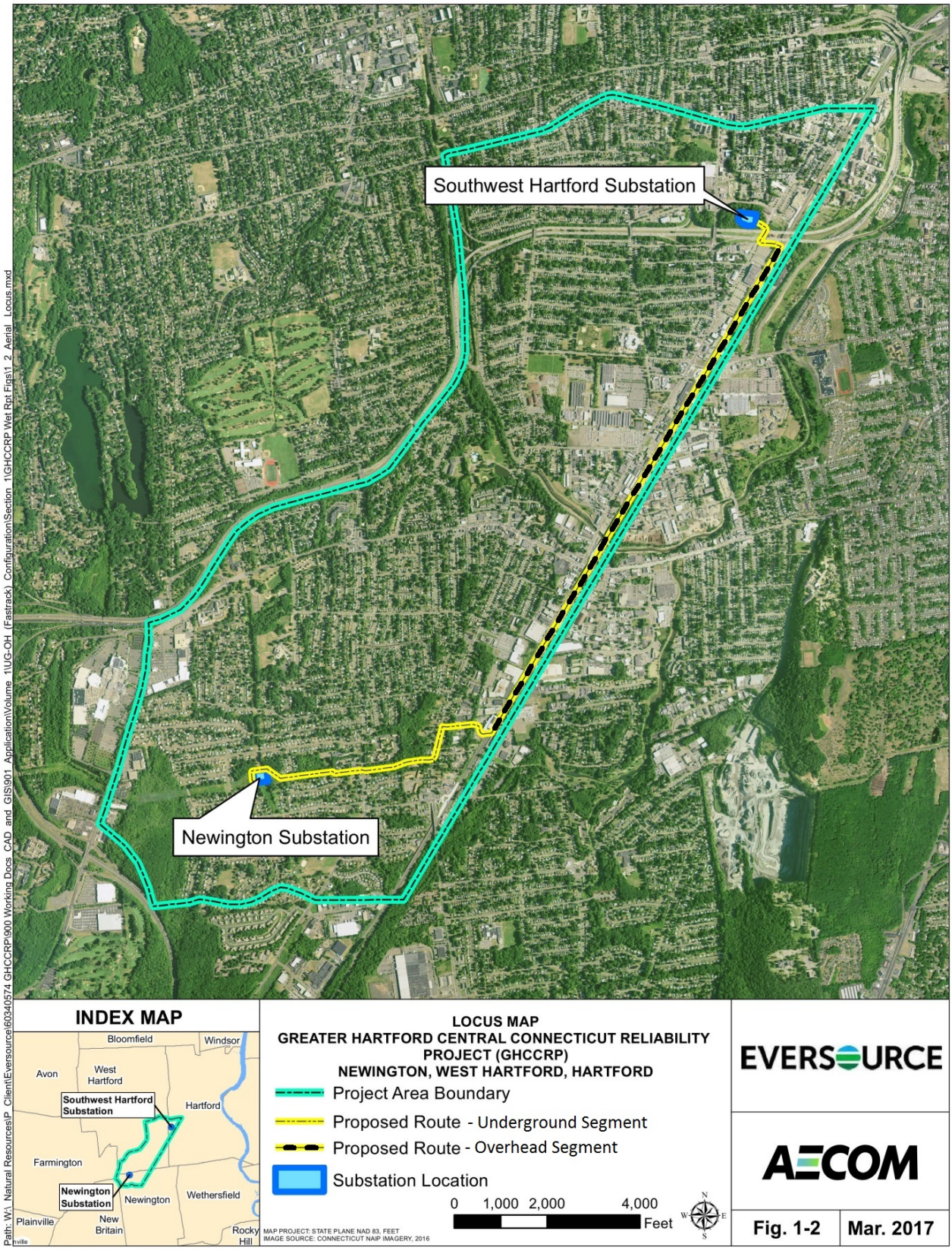


Figure 1-2: Aerial Locus Map and Proposed Route

1.1 Proposed Project Activities

The Proposed Project would involve construction activities on Eversource properties at the Newington and Southwest Hartford substations, as well as along Eversource ROWs, select pubic road ROWs, and along the Amtrak ROW, as shown on Figure 1-2. Additional detail and depiction of the Proposed Route is included in the accompanying CSC *Application* Volume 1 and Volume 3 materials. The Proposed Project activities include:

- **Newington Substation Improvements (185 Cherry Hill Road, Newington):** This substation occupies approximately 1.5 acres of an existing Eversource parcel. Proposed improvements include a 0.3-acre expansion of the substation limits to the south and west of the existing fence lines and installation of a new retaining wall. Equipment installation and upgrades are proposed within the substation fence. Overhead transmission line improvements are also proposed at this parcel, as outlined below.

- **Newington Tap Modifications:** Adjacent to Newington Substation, Eversource proposes to modify a 0.01-mile segment of an existing 115-kV overhead line (the 1783 Line) that connects to the substation. The 1783 Line connects to the Newington Substation via an overhead transmission line, referred to as the Newington Tap. The Newington Tap line will be removed, relocated, and rebuilt with larger conductors. Existing overhead transmission structures will be removed and/or replaced with new structures to support this work.

- **115-kV Transmission Line Installation**. The proposed 3.7-mile 115-kV transmission line would extend along existing ROWs or within developed areas, as follows:

  - **Existing Eversource Distribution ROW and Road ROWs in Newington:** Between Newington Substation and the Amtrak ROW, Eversource proposes to construct approximately 1.1 miles of new underground transmission line, including approximately 0.8 mile of underground cable within Eversource's substation property and along the existing ROW. The remainder of this underground cable segment would be aligned along existing roadways and parking lots.

  - **Overhead 115 kV Transmission Line Installation – Amtrak ROW in Newington, West Hartford, and Hartford:** Eversource would install approximately 2.4 miles of the new 115-kV line in an overhead configuration; transmission line structures would be located within the Amtrak ROW, east of the eastern-most rail line and within the railroad bed material. Along the Amtrak ROW, approximately 0.2 mile of the overhead segment would be in the Town of Newington, approximately 1.6 miles would be in the Town of West Hartford, and approximately 0.6 mile would be in the City of Hartford.

  - **Parking Lot and Road ROW in Hartford:** Approximately 0.2 mile of new underground transmission cable would be constructed between the Amtrak ROW and Southwest Hartford Substation. This short underground cable segment would be situated within a private parking lot and along New Park Avenue.

- **Southwest Hartford Substation (271 New Park Avenue, Hartford):** This substation occupies approximately 2.0 acres of an Eversource parcel. Proposed improvements include a 0.3-acre expansion of the substation limits to the east of the existing fence line and equipment installation and improvements within the substation fence.

1.2 Project Area Geographic Overview

The Proposed Route and the Project area are depicted on Figures 1-1 and 1-2. As these figures illustrate, the Project area is densely developed and is characterized by a variety of residential, commercial, and industrial uses, as well as a defined network of major highways (Interstate 84), local and state roads, utility ROWs, and public transportation corridors (i.e., the Amtrak ROW and CT*fastrak*). As a result, wetlands and watercourses are found in only limited and well-defined locations. In addition, and as noted in Figure 3-1, the Proposed Route is located beyond the extents of any state and federal listed species and significant natural communities, per the current Connecticut Department of Energy and Environmental Protection (CT DEEP) Natural Diversity Data Base (NDDB) Areas mapping[5].

Wetlands and watercourses were assessed along the Proposed Route, as well as along route variations and alternatives in the Project area. As noted above, wetlands and watercourses located along the all-underground route (which is no longer being advanced as the proposed route), were also previously investigated in detail.

In addition, wetland investigations were completed at the two Project substation parcels (Newington Substation and Southwest Hartford Substation), including field investigations in the vicinity of the proposed Newington Tap modifications (i.e., ROWs located immediately west and south of the Newington Substation).

1.3 Physiographic and Geologic Overview

The Project area is situated within the Central Valley physiographic region of Connecticut[6]. This region is characterized by variably hilly terrain with local areas of considerable topographic relief and rugged hills. The area contains relatively younger bedrock (Triassic/Jurassic age), sedimentary brownstone, and shale with intrusive, erosion-resistant igneous basalts making up the Metacomet Ridge. Glaciers and associated outwash meltwaters have resulted in a flattened Connecticut River Valley. Bedrock is comprised of brownstone, a sedimentary rock that erodes easily; therefore, the Connecticut River Valley's Central Valley is almost totally free of boulders. The predominant surficial deposits along the Proposed Route are comprised of fine glacial meltwater deposits with flat to moderate topography. Bedrock depths generally exceed 30 feet beneath the sand, gravel, and fines deposits, and are often more than 100 feet below the ground surface. Floodplain deposits are post-glacial deposits comprised of alluviums of fine outwash associated with Trout Brook. Bedrock is generally deep (greater than 30 feet) beneath these alluvial floodplain deposits.

[5] CT DEEP West Hartford Endangered Species Map. http://www.depdata.ct.gov/naturalresources/endangeredspecies/nddbpdfs.asp?nddbsel=155. Accessed May 1, 2017.

[6] Connecticut Geologic Survey Department of Energy and Environmental Protection. 1990, revised 2013.

2.0 Wetland and Watercourses Regulations

AECOM soil and wetland scientists identified wetlands and watercourses in the Project area subject to state and federal jurisdiction based upon the Connecticut Inland Wetlands and Watercourses Act (C.G.S. Section 22a-36 through 45) and the Federal Clean Water Act (33 U.S.C. 1344). The Project does not cross any *Navigable Waters of the United States* subject to Section 10 of the Rivers and Harbors Act (33 U.S.C. 403).

During the process of delineating wetlands along potential transmission line routes and on Eversource's substation properties, both state and federal methodologies were employed. In Connecticut, state and federal boundaries can differ due to the different delineation methodologies. Frequently, areas of alluvial and floodplain soils that qualify as wetlands in Connecticut may not exhibit a wetland plant community and evidence of wetland hydrology, as required by the federal U.S. Army Corps of Engineers (USACE) methodology. As a result, some locations on the Connecticut landscape do require distinct state and federal wetland boundaries. However, all of the wetlands identified along the Proposed Route met both state and federal criteria.

2.1 Clean Water Act – Section 404

Wetlands, springs, and other waters of the United States are regulated under Section 404 of the Federal Clean Water Act (CWA) by the USACE. Federal jurisdictional wetlands include interstate wetlands, wetlands adjacent (i.e., bordering, contiguous, or neighboring) to waters of the United States, and intrastate wetlands whose degradation or destruction could affect interstate or foreign commerce as per the application of the CWA. According to the 1987 *Corps of Engineers Wetland Delineation Manual (USACE Manual)*[7], areas must exhibit three distinct characteristics to be considered wetlands:

- Hydrophytic Vegetation: Plants growing in water or in a substrate that is at least periodically deficient in oxygen during a growing season as a result of excessive water content;
- Hydric Soils: Soils that, in an undrained condition, are saturated, flooded, or ponded long enough during a growing season to develop an anaerobic condition that supports the growth and regeneration of hydrophytic vegetation; and
- Wetland Hydrology: Inundation or saturation by surface or groundwater at a frequency and duration during the growing season sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions.

Wetlands satisfying these three criteria are subject to federal jurisdiction under Section 404 of the CWA.

In January 2012, the USACE issued a Regional Supplement to the Corps of Engineers Delineation Manual[8] (Regional Supplement), which provides further guidance for wetland delineations in the

[7] Environmental Laboratory. 1987. Corps of Engineers Wetlands Delineation Manual. Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

[8] 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

northeastern United States. The Regional Supplement provides wetland indicators, delineation guidance, and other information specific to the Northcentral and Northeast Regions, supplementing the 1987 USACE Manual. Indicators and procedures in the Regional Supplement are designed to identify wetlands as defined jointly by the USACE (33 CFR 328.2) and the U.S. Environmental Protection Agency (40 CFR 230.3) and subject to regulation under Section 404 of the CWA.

2.2 Connecticut Inland Wetlands and Watercourses Act

Connecticut regulates work in and around inland wetlands under the Inland Wetlands and Watercourses Act (the Act). Typically, the state statutes are implemented through the Inland Wetlands and Watercourse Regulations as administered by individual municipalities.

Under Section 2 of the Act, a wetland is defined as "land, including submerged land…which consists of poorly drained, very poorly drained, alluvial and floodplain soils as defined by the National Cooperative Soils Survey. Such areas may include filled, graded or excavated sites which possess an aquic (saturated) moisture regime as defined by the United States Department of Agriculture (USDA) Cooperative Soil Survey." As written, the statute assigns no bearing to vegetation when performing wetland delineations. According to the CT DEEP website, approximately 17 percent of the state's land area is comprised of wetlands under the Connecticut wetland definition; however, "under the federal definition only roughly half of this same area would be classified as wetlands".

Watercourses are defined in the Act as "rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs and all other bodies of water, natural or artificial, vernal or intermittent, public or private, which are contained within, flow through or border upon the state or any portion thereof." The Act defines Intermittent watercourses as having a defined permanent channel bed and bank and the occurrence of two of the following: a) evidence of scour or deposits of recent alluvium or detritus, b) the presence of standing or flowing water for a duration of longer than a particular storm incident, or c) the presence of hydrophytic vegetation.

3.0 Wetland Delineation Procedures

During May 2015, January 2016 and August 2016 investigations of the Project area, AECOM soil and wetland scientists delineated wetlands and watercourses along the Proposed Route and along route alternatives and variations. Pre-survey desktop investigations and on-site field investigations were used to identify and confirm wetland and watercourse resource areas along Proposed Route and along other Project route alternatives[9]. In addition, AECOM biologists performed vernal pool investigations along the Proposed Route in March, April, and May 2017. Additional detail regarding the vernal pool survey methodologies, survey personnel and field results are presented in Appendix D.

3.1 Pre-Survey Desktop Investigations

Prior to the commencement of field surveys, AECOM reviewed information from multiple sources to determine the potential extent of state and federal wetlands in the Project area. Information reviewed during the pre-survey desktop investigations included:

- United States Geological Survey (USGS) topographical quadrangles;
- USGS National Hydrography Dataset (NHD);
- National Wetlands Inventory (NWI) maps;
- Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM);
- U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) web soil surveys; and,
- CT DEEP online wetland mapping services and Natural Diversity Data Base (NDDB) information.

A map showing CT DEEP Inland Wetlands and FEMA floodplain information along the Proposed Route and in the Project area in general is provided in Figure 3-1.

3.2 Field Surveys

AECOM soil and wetland scientists Kyle Purdy, Molly Notestine, Scott Egan, Kris van Naerssen and Tim O'Sullivan delineated or reviewed wetlands within the Project area, in accordance with USACE New England District guidance including the 1987 USACE Manual and its Regional Supplement, the *Field Indicators for Identifying Hydric Soils in New England, Version 3*[10] as well as the State of Connecticut Inland Wetlands and Watercourses Act. Copies of AECOM soil and wetland scientist résumés are found in Appendix C. Vegetation, soils, and hydrology data were assessed during the field surveys to determine if state and federal wetland criteria described in Section 2.0 were satisfied for each potential wetland area.

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[9] This report includes information pertaining to wetlands and watercourses identified along the current Proposed Route and its variations. Investigations conducted for the previously-proposed all-underground alignment (and its variations) resulted in identification of additional features and potential crossings, as described in Section 4.0. The all-underground route's wetland and watercourse investigations were completed from publicly accessible areas and were based on initial route designs. The original all-underground route, although no longer being advanced as the Proposed Route, is described In Volume 1, Section 11.6. The wetland data form for Trout Brook (the primary wetland crossing on the all-underground route) is included herein.

[10] 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.

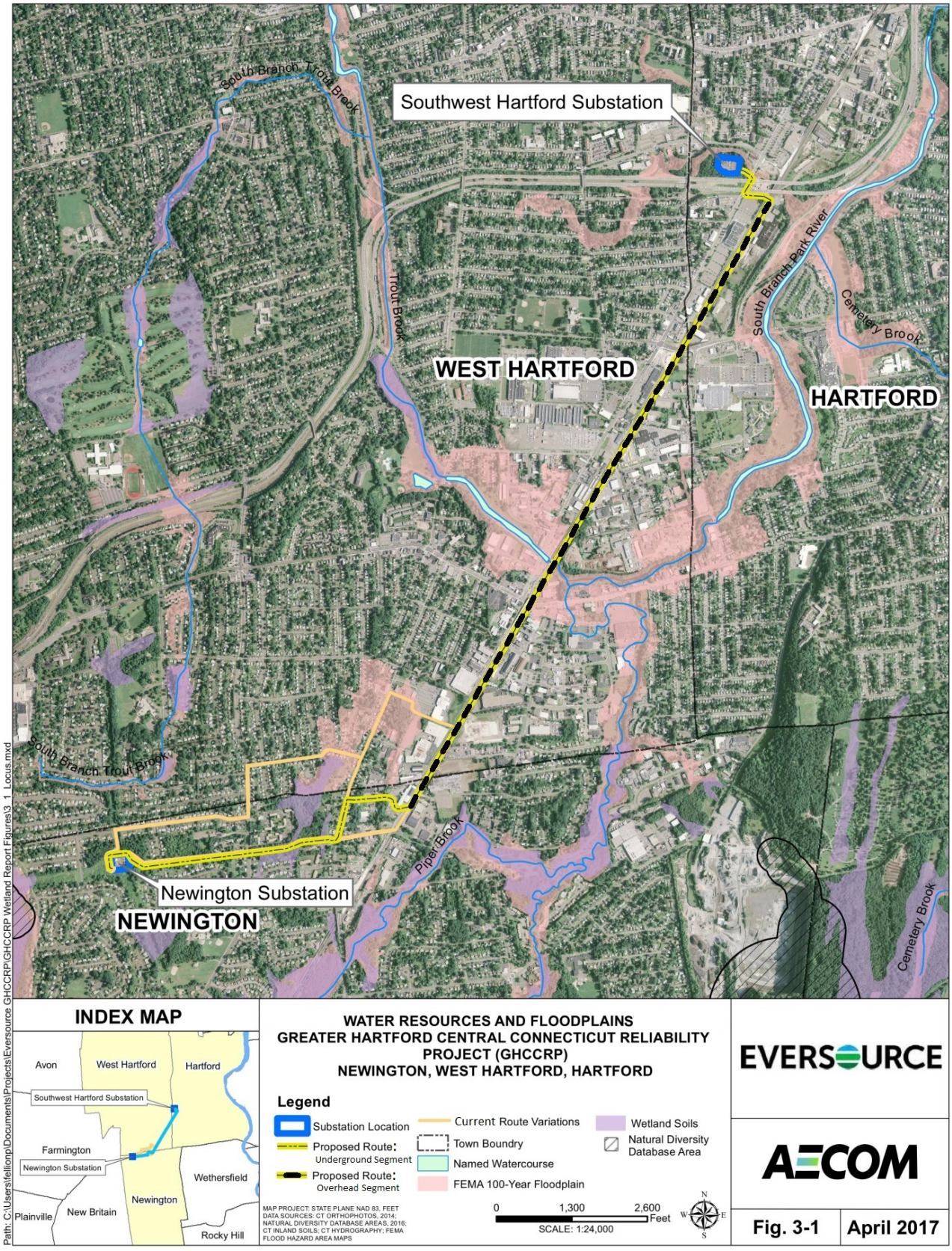


Figure 3-1: Wetlands, Watercourses and Floodplain Map – Proposed Route and Current Route Variations

During the field investigations, the boundary between the wetland and/or watercourse and the upland area was identified, and the boundary was delineated with survey flagging. The results of the field delineations are presented on the Project maps included in Volume 3 of the CSC *Application*.

Field data summary sheets were completed to provide documentation and confirmation of boundaries at specific locations for each delineated wetland or watercourse (see Appendix A). Each wetland and watercourse was given a unique Project-specific alphanumeric designation, which was used to identify the wetlands and watercourses on associated Project mapping. Appendix B includes representative photographs of the water resources taken during the delineations.

The specific methods for characterizing and evaluating vegetation, hydrology, and soils used in the determination for the presence or absence of a wetland are described below.

3.2.1 Soils

At the center of each data plot, the soil and wetland scientists completed borings with a hand-held auger to determine a soil's hydric status (typically 18 to 24 inches below ground surface). The information collected for each soil profile included soil horizons, depth, texture, color, and the presence or absence of redoximorphic features (mottles and other features). Colors of the soil matrix and mottles were identified using Munsell Soil Color Charts. Hydric soil determinations were based on criteria established in the 1987 USACE Manual, the Regional Supplement, and the *Field Indicators for Identifying Hydric Soils in New England-Version 3*. Additionally, the presence of any saturation and/or standing water encountered during the soil profile was noted.

Multiple soil types, representing a variety of soil series designations, were identified during the wetland and watercourse inventory. Information regarding the soils along the Proposed Route was obtained from on-line county soil surveys and maps published by the USDA NRCS[11]. These surveys and maps provide soil classifications and characteristics, including depth to bedrock, slope, drainage, and erosion potential. Field investigations of soils were required to confirm Connecticut Inland Wetlands, which are defined based on the presence of poorly drained, very poorly drained, or floodplain soils.

3.2.2 Vegetation

Absolute percent cover of dominant species was visually estimated in both upland and wetland communities. Trees and woody vines were recorded within a 30-foot radius from the center of each documentation plot. Shrubs and saplings were recorded within a 15-foot radius of the center of the plot and herbaceous vegetation was recorded within a 5-foot radius of the plot. The indicator status of each species was identified using the *National List of Plant Species That Occur in Wetlands, Region 1 – Northeast*[12]. Hydrophytic vegetation was determined to be prevalent when greater than 50 percent of the dominant species were classified as having a wetland indicator status of facultative (FAC), facultative wetland (FACW) or obligate wetland (OBL).

[11] Web Soil Survey, http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm accessed 2015.

[12] National Wetland Plant List. July 2013. U.S. Army Engineer Research and Development Center, Vicksburg, MS

3.2.3 Hydrology

Hydrology was evaluated during field surveys by initially observing whether the soil at the surface was inundated or saturated. If the ground surface was dry, the depth to freestanding groundwater or saturated soil was measured, and the presence or absence of other indicators of wetland hydrology (e.g., drift lines, water-stained leaves, etc.) was noted. The wetland hydrology criterion was met if one or more primary or two or more secondary field indicators were present.

3.2.4 GPS Mapping

Wetland and watercourse flag positions and data point locations were field located by AECOM personnel using a Trimble global positioning system (GPS) data collection device capable of sub-meter accuracy. The collected GPS data points were then corrected, geo-referenced, and plotted on aerial photograph imagery.

3.3 Wetland and Watercourse Classification

While in the field, AECOM soil and wetland scientists classified the various wetlands and watercourses according to the "Cowardin system", which is a process discussed in *Classification of Wetlands and Deepwater Habitats of the United States*[13]. Identified wetlands were classified as Palustrine Forested (PFO), Palustrine Scrub-Shrub (PSS), or Palustrine Emergent (PEM), all of which are further described below. In some cases, a wetland complex contained more than one wetland classification type. In those situations, each wetland type is listed and the first classification type represents the more dominant characteristic.

3.3.1 Palustrine Forested Wetlands (PFO)

Palustrine forested wetlands or PFO are characterized by woody vegetation that is six meters (approximately 20 feet) tall or taller. These areas normally contain an overstory of trees, an understory of young trees and/or shrubs, and an herbaceous layer. In the Project area, these wetland types are located predominantly in unmanaged or non-cleared areas of the existing Eversource ROW or in adjacent off-ROW areas.

3.3.2 Palustrine Scrub-Shrub Wetlands (PSS)

Palustrine scrub-shrub wetlands or PSS are typically dominated by woody vegetation less than six meters (approximately 20 feet) tall. Areas classified as scrub-shrub cover types may represent a successional stage that through natural processes would transition to a forested wetland; or may contain trees or shrubs that are small and/or stunted due to environmental conditions.

3.3.3 Palustrine Emergent Wetlands (PEM)

Palustrine emergent wetlands or PEM are characterized by erect, rooted, herbaceous hydrophytes not including mosses and lichens. These wetlands maintain the same appearance year after year and are typically dominated by perennial plants that are present for the majority of the growing season.

[13] Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. Washington, D.C.

3.3.4 Watercourses

According to the Act, “Rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs and all other bodies of water, natural or artificial, vernal or intermittent, public or private, which are contained within, flow through or border upon the state or any portion thereof” are considered watercourses. The “top of bank” was used to demarcate the limits of a watercourse when no wetlands were adjacent to the channel. Watercourses were investigated to determine if they are listed as a National Wild and Scenic River under the National Wild and Scenic Rivers Act (16 U.S.C. §§ 1271-1287) or rivers designated by the CT DEEP Protected Rivers Act (C.G.S. §§ 25-200 through 25-210). Water quality designations were determined using CT DEEP mapping resources.

3.4 Post-Survey Desktop Analysis

The wetland and watercourse boundaries were plotted on aerial imagery and subsequently reviewed and confirmed by AECOM field personnel. The aerial-based maps (refer to Volume 3 of the *Application*) show the locations of the delineated resources relative to the proposed limits of the Project. The results of the desk-top and field efforts are described in Section 4.0.

4.0 Results

A total of seven wetlands and five watercourses were identified adjacent to the Newington and Southwest Hartford substations and along the Proposed Route; these water resources are listed in Table 4-1 and described in greater detail below.

Table 4-1: Wetlands and Watercourses along the Proposed Route[14].

Municipality	Number of Wetlands[15]	Number of Watercourses[16]	100-Scale Map Sheet Number*
Newington	6**	3	1, 2, 3 & 4
West Hartford	0	1	7
Hartford	1	1	12 & 12A
Total Features	7	5	-

* Volume 3 of the CSC *Application*
** Tallies Wetlands N-1 and N-1A separately. Wetlands identified in Newington include N-1, N-1A, N-2, N-3, N-4 and N-5.

4.1 Wetlands

Seven wetlands were identified and delineated along the Project ROWs (Proposed Route, Newington Tap) and on Eversource substation properties (refer to Table 4-2 and to the Volume 3 maps). As the Project area is heavily developed, the wetlands are primarily located in the undeveloped vegetated areas found adjacent to the Newington Substation and along the Eversource ROW in Newington.

Specifically, two of the wetlands are associated with the Newington Substation (Wetlands N-1 and N-1A) and three are found along the Eversource ROW in Newington (Wetlands N-2, N-3 and N-4; all found along the ROW between Avery Road and State Route 173).

[14] As access agreements along the overhead portion of the Proposed Route that would be collocated in the Amtrak ROW are being finalized, this report excludes field-confirmed boundaries of wetlands and watercourses located along the Amtrak/*CTfastrak* corridor. A comprehensive in-field construction review of proposed Project features and natural resources will be completed along the overhead segment, once access is secured. Eversource has completed desktop reviews and in-field investigations along this segment from publicly accessible areas. The report will be updated accordingly once access has been secured and field surveys are conducted. Based upon initial desktop reviews along the overhead segment, and given the extensive urban development within and adjacent to the Amtrak corridor, wetland and watercourse resource areas (beyond Trout Brook) are not anticipated along the overhead alignment. The proposed transmission line would span Trout Brook in an overhead configuration.

[15] In addition to the wetlands identified along the Proposed Route which are described herein, an additional wetland (Wetland WH-1) was identified in West Hartford along a variation to the previously proposed all-underground route. Wetland WH-1 is a floodplain wetland near Chelton Avenue. This feature is depicted on the Volume 3 (400-scale) mapping and its associated data sheets are included in Appendix B. The route variation along which Wetland WH-1 is situated was not ultimately included in the all-underground route configuration described in Volume 1, Section 11.6.

[16] In addition to the watercourses identified along the Proposed Route described herein, eight potential watercourse crossings were identified in West Hartford along the previously proposed all-underground route or its variations, including: potential crossings of the Unnamed Tributary to Piper Brook culverted beneath Sampson Street, Somerset Street and Newington Road; potential crossings of Trout Brook near South Quaker Lane, Chelton Avenue, or New Park Avenue; and, potential crossings of the Unnamed Tributary to the South Branch of the Park River culverted at St. Augustine Street and at Westphal Street. None of these routes are part of the current Proposed Route.

One additional wetland was identified along a tributary of Piper Brook near Shepard Drive in Newington (Wetlands N-5) and another was identified on the northwestern portion of the Southwest Hartford Substation parcel.

Wetland delineation field forms are provided in Appendix A and representative photographs are included in Appendix B.

Table 4-2: Wetlands Delineated in the Vicinity of Proposed Project Activities*

Wetland No.	Location	Municipality	Proposed Project Activity	Dominant NWI Class **	Other NWI Classes	100-Scale Map Sheet Number***
N-1	Newington Substation	Newington	Newington Tap / Substation Expansion	PSS	-	1
N-1A	Newington Substation	Newington	Newington Tap	PSS	-	1
N-2	Eversource ROW	Newington	Underground cable	PEM	PSS/PFO	1 & 2
N-3	Eversource ROW	Newington	Underground cable	PSS	PEM/ PFO	3
N-4	Eversource ROW	Newington	Underground cable	PEM	PSS/PFO	3
N-5	Shepard Drive	Newington	Underground cable	PFO	-	4
H-1	Southwest Hartford Substation	Hartford	Substation Expansion (all in upland east of wetland)	PFO	-	12

* i.e., Newington Substation, Newington Tap, along underground segment of the Proposed Route, and on Southwest Hartford Substation property.
** Cowardin, L., V. Carter, F. Golet and E. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. US Fish and Wildlife Service
*** Volume 3 of the CSC *Application*

4.1.1 Wetland Soils

Wetlands along the Proposed Route, in the vicinity of the Newington Tap, and adjacent to the two substations were delineated by AECOM registered professional soil and/or wetland scientists. Table 4-3 summarizes the principal soil associations, as identified by the USDA NRCS, along and in the general vicinity of the substations and the Proposed Route. Soils with wet conditions for a sufficient period of time and that contain easily observed field markings (i.e., mottling, etc.) are considered hydric. Hydric soil conditions were verified in the field at each delineated wetland during the 2015 and 2016 field investigations.

The only hydric soil type identified by the NRCS within the Project Area is the Scitico, Shaker, and Maybid series (9). This soil is found along the Proposed Route within the existing Eversource ROW between West Hartford Road and Willard Avenue (State Route 173). Soils with potential hydric inclusions along the Proposed Route include Ellington silt loam series (20A) and Udorthents (flood control) series (309). Ellington silt loam is found adjacent to the Newington Substation and within the Eversource ROW near Avery Road. The Udorthents (flood control) series is associated with Trout Brook where soils have been cut and filled due to urban development and also include wetland inclusions.

4.1.2 Wetland Vegetation

The two wetlands located adjacent to the Newington Substation (Wetlands N-1 and N-1A) are classified as palustrine scrub-shrub (PSS) and are dominated by the following hydrophytic plant species: spotted joe-pye weed (*Eutrochium maculatum*), tussock sedge (*Carex stricta*), black willow (*Salix nigra*), river grape (*Vitis riparia*), red-osier dogwood (*Cornus sericea*), sensitive fern (*Onoclea sensibilis*), cinnamon fern (*Osmundastrum cinnamomeum*), silver maple (*Acer saccharinum*), and moneywort (*Lysimachia nummularia*), as well as the invasive species common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), Amur honeysuckle (*Lonicera maackii*), and multiflora rose (*Rosa multiflora)*.

The wetlands located along the Eversource ROW (Wetlands N-2, N-3 and N-4) are classified as palustrine emergent/palustrine scrub shrub (PEM/PSS) within the maintained existing maintained ROW, and are classified as palustrine forested (PFO) in areas adjacent to the maintained ROW. The wetland located off of Shepard Drive (Wetland N-5) is classified as PFO. These wetlands are dominated by the following hydrophytic plant species: silver maple, silky dogwood (*Cornus amomum*), southern arrowwood (*Viburnum dentatum*), common jewelweed (*Impatiens capensis*), horsetail (*Equisetum sp.)*, sedges (*Carex* spp.), broadleaf cattail (*Typha latifolia*), elderberry (*Sambucus nigra*), and goldenrod species (*Solidago* spp.), as well as the invasive species reed canary grass, common reed, purple loosestrife, and multiflora rose. Portions of these wetlands within the maintained existing ROW are dominated by invasive species.

The wetland identified adjacent to the Southwest Hartford Substation (Wetland H-1) is classified as PFO and is dominated by the following hydrophytic plant species: box elder maple (*Acer negundo*), American elm (*Ulmus americana*), red maple (*Acer rubrum*), eastern cottonwood (*Populus deltoides*), willow (*Salix spp.*), American black elderberry (*Sambucus canadensis*), maple-leafed viburnum (*Viburnum acerifolium*), jewelweed, and river grape, as well as poison-ivy (*Toxicodendron radicans*). The invasive species Tartarian honeysuckle (*Lonicera tatarica*) was also observed.

4.1.3 Wetland Hydrology

Evidence of hydrology observed in the field was identified on the field data forms, which are provided in Appendix A. Primary indicators of hydrology observed include surface water, high water table, soil saturation, water marks, water-stained leaves, and presence of reduced iron. Secondary indicators of hydrology include drainage patterns in wetlands, microtopographic relief, and the FAC-neutral test. In addition, the depth to groundwater for the various soils types is provided in Table 4-3.

4.2 Watercourses

Five watercourses are located adjacent to the existing substations or along the Proposed Route, as summarized in Table 4-4 and shown on Project plans in Volume 3. These watercourses include:

- An intermittent stream near Newington Substation (Newington)
- An intermittent stream located within the Eversource ROW east of Avery Road (Newington).
- An unnamed tributary to Piper Brook located near Shepard Dive (Newington).
- Trout Brook, which is spanned by the Amtrak ROW (West Hartford).
- An unnamed tributary to the South Branch of the Park River near the Southwest Hartford Substation (Hartford).

Table 4-3: Soils and Soil Characteristics

Unit No.	Name	Slope (%)	Parent Material	Hydric Soil	Depth to Restrictive Feature (inches)	Depth to Water Table (inches)	Bedrock	Proposed Route	Newington Substation	Southwest Hartford Substation
9	Scitico, Shaker, Maybid soils	0 to 5	Very deep, poorly drained soils formed in silty and clayey sediments	Yes	>72	10-12	Very deep	Yes	No	No
20A	Ellington silt loam	0 to 5	Coarse-loamy eolian deposits over sandy and gravelly glaciofluvial deposits derived from sandstone and shale and/or basalt	Possible Inclusions	>72	18-30	Very deep	Yes	No	No
30B	Branford silt loam	3 to 8	Very deep, well drained soils formed in loamy over sandy, gravelly outwash	No	>72	>72	Very deep	Yes	Yes	No
87B	Wethersfield loam	3 to 8	Coarse-loamy lodgment till derived from basalt and/or sandstone and shale	No	20-40 to Densic material	18-30	Very deep	Yes	No	No
230B	Branford-Urban land complex	0 to 8	Coarse-loamy eolian deposits over sandy and gravelly glaciofluvial deposits derived from sandstone and shale and/or basalt	No	>72	>72	Very deep	No	Yes[17]	No
302	Dumps	varies	Variable	No	>72	>72	Very deep	Yes	No	No
306	Udorthents-Urban land complex	varies	Urban land, variable	No	>72	54-72	Very deep	Yes	No	Yes
307	Urban land	varies	Urban land, variable	No	Variable	Variable	Variable	Yes	No	Yes[18]
308	Udorthents, smoothed	varies	Urban land, variable	No	>72	24-54	Very deep	Yes	No	Yes
309	Udorthents, flood control	varies	Moderately well drained	Possible Inclusions	>72	24-54	Very deep	Yes	No	No

[17] This soil type is outside of the substation proper, but access from Cherry Hill Drive to the substation goes through it.

[18] A small portion of the access road to the substation is 307, but this soil type is not in the substation proper.

The Proposed Route does not cross any rivers designated as a National Wild and Scenic River under the National Wild and Scenic Rivers Act or rivers designated by the CT DEEP Protected Rivers Act. As a central element of the state's clean water program, the CT DEEP has established Water Quality Standards and Classifications (2011) which identify the water quality management objectives for all waterbodies in the state[19]. Table 4-4 includes the water quality classification for each waterbody crossed by the Proposed Route[20].

Table 4-4: Watercourses Identified along the Proposed Route or near Project Facilities[21]

Watercourse Name / Project Identifier	Municipality	Water Quality [1]	Watercourse Frequency [2]	100-Scale Map Sheet No. **
Intermittent Stream 1 (IS-1)	Newington	A*	Intermittent	1
Intermittent Stream 2 (IS-2)	Newington	A*	Intermittent	2
Unnamed Tributary to Piper Brook (PS-1)	Newington	A	Perennial	4
Trout Brook (PS-2)	West Hartford	A	Perennial	7
Unnamed Tributary to South Branch of Park River (PS-3)	Hartford	A	Perennial	12 & 13

[1] Connecticut Water Quality Standards, February 2011:
A Habitat for fish and wildlife, potential drinking water supply, recreation, navigation, water supply for industry and agriculture.
B Habitat for fish and wildlife, recreation, recreation, water supply for industry and agriculture.
* Considered "Class A", in accordance with the CT Water Quality Standards for unclassified surface waters.

[2] Designated using the Connecticut Inland Wetland and Watercourses Act

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4.2.1 Intermittent Stream 1 (IS-1)

Intermittent stream (IS-1) is located to the south of the Newington Substation and within the Piper Brook watershed. IS-1 crosses the western portion of the Newington Substation parcel and connects Wetland N-1A with Wetland N-1. The stream is partially confined to a man-made drainage ditch with excavated banks on portions of the property. This channelized feature appears to convey drainage received from areas west of the Newington Substation parcel. During field investigations performed by AECOM, IS-1 was observed under both dry and flowing conditions at various times of the year. Water depths of approximately 2 to 6 inches were noted in the stream during flowing conditions.

IS-1 originates to the west of Quincy Lane, flows through Wetland N-1A and then southeast across the Newington Substation parcel, where it connects with Wetland N-1. Within the proposed Newington Tap work area, IS-1 crosses beneath Eversource's existing 1783 Line ROW, flows near residential backyards,

[19] http://www.ct.gov/deep/lib/deep/water/water_quality_standards/wqs_final_adopted_2_25_11.pdf

[20] CT DEEP Water Quality Classifications Maps; November 2016 (Accessed January 2017): http://www.ct.gov/deep/cwp/view.asp?a=2719&q=522518&deepNav_GID=1654

[21] As property access has not yet been gained, this report excludes field-confirmed boundaries of wetlands and watercourses located along the Amtrak/*CTfastrak* corridor. The report will be updated accordingly once access has been secured and field surveys have been conducted.

and extends along the existing overhead transmission line (1785 Line) located south of the substation. IS-1 then flows south, along the eastern edge of the 1785 Line ROW, before flowing into a culvert beneath Reservoir Road.

4.2.2 Intermittent Stream 2 (IS-2)

Intermittent stream IS-2, which is located within Wetland N-2 along Eversource's ROW, is located approximately 350 feet east of Avery Road and flows to the north through a dense stand of common reed (*Phragmites australis*). IS-2 conveys flow from a small culvert located on the southern edge of the ROW. This small culvert feature appears to convey surface flow from a residential backyard. The stream has been observed under both dry and flowing conditions at various times of the year. At the proposed transmission line crossing, this watercourse is approximately 4 feet wide. In accordance with the CT DEEP 2011 Connecticut Water Quality Standards, intermittent streams that lack a designated water quality classification are considered Class A waters.

4.2.3 Unnamed Tributary to Piper Brook (PS-1)[22]

The underground segment of the Proposed Route would cross an unnamed perennial tributary to Piper Brook located beneath Shepard Drive. On either side of the road crossing, the tributary is bordered by a narrow riparian strip of wooded vegetation. The stream is approximately 21 feet wide at the proposed crossing location and flows beneath Shepard Drive just downstream of the crossing via three approximately 30-foot long by 6-foot diameter culverts. Wetland N-5 is located on the south of the proposed crossing location, and extends along the western bank of the tributary, south of Shepard Drive. This tributary has been altered by human activity, including rerouting and channelization in the vicinity of the crossing. At the proposed crossing location, CT DEEP has assigned the tributary a classification of A.

As part of the siting process, a Route Variation utilizing Spring Street was considered for the Project. Under this Spring Street variation, the crossing of the unnamed tributary to Piper Brook (PS-1) would be located approximately 600 feet south of the Shepard Drive crossing location described above. PS-1 has a similar stream configuration at Spring Street, as is described above (i.e. PS-1 is a channelized feature near Spring Street, of approximately the same width, and it flows through existing culverts).

4.2.4 Trout Brook (PS-2)[23]

Trout Brook is a large perennial stream that flows from northeast to southwest through the central portion of the Project area in West Hartford. PS-2 is an open warm water, relatively shallow stream system with

[22] As noted above, potential crossings of the Unnamed Tributary to Piper Brook were previously identified in association with the all-underground route (which is no longer being advanced as preferred). PS-1 is culverted beneath Sampson Street, Somerset Street and Newington Road in West Hartford in the vicinity of the former investigation areas. The locations of PS-1 in the vicinity of these previously considered crossings were identified in the field in June 2015. The stream is contained within a series of conduits beneath roads and near residences in this vicinity before it daylights to the east of Newington Road/State Route 173. Section 4.2.3 presents details regarding PS-1 near proposed crossing locations currently under consideration.

[23] As noted above, potential crossings of Trout Brook near South Quaker Lane, Chelton Avenue, and New Park Avenue were previously identified in association with the all-underground route (which is no longer being advanced as preferred). The in-stream conditions of Trout Brook at these previously considered crossing locations are generally consistent with those described above. However, the embankments at the former crossing locations are wider and more fully vegetated. In addition, recreational features including trails and public parks are located in vicinity to the formerly considered crossing locations. Section 4.2.4 presents details regarding PS-2 near the crossing along the Proposed Route.

a bankfull width of approximately 60 feet at the overhead transmission line crossing location proposed along the Amtrak/CT*fastrak* corridor. The existing elevated railroad/busway corridor bridge spans Trout Brook at the proposed crossing location. The bridge's concrete abutments and wingwalls confine the watercourse at this location. The approximate length of the aerial crossing over Trout Brook is approximately 35 feet at this location, relative to its span across ordinary high water.

The area immediately upstream of the proposed crossing location includes developed uplands (open lots) and a confined bank. The stream banks downstream of the railroad/busway corridor crossing are sparsely vegetated and have largely been cleared of trees as part of a recent CT DEEP flood control project[24]. Stands of herbaceous vegetation, small shrubs and some trees are located along the banks. Dense stands of Japanese knotweed (*Fallopia japonica*) were also noted along the banks.

The segment of Trout Brook in the Project vicinity has been altered by human activities, including rerouting and channelization activities prior to 1985. Several local flood control works, including dikes and a pumping station, are also located in this vicinity. The South Branch Park River confluence is located just downstream of the proposed overhead transmission line crossing location.

To the northwest of the proposed overhead crossing location (near New Britain Avenue in West Hartford), a system of recreational pedestrian paths border PS-2 on both the north and south banks. The recreational trails are absent in the immediate vicinity of the Proposed Route crossing.

Trout Brook has a water quality classification of A and its designated uses include potential drinking water supply, habitat for fish and other aquatic life and wildlife, recreation, and industrial and agricultural water supply. The Trout Brook watershed consists of 63% urban area and three segments of Trout Brook are listed as impaired waterbodies on the CT DEEP's 2010 303(d) list, including the segment crossed by the Proposed Route along the Amtrak ROW. These segments of the brook are impaired due to elevated bacteria concentrations, affecting the designated use of recreation and aquatic habitat provision.

4.2.5 Unnamed Tributary to the South Branch of the Park River (PS-3)[25]

The unnamed tributary to the South Branch of Park River is a perennial watercourse that is located in the northern portion of the Project area near the Southwest Hartford Substation in Hartford. Specifically, this feature is located in northern portion of Eversource's Southwest Hartford Substation property (refer to the Volume 3 maps for additional detail). This perennial watercourse is approximately 25 feet wide from bank to bank and flows to the east. This tributary has been altered by human activity, including rerouting and channelization within the Project area. No crossing of this watercourse is proposed.

On Eversource's property, the watercourse is bordered by woody vegetation, including box elder maple, American elm, red maple, eastern cottonwood, and willow, as well as stands of the invasive Japanese knotweed. The tributary flows through a culvert which extends beneath New Park Avenue and daylights

[24] CT DEEP South Branch Park River (SBPR) Flood Control System Maintenance Project website: http://www.ct.gov/deep/cwp/view.asp?a=2720&Q=573044&deepNav_GID=1654Accessed 10/04/2016

[25] As noted above, potential crossings of the Unnamed Tributary to the South Branch of the Park River at St. Augustine Street and at Westphal Street were previously identified in association with the all-underground route (which is no longer being advanced as preferred). In these previously examined crossing locations, PS-3 is approximately 15 feet wide and is bordered by typical urban riparian vegetation. Section 4.2.5 presents details regarding PS-3 near the proposed Project.

southeast of the road. The watercourse then flows in an easterly direction, beneath and next to existing transportation infrastructure (i.e., I-84, Amtrak ROW), to the South Branch of the Park River. Downstream of this tributary, the Park River has a water quality classification of B.

4.3 Floodplains

Figure 3-1 illustrates the mapped FEMA floodplains in the Project area. As this figure shows, the Proposed Route crosses only one mapped floodplain: the 100- and 500-year flood zones of Trout Brook. At this proposed crossing location, the new 115-kV line would be aligned overhead, within the Amtrak ROW. As a result, the proposed transmission line would span the floodplain. No work is proposed within the flood zones. Additional detail regarding floodplain resources in the Project vicinity is presented in the Volume 3 mapping (100-scale figures).

Trout Brook is managed for flood control purposes by the CT DEEP as part of the South Branch Park River (SBPR) Flood Control System[26]. In the proposed Project area, Trout Brook is bordered by a confining embankment and upstream pumping station, which were constructed as a public safety infrastructure project. To maintain NRCS certifications[27] along this system, the CT DEEP is conducting maintenance activities, including tree clearing, stump grinding, dredging, and soil stabilization activities along the SBPR Flood Control System. Such maintenance activities were conducted in the vicinity of the Proposed Route crossing of Trout Brook in 2016. The proposed 115-kV transmission line would be located within the Amtrak ROW and would extend over Trout Brook, thus spanning these SBPR Flood Control System features.

[26] CT DEEP South Branch Park River (SBPR) Flood Control System Maintenance Project website: http://www.ct.gov/deep/cwp/view.asp?a=2720&Q=573044&deepNav_GID=1654 Accessed 10/04/2016

[27] Ibid. Per the above CT DEEP webpage (website content has since been updated): "The federal Natural Resource Conservation Service (NRCS) informed DEEP that maintenance work must be performed to bring the channel system back to its original condition or the flood control system would be decertified. There are significant financial consequences if the system is decertified, as well as increased risks to property and public safety."

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Appendix A
Wetland Delineation Field Data Forms

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 5/15/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-1A-PSS

Investigator(s): K. Purdy & K. Van Naerssen Section, Township, Range:

Landform (hillside, terrace, etc.): Lowland Local relief (concave, convex, none): concave Slope %: 5

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: NULL Long: NULL Datum:

Soil Map Unit Name: Branford silt loam, 3-8% slopes NWI classification: PSS

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No ____	**Is the Sampled Area**
Hydric Soil Present?	Yes X	No ____	**within a Wetland?** **Yes** X **No** ____
Wetland Hydrology Present?	Yes X	No ____	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- X Surface Water (A1)
- ____ High Water Table (A2)
- X Saturation (A3)
- X Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- ____ Inundation Visible on Aerial Imagery (B7)
- ____ Sparsely Vegetated Concave Surface (B8)
- X Water-Stained Leaves (B9)
- ____ Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- X Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- ____ Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- ____ Drainage Patterns (B10)
- ____ Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- ____ Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes X	No ____	Depth (inches): 2
Water Table Present?	Yes ____	No ____	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes X	No ____	Depth (inches): 12

Wetland Hydrology Present? **Yes** X **No** ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Several primary hydrology indicators present. Wetland hydrology criteria met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-1A-PSS

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Acer saccharinum*	20	Yes	FACW
2. *Cornus alba*	10	Yes	FACW
3.			
4.			
5.			
6.			
7.			
	30 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Phalaris arundinacea*	80	Yes	FACW
2. *Lysimachia nummularia*	30	Yes	FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
	110 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	0	x 1 =	0
FACW species	140	x 2 =	280
FAC species	0	x 3 =	0
FACU species	0	x 4 =	0
UPL species	0	x 5 =	0
Column Totals:	140 (A)		280 (B)

Prevalence Index = B/A = 2.00

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

X 2 - Dominance Test is >50%

X 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)
Hydrophytic vegetation indicators present. Wetland vegetation criteria met.

SOIL

Sampling Point N-1A-PSS

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-8	10YR 3/2	100					Loamy/Clayey	Silty clay
8-12	10YR 3/3	95	10YR 4/2	5	D	M	Loamy/Clayey	Sandy loam

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- X Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

Hydric soil indicator present; therefore, hydric soil criterion is met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 5/15/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-1A-UPL

Investigator(s): K. Purdy & K. Van Naerssen Section, Township, Range:

Landform (hillside, terrace, etc.): hillside Local relief (concave, convex, none): none Slope %: 5

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: NULL Long: NULL Datum:

Soil Map Unit Name: Branford silt loam, 3-8% slopes NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No X	**Is the Sampled Area**
Hydric Soil Present?	Yes ____	No X	**within a Wetland?** **Yes** ____ **No** X
Wetland Hydrology Present?	Yes ____	No X	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ Microtopographic Relief (D4)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Primary hydrology indicators absent. Wetland hydrology criteria not met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-1A-UPL

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Rosa multiflora*	60	Yes	FACU
2.			
3.			
4.			
5.			
6.			
7.			
	60 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Polystichum acrostichoides*	30	Yes	FACU
2. *Securigera varia*	10	No	UPL
3. *Echinochloa crus-galli*	40	Yes	FAC
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
	80 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 33.3% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	0	x 1 =	0
FACW species	0	x 2 =	0
FAC species	40	x 3 =	120
FACU species	90	x 4 =	360
UPL species	10	x 5 =	50
Column Totals:	140 (A)		530 (B)

Prevalence Index = B/A = 3.79

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

___ 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** ___ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)
Hydrophytic vegetation indicators absent. Wetland vegetation criteria is not met.

SOIL

Sampling Point N-1A-UPL

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-4	10YR 4/3	100					Sandy	Sandy loam
4-12	10YR 5/3	100					Sandy	Sandy loam

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** ___ **No** X

Remarks:

Hydric soil indicators are absent; therefore, hydric soil criterion is not met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 5/15/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-1-PSS

Investigator(s): K. Purdy Section, Township, Range:

Landform (hillside, terrace, etc.): Lowland Local relief (concave, convex, none): concave Slope %: 5

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.717788 Long: -72.747947 Datum:

Soil Map Unit Name: Branford silt loam, 3-8% slopes NWI classification: PSS

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No ____	**Is the Sampled Area**
Hydric Soil Present?	Yes X	No ____	**within a Wetland?** **Yes** X **No** ____
Wetland Hydrology Present?	Yes X	No ____	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ____ Surface Water (A1)
- ____ High Water Table (A2)
- X Saturation (A3)
- X Water Marks (B1)
- ____ Sediment Deposits (B2)
- ____ Drift Deposits (B3)
- ____ Algal Mat or Crust (B4)
- ____ Iron Deposits (B5)
- ____ Inundation Visible on Aerial Imagery (B7)
- ____ Sparsely Vegetated Concave Surface (B8)
- X Water-Stained Leaves (B9)
- ____ Aquatic Fauna (B13)
- ____ Marl Deposits (B15)
- ____ Hydrogen Sulfide Odor (C1)
- ____ Oxidized Rhizospheres on Living Roots (C3)
- ____ Presence of Reduced Iron (C4)
- ____ Recent Iron Reduction in Tilled Soils (C6)
- ____ Thin Muck Surface (C7)
- ____ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ____ Surface Soil Cracks (B6)
- ____ Drainage Patterns (B10)
- ____ Moss Trim Lines (B16)
- ____ Dry-Season Water Table (C2)
- ____ Crayfish Burrows (C8)
- ____ Saturation Visible on Aerial Imagery (C9)
- ____ Stunted or Stressed Plants (D1)
- ____ Geomorphic Position (D2)
- ____ Shallow Aquitard (D3)
- ____ Microtopographic Relief (D4)
- ____ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes X	No ____	Depth (inches): 0

Wetland Hydrology Present? **Yes** X **No** ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Primary hydrology indicators present. Wetland hydrology criteria met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-1-PSS

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Cornus alba*	40	Yes	FACW
2. *Alnus serrulata*	10	Yes	OBL
3.			
4.			
5.			
6.			
7.			
	50 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Onoclea sensibilis*	30	Yes	FACW
2. *Osmundastrum cinnamomeum*	20	Yes	FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
	50 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	10	x 1 =	10
FACW species	90	x 2 =	180
FAC species	0	x 3 =	0
FACU species	0	x 4 =	0
UPL species	0	x 5 =	0
Column Totals:	100 (A)		190 (B)

Prevalence Index = B/A = 1.90

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

X 2 - Dominance Test is >50%

X 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)
Dominance test and prevalence index indicate presence of Hydrophytic vegetation. Wetland vegetation criteria is met.

SOIL

Sampling Point N-1-PSS

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-6	10YR 3/2	100					Sandy	
6-12	10YR 4/2	80	10YR 4/4	20	C	M	Loamy/Clayey	Distinct redox concentrations

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ? Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

Hydric soil indicators are present; therefore, hydric soil criterion is met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 5/15/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-1-UPL

Investigator(s): K. Purdy & K. Van Naerssen Section, Township, Range:

Landform (hillside, terrace, etc.): hillside Local relief (concave, convex, none): none Slope %: 5

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: NULL Long: NULL Datum:

Soil Map Unit Name: Branford silt loam, 3-8% slopes NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No X	**Is the Sampled Area**
Hydric Soil Present?	Yes ____	No X	**within a Wetland?** **Yes** ____ **No** X
Wetland Hydrology Present?	Yes ____	No X	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ Microtopographic Relief (D4)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Primary hydrology indicators absent. Wetland hydrology criteria not met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-1-UPL

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Rosa multiflora*	30	Yes	FACU
2.			
3.			
4.			
5.			
6.			
7.			
	30 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Polystichum acrostichoides*	20	Yes	FACU
2. *Securigera varia*	10	Yes	UPL
3. *Panicum capillare*	5	No	FAC
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
	35 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 0 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 0.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	0	x 1 =	0
FACW species	0	x 2 =	0
FAC species	5	x 3 =	15
FACU species	50	x 4 =	200
UPL species	10	x 5 =	50
Column Totals:	65 (A)		265 (B)

Prevalence Index = B/A = 4.08

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

___ 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** ___ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)
Hydrophytic vegetation indicators absent. Wetland vegetation criteria is not met.

SOIL

Sampling Point N-1-UPL

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-3	10YR 4/4	100					Sandy	Silty sand
3-12	10YR 5/3	100					Loamy/Clayey	Silt loam

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** ___ **No** X

Remarks:

Hydric soil indicators are absent; therefore, hydric soil criterion is not met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6/23/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-2-PEM

Investigator(s): M. Notestine & K. Van Naerssen Section, Township, Range:

Landform (hillside, terrace, etc.): Slight hillside on ROW Local relief (concave, convex, none): concave Slope %: 5

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.717788 Long: -72.747947 Datum:

Soil Map Unit Name: Branford silt loam, 3-8% slopes & Ellington silt loam, 0-5% slopes NWI classification: PEM/PSS

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No ____	**Is the Sampled Area**
Hydric Soil Present?	Yes X	No ____	**within a Wetland?** **Yes** X **No** ____
Wetland Hydrology Present?	Yes X	No ____	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- X Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- X Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- X Microtopographic Relief (D4)
- X FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes X	No ____	Depth (inches): 12

Wetland Hydrology Present? **Yes** X **No** ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Soils only lightly saturated; however several other indicators of hydrology also present.

VEGETATION – Use scientific names of plants.

Sampling Point: N-2-PEM

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Cornus amomum*	20	Yes	FACW
2.			
3.			
4.			
5.			
6.			
7.			
	20 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Phragmites australis*	55	Yes	FACW
2. *Impatiens capensis*	25	Yes	FACW
3. *Symplocarpus foetidus*	15	No	OBL
4. *Onoclea sensibilis*	5	No	FACW
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
	100 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 3 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	15	x 1 =	15
FACW species	105	x 2 =	210
FAC species	0	x 3 =	0
FACU species	0	x 4 =	0
UPL species	0	x 5 =	0
Column Totals:	120 (A)		225 (B)

Prevalence Index = B/A = 1.88

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

X 2 - Dominance Test is >50%

X 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)
Dominance test and prevalence index indicate presence of hydrophytic vegetation. Hydrophytic vegetation criteria is met.

SOIL

Sampling Point N-2-PEM

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-10	10YR 3/2	100					Loamy/Clayey	
10-18	5YR 5/2	80	10YR 6/6	10	RM	PL	Loamy/Clayey	
			5YR 4/6	10	RM	PL		

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

Hydric soil indicators are present; therefore, hydric soil criterion is met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6/23/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-2-UPL

Investigator(s): K. Van Naerssen & M. Notestine Section, Township, Range:

Landform (hillside, terrace, etc.): flat ROW area Local relief (concave, convex, none): None Slope %: 0

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.718089 Long: -72.744627 Datum:

Soil Map Unit Name: Branford silt loam, 3 to 8 percent slopes NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No ____	**Is the Sampled Area**
Hydric Soil Present?	Yes ____	No X	**within a Wetland?** **Yes** ____ **No** X
Wetland Hydrology Present?	Yes ____	No X	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)
Although wetland vegetation is present throughout this location, no evidence of hydrology or hydric soils is present.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ Microtopographic Relief (D4)
- X FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
No evidence of wetland hydrology; therefore hydrology criterion is not met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-2-UPL

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Lonicera maackii*	80	Yes	UPL
2.			
3.			
4.			
5.			
6.			
7.			
	80 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Impatiens capensis*	50	Yes	FACW
2. *Phragmites australis*	50	Yes	FACW
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
	100 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 3 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 66.7% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	0	x 1 =	0
FACW species	100	x 2 =	200
FAC species	0	x 3 =	0
FACU species	0	x 4 =	0
UPL species	80	x 5 =	400
Column Totals:	180 (A)		600 (B)

Prevalence Index = B/A = 3.33

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

X 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point N-2-UPL

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-10	10YR 3/2	100					Loamy/Clayey	fill likely. Silt loam
10-14	10YR 3/2	100					Loamy/Clayey	fine sandy loam
14-20	2.5Y 5/1	99	7.5YR 4/6	1	RM	PL	Loamy/Clayey	sandy clay loam

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** ___ **No** X

Remarks:

Hydric soil indicators are not present; therefore, hydric soil criterion is not met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6/23/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-3-PEM

Investigator(s): M. Notestine & K. Van Naerssen Section, Township, Range:

Landform (hillside, terrace, etc.): Slight hillside on ROW Local relief (concave, convex, none): concave Slope %: 5

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.718585 Long: -72.740259 Datum:

Soil Map Unit Name: Scitico, Shaker, and Maybid soils NWI classification: PEM/PSS

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No (If no, explain in Remarks.)

Are Vegetation , Soil , or Hydrology significantly disturbed? Are "Normal Circumstances" present? Yes X No

Are Vegetation , Soil , or Hydrology naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No	**Is the Sampled Area**
Hydric Soil Present?	Yes X	No	**within a Wetland?** **Yes** X **No**
Wetland Hydrology Present?	Yes X	No	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- X Surface Water (A1)
- High Water Table (A2)
- X Saturation (A3)
- Water Marks (B1)
- Sediment Deposits (B2)
- Drift Deposits (B3)
- Algal Mat or Crust (B4)
- Iron Deposits (B5)
- Inundation Visible on Aerial Imagery (B7)
- Sparsely Vegetated Concave Surface (B8)
- X Water-Stained Leaves (B9)
- Aquatic Fauna (B13)
- Marl Deposits (B15)
- Hydrogen Sulfide Odor (C1)
- Oxidized Rhizospheres on Living Roots (C3)
- X Presence of Reduced Iron (C4)
- Recent Iron Reduction in Tilled Soils (C6)
- Thin Muck Surface (C7)
- Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- Surface Soil Cracks (B6)
- Drainage Patterns (B10)
- Moss Trim Lines (B16)
- Dry-Season Water Table (C2)
- Crayfish Burrows (C8)
- Saturation Visible on Aerial Imagery (C9)
- Stunted or Stressed Plants (D1)
- Geomorphic Position (D2)
- Shallow Aquitard (D3)
- Microtopographic Relief (D4)
- X FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes X	No	Depth (inches): 2
Water Table Present?	Yes	No X	Depth (inches):
Saturation Present? (includes capillary fringe)	Yes X	No	Depth (inches): 0

Wetland Hydrology Present? **Yes** X **No**

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Soils saturated and standing water is present; therefore wetland hydrology criterion is met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-3-PEM

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Cornus amomum*	15	Yes	FACW
2. *Viburnum dentatum*	25	Yes	FAC
3. *Lindera benzoin*	3	No	FACW
4. *Rosa multiflora*	7	No	FACU
5.			
6.			
7.			
	50 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Phragmites australis*	10	No	FACW
2. *Impatiens capensis*	30	Yes	FACW
3. *Scirpus atrovirens*	10	No	OBL
4. *Asclepias incarnata*	10	No	OBL
5. *Phalaris arundinacea*	20	Yes	FACW
6. *Solidago spp.*	20	Yes	
7.			
8.			
9.			
10.			
11.			
12.			
	100 =Total Cover		
Woody Vine Stratum (Plot size:)			
1. *Vitis*	20	Yes	
2.			
3.			
4.			
	20 =Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 4 (A)

Total Number of Dominant Species Across All Strata: 6 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 66.7% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	20	x 1 =	20
FACW species	78	x 2 =	156
FAC species	25	x 3 =	75
FACU species	7	x 4 =	28
UPL species	0	x 5 =	0
Column Totals:	130 (A)		279 (B)

Prevalence Index = B/A = 2.15

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

_X_ 2 - Dominance Test is >50%

_X_ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point N-3-PEM

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-12	10YR 3/2	100					Loamy/Clayey	
12-18	10YR 5/2	90	7.5YR 6/8	10	RM	PL	Loamy/Clayey	
18-20	7.5YR 4/4	100					Loamy/Clayey	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

Hydric soil indicators are present; therefore, hydric soil criterion is met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6/23/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-3-UPL

Investigator(s): K. Van Naerssen & M. Notestine Section, Township, Range:

Landform (hillside, terrace, etc.): slight hillside on ROW Local relief (concave, convex, none): convex Slope %: 5

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.718808, Long: -72.739100 Datum:

Soil Map Unit Name: Wethersfield loam, 3 to 8 percent slopes NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No X	**Is the Sampled Area**
Hydric Soil Present?	Yes ____	No X	**within a Wetland?** **Yes** ____ **No** X
Wetland Hydrology Present?	Yes ____	No X	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ Microtopographic Relief (D4)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
No evidence of wetland hydrology; therefore hydrology criterion is not met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-3-UPL

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1. *Quercus rubra*	5	Yes	FACU
2. *Rubus occidentalis*	10	Yes	UPL
3.			
4.			
5.			
6.			
7.			
	15 =Total Cover		
Herb Stratum (Plot size: 5)			
1. *Dichanthelium clandestinum*	30	Yes	FACW
2. *Solidago rugosa*	20	Yes	FAC
3. *Potentilla simplex*	5	No	FACU
4. *Agrostis gigantea*	5	No	FACW
5. *Phleum pratense*	10	No	FACU
6.			
7.			
8.			
9.			
10.			
11.			
12.			
	70 =Total Cover		
Woody Vine Stratum (Plot size: 30)			
1. *Celastrus orbiculatus*	10	Yes	UPL
2.			
3.			
4.			
	10 =Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 40.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	0	x 1 =	0
FACW species	35	x 2 =	70
FAC species	20	x 3 =	60
FACU species	20	x 4 =	80
UPL species	20	x 5 =	100
Column Totals:	95 (A)		310 (B)

Prevalence Index = B/A = 3.26

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

___ 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** ___ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point N-3-UPL

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-10	7.5YR 4/3	100					Loamy/Clayey	fine sandy loam
10-16	7.5YR 4/4	100					Loamy/Clayey	fine sandy loam

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** ___ **No** X

Remarks:

Hydric soil indicators are not present; therefore, hydric soil criterion is not met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6/23/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-4-PSS

Investigator(s): K. Van Naerssen & M. Notestine Section, Township, Range:

Landform (hillside, terrace, etc.): Slight hillside on ROW Local relief (concave, convex, none): concave Slope %: 7

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.718958 Long: -72.737857 Datum:

Soil Map Unit Name: Wethersfield loam, 3 to 8 percent slopes NWI classification: PSS/PEM

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No ____	**Is the Sampled Area**
Hydric Soil Present?	Yes X	No ____	**within a Wetland?** **Yes** X **No** ____
Wetland Hydrology Present?	Yes X	No ____	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- X Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- X Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ Microtopographic Relief (D4)
- X FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes X	No ____	Depth (inches): 0

Wetland Hydrology Present? **Yes** X **No** ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Soils saturated at surface; therefore wetland hydrology criterion is met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-4-PSS

Tree Stratum (Plot size: 30)	Absolute % Cover	Dominant Species?	Indicator Status
1. *Acer saccharinum*	10	Yes	FACW
2.			
3.			
4.			
5.			
6.			
7.			
	10	=Total Cover	
Sapling/Shrub Stratum (Plot size: 15)			
1. *Cornus amomum*	15	Yes	FACW
2. *Viburnum dentatum*	5	Yes	FAC
3. *Sambucus nigra*	5	Yes	FACW
4.			
5.			
6.			
7.			
	25	=Total Cover	
Herb Stratum (Plot size: 5)			
1. *Typha latifolia*	75	Yes	OBL
2. *Carex lurida*	5	No	OBL
3. *Carex crinita*	5	No	OBL
4. *Juncus effusus*	5	No	OBL
5. *Carex stipata*	5	No	OBL
6. *Solidago spp.*	5	No	
7.			
8.			
9.			
10.			
11.			
12.			
	100	=Total Cover	
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
		=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 5 (A)

Total Number of Dominant Species Across All Strata: 5 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	95	x 1 =	95
FACW species	30	x 2 =	60
FAC species	5	x 3 =	15
FACU species	0	x 4 =	0
UPL species	0	x 5 =	0
Column Totals:	130 (A)		170 (B)

Prevalence Index = B/A = 1.31

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

X 2 - Dominance Test is >50%

X 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point N-4-PSS

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-10	10YR 3/2	100					Loamy/Clayey	sandy clay loam
10-16	7.5YR 4/2	90	10YR 4/4	10	RM	PL	Loamy/Clayey	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- X Depleted Matrix (F3)
- X Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

Hydric soil indicators are present; therefore, hydric soil criterion is met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6/23/2015

Applicant/Owner: Eversource State: CT Sampling Point: N-4-UPL

Investigator(s): K. Van Naerssen & M. Notestine Section, Township, Range:

Landform (hillside, terrace, etc.): streambank Local relief (concave, convex, none): concave Slope %: 30

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.734046 Long: -72.726784 Datum:

Soil Map Unit Name: Udorthents, smoothed NWI classification: N/A

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No X	**Is the Sampled Area**
Hydric Soil Present?	Yes ____	No X	**within a Wetland?** **Yes** ____ **No** X
Wetland Hydrology Present?	Yes ____	No X	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ Microtopographic Relief (D4)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
No evidence of wetland hydrology; therefore hydrology criterion is not met.

VEGETATION – Use scientific names of plants.

Sampling Point: N-4-UPL

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Herb Stratum (Plot size: 5)			
1. *Asclepias syriaca*	5	No	UPL
2. *Solidago rugosa*	40	Yes	FAC
3. *Cytisus scoparius*	10	No	UPL
4. *Vicia sativa*	20	Yes	FACU
5. *Phleum pratense*	10	No	FACU
6. *Cirsium arvense*	10	No	FACU
7.			
8.			
9.			
10.			
11.			
12.			
	95 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 50.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	0	x 1 =	0
FACW species	0	x 2 =	0
FAC species	40	x 3 =	120
FACU species	40	x 4 =	160
UPL species	15	x 5 =	75
Column Totals:	95 (A)		355 (B)

Prevalence Index = B/A = 3.74

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

___ 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** ___ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point N-4-UPL

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-12	10YR 3/3	100					Loamy/Clayey	clay loam
12-16	10YR 3/4	100					Loamy/Clayey	sandy clay loam

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** ___ **No** X

Remarks:

Hydric soil indicators are not present; therefore, hydric soil criterion is not met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6.23.15

Applicant/Owner: Eversource State: CT Sampling Point: W-WH-1

Investigator(s): K. Van Naerssen & M. Notestine Section, Township, Range:

Landform (hillside, terrace, etc.): wetland shelf along floodplain Local relief (concave, convex, none): concave Slope %: 1

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.734100, Long: -72.727228 Datum:

Soil Map Unit Name: Udorthents, flood control NWI classification: PEM

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes X No

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X	No	**Is the Sampled Area**
Hydric Soil Present?	Yes X	No	**within a Wetland?** **Yes** X **No**
Wetland Hydrology Present?	Yes X	No	If yes, optional Wetland Site ID:

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- Water Marks (B1)
- Sediment Deposits (B2)
- Drift Deposits (B3)
- Algal Mat or Crust (B4)
- Iron Deposits (B5)
- Inundation Visible on Aerial Imagery (B7)
- Sparsely Vegetated Concave Surface (B8)
- Water-Stained Leaves (B9)
- Aquatic Fauna (B13)
- Marl Deposits (B15)
- Hydrogen Sulfide Odor (C1)
- Oxidized Rhizospheres on Living Roots (C3)
- Presence of Reduced Iron (C4)
- Recent Iron Reduction in Tilled Soils (C6)
- Thin Muck Surface (C7)
- Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- Surface Soil Cracks (B6)
- X Drainage Patterns (B10)
- Moss Trim Lines (B16)
- Dry-Season Water Table (C2)
- Crayfish Burrows (C8)
- Saturation Visible on Aerial Imagery (C9)
- Stunted or Stressed Plants (D1)
- Geomorphic Position (D2)
- Shallow Aquitard (D3)
- Microtopographic Relief (D4)
- X FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes X	No	Depth (inches): 4
Water Table Present?	Yes X	No	Depth (inches): 0
Saturation Present? (includes capillary fringe)	Yes X	No	Depth (inches): 0

Wetland Hydrology Present? **Yes** X **No**

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
Soils saturated at surface and standing water pooled to a depth of 4"; therefore wetland hydrology criterion is met.

VEGETATION – Use scientific names of plants.

Sampling Point: W-WH-1

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
		=Total Cover	
Sapling/Shrub Stratum (Plot size:)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
		=Total Cover	
Herb Stratum (Plot size: 5)			
1. *Typha latifolia*	38	Yes	OBL
2. *Scirpus atrovirens*	5	No	OBL
3. *Carex crinita*	2	No	OBL
4. *Phalaris arundinacea*	48	Yes	FACW
5. *Carex stipata*	2	No	OBL
6. *Solidago spp.*	5	No	
7.			
8.			
9.			
10.			
11.			
12.			
	100	=Total Cover	
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
		=Total Cover	

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 100.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	47	x 1 =	47
FACW species	48	x 2 =	96
FAC species	0	x 3 =	0
FACU species	0	x 4 =	0
UPL species	0	x 5 =	0
Column Totals:	95 (A)		143 (B)

Prevalence Index = B/A = 1.51

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

X 2 - Dominance Test is >50%

X 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** X **No** ___

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point W-WH-1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-14	10YR 4/1	100					Mucky Loam/Clay	
								rock below 14"

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- X Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** X **No** ___

Remarks:

Hydric soil indicators and aquic conditions are present; therefore, hydric soil criterion is met.

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WETLAND DETERMINATION DATA FORM – Northcentral and Northeast Region

Project/Site: GHCCRP City/County: Newington/Hartford Sampling Date: 6.23.15

Applicant/Owner: Eversource State: CT Sampling Point: ~~W-WH-1-UP~~

Investigator(s): K. Van Naerssen & M. Notestine Section, Township, Range:

Landform (hillside, terrace, etc.): streambank Local relief (concave, convex, none): concave Slope %: 30

Subregion (LRR or MLRA): LRR R, MLRA 145 Lat: 41.734046, Long: -72.726784 Datum:

Soil Map Unit Name: Udorthents, smoothed NWI classification: non WL

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ____ (If no, explain in Remarks.)

Are Vegetation ____, Soil ____, or Hydrology ____ significantly disturbed? Are "Normal Circumstances" present? Yes ____ No ____

Are Vegetation ____, Soil ____, or Hydrology ____ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ____	No X	**Is the Sampled Area**
Hydric Soil Present?	Yes ____	No X	**within a Wetland?** **Yes** ____ **No** X
Wetland Hydrology Present?	Yes ____	No X	If yes, optional Wetland Site ID: ____

Remarks: (Explain alternative procedures here or in a separate report.)

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ Marl Deposits (B15)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Moss Trim Lines (B16)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ Microtopographic Relief (D4)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present?	Yes ____	No X	Depth (inches): ____
Water Table Present?	Yes ____	No X	Depth (inches): ____
Saturation Present? (includes capillary fringe)	Yes ____	No X	Depth (inches): ____

Wetland Hydrology Present? **Yes** ____ **No** X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:
No evidence of wetland hydrology; therefore hydrology criterion is not met.

VEGETATION – Use scientific names of plants.

Sampling Point: W-WH-1-UP

Tree Stratum (Plot size:)	Absolute % Cover	Dominant Species?	Indicator Status
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Sapling/Shrub Stratum (Plot size: 15)			
1.			
2.			
3.			
4.			
5.			
6.			
7.			
	=Total Cover		
Herb Stratum (Plot size: 5)			
1. *Asclepias syriaca*	5	No	UPL
2. *Solidago rugosa*	40	Yes	FAC
3. *Cytisus scoparius*	10	No	UPL
4. *Vicia sativa*	20	Yes	FACU
5. *Phleum pratense*	10	No	FACU
6. *Cirsium arvense*	10	No	FACU
7.			
8.			
9.			
10.			
11.			
12.			
	95 =Total Cover		
Woody Vine Stratum (Plot size:)			
1.			
2.			
3.			
4.			
	=Total Cover		

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 1 (A)

Total Number of Dominant Species Across All Strata: 2 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 50.0% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:	
OBL species	0	x 1 =	0
FACW species	0	x 2 =	0
FAC species	40	x 3 =	120
FACU species	40	x 4 =	160
UPL species	15	x 5 =	75
Column Totals:	95 (A)		355 (B)

Prevalence Index = B/A = 3.74

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

___ 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Definitions of Vegetation Strata:

Tree – Woody plants 3 in. (7.6 cm) or more in diameter at breast height (DBH), regardless of height.

Sapling/shrub – Woody plants less than 3 in. DBH and greater than or equal to 3.28 ft (1 m) tall.

Herb – All herbaceous (non-woody) plants, regardless of size, and woody plants less than 3.28 ft tall.

Woody vines – All woody vines greater than 3.28 ft in height.

Hydrophytic Vegetation Present? **Yes** ___ **No** X

Remarks: (Include photo numbers here or on a separate sheet.)

SOIL

Sampling Point W-WH-1-UP

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth	Matrix		Redox Features					
(inches)	Color (moist)	%	Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0-12	10YR 3/3	100					Loamy/Clayey	clay loam
12-16	10YR 3/4	100					Loamy/Clayey	sandy clay loam

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Dark Surface (S7)
- ___ Polyvalue Below Surface (S8) (**LRR R, MLRA 149B**)
- ___ Thin Dark Surface (S9) (**LRR R, MLRA 149B**)
- ___ High Chroma Sands (S11) (**LRR K, L)**
- ___ Loamy Mucky Mineral (F1) (**LRR K, L**)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)
- ___ Marl (F10) (**LRR K, L**)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10) (**LRR K, L, MLRA 149B**)
- ___ Coast Prairie Redox (A16) (**LRR K, L, R**)
- ___ 5 cm Mucky Peat or Peat (S3) (**LRR K, L, R**)
- ___ Polyvalue Below Surface (S8) (**LRR K, L**)
- ___ Thin Dark Surface (S9) (**LRR K, L**)
- ___ Iron-Manganese Masses (F12) (**LRR K, L, R**)
- ___ Piedmont Floodplain Soils (F19) (**MLRA 149B**)
- ___ Mesic Spodic (TA6) (**MLRA 144A, 145, 149B**)
- ___ Red Parent Material (F21)
- ___ Very Shallow Dark Surface (F22)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? **Yes** ____ **No** X

Remarks:

Hydric soil indicators are not present; therefore, hydric soil criterion is not met.

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Appendix B
Representative Site Photographs

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PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 1	**Date:** 1/22/2016

Direction Photo Taken:

West

Description:

View towards Wetland N-1A. Photograph taken within existing distribution line ROW, to the west of the Newington Substation.



Photo No. 2	**Date:** 1/22/2016

Direction Photo Taken:

West

Description:

View of Wetland N-1A from delineation flag W2-18. Photograph taken on the western side of the Newington Substation Parcel, in Newington.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 3	**Date:** 5/15/2015

Direction Photo Taken:

West

Description:

View of the south side of the Newington Substation and fence line expansion area.

Newington Tap features are visible in the photo background.
Wetland N-1 is located at the base of the existing embankment.



Photo No. 4	**Date:** 5/15/2015

Direction Photo Taken:

South

Description:

View of the west side of the Newington Substation and fence line expansion area.

Wetland N-1 and Newington Tap features are visible in the photo background.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 5	**Date:** 6/23/2015

Direction Photo Taken:

Southeast

Description:

View of Wetland N-1 at the Newington Substation Site.



Photo No. 6	**Date:** 1/22/2016

Direction Photo Taken:

Southeast

Description:

View of Wetland N-1 and Intermittent Stream 1 (IS-1) on the Newington Substation parcel in Newington.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 7	**Date:** 6/23/2015

Direction Photo Taken:

Southeast

Description:

View of Wetland N-2. Wetland located along the existing distribution line ROW in Newington, CT to the east of Avery Road.



Photo No. 8	**Date:** 6/23/2015

Direction Photo Taken:

East

Description:

View of wetland N-3 along the existing distribution line ROW in Newington.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No. 9	**Date:** 6/23/2015

Direction Photo Taken:

East

Description:

View of Wetland N-4 in Newington. Willard Avenue is located on the opposite side of the steel lattice structures, which are part of the Willard Avenue Distribution Line Switching Station.



Photo No. 10	**Date:** 6/23/2015

Direction Photo Taken:

North

Description:

Wetland N-4 located along the existing distribution line ROW in Newington.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No.	**Date:**
11	08/01/16

Direction Photo Taken:

South

Description:

View of Perennial Stream P-1 (Unnamed Tributary to Piper Brook) in Newington. View is from Shepherd Drive.

Wetland N-5 is located on the right side of the photograph.



Photo No.	**Date:**
12	08/01/16

Direction Photo Taken:

South

Description:

View of Perennial Stream P-1 in Newington, downstream of Shepherd Drive.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No.	**Date:**
13	08/01/16

Direction Photo Taken:

North

Description:

View of Perennial Stream P-1 (Unnamed Tributary to Piper Brook) in Newington. View is upstream of Shepherd Drive.



Photo No.	**Date:**
14	08/01/16

Direction Photo Taken:

East

Description:

View of bridge abutment above Perennial Stream P-2 (Trout Brook) in West Hartford.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No. 15	**Date:** 09/01/16

Direction Photo Taken:

Southeast

Description:

View of Perennial Stream P-2 (Trout Brook) in West Hartford. Proposed crossing would be located within the elevated railroad ROW corridor.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No. 16	**Date:** 09/01/16

Direction Photo Taken:

East

Description:

View of Perennial Stream P-2 (Trout Brook) in West Hartford from the Amtrak ROW.

The Trout Brook and Piper Brook confluence is located in the background of this photograph. The South Branch of the Park River forms at this confluence.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No. 17	**Date:** 06/23/15

Direction Photo Taken:

Northwest

Description:

View of PS-3 (Unnamed Tributary to South Branch of Park River) culverted crossing beneath New Park Avenue in Hartford.

Access driveway to the Southwest Hartford Substation is on the left side of photograph



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No. 18	**Date:** 05/15/15

Direction Photo Taken:

Southeast

Description:

Southwest Hartford Substation main entrance and access drive. Proposed substation expansion area visible in photo.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No.	**Date:**
19	05/15/15

Direction Photo Taken:

South

Description:

PS-3 (Unnamed Tributary to South Branch of the Park River). Watercourse is located to the east and south of the Southwest Hartford Substation, downgradient of a steep embankment to the south and east of the access drive.

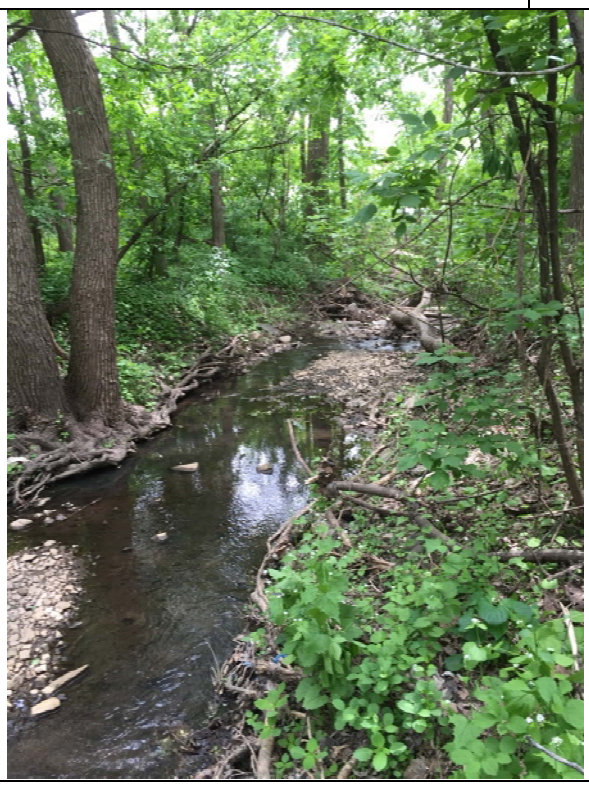


Photo No.	**Date:**
20	05/05/15

Direction Photo Taken:

Southwest

Description:

PS-3 (Unnamed Tributary to South Branch of the Park River) in the foreground and Wetland H-1 in the photo background.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No.	**Date:**
21	06/23/15

Direction Photo Taken:

Northwest

Description:

View of unnamed tributary to South Branch of Park River. The outfall is located downstream of crossing located beneath New Park Avenue.



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Appendix C
Resumes of AECOM Personnel

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Liam B. Bevan, PWS
Environmental Inspector

Education

MS, Geology (Hydrogeology), University of Massachusetts, College of Natural Science and Mathematics, 2014

BS, Geology, Wildlife and Fisheries Conservation (minor), University of Massachusetts, College of Natural Science and Mathematics, 2004

Years of Experience

11

Professional Affiliations

Society of Wetland Scientists

Massachusetts Association of Conservation Commissions

Association of State Wetland Managers

Training and Certifications

Basic Wetland Delineation and Northeast Regional Supplement Training

40 Hour OSHA HAZWOPER

Mr. Bevan has 11 years of professional and academic experience. He has a Bachelor of Science degree in Geology and a Master of Science degree in Geosciences (Hydrogeology) from the University of Massachusetts, Amherst. He has performed multiple hydrological and environmental studies involving soil, groundwater and surface water and has considerable experience overseeing environmental compliance during energy facility construction projects. Mr. Bevan has coordinated wetland delineation surveys and has prepared permitting documents in accordance with U.S. Army Corps of Engineers standards.

Experience.

Eversource, 348 Line Structure Replacement Project, Montville/Waterford, CT. Provided environmental compliance inspection services during the in-kind replacement of transmission structures along the existing 348 Line right-of-way. Services were provided in 2016. .

Northeast Utilities, Greater Springfield Reliability Project, MA and CT. Served as Environmental Inspector/Threatened and Endangered Species Monitor during the construction of 39 miles of new overhead electrical transmission lines and 13 substation and switching station upgrades. Responsibilities included project-wide federal and state regulatory compliance inspection (SWPPP & SPCP Conservation Management Plan), acting as liaison between the Project and the Connecticut Siting Council during third party inspections, performing a Project wide invasive plant inventory within delineated wetland boundaries, working with construction contractors to identify field conditions that may lead to non-compliance with federal and state permitting requirements and recommending mitigation measures as necessary. Services were completed between 2011 and 2013.

Northeast Utilities, Manchester to Meekville Junction Project, CT. Served as Environmental Inspector during the construction of 2.7 miles of new overhead electrical transmission lines and substation upgrades. Responsibilities included project-wide federal and state regulatory compliance inspection (SWPPP & SPCP Conservation Management Plan), served as liaison between the Project and the Connecticut Siting Council during third party inspections, performed a Project wide invasive plant inventory within delineated wetland boundaries, worked with construction contractors to identify field conditions that may lead to non-compliance with federal and state permitting requirements and recommend mitigation measures as necessary. Services were completed between 2011 and 2012.

Tennessee Gas Pipeline Company, Fitchburg Expansion Project, Lunenburg, MA. Served as Chief Environmental Inspector during the construction of 5.15 miles of new 12-inch high-pressure natural gas pipeline. Responsibilities included project-wide regulatory compliance during construction and erosion and sedimentation control inspection, construction oversight, serving as liaison between the Project Federal Energy Regulatory Commission and Massachusetts Department of Environmental Protection representatives. Services were completed in 2010.

Algonquin Gas Transmission, LLC, Ramapo Expansion Project, CT and NY. Served as Environmental Inspector for the development and construction of compressor stations, metering stations, wareyards and a 36" natural gas pipeline. Responsibilities included project-wide regulatory compliance inspection, construction oversight, serving as liaison between the Project Federal Energy Regulatory Commission, Connecticut Inland Wetlands Enforcement Agents, and the New York City Department of Environmental Protection Representatives. Services were completed in 2008.

Algonquin Gas Transmission, LLC, Cape Cod Lateral Pipeline Project, Bourne and Sandwich, MA. Served as Environmental Inspector/Threatened and Endangered Species Monitor for the development and construction of 3.5 miles of new 18" high-pressure natural gas pipeline. Responsibilities included radio telemetry and GPS monitoring of a population of eastern box turtles (*Terrapene carolina*) using radio telemetry tagging and tracking techniques as well as GPS, implementation of MA NHESP and approved turtle protection program during construction during construction in compliance with the project Construction Management Plan, project-wide regulatory compliance inspection, construction oversight, serving as project liaison to the Federal Energy Regulatory Commission during compliance inspections. Services were completed in 2007.

Tennessee Gas Pipeline Company/Kinder Morgan, Northeast Energy Direct Pipeline Project, MA & NY. Served as Environmental Coordinator for wetland and threatened and endangered species surveys for a 420 mile interstate natural gas pipeline project. Responsibilities included wetland and biological survey data management and auditing for quality control per project standard operating procedures and in accordance with U.S. Army Corps of Engineers guidelines, providing technical training to GPS technicians as well as health and safety training for other project personnel, initiation of federal and state agency consultations in support of environmental permitting efforts, developing Resource Reports for submittal to the Federal Energy Regulatory Commission, assisting with wetland delineations in accordance with U.S. Army Corps of Engineers standards and developing technical memoranda related to the constructability of transmission facilities with respect to sensitive environmental resources. Services were provided from 2014 to 2016.

Eversource, 1620/1975 Line Rebuild Project, Haddam, CT. Provided wetland delineations and mapping services, supported USACE permitting efforts and coordinated endangered species consultations for the replacement of 59 structures along 7.9 miles of existing electrical transmission right-of-way. Services were provided in 2016

Industrial and Commercial Properties - Phase I, II and III Environmental Site Assessments and Remediation Oversight, RI, CT, MA and NY. Served as Field Geologist for groundwater and soil contamination investigations at commercial and industrial sites. Responsibilities included the execution of Phase I Environmental Site Assessments for industrial and commercial properties in accordance with Connecticut Transfer Act requirements as well as ASTM E-1527-13, remediation system operation and maintenance, groundwater, surface water and soil sampling, soil boring, soil characterization and groundwater monitoring well installation, spill response oversight, supervision of underground storage tank and appurtenant system decommissioning, Phase II and III environmental site assessment execution and reporting, remediation site audits and hydrological data reviews, EPA - Screening Level Ecological Risk Assessment preparation.

Scott Egan, MS, CPSS
Wetland and Wildlife Ecologist

Education

MS, Natural Resources Science, University of Rhode Island

BS, Plant and Soil Sciences, University of Massachusetts

AAS, Landscape Contracting, Stockbridge School of Agriculture

Years of Experience

25

Professional Affiliations

Society for Conservation Biology

Soil Science Society of America

Training and Certifications

Certified Professional Soil Scientist (CPSS # 21734)

Mr. Egan has 25 years of professional and academic experience. He has a Bachelor of Science in plant and soil sciences from the University of Massachusetts and a Master's degree in natural resources science from the University of Rhode Island. He has performed multiple ecological and environmental studies involving wildlife, wetlands, stream, lake, and watershed topics. Mr. Egan's abilities include wetland delineations and evaluations, wetland restoration design, construction and monitoring, wetland permitting, vegetation surveys, and wildlife habitat assessments including long-term radio telemetry studies of rare state-listed turtle species, drift-fence surveys to monitor amphibian population dynamics, and development of conservation and management plans. He is a Certified Professional Soil Scientist under the American Society of Agronomy. He is also proficient in the use of ESRI ArcGIS, and associated extensions for map production and spatial analyses. His Master's thesis included conducting a 2.5-year field research program that investigated within-pond and landscape-level factors influencing the breeding effort of two amphibian species, wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*) within 136 potential breeding ponds. The results of this research have been published by peer-reviewed journals of the Society of Wetland Scientists, Herpetological Review and the Society for the Study of Amphibians and Reptiles.

Experience

University of Rhode Island, Habitat Use by Pond-breeding Amphibians, Rhode Island. Conducted a 2.5-year field research program that investigated within-pond and landscape-level factors influencing the breeding effort of two amphibian species, wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*) within 136 potential breeding ponds. Responsibilities included overall study design and implementation, photographic interpretation and development of standardized sampling protocols for amphibians, aquatic macro-invertebrates, and vegetation composition, and all spatial and statistical analyses using ArcGIS and various computer software programs.

United States Navy, Rare Turtle Population and Habitat Study, Weymouth, MA. Designed and implemented a long term mark-recapture program from 1999 through 2007 to assess population demographics, habitat use, and home range of rare turtle species; the spotted turtle (*Clemmys guttata*), and the eastern box turtle (*Terrapene carolina*), in preparation for remedial construction efforts led by the US Navy.

Construction Oversight and Monitoring, Weymouth, MA. Implemented Construction Period Monitoring and Protection plans designed to protect state-listed turtle species during remedial activities including closure and capping of a 6-acre landfill, construction of a new ~7300-linear foot parkway, and construction of box turtle Habitat Management Areas located within Priority Habitat. Worked with the US Navy, and two different design-build teams to complete this work in compliance with Natural Heritage and Endangered Species Program state-issued permits.

Northeast Utilities, Interstate Reliability Project, CT. In preparation of a proposed power line expansion/reliability project, wetland delineations, habitat evaluations and

vernal pool surveys along roughly 28 miles of existing rights-of-way were conducted. In addition, biological, wetland, and certified soil scientist reports were prepared in support of project permitting with the CTDEEP.

Northeast Utilities/NSTAR, Rare Turtle Population Survey, Southeastern, MA. Conducted canine assisted field surveys, and radio-telemetry tracking of Eastern Box Turtles (*Terrapene carolina*) and Wood Turtles (*Glyptemys insculpta*) in preparation for tree clearing activities along approximately 2.5 miles of right-of-way. Surveys and radio transmitters were necessary to identify hibernation locations to be avoided during timing-restricted winter tree clearing activities.

Northeast Utilities, Rare Turtle Population Monitoring, Agawam, MA. Conducted canine assisted field surveys, radio-telemetry tracking and oversight to protect Eastern Box Turtles (*Terrapene carolina*) during construction of an electrical reliability project. Project included an analysis of alternatives, impact avoidance and minimization, and net benefit, and development and implementation of an NHESP approved turtle protection plan.

Northeast Utilities, Environmental Inspector, Agawam and Springfield, MA. Provided environmental inspection/construction management services for compliance with federal and state permit conditions for approximately 11-miles of new 345-kilovolt (kV) and upgraded 115-kV overhead electric transmission structures. Responsibilities included SWPPP inspections for wetland and water resource protection, rare species habitat protection and monitoring, and protection of archeological/historical sites.

Northeast Utilities System, Vernal Pool Assessment and Habitat Evaluation, Wilbraham, MA. During alternatives assessment for construction of a proposed electrical reliability project, a single season evaluation of fourteen vernal pools for the presence of state-listed blue-spotted salamanders (*Ambystoma laterale*) was conducted. Surveys included dip-net sweeps through appropriate habitat, egg mass counts and an extensive 5-week trapping program (n = 104 minnow traps).

National Grid, I-135N Reconductoring Project, Fitchburg, MA to Walpole, NH. Conducted wetland delineations and habitat evaluations, and worked with state Natural Heritage Programs to address potential impacts to state-listed species in preparation for upgrading a 115-kV overhead electric transmission line. Developed construction plans identifying sensitive resource areas in ArcGIS, and conducted weekly SWPPP inspections of access routes and work zones to ensure protection of those resources.

Kinder Morgan Company, Connecticut Expansion Project, Agawam, MA to East Granby, CT. In preparation for a proposed gas line expansion project, wetland delineations, habitat evaluations and vernal pool surveys along 10 miles of existing pipeline corridor were conducted. Prepared components of state permit application to CTDEEP including project specific wetland delineation and certified soil scientist reports.

Williams Companies, Constitution Pipeline Project, PA and NY. Performed federal wetland/waterbody delineations and invasive species mapping along 126-miles of proposed natural gas pipeline right-of-way within Pennsylvania and New York and assisted with comprehensive federal environmental permitting services for the proposed installation of new 30-inch natural gas pipeline in New York.

Massachusetts Electric Company, Wetland Delineation, and Evaluation, Merrimack Valley District, MA. Conducted wetland delineations and modified project plans to include jurisdictional resource areas for numerous transmission (115kV and 34.5kV) and distribution line (13kV, 23kV) pole replacement and reconductoring, new pole installation, and duct bank installation projects in Georgetown, Groveland, Haverhill, Newburyport, North Andover, and Rowley, Massachusetts.

Timothy P. O'Sullivan, MS, PWS
Project Manager
Wetland and Wildlife Biologist

Education

MS, Wetlands Conservation, University of Massachusetts

BS, Environmental Science, University of Maine

AS, Natural Resources, Finger Lakes Community College

Years of Experience

18

Professional Affiliations

Professional Wetland Scientist, Society of Wetland Scientists

Registered Soil Scientist, The Society of Soil Scientists of Southern New England

Xi Sigma Pi , Forest Resources Management Academic Honor Society

Massachusetts Association of Wetland Scientists

Connecticut Association of Wetland Scientists

Training and Certifications

Professional Wetland Scientist (PWS) #1389

Mr. O'Sullivan is a Project Manager in AECOM Environment's Impact Assessment and Permitting group. Mr. O'Sullivan has been working in the linear permitting industry in the Northeast for seventeen years and has assisted in the successful permitting of electric transmission and natural gas pipeline projects for a variety of clients including Eversource Energy, Algonquin Gas Transmission, Tennessee Gas Pipeline Company, and Iroquois Gas. Mr. O'Sullivan is currently serving as the Project Manager for Eversource's Stamford Reliability Cable Project and the Interstate Reliability Project and has served as Project Manager and Task Manager for the Greater Springfield Reliability Project. Previous tasks/assignments include environmental report preparation and permitting under the Connecticut Siting Council (CSC), Connecticut Department of Energy and Environmental Protection, Massachusetts Department of Environmental Protection, Rhode Island Department of Environmental Management, and United States Army Corps of Engineers for a variety of energy transmission projects. Mr. O'Sullivan has a broad range of experience regarding the analysis of local, state, and federal regulations and coordination of the regulatory permitting processing at the federal, state, and local levels.

Experience

Eversource Energy Interstate Reliability Project, Connecticut. Mr. O'Sullivan served as the project manager for environmental report preparation and permitting under the Connecticut Siting Council, Connecticut Department of Energy and Environmental Protection, United States Army Corps of Engineers, and municipal review processes. Now that the Project is under construction, he is AECOM's project manager for the environmental inspection component of the Project. The Project consists of the construction of an approximately 30 mile 345-kV transmission line in northeastern Connecticut.

Northeast Utilities Service Company Greater Springfield Reliability Project, Massachusetts and Connecticut. Mr. O'Sullivan served as the project manager for environmental report preparation and permitting under the Connecticut Siting Council, the Massachusetts Energy Facilities Siting Board, Connecticut Department of Energy and Environmental Protection, Massachusetts Department of Environmental Protection, United States Army Corps of Engineers, and municipal review processes. The Project consisted of the construction of approximately 36 miles of 345-kV transmission line in Connecticut and Massachusetts.

Northeast Utilities Service Company Stamford Reliability Cable Project, Stamford Connecticut. Mr. O'Sullivan served as the project manager for environmental report preparation and permitting under the Connecticut Siting Council. In conjunction with the larger Project Team he was responsible for the Municipal Consultation Filing, the CSC Application and the Development and Management Plan. Mr. O'Sullivan is currently managing the environmental inspection component of the Project.

Northeast Utilities Service Company East Hartford 115-kV Transmission Project, East Hartford, Manchester & Hartford Connecticut. Mr. O'Sullivan served as a project technical specialist and assistant project manager for environmental report preparation and permitting under the Connecticut Siting Council, Connecticut Department of Environmental Protection, United States Army Corps of Engineers, and municipal review processes. The Project consisted of the construction of an approximately 3-mile 115-kV linear transmission line and associated substation work in Hartford, East Hartford, and Manchester.

Northeast Utilities Service Company Hartford Cables Project, Hartford, Connecticut. Mr. O'Sullivan served as a project technical specialist and assistant project manager for environmental report preparation and permitting under the Connecticut Siting Council, Connecticut Department of Environmental Protection, United States Army Corps of Engineers, and municipal review processes. The Project consisted of the construction of approximately 7-miles of underground 115-kV linear transmission cables and associated substation improvements within the City of Hartford.

Northeast Utilities Service Company, Oxford Substation Project, Oxford, Connecticut. Mr. O'Sullivan served as the project specialist for permitting a new substation in the Town of Oxford Connecticut under Connecticut Siting Council requirements, Connecticut Department of Environmental Protection permitting, United States Army Corps of Engineers permitting, and municipal review processes.

Algonquin Gas Transmission, LLC, Ramapo Expansion Project, Rockland County, New York, Putnam County, New York, Morris County, New York and New Haven County, Connecticut. Mr. O'Sullivan served as the project specialist for permitting under Federal Energy Regulatory Commission requirements, United States Army Corps of Engineers permitting, various state environmental agency permitting, and multiple municipal agency review processes. The Project consists of replacement approximately 5.00 miles of existing 26-inch outside diameter ("OD") pipeline with 42-inch OD pipeline; miscellaneous pipeline modifications and meter station modifications; modifications to two existing natural gas compressor stations and one existing compressor station; and construction of one new natural gas compressor station.

New England Power Company, Circuit S-19 Transmission Line Refurbishment. Mr. O'Sullivan served as Assistant Project Manager/Senior Wetland Scientist for refurbishment of 12 miles of 69kV overhead electric transmission line in Central, Massachusetts. Phase I activities included completion of: wetland delineation and identification of stream crossings and vernal pools habitats; regulatory review to identify special designations or sensitive habitats; field location of primary and secondary construction access routes and recommendations for the use of swamp mats; environmental permitting assessment to determine regulatory implications, permitting needs, and available maintenance exemption provisions; and updating of New England Power T-Sheets to depict boundaries of wetlands, waterways, buffer zone, and construction access routes. Phase II activities include preparation of: federal and state consultation letters; agency liaison with local conservation commissions; preparation of permit application filings; preparation of wildlife/rare species mitigation plans; and construction environmental monitoring during construction.

Algonquin Gas Transmission Company 36-Inch Pipeline Looping Project, Connecticut. Mr. O'Sullivan Provided project management, field survey protocols, delineated wetlands, conducted habitat assessments and prepared reports and permit applications, and construction inspection for an 8.9 mile pipeline looping project.

Avian Survey, Long Island, New York. Conducted Aerial and Boat field surveys over multiple years establishing baseline avian utilization of an approximately fifty square mile area of the Atlantic Ocean off the south shore of Long Island, New York for a proposed wind park. Bird identification determined mainly through direct observation.

Avian Survey, Dedham-Westwood Massachusetts Water District, Fowl Meadow Wetland Public Water Supply Well Sites. Conducted field surveys over multiple years in various wetland cover types, establishing pre and post water withdrawal avian utilization of the Fowl Meadow wetland system. Bird identification was determined using auditory cues such as songs and calls as well as direct observations. Prepared reports for appropriate regulatory authorities.

Northeast Utilities Service Company, Rare Turtle Population Study, Massachusetts. Conducted field surveys and radio-telemetry tracking for Eastern Box Turtles (Terrapene carolina) from 2009 through 2010 in preparation for an electrical reliability project. All turtles were outfitted with radio-transmitters to identify critical habitats prior to commencement of construction. Prepared the Conservation and Management Plan (CMP) including alternatives analysis, avoidance and minimization, mitigation, net benefit analysis, and an Eastern Box Turtle Protection Plan. During 2011-2013, AECOM implemented the NHESP approved turtle protection plan. All work was conducted in compliance with the CMP and no project related turtle mortalities were documented.

Spotted Turtle (*Clemmys guttata*) and Box Turtle (*Terrapene carolina*) Radio Tracking and Habitat Study, South Weymouth, Massachusetts. Conducted field surveys, radio telemetry tracking, and trapping activities to document spotted turtle and box turtle habitat utilization at a Naval Air Station in Eastern Massachusetts to facilitate the least damaging remediation options at several CERCLA sites. Documented characteristics of habitat utilized by spotted and box turtles. Prepared reports for appropriate regulatory authorities.

Spotted Turtle (*Clemmys guttata*) Radio Tracking and Habitat Study, New Bedford Massachusetts. Conducted field surveys, radio telemetry tracking, and trapping activities to document spotted turtle habitat utilization at the New Bedford Regional Airport for a master plan and an environmental impact statement. Documented characteristics of habitat utilized by spotted turtles. Prepared reports for appropriate regulatory authorities.

Spotted Turtle (*Clemmys guttata*) Habitat Assessment, Waltham, Massachusetts. Performed a habitat evaluation on a fifty (50) acre site in reference to spotted turtles. Data was collected relative to important wildlife functions (feeding, basking, breeding, over-wintering, shelter, escape cover, and migration) potentially provided for the spotted turtle. Information pertaining to the hydrology, micro-topography, and vegetative composition and structure was also collected. Prepared report for appropriate regulatory authorities.

Bog Turtle (*Clemmys muhlenbergii*) Habitat Assessment, Dover, New York. Performed a habitat evaluation on a forty-five (45) acre site in reference to bog turtles. Data was collected relative to important wildlife functions (feeding, basking, breeding, over-wintering, shelter, escape cover, and migration) potentially provided for the bog turtle. Information pertaining to the soils, hydrology, micro-topography, and vegetative composition and structure was also collected. Prepared report for the U.S. Fish and Wildlife Service and New York State Department of Environmental Conservation.

Bog Turtle (*Clemmys muhlenbergii*) Habitat Assessment, Stony Point, New York, South East, New York, Ramapo, New York, Haverstraw, New York. Performed habitat evaluations on multiple sites in reference to bog turtles. Data was collected relative to important wildlife functions (feeding, basking, breeding, over-wintering, shelter, escape cover, and migration) potentially provided for the bog turtle. Information pertaining to the soils hydrology, micro-topography, and vegetative composition and structure was also collected. Assisted in the preparation of reports submitted to the U.S. Fish and Wildlife Service.

Vernal Pool Habitat and Amphibian Studies, Norfolk, MA and Bedford, MA, Worcester, MA. Conducted habitat studies and qualitative population studies of multiple vernal pools to determine amphibian populations, and investigate for rare species. Installed, maintained, and monitored approximately 600 meters of drift fence traps. Recorded the presence of reptiles and amphibians, identified aquatic invertebrates and documented general habitat characteristics as well as physical and chemical conditions in the pools. Prepared report for appropriate regulatory

authorities.

Rare Species Habitat / Vernal Pool Assessment, Upton, Massachusetts. Investigated 164 acre parcel, portions of which were mapped as habitat for several state listed species. Data was gathered in upland and wetland habitats relative to important wildlife functions potentially provided for the listed species. Investigations included habitat type characterizations, generation of plant species lists, and dip net surveys of two (2) certified vernal pools.

Vernal Pool Monitoring, Worcester, Massachusetts. Collected baseline data relative to biological and hydrologic conditions in four (4) certified vernal pools. Collected hydrologic data using staff gauges and monitoring wells. Collected water quality data including pH, conductivity, turbidity, and dissolved oxygen. Collected biological data through weekly dip net surveys. Documented baseline conditions for comparison to post development conditions within the vernal pools.

Oxford Green Development, Oxford, Connecticut. Delineated wetlands on over 700 acres of land for golf course development. The delineations were conducted in accordance with the Connecticut Inland Wetlands and Watercourses Act and the federal procedures utilizing the Corps of Engineers Wetland Delineation Manual. Assisted in the compilation of the master vegetation list.

Cigna Corporation, Bloomfield, Connecticut. Delineated wetlands on over 200 acres of land. Delineations were conducted in accordance with the Connecticut Inland Wetlands and Watercourses Act and federal procedures utilizing the Corp of Engineers Wetland Delineation Manual.

PolyMet Corporation, Aurora Minnesota. Ground-truthed aerial photographs for wetland/upland Boundaries on a seven thousand acre parcel in northern Minnesota. Wetland boundaries were investigated on the ground as well as from a helicopter, with reference to the Army Corp of Engineers Wetland Delineation Manual.

Wetland Delineations: Agawam, Bedford, Concord, Douglas, Greenfield, Sandisfield, Sturbridge, Tyringham, Stoughton, Wilmington, Massachusetts. Delineated Wetlands on sites varying in size from one to several hundred acres in accordance with federal procedures utilizing the Army Corp of Engineers Wetland Delineation Manual and the State of Massachusetts DEP Manual, Delineating Bordering Vegetated Wetlands.

Wetland Replication Area Design and Monitoring: Agawam, MA, East Hartford CT, Vernon CT, Bloomfield CT, Bedford MA, Weymouth MA, Saugus MA. Designed and monitored construction and planting of wetland replication areas varying in size from 2,000 square feet up to two acres for a wide range of clients as compensation for filling of on-site wetlands. Investigated and documented the conditions of the vegetation, soil, and surface hydrology of wetland replication areas. Generated plant species lists, documented wildlife utilization and prepared reports for submission to applicable regulatory authorities.

Molly Notestine, PWS

Senior Wetland Ecologist

Education

MS, Plant, Soil, and Insect Sciences, University of Massachusetts, Amherst

BS, Resource Ecology and Management, University of Michigan, Ann Arbor

Technical Specialties

Wetland and Terrestrial Ecology

Threatened Endangered and Species

Preparation of environmental documents pursuant to NEPA, Endangered Species Act, and Clean Water Act

Federal, State, and Local Environmental Inland and Coastal/Waterfront Permitting (NEPA, CWA 404 & 401, USFWS)

FERC Permitting

Wetlands Mitigation and Ecological Restoration

Wetlands Delineation, Functions and Values Assessments

Professional Affiliations

Society of Wetland Scientists

Entomological Society of America

Training and Certifications

Professional Wetland Scientist

OSHA 40-Hour Health and Safety Certification (HAZWOPER)

FEMA National Environmental Policy Act and National Historic Preservation Act Training

FERC Environmental Review and Compliance for Natural Gas Facilities Training

Ms. Notestine is a Professional Wetland Scientist (PWS) responsible for conducting environmental/ecological field studies, environmental permitting, documentation and reporting, regulatory agency coordination and meetings, and quality assurance/quality control on public and private utility and infrastructure projects throughout the United States.

Ms. Notestine has extensive experience permitting natural gas pipeline projects with the Federal Energy Regulatory Commission (FERC). Her FERC filing experience includes Prior Notice Blanket Certification, Conventional 7(c) filings, and FERC's 7(c) National Environmental Policy Act (NEPA) Pre-Filing Process. Her responsibilities include oversight of all environmental studies and field surveys and coordination with regulatory agencies including US Army Corps of Engineers (USACE), US Fish and Wildlife Service (USFWS), US Environmental Protection Agency (EPA), and state and local offices. She has a broad understanding of NEPA regulations and has filed numerous Categorical Exclusions (CATEXs) and has served as a primary author on multiple NEPA Environmental Assessments (EAs) and as contributing author on several Environmental Impact Statements (EISs).

Ms. Notestine has a diversified background in environmental services and is experienced in wetland delineations, wetland functional assessments, wetland restoration and mitigation, invasive species control, erosion and sedimentation control methods, construction monitoring, research, and agency consultation. She is well versed in report writing, data organization, and environmental project coordination.

Representative Projects

Kinder Morgan Northeast Energy Direct Pipeline, FERC-Regulated Project, Multiple Northeastern States. Served as one of the State Permitting Leads and was responsible for assisting with public meetings, agency consultation, wetlands delineation, rare species coordination, and Federal, state, and local environmental permitting for the portion of the project through Massachusetts. Assisted with preparation of the FERC Environmental Resource Reports in support of certificating the project via the FERC 7(c) process.

National Grid LNG, Fields Point Liquefaction Project, FERC-Regulated Project, Providence, Rhode Island. Served as an author of the FERC Environmental Resource Reports in support of certificating the Project via the FERC 7(c) process. Contributions to this project, located within the City of Providence, were focused on socioeconomics and environmental justice issues.

Spectra Energy Partners, LP 2016 Penn Jersey Integrity Project, Multiple Counties across Pennsylvania. Served as an Environmental Specialist responsible for performing wetland delineations and environmental surveys across remote, rough terrain in support environmental permitting required for approximately 550 anomaly investigations along Spectra Energy's right-of-way under the Pennsylvania Programmatic General Permit.

Eversource, Greater Hartford – Central Connecticut Reliability Project, Hartford, Connecticut. Served as an Environmental Permitting Specialist responsible for performing wetland delineations and environmental surveys and authoring the existing conditions and wetland delineation report for this project involving a proposed underground connection between two substations and other utility improvements.

AECOM

Prior Experience – Hatch Mott MacDonald, Holyoke, Massachusetts

National Fuel Gas, West-to-East Overbeck to Leidy Pipeline, FERC-Regulated Project, 80 Miles of 24-inch Natural Gas Pipeline in Multiple Counties, PA Served as an Environmental Project Coordinator responsible for agency consultation, research, site/route selection, wetlands delineation, rare species coordination, and Federal, state, and local environmental permitting. In support of the FERC 7(c) NEPA Pre-Filing process, HMM coordinated early in the Project schedule with multiple Federal and state agencies, representatives from Federal and state forests and park lands, and coordinated public meetings. Prepared FERC Environmental Resource Reports in support of certificating the Project with FERC. The project involved the construction of 80 miles of new 24-inch natural gas pipeline across multiple counties in central Pennsylvania, including multiple National and State Forest crossings.

Eastern Shore Natural Gas, Greenspring Expansion Project, FERC-Regulated Project, 11 Miles of 16-inch Natural Gas Pipeline in DE. Served as the Environmental Project Coordinator responsible for overseeing all aspects of agency consultation, background research, route selection, wetlands delineation, rare species coordination, coordination of cultural resources and endangered species subconsultants, and Federal, state, and local environmental permitting. In support of a Conventional 7(c) FERC filing, drafted and finalized FERC Environmental Resource Reports and coordinated multiple responses to public comments. Project involved installation of 11 miles of natural gas pipeline across multiple small towns in coastal Delaware.

Millennium Pipeline Company, Minisink Compressor Project, FERC-Regulated Project, Construction of New Compressor Station in Minisink, NY. Served as an Environmental Project Coordinator responsible for assisting with agency consultation, research, wetlands delineation oversight, rare species coordination, and Federal, state, and local environmental permitting. In support of a Conventional 7(c) FERC filing, drafted and finalized FERC Environmental Resource Reports, coordinated responses to public comments, and assisted with public open houses. Project involved the construction of a new compressor station site in a semi-rural area of New York.

Eastern Shore Natural Gas, Worcester County Extension Project, FERC-Regulated Project, - 20 Miles of 16-inch Natural Gas Pipeline in DE & MD. Served as the Environmental Project Coordinator responsible for overseeing agency consultation, background research, route selection, wetlands delineation, rare species coordination, and Federal, state, and local environmental permitting. In support of a FERC Prior Notice Filing, prepared the FERC Prior Notice documentation. Project involved installation of 20 miles of natural gas pipeline along a highway right-of-way in Delaware. All wetland and stream impacts were avoided by utilizing the horizontal directional drill method at all wetland and stream crossings.

National Fuel Gas - Empire Tioga Pipeline, FERC-Regulated Project, Tioga County Extension Project - 17 Miles of 24-inch Natural Gas Pipeline in NY & PA. Served as the Environmental Project Coordinator with responsibilities in all aspects of agency consultation, background research, route selection, wetlands delineation oversight, rare species coordination, coordination of cultural resource subconsultant, and Federal, state, and local environmental permitting. In support of the FERC 7(c) NEPA Pre-Filing process, drafted and finalized FERC Environmental Resource Reports and coordinated multiple responses to public comments. Coordinated the applicant-prepared draft Environmental Assessment in support of certificating the Project with FERC. The project consisted of the installation of 17 miles of 24-inch natural gas pipeline across rural counties in New York and Pennsylvania.

Talisman Energy Inc. - Multiple Gas Gathering and Treatment Projects, Multiple Counties throughout Texas. Served as the Environmental Project Coordinator responsible for environmental oversight and management of all ongoing Talisman projects, including coordination of numerous environmental subconsultants. Served as a liaison between Talisman and the subconsultant representatives, providing direction on agency regulations and consultations and review of project documentation, reports, and permit applications for multiple (100+) projects across south Texas.

Antero Resources Appalachian Corporation, White Oak Gathering Line Project, 21 Miles of 20-inch Gathering Line in Ritchie and Doddridge Counties, WV. Served as an Environmental Project Coordinator responsible for all aspects of agency consultation, research, wetlands delineation oversight, rare species coordination, cultural resources coordination, and Federal, state, and local environmental permitting, including floodplain permitting. In support of USACE Nationwide Permit Pre-Construction Notification Process, prepared and submitted all necessary permit documents, project mapping, and erosion and sediment control drawings and plans. The projects consisted of the installation of 21 miles of 20-inch natural gas pipeline across rural rugged terrain in Ritchie and Doddridge Counties, West Virginia.

Antero Resources Appalachian Corporation, Multiple Midstream/Gathering Projects, 20+ Miles of 16-inch Gathering Line in WV. Served as an Environmental Project Coordinator responsible for all aspects of agency consultation, research, route selection, wetlands delineation oversight, rare species coordination, cultural resources coordination, and Federal, state, and local environmental permitting for approximately 10 natural gas midstream/gathering projects for Antero Resources. Prepared and submitted all necessary permit documents, Project mapping, and erosion and sediment control drawings and plans. The projects consisted of the installation of 20+ miles of 16-inch natural gas pipeline across multiple rural counties in West Virginia.

Kyle Purdy

Environmental Permitting Specialist and Wetlands Scientist

Professional History
AECOM
Practical Applications, Inc.
C.T. Male Associates, P.C.

Education
BS, Biology, State University of New York at Oneonta

Licenses and Registrations
CPESC # 5049

Experience

Mr. Purdy has 8 years of professional experience. He has a Bachelor of Science degree in biological sciences from the State University of New York at Oneonta. He has performed multiple ecological and environmental studies involving wildlife, wetlands, stream, lake, and watershed topics. Mr. Purdy's abilities include wetland delineations and evaluations, wetland restoration design, construction and monitoring, wetland permitting, vegetation surveys, wildlife habitat assessments, stormwater site examinations, air quality monitoring, environmental compliance inspections, environmental monitoring of wetland creation and construction observation of wetland mitigation projects. He is a Certified Professional in Erosion and Sediment Control. He is also proficient in the use of ESRI ArcGIS, and associated extensions for map production and spatial analyses.

Select Projects

State Division of Military and Naval Affairs; Guilderland, New York.
Performed wetland delineation review work of proposed bridge replacement; formulated site location, state and federal wetland, soils, archeosensitive, short-nosed sturgeon species range and floodplain mapping. Delineation work was completed in accordance with USACOE and NYSDEC permit conditions. Field reviews included characterizing vegetation, soils, ordinary high water mark of the Norman's Kill and the presence of invasive species on the created or restored wetland project sites. Summary reports that were prepared included a sketch map, photo documentation, a discussion of field conditions at the wetland mitigation site and recommendations for the site before undergoing bridge reconstruction.

Luther Forest Technology Campus, Saratoga, New York.
Assisted in mitigation plan of the Electric Transmission Line including performed monitoring well data of groundwater height, engineering of weir system, test pit logs and ground level water data, air quality monitoring, threatened and endangered species field review.

Lowe's of Oneonta; Oneonta, New York.
Field reviews included characterizing vegetation, soils, and the presence of invasive species in the created wetland once construction had been completed. Wrote Post-Construction Monitoring Plan that provided photo documentation of the project site after construction, a detailed description of field design modifications that occurred during construction, an itemized list of plant species and quantities that were installed on the project site as of the date of the monitoring report, conducted biannual monitoring visits on site to assess success of wetland and stream mitigation activities.

Wheelabrator, Shrewsbury Landfill; Shrewsbury, Massachusetts.

Conducted wetland delineation and habitat evaluation within the Phase III portion of the landfill site. Located flagging utilizing GPS equipment and prepared representative mapping of the site.

Julia A. Stearns

Wetland Scientist

Education

B.A. (Coastal Zone Managment) University of Rhode Island
(Graduate Level Course work in Wetland Science) University of Massachusetts, Amherst
(Graduate Level Course work in Natural Resouces) University of Rhode Island

Training and Certifications

US Army Corps of Engineers Wetlands Delineator Certification Program Training
40-Hour General On-Site Staff Certification Program, Hazardous Waste Operator and Emergency Response

Technical Specialties

Wetland Delineations
Threatened and Endangered Species Surveys
Global Positioning Systems (GPS)
Geographical Information Systems (GIS)
Stream Ecosystem Assessment
Biological Monitoring
Biological Sampling

Ms. Stearns is a Senior Wetland Scientist working for AECOM's Design and Consulting Services/Natural Resource Studies with 18 years of professional environmental consulting experience focusing on environmental permitting, wetlands assessment/ecological restoration/biological surveys in support of energy transmission, industrial, and transportation projects. Ms. Stearns manages projects that involve federal, state and local wetland and environmental permitting and provides support for larger, complex projects, as well as development and transportation projects. On such projects she provides support in site environmental permitting, wetland restoration and mitigation design, construction and biological surveys and monitoring as well as post-construction monitoring. Ms. Streans is proficient in Global Positioning System (GPS), Geographical Information Systems (GIS) technologies, wetland delineations, and biological surveys.

Experience

Massachusetts Department of Transportation – Highway Division Bridge V Add-a-Lane Project. Conducted environmental field surveys, GPS survey, and natural resource data collection and permitting. Wetland and wildlife surveys including vernal pool species identification and wetland delineations for the widening of I95 in Needham and Wellesley Massachusetts. Ms. Stearns provides monitoring of highway construction and construction of mitigation and restoration activities as required by federal (Section 404), state (Section 401 Water Quality Certificate) as well as local Order of Conditions.

Kinder Morgan Company, Connecticut Expansion Project, Bethlehem, NY, and Agawam, MA to East Granby, CT. In preparation for a proposed gas line expansion project, wetland delineations, habitat evaluations and vernal pool surveys along 10 miles of existing pipeline corridor were conducted. Prepared components of state permit application to CTDEEP including project specific wetland delineation and certified soil scientist reports.

Eversource Energy Interstate Reliability Project (IRP) - CT & Greater Springfield Reliability Project (GSRP) – CT/MA. Conducted environmental field surveys, endangered species monitoring during construction, natural resource data collection and permitting. Wetland and wildlife surveys including vernal pool identification, wetland delineations and threatened and endangered species surveys and monitoring for the installation of new 345-kV transmission lines, including expansion of existing substations and rebuilds of existing 115-kV transmission lines in Connecticut and Massachusetts. Provided support for federal, state and local permitting, as well as filings with the Connecticut Siting Council and the Massachusetts Energy Facilities Siting Board.

Eversource Energy 1990 Structure Replacement Project. Mr. Stearns conducted field surveys and wetland and watercourse delineations in support of environmental report preparation and permitting under the Connecticut Siting Council, Connecticut Department of Energy and Environmental Protection, United States Army Corps of Engineers, and municipal review processes. The Project consists of replacing aging steel structures over a 20-mile section of overhead transmission line with new steel pole structures.

Eversource Energy East Hartford 115-kV Transmission Project, East Hartford, Manchester & Hartford Connecticut. Ms. Stearns assisted with environmental report preparation and permitting under the Connecticut Siting Council, Connecticut Department of Environmental Protection, United States Army Corps of Engineers, and municipal review processes. The Project consisted of the construction of an approximately 3-mile 115-kV linear transmission line and associated substation work in Hartford, East Hartford, and Manchester.

Northeast Utilities, Vernal Pool Surveys, Interstate Project. Conducted vernal pool surveys of the entire right-of-way to identify wetland areas being utilized as breeding habitat by obligate vernal pool organisms. Visual observation surveys and dip-netting were used to locate and identify obligate vernal pool species egg masses and larvae. Morphological characteristics of each vernal pool area and corresponding obligate species information were recorded.

Northeast Utilities, Marine and Environmental Monitoring, Long Island Sound. Daily monitoring of construction activities as they pertained to environmental and water quality issues affected during the removal of seven utility cables across Long Island Sound, from Northport, New York to Norwalk, Connecticut. Monitoring included daily inspection and reporting of construction site/barge for potential environmental and water hazards, informing construction managers of all potential issues, and reporting incidents to project managers as well as construction managers.

Block Island Deepwater Wind Project, Block Island Power Company. Ms. Stearns conducted wetland delineations, coastal resources delineations, rare species and wildlife surveys as well as environmental and natural resource data collection for permitting. Ms Stearns conducted report and permit preparations for the installation of new transmission lines off the coast and inlands areas of southern Rhode Island.

Army Corps Facilities, Permitting, Rutland, Vermont. Participated with team assisting Unites States Army Reserve 99th Regional Support Command in their implementation of BRAC05 Realignment Actions in Rutland, Vermont. Primary responsibilities included: 1) delineation of all wetland systems on a 104-acre property and 2) development and submittal of a CWA Section 404 Category 2 Permit Application to the Army Corps of Engineers Regulatory in Vermont, regarding the proposed United States Army Reserve 99th Regional Support Command site development for new support facilities and grounds in Rutland, VT.

Kristoffer J. van Naerssen

Environmental Scientist – Water & Natural Resources

Professional History

ENSR/AECOM Environment, Chelmsford, MA & Rocky Hill CT – Aquatic Ecologist

APEX Environmental, Boston, MA – Environmental Scientist

A.I.S., Inc., New Bedford, MA, NOAA Fisheries Observer

Beals Associates, Boston, MA, Environmental Intern

VHB, Inc, Watertown, MA, Environmental Intern

Education

M.E.M. Freshwater Conservation / River Restoration, Yale School of Forestry & Environmental Studies

Graduate Coursework, Natural Resources Management, University of Massachusetts

B.S. Biology / Environmental Studies, St. Lawrence University

Technical Specialties

Wetland & Vernal Pool Delineations

Environmental Permitting

Natural Resources Investigations

Sediment Remediation / Dredging

Geographic Information Systems

Professional Training

OSHA 40-HR HAZWOPER

OSHA 10-HR Construction Safety

OSHA Confined Space Entry

US DOT Haz-Mat Awareness

USACE Wetland Delineation and Management

NMFS Domestic Fisheries Observer

USCG Vessel Safety and Survival

PADI Open Water Diver

MBCR Railway Worker Awareness

Amtrak Safety&Security Awareness

Mr. van Naerssen has over fifteen years of environmental consulting experience and has worked on a broad range of freshwater, marine and terrestrial projects. His project experience includes natural resource investigations, permitting, sediment and soil remediation, and construction oversight projects in rivers, wetlands and ports and harbors throughout the nation.

Select Wetland and Watercourse Permitting Experience:

Aquatic Resource Permitting, Various Clients, ME, NH, MA, RI and CT. Wetland permitting lead on multiple projects. Prepared and filed local, state and federal permit applications for proposed activities in and adjacent to wetlands, watercourses, vernal pools and floodplain resource areas. Extensive consultation and compliance experience with: Environmental Policy Acts (i.e. MEPA/NEPA); Clean Water Act Sections (CWA) 401 and 404; Massachusetts Chapter 91; Endangered Species Act Section 7; Essential Fish Habitat (EFH) Assessments; and, other state and local environmental regulations. Regularly utilize Geographic Information System (GIS) and Global Positioning System (GPS) technologies in preparing deliverables.

Great Lakes Dredge & Dock, Dredge Material Permitting, Cape Cod, MA. Project Manager for dredging project beneath a federal Navigation Project. Characterized and permitted the removal of Cape Cod Canal sand for re-use as Boston Harbor CAD cell cap material. Prepared Health and Safety, Sampling and Analysis Plans, oversaw vibrocore sediment sampling and coordinated with analytical laboratory. Filed appropriate local, state and federal wetland and waterways permits including CWA Section 401 and 404 applications and Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form. Worked with various regulators to obtain project approval.

Energy Provider, Wetland Delineation and Permitting, Brockton, MA. Performed wetland delineations and ecological planting for proposed municipal stormwater conveyance upgrades and riverbank work. Filed wetland permit applications with MassDEP and USACE. Site upgrades and restoration activities conducted in support of site closure under the MCP.

Natural Gas Provider, Gas Main Retrofit, Fall River and Somerset, MA. Permitting lead for proposed natural gas main upgrades in the Taunton River. Performed resource area surveys and wetland delineations. Filed appropriate permit applications, including Notices of Intent under MA Wetlands Protection Act, MADEP Waterways License Modification request and USACE application.

Town of Yarmouth, Dredging and Beach Nourishment Comprehensive Plan, Yarmouth, MA. Conducted dredging and beach nourishment permit inventory. Developed comprehensive plan for Yarmouth's future permitting and recreational needs. Work included resource area surveys, permit summarization, stakeholder interviews and developing recommendations.

Massachusetts Department of Transportation, Pelham Bridge Improvements, Amherst, MA. Prepared required permit applications for proposed bridge upgrades, under the MassDOT Accelerated Bridge Program. Regulatory applications included: 401 Water Quality Certification, CWA Section 404 and associated resource coordination (including NHESP). Collaborated

with MassDOT and AECOM Transportation Engineers regarding permit implications of proposed work at Pelham Bridge.

Town of Haverhill Emergency Bridge Repair work – Whittier Bridge Town Haverhill, MA. Performed resource area assessments and wetland delineations for a town-sponsored highway bridge repair project. Filed an Emergency Certification Form under the Massachusetts Wetlands Protection Act, conducted NHESP, USACE MA PGP and MHD coordination for the proposed bridge rehabilitation project.

Manufacturing Client, Remedial Permitting, East Hartford, CT. Permit lead for remedial efforts at former manufacturing facility. Historic operations require remedial activities in wetland and floodplain areas. Obtained state, federal and local project authorizations. Project ecologist for the proposed Connecticut River floodplain wetland restoration design and construction specification package preparation.

Manufacturing Client, Wetland Construction Permitting, East Greenwich, RI. Conducted wetland delineations and filed regulatory permit applications for remedial efforts at a manufacturing facility. Designed project's wetland restoration components and authored the wetland mitigation design specifications. Received RI DEM and USACOE authorizations for proposed activities. Oversaw construction operations within regulated resource areas.

Eversource Energy, Greater Hartford – Central Connecticut Reliability Project (GHCC), Newington, West Hartford and Hartford, CT. Task manager for environmental data collection and associated project mapping in support of permit application and Connecticut Siting Council (CSC) materials. Provided technical details for Municipal Consultation Filing (MCF) and CSC Application for the project, which involves a proposed 115 kV underground utility connection between two substations and related utility improvements.

Eversource Energy, Bloomfield to Windsor Upgrades Project, Bloomfield and Windsor, CT. Task manager for environmental data collection, permitting and associated project mapping in support of Connecticut Siting Council (CSC) Petition application. The project involves proposed modifications to multiple transmission lines and substations. Regulatory approvals sought include Clean Water Act Section 401 and 404 authorizations, as well as an SWPP approval.

Former Manufacturing Client, Remedial Permitting, Waterbury, CT. Wetland permitting lead supporting remedial site investigations. Conducted wetland resource area delineation for proposed remedial activities at a former manufactured gas plant. Received appropriate local and state wetlands and watercourses approvals for proposed subsurface evaluation activities.

Nuclear Energy Provider, Proposed Facility Permitting, Lake Ontario, NY. Prepared USACE and NYSDEC Joint Wetlands Permitting Application for construction of a proposed nuclear generation facility. Compiled US Clean Water Act Section 404 and NYSDEC Freshwater Wetlands Joint Application for Permit. Collaborated with proponent to develop appropriate mitigation strategy for the project's proposed wetland fill.

Confidential Client, SAV Planting, Upstate, NY. Sourced appropriate Submerged Aquatic Vegetation (SAV) for a Hudson River restoration project and wiorked with regional contractors and nursuries to secure plant materials for a multi-acre SAV restoration planting project.

Manufacturing Client, Sediment Investigations and Permitting, Sprague, CT. Conducted sediment sampling activities supporting a VOC, PCB and metal remediation project in two freshwater ponds and a perennial stream. Prepared local permit documentation. Performed submerged aquatic vegetation (SAV) inventories surveys and completed electrofishing inventories of waterbodies.

Manufacturing Client, Sediment Investigations, Permitting and Wetland Restoration Design, Rensselaer, NY. Conducted sediment sampling supporting a VOC, PCB and metal remediation project on the Hudson River. Wetland permit lead for proposed dredging, capping, wetland restoration and SAV enhancement project. Coordinated with NOAA regarding two rare sturgeon species and EFH preparation. Collaborated with project engineers to design appropriate riverine habitat and wetland restoration components.

Select Media Assessment / Ecological Services Experience:

Natural Resource Inventories and Ecological Planning, Various Clients, New England and Mid-Atlantic. Performed wetland delineations, vernal pool surveys, habitat evaluations and associated permitting in support of proposed infrastructure upgrades and remedial activities. Prepared wetland functions and values assessments, stream classifications and ecological restoration designs. Completed rare mammal habitat surveys (Indiana Bat and Long Eared Bat), aquatic wildlife assessments and electrofishing inventories. Coordinated with regulators and implemented a rare plant transplantation and conservation program.

US Army Corps of Engineers, New Bedford Harbor CERCLA Site, New Bedford, MA. Led wetland habitat desktop assessment and completed in-field investigations in support of proposed saltmarsh restoration. Project involves 60+ acre saltmarsh and tidal flat assessment, restoration and conservation program. Restoration efforts are proposed in connection with anticipated wetland disturbance from proposed removal of PCB impacted sediments. Prepared project GIS mapping, provided technical support and coordinated with multi-agency team supporting the project. Tidal nature of the investigations required terrestrial / wetland surveys and boat-based access in intertidal zones.

Town of Haverhill Emergency Bridge Repair work – Millvale Bridge Haverhill, MA. Performed watercourse and wetland delineations for a town-sponsored highway bridge repair project. Delineations completed in accordance with Massachusetts Wetlands Protection Act and Federal methodologies.

Town of Andover, Footprint Bridge Replacement – Stevens Street Bridge, Andover, MA. Performed resource area and wetland delineations for a town-sponsored highway bridge repair and upgrade project. Filed Notice of Intent under the Massachusetts Wetlands Protection Act for proposed upgrades.

Energy Provider, Wetland Delineation and Permitting, Brockton, MA. Performed wetland delineations and ecological restoration planting plan for proposed municipal stormwater conveyance upgrades and riverbank work. Filed wetland permit applications with Massachusetts Department of Environmental Protection (MassDEP) and U.S. Army Corps of Engineers (USACE). Site upgrades and restoration activities conducted in support of site closure under the Massachusetts Contingency Plan (MCP).

Natural Gas Provider, Gas Main Retrofit, Fall River and Somerset, MA. Performed resource area surveys and wetland delineations using state and federal methodologies for proposed natural gas main upgrades in the Taunton River. Permitting lead for Project; filed appropriate permit applications, including Notices of Intent under MA Wetlands Protection Act, MADEP Waterways License Modification request and USACE application.

Boston Redevelopment Authority, Essential Fish Habitat Assessment, Boston, MA. Collected and categorized benthic invertebrate samples in support of Essential Fish Habitat Assessment in East Boston, MA.

US Navy, Benthic Sediment Sampling, Boston, MA. Collected benthic invertebrate samples and video data in support of Essential Fish Habitat Assessment at the USS Constitution, Boston, MA.

Massachusetts Water Resources Authority (MWRA), Bathymetric Surveys, Wachusett Reservoir, MA. Field lead for bathymetric data collection in Wachusett Reservoir, potable water source for over fifty MA communities. Processed electronic data in Oasis Montaj, AutoCAD and GIS, produced project figures and determined reservoir storage capacity change over time.

Massachusetts Department of Conservation and Recreation (MA DCR), Shellfish Survey and EFHA, New Bedford, MA. Completed Essential Fish Habitat Assessment field activities and literature reviews to in support of proposed replacement of New Bedford Harbor's State Pier. Operated the sampling vessel and was support diver during sample collection. Inventoried and classified shellfish and other benthic invertebrates for EFHA.

Inima USA, Taunton River Desalination Plant, North Dighton, MA. Member of AECOM's scientific SCUBA diving team tasked with evaluating fisheries impingement and entrainment impact analysis at first desalination facility in MA. Performed vessel operations and diver support in this tidal facility.

Marina Developer, Offshore Disposal / Marine Mammal Oversight, Scituate, MA. Performed NOAA Fisheries / Army Corps marine mammal observer duties for dredged material disposal at Cape Cod Bay Disposal Site.

Natural Gas Provider, Threatened and Endangered Species Habitat Surveys. Northeastern PA. Conducted field surveys for potential Indiana Bat summer roosting habitat in support of proposed natural gas pipeline installation in Pennsylvania. Habitat survey conducted under state and federal natural resource agency guidance.

Natural Gas Provider, Wetland, Watercourse and Natural Resource Surveys. Northeastern PA. Conducted aquatic resource and invasive plant field surveys in support of proposed natural gas pipeline installation in Pennsylvania. Wetland survey conducted in accordance with state and federal methodologies. Recorded ecological data using GPS units.

ConnDOT, West Center Street Extension Bridge Superstructure Replacement, Southington, CT. Reviewed and delineated state and federally jurisdictional water resources in the vicinity of the Eight Mile River in support of proposed bridge replacement activities. Completed a desktop review of onsite resources include in Connecticut Natural Diversity Data Base listed species.

Manufacturing Client, Habitat Restoration Comparison, Newark, NJ. Completed remedial project inventories for over 35 potential habitat and wetland restoration projects within an impacted estuarine river system in the metro NYC area. Potential habitat restoration project were weighted on remedial outcomes, restoration objectives and cost effectiveness.

Confidential Client, Sediment Investigations, Newark, NJ. Field Team Lead for multidisiplinary teams conducting sediment investigations throughout a thirteen-mile reach of a contaminated urban river. Coordinated daily in-field efforts of more than twenty-five environmental scientists during field programs ranging from two to ten weeks; interacted with EPA representatives, program managers and client representatives daily. Coordinated NJ OneCall activities in support of submerged utilities avoidance.

NOAA Fisheries, Domestic Fisheries Observation, Atlantic Ocean, Various New England Ports. Observed operations aboard domestic commercial fishing vessels on behalf of the National Marine Fisheries Services (NMFS). Logged catch and bycatch data during nearshore daytrips and multi-week off shore trips. Identified fish, invertebrate, turtle, bird and marine mammal species in the northwestern Atlantic. Data were used in making federal fisheries regulations.

Appendix D
Vernal Pool Assessment

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GREATER HARTFORD-CENTRAL CONNECTICUT RELIABILITY PROJECT

VERNAL POOL ASSESSMENT REPORT

Prepared for:

Eversource Energy

107 Selden Street

Hartford, CT 06141

Prepared by:

AECOM

500 Enterprise Drive

Rocky Hill, CT 06067

May 2017

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Attachments

Attachment A: Vernal Pool Survey Photographs

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1.0 Introduction

In support of Eversource's Greater Hartford-Central Connecticut Reliability Project (GHCCRP or Project), AECOM has prepared this Vernal Pool Assessment Report (Report), which documents the methodology and results of recent vernal pool assessment surveys completed in the GHCCRP study area. The study area includes Eversource's proposed 115-kilovolt (kV) transmission line route, which is aligned along various rights-of-way (ROWs) extending from the Newington Substation to the Southwest Hartford Substation, as well as the Eversource properties at the two substation sites.

The proposed 115-kV transmission line would extend for approximately 3.7 miles through the Towns of Newington and West Hartford and the City of Hartford (Hartford County). The Proposed Route includes approximately 1.3 miles of underground cable as well as an approximately 2.4 mile overhead alignment. The proposed underground segment includes an approximately 0.8-mile Eversource distribution line ROW in Newington, an underground alignment within paved roads/parking lots in Newington, as well as an underground segment in Hartford. The overhead alignment is proposed within an Amtrak railroad ROW located in Newington, West Hartford, and Hartford. The combined 3.7 mile overhead/underground alignment is referred to as the "Proposed Route". In addition to the Proposed Route, the Project also includes minor expansions of the Newington and Southwest Hartford substations and modification to the Newington Tap connection into the Newington Substation; all such modifications would be on Eversource properties.

AECOM conducted field investigations of the substation sites and underground routes in 2015 through 2017. Field reconnaissance of the Amtrak ROW, which extends through densely developed industrial and commercial areas, was performed in 2017[1].

The majority of the Proposed Route for the 115-kV line traverses densely-developed, upland urban/suburban areas. However, although bordered by suburban residential areas, the 0.8-mile portion of the Proposed Route located within the Eversource ROW would cross four wetlands, as well as forested and scrub/shrub uplands. Wetlands also are located near the Newington and Southwest Hartford substations.

Two possible vernal pools were identified in Wetlands N-3 and N-4 located along the Eversource ROW during August 2016 wetland delineation surveys. Because these pools were identified outside of the typical spring-early summer amphibian breeding and migration seasons, field investigations targeting the identification of vernal pool species/breeding areas were completed by AECOM in the spring of 2017.

On March 29, 2017, AECOM completed an initial springtime assessment of the conditions at the locations of the previously identified possible vernal pools (i.e., depressional features located in Wetlands N-3 and N-4). On April 7, 2017, AECOM performed a comprehensive vernal pool survey of the Eversource ROW and the substation parcels. During this comprehensive survey, which included investigations for evidence of amphibian breeding (including observable egg masses and other vernal pool indicators), no vernal pools were confirmed and no other possible vernal pools were located. To ensure that a sufficiently-wide potential breeding season window was covered, AECOM biologists determined that additional investigations were warranted later in the spring breeding season.

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[1] In addition to in-field investigations along the underground alignment, AECOM completed desktop reviews and observations, from publicly-accessible areas, of the overhead segment along the Amtrak ROW. Access agreements along the overhead portion of the Proposed Route that would be collocated in the Amtrak ROW are being finalized. A comprehensive in-field construction review of proposed Project features and natural resources will be completed along the overhead segment, once access is secured. Based on initial investigations, AECOM does not anticipate that vernal pool resources will be located along the overhead segment of the Proposed Route.

Accordingly, additional investigations were completed in Wetlands N-3 and N-4 on April 28 and May 3, 2017. The purpose of these later spring investigations was to further verify whether the previously identified depressional areas serve as vernal pools. Similar to earlier efforts, the April 28 and May 3 investigations were conducted to look for evidence of breeding vernal pool species via dip net sweeps (including observable egg masses and/or juvenile amphibians), as well as other vernal pool indicators. Information regarding these field surveys is presented below.

Based on the results of AECOM's field reviews and in the absence of vernal pool indicator species, no vernal pools were confirmed along the Proposed Route (underground segment within the Eversource ROW and substation parcels). Vernal pool surveys were conducted in accordance with industry standard methods, including select assessment methods outlined in *Best Development Practices, Conserving Pool-Breeding Amphibians in Residential and Commercial Developments in the Northeastern U.S.*[2]

2.0 Description and Definitions of Vernal Pools

2.1 Vernal Pool Descriptions

Vernal pools are small bodies of standing fresh water found throughout the spring that typically result from various combinations of snowmelt, precipitation, and high water tables associated with the spring season. These depressions can be natural or man-made. In most years, these areas become completely dry, losing water through infiltration and evapotranspiration. Vernal pools vary in many aspects including appearance, water source, hydroperiod, water quality and surrounding habitats. Field investigations must coincide with the amphibian breeding and/or larval development time periods to determine if an area is functioning as a vernal pool.

As noted by Calhoun and Klemens[3] and The University of Connecticut and the Forest Stewardship Program[4], the following features are typically required in Connecticut for an area to be considered a vernal pool:

- Presence of one or more obligate vernal pool species;
- Contains water for approximately two months during the growing season;
- Occurs within a confined depression or basin that lacks a permanent outlet stream;
- Lacks any fish populations; and
- Dries out most years, usually by late summer.

Many organisms rely critically on vernal pool habitat for reproductive success. These species are referred to as indicator (or obligate) vernal pool species. Proposed[5] obligate vernal pool species which may have ranges within or near the Project area include the following:

- wood frog (*Lithobates sylvatica*)

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2 Calhoun, A.J.K. and M.W. Klemens. 2002 Best Development Practices: Conserving Pool-Breeding Amphibians in Residential and Commercial Developments in the Northeastern United States. MCA Technical Paper No. 5, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York.

3 Ibid.

4 Donahue, D. F. 1996. A guide to the identification and protection of vernal pool wetlands of Connecticut. University of Connecticut Cooperative Extension Program

5 Calhoun, A.J.K. and M.W. Klemens. 2002 Best Development Practices: Conserving Pool-Breeding Amphibians in Residential and Commercial Developments in the Northeastern United States. MCA Technical Paper No. 5, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York.

- eastern spadefoot toad (*Scaphiopus holbrookii*)
- spotted salamander (*Ambystoma maculatum*)
- Jefferson salamander (*Ambystoma jeffersonianum*)
- marbled salamander (*Ambystoma opacum*)
- fairy shrimp (*Eubranchipus spp.*)

The eastern spadefoot toad and Jefferson salamander are listed by the Connecticut Department of Energy and Environmental Protection (CT DEEP) as State-Endangered and Species of Special Concern, respectively, though neither are anticipated to be found near the Project area[6,7]. During the vernal pool investigations, none of the above indicator species (including state-listed species) were observed within wetlands and adjacent upland areas along the proposed 115-kV transmission line ROW.

Facultative vernal pool species are fauna that utilize, but do not necessarily require, vernal pools for reproductive success. Examples of facultative species include spring peeper (*Pseudacris crucifer*), gray tree frog (*Hyla versicolor*), caddisflies (*Limnephilidae spp., Phryganeidae spp.*), American toad (*Anaxyrus americanus*), Eastern spadefoot toad (*Scaphiopus holbrookii*), Fowler's toad (*Anaxyrus fowleri*) and fingernail clams (*Sphaeriidae* spp*., Pisidiidae spp.*)[8]. Others may include spotted turtle (*Clemmys guttata*), red-spotted newt (*Notophthalmus viridescens viridescens*), green frog (*Rana clamitans*) and bull frog (*Rana catesbeiana*). Facultative species such as those mentioned above can utilize vernal pool habitats. However, these species can also breed successfully in the margins of permanent water bodies including streams, rivers, and lakes.

2.2 Vernal Pool Regulatory Definitions

The U.S. Army Corps of Engineers (USACE or Corps) General Permits (GPs) for the State of Connecticut define vernal pools as "*an often temporary body of water occurring in a shallow depression of natural or human origin that fills during spring rains and snow melt and typically dries up during summer months. Vernal pools support populations of species specially adapted to reproducing in these habitats. Such species* ***may*** [emphasis added] *include wood frogs, mole salamanders (Ambystoma sp.), fairy shrimp, fingernail clams, and other amphibians, reptiles and invertebrates*. *Vernal pools lack breeding populations of fish*".

As noted on the USACE New England District Draft Vernal Pool Assessment and accompanying Characterization Form currently available on the Corps' website[9], "*Vernal pools are depressional aquatic resource basins that typically go dry in most years and may contain inlets or outlets, typically of intermittent flow. Vernal pools range in both size and depth depending upon landscape position and parent material(s). Pools usually support one or more indicator species, including: wood frog, spotted salamander, blue-spotted salamander, marbled salamander, Jefferson's salamander, and fairy shrimp;*

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6 CT DEEP. Eastern Spadefoot Toad. http://www.ct.gov/deep/cwp/view.asp?a=2723&q=326002. Accessed 04/19/17.

7 CT DEEP. Jefferson Salamander. http://www.ct.gov/deep/cwp/view.asp?a=2723&q=568058&deepNav_GID=1655. Accessed 04/19/17.

8 USACE. Vernal Pool Characterization Form. http://www.nae.usace.army.mil/Portals/74/docs/regulatory/StateGeneralPermits/NEGP/VPCharacterizationFormDRAFT.pdf. Accessed 05/01/17.

9 USACE. Vernal Pools. Last updated 01/29/2015. http://www.nae.usace.army.mil/Missions/Regulatory/Vernal-Pools. Accessed 05/01/17.

however, they should preclude sustainable populations of predatory fish."[10] Its accompanying Draft Vernal Pool Characterization Form[11] lists only those obligate species identified in Section 2.1, as well as Blue-spotted Salamander (*Ambystoma laterale*), as Indicator Species.

As noted in the CT GPs, only vernal pools that meet the current definition of waters of the U.S. are regulated by the USACE[12]. Further, as noted in the CT GPs, "all vernal pools are subject to the jurisdiction of the CT DEEP under the Connecticut Water Quality Standards".

As noted on the CT DEEP website, "Under Connecticut law, vernal pools, which contain a specific ecology, are one type of vernal watercourse." [13] In comparison to some other New England states, Connecticut lacks a regulatory definition of vernal pools. The state does regulate vernal pools as vernal watercourses under the Connecticut Inland Wetlands and Watercourses Act, as well as surface water under the Connecticut Water Quality Standards Regulations.

3.0 Wetland Descriptions

The 1"=100" scale, digital aerial mapping, provided in Volume 3 of the CSC Application, identifies delineated wetland areas along the Proposed Route and at the Newington and Southwest Hartford substations. All wetlands along the Proposed Route and at the substation sites were delineated during the 2015 and 2016 field investigations. In total, six wetlands (designated N-1, N-1A, N-2, N-3, N-4, and N-5) were identified at Newington Substation and along the proposed 115-kV line route in Newington, while one wetland (designated H-1) was identified on Eversource's Southwest Hartford Substation property located in Hartford.

With the exception of wetland N-5, which is associated with a small stream adjacent to commercial/ industrial areas, all of the wetlands identified in the Newington portion of the Project area are on Eversource's substation property (wetlands N-1, N-1A) or along the Eversource ROW (wetlands N-2 through N-4). Wetland H-1, a forested wetland west of the developed portion of Southwest Hartford Substation, is associated with a tributary of the South Branch of the Park River.

Each wetland along the Proposed Route and at the substations was surveyed one or more times in April 2017. Two wetlands that exhibited the highest potential for providing vernal pool breeding habitat for amphibians (Wetland N-3 and Wetland N-4) were investigated multiple times during spring 2017. Descriptions of these areas are presented below.

General conditions observed within Project wetland areas included pockets of standing water at depths of 2 to 8-inches noted during the April 7, 2017 survey with thick scrub-shrub vegetative cover within the Project ROW (i.e., in Wetlands N-1, N-1A, N-2, and N-3) and discrete areas of forested cover type beyond the wetlands in the maintained ROW.

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[10] CT DEEP. Draft Vernal Pool Assessment Form. http://www.nae.usace.army.mil/Portals/74/docs/regulatory/StateGeneralPermits/NEGP/VPAssessmentDRAFT.pdf Accessed 04/18/2017.

[11] Ibid.

[12] USACE. *Department of the Army General Permits for the State Of Connecticut*. Effective August 19, 2016. http://www.nae.usace.army.mil/portals/74/docs/regulatory/publicnotices/CT_General_Permit_2016%20_Public%20Notice(Update).pdf. Accessed 03/01/17.

[13] CT DEEP. Vernal Pools. http://www.ct.gov/deep/cwp/view.asp?a=2720&q=325676&depNav_GID=1654. Webpage accessed 04/18/2017.

Wetland N-3 is located east of West Hartford Road in Newington. Wetland N-3 is classified primarily as a palustrine scrub shrub or PSS[14] system within the ROW. Forested wetland areas (palustrine forested or PFO) border the PSS portion of this wetland to the south and northeast. This wetland included an approximately 1,600 square foot (SF) area of standing water with depths of 12-24-inches noted during the April 7, 2017 survey. During the April field investigations, the standing water extended for approximately 150 feet along the ROW in a depression that was likely created by vehicle traffic through the wetland at some point in the past. Water depths within this feature were noted to be up to approximately 18 inches during the April 28 investigation. During the May 3, 2017 field survey, the standing surface water in the feature had shrunk to an approximately 135-foot-long area; water depths had decreased to 12 inches or less. Algal growth and various invertebrates were observed in this feature on multiple occasions. Evidence of three facultative species (as listed in Section 2) was also noted in the depression feature within this wetland area.

Wetland N-4 is located in the Eversource ROW, directly west of Eversource's fenced distribution transition area on Willard Avenue. This wetland is classified primarily as a palustrine emergent (PEM) wetland under the Cowardin system. Forested areas border the PEM portion of this wetland, which included an area of approximately 1,200 SF of standing water with depths of up to 36-inches, as noted during the April 7, 2017 survey. Water depths were noted to be up to approximately 12 inches during the April 28 investigation, and the area of standing surface water had decreased by approximately 1/3 since the April 7 visit. Algal growth and various invertebrates were noted in this feature on multiple occasions.

4.0 Methodology

The spring 2017 period (March 29 through May 3) during which AECOM conducted the vernal pool investigations corresponds to the appropriate time of the year to identify areas that may function as (or lack) amphibian breeding habitat based on the presence of egg masses and developing larvae. Early April, 2017 was determined to be an optimal time to conduct the initial vernal pool field surveys, based on observed weather conditions and on reports and observations of vernal pool species movements in other nearby areas of Connecticut.

The March 29, 2017 investigation was conducted by an AECOM biologist to assess potential pool conditions and was limited to the previously identified possible vernal pools in Wetlands N-3 and N-4. On April 7, 2017, AECOM surveyed the entirety of the proposed 115-kV underground transmission route, as well as at Newington and Southwest Hartford substations to determine if breeding amphibians (obligate or facultative) were present, in an effort to positively identify any vernal pools in the vicinity of proposed Project.

The April 7, 2017 survey was completed after a significant rainfall event and when the evening low temperature remained in the 40°s (degrees Fahrenheit). These weather conditions facilitate inward migration of amphibians to the pools for the purpose of breeding. AECOM biologists conducted visual surveys and used dip nets to sweep the water column to assist in determining the presence or absence of amphibians and other vernal pool species. In addition, AECOM biologists listened for audible choruses of breeding frogs.

Wetlands were surveyed for pooled and ponded areas that might meet vernal pool criteria. Standing pools of water observed in Wetland N-3 and N-4 were visually examined for evidence of obligate and

[14] Cowardin, L., V. Carter, F. Golet and E. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. US Fish and Wildlife Service

facultative species, which could include egg masses and/or salamander spermatophors. In addition, the water column was examined for invertebrates such as fairy shrimp and copepods.

Candidate pool areas were examined visually for egg masses and for invertebrates with dip net surveys through the water column. Dip nets were swept through the water column at an extent that covered the entire pooled area. Leaf litter and debris were investigated visually during the surveys to capture evidence of fingernail clams. Each wetland was examined for at least one hour.

On April 28 and May 3, 2017, AECOM remobilized to previously identified depressional areas in the Eversource ROW to further confirm the presence or absence of vernal pool conditions. AECOM biologists visually and audibly assessed conditions in Wetland N-3 and Wetland N-4 during these subsequent visits in order to document conditions in these depressions later in the spring breeding season.

Along Eversource's ROW and on the substation parcels, forested areas adjacent to wetlands along the Project were also surveyed for terrestrial species such as wood frogs. Approximately one hour was spent listening for the audible chorus of wood frogs. Data recorded during the spring 2017 investigations included approximate size and depth of observed pooled or ponded water areas, substrate type and general comments. Biologists took photographs during each visit to document the conditions of areas that exhibited the most potential for providing vernal pool habitat, and/or as follow-up documentation to previously identified possible vernal pool areas. Attachment A includes representative photographs taken during the surveys.

5.0 Survey Results and Conclusion

On April 7, 2017, AECOM conducted extensive vernal pool surveys of all wetlands along the portion of the Proposed Route within Eversource's ROW and on the substation parcels. The surveys did not result in the observation or identification of any obligate vernal pool species in water bodies (including standing water, pools, and ponded areas). Prior to the survey, the weather was characterized by heavy rain and night temperatures in the 40°Fs. These conditions typically create the optimal environment for amphibian migrations toward vernal pools in early spring.

The investigations and breeding season vernal pool surveys conducted on March 29, April 7, April 28, and May 3, 2017 did not document the visual or audible presence of obligate vernal pool species in any wetlands or other areas located along or adjacent to the proposed Project areas. However, three facultative vernal pool species were noted within Wetland N-3 on April 28 and May 3, 2017. Specifically, American toad (six individual tadpoles and one adult), several fingernail clams and one larval caddisfly were observed in the linear tire rut depression located in Wetland N-3 on April 28 (collected over 30 dip net sweeps). By the May 3, 2017 investigation, only one American toad tadpole was observed over the same number of dip net sweeps. No associated remnant egg masses were observed during either visit. Again, no obligate vernal pool species were observed.

Given the weather conditions and evidence of migrations in surrounding areas, the April and May 2017 vernal pool surveys were conducted under favorable conditions for observations of indicator vernal pool species. Because no such evidence was found, it is therefore unlikely that the investigated wetland areas are utilized as breeding habitat for indicator vernal pool species.

As no vernal pool indicator species were encountered during AECOM's multiple surveys on Eversource's substation properties and along the underground Project Route in spring 2017, no vernal pools were confirmed.

Attachment A
Vernal Pool Survey Photographs

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PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 1	**Date:** 4/7/2017

Direction Photo Taken:

East

Description:

View of Wetland N-1A. Thick vegetation and standing water.



Photo No. 2	**Date:** 4/7/2017

Direction Photo Taken:

North

Description:

View of Wetland N-1A. Thick invasive vegetation (common reed) and standing water.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 3	**Date:** 4/7/2017

Direction Photo Taken:

West

Description:

View of Wetland N-1. Thick vegetation in standing water.



Photo No. 4	**Date:** 4/7/2017

Direction Photo Taken:

North

Description:

Wetland N-1. Water depth approximately 4-inches.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 5	**Date:** 4/7/2017

Direction Photo Taken:

Southwest

Description:

View of forested edge adjacent to ROW of Wetland N-2. Water depth approximately 2-inches.



Photo No. 6	**Date:** 4/7/2017

Direction Photo Taken:

Southeast

Description:

View of ROW portion of Wetland N-2.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP, Newington, CT	**Project No.** 60340574

Photo No. 7	**Date:** 4/7/2017

Direction Photo Taken:

West

Description:
View of standing water in Wetland N-3. Water depth approximately 6-24 inches. Algal growth and other evidence of stagnant water.

A possible vernal pool was previously identified (summer 2016) in Wetland N-3; however, vernal pool functionality and/or evidence of obligate species were not observed during the April 7 investigations.



Photo No. 8	**Date:** 4/7/2017

Direction Photo Taken:

South

Description:

View of forested portion of Wetland N-3.

No pooled or standing water was observed in the forested areas adjacent to or within Wetland N-3.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No.	**Date:**
9	3/29/2017

Direction Photo Taken:

West

Description:

View of Wetland N-3 during the initial Spring 2017 vernal pool reconnaissance investigation.



Photo No.	**Date:**
10	3/29/2017

Direction Photo Taken:

Northeast

Description:

View of Wetland N-4 during the initial Spring 2017 vernal pool reconnaissance investigation. Water depth approximately 12-36 inches.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No. 11	**Date:** 4/7/2017

Direction Photo Taken:

Southeast

Description:

View of wetland N-4. Water depth of approximately 12-36 inches.

A possible vernal pool was previously identified (summer 2016) in Wetland N-4; however, vernal pool functionality was not observed during the breeding season surveys at Wetland N-4



Photo No. 12	**Date:** 4/7/2017

Direction Photo Taken:

N/A

Description:
Representative sample taken during Wetland N-4 dip net survey. Leaves and herbaceous vegetation were also examined for egg mass and spermatophore evidence.

Evidence of amphibian breeding, or obligate vernal pool species use, was not observed during the breeding season surveys.



PHOTOGRAPHIC LOG

Client Name: Eversource	**Site Location:** GHCCRP	**Project No.** 60340574

Photo No.	**Date:**
13	4/28/2017

Direction Photo Taken:

West

Description:
View of depressional area in Wetland N-3. Water depths up to approximately 18 inches were noted during the April 28 visit.

Facultative vernal pool species American toad, fingernail clam, and larval caddisfly were observed in this linear tire rut depression. No obligate species were observed.



Photo No.	**Date:**
14	5/3/2017

Direction Photo Taken:

East

Description:

View of depressional area in Wetland N-3. Water depths up to approximately 12 inches were noted during the May 3, 2017 visit.

Obligate species were not observed (eggs, larval/juvenile or adult) in this seasonal depression.



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Exhibit 2.B Cultural Resources Supporting Information

2.B.1 *Phase IB Cultural Resources Reconnaissance Survey of the Greater Hartford Central Connecticut Reliability Project Corridor in Newington, Connecticut* (Heritage Consultants, LLC, April 2017). Including the appendix:

Cultural Resources Review Report Addendum (Heritage Consultants, LLC, November 4, 2016)

2.B.2 *Cultural Resources Review of the Project Region Associated with the Greater Hartford Connecticut Reliability Project* (Heritage Consultants, LLC, May 19, 2015)

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2.B.1 ***Phase IB Cultural Resources Reconnaissance Survey of the Greater Hartford Central Connecticut Reliability Project Corridor in Newington, Connecticut*** **(Heritage Consultants, LLC, April 2017). Including the appendix:**

Cultural Resources Review Report Addendum **(Heritage Consultants, LLC, November 4, 2016)**

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APRIL 2017

PHASE IB CULTURAL RESOURCES RECONNAISSANCE SURVEY OF THE GREATER HARTFORD CENTRAL CONNECTICUT RELIABILITY PROJECT CORRIDOR IN NEWINGTON, CONNECTICUT.

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ABSTRACT

The Connecticut Light and Power Company doing business as Eversource Energy (Eversource) proposes to improve the reliability of the electric transmission system in the Greater Hartford and Central Connecticut area by constructing and operating a new approximately 3.7-mile 115-kilovolt (kV) transmission line between the Newington Substation located in Newington and the Southwest Hartford Substation, and by modifying both substations. Referred to as the Greater Hartford Central Connecticut Reliability Project (Project), the proposed transmission line and substation modifications would be located in Newington, West Hartford, and Hartford, Connecticut. The new transmission line would be constructed underground (within road and utility rights-of-way [ROWs]) for approximately 1.3 miles and overhead (along an Amtrak railroad ROW) for about 2.4 miles.

In 2015, Eversource retained Heritage Consultants, LLC (Heritage) to perform cultural resources studies of the Project. Between the spring of 2015 and February 2017, Heritage conducted research and assessment studies of the Project area and, as the Project evolved, performed field investigations of various transmission line route alternatives and overhead/underground line configurations. The results of those studies, including a Phase 1A cultural resources assessment survey report (November 14, 2016), were submitted previously to the Connecticut State Historic Preservation Office (SHPO).

This report documents the results of a Phase IB cultural resource reconnaissance survey conducted along an approximately 0.7-mile portion of the proposed electric transmission line route. The Phase IB study corridor extends between the Newington Substation and Willard Avenue in Newington, Connecticut and consists of an Eversource distribution line ROW, also known as the "East ROW". This ROW is occupied by five existing Eversource distribution lines; four located overhead on wood poles and one located underground. The Phase IB study examined Eversource's proposed all underground transmission line alignment within the East ROW, as well as a potential alternate underground/overhead configuration for the new 115-kV line along this ROW segment.

The Phase IB investigation resulted in the identification of a single archaeological site (94-1) that yielded both historic artifacts dating from the nineteenth century and prehistoric artifacts dating from the Late Archaic period of Connecticut prehistory. Delineation shovel testing of Site 94-1 was completed and Heritage determined that neither the historic nor the prehistoric component of the site retained intact cultural deposits or the qualities of significance as defined by the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]). No additional examination of Site 94-1 was recommended by Heritage.

No other archeological deposits were identified during the Phase IB cultural resources reconnaissance survey. As noted in previous correspondence to the SHPO, and due to the previously disturbed nature of lands in the area, none of project components located along the proposed corridor are anticipated to have adverse effects to prehistoric or historic resources, or to areas listed as National Register of Historic Places. It is therefore the professional opinion of Heritage, that there will be no adverse effect to cultural resources as a result of the proposed electrical transmission line project.

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Figure 3; Sheet 3. Excerpt from a 2016 aerial image showing the locations of the proposed project items associated with the Hybrid option within the East ROW, shovel test locations, and wetlands in Newington, Connecticut.

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Appendix I: Phase IA Cultural Resources Assessment Survey Report

Appendix II: Site Form for Site 94-1

CHAPTER I

INTRODUCTION

Project Description

As discussed in a previously submitted Phase IA report dated November 4, 2016 and submitted to the Connecticut State Historic Preservation Office (SHPO), The Connecticut Light and Power Company doing business as Eversource Energy (Eversource) proposes to improve the reliability of the electric transmission system in the Greater Hartford and Central Connecticut area by constructing and operating a new 115-kilovolt (kV) transmission line within the proposed project corridor between the Newington Substation located in Newington and the Southwest Hartford Substation located in Hartford, Connecticut (see Appendix I). This report documents the results of a Phase IB cultural resource reconnaissance survey conducted along a portion of the proposed electric transmission line project. The Phase IB study corridor extends between the Newington Substation and Willard Avenue in Newington, Connecticut (Figure 1), an area also known as the "East ROW". As detailed below, the Phase IB study examined the proposed all underground Project alignment within the East ROW, as well as a potential alternate underground/overhead configuration for the Project through the East ROW.

The proposed transmission line will consist of an underground (UG) cable that extends from the Newington Substation to Willard Avenue (Route 173) within an existing Eversource distribution line ROW (hereafter referred to as the "East ROW"), along portions of which vegetation is cleared and managed consistent with utility line use. The UG transmission line will then extend north on Willard Avenue beneath the road surface before turning east on Shepard Drive and intersecting with the Amtrak railroad/*CT Fastrak* corridor, where the transmission line will transition to an overhead (OH) line and continue north within the Amtrak railroad/*CT Fastrak* corridor through West Hartford and into Hartford. Just south of Interstate 84, the OH transmission line will transition back UG and interconnect with New Park Avenue, extending north beneath the road surface before and turning west into the Southwest Hartford Substation (see Appendix I and Figure 2; Sheets 1 through 3). The all-underground proposed route alignment located between the Newington Substation and the Amtrak railroad/*CT Fastrak* corridor is known as "Route Variation 8".

The UG construction method within the East ROW will include an open cut trench for a buried cable, a linear soil stockpile area adjacent to the trench, and a parallel gravel access road. The work corridor associated with UG project elements will measure approximately 12.2 m (40 ft) in width in the East ROW. OH Project components within the Amtrak railroad/*CT Fastrak* corridor, as well as associated work areas and access components, are currently in final design. The OH line would be located on the east side of the Amtrak railroad corridor and have appropriate corridor widths to accommodate line clearances and other access and work areas considerations.

Eversource previously conducted Phase IA survey of the proposed route (see Appendix I). Based on the Phase IA survey results, the portion of the proposed route from Newington Substation east to Willard Avenue (Route 173) was the only location that would necessitate further survey for the potential occurrence of cultural resources. Based on correspondence with the Project team, it is Heritage's understanding that the proposed route will likely follow the UG configuration through the East ROW, and would follow an OH alignment in the Amtrak ROW, as outlined above.

In addition to the UG construction method that is proposed for the transmission line alignment between the Newington Substation and Willard Avenue (Route 173), Eversource concurrently surveyed a Hybrid option that would consist of a combination of both underground cabling and overhead structures within this East ROW area. Under this variation, an UG line would exit out of the Newington Substation, then transition to an OH line from just east of Substation to a point approximately 121.9 m (400 ft) west of Willard Avenue and outside the Newington Junction North Historic District. At that point, the transmission line would transition to UG and extend through the Newington Junction North Historic District, avoiding indirect visual impacts on the district from views of the OH T-line structures (see Appendix I and Figure 3; Sheets 1 through 3). The potential hybrid route alignment (OH and UG) located between the Newington Substation and the Amtrak railroad/*CT Fastrak* corridor is known as "Route Variation 10B".

The Phase IB cultural resources reconnaissance survey was conducted to account for construction of either route configuration between the Newington Substation and Willard Avenue (i.e. either the Route Variation 8 UG configuration or the Route Variation 10B Hybrid configuration within the "East ROW"). As part of the Phase IB cultural resources reconnaissance survey, various project components such as trench areas, anticipated access roads, structure locations, work pad,s and truck turnaround areas associated with the East ROW's UG and Hybrid configurations were examined where these features occurred in upland areas. No archaeological investigations were required or performed for those items occurring in wetland areas. The portion of the proposed electrical line between Willard Avenue and the Southwest Hartford Substation has already been reviewed for cultural resources and is discussed in the November 4, 2016 report in Appendix I.

Field investigations for this project were completed on behalf of Eversource by Heritage during December 2016 and February 2017. All work was performed in accordance with the National Historic Preservation Act of 1966, as amended; the National Environmental Policy Act of 1969, as amended; and the *Environmental Review Primer for Connecticut's Archaeological Resources* (Poirier 1987). The remainder of this document presents a description of the proposed project area, the methods by which the Phase IB cultural resources reconnaissance survey was completed, the results of the investigation, and management recommendations for identified cultural resources.

Background Research

This Phase IB cultural resources reconnaissance survey was completed using a three-step approach. The first step consisted of historic research and records review that focused on the portion of Newington encompassing the East ROW. This was followed by the review of forms on file with the Connecticut State Historic Preservation Office related to previously recorded archeological sites and National Register of Historic Places properties situated within the immediate vicinity of the project corridor. Background research also included analysis of readily available historic maps and aerial imagery depicting the landforms containing the East ROW; an examination of the modern USGS 7.5' series topographic quadrangle depicting the region; and a review of digital records archived by Heritage. The intent of this review was to identify all previously recorded cultural resources situated within the vicinity of the East ROW. This information was used to develop the archeological context for assessing cultural resources that may be identified during survey. This information also was used to design survey methods and techniques appropriate for evaluating the National Register significance of each cultural resource that may be identified during the execution of the subsequent cultural resources survey. As outlined herein and previous assessments (Appendix I), the current project approach entailed the completion of a Phase IB cultural resources reconnaissance survey.

Project Location & Field Methods

The East ROW is bounded to the north and south by residential neighborhoods, to the east by Willard Avenue, and to the west by the existing Newington Substation (Figure 1, Figure 2; Sheets 1 through 3, and Figure 3; Sheets 1 through 3). The project corridor is characterized by a mixture of manicured lawns and secondary growth (Figures 4 through 13). Elevations throughout the region range from ~25 m (~80 ft) NGVD in the east to ~45 m (~150 ft) NGVD in the west, and soils in the area comprised primarily of silty loam. The Phase IB cultural resources reconnaissance survey included pedestrian survey, photo-documentation, mapping, and systematic shovel testing. The field strategy was designed such that the entire East ROW was examined visually and photographed. The field methodology also included subsurface testing of those undisturbed portions of the proposed project corridor that were scheduled for impacts related to construction. During the Phase IB fieldwork effort, the East ROW was examined using a single transect of shovel tests positioned along the centerline of the proposed UG option (Route Variation 8). These shovel tests were situated at 15 m (49.2 ft) intervals along the transect. In addition, shovel tests were also excavated in the corners of the proposed work pads associated with UG and hybrid options, as well as anticipated structure locations as part of the Hybrid option (Route Variation 10B). Finally, shovel tests were also placed in the work areas that will be used for truck turn arounds, temporary workspaces and/or placement of frac tanks if required for dewatering (see Figure 2; Sheets 1 through 3 and Figure 3; Sheets 1 through 3).

Results of Fieldwork

During the survey, a total 86 of 108 (80 percent) planned shovel tests were excavated successfully throughout the East ROW Investigation Area (Figure 2; Sheets 1 through 3 and Figure 3; Sheets 1 through 3). The 22 planned, but unexcavated, shovel tests fell within areas of previous disturbances around the Newington Substation and/or in wetlands. Shovel testing conducted throughout the proposed East ROW resulted in the identification of a single archeological site (Site 94-1). An official State of Connecticut site form for this cultural resource is included in Appendix II. The data collected from Site 94-1 indicates that it contains both prehistoric and historic period components.

The prehistoric component of Site 94-1 is characterized by two lithic artifacts, one of which is a Brewerton side notched projectile point dating from the Late Archaic period of Connecticut prehistory (ca., 6,000 to 3,700 B.P.). The historic component consists of a small assemblage of nineteenth/early twentieth century artifacts that represents field scatter. None of the artifacts collected from the site area were found in association with any cultural features, and all originated from the disturbed plowzone deposit. Thus, based on the collected data, both components associated with Site 94-1 are not considered significant when applying the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]), and no additional testing of this archaeological site is recommended prior to construction.

Finally, no other archeological deposits were identified during Phase IB cultural resources reconnaissance survey of the remainder of the proposed East ROW survey corridor. It is the professional opinion of Heritage that there will be no adverse effect on cultural resources as a result of the proposed electrical transmission line project.

CHAPTER II

NATURAL SETTING

Introduction

The State of Connecticut exhibits considerable variability in geology, hydrology, soils, flora, and fauna, despite the fact that its boundaries encompass only approximately 5,000 mi^2 or roughly 1,295,040 ha (3,200,000 ac) of land. Connecticut's landscape, which lies in the northern temperate deciduous forest biome (Braun 1950; Shelford 1963), contains many subregions, including areas of locally high relief such as the eastern and western uplands areas; extensive riverine systems dominated by wide alluvial floodplains such as those in the north-central part of the state; widespread and extensive wetland systems composed of swamps, freshwater marshes, and tidal estuaries; and, finally, coastal areas. Regional differences in climatic variables, including precipitation, temperature, and growing season, as well as differences in topography and distance from the Long Island Sound, are reflected in the distribution of various floral and faunal resources (Dowhan and Craig 1976:25).

Ecoregions of Connecticut

Throughout the Pleistocene and Holocene Periods, Connecticut has undergone numerous environmental changes. Variations in climate, geology, and physiography have led to the "regionalization" of Connecticut's modern environment. It is clear, for example, that the northwestern portion of the state has very different natural characteristics than the coastline. Recognizing this fact, Dowhan and Craig (1976), as part of their study of the distribution of rare and endangered species in Connecticut, subdivided the state into various ecoregions. Dowhan and Craig (1976:27) defined an ecoregion as:

> "an area characterized by a distinctive pattern of landscapes and regional climate as expressed by the vegetation composition and pattern, and the presence or absence of certain indicator species and species groups. Each ecoregion has a similar interrelationship between landforms, local climate, soil profiles, and plant and animal communities. Furthermore, the pattern of development of plant communities (chronosequences and toposequences) and of soil profile is similar in similar physiographic sites. Ecoregions are thus natural divisions of land, climate, and biota."

Dowhan and Craig defined nine major ecoregions for the State of Connecticut. They are based on regional diversity in plant and animal indicator species (Dowhan and Craig 1976). Only one of the ecoregions is germane to the current investigation: North-Central Lowlands ecoregion. A brief summary of the North-Central Lowlands is presented below. It is followed by a discussion of the geology of the State of Connecticut, as well as by overviews of the hydrology, soils, flora, fauna, and climate characteristic of the region containing the proposed project area.

North Central Lowlands Ecoregion

The North-Central Lowlands region consists of a broad valley located between approximately 40.2 and 80.5 km (25 and 50 mi) to the north of Long Island Sound (Dowhan and Craig 1976). It is characterized by extensive floodplains, backwater swamps, and lowland areas situated near large rivers and tributaries. Physiography in this region is composed of a series of north-trending ridge systems, the easternmost of which is referred to as the Bolton Range (Bell 1985:45). These ridge systems comprise portions of the terraces that overlook the larger rivers such as the Connecticut and Farmington Rivers. Elevations in the North-Central Lowlands range from 15.2 to 76.2 m (50 to 250 ft) above sea level, reaching a maximum of nearly 274 m (900 ft) above sea level along the trap rock ridges that surround the central valley. The bedrock of the region is composed of Triassic sandstone, interspersed with very durable basalt or

"traprock" (Bell 1985). Soils found in the upland portion of this ecoregion are developed on red, sandy to clayey glacial till, while those soils situated nearest to the rivers are situated on widespread deposits of stratified sand, gravel, silt, and alluvium resulting from the impoundment of glacial Lake Hitchcock

The major forest type found in the North-Central Lowlands region is the Central Hardwoods-Hemlock-White Pine type. Major tree species identified in this area include red, black, and white oaks (*Quercus rubra, Q, velutina,* and *Q. alba*), shagbark, pignut and butternut hickories (*Carya ovata, C. glabra,* and *C. cordiformis*), hemlock (*Tsuga canadensis*), and white pine (*Pinus strobes*). White pine reaches its southern limit in this region. Other trees identified in the North-Central Lowlands region include red cedar (*Juniperus virginiana*), black birch (*Betula lenta*), gray birch (*Betula populifolia*), and white ash (*Fraxinus americana*). Maples (*Acer* sp.) are also common in disturbed and secondary successional habitats that are characteristic of the area. As discussed in more detail below, the various resources found within the Central Hardwoods-Hemlock-White Pine forests were exploited by prehistoric Native American and historic residents of the area. They consisted of foodstuffs, wood for fuel, and raw materials for tool production.

The Geology of Connecticut

The development of Connecticut's ecoregions is tied to its underlying geology. The geology of the State of Connecticut is complex, and it is the product of both large scale and long-term constructional and destructional processes. These processes are described briefly below.

Continental Drift, Erosion, and the Early Development of Connecticut

The geology of Connecticut as expressed today has its origins in developmental processes that began as early as 500 million years ago (mya) (Bell 1985). At that time, the earth was characterized by the presence of several proto-continents and large islands that were distributed around the equator and within the southern hemisphere. By approximately 250 mya, these proto-continents and islands, i.e., large tectonic plates, had "drifted" together to form the supercontinent of Pangea. The supercontinent remained in place as a large landmass for approximately 50 million years, after which it began to split into several large pieces that are recognized today as the seven continents. During this early developmental sequence, the land that was to become known as Connecticut was positioned within the heart of Pangea. As a result, the formation and eventual disintegration of Pangea has left its mark on the geology of Connecticut (Bell 1985; Robinson and Hall 1980).

Connecticut's Four Terranes

Geologists recognize that the State of Connecticut is composed of four major underlying terranes that were pushed into close proximity with one another during the formation of Pangea (Bell 1985). These terranes are defined on the basis of shared geological attributes, specifically rocks and strata with similar histories and chemical compositions. The four terranes underlying Connecticut's landscape are known as the Proto North American, Newark, Avalonia, and Iapetos terrenes; the proposed project lies within the Iapetos terrain (Bell 1985:140). The eastern edge of the Proto North American terrane, corresponding to today's Northwest Highlands ecoregion, once formed the eastern shoreline of the area now known as the United States. The Newark terrane, corresponding in area to the Central Valley, formed as Pangea began to break apart. This area underwent tremendous stresses as it was pulled apart slowly by the disintegration of Pangea. Avalonia, which can be identified today as a series of gneiss and granitic rocks distributed in a broad arc in the southeastern portion of the state, once was part of a large island that was situated to the southeast of the Proto North American continent prior to the formation of Pangea. Finally, The Iapetos terrane, corresponding roughly to the Eastern and Western Uplands areas, formed during the coalescence of Pangea. These portions of the state represent areas that once were shallow portions of the Iapetos Ocean; it eventually was filled with sediments eroding from the Proto North American terrane and Avalonia. Both the Proto North American terrane and Avalonia, because they existed prior to the formation of Pangea, predate the Iapetos and Newark terranes. They date from prior to 570 mya, whereas

the intervening Iapetos and Newark terranes, formed during the period of continental collision, date from approximately 500 to 250 mya (Bell 1985:153).

While these four terranes underlie Connecticut's approximately 160.9 km (100 mi) wide modern landscape, they once spanned more than 804.6 km (500 mi) from east to west (Bell 1985:147). During the course of the formation of Pangea, Avalonia was pushed westward. Sediments from Avalonia and the Proto North American continent eroded and washed into the shrinking Iapetos Ocean, forming what was to become the Eastern and Western Uplands of Connecticut. When Pangea formed, the area became cemented together and confined to the space between the state's modern borders (Bell 1985).

As the supercontinent divided, tremendous forces were put upon the area, forming a large fissure that eventually became the Newark terrane. The Newark terrane was filled with sediments eroding from the east and west, forming the distinctive sandstone and brownstone strata of the Central Valley of Connecticut. As this area continued to expand, the underlying bedrock began to tilt towards the east, allowing large lava flows to reach the surface and cool into a series of traprock ridges. These ridges still are visible today; prominent among them is Metacomet Ridge. Eventually, the pressures acting upon the Newark terrane were relieved when a larger fissure opened to the east, allowing the European and African continents to move off to the east and the Atlantic Ocean to occupy the intervening area (Bell 1985).

For millennia after the breakup of Pangea, the area that has become known as Connecticut has undergone extensive erosion. Continued washing away of sediments originating from what was Proto North America, the Iapetos terrane, and Avalonia have aided in the formation of today's landscape. These forces, coupled with the tremendous power of the glaciers that scoured the area during the Pleistocene, have left Connecticut what it is today, a rich and varied landscape consisting of a mosaic of mountains, rolling hills, fertile valleys, a rocky coastline, and numerous watercourses.

The Geology of the Connecticut Valley

Connecticut lies within the New England province. This province is characterized by rocks that have been compressed, metamorphosed, and uplifted. The New England province extends from roughly southeastern New York and northern New Jersey to as far inland as Canada. The surface of the uplands forms a peneplain that slopes southeastward from maximum inland altitudes of approximately 670.5 m (2,200 ft) to 121.9 m (400 ft) or 152.4 m (500 ft) before reaching the seaboard lowlands. The topography is that of a maturely dissected plateau with numerous hills and mountains rising above the general level of the upland.

Bell (1985) has re-interpreted the geology of Connecticut and has divided the state into four smaller geological regions. These regions consist of the Western Uplands, the Central Valley, the Eastern Uplands and the Coastal Slope. The proposed project area is located within the heart of the Central Valley, designated by Dowhan and Craig (1976) as the North-Central Lowlands ecoregion. This area is discussed in more detail below.

The Connecticut River Valley has been referred to by many names, including the Central Valley, the Connecticut Valley, the Hartford Basin, the Mesozoic Valley, and the Newark Terrane (Bell 1985:13). These descriptors indicate that the valley is centrally located in the state and that it dates from between 225 to 65 mya. The Central Valley consists of an area that measures approximately 152.8 km (95 mi) in length by 32.2 km (20 mi) in width. It reaches its southernmost point in the vicinity of the towns of Glastonbury and Rocky Hill, Connecticut. The Central Valley has a moderately rolling floor and it averages between 15.2 and 76.2 m (50 and 250 ft) NGVD. As noted above, the underlying rocks found in this area include Triassic sandstones, conglomerate, shale, and traprock. The constant erosion of the bedrock gives this region its distinctive red soils (Bell 1985).

Following deglaciation between approximately 17,000 and 13,000 years ago, the Central Valley was inundated by glacial Lake Hitchcock (Thorson and Schile 1995). Named after Reverend Edward S. Hitchcock, this impoundment of a large glacial meltwater lake was facilitated by a massive build-up of glaciolacustrine sediments between Glastonbury and Middletown, Connecticut. Glacial Lake Hitchcock extended for more than 241.4 km (150 mi) in a north-south direction and for approximately 32.2 km (20 mi) in an east-west direction (Bell 1985: 20-21).

A chronology for Lake Hitchcock first was established by Antev (1922) through his detailed examination of lake varves deposited in the region. Subsequent radiocarbon correlations with Antev's study indicates that Lake Hitchcock formed approximately 15,600 years ago and that it remained in place for approximately 3,000 years. At approximately 12,400 years ago the buildup of sediments at Middletown, Connecticut was breached and the lake drained rapidly (Ridge and Larsen 1990), creating major changes in downstream landscapes.

Geological investigations of the dry lakebed soils indicate that the draining of glacial Lake Hitchcock was very rapid, and that it produced many unique geological features within the Central Valley. Most notable among these are eolian features such as massive sand dunes and lacustrine spits that provide the basis for modern terrace and inland physiography (Thorson and Schile 1995). In addition, sediments found in the Central Valley proper contain very few rocks, and with the addition of massive amounts of nutrients from the regular flooding of the Connecticut River, they have become some of the best agricultural soils in New England.

In addition to the low rolling valley floor, the Central Valley also contains a series of high traprock ridges. The largest of these ridges flanks the western border of the Central Valley and it is known as Metacomet Ridge. The Metacomet Ridge extends from Branford, Connecticut in the south to Northampton, Massachusetts in the north. It consists of dense traprock or basalt. Unlike the remainder of the Central Valley's easily eroded sandstone and brownstone, the basalt of Metacomet ridge is very erosion-resistant. The igneous rock of Metacomet Ridge was formed when lava breached the ground surface and cooled. The basalt from the traprock ridges has been quarried by prehistoric Native American groups and used for stone tool manufacturing (Calogero 1991).

Soils in the Vicinity of the Proposed Project Corridor

Soil formation is the direct result of the interaction of a number of variables, including climate, vegetation, parent material, time, and organisms present (Gerrard 1981). Once archeological deposits are buried within the soil, they are subject to a number of diagenic processes. Different classes of artifacts may be preferentially protected, or unaffected by these processes, whereas others may deteriorate rapidly. Cyclical wetting/drying, freezing/thawing, and compression can accelerate chemically and mechanically the decay processes for animal bones, shells, lithics, ceramics, and plant remains. Lithic and ceramic artifacts are largely unaffected by soil pH, whereas animal bones and shells decay more quickly in acidic soils such as those that are present in the current study area. In contrast, acidic soils enhance the preservation of charred plant remains. A brief review of the soils located within the study region is presented below.

Scitico Soils:

Ap-- 0 to 8 inches; very dark grayish brown (2.5Y 3/2) silt loam, light gray (5Y 7/1) dry; moderate fine and medium granular structure; friable, sticky, plastic; few very fine, fine and medium roots; slightly acid; clear smooth boundary. (6 to 12 inches thick)

Eg-- 8 to 11 inches; olive gray (5Y 5/2) silt loam; moderate medium blocky structure; friable, sticky, plastic; few very fine and fine roots; common fine prominent light olive brown (2.5Y 5/4), yellowish

brown (10YR 5/4), and dark yellowish brown (10YR 4/4) masses of iron accumulation; slightly acid; clear smooth boundary. (0 to 6 inches thick)

Bg1-- 11 to 18 inches; olive gray (5Y 5/2 and 5Y 4/2) silty clay loam; moderate coarse blocky structure; firm, very sticky, plastic; few fine roots between peds; continuous distinct gray (5Y 5/1) coatings on ped faces; common fine prominent dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) masses of iron accumulation; neutral; clear smooth boundary.

Bg2-- 18 to 30 inches; dark gray (5Y 4/1) silty clay loam; moderate coarse prismatic structure parting to coarse blocky; firm, very sticky, plastic; few fine roots between peds; continuous distinct gray (5Y 5/1) coatings on vertical structure faces; few worm casts along prism faces; many fine prominent dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) masses of iron accumulation; neutral; clear smooth boundary.

Bg3-- 30 to 38 inches; olive gray (5Y 5/2) and grayish brown (2.5Y 5/2) silty clay; weak coarse prismatic structure; firm, very sticky, plastic; few fine roots between prisms; continuous distinct gray (5Y 5/1) coatings on vertical structure faces; few worm casts along prism faces; many fine prominent yellowish brown (10YR 5/6) and dark yellowish brown (10YR 5/6) masses of iron accumulation; neutral; clear smooth boundary. (Combined thickness of the Bg horizons is 10 to 30 inches.)

Cg1-- 38 to 52 inches; olive gray (5Y 5/2), dark gray (5Y 4/1), grayish brown (2.5Y 5/2), and light olive brown (2.5Y 5/4) varved silt and clay (silty clay loam weighted average texture); few yellowish brown (10YR 5/6, 5/8) masses of iron accumulation; massive separating to weak thin plates along varved bedding planes; firm, very sticky, plastic; few fine prominent yellowish brown (10YR 5/6 and 10YR 5/8) masses of iron accumulation; neutral; clear smooth boundary. (0 to 30 inches thick)

Cg2-- 52 to 65 inches; olive gray (5Y 5/2), gray (5Y 5/1), grayish brown (2.5Y 5/2), and light olive brown (2.5Y 5/4) varved silt and clay (silty clay weighted average texture); massive separating to weak thin plates along varved bedding planes; firm, very sticky, plastic; few fine prominent dark yellowish brown (10YR 4/4 and 10YR 4/6) masses of iron accumulation; neutral.

Ellington Soils

p--0 to 8 inches; dark reddish brown (5YR 3/2) silt loam; pinkish gray (7.5YR 6/2) dry; weak medium granular structure; friable; few fine roots; 5 percent gravel; slightly acid; clear smooth boundary. (6 to 12 inches thick)

Bw1--8 to 18 inches; reddish brown (5YR 4/4) silt loam; weak medium subangular blocky structure; friable; few fine roots; 5 percent gravel; moderately acid; gradual wavy boundary.

Bw2--18 to 26 inches; reddish brown (5YR 4/4) very fine sandy loam; massive; friable; 10 percent gravel; common medium distinct reddish gray (5YR 5/2) iron depletions and dark red (2.5YR 3/6) masses of iron accumulation; strongly acid; abrupt smooth boundary. (Combined thickness of the Bw horizons is 12 to 36 inches.)

2C--26 to 65 inches; dark reddish brown (5YR 3/4) stratified sand and gravel with a few thin lenses of sandy loam; single grain; loose; 50 percent gravel; few fine distinct reddish gray (5YR 5/2) iron depletions and few fine faint yellowish red (5YR 4/6) masses of iron accumulation; strongly acid.

Branford Soils

Ap--0 to 8 inches; dark reddish brown (5YR 3/3) silt loam, light reddish brown (5YR 6/3) dry; weak medium granular structure; friable; common very fine and fine roots; 10 percent gravel; moderately acid; clear smooth boundary. (6 to 12 inches thick)

Bw1--8 to 18 inches; reddish brown (5YR 4/4) loam; weak medium subangular blocky structure; friable; few fine roots; common earthworm holes and worm casts; 10 percent gravel; strongly acid; gradual wavy boundary.

Bw2--18 to 24 inches; reddish brown (5YR 4/4) loam; weak coarse subangular blocky structure; very friable; few fine roots; 14 percent gravel; strongly acid; clear wavy boundary. (Combined thickness of the Bw horizon is 12 to 30 inches)

2C--24 to 65 inches; reddish brown (5YR 4/3) stratified sand and gravel; single grain; loose; 25 percent gravel; strongly acid.

Wethersfield Soils:

Oe--0 to 3 cm; black (10YR 2/1) moderately decomposed plant material. (0 to 10 cm thick)

A--3 to 8 cm; dark brown (7.5YR 3/2) loam; moderate medium granular structure; friable; many fine and medium roots; 10 percent gravel; strongly acid; clear wavy boundary. (5 to 10 cm thick)

Bw1--8 to 22 cm; reddish brown (5YR 4/4) loam; weak medium subangular blocky structure; friable; common fine and medium roots; 10 percent gravel; strongly acid; clear wavy boundary.

Bw2--22 to 69 cm; dark reddish brown (5YR 3/3) gravelly loam; weak medium subangular blocky structure; friable; few medium roots; 15 percent gravel and cobbles; strongly acid; clear wavy boundary. (Combined thickness of the Bw horizons is 46 to 94 cm.)

Cd--69 to 165 cm; reddish brown (2.5YR 4/4) gravelly loam; weak thick platy structure; very firm, brittle; few silt films and black coatings on some plates; 20 percent gravel and cobbles; strongly acid.

Udorthents:

This complex consists of moderately well drained to excessively drained soils that have been disturbed by cuffing or filling, and areas that are covered by buildings and pavement. Most cut areas were used as a source of fill material, but in some areas cuts were made in order to level sites for buildings, recreational facilities, and roads. Most of the filled areas were built up and leveled for urban development. In some areas, fill has been used to build up recreational areas and highways. These areas retain no depositional integrity and possess no potential to yield intact cultural deposits.

CHAPTER III

PREHISTORIC SETTING

Introduction

Prior to the late 1970s and early 1980s, very few systematic archeological surveys of large portions of the state of Connecticut had been undertaken. Rather, the prehistory of the region was studied at the site level. Sites chosen for excavation were highly visible and they were located in such as areas as the coastal zone, e.g., shell middens, and Connecticut River Valley. As a result, a skewed interpretation of the prehistory of Connecticut was developed. It was suggested that the upland portions of the state, i.e., the northeastern and northwestern hills ecoregions, were little used and rarely occupied by prehistoric Native Americans, while the coastal zone, i.e., the eastern and western coastal and the southeastern and southwestern hills ecoregions, were the focus of settlements and exploitation in the prehistoric era.

This interpretation remained unchallenged until the 1970s and 1980s when several town-wide and regional archeological studies were completed, including the Eastern Coastal, Southeast Hills, North-Central Lowlands, and Northeast Hills Ecoregions. In the North-Central Lowlands ecoregion, for example, McBride, Dewar, and Wadleigh (1979) and McBride, Wadleigh, Dewar, and Soulsby (1980) completed town-wide surveys of South Windsor and Glastonbury, respectively. In addition, town-wide surveys were completed in East Haddam and Haddam, e.g., Southeast Hills ecoregion, and in Woodstock, e.g., Northeast Hills ecoregion, in the early 1980s (McBride, Dewar, and Wadleigh 1979; McBride 1984), as well as while conducting the Route 6/1-84 Relocation Survey (McBride and Soulsby 1989). These investigations led to the creation of several archeological phases that subsequently were applied to understand the prehistory of Connecticut.

The remainder of this chapter provides an overview of the prehistoric setting of the region encompassing the proposed project area. For the sake of ease and clarity, the chronology used below employs the standard period/subperiod that has characterized Connecticut prehistory for decades. However, when applicable, the identified archeological phases will be discussed to shed additional light on prehistoric settlement and subsistence patterns noted for particular period of time. Table 7 depicts the prehistoric cultural periods and various archeological phases of Connecticut as they have been presented in all major discussions of the area. The phase names and associated dates are adapted from McBride's (1984) unpublished dissertation entitled "*Prehistory of the Lower Connecticut River Valley."*

Paleo-Indian Period (12,000-10,000 B.P.)

The earliest inhabitants of the area encompassing the present-day State of Connecticut, referred to as Paleo-Indians, probably arrived in southern New England after the end of the Wisconian Glaciation (ca. 14,000 B.P.) (Gramly and Funk 1990; Snow 1980). At glacial maximum, sea level was as much as 130 m (426 ft) below its present level (Edwards and Emery 1977; Edwards and Merrill 1977), exposing a large portion of the continental shelf that was suitable for use by human populations that may have moved there from the west and southwest. By the time the glaciers receded from the area (ca. 11,000 B.P.), sea level was still much lower in southern New England than at present (Edwards and Emery 1977). While deglaciation occurred slowly, most of Connecticut was clear of ice by about 13,500 B.P., and the central portion of the state was inundated under glacial Lake Hitchcock (Bell 1985; Snow 1980; Gramly and Funk 1990). Megafauna that existed in the area at the time included mammoth, mastodon, horse, and bears, as well as elk, caribou, giant beaver, and musk ox (Gramly and Funk 1990; Martin and Guilday 1967; Ritchie 1969). Due to the presence of large Pleistocene mammals and the ubiquity of large fluted projectile points at this time, Paleo-Indians often are described as big-game hunters (Ritchie and Funk

1973; Snow 1980); however, as discussed further below, it is more likely that they hunted a broad spectrum of small and medium sized animals.

According to pollen studies, the tundra environment that developed shortly after deglaciation transformed rapidly into a forested biome, with a spruce forest in place by approximately 12,000 B.P. (Davis 1969). The spread of birch, pine, larch, and fir into the region, as well as limited amounts of oak, occurred by approximately 10,000 B.P. (Davis 1969; Thorson and Webb 1991). It was in this type of environment that Paleo-Indian culture flourished.

While there have been numerous finds of Paleo-Indian projectile points throughout the State of Connecticut, only two sites, the Templeton Site (6-LF-21) in Washington, Connecticut and the Hidden Creek Site (72-163) in Ledyard, Connecticut, have been studied in detail and dated using the radiocarbon method (Jones 1997; Moeller 1980). Almost all other Paleo-Indian sites located in Connecticut are surface finds. Many of these occur within the limits of the former glacial Lake Hitchcock basin (Curren and Dincauze 1977), demonstrating that the lake had drained close in time to the arrival of Paleo-Indian groups in the area.

The Templeton Site (6-LF-21), located in Washington, Connecticut was excavated by Roger Moeller (1980), and is positioned on a terrace overlooking the Shepaug River. Moeller (1980:19) indicates that the site area was located approximately 3.4 m (11.5 ft) above the river, and that the site area was characterized by loamy fine sand. Carbon samples recovered during excavation of the site area produced radiocarbon age of 10,190±300 B.P., for the occupation; thus, the site was used sometime between 10,490 and 9,890 years ago. In addition to a single large and two small fluted points, the Templeton Site produced gravers, drills, core fragments, scrapers, and channel flakes, indicating that the full range of lithic reduction took place within the site area (Moeller 1980). Moreover, use of both exotic and local raw materials was documented in the recovered lithic assemblage, suggesting that the site's occupants also had access to distant lithic sources. Use of these distant sources provides evidence for some level of embedded procurement of lithic raw materials during movement from region to region.

The only other Paleo-Indian site studied in detail in Connecticut is the Hidden Creek Site (72-163) (Jones 1997). Identified in 1992, the Hidden Creek Site is situated on the southeastern margin of the Great Cedar Swamp on the Mashantucket Pequot Reservation in Ledyard, Connecticut. The site area is positioned on a kame terrace that overlooks a small tributary stream that drains into the Great Cedar Swamp. While excavation of the Hidden Creek Site produced evidence of both Terminal Archaic and Woodland Period components in the uppermost soil horizons, the lower levels of the site area yielded artifacts that have been attributed to the Paleo-Indian Period by Jones (1997). Paleo-Indian artifacts recovered from the site area include broken bifaces, side scrapers, a fluted preform, gravers, and end scrapers. Jones (1997:76) argued that based on typological considerations the artifacts likely date from ca., 10,000 to 9,500 years ago.

Based on the types and number of tools present, Jones (1997:77) has hypothesized that the Hidden Creek Site represents a short-term occupation, probably in the range of 7 to 18 days in duration. Moreover, the distribution of artifact types and kinds of lithic debris indicate that discrete activity areas are discernible within the site area. Jones (1997:73-74) contends that separate lithic reduction and tool rejuvenation areas are indicated, and, since they were noted within an oval pattern, they are located within the confines of a former structure, possibly a skin tent.

While the evidence for Paleo-Indian occupation is scarce in Connecticut, combined with data from such sites as the West Athens Road and King's Road Site in the Hudson drainage, and the Davis and Potts Sites in northern New York, the hypothesis that there was human occupation of southern New England by 11,000 to 10,000 B.P. (Snow 1980) is supported. Further, the site types currently known suggest that the

settlement pattern is characterized by a high degree of mobility, with groups moving from region to region in search of seasonally abundant food resources, as well as for the procurement of high quality raw materials from which to fashion hunting and processing tools.

Archaic Period (10,000 to 2,700 B.P.)

The Archaic Period, first designated by Ritchie (1943) to describe all pre-ceramic cultures of the Northeast, began by ca., 10,000 B.P. (Ritchie and Funk 1973; Snow 1980). Later, Griffin (1967) and Snow (1980) divided the Archaic Period into three subperiods: Early Archaic (10,000 to 8,000 B.P.), Middle Archaic (8,000 to 6,000 B.P.), and Late Archaic (6,000 to 3,400 B.P.). These periods were meant to describe all non-horticultural populations in the Northeast. Moreover, the populations lacked ceramic technology.

After additional investigations, northeastern archeologists added a final "transitional" Archaic Period, the Terminal Archaic Period (3,400-2,700 B.P.), which was meant to describe those groups that existed in the area just prior to the onset of the Woodland Period and the widespread adoption of ceramics into the toolkit (Snow 1980; McBride 1984; Pfeiffer 1984, 1990; Witthoft 1949, 1953). Although these divisions are used commonly by northeastern archeologists, McBride (1984) and others have found substantial temporal and stratigraphic overlap in the distribution of "diagnostic" artifact types, especially for the Archaic. As discussed in detail below, this overlap and the presence or absence of various cultural traits has led to the formation of several cultural phases for the Archaic Period of southern New England (McBride 1984).

Early Archaic Period (10,000 to 8,000 B.P.)

To date, very few Early Archaic sites have been identified in southern New England. As a result, researchers such as Fitting (1968) and Ritchie (1969), have suggested the lack of sites of this age likely is tied to cultural discontinuity between the Early Archaic and preceding Paleo-Indian Period, as well as a population decrease from earlier times. However, with continued identification Early Archaic sites in the region, and the recognition of the problems of preservation and visibility of these sites in New England (McBride 1984), it is difficult to maintain the discontinuity hypothesis (Curran and Dincauze 1977; Snow 1980).

In addition to the problems of differential preservation, Early Archaic Period occupations in southern New England, unlike other portions of the country (notably the Southeast), are difficult to identify. Like their Paleo-Indian predecessors, Early Archaic sites tend to be very small, and they produce few artifacts, most of which are not temporally diagnostic. While Early Archaic sites in other portions the United States are represented by projectile points of the Kirk series (Ritchie and Funk 1973) and by Kanawha types (Coe 1964), sites of this age in southern New England are identified based on the recovery of a series of ill-defined bifurcate-based projectile points. These projectile points are identified by the presence of their characteristic bifurcated base, and they generally are made from high quality raw materials, though some quartz and quartzite specimens have been recovered. Moreover, finds of these projectile points have rarely been in stratified contexts. Rather, they occur commonly either as surface expressions or intermixed with artifacts representative of later periods of prehistory.

In Connecticut, a notable site that has produced stratified deposits dating from the Early Archaic Period is the Dill Farm Site in the lower Connecticut River Valley (McBride 1984; Pfeiffer 1986), and others (Barber 1980; Thomas 1980). Extrapolating from the Dill Farm Site, which dates from 8,050±90 B.P., and from regional surveys in the lower Connecticut River Valley, McBride (1984) has determined that Early Archaic sites generally are positioned within 0.2 km (0.5 mi) of the Connecticut River. This site distribution, combined with a shift in projectile point technology from large lanceolate points in the Paleo-Indian Period to shorter, more robust bifurcate-based projectile points suggests a "settling in" process occurred and that groups became more focused on locally available and smaller game species.

Occupations of this time period are represented by camps that moved periodically to take advantage of seasonally available resources (McBride 1984). In this sense, a foraging type of settlement pattern was employed during the Early Archaic Period.

Middle Archaic Period (8,000 to 6,000 B.P.)

By the onset of the Middle Archaic Period, essentially modern deciduous forests had developed in southern England (Davis 1969). It is at this time that increased numbers and types of sites are noted in the region (McBride 1984). The most well-known Middle Archaic site in New England is the Neville Site, which is located in Manchester, New Hampshire and which was studied in detail by Dincauze (1976). The Neville Site produced the first evidence of a Middle Archaic component that was stratigraphically intact and which could be dated reliably using the radiocarbon method.

Careful analysis of the Neville Site indicated that the Middle Archaic occupation dated from between ca., 7,700 and 6,000 years ago. In fact, Dincauze (1976) obtained several radiocarbon dates from the Middle Archaic component of the Neville Site. The dates, associated with the then-newly named Neville type projectile point, ranged from 7,740±280 and 7,015±160 B.P. (Dincauze 1976). Dincauze argued that the Neville projectile point, which is the oldest type of Narrow-Stemmed projectile point in the region (see below), is typologically similar to, but distinct from, the Stanley projectile point described by Broyles (1966) and (Coe 1964) at the St. Albans and Doerschuck Sites in the Southeast.

In addition to Neville projectile points, Dincauze (1976) described two other projectile points styles recovered from stratified contexts at the Neville Site that are attributable to the Middle Archaic Period. They are the Stark and Merrimac projectile points. While no absolute dates were recovered from deposits that yielded Stark points, the Merrimac type dated from 5,910±180 B.P. She argued that both the Neville and later Merrimac and Stark occupations were established to take advantage of the excellent fishing that the falls situated adjacent to the site area would have afforded Native American groups.

As a result of the investigations at the Neville Site, Dincauze (1976) proposed that the Middle Archaic Period is characterized by the "Atlantic Slope Cultural Area," which is represented by the oldest, small or narrow stemmed projectile points in the region. This concept was devised by Dincauze (1976) to unite sites of this age from both the Southeast and Northeast into a single cultural unit, as well as to distinguish this area from other areas to the west of the Appalachian highlands.

During the late 1970s and early 1980s, McBride (1984) conducted archeological investigations in the lower Connecticut River Valley in an attempt to better describe the prehistoric settlement and use of the area. While radiocarbon dates are largely lacking, McBride (1984) noted that Middle Archaic sites in the lower Connecticut River Valley tend to be represented by moderate density artifact scatters that produce examples of Neville and Stark projectile point types; Merrimac projectile points are largely lacking in the region. Further, archeological investigations in the area led to the determination that the lower Connecticut River Valley was occupied fairly intensively by Middle Archaic times, and that occupations identified in the area represent a "diversity of site types, with both large-scale occupations and small special purpose present (McBride 1984:96). As McBride (1984) has pointed out, Middle Archaic sites are distributed in both riverine and upland locales. Based on the available archeological evidence, the Middle Archaic Period is characterized by continued increases in diversification of resources exploited, as well as by sophisticated changes in the settlement pattern to include different site types, including both base camps and task-specific sites (McBride 1984:96).

Late Archaic Period (6,000 to 3,700 B.P.)

The Late Archaic Period in southern New England is divided into two major cultural traditions that appear to have coexisted in the region. They include the Laurentian and Narrow-Stemmed Traditions

(Funk 1976 McBride 1984; Ritchie 1969a and b). Archeological sites, cultural traits, settlement patterns, and land use patterns characteristic of these two traditions are discussed below.

The Laurentian Tradition (ca., 6,000 to 4,200 B.P.)
The Late Archaic of the Northeast was much more regionally diversified than either the Early or Middle Archaic Periods. This difference is attributed to environmental stabilization and population increases. The earliest Late Archaic sites in southern New England can be ascribed loosely to cultures of the Laurentian tradition (ca., 6,000 to 4,200 B.P.) (Dincauze 1974:48-49, Ritchie 1969a:233). They cannot, however, be strictly considered "Laurentian" because they lack many of the traits associated with that complex. Rather, they are local manifestations that rarely exhibit more than the diagnostic projectile point forms associated with the Laurentian Tradition (Snow 1980:2 19).

Artifacts assigned to the Laurentian Tradition include ground stone axes, adzes, gouges, ulus (semi-lunar knives), pestles, atlatl weights and scrapers. The diagnostic projectile point forms of this time period in southern New England include the Brewerton Eared-Notched, Brewerton Eared and Brewerton Side-Notched varieties (McBride 1984; Ritchie 1969a). In general, the lithic assemblage of this tradition is characterized by flint, felsite, rhyolite and quartzite, while quartz was largely avoided as a raw material for stone tool manufacturing.

In terms of settlement and subsistence, archeological evidence in southern New England suggests that Laurentian Tradition populations consists of groups of mobile hunter-gatherers. While a few large Laurentian Tradition occupations have been identified and studied, they generally encompass less than 500 m^2 in area. These base camps reflect frequent movements by small groups of people in search of seasonally abundant resources. The overall settlement pattern of the Laurentian Tradition was dispersed in nature, with base camps located in a wide range of microenvironments, including riverine as well as upland zones (McBride 1984:252).

Subsistence strategies of Laurentian Tradition focused on hunting and gathering of wild plants and animals from multiple ecozones. While White-tailed deer comprised a prominent part of the diet, plant foods, including seeds and hickory nuts, were utilized. For example, the Bashan Lake Site, a Laurentian Tradition campsite located in East Haddam, Connecticut, has yielded evidence of Brewerton projectile points, net sinkers, grinding stones, hearths and charred hickory nuts dating from 4,730$\pm$280 years ago (Pfeiffer 1983:10).

The relative absence of storage pits and structural remains from the Laurentian Tradition occupations in southern New England indicates a lifestyle dominated by a high degree of mobility. Small groups of hunter/gatherers moved across the landscape in pursuit of seasonally abundant resources. An exception to this pattern is the Bliss-Howard Site discovered by Pfeiffer (1984:74-75). The Bliss-Howard Site, located in Old Lyme, Connecticut, is a cremation/occupation complex dating from approximately 4,700 years ago. At this site, Pfeiffer (1984) identified 21 cremation burials with grave offerings including Brewerton projectile points, atlatl weights, axes, pestles, scrapers, faunal remains, and carbonized seed and nut remains (Pfeiffer 1984:74-75). Adjacent to the cremation cemetery is situated a large Laurentian Tradition occupation site. Pfeiffer (1984) argued convincingly that the habitation and cemetery were contemporaneous because artifacts found in these two contexts cross-mended in some cases. The cremation/occupation complex may have been a place where families aggregated for a period of time during the year. Large sites, such as Bliss-Howard and Bashan Lake, suggest that aggregations occurred for at least a portion of the year.

In his study of prehistoric settlement patterns of the lower Connecticut River Valley, McBride (1984) suggested the use of the term Golet phase to discuss occupation sites that have produced Laurentian projectile point types (e.g., Vosburg and Brewerton series). By obtaining radiocarbon dates from a

variety of sites that produced Vosburg and Brewerton projectile points, McBride (1984) derived a time span of 4,700 to 4,200 B.P., for the Golet Phase. The evidence from occupation sites such as Bashan Lake and burial areas such as Bliss-Howard indicate that a significant population of hunter-gatherers inhabited the lower Connecticut River Valley during the early part of the Later Archaic Period (e.g., during the Golet phase). According to McBride (1984) Golet phase populations employed a settlement patter that "appears to be very dispersed, with small mobile groups exploiting a wide range of microenvironments and environmental locales."

The Narrow Stemmed Tradition (ca. 4,200 to 2,900 B.P.)

The latter portion of the Late Archaic is dated between 4,200 and 2,900 years ago, and it is represented by local manifestations of the largest cultural tradition indigenous to southern New England and the mid-Atlantic regions (Dincauze 1975:47, McBride 1984:110). Known regionally as the Narrow-Stemmed Tradition, it is unlike the Laurentian Tradition; it likely represents a different cultural adaptation. The Narrow Stemmed tradition is recognized by the presence of quartz and quartzite narrow stemmed projectile points, triangular quartz Squibnocket projectile points, and a bipolar lithic reduction strategy (McBride 1984).

In general, the Narrow-Stemmed Tradition corresponds to when Late Archaic populations in southern New England began to "settle into" well-defined territories. As mentioned above, the lithic industry of this period was dominated almost exclusively by the use of locally available quartz cobbles. The characteristic narrow-stemmed projectile points were manufactured using a bipolar reduction technique whereby a quartz cobble was crushed using a hammerstone and anvil to produce raw material for stone tool manufacture. Other tools found in Narrow-Stemmed Tradition artifact assemblages include choppers, adzes, pestles, antler and bone projectile points, harpoons, and awls, as well as notched atlatl weights. Many of these tools, notably the projectile points and pestles, indicate a subsistence pattern dominated by hunting and collecting of plant foods, especially nuts (Snow 1980:228).

In addition to terrestrial fauna and flora, evidence for the use of shellfish increased during the Narrow-Stemmed Tradition. For example, at the Archaic Midden site in Haddam, Connecticut, a Narrow-Stemmed Tradition site dating to 3 990$\pm$60 years ago, McBride (1984:112) recovered evidence for the use of freshwater clams, oyster, and quahog. Similarly, Ritchie has found abundant evidence for use of the same species on the Horn Blower II site on Martha's Vineyard. The date for the Horn Blower II site is ca., 4,000 years ago (Ritchie 1969b:38).

Further, Narrow-Stemmed Tradition settlement patterns are marked by an increase in the types of sites utilized. Whereas the Laurentian Tradition usually is characterized by smaller sites and higher mobility, the Narrow-Stemmed Tradition witnessed the introduction of large base camps supported by small task-specific sites and temporary camps. The introduction of these new site types suggests a more entrenched settlement pattern than that of the preceding Laurentian Tradition. This is evidenced by the archeological deposits at the Woodchuck Knoll Site (McBride 1978:124).

Woodchuck Knoll is a large Narrow-Stemmed Tradition base camp located on the floodplain of the Connecticut River in South Windsor, Connecticut. The associated radiocarbon dates for Woodchuck Knoll fall between 3,760 and 3,500 years ago. The site is particularly important for understanding Narrow-Stemmed Tradition settlement patterns because it demonstrates the re-occupation of a single area many times, something which was largely lacking during preceding periods. Moreover, Woodchuck Knoll exhibits the remains of numerous features, including hearths, caches and storage pits, all of which indicate a long term, perhaps multi-season, use of the site. This is particularly true of storage pits, which, until Narrow-Stemmed Tradition times, apparently were not utilized in southern New England. Storage pits at the Woodchuck Knoll Site contained the charred remains of hickory, walnut, hazelnut, and *Chenopodium* sp., indicating a heavier reliance on local plant foods (McBride 1978:130).

In addition to the Woodchuck Knoll Site, many task-specific and temporary camps of the Narrow-Stemmed Tradition have been detected in almost every microenvironment in southern New England, including riverine areas, around interior wetlands, upland streams, coastal zones, and lacustrine settings. These sites were utilized as support mechanisms for the larger base camps, such as Woodchuck Knoll. Further, they attest to a more well-established settlement pattern during the Narrow-Stemmed Tradition. While this pattern was well established, it still relied on frequent groups movement. The difference at this time is that group movements were made between areas that were frequented over and over in the past.

Based on recovered archeological evidence, McBride (1984) has suggested two separate phases for the Narrow Stemmed Tradition. They are the Vibert and Tinkham phases. The Vibert phase was identified first at the Woodchuck Knoll (McBride 1978), while the Tinkham phase was interpreted from archeological deposits encountered at the Tinkham Site in Tolland, Connecticut. In terms of temporally diagnostic tool types, the Vibert Phase IBs recognized by the presence of small, triangular Squibnocket projectile points, while the Tinkham Phase IBs represented by the ubiquitous narrow stemmed projectile point. In addition, the Vibert and Tinkham phases were marked by the introduction of new and diverse site types, a heavier reliance on local plant foods, and re-occupation of and longer stays at base camps. These data suggest larger seasonal aggregations of people than the previous Golet phase, as well as decreased mobility. The increased number of temporary and task specific sites, especially those belonging to the Tinkham phase, indicates frequent movements out of and back into base camps for the purpose of resource procurement; however, the base camps were relocated seasonally to position groups near frequently used, but dispersed, resources (McBride 1984:262).

The Terminal Archaic Period (3,700 to 2,700 B.P.)

The Terminal Archaic, which lasted from ca., 3,700 to 2,700 BP, is perhaps the most interesting, yet confusing of the Archaic Periods in southern New England prehistory. Originally termed the "Transitional Archaic" (Witthoft 1953) and recognized by the introduction of technological innovations, e.g., broadspear projectile points and soapstone bowls, the Terminal Archaic has long posed problems for southern New England archeologists. While the Narrow-Stemmed Tradition persisted through the Terminal Archaic and into the Early Woodland Period, the Terminal Archaic is coeval with what appears to be a different technological adaptation, namely the Susquehanna Tradition (McBride 1984; Ritchie 1969b). The Susquehanna Tradition is recognized in southern New England by the presence of a new lithic industry that was based on the use of high quality raw materials for stone tool production and a settlement pattern different from the "coeval" Narrow-Stemmed Tradition.

The Susquehanna Tradition is based on the classification of several Broadspear projectile point types and associated artifacts. There are several local sequences within the tradition, and they are based on projectile point type chronology. Temporally diagnostic projectile points of these sequences include the Snook Kill, Susquehanna Broad, Mansion Inn, and Orient Fishtail types (Lavin 1984; McBride 1984; Pfeiffer 1984). Generally, the initial portion of the Terminal Archaic Period (ca., 3,700-3,200 BP) is characterized by the presence of Snook Kill and Susquehanna Broadspear projectile points, while the latter Terminal Archaic (3,200-2,700 BP) is distinguished by the use Orient Fishtail projectile points (McBride 1984:119; Ritchie 1971). There is much variation within the suite of artifacts within the Susquehanna Tradition, and, as a result, it should not be interpreted directly as a cultural system (Snow 1980:239).

The Susquehanna Tradition lithic industry was based on the use and modification of such raw material types as flint, chert, argillite, hornfels, rhyolite, and quartzite. Locally abundant quartz was avoided because of its poor fracturing qualities (McBride 1984:115-116). Thus, it can be said that the Narrow-Stemmed Tradition differs from the Susquehanna Tradition in technology, morphology, and raw material preferences. In addition, the material culture of the Terminal Archaic includes soapstone vessels, chipped

and ground stone adzes, atlatl weights, drills, net sinkers, plummets and gorgets (Lavin 1984; McBride 1984; Ritchie 1969a and 1969b; Snow 1980), the most temporally diagnostic of which soapstone or steatite bowl. These vessels are shallow, have flat bottoms, are oval or rectangular in shape, have lugged handles at the narrow ends, and range from 12 to 50 cm (5 to 20 in) in length. The finished bowls are heavy and they demonstrate extended use; that is, many often have evidence of repairs (Snow 1980:240). It has been suggested that they are modeled after wooden prototypes (Snow 1980:240). The soapstone bowls tend to be found only at base camps along river terraces.

In the late Terminal Archaic there also is the appearance of interior cord marked, grit tempered, thick walled ceramics with conoidal bases; these ceramics occur in very minor amounts. These are the first ceramics in the Northeast and are named Vinette I (Ritchie 1969a; Snow 1980:242); this type of ceramic vessels appears with much more frequency during the ensuing Early Woodland Period. The adoption and widespread use of soapstone bowls, as well as the implementation subterranean storage, suggests that Terminal Archaic groups were characterized by reduced mobility (Snow 1980:250).

In addition, the recovery of soapstone bowls from numerous archeological sites in Connecticut indicates that local populations had access to and participated in regional exchange networks. For example, soapstone, or steatite, bowls appear to be tied into large inter-regional exchange networks that extended across the Northeast (Snow 1980:240). Moreover, the increased percentage of high quality lithics, e.g., chert, flint, felsite, etc., recovered from Terminal Archaic sites in the region also attests to the maintenance of long distance exchange networks, since these raw materials do not exist naturally within the borders of the State of Connecticut. As such, this is the best and earliest evidence of trade and exchange in southern New England. The majority of raw materials exchanged at this time can be found in riverine settings, and settlement along the major drainages would have facilitated trade.

There also are a large number of Terminal Archaic cremation cemeteries with burials that have produced broadspear points and radiocarbon dates between 3,700 and 2,700 B.P. (Pfeiffer 1990). Among the grave goods are ritually "killed" (intentionally broken) steatite vessels, as well as ground stone and flaked stone tools (Snow 1980:240); however, this represents an important continuation of traditions from the Late Archaic and it should not be regarded as a cultural trait unique to the Susquehanna Tradition (Snow 1980:244).

In addition, just as the artifact assemblage of the Susquehanna Tradition differed from Narrow-Stemmed Tradition, so too did settlement patterns. While Susquehanna Tradition settlement patterns are centered around large base camps that are analogous to that unearthed at the Late Archaic Woodchuck Knoll Site, they were located in a different ecozone: terrace edges overlooking floodplains. Terminal Archaic settlements generally are situated on river terraces with few, very small task specific upland sites located nearby (McBride 1984:282, Lavin 1988). Ritchie and Funk (1973), for example, noted that nearly all the Orient Fishtail components of the Susquehanna Tradition are located near seashores or along major rivers, usually in locations protected from prevailing winds (see also Snow 1980:249). The Timothy Stevens Site is an example of such a large Terminal Archaic base camp in the Connecticut River drainage. This site, radiocarbon dated from 2,740±60 years ago, is situated on the edge of a terrace adjacent to the Connecticut River floodplain in central Connecticut. The site area has produced evidence of house remains, hearths, caches and storage pits, all of which are indicative of a large-scale, long term occupation (Pagoulatos 1988:76). Prolonged occupation of these sites may explain partially the changes in settlement from occupying the floodplain to moving up onto the terraces. That is, the terraces can be occupied earlier in the spring because they are not threatened by the annual spring flooding.

Acting as support facilities for the large Terminal Archaic base camps were numerous task specific sites and temporary camps. In general, these sites measure between 100 to 200 and 300 m^2 or larger in size, respectively. Such sites were used as extraction points for the procurement of resources not found in the

immediate vicinity of the base camps, and they generally were located adjacent to upland streams and wetlands (McBride 1984:282). It is generally accepted that base camps were occupied from spring to fall in order to harvest anadromous and catadromous (migratory) fish runs, while interior sites were occupied during the colder months (Snow 1980:249).

While superficially it would appear those sites that have produced Susquehanna Tradition materials and sites containing Narrow-Stemmed Tradition materials were similar in nature, they were not. McBride (1984) indicated that settlement patterns associated with the Narrow-Stemmed Tradition, were characterized by large base camps, task-specific sites and temporary camps that were relatively evenly distributed across the landscape; they were ascribed to the above-referenced Tinkham phase. As mentioned above, Tinkham phase occupations appeared in all microenvironments, including riverine, upland, inland wetlands and lakeshores. Susquehanna Tradition settlements, on the other hand, which McBride (1984:278) argues belong to the Salmon Cove phase, were not so evenly distributed. That is, whereas Tinkham phase base camps sometimes occurred in upland locales, Salmon Cove phase base camps appeared almost exclusively within riverine settings (McBride 1984:278). In addition, those Salmon Cove phase temporary camps and task-specific occupations located in the uplands were of short duration, long enough only to replenish supplies for the riverine base camps.

Unlike settlement patterns, however, Terminal Archaic Salmon Cove phase subsistence patterns were analogous to earlier patterns. The subsistence pattern still was diffuse in nature, and it was scheduled carefully. For example, food remains recovered from the Timothy Stevens Site included fragments of white-tailed deer, beaver, turtle, fish and various small mammals. Botanical remains recovered from the site area consisted of *Chenopodium* sp., hickory, butternut and walnut (Pagoulatos 1988:81). Such diversity in food remains suggests at least minimal use of a wide range of microenvironments for subsistence purposes.

Woodland Period (2,700 to 350 B.P.)

Traditionally, the advent of the Woodland Period in southern New England has been associated with the introduction of pottery; however, as mentioned above, early dates associated with ceramics now suggest the presence of Vinette I ceramics appeared toward the end of the preceding Terminal Archaic Period (Ritchie 1969a; McBride 1984). Like the Archaic Period, the Woodland Period has been commonly divided into three subperiods: Early, Middle, and Late Woodland. In contrast, Snow (1980) has segmented the Woodland Period into two subperiods. He combined the Early and Middle Woodland to form the Early Horticultural Period (2,700 to 1,000 B.P.), while he renamed the Late Woodland into the Late Prehistoric Period (1,000-350 B.P.).

While Snow's (1980) reconfiguration of the Woodland Period is not without merit, it has met with resistance among southern New England archeologists, who continue in large measure to use the traditional three subperiod nomenclature. An exception to this rule can be found in McBride's (1984) study of the lower Connecticut River Valley, where he subdivides the Woodland period into four phases: the Broeder Point Phase (ca., 2,700 to 2,000 B.P.), The Roaring Brook phase (ca., 2,000 to 1,250 B.P.), the Selden Creek phase (1,250 to 450 B.P.), and the Niantic phase (ca., 450 to 350 B.P.). The latter phase typically is referred to as the "Final Woodland" period. The various Woodland subperiods and phases are discussed in detail below.

<u>Early Woodland Period (ca., 2,700 to 2,000 B.P.)</u>

The Early Woodland period of the northeastern United States dates from ca., 2,700 to 2,000 B.P., and it has thought to have been characterized by the advent of horticulture, the initial use of ceramic vessels, and increasingly complex burial ceremonialism, with the use of mounds to bury the dead in the Midwest (Dragoo 1967; Griffin 1967; Ritchie 1969a and 1969b; Snow 1980). In the Northeast, the earliest

ceramics of the Early Woodland period are thick walled, cord marked on both the interior and exterior, and possess grit temper.

In southern New England and New York, two different regional complexes have been described for the Early Woodland Period. They are the Meadowood Complex in New York (Ritchie 1969a) and the Lagoon Complex on Martha's Vineyard (Ritchie 1969b). Both are characterized by the presence of Meadowood and Rossville projectile points, settlement patterns focused on riverine and coastal settings, and thick grit-tempered ceramic vessels.

In his study of the lower Connecticut River Valley, McBride (1984) identified a distinct phase for the Early Woodland Period. McBride (1984:294) named it the Broeder Point phase, and it encompasses the entirety of the Early Woodland Period (i.e., 2,700 to 2,000 B.P.). As described, the Broeder Point phase "is characterized by a quartz cobble lithic industry, narrow-stemmed points, an occasional Meadowood projectile point, thick, cord-marked ceramics, and perhaps human cremations" (McBride and Soulsby 1989:50).

Despite this description, data associated with Broeder Point phase are not recovered often; however, one the best-known sites of this phase is the Waldo-Hennessey Site in Branford, Connecticut McBride (1984:125). Excavation of the site area revealed the presence of several small seasonal, and perhaps sequential, occupations situated adjacent to a tidal estuary. Careful investigation of the site area also resulted in the recovery of narrow stemmed projectile points in association with ceramic sherds and subsistence remains, including specimens of White-tailed deer, soft and hard shell clams, and oyster shells (McBride 1984:296-297). McBride (1984) argued that the combination of the subsistence remains and the recognition of multiple superimposed cultural features indicates that the site was reoccupied on a seasonal basis by a small co-residential group.

In terms of regional settlement patterns, Broeder Point phase sites, like those of the Late Archaic Tinkham phase, are located in a variety of different ecozones; however, the largest settlements associated with this phase were focused on floodplain, terrace, and lacustrine environments (McBride 1984:300). Thus, while there is similarity to settlements patterns of the Tinkham phase, it is a superficial one. The main difference between the phases is that the Broeder Point phase is characterized by "population aggregations along major rivers, interior lakes, and wetlands" (McBride and Soulsby 1989:50), whereas Tinkham phase occupations reflect seasonal groups movements by smaller numbers of people.

Despite this difference, McBride (1984:299) suggests that the Broeder Point phase was characterized by seasonal base camps only; that is, task-specific and temporary camps are largely lacking during this phase. This may reflect two different situations. First, such site types were not employed for the collection of resources, which seems unlikely. Second, Broeder Point temporary and task-specific sites are largely unrecognizable because of both their size and the fact that they do not produce the whole suite of Broeder Point technology, namely narrow stemmed projectile points and ceramics. If lacking the latter, such sites are likely to be misinterpreted as Tinkham phase occupations, which were characterized by the presence of narrow stemmed projectile points and the absence of ceramic technology. As a result, it is very likely that southern New England archeologists are misidentifying many Broeder Point phase sites, ultimately leading to the interpretation that the area was occupied by a population smaller than that of previous prehistoric periods (Dincauze 1974).

In terms of Broader Point phase occupations that have been identified and investigated in detail, McBride and Soulsby (1989:50-51) discussed five sites that were identified during the Route 6/I-84 expansion project. They indicate that the identified sites were "distributed fairly evenly between upland streams and interior swamps, and generally found less than 20 meters from a water source" (McBride and Soulsby 1989:50). Radiocarbon samples obtained from Sites 22-2, 19-6, and 12-2 returned dates of 2,380$\pm$210

B.P., 2,650±90 B.P., and 2,060±90 B.P., respectively (McBride and Soulsby 1989:50-51). The sites produced multiple cultural features, as well as significant amounts of quartz debitage, including resharpening flakes, which indicate that both tool manufacture and maintenance activities took place within the limits of each site area. McBride and Soulsby (1989:51) argue that the recovered lithic assemblage is reflective of "woodworking, animal butchering, skin working, and plant processing activities." In addition, the recovered faunal assemblage consisted of specimens of raccoon, snake, White-tailed deer, and hickory and walnut shell fragment. Their recovery, as well as the evidence for multiple cultural features and tool manufacturing and curation, suggest that the sites reflect multi-season use as base camps (McBride and Soulsby 1989:51).

In sum, archeological evidence collected by McBride (1984) during his dissertation research in the lower Connecticut River Valley, as well as that noted by McBride and Soulsby (1989) during their survey of the then-proposed Route 6/I-84 expansion corridor, indicates that Broeder Point phase populations consisted of mobile hunter/gatherers that moved seasonally throughout a diversity of environmental zones in search of available plant and animal resources. As such, Broeder Point phase populations employed a foraging type of resource exploitation strategy, reflecting somewhat of a return to a Late Archaic lifestyle.

Middle Woodland Period (2,000 to 1,200 B.P.)

The Middle Woodland Period of southern New England prehistory is marked by an increase in the number of ceramic types and forms utilized (Lizee 1994a), as well as an increase in the amount of exotic lithic raw material used in stone tool manufacture (McBride 1984). The latter indicates that regional exchange networks were operationalized once again, and that they were used extensively to supply local populations with necessary raw materials (McBride 1984; Snow 1980). Specifically, the recovery of certain types of chert and jasper indicate that Middle Woodland populations of the lower Connecticut River Valley had obtained raw material for stone tool manufacturing from the Hudson Valley (cherts) and eastern Pennsylvania (jasper) (George and Tryon 1996). Some authors have argued that the changes in ceramic technology and the increased reliance on regional exchange signified the beginning of a trend toward sedentism (McBride 1984; Snow 1980; Ritchie 1969a, 1969b); this argument is bolstered by the increased use of shellfish on the coast, as well as by the diversification of the diet to include additional types of wild plant foods and animal resources. These trends are discussed in more detail below.

In Connecticut, the Middle Woodland Period is represented archeologically by the Roaring Brook phase, which was defined by McBride (1984:134) during his investigations of settlement patterns in the lower Connecticut River Valley. In particular, McBride (1984:135) indicates that the Roaring Brook phase marked by use of narrow stemmed and Jack's Reef projectile points; increased amounts of exotic raw materials in recovered lithic assemblages, including chert, argillite, jasper, and hornfels; and conoidal ceramic vessels decorated with dentate stamping. Ceramic types indicative of the Roaring Brook Phase Include Linear Dentate, Rocker Dentate, Windsor Cord Marked, Windsor Brushed, Windsor Plain, and Hollister Stamped (Lizee 1994a:200. In addition, Lizee (1994a:200) has noted that shifts in Roaring Brook phase "vessel morphology includes two contemporary forms: conoidal and elongated conoidal." He further indicates that this change was gradual and that it happened throughout the Roaring Brook phase; in addition to morphological changes, the Roaring Brook phase witnessed the first use of shell tempering in ceramic vessels (Lizee 1994a:200).

What this shift in ceramic technology reflects is difficult to say at present because large-scale investigations of Roaring Brook phase components have been conducted only infrequently. However, in his 1987 article, Braun suggested that changes in ceramic technology, specifically morphological evolution from conoidal toward elongated and globular with constricted necks, may represent a subsistence shift to include the use of starchy plant foods such as maize and/or other domesticated plant foods, e.g., *Chenopodium* sp., which required suspension of pots over fires rather than placement within a heating source. In addition, the addition of shell temper to ceramics has been demonstrated to reduce the

amount of thermal shock to a pot that is put under slow boiling conditions such as would have been the case with the preparation of maize and other domesticated plant foods (Braun 1987).

In terms of settlement patterns, the Roaring Brook phase is characterized by the occupation of village sites by large co-residential groups. These sites were the principal place of occupation, and they were positioned in close proximity to major river valleys, tidal marshes, estuaries, and the nearby coastline, all of which would have supplied an abundance of plant and animal resources (McBride 1984:309). In addition to villages, numerous temporary and task-specific sites were utilized in the surrounding upland areas, as well as in closer ecozones such as wetlands, estuaries, and floodplains. The use of temporary and task-specific sites to support large village populations indicates that the Roaring Brook phase was characterized by a resource acquisition strategy that can best be termed as logistical collection (McBride 1984:310).

Late Woodland Period (ca., 1,200 to 350 B.P.)

The Late Woodland period in southern New England dates from ca., 1,200 to 350 B.P., and it is characterized by the Selden Creek and Niantic phases (McBride 1984). The Selden Creek Phase, which dates from ca., 1,200 to 450 B.P., is considered significant by Connecticut archeologists because it has produced the earliest evidence for the use of maize in the lower Connecticut River Valley (Bendremer 1993; Bendremer and Dewar 1993; Bendremer et al. 1991; George 1997; McBride 1984); an increase in the frequency of exchange of non-local lithics (Feder 1984; George and Tryon 1996; McBride 1984; Lavin 1984); increased variability in ceramic form, function, surface treatment, and decoration (Lavin 1980, 1986, 1987; Lizee 1994a, 1994b); and a continuation of a trend towards larger, more permanent settlements in riverine, estuarine, and coastal ecozones (Dincauze 1973, 1974; McBride 1984; Snow 1980).

Lithic assemblages associated with Selden Creek Phase occupations, especially village-sized sites, are functionally variable and they reflect plant and animal resource processing and consumption on a large scale. McBride (1984:322) argued that lithic assemblages recovered from Selden Creek Phase sites typically contain approximately 20 percent non-local lithics at the beginning of the phase, whereas they reach densities of 60 to 70 percent by the end of the phase. Finished stone tools recovered from Selden Creek Phase sites include Levanna and Madison projectile points; drills; side-, end-, and thumbnail scrapers; mortars and pestles; nutting stones; netsinkers; and celts, adzes, axes, and digging tools. These tools were used in activities ranging from hide preparation to plant processing to the manufacture of canoes, bowls, and utensils, as well as other settlement and subsistence-related items (McBride 1984; Snow 1980.

In addition, ceramic assemblages recovered from Selden Creek Phase sites are as variable as the lithic assemblages. Ceramic types identified in Selden Creek Phase settlements include Windsor Fabric Impressed, Windsor Brushed, Windsor Cord Marked, Windsor Plain, Clearview Stamped, Sebonac Stamped, Selden Island, Hollister Plain, Hollister Stamped, and Shantok Cove Incised (Lavin 1980; Lizee 1994a; Pope 1953; Rouse 1947; Salwen and Ottesen 1972; Smith 1947). These types are more diverse stylistically than their predecessors, with incision, shell stamping, punctation, single point, linear dentate, rocker dentate stamping, and stamp and drag impressions common (Lizee 1994a:216). Surface treatments of Selden Creek Phase ceramics include fabric impression, cord marking, smoothing, and brushing (Lavin 1980; Lizee 1994a; McBride 1984).

Further, ceramic vessel morphology underwent extensive changes during the Selden Creek Phase. For example, Selden Creek Phase vessels exhibit a more globular form, with rounded bottoms, constricted necks, and out-flaring rims becoming common. They also are thinner than their earlier counterparts, and they include collars and castellations, as well as some new forms of lip treatment. The use of shell

tempering also became common and geographically widespread during the Selden Creek Phase (Lavin 1980; Lizee 1994a; McBride 1984).

In addition, as a result of his investigation of the distribution, size, and inferred function of archaeological sites in the lower Connecticut River Valley, McBride (1984:323-329) characterized Selden Creek Phase settlement patterns as more nucleated than the preceding Roaring Brook phase, with fewer, larger sites situated in estuarine and riverine ecozones. Both river confluences and coastal zones were favored for the establishment of large village sites that contain numerous hearths, storage pits, refuse pits, ceramic production areas, house floors, and human and dog burials (Lavin 1988b; McBride 1984). McBride (1984:326) has argued that these sites certainly reflect multi-season use, and were perhaps occupied on a year-round basis (see also Bellantoni 1987).

In addition to large village sites, McBride (1984:326) identified numerous temporary and task-specific sites in the uplands of the lower Connecticut River Valley and along the coastline. These sites likely were employed for the collection of resources such as plant, animal, and lithic raw materials. These sites tend to be very small, lack internal organizational structure, and usually contain a limited artifact assemblage and few cultural features, suggesting that they were occupied from only a few hours to perhaps overnight. Temporary camps, on the other hand reflect a longer stay than task-specific camps, perhaps on the order of a few days to a week, and they contain a more diverse artifact assemblage indicative of more on-site activities, as well as more features (McBride 1984:328-329). In sum, settlement patterns of the Selden Creek Phase in the lower Connecticut River Valley and adjacent coastline area are characterized by "1) aggregation in coastal/riverine areas; 2) increasing sedentism, and; 3) use of upland areas by small task groups of individuals organized for specific tasks" (McBride 1984:326).

In addition to the Selden Creek Phase, the Late Woodland Period encompasses the Niantic phase of Connecticut prehistory. The Niantic phase, sometimes referred to the Final Woodland Period, spans from ca., 450 to 350 B.P. (McBride 1984:145). While encompassing a short period of time, this phase characterized by the continued increase in the reliance on non-local lithic raw materials for stone tool manufacture, use of maize horticulture, and a decrease in the number of ceramic types utilized. Projectile points characteristic of the Niantic phase include the Levanna type (McBride 1984).

In his dissertation research of the Windsor Tradition ceramics, Lizee (1994a) indicated that stylistic diversity in Niantic phase ceramics decreased, while the numbers and types of tools used to produce and decorate vessels increased. Lizee (1994a:233) argues that decreases in stylistic variation may reflect the consolidation of ceramic production techniques and decorative styles, with such changes possibly related to the evolution of tribal groups within the area. Lizee (1994a) also suggests that increased variety in vessel sizes during the Niantic phase may be attributed to shifts in ceramic vessel function. Various vessel functions apparent at this time include cooking versus storage, among others.

It is important to note that numerous researchers have indicated that maize horticulture is a central feature of the subsistence pattern by Niantic phase times in Connecticut (Bendremer 1993; Bendremer and Dewar 1993; George 1997; Lizee 1994a; Lavin 1988; McBride 1984). This is consistent with Lizee's (1994a) arguments concerning ceramic treatments and the possible development of tribal entities at this time. Interestingly, however, Niantic phase settlement patterns are different from those of the preceding Selden Creek phase. While large village sites still are found in a multitude of ecozones, including riverine, estuarine, tidal, lake, and coastal areas, smaller seasonal camps appear in the archeological record at this time. Such sites were absent during the previous Roaring Brook and Selden Creek phases, and their appearance represents a shift in land use patterns during the Niantic phase.

McBride (1984:337) argues that the small seasonal camps of the Niantic phase are located primarily in upland settings near streams and interior wetlands. This is in contrast to Selden Creek settlement patterns,

McBride (1984), McBride and Bellantoni (1983), and McBride and Dewar (1987) suggest that this shift represents the dispersal of village populations at certain times of the year into smaller seasonal camps that likely were occupied by single families. McBride (1984:340) argues that this represents a return to a more mobile settlement pattern for the collection of resources; however, this shift occurs at a time when European contact with Native Americans first occurs and the trade in furs was initiated. Thus, the placement of seasonal camps in upland stream and interior wetland locations may be related to individual families moving to areas favorable to hunting beaver and other fur-bearing animals.

Summary

In sum, the prehistory of Connecticut spans from ca., 12,000 to 350 B.P., and it is characterized by numerous changes in tool types, subsistence pattern, and land use strategies. For the majority of the prehistoric era, local Native American groups practiced a subsistence pattern based on a mixed economy of hunting and gathering wild plant and animal resources. It is not until the Selden Creek phase that incontrovertible evidence for the use of maize horticulture as an important subsistence pursuit is available. Further, settlement patterns throughout the prehistoric era shifted from seasonal occupations of small co-residential groups to large aggregations of people in riverine, estuarine, and coastal ecozones. In terms of the region containing the proposed project items, a variety of prehistoric site types may be expected. These range from seasonal camps utilized by Archaic populations to temporary and task-specific sites of the Woodland era.

CHAPTER IV

HISTORIC SETTING

Introduction

The Eversource distribution ROW (i.e., East ROW), along which Phase IB survey was completed, is located in the northern part of the town of Newington, Connecticut[1]. Incorporated in 1871, Newington is a daughter town of Wethersfield, which was established in the 1630s as one of the first three towns of the Connecticut Colony. The project corridor begins at the Newington Substation, then runs eastward across Avery Road and West Hartford Road to end at the west side of Willard Avenue. This area actively farmed until the middle of the twentieth century, when Newington began transitioning from a thinly-populated agricultural town to a modern, automobile-oriented residential suburb.

Hartford County Overview

Hartford County extends northward to the Massachusetts border and lies on both sides of the Connecticut River, with more of its area to the west than to the east. This was not always the case, however, as when it was established in 1666 it included all of Tolland County on the east and parts of the other adjoining counties as well, which were established later. Of the 29 towns that lie within this descriptive area (a county is not, in Connecticut, a governmental entity at present), Hartford has long been economically and politically dominant. In the 1630s, of course, it was only one of the three towns (the others being Windsor, to its north, and Wethersfield, to its south). The excellent farmland of the valley of the Connecticut River helped to foster the county's growth throughout the colonial period and into the nineteenth century, even as the industrial development of Hartford and a few other places in the county displaced agriculture in importance (Crofut 1937). The suburbanization trend that began in many places in the United States during the twentieth century affected many of the towns around Hartford, as residents left the city in search of a more comfortable, single-family-home "rural" lifestyle.

Native American History

At the time of contact, tradition based on the historical records holds, the portion of the State of Connecticut containing the proposed region was occupied by a people called Wongunks, whose leader was named Sowheag, and whose main village was at Pyquang. By 1638, however, the leader and his heirs had relocated southward to Mattabeseck, which later became Middletown. Other members of the community remained in Wethersfield, mainly on the east side of the river, and were still there in 1693 when the new town of Glastonbury was formed. They probably sold the Wethersfield territory before 1638, but the actual deed has been lost and the only information about it is from the original surveyor's testimony about the limits (five miles west of the Connecticut River and three miles east of it, and six miles north and south) in 1665. The fact that Sowheag moved out of the area in the 1630s suggests a breakdown in relations with the colonists. During the Pequot War, when several Wethersfield colonists were killed and kidnapped, he was even suspected of colluding with the perpetrators. That the "sold" status of the Wethersfield land was itself uncertain is suggested by the new deed given by Sowheag's heirs in 1671. This deed, however, gave six miles west of the Connecticut River instead of five, and stopped at the Connecticut River on the east. The deed was signed by Sowheag's son Turramuggus,

[1] The entire 3.7-mile route of the proposed 115-kV line extends through portions of Newington, West Hartford, and Hartford, Connecticut, and research regarding the entire Project is included in the previously submitted Phase IA investigation (Appendix I).

Sowheag's daughter (identified only as someone's wife), and four other members of the tribe. Turramuggus also gave deeds to large areas in Middletown and elsewhere along the Connecticut River (Adams and Stiles 1904). These transactions reflect the colonists' insistence that the Native Americans produce a "sovereign" who "owned" the territory as an individual, just as the British monarch did. Although the multiple signatories on many deeds suggest the real collective nature of Native American social organization and involvement in some sales, the fiction of European-style monarchial sovereignty continued to be imposed, as the Turramuggus deeds indicate – and as does the old history cited here, which assumes the "Sowheag dynasty" was a genuine thing.

By 1765, the heirs of Sowheag's people still owned 200 acres of land in Wongunck (now East Hampton) with only a few poor people living on it, and the legislature ordered the land sold to benefit the forty scattered, surviving members as well as the remaining residents. One of the reservation residents was Mary, the elderly widow of the reputed last sachem of the group, Cushoy. A series of land sales resulted, with the last being in 1774 (Adams and Stiles 1904). Their original territory in Wethersfield and Newington had long since been taken over entirely by the European colonists.

Seventeenth and Eighteenth Century History of Newington, Connecticut

The white colonists first settled themselves in the riverside part of Wethersfield, for the most part leaving the western parts to later generations. By the 1670s, however, a group of men had received grants of Newington-area woodland to exploit for making "pipe staves," which is a term for the wooden slats used to make barrels. The town voted in 1671 to distribute the western part of town, which included the future Newington, among its rights holders, but the new owners continued to reside elsewhere at first (Baxter 1971, Crofut 1937). According to the available information, all or most of the area the transmission line crosses was probably originally distributed to a Mrs. Hollister, though part of it may also have belonged to Rev. John Woodbridge. Hollister's piece was a strip one mile wide and 26 rods (429 feet) high, while Woodbridge's grant was given to him by the town in 1686 and surveyed in 1727; the road that became Willard Avenue ran between them (Baxter 1971, 16). Over succeeding generations, the land would have been managed for family economic purposes: the options included leaving it wooded (to provide timber and firewood for home use or sale), clearing it for planting crops or grazing animals, building farmhouses and related structures (barns, sheds, etc.), and of course resale for profit.

By the 1680s a few colonists were living in the area and in 1713 the colonial legislature created a new Congregational Church society called Wethersfield West Society, which was renamed Newington in 1721 (Baxter 1971, Crofut 1937). This indicates that there were enough people living in the area to support a minister's salary and construction of a church building via the taxes that church societies were empowered to impose on residents in their jurisdictions. It also was often an intermediate step toward the creation of a separate town, but in Newington's case that change did not occur for well over a century after this. The Society built its meetinghouse between 1716 and 1720. In the 1720s, a schoolhouse was established in the society, with others being added later as the population grew. In 1754, the last undivided land in Wethersfield was distributed. The Newington society's participation in the Revolutionary War took the form of sending about 100 men to fight, as well as providing shoes specifically (Baxter 1971, Crofut 1937). No doubt they also provided the usual food, other goods, and money to support the war effort.

The colony government took three censuses during the second half of the eighteenth century, and the new federal government took one in 1790. These show the population of Wethersfield rising steadily from 2,771 residents in 1762 to 3,806 in 1790 – an increase of over a thousand over those 28 years. Such numbers place Wethersfield among the 20 largest towns in Connecticut during this time period, though not in the same league as soon-to-be urbanizing places like nearby Hartford. Despite its venerable age and proximity to Hartford, Wethersfield, which contained the future Town of Newington, remained largely an agricultural town well into the twentieth century.

Nineteenth and Twentieth Century History of Newington, Connecticut

In the 1830s, the Society of Newington had a central village and about 650 inhabitants, mostly engaged in agriculture; there were a Congregational and a Methodist church in the area (Barber 1837). The 1850 federal census of industry for Wethersfield found only eight firms making products valued at $500 or more. One of them was the state prison, where inmates manufactured chairs, chair seats, and cutlery; three others were seasonal river fishing enterprises that only employed four men each. Another three were textile mills, the largest of which employed 10 men and seven women. The last was an edge tool company that employed twelve men (U.S. Census 1850). An 1855 map indicates that the M. Kellogg & Son satinet factory was 12 at Newington Junction (Figure 14). This factory worked on water power and employed seven men and seven women (who received an average monthly wage of $175 and $100, respectively) to produce 40,000 yards (valued at $20,000) of this wool/cotton blend fabric, based on $15,000 capital (U.S. Census 1850, Schedule 5). Even with only 14 employees, it was still the largest non-farming employer in the area.

The 1855 map also shows that the streets now called Willard Avenue, West Hartford Road, and the road segment that connected them (West Hill Road) all existed at this time, but not any of the roads further to the west that now exist. On the map, two houses are shown on the west side of West Hartford Road. Examination of later maps and aerial photographs indicates that the proposed transmission line runs close to the former location of the southerly of the two, labeled Jerusha Seymour in this 1855 map. It is possible, however, that the owners of other nearby houses may have owned some or all of the project region as well. The family north of the Seymour house was headed by Seth Purinton, according to the map. The house on the north side of West Hill Road, south of the proposed transmission line's course, was owned by Capt. A. S. Hurn. On the east side of Willard Avenue, opposite the southeastern corner of the proposed transmission line, was the house of Samuel Clark (Figure 14).

According to the 1850 U.S. Census, Jerusha Seymour was an 80-year-old woman who owned $3,000 in real estate, and she shared her household with 76-year-old Nancy S. Wells, who owned $1,000 in real estate, and 24-year-old Irishman Thomas Riley, who presumably worked their farmland for them (U.S. Census 1850). In 1860, Jerusha Seymour was still alive at age 90, owning $1,750 in real estate and $500 in personal estate; her household then included Ellen D. Stedman (age 55) and Leonard Deming (age 60), a farm laborer (U.S. Census 1860). As for her neighbor to the north, in 1850 the census reported that a Seth and Betsey "Purrington" were middle-aged, Massachusetts-born farmers who owned $3,500 in real estate; the birthplaces of their five children indicate that they came to Connecticut by way of New York (U.S. Census 1850). In 1860, Seth "Purlington" (age 54) was a farmer who owned $19,200 in real estate and $2,000 in personal estate, a vast increase since the 1850 census. He had also married Ann (age 40) within the past year; four of his children still lived with them, as well as a male farmhand and a female servant (U.S. Census 1860). It should be noted that according to the family monument in the Newington Cemetery, the correct spelling of the family name was "Purrinton" (*Find A Grave* n.d.).

The occupants of the house to the southeast (on the north side of West Hill Road) were 71-year-old farmer David Hunn, who was the official head of a household that included Abigail Hunn, 63, and Rebecca Hunn, 69 (their relationship to David is not stated in the form). There was also 37-year-old Albert S. Hunn, a farmer who owned $5,000 in real estate; 39-year-old Minerva C. Hunn; and 22-year-old William Applebee, who worked in farming, presumably for the Hunn family (U.S. Census 1850). By 1860, the household was headed by Albert L. Hunn. He was 47 years old, a farmer owning $10,000 in real estate and $5,000 in personal estate; he lived with Minerva C. Hunn (age 49), Rebeca Hunn (age 78), Abagail Hunn (age 74), a 10-year-old boy named Edward H. Crosby, three farm laborers (two Irish and one English), and a presumed woman servant from Ireland (U.S. Census 1860). Finally, there is some

limited information about the Samuel Clark noted as living on the east side of Willard Avenue in the 1855 map. The 1850 census reported one S. W. Clark, age 36, owning $6,000 in real estate and having no occupation; E. W. Clark, age 34, lived with him and owned the same amount of real estate and occupation (U.S. Census 1850). No Clark was found in the area in the 1860 census.

Overall there is a clear pattern here of younger families (the Purringtons and Hunns) being able to acquire larger areas of land during the decade from 1850 to 1860, some of which was likely to have included the East ROW segment of the project area, and thus farming remained an economically viable occupation in this area. In both years, the vast majority of people listed on these census pages were identified as born in Connecticut, with the few foreign-born people hailing from Ireland (or in one case, England). Almost all were engaged in farming occupations, with a few exceptions. The 1850 census pages included two shoemakers and a mason, and also continued on into the village, where a boarding house provided housing for workers in the satinet factory (including an English-born manager). In the 1860 census the people were all farmers or farm laborers, except for one youth who reported that he was a "burnisher" (meaning he worked in the metal industry). The population was overwhelmingly white, except that in 1850 the village had an African-American family of seven, headed by William and Harriet Dee (U.S. Census 1850, 1860).

The two railroads depicted on the 1855 map, the Hartford, Providence & Fishkill and the Hartford & Springfield, were already among the oldest in the state. The latter name was a mislabeling of the Hartford & New Haven railroad, incorporated in 1832, which encountered opposition from Newington residents, but opened between Hartford and Meriden in 1838 despite that. The Hartford, Providence & Fishkill railroad was created in 1849 out of a merger of two slightly older corporations, with the goal of building a road between Providence and Fishkill (a town on the Hudson River in New York). The section between Hartford and Bristol, passing through Newington, opened in 1850. Both railroads became caught up in consolidations of the Connecticut transportation system in later decades, with resulting name changes, but they were among the first key elements of that system (Turner and Jacobus 1989). Newington Junction received its name, unsurprisingly, from the fact that these two roads met there and ran in parallel into the city of Hartford. According to Baxter, the satinet factory remained in place until it burned down in 1890, and there was also a brickyard at or near the Junction (Baxter 1971).

The 1869 historical map alters the spatial picture somewhat. There were three houses marked on the west side of West Hartford Road – from north to south, J. D. "Parinton" (instead of Purrinton), J. C. Tracy, and J. C. Gaylord. A. S. Hunn was still marked on the north side of West Hill Road, while the instead of the Clarks, there was a J. P. Marsh. Neither Tracy nor Marsh was found in the area in the 1860 census. The map also shows that the Kellogg satinet factory, and a combined train station and post office were located in the village (Figure 15). It seems clear that J. C. Tracy had acquired Jerusha Seymour's house, the one that the East ROW segment of the proposed transmission line passes closest to. According to the 1870 census, John C. Tracy broke with the farming tradition of the area; he was a bank president, who owned $10,000 in real estate and $10,000 in personal estate. He was the same age, 40, as his wife Louise L., and they had five children (all under 12), and their household also included a male farmhand and a Virginia-born black domestic servant named Eliza Douglas (age 19) (U.S. Census 1870). In the 1880 census, John C. Tracy was listed as a bookkeeper living with his wife, L. Louise (this census stopped asking for property value information). They had six children at home, of whom the oldest, Louis A. (age 21) was working as a bank clerk; they also had a black farm laborer named David Riley living in their household (U.S. Census 1880). A secondary source reports that John C. Tracy served as moderator of Newington's first town meeting in July 1871, and was then elected Treasurer at the meeting (Baxter 1971). The family to the north, according to the 1870 census, was headed by Anna Purrinton (age 50), who was keeping house, with her stepson Joseph T. Purrinton (age 24) listed as a farmer owning $15,000 in real estate and $2,000 in personal estate; he had married Jennie E. (age 22) and they had two small daughters. One of Anna's stepdaughters also still lived with the family, as did a single Irish farmhand (U.S. Census 1870).

The Purrintons under any spelling were no longer listed in this area in the 1880 census or later ones. In the 1870 census, the household to the south of the Seymour/Tracy house was presumably occupied solely by Joseph Gaylord (age 46), though he was listed out of order, and he owned $5,000 in real estate and $300 in personal state, but also designated "Insane" (U.S. Census 1870). In 1880, Joseph C. Gaylord was still living alone and working as a farmer (and not listed as ill any more) (U.S. Census 1880).

The Hunn family was still headed by Albert C. Hunn (age 57) in 1870, who was still a farmer, owning $15,000 in real estate and $10,000 in personal estate; his wife was erroneously listed as Mary M. (age 59), and two New York-born young women surnamed Hart also lived in the household (U.S. Census 1870). According to the Hunn family monument in Newington Cemetery, her husband's correct name was Albert S. Hunn (and he died in 1878), and her previous name was Minerva C. Hart (and she died in 1887, well after this 1870 census) (*Find A Grave* n.d.). Therefore, the two Hart women in the census must have been her relatives. By 1880, as noted, Albert had passed away, and Minerva C. Hunn was living alone (U.S. Census 1880). Prior to his death, Albert Hunn was a cattle dealer who partnered with members of the Whaples family in his business, and reportedly recruited many Scandinavian immigrants to work for him (Baxter 1971).

In both the 1870 and 1880 Census returns, the household of Shubael and Mary M. Whaples appears next to the Hunn household. The J. P. Marsh listed on the 1869 map was not found in either census. In the 1870 census, notwithstanding the information about Scandinavian workers, the few foreign-born people on the pages were uniformly from Ireland; the U.S.-born people were still overwhelmingly Connecticut-born people, with a slight leavening of people from Massachusetts, New York, and Maine, and one each from Virginia and Alabama. There were seven households on this census page, of which four were headed by a farmer; the others were Tracy the bank president, an insurance agent, and a road contractor.

In the 1880 census, two of the farm laborers and one servant were from Sweden, one male head of household from Germany, and one wife from Scotland. All but a handful of the other 47 people were still born in Connecticut. Twelve households appeared on this page, of whom only six were in farming. One of the others as Tracy the bookkeeper, and there was also a store clerk, a machinist, a postmaster, and a physician (the twelfth was Mrs. Hunn, whose occupation was "Keeping House"). The occupation changes, led by the Tracy family, showcase the tendency, in the late nineteenth century, for a certain number of city workers to move out into the "countryside" and commute to work by train, even as many of their rural neighbors continued to farm. The proximity of the station at Newington Junction made this a very practicable option for those who wished to take it.

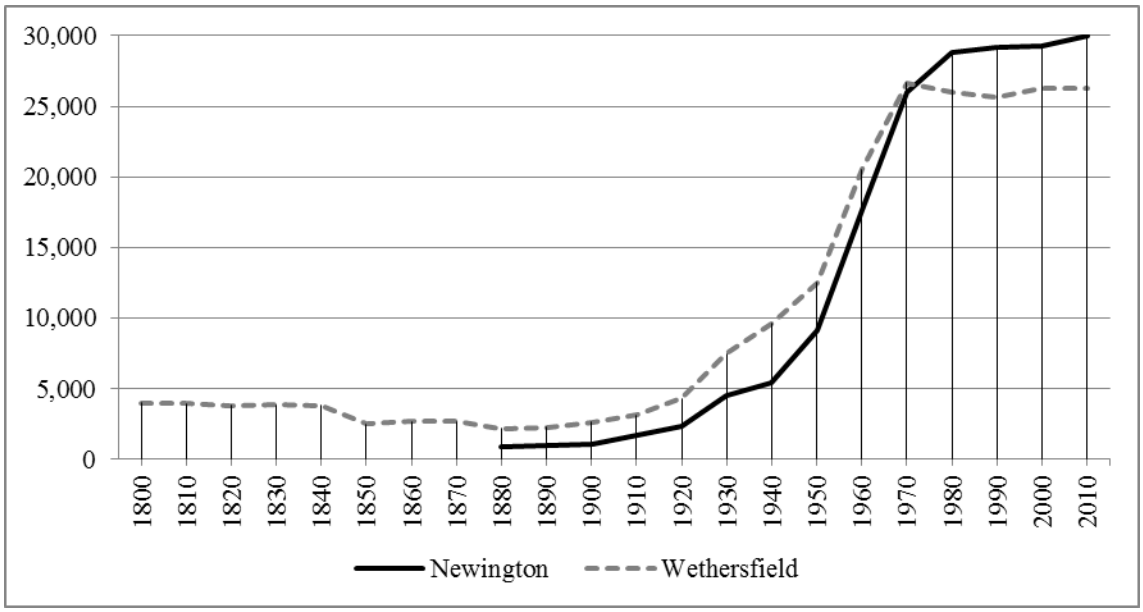
An unusual map from 1884 shows the northernmost house on West Hartford Road as owned by Bramley, and the other two by Brinley; on the north side of West Hill Road, the house was marked as Whaples instead of Hunn; and on the east side of Willard Avenue, there was a store and then a row of seven unlabeled structures (Figure 16). The Brinley identified in this map was probably George Brinley, who is recorded as owning the former Seymour home. He was a hobby farmer whose main job was at the Travelers Insurance Company in Hartford. He imported a herd of Jersey cows from the Isle of Jersey along with their herdsman, a Mr. Bramley, built a very large modern barn, and built a reservoir to provide water for them; this gave the name Reservoir Road to the road that extends westward from the end of West Hill Road, south of the project area (Baxter 1971). In addition to these farming and insurance activities, George Brinley was a noted collector of books published in and about America, such that the auction of his collection of 33,000 volumes after his 1875 death was a major event in the book world that supplied many public institutions with important volumes (Puvogel 1991).

The 1890 census having been lost many years ago, we must turn to the 1900 census. By this time, the New York-born Mary E. Brinley (age 51) was the widowed head of her family; her Canadian-born son George (age 27) lived with her and worked as an insurance clerk. Four of her other children (she had a

total of six) also still lived with her, as did two servants, one of whom was from Russia. There was no Bramley listed in this census, but there was the widowed Mary M. Whaples (age 54), whose two surviving children (a daughter aged 33 and a son aged 15) still lived with her, along with three Swedish servants and farm laborers. The rest of the census page shows a similar increase in the range of foreign-born adults, including an English family named Brideaux (possibly the Brinleys' neighbors on the north), a couple from Denmark and Sweden, a Polish servant, and three Irish families. The Connecticut-born majority on the page was due mainly to the families' children, although there were two Connecticut-born families named Fish who were involved the meat trade – possibly carrying on what had been the Hunn/Whaples business. Only two heads of household gave their occupation as in farming, although Mrs. Whaples might also be counted since she employed farm laborers, but her daughter was working as a teacher and her son was still at school. Mrs. Brinley's eldest son was an insurance clerk and her second-eldest was at college; other occupations included postmaster/station agent, expressman, carpenter, railroad laborer, laborer in a pottery, and a family with an insurance clerk, a stenographer, a teacher, and a carpet salesman (U.S. Census 1900). The dominance of farming was clearly on the wane in this area, and the infiltration of immigrants from a wider variety of European regions was under way.

Without additional maps for definite reference, it becomes more difficult to follow people through the census returns. Nonetheless, it appears that in 1910 the street now called West Hartford Road was sometimes called Francis Avenue; the two Fish families and the Danish/Swedish Madsen family were there, as was Mary E. Brinley (age 67), who reported that she had borne 10 children of whom only six were still living (Mrs. Madsen, sadly, reported having three children who had all died). The Brinley family included four children between the ages of 23 and 32; the elder son was a schoolteacher at a private school, while the younger, Edward C. Brinley, worked as a farmer on his own farm. The family also had a Lithuanian woman servant and a Russian-speaking Polish farm laborer in the household. Their neighbors on the other side were a Russian Jewish family (they spoke Yiddish) who farmed on their own farm. The Madsens had Danish servants (and a brother), and another household had a German mother-in-law, but overall with the children counted, Connecticut-born people still dominated. Occupations had likewise continued to increase in variety; 11 individuals identified themselves as farmers or farm laborers, but other occupations included merchant, grocery clerk, factory hand, servant, iron molder, and machinist (U.S. Census 1910). This trend away from farming continued throughout the succeeding censuses up to the last available, 1940.

As the chart below shows, Wethersfield's population remained below 5,000 throughout the nineteenth century, like most primarily agricultural towns in the state. The fall in population between 1840 and 1850 was the result of the separation of Rocky Hill in 1843, and the fall between 1870 and 1880 was due to the separation of Newington in 1871. The new town of Newington's first census return stated its population as 934, and it just passed the 1,000 mark by 1900. Then the population began to increase in earnest, more than quadrupling between 1900 and 1930 (Keegan 2012). In 1932, nonetheless, Newington's principal industry was still identified as agriculture; but it had the main railroad link (with two stations) and also a trolley line connecting it to Hartford and New Britain, making the town accessible to those with the money and time to commute (Connecticut 1932). In 1937, Newington Junction could still be called "the railroad station of the town" (Crofut 1937, 311). At the time, the town also contained a large sanitarium for tuberculosis patients, a home for disabled children (established 1930), and the U.S. Veterans' Hospital (established 1931, and still there) (Crofut 1932). These institutions can also help to explain the town's rising population, but as the chart shows, during the 1930s the growth leveled off. It was in the period 1940 to 1980 – the peak of the suburbanization trend in the United States – that saw the town's fastest growth, with the population rising from 5,449 on 1940 to 28,841 in 1980. The latter number made it the 30th largest of 169 municipalities in that year, and the ninth largest in Hartford County. Growth then leveled off, probably because most of the town's available land had been built on, though the population almost reached 30,000 in 2010.



Aerial photographs and maps from the twentieth century illustrate how this population growth drastically changed the landscape around the project area, and also provide some additional information about property owners and structures in the vicinity. A 1931 map indicates that 104 acres on the west side of West Hartford Road belonged to the estate of Thomas Holt, 18 acres between that road and Willard Avenue (labeled Newington Road) belonged to the estate of Albert D. Whaples, and 33.5 acres north of that belonged to the estate of George P. Brinley (Figure 17). This Thomas Holt must have been the man who reportedly bought a farm of a Scandinavian man named Madsen, at one time the manager of the Whaples farm, who improved a nearby farm to the point that "when Thomas Holt became Dairy Commissioner he bought the place" (Baxter 1971:179). The subsequent 1934 aerial photograph shows that the project area and its vicinity were still farmland, with standing structures on the west side of West Hartford Road and one on the north wide of West Hill Road (Figure 18). The future location of the substation was a cleared field, surrounded by some area of forest; the Seymour/Tracy/Brinley house, immediately north of the transmission line, seems to have had a circular driveway around it. South of the project area was a large farmstead, presumably the Thomas Holt dairy farm, with a large barn and multiple other structures. To the north of the East ROW segment of the proposed transmission line, the most visible structures were a substantial barn set back from the road and another closer to the road. In addition, several houses had been built on the west side of Willard Avenue, although there were still more on the east side. Given its location on the north side of Reservoir Road, the large farm should probably be designated the Gaylord/Brinley/Holt farm for reference.

According to the 1920 U.S. Census, Thomas Holt had been born in England, was 56 years old, and had immigrated in 1882; his wife, Mary E., was also England-born and had immigrated in 1883. Thomas's occupation was "Dairy and Food Commissioner." They had a son George, age 23, who worked on the family farm (U.S. Census 1920). In the 1930 census, Thomas Holt's occupation was still given as "Dairy & Food Comm. of Ct." and his house was valued at $5,000. He lived with his wife Helen, age 53, who had been born in Pennsylvania. Next door was George Holt, who was 33 years old, rented his home, and worked as a farm manager – most probably for Thomas, presumably his father. George's household included wife Esther (age 32) and two young daughters (U.S. Census 1930). Then in the 1940 census, only the George and Esther F. Holt family was still present. He owned and managed his own dairy farm; their two children were teenagers. The heads of two families next door to them gave their occupations as laborers on a dairy farm (U.S. Census 1940). Thus, the dairy farm was still an existing entity in 1940.

The story is different for the Brinley and Whaples families, however, who probably occupied the Seymour/Tracy/Brinley house and the Hunn/Whaples house. The 1931 map's designation "George P. Brinley Est." overlooks the fact that his widow Mary E. Brimley was still alive. In 1920, she was 74 years old and lived with her son John H. W. (age 44) who was a clerk for a fire insurance company, and two daughters (Frances E., 44, and Henrietta W., 32). All three children were still single (U.S. Census 1920). In 1930 she was living in a home that appears to have been valued at $75,000, which (given the general price range of houses in the area) was probably an error for $7,500. She lived with her two middle-aged daughters and one son, who worked as an insurance company clerk, and also a fourteen-year-old granddaughter. Given that all three of her children's marital status was still single, it is not clear where this child came from (U.S. Census 1930). In the 1940 census, John H. W. Brinley (age 64) was head of household, working as an insurance company claim clerk; his sisters were still living with him, as was his niece, who had somehow become 33 years old and worked as a public-school teacher (U.S. Census 1940). Albert D. Whaples's occupation in 1920 was clerk at a life insurance company; he was 35 years old and lived with his wife, Helen R., age 42, who had immigrated from Canada in 1877; they had two small children, and part of their house was partitioned into an apartment for Mary M. Whaples (age 74) (U.S. Census 1920). He was also still alive in the 1930 census, still working as a clerk at an insurance company, his house valued at $5,000; he lived with his wife Helen R. (born in French Canada) and their two teenage children (U.S. Census 1930). In 1940 Albert D. Whaples was still there, aged 56, giving his occupation as supervisor at City Mortgage Insurance; his wife Helen R. (age 62) gave her birthplace specifically as Quebec, and worked keeping house. Their 25-year-old daughter worked as a clerk for the Christmas Club at a state bank, and their 23-year old son gave no employment. The family also owned a vacant house next door (U.S. Census 1940). In other words, by 1920 the two families were definitely not farmers any more, though they continued to own tracts of land; most likely they rented it out, perhaps even to the nearby Holt family.

A 1939 topographic map from the Metropolitan District Commission (MDC) has been found that includes the eastern portion of the East ROW segment of the proposed transmission line. This map shows that a Hartford Electric Light Company transmission line already existed here by that year, extending westward from Willard Avenue. The structures in the area were widely-spaced two-story houses, including what must have been the Hunn/Whaples house on the north side of what is now West Hill Road (Figure 19). In the 1941 aerial photograph, the only discernible change in the vicinity was that the back-lot barn north of the transmission line had been taken down, though its location can still be discerned; otherwise, farming appeared to still be going on as usual here. Although we know that a transmission line crossed this area, it is not easily visible in these photographs, since it passed over fields that were cleared anyway (Figure 20). It is in the 1951 aerial photograph that significant impact of Newington's increasing population can first be seen. Here, a small-lot housing development had been put in north of the transmission line, and numerous others can be seen further north, in West Hartford. The actual project area and most of its vicinity, however, were still agricultural fields, with the same structures and patches of woods as before. This photograph has had proposed new roads marked on it, however, including Fenn Road, running southwesterly from the intersection of West Hartford Road and West Hill Road (Figure 21). This presaged the coming changes to the old farm neighborhood.

For the year 1957, MDC topographic map of the western end of the project area is available. This shows the substation in place, surrounded by new subdivisions of small one-story houses (Figure 22); the transmission line right of way proceeded eastward through both cleared and forested land. At West Hartford Road, it shows the old two-story frame house of the Seymour/Tracy/Brinley families standing just north of the transmission line, and a second two-story frame house north of that which was probably the Purrinton/Bramley house. Of the Gaylord/Brinley/Holt farmstead to the south, however, only one two-story house and a group of one-story structures remained; the barn had been reduced to a marked foundation and associated silos. An aerial photograph set from the same year covers the whole project area and shows that by this time, the main crop being produced in this area (when the town's population

was approaching 20,000) was housing developments. The absence of the large barn is clear, but the old houses can still be seen among the newer ones (Figure 22).

A 1965 MDC topographic map covers the eastern end of the right-of-way only, showing that the two-story house that once stood just south of the Willard Avenue ROW terminus had been replaced by a new one-story house, and another one-story house stood immediately north of the ROW. Other older two-story houses in the area had also survived, including the Hunn/Whaples house on the north side of West Hill Road – despite the construction of a new subdivision near and around it (Figure 23). An aerial photograph that covers the whole area shows that housing developments had taken over almost all of the project area's vicinity, though the older houses also appeared to still be present; the structures associated with the large farmstead seem to be gone, however, and Fenn Road had been built and the intersection reorganized (Figure 24). The 1975 MDC topographic maps that cover the whole area show that the development of the area was largely complete. At the east end, another new subdivision (in a different configuration than the older one) had been built south of the transmission line, while a patch of forest (no longer cleared agricultural fields) persisted to the north. At the west end, the old farmstead had been completely built over with new structures and the old barn foundation and silos were no longer marked, although the three old two-story structures on West Hartford Road were still present. Near the substation, a few more houses had been built on the road to the west (Figure 25).

Skipping forward to the 1991 aerial photograph, we find that the main change was that the Seymour/Tracy/Brinley house once located just north of the proposed transmission line had been replaced by a small, dense development on what is called "Brinley Road." Otherwise, the area seems mostly the same in this photograph, with only a few areas of forest/brush left (Figure 26).

The town's current plan of conservation and development specifically notes that 92 percent of the town's land had been developed, and protecting surviving open space and protecting additional space should be a priority, as should preservation of historic resources and encouragement of the re-use of previously developed commercial and industrial areas. It also noted that despite the slowdown in population growth due to the lack of new housing space, employment in the town had continued to grow through the year 2000, with an increasing focus on service-sector activity while manufacturing employment remained steady or declined. According to the report, there were also still two farms in the town, which it designated "community assets" and presumably hoped to preserve (Newington 2010).

Conclusions

The documentary record indicates that the East ROW portion of the proposed transmission line is unlikely to contain any significant historical resources beyond remnants of its agricultural past such as stone walls and fences. The historical features (e.g., house, barns, silos, etc.) discussed above have long been destroyed and one of them fell within the proposed project area.

CHAPTER V

PREVIOUS INVESTIGATIONS

Introduction

This chapter presents an overview of previous cultural resources research completed within the vicinity of the East ROW in Newington, Connecticut. This discussion ensures that the potential impacts to all previously recorded cultural resources located within the general vicinity of the project area are taken into consideration. Specifically, this chapter reviews all previously identified archeological sites and National Register of Historic Places properties located within the project region (Figures 27 and 28). The discussions presented below are based on information currently on file at the Connecticut State Historic Preservation Office. In addition, the electronic site files maintained by Heritage consultants, LLC also were examined during the course of this investigation. Information contained in the examined cultural resources survey reports and site forms is reflected in this document.

Previously Recorded Archeological Sites Located in the Vicinity of the Project Corridor

A review of data currently on file at the Connecticut State Historic Preservation Office, as well as the electronic site files maintained by Heritage Consultants, LLC resulted in the determination that no previously recorded archaeological sites are situated within the general project region (Figure 26). In fact, there are no previously recorded archaeological sites within the Town of Newington.

Previously Recorded National Register of Historic Places Properties Located in the Vicinity of the Project Corridor

A review of data currently on file at the Connecticut State Historic Preservation Office, as well as the electronic site files maintained by Heritage Consultants, LLC resulted in the identification of three National Register of Historic Places historic districts in the immediate vicinity of the proposed project corridor (Figure 28). These are the Newington Junction North Historic District, the Newington Junction West Historic District, and the Newington Junction Railroad Depot Historic District. Each of these districts are discussed below.

As noted in Heritage's November 4, 2016 report to the SHPO regarding this project, the Newington South Historic District and Willard Avenue Homestead (372 Willard) are also National Register of Historic Places resources in the Project vicinity; however, these are omitted from the following discussion, as they are located further from the East ROW, and in Heritage's professional opinion would not be impacted by the Project.

<u>Newington Junction North Historic District</u>

The Newington Junction North Historic District, which was listed on the National Register of Historic Places in June of 1987, is situated along Willard Avenue to the north of its intersection with West Hill Road (Figure 28). This historic district is comprised of 13 contributing and three non-contributing buildings that are situated throughout an area of more than 10 acres. The buildings in the historic district, all of which are residences, consist of examples of Colonial Revival, Late Victorian, and Queen Anne styles. These building styles typify the architecture of the period between 1850 through 1949. The Newington Junction North Historic District currently consists of a mixed-use area divided by Willard Avenue. The Newington Junction North Historic District is a group of complementary structures that

remains in a good state of preservation, and it is considered significant under Criterion C of the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]). As seen in Figure 28, the existing Eversource distribution line ROW extends through the Newington Junction North Historic District. It was built prior to the nomination and listing of the Newington Junction North Historic District on the National Register of Historic Places.

Newington Junction West Historic District

The Newington Junction West Historic District, which was listed on the National Register of Historic Places in June of 1987 consists of a series of residences, garages, an outbuilding, and a municipal building located on either side of West Hill Road (Figure 28). The district contains approximately eight acres of land, and of the 16 major buildings within it, 13 contribute to its National Register of Historic Places significance. The contributing buildings include eight residences, four garages, a nineteenth century farm related building, and an early twentieth century firehouse. The architectural styles represented within the Newington Junction West Historic District include Colonial, Greek Revival, Italianate, Queen Anne, and Victorian. The oldest building in the district is the John Camp House, which dates from 1710 and is built in the Saltbox style. The majority of the contributing buildings in the district date from the nineteenth and early twentieth centuries. Each contributing residence is a good example of a period architectural style. As a result, the Newington Junction West Historic District is considered significant under Criterion C of the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]).

Newington Junction Railroad Depot Historic District

The Newington Junction Railroad Depot Historic District also was listed on the National Register of Historic Places in June of 1987 (Figure 28). The Hartford and New Haven Railroad constructed a line through Newington in 1839, but did not open the Newington Depot Station until 1852. This small station was built on the west side of the railroad tracks, and in 1892 was replaced by a larger station on the east side of the tracks, as well as a freight warehouse to the south of the new station. The two 1892 buildings remain in their original locations and retain many of their historical characteristics. The earlier western station, however, has been moved and was transformed during the recent construction of the Connecticut *Fastrak* bus rapid transit line. While the western portion of the Newington Junction Railroad Depot Historic District has undergone large scale changes, the district remains listed on the National Register of Historic Places criteria for evaluation and is considered significant under Criteria A and C of the criteria for evaluation (36 CFR 60.4 [a-d]).

Summary

The review of previously identified cultural resources in the vicinity of the proposed project corridor failed to identify any previously recorded archaeological sites, but did result in the identification of three historic districts in close proximity to the East ROW. The absence of archaeological sites in the area is undoubtedly due to a lack of professional cultural resources reconnaissance surveys. Further, despite the presence of the Newington Junction West Historic District and Newington Junction Railroad Depot Historic District in the vicinity of the East ROW, neither of these areas will be impacted either directly or indirectly by the proposed construction. Finally, as discussed in the November 4, 2016 report (contained in Appendix I), the UG option within the East ROW, the Hybrid option in the East ROW, or the overall proposed transmission line project would not have adverse effects to the Newington Junction North Historic District.

CHAPTER VI

FIELD AND LABORATORY METHODS

Field Methods

Following the completion of all background research, the project corridor was subjected to a Phase IB cultural resources reconnaissance survey utilizing pedestrian survey, photo-documentation, mapping, and systematic subsurface testing in undisturbed areas. The field strategy was designed such that the East ROW, which extends from the Newington Substation to Willard Avenue, was examined visually and photographed, in its entirety. The pedestrian survey portion of this investigation included visual reconnaissance of all proposed construction areas within this segment of the proposed project. These areas also were subjected photo-documentation such that the local landforms, vegetation, and overall character of the proposed project corridor were recorded.

During this Phase IB fieldwork effort, the East ROW was examined using shovel tests positioned such that there was adequate coverage of the proposed trench, spoil pile, access road, additional workspace areas associated with the UG options, as well as at structure locations and work pads associated with the Hybrid option (see Figure 2; Sheets 1 through 3 and Figure 3; Sheets 1 through 3). Along the area containing the proposed trench, spoil pile, access road associated with the UG option, shovel tests were situated at 15 m (49.2 ft) intervals along a single transect. In addition, shovel tests were also excavated in the corners of each proposed work pad and at the proposed structure locations associated with the Hybrid option. Finally, shovel tests were also placed in the extra workspace areas that will be used for truck turn arounds, temporary workspaces, and/or placement of frac tanks if required for dewatering (see Figure 2; Sheets 1 through 3).

Each shovel test measured 50 x 50 cm (19.7 x 19.7 in) in size and each was excavated to a minimum depth of 50 cmbs (19.7 inbs) or until C-horizon soils, glacial till, or immovable objects (e.g., large roots or boulders) were encountered. Each shovel test was excavated in 10 cm (3.9 in) arbitrary levels within natural strata, and the fill from each level was screened separately. All shovel test fill was screened through 0.635 cm (0.25 in) hardware cloth and examined visually for cultural material. Soil characteristics were recorded in the field using Munsell Soil Color Charts and standard soils nomenclature. Finally, each shovel test was backfilled immediately upon completion of the archeological recordation process.

Archeological Site Delineation

When identified during the survey process, archeological deposits were examined to ascertain their nature, size, depth, integrity, age, and cultural affiliation. Site delineation also was used to assess the stratigraphic placement, density, and research potential of each identified site. In addition, information was gathered to assist in the subsequent assessment of whether or not a site was considered not significant or potentially significant applying the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]). Archeological recordation included the following: (1) establishment of a site datum; (2) intensive surface reconnaissance of the site area; (3) excavation of shovel tests at 5 m (16.4 ft) intervals along rays emanating from datum to delineate the site's boundaries, size, and configuration as they existed within and immediately adjacent to the proposed project corridor; (4) mapping of the site area; and (5) photographic documentation of the surrounding area.

Laboratory Analysis of Recovered Cultural Material

Laboratory analysis of all recovered cultural material was completed following established archeological protocols. All field specimen bag proveniences first were cross-checked against the field notes and the specimen inventories for accuracy and completeness. Following this quality-control process, all recovered material was washed by hand, air-dried, and sorted into basic material categories.

The nature and structure of the laboratory analysis was determined by the goals of the project. In general, the artifact analysis consisted of making and recording a series of observations for each specimen. The observations were chosen to provide the most significant and diagnostic information about each specimen. A total of two separate relational databases were employed to store, organize, and manipulate the data generated by the analytical process. Separate databases were used for the analysis of the recovered historic/modern cultural material and prehistoric lithic objects. The different databases reflected the differences in the analytical protocols used to study the two types of materials.

Historic Cultural Material Analysis

The analysis of the historic cultural material was organized by class, functional group, type, and subtype. The first level, class, represented the material category, e.g., ceramic, glass, metal. The second level, functional group, e.g., architecture, kitchen, or personal, was based on classifications established by South (1977). The third and fourth levels, type and subtype, described the temporally and/or functionally diagnostic artifact attributes. The identification of artifacts was aided by consulting standard reference works, including Fike (1987), Florence (1990), Kovel and Kovel (1986), Miller (1980, 1991), Nelson (1968), South (1977), Switzer (1974), Toulouse (1971, 1977) and Wilson (1981).

Prehistoric Lithic Analysis

The lithic analysis protocol used in this project was a "technological" or "functional" one designed to identify prehistoric reduction trajectories, lithic industries, and tool functions. The protocol therefore focused on recording technological characteristics of the recovered lithic artifacts. The lithic artifact database was organized by lithic material group, type, and subtype. The first level described the raw material type of the artifact. Lithic material was identified utilizing recognized geological descriptions and terminology, and with the use of type specimens of known source. Lithic raw materials were divided into distinct categories based on three factors: texture, color, and translucence.

The second analysis level, type, was used to define the general class, e.g., unmodified flake, core, or preform, of lithic artifact, while the last level, subtype, was employed to specify morphological attributes, e.g., primary cortex, extensively reduced, or corner-notched. These levels followed classifications outlined by such authors as Callahan (1979) and Crabtree (1972), among others. Typological identifications for temporally and regionally diagnostic tools also were included in the analysis. Such identifications were made by reference to established lithic artifact typologies, e.g., Justice 1987, Ritchie 1972.

Curation

Following the completion and acceptance of the Final Report of Investigations, all drawings, maps, photographs, and field notes will be curated with:

Dr. Brian Jones
Connecticut State Archaeologist
Connecticut Archaeology Center
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CHAPTER VII

RESULTS OF THE INVESTIGATION

East ROW Investigation Results

During survey, a total 86 of 108 (80 percent) planned shovel tests were excavated successfully throughout the East ROW, including along the proposed cable trench, dirt stockpile area, and access road associated with the UG option, as well as at the corners of the work pads and tower locations associated with the Hybrid option. Shovel tests also were excavated within the proposed truck turn around areas and the work areas/anticipated frac tank locations (Figure 2; Sheets 1 through 3). The 22 planned, but unexcavated shovel tests fell within areas of previous disturbances around the Newington Substation and/or wetland soils.

A typical shovel test was excavated to a depth of 50 cmbs (19.7 inbs) and it exhibited two strata in profile. Stratum I, a deposit of dark brown (10YR 3/3) sandy loam, extended from the surface to 20 cmbs (0 to 7.9 inbs). Underlying Stratum I was Stratum II, a deposit of strong brown (7.5YR 4/6) loamy sand mixed with pebbles; it continued from 20 to 50 cmbs (7.9 to 19.7 inbs). Generally speaking, C-horizon was encountered at 50 cmbs (19.2 inbs). Shovel testing conducted throughout the proposed East ROW corridor resulted in the identification of a single archaeological site (94-1), which is discussed below.

Site 94-1

Site 94-1, a multi-component archaeological deposit, was identified during Phase IB cultural resources reconnaissance survey to the east of the Newington Substation (Figures 2; Sheet 1). Situated at an approximate elevation of 45.7 m (150 ft) NGVD, the site is characterized by tall grasses and bushes (Figures 6, 12, and 13). Site 94-1 was described as ovoid in configuration, and it encompassed an area that measured approximately 10 x 15 m (32.8 x 29.2 ft); the site area was not delineated outside of the proposed project corridor to the north due to the presence of a large disturbed area that contained modern trash and soil push piles. In addition to the single positive shovel test, a total of 13 of 13 (100 percent) delineation shovel tests were excavated successfully at 5 m (16.4 ft) intervals around the location of the original find, in an effort to identify additional cultural material and/or cultural features (Figure 2; Sheet 1).

A typical shovel test excavated within the Site 94-1 area extended to a depth of 65 cmbs (26 inbs) and it exhibited two strata in profile. Stratum I, which consisted of a deposit of dark brown (10YR 3/3) sandy loam, extended from the surface to 40 cmbs (0 to 16 inbs); it represented a plowzone deposit. Underlying Stratum I was Stratum II, a deposit of strong brown (7.5YR 4/6) loamy sand mixed with pebbles; it continued from 40 to 65 cmbs (16 to 26 inbs). The C-horizon was encountered at 65 cmbs (26 inbs) and excavations were terminated at this point. No evidence of either prehistoric or historic cultural features was identified in the shovel tests excavated within the Site 94-1 area.

The prehistoric component of Site 94-1 yielded a single quartz secondary thinning flake and 1 quartz Brewerton side-notched projectile point from the plowzone deposit (Figure 28; Table 1). The latter dates from the Late Archaic period (ca. 6,000 to 3,700 B.P.). The prehistoric use of the area most likely represents a very short-term occupation or perhaps even a single tool manufacturing event. The prehistoric component of Site 94-1 lacks evidence of intact cultural deposits and/or cultural features. As a result, it was determined that the prehistoric component of Site 94-1 does not possess research potential and/or the qualities of significance as defined by the National Register of Historic Places criteria for

evaluation (36 CFR 60.4 [a-d]). No additional testing of the prehistoric component of Site 94-1 is recommended.

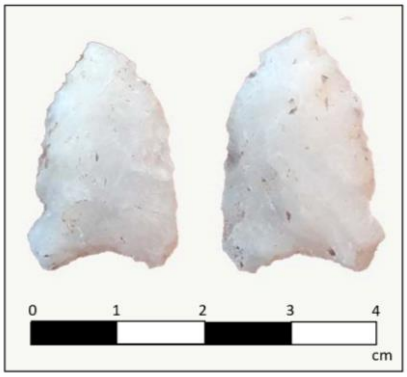


Figure 29. Photo of the obverse and reverse of the Brewerton side notched projectile point recovered from Site 94-1

The historic component of Site 94-1 produced 5 undecorated whiteware sherds, a single undecorated whiteware handle fragment, 1 undecorated whiteware basal sherd, 1 quahog shell fragment, and 2 of large mammal long bone fragments. The bone fragments are representative of cow (*Bos taurus*). A review of the project area, as well as historic maps and aerial images failed to reveal any evidence of historic cultural features (i.e., houses, barns, outbuildings, etc.) in this area. As a result, the historic component of Site 94-1 was interpreted as a light field scatter of artifacts that cannot be associated with any particular occupation of the area. The recovered historic artifacts are very common nineteenth/early twentieth century artifacts found in the archaeological record of Connecticut. Consequently, the historic component of Site 94-1 also does not possess research potential and/or the qualities of significance as defined by the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]). No additional testing of the historic component of Site 94-1 is recommended.

Table 1. Cultural material collected from Site 94-1 during the Phase I Survey.

Site Number	Shovel Test	Stratum	Level	Depth	Material	Type	Subtype	Attributes	Count
94-1	7	I	1	0-10	Lithic	Quartz	Brewerton Projectile Point	Complete	1
94-1	7	I	1	0-10	Ceramic	Whiteware	Plain		3
94-1	7	I	1	0-10	Ceramic	Whiteware	Plain	handle	1
94-1	7	I	1	0-10	Faunal	Shell	Fragment		1
94-1	N1000, E990	I	3	20-30	Lithic	Quartz	Secondary Thinning Flake		1
94-1	N1000, E990	I	3	20-30	Ceramic	Whiteware	Plain	base	1
94-1	N1000, E990	I	3	20-30	Faunal	Bone	Long Bone	Cow, Cut	1
94-1	N1010, E990	I	3	20-30	Ceramic	Whiteware	Plain		1
94-1	N1005, E990	I	2	10-20	Ceramic	Whiteware	Plain		1
94-1	N1005, E990	I	2	10-20	Faunal	Bone	Long Bone	Cow, Cut	1

Summary
The Phase IB cultural resources reconnaissance survey completed along the East ROW extending between the Newington Substation and Willard Avenue in Newington, Connecticut resulted in the identification of a single multicomponent archaeological site (Site 94-1). Neither the prehistoric nor the historic period component of Site 94-1 possesses research potential or the qualities of significance as defined by the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]). Thus, no additional testing of Site 94-1 is recommended. No other archaeological deposits were identified during Phase IB cultural resources reconnaissance survey of the remainder of the East ROW. It is the professional opinion of Heritage Consultants, that there will be no adverse effect on cultural resources as a result of the proposed electrical transmission line project.

CHAPTER VIII

MANAGEMENT RECOMMENDATIONS

The Phase IB cultural resources reconnaissance survey of the proposed project located between the Newington Substation and Willard Avenue in Newington, Connecticut resulted in the identification of a single archaeological site (94-1). The data collected from Site 94-1 indicates that it contains both prehistoric and historic period components. The prehistoric component is limited to two lithic artifacts, one of which is a Brewerton side notched projectile point dating from the Late Archaic period of Connecticut prehistory (ca., 6,000 to 3,700 B.P.). The historic component appears to represent a small collection of nineteenth/early twentieth century artifacts that represents field scatter. None of the artifacts collected from the site area were found in association with any cultural features, and all originated from the disturbed plowzone deposit. Thus, based on the collected data, both components associated with Site 94-1 are not significant applying the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]), and no additional testing of this archaeological site is recommended prior to construction. No other archaeological deposits were identified during Phase IB cultural resources reconnaissance survey of the remainder of the proposed project corridor within the East ROW. It is therefore the professional opinion of Heritage Consultants, that there will be no adverse effect on cultural resources as a result of the proposed electrical transmission line project.

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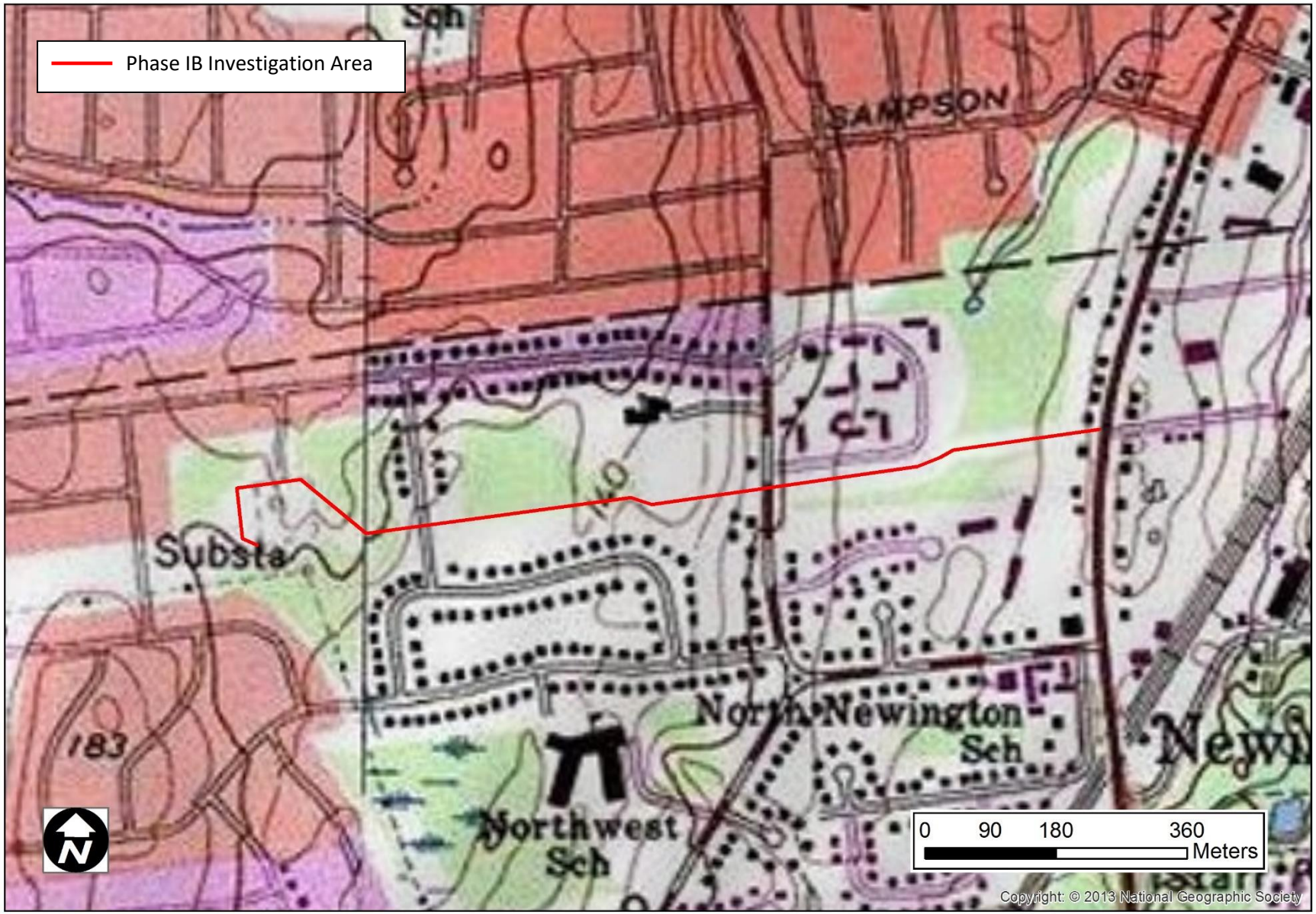


Figure 1. Excerpt from a 1996 USGS 7.5'series topographic quadrangle depicting the location of the project area between the Newington Substation and Willard Avenue (i.e., East ROW) in Newington, Connecticut.

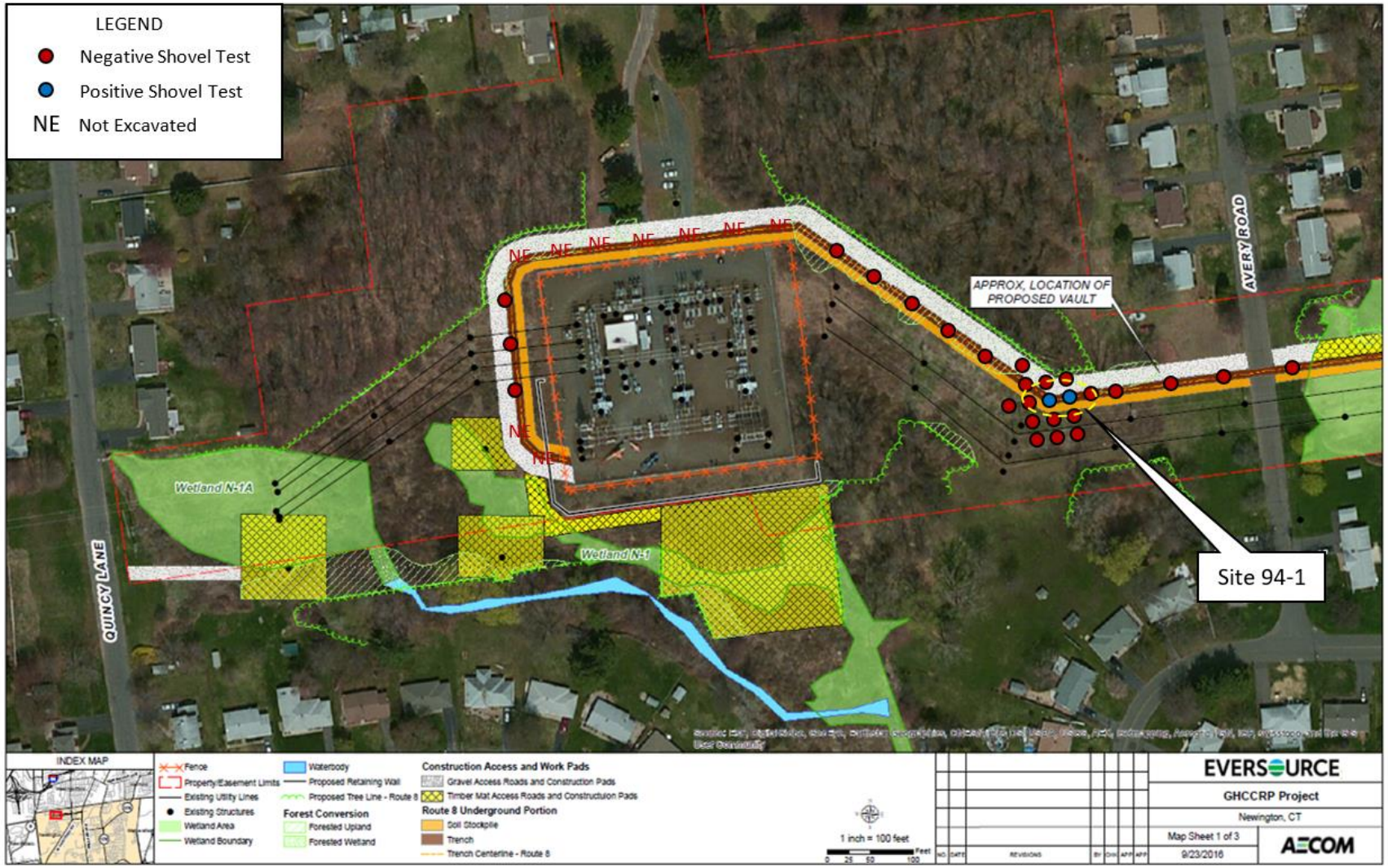


Figure 2; Sheet 1. Excerpt from a 2016 aerial image showing the locations of the proposed project items associated with the UG option within the East ROW, shovel test locations, wetlands, and Site 94-1 in Newington, Connecticut.

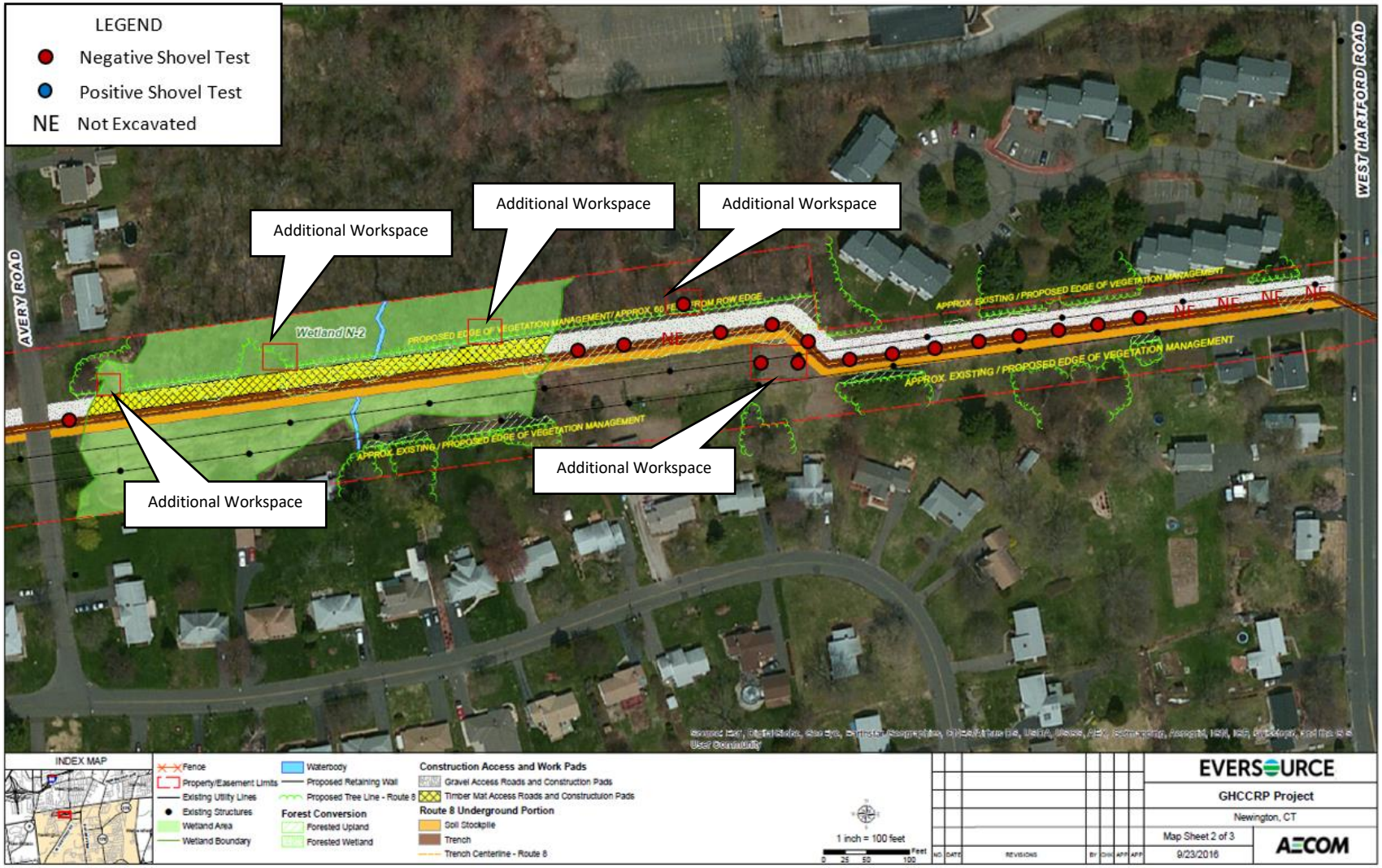


Figure 2; Sheet 2. Excerpt from a 2016 aerial image showing the locations of the proposed project items associated with the UG option within the East ROW, shovel test locations, and wetlands in Newington, Connecticut.



Figure 2; Sheet 3. Excerpt from a 2016 aerial image showing the locations of the proposed project items associated with the UG option within the East ROW, shovel test locations, and wetlands in Newington, Connecticut.

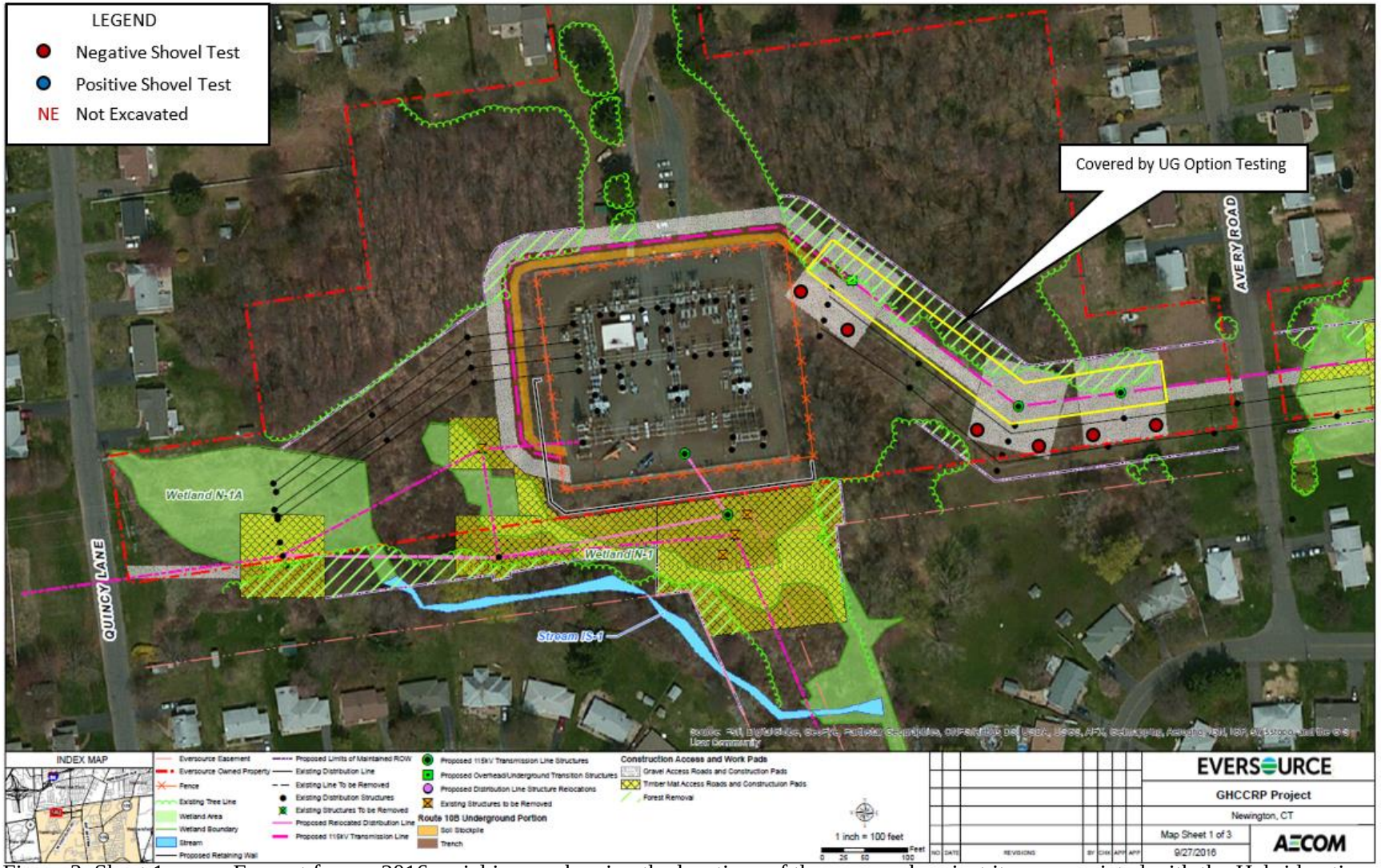


Figure 3; Sheet 1. Excerpt from a 2016 aerial image showing the locations of the proposed project items associated with the Hybrid option within the East ROW, shovel test locations, and wetlands in Newington, Connecticut.

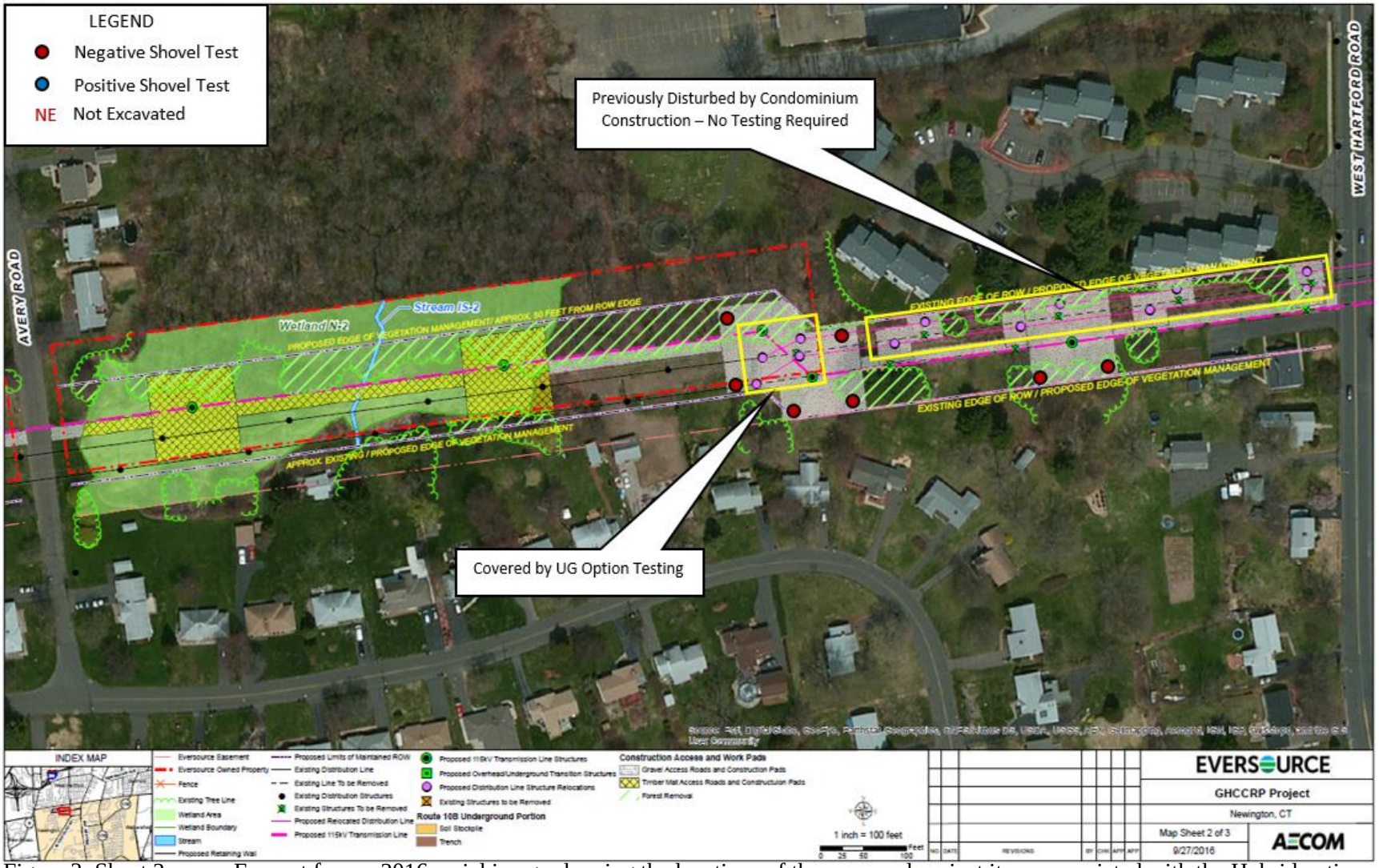


Figure 3; Sheet 2. Excerpt from a 2016 aerial image showing the locations of the proposed project items associated with the Hybrid option within the East ROW, shovel test locations, and wetlands in Newington, Connecticut.



Figure 3; Sheet 3. Excerpt from a 2016 aerial image showing the locations of the proposed project items associated with the Hybrid option within the East ROW, shovel test locations, and wetlands in Newington, Connecticut.



Figure 4. Overview photo of the proposed project corridor to the west of the Newington Substation facing north.



Figure 5. Overview photo of the proposed project corridor to the north of the Newington Substation facing east.



Figure 6. Overview photo of the proposed project corridor to the east of the Newington Substation facing west (note Site 94-1 is located at the top of rise in photo).



Figure 7. Overview photo of the proposed project corridor to the east of the Avery Road facing east (note wetlands in this area).



Figure 8. Overview photo of the proposed project corridor to the east of the West Hartford Road facing north.



Figure 9. Overview photo of a proposed frac/tank truck turn around area in the middle of the project corridor facing east.



Figure 10. Overview photo of the proposed project corridor to the east of the West Hartford Road facing east.



Figure 11. Overview photo of the proposed project corridor to facing east towards Willard Avenue.



Figure 12. Overview photo of Site 94-1 facing north.



Figure 13. Overview photo of Site 94-1 facing west.



Figure 14. Excerpt from an 1855 map depicting the location of the East ROW of the project route located in Newington, Connecticut.



Figure 15. Excerpt from an 1869 map depicting the location of the East ROW of the project route located in Newington, Connecticut.

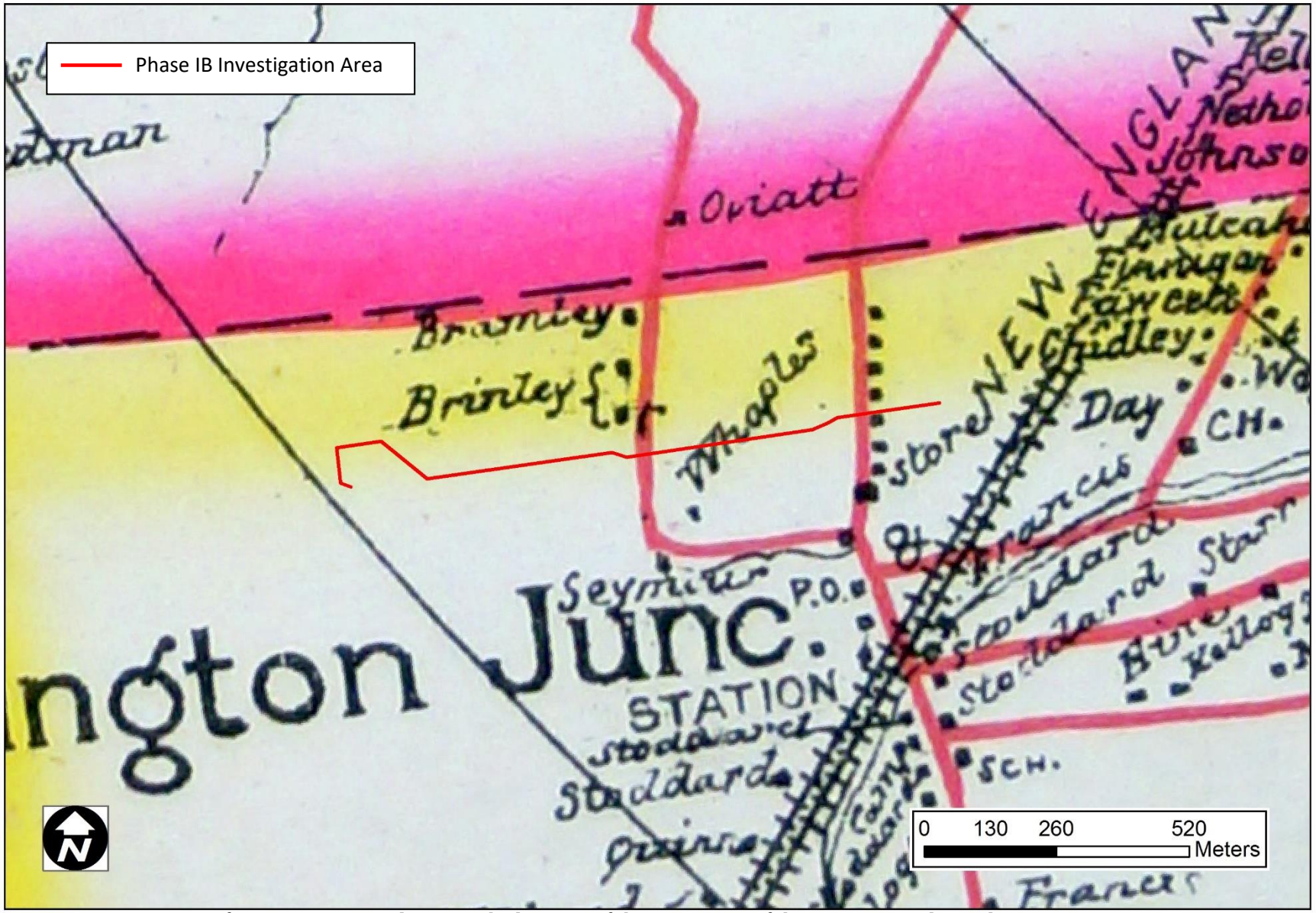


Figure 16. Excerpt from an 1884 map depicting the location of the East ROW of the project route located in Newington, Connecticut.

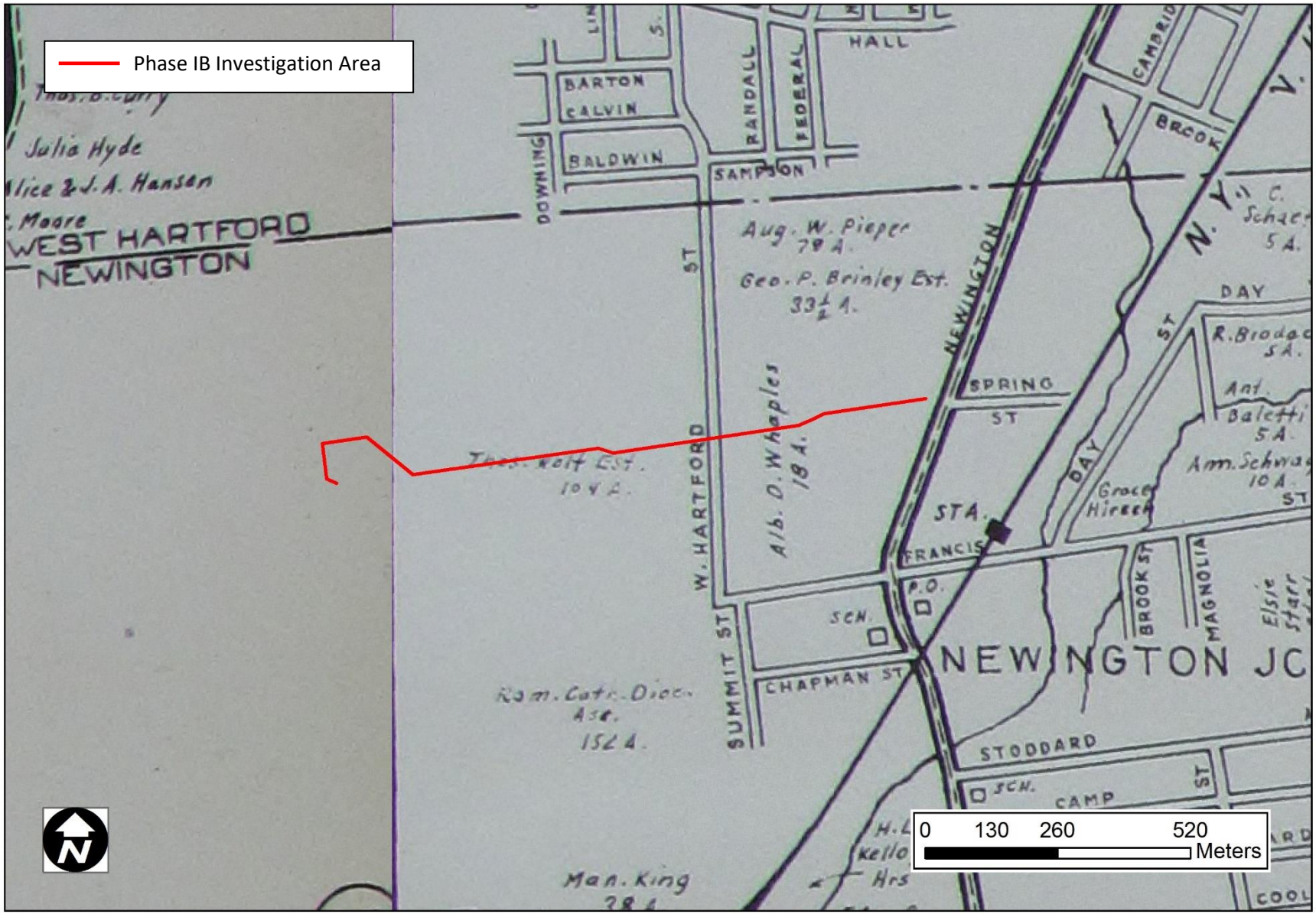


Figure 17. Excerpt from a 1931 map depicting the location of the East ROW of the project route located in Newington, Connecticut.



Figure 18. Excerpt from a 1934 aerial image depicting the location of the East ROW of the project route located in Newington, Connecticut.

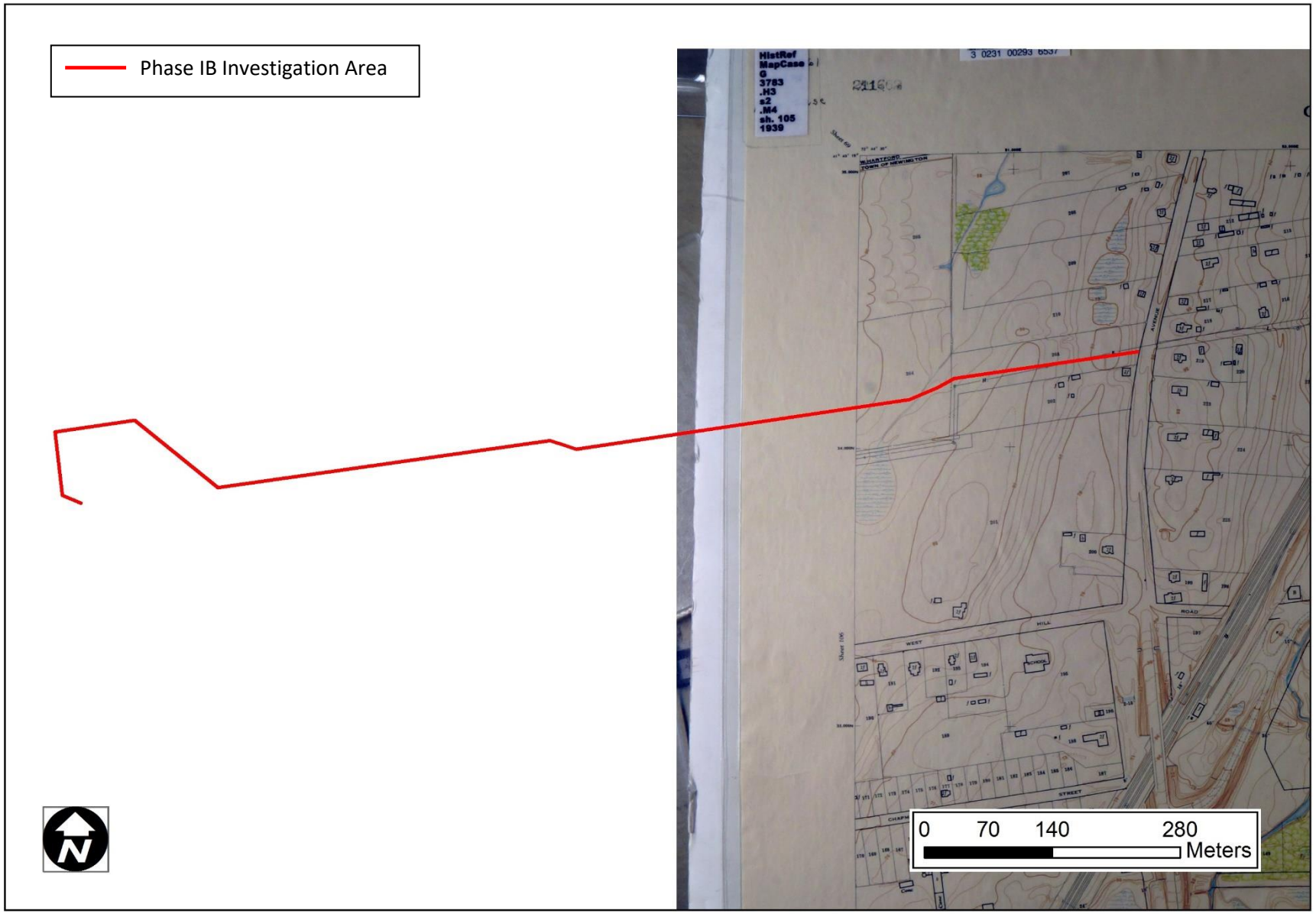


Figure 19. Excerpt from a 1939 map depicting the location of the East ROW of the project route located in Newington, Connecticut.

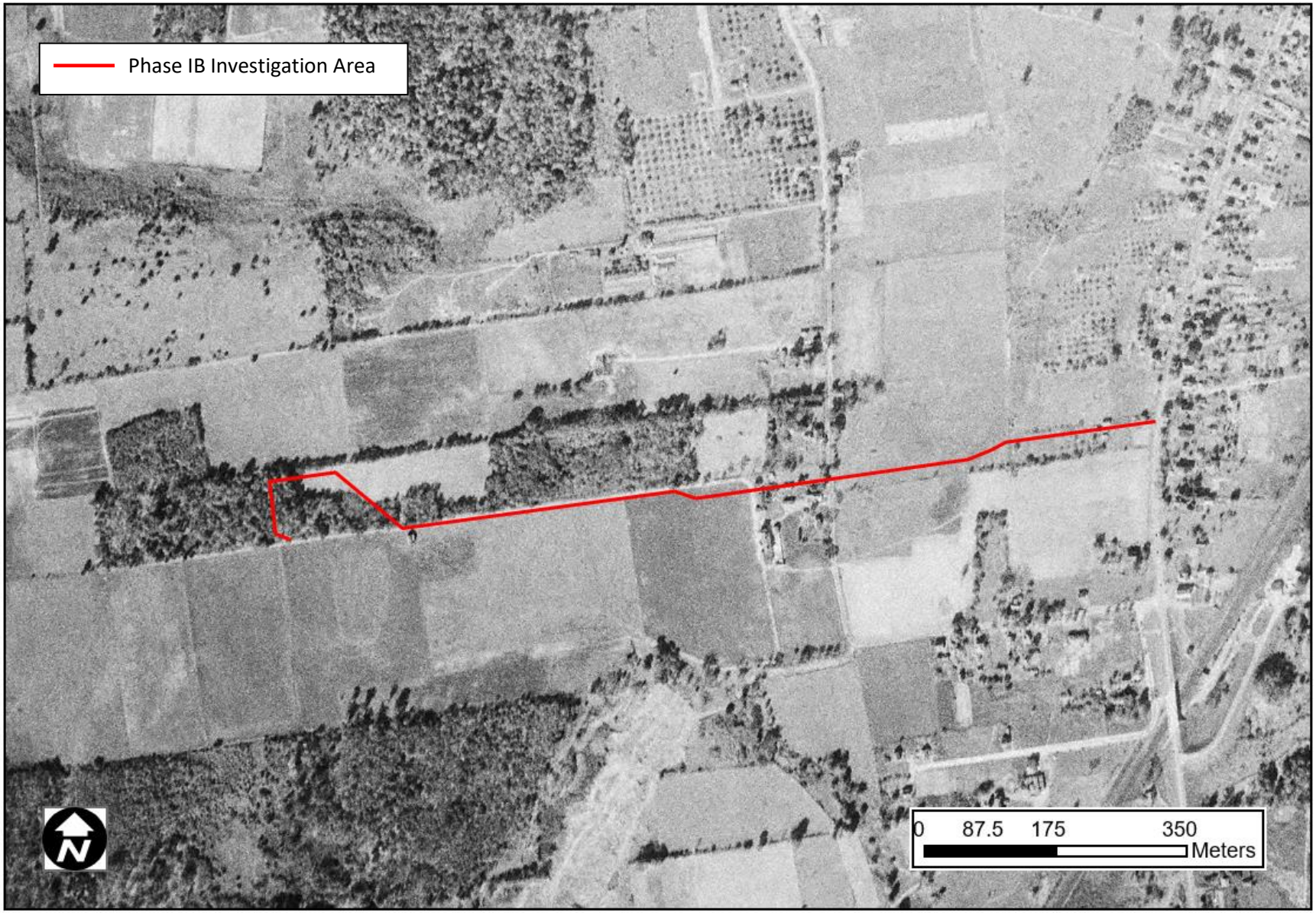


Figure 20. Excerpt from a 1941 aerial image depicting the location of the East ROW of the project route located in Newington, Connecticut.

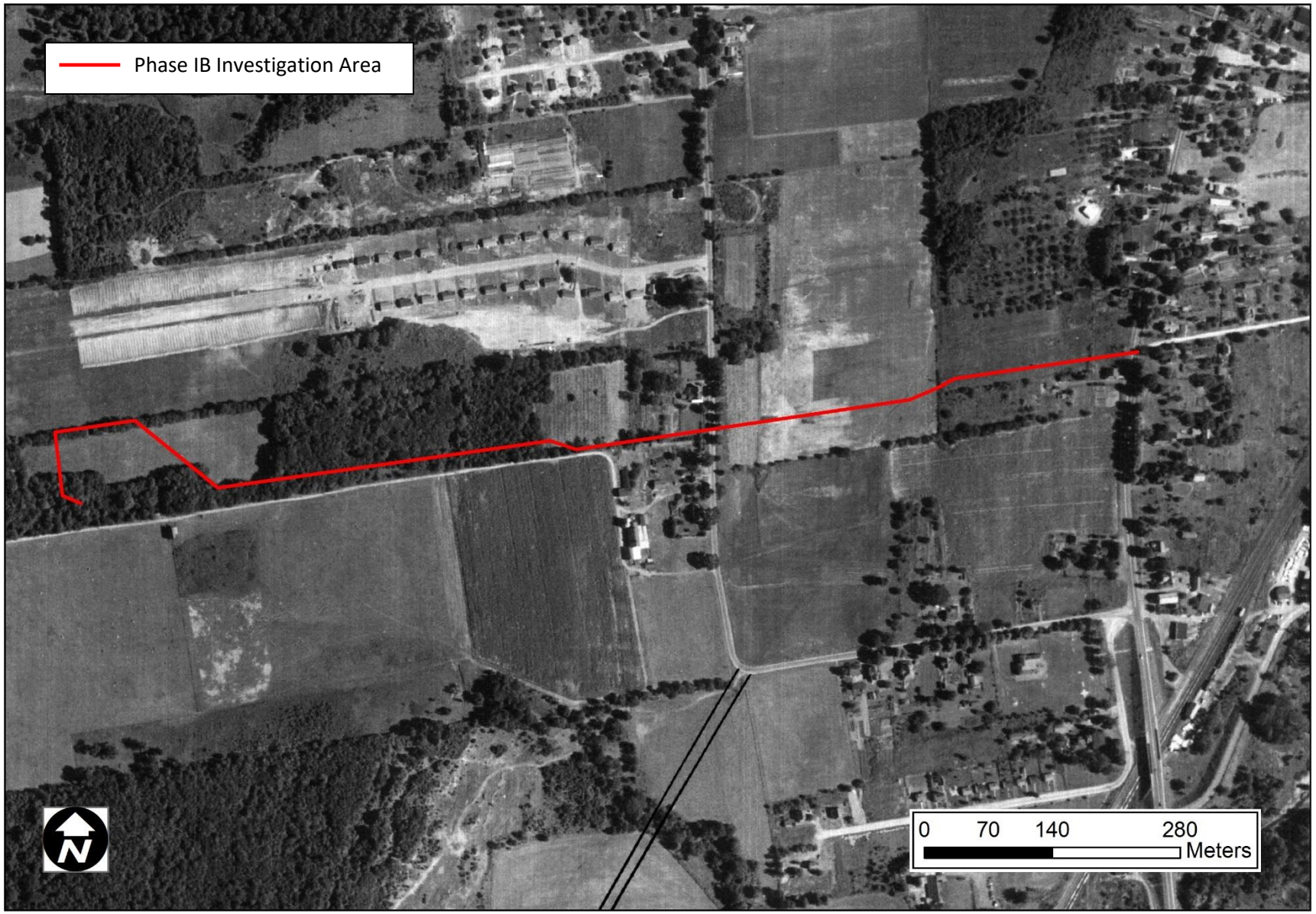


Figure 21. Excerpt from a 1951 aerial image depicting the location of the East ROW of the project route located in Newington, Connecticut.

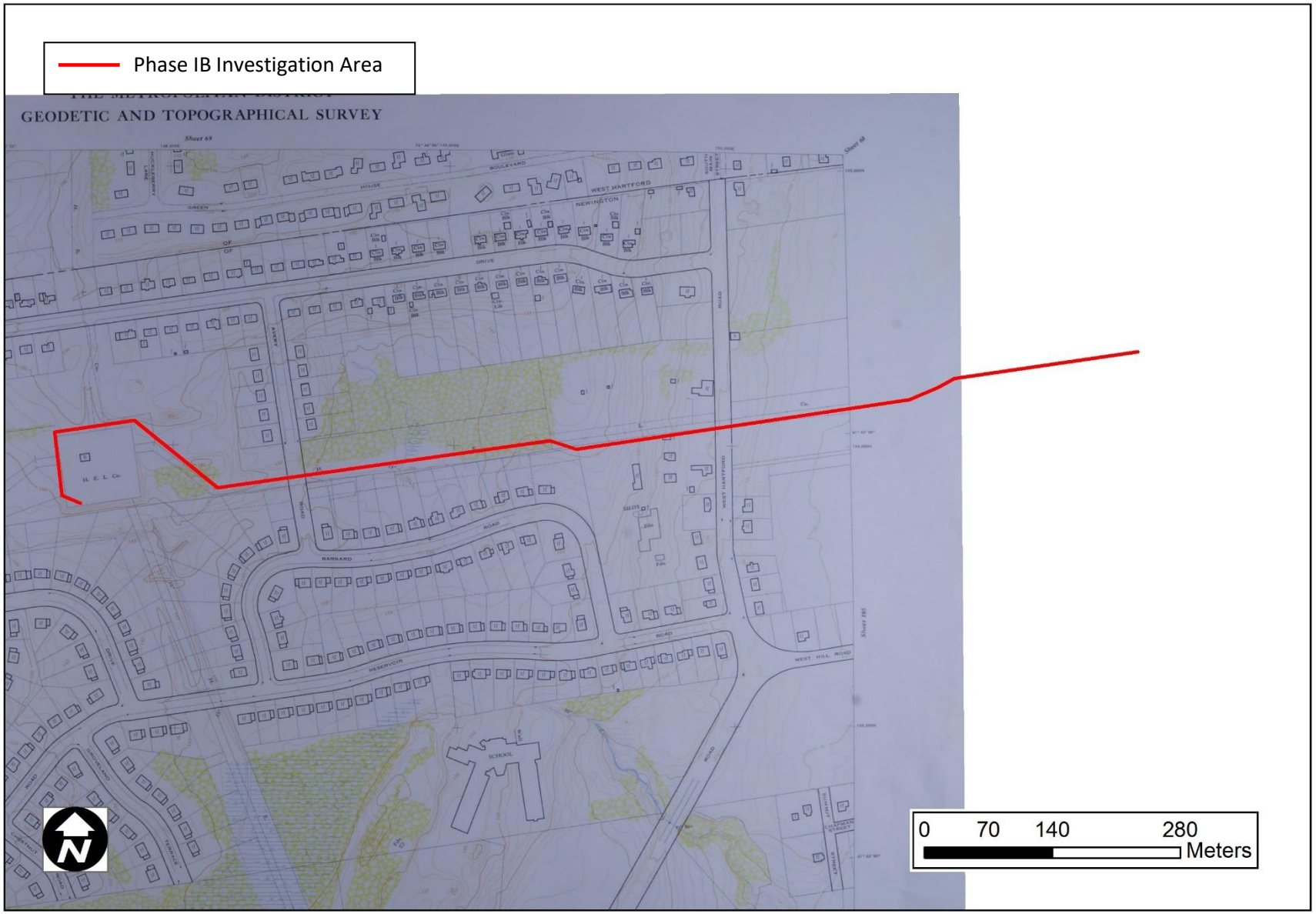


Figure 22. Excerpt from a 1957 MDC topographic map depicting the location of the East ROW of the project route located in Newington, Connecticut.

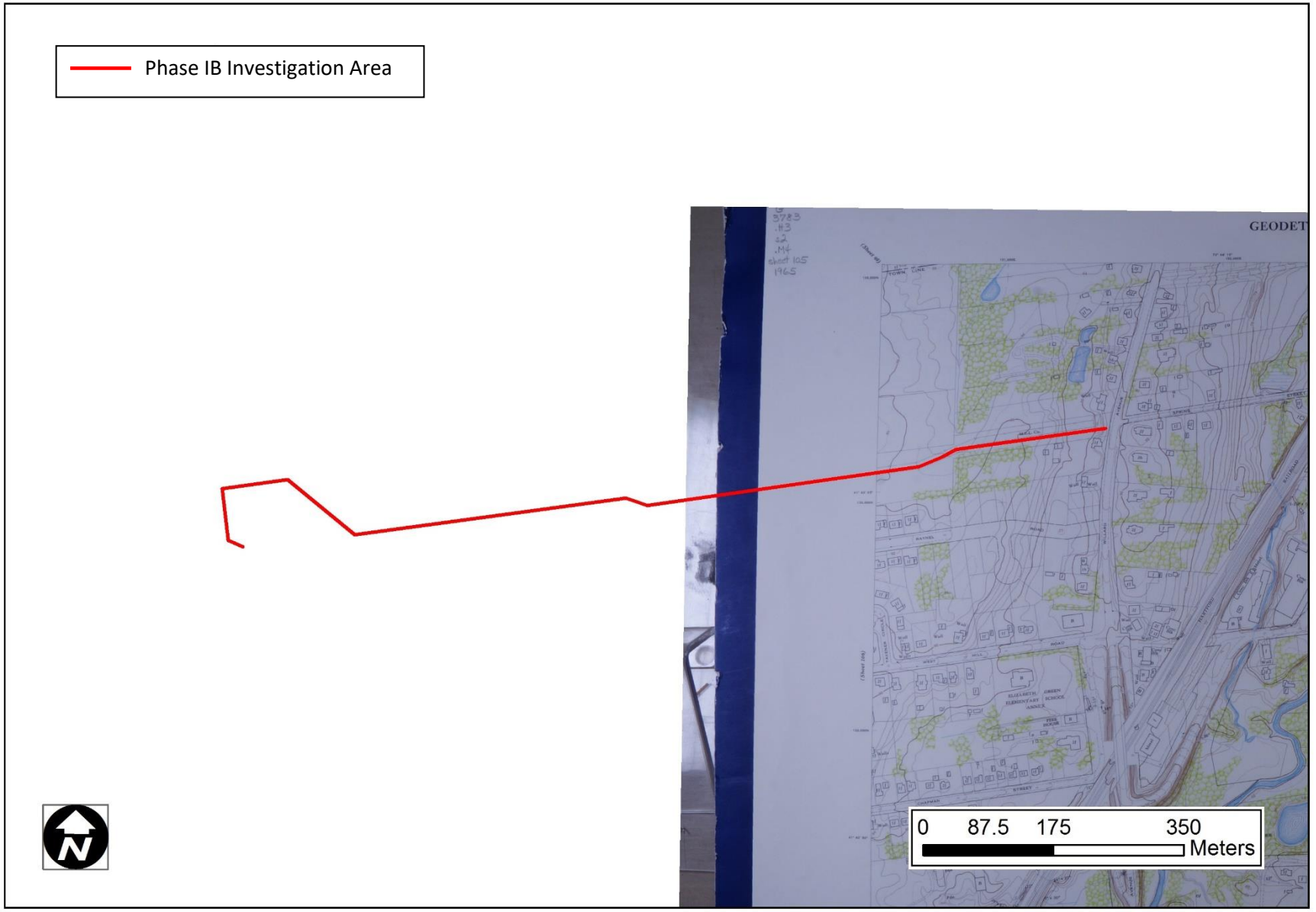


Figure 23. Excerpt from a 1965 MDC topographic map depicting the location of the East ROW of the project route located in Newington, Connecticut.

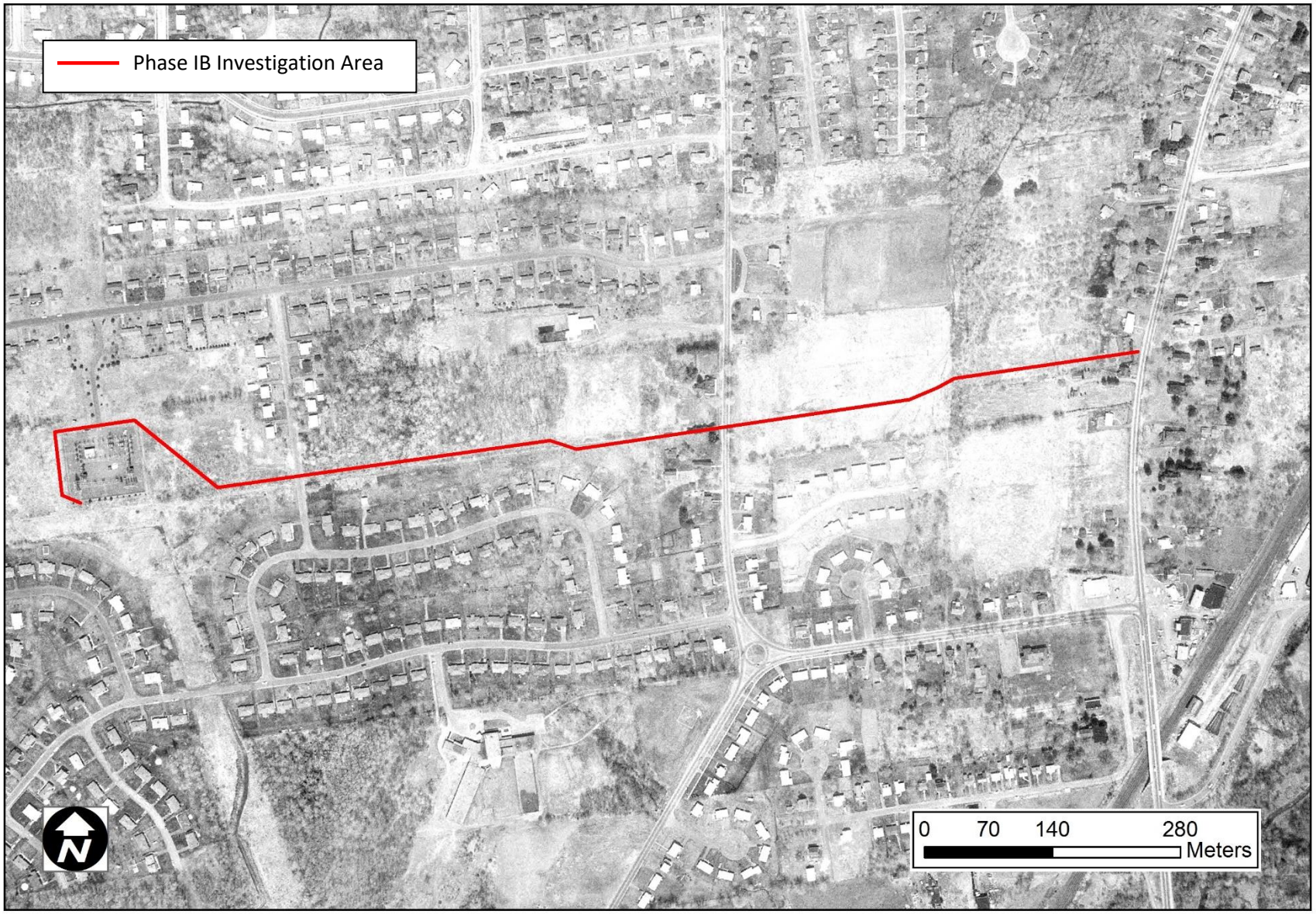


Figure 24. Excerpt from a 1965 aerial image depicting the location of the East ROW of the project route located in Newington, Connecticut.

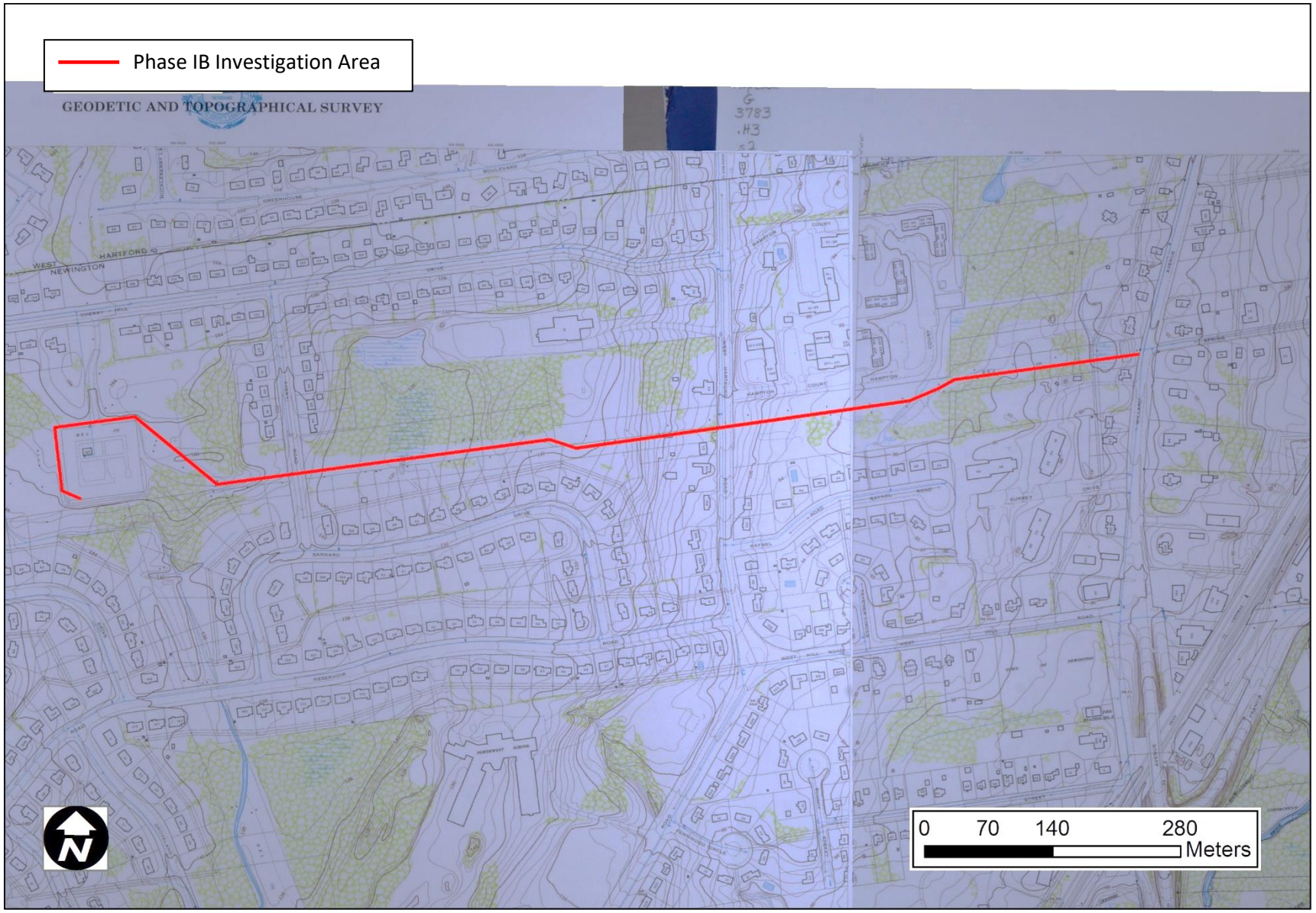


Figure 25. Excerpt from a 1975 MDC topographic map depicting the location of the East ROW of the project route located in Newington, Connecticut.



Figure 26. Excerpt from a 1991 aerial image depicting the location of the East ROW of the project route located in Newington, Connecticut.

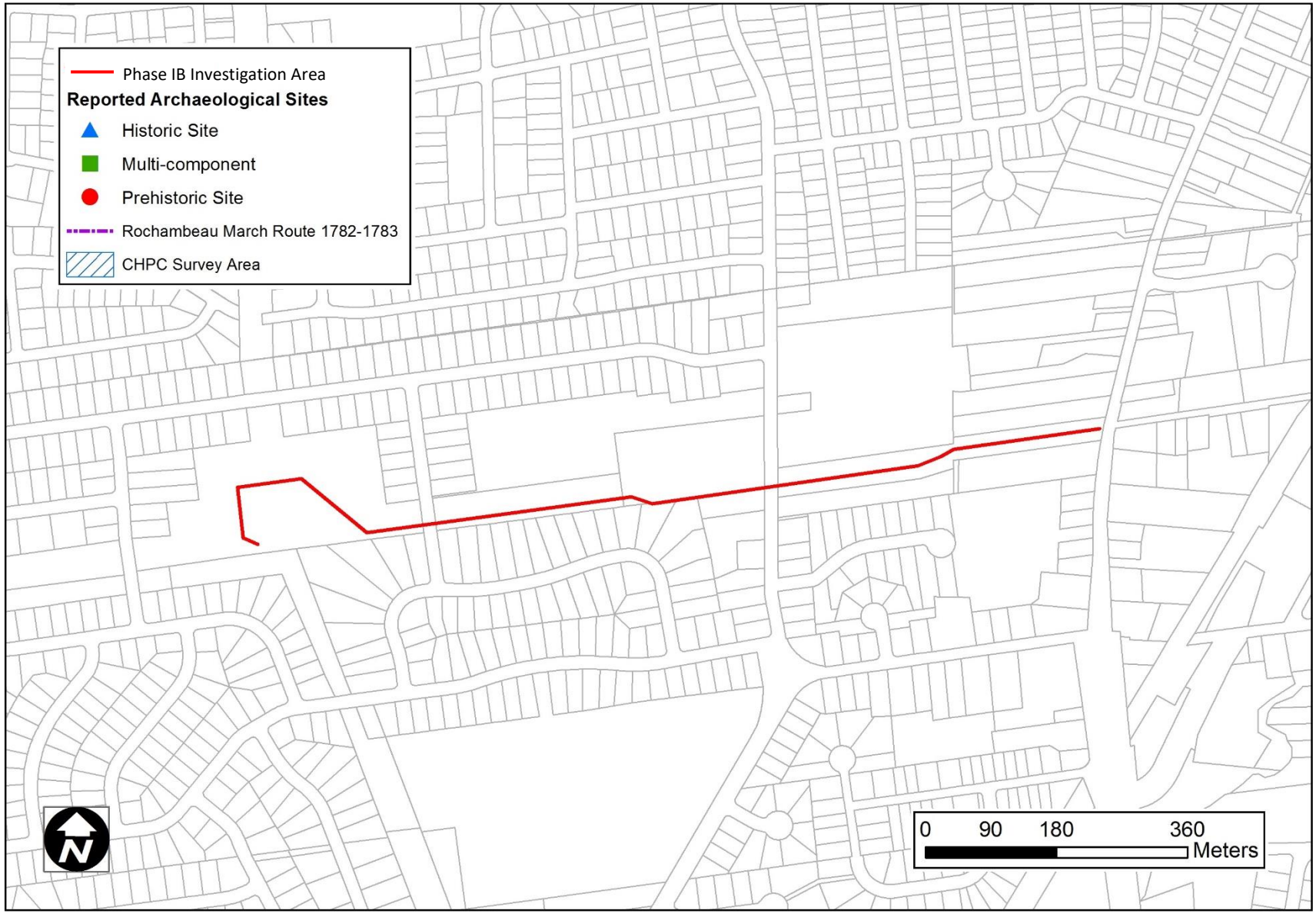


Figure 27. Digital map showing the locations of previously identified archaeological sites in the immediate vicinity of the East ROW of the project route located in Newington, Connecticut.

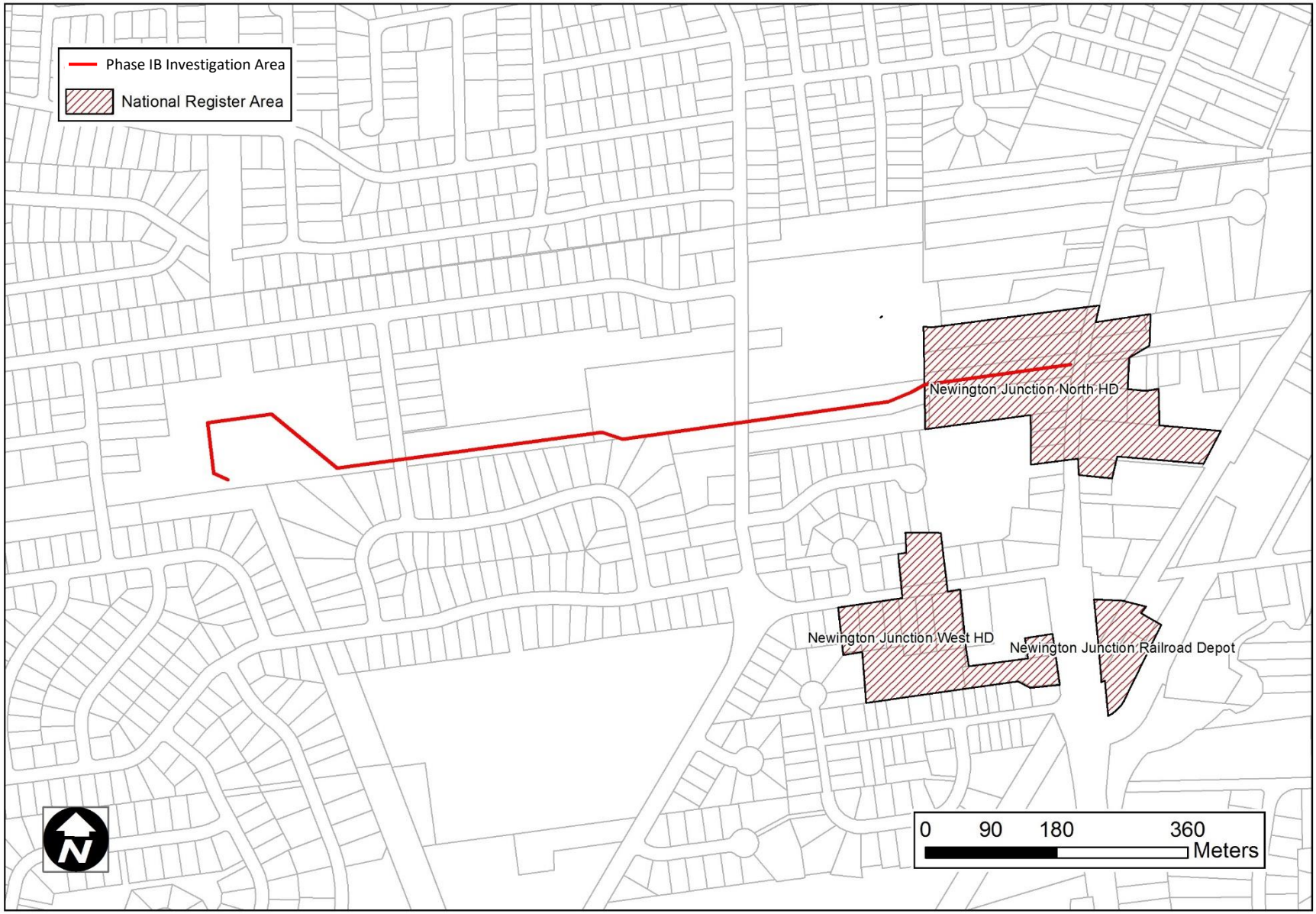


Figure 28. Digital map showing the locations of previously identified National Register of Historic Places in the immediate vicinity of the East ROW in Newington, Connecticut.

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APPENDIX I

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HERITAGE CONSULTANTS, LLC

INTEGRATED HISTORIC PRESERVATION PLANNING

November 4, 2016

Mr. Chris Newhall, PWS, CPESC
Project Manager
AECOM
9 Jonathan Bourne Drive
Pocasset, Massachusetts 02559

RE: Addendum to the Cultural Resources Review of the Project Region Associated with the Greater Hartford Central Connecticut Reliability Project: Cultural Resources Review of the Proposed Amtrak Right-of-Way, Newington, West Hartford, and Hartford, Connecticut

Mr. Newhall:

Heritage Consultants, LLC (Heritage) is pleased to provide this Addendum to the *Cultural Resources Review of the Project Region Associated with the Greater Hartford Central Connecticut Reliability Project*, which was prepared in May 2015 on behalf of The Connecticut Light and Power Company doing business as Eversource Energy (Eversource) and AECOM, Eversource's environmental consultant. As discussed in the original report, which was dated May 2015 and submitted to the Connecticut State Historic Preservation Office (SHPO) earlier this year, Eversource proposes to improve the reliability of the electric transmission system in the Greater Hartford and Central Connecticut area by constructing and operating a new 115-kilovolt (kV) transmission line and modifying existing substations.[1]

These improvements, referred to as the Greater Hartford Connecticut Central Connecticut Reliability Project (GHCCRP), include the construction and operation of a new, approximately 3.7-mile 115-kV transmission line between Eversource's existing Newington Substation (Town of Newington), through the Town of West Hartford, to Eversource's existing Southwest Hartford Substation in the City of Hartford. There is presently no transmission line connection between Newington and Southwest Hartford substations. Modifications also are planned to both substations, including a 0.3-acre expansion of the Newington Substation and modifications to the Newington Tap connection to the substation. Modifications to the Southwest Hartford substation will take place within the existing substation footprint.

1. PROJECT BACKGROUND

In early 2015, Eversource contracted with Heritage to provide a cultural resources review of the GHCCRP. At that time, given the dense urban-suburban development in the Newington-West Hartford–Hartford project study area, and the lack of any existing transmission line right-of-way (ROW) connecting the Newington and Southwest Hartford substations, Eversource anticipated that the new 115-kV transmission line would be configured underground and aligned principally along public roads. Heritage's analyses of

[1] As described in the May 2015 report, the original GHCCRP included proposed modifications to Eversource's existing Berlin Substation in the Town of Berlin. Eversource now plans to implement the Berlin Substation modifications separately from the GHCCRP.

the project study area and the initial (2015) underground GHCCRP transmission line routes are detailed in the May 2015 cultural resources report.

In the 2015 report, Heritage's research encompassed the project region in the vicinity of and between the Newington and Southwest Hartford substations (refer to maps included in the 2015 report). The eastern boundary of the project study area included an Amtrak railroad corridor that extends generally southwest-to-northeast through Newington, West Hartford, and Hartford. This corridor includes two active railroad lines, as well as the recently developed CT*fastrak*, a bus rapid transit line operated by the Connecticut Department of Transportation (ConnDOT) that is situated west of the two Amtrak rail lines, on property owned by Amtrak.

The southern boundary of the project study area encompasses an existing Eversource distribution line ROW, which is generally 100 feet wide and extends from Newington Substation east to State Route 173 (Willard Avenue / Newington Road). This distribution line ROW is occupied by two overhead distribution lines and one underground distribution cable. In 2015, the distribution line ROW was reviewed as a route alternative for a segment of the underground 115-kV line.

As described in the May 2015 report, Heritage determined that as long as the transmission line was to be buried in previously disturbed and paved areas, no additional archaeological research was recommended. Heritage also recommended that "if a route [was] eventually selected where the proposed transmission line (above ground or underground) will follow the existing power line corridor in the southwestern and southern portion of the proposed GHCCRP region, these areas should be subjected to Phase IB subsurface testing prior to construction of the GHCCRP" (Heritage Consultants, LLC 2015). Possible effects to above-ground cultural resources were not considered in the 2015 study since the proposed 115-kV transmission line construction was expected to be entirely below grade.

Since the preparation of the 2015 cultural resources report, Eversource consulted with both Amtrak and ConnDOT and conducted additional studies of the potential feasibility of collocating approximately 2 miles of the proposed new 115-kV line, in an overhead configuration, within the eastern portion of the Amtrak ROW. In the summer of 2016, Eversource submitted detailed information to Amtrak regarding the potential overhead line configuration; Amtrak's review is pending.

Within the Amtrak ROW, Eversource proposes to install the new transmission line on monopole structures that are approximately 100 feet in height and located along the east side of the ROW. Since the Newington and Southwest Hartford substations are located to the west of the Amtrak corridor, Eversource would also install approximately 100-foot tall structures at the northern and southern ends of this new line segment directly west of the CT *fastrak* busway within the Amtrak ROW. From these structures, the new 115-kV line would extend, in an overhead configuration, above the Amtrak railroad tracks and busway to the monopole along the east side of the corridor.

Neither the Newington Substation nor the Southwest Hartford Substation connect directly to the Amtrak corridor. Consequently, as part of the evaluation of the use of the Amtrak ROW, Eversource also identified and investigated options for routing the portions of the new 115-kV line between Newington Substation and the Amtrak ROW and from the Amtrak ROW to Southwest Hartford Substation. Due to the proximity of Interstate 84 to Southwest Hartford Substation, only one option was identified for the portion of the proposed new transmission line extending from the Amtrak ROW to Southwest Hartford Substation. Specifically, along this segment, the new 115-kV line would extend in an underground configuration through a paved movie theater parking lot, under New Park Avenue, and then into Southwest Hartford Substation (Refer to Figure 1 and other maps located in Appendix A to this Addendum.)

In contrast, six options were identified and evaluated for the portion of the transmission line route between Newington Substation and the Amtrak ROW (refer to Appendix A, Figure 1). These six options include underground configurations along road ROWs and within paved parking lots, as well as both overhead and underground configuration alternatives along Eversource's existing approximately 0.7-mile distribution line ROW in Newington.

This Addendum supplements the 2015 cultural resources report by reviewing the 2016 GHCCRP route along the Amtrak ROW and the routing options between Newington Substation and the Amtrak corridor, as well as the proposed route between the Amtrak corridor and Southwest Hartford Substation. Because the original (2015) GHCCRP did not contemplate either an overhead transmission line design or transmission construction activities outside of road ROWs or other paved areas, this Addendum also evaluates the potential visual effects of overhead line segments on National Register of Historic Places (NHRP) districts located in both Hartford and Newington, and provides a sensitivity analysis of the Eversource distribution line ROW, which could potentially contain subsurface archaeological sites.

The Eversource distribution line ROW extends through the Newington Junction North NRHP district, which includes a collection of buildings located along Willard Avenue and Spring Street in Newington. Other Newington NHRP districts are located along and in the vicinity of Willard Avenue to the south. The Parkville NRHP district, which is located in the City of Hartford, is situated north of Southwest Hartford Substation.

2. OVERVIEW OF 2016 ROUTE OPTIONS

The following section describes the six route options considered for the alignment of the new 115-kV line between Newington Substation and the Amtrak ROW (refer to Appendix A, Figure 1 for the location of these options). Under Option 1, the route along the Amtrak ROW (overhead transmission line configuration) and the underground segment from the Amtrak ROW to Southwest Hartford Substation also is described. This overhead configuration along the Amtrak ROW and proposed underground line alignment into Southwest Hartford Substation is common to all six of the route options.

Route Option 1: Underground along Roads (to Jacob Road)

Option 1 would be constructed underground and it would extend beneath local streets until it intersects the Amtrak Corridor (Appendix A, Figure 1). It will exit the Newington Substation property to the north, turn east down Cherry Hill Road until it intersects South Main Street. From there, it will head north along South Main Street and turn east along Sampson Street to its intersection with Newington Road. The alignment then will extend north along Newington Road (State Route 173) until turning east along Jacob Road and traversing to the western edge of the Amtrak corridor (Appendix A, Figure 1). At that point, the proposed line will transition from underground to overhead utilizing a proposed 100-foot-tall monopole structure on the western side of the Amtrak ROW. It will cross over the Amtrak ROW to a second proposed 100-foot-tall monopole structure and then extend northeast along the railroad corridor on a series of monopoles situated on the east side of the Amtrak corridor. The monopoles will measure approximately 100 feet in height and the overhead line will extend north to the Bowtie Cinema at the Palace in southwest Hartford. At that point, the overhead line will cross back to the west side of the Amtrak/CT*fastrak* corridor on a 100-foot-tall monopole and transition to an underground configuration through the cinema's paved parking lot and then northeast along New Park Avenue to Southwest Hartford Substation.

Route Option 2: Underground along Roads (to Shephard Street)

Option 2 mirrors option 1 until the point where it intersects Newington Road. Instead of turning north along Newington Road, Option 2 will turn south to Shepard Avenue where it will turn east and reach the western edge of the Amtrak Corridor (Appendix A, Figure 1). At that point, the proposed line will

transition from underground to overhead, and would proceed along the route as described for Option 1.

Route Option 3: Underground along Eversource ROW to Spring Street

Option 3, which also would be constructed underground until reaching the western edge of the Amtrak corridor, would exit Newington Substation and head east along Eversource's existing distribution line ROW (Appendix A, Figure 1). It will cross under Willard Avenue and continue underground along Spring Street until it reaches the western edge of the Amtrak corridor. At that point, the proposed 115-kV line would transition from underground to overhead and would be aligned as described for Option 1.

Route Option 4: Underground along Eversource ROW to Shephard Street

Option 4, which also will be constructed underground until reaching the western edge of the Amtrak Corridor, will exit Newington Substation and head east along Eversource's distribution line ROW until reaching Willard Avenue (Appendix A, Figure 1). There, the route would turn north to follow State Route 173 until reaching Shepard Street, where it will turn east and extend underground to the western edge of the Amtrak corridor. At that point, the proposed line would transition from underground to overhead, and would proceed north along the Amtrak ROW and into Southwest Hartford Substation as described for Option 1.

Route Option 5: Overhead along Eversource ROW and Underground along Spring Street

Option 5 would align the new 115-kV line underground at its exit point and in the immediate vicinity of Newington Substation (Appendix A, Figure 1). However, the line would quickly transition to an overhead configuration, with the line supported on structures approximately 75 feet tall, and would extend along the Eversource distribution line ROW to a transition structure to be located west of Willard Avenue, near the Newington Junction North NRHP district. There are two options proposed for the transition structure. The first option would be a 75-foot tall monopole. The second option would be a 3-pole, 55-foot-tall structure. Either option would be situated three span lengths west of Willard Avenue in order to minimize potential visual effects on the Newington Junction North NRHP district.

Visual simulations were prepared of the potential appearance of this transition structure, as viewed from the Newington Junction North NRHP district; these simulations are included in Appendix E and discussed in Section 5 of this Addendum. At the transition structure, the 115-kV line would change to an underground configuration, traversing within the Eversource ROW, crossing Willard Avenue, and extending along Spring Street to another transition structure west of the Amtrak ROW at the end of Spring Street. From there, the line would change to an overhead configuration and would be aligned along the Amtrak ROW to the Southwest Hartford Substation as described for Option 1.

Route Option 6: Overhead along Eversource ROW and Underground along Shepard Street

Between Newington Substation and Willard Avenue, Option 6 would follow the same alignment and underground/overhead/underground configuration as Option 5. However, at Willard Avenue (State Route 173), Option 6 would be aligned underground, following State Route 173 north to Shepard Street (Appendix A, Figure 1). The route option would extend east along Shepard Street to a transition structure west of the Amtrak corridor and then would follow the same alignment north to Southwest Hartford Substation as described for Option 1.

Route Option Summary

The portions of the proposed 115-kV line route that would extend, in an overhead configuration, along the Amtrak ROW and, in an underground configuration, from the Amtrak ROW to the Southwest Hartford Substation are common to all options. As described in this Addendum, these portions of the transmission line route would be constructed in areas where past land use activities (e.g., roads, railroad construction)

have disturbed the subsurface. Thus, no archaeological testing is recommended in these areas. However, analyses were conducted of the potential indirect visual effects of the transmission line structures on nearby NRHP districts. These analyses are discussed below in Sections 3 and 5.

Of the six route options identified by Eversource between Newington Substation and the Amtrak ROW, two (Options 1 and 2) would entail underground line installation along previously disturbed road ROWs or other paved areas. Thus, similar to the findings in the May 2015 report, no archaeological testing is recommended for these routes.

All of the four remaining route options (Options 3 – 6) would involve alignments along, in part, the 0.7-mile Eversource distribution line ROW, which encompasses both upland and wetland areas and also crosses a portion of the Newington Junction North NRHP district. Thus, it is possible that the construction of the proposed transmission line, in either overhead or underground configurations, along the Eversource ROW could affect archaeological sites. Further, installation of the new 115-kV line in an overhead configuration along this ROW could potentially affect the NRHP district. Accordingly, Sections 3-5 of this Addendum discuss the analyses performed to date, and those recommended in the future for these options.

3. CULTURAL RESOURCES REVIEW METHODS AND RESULTS

For this Addendum, the cultural resources review entailed the completion of an existing conditions cultural resources summary based on the examination of cultural resources data obtained from the Connecticut SHPO, as well as historic maps, aerial photographs, and topographic quadrangles maintained by Heritage Consultants, LLC. This study also included a pedestrian survey of the accessible portions of the proposed options (for safety reasons, personnel representing Heritage Consultants, LLC did not enter the Amtrak ROW; instead this area was visually examined from overpasses and at- grade road crossings). This investigation is based upon project location information provided to Heritage Consultants, LLC by AECOM. The objectives of this Addendum study were: (1) to gather and present data regarding previously identified cultural resources situated within the vicinity of proposed project area; (2) to investigate the area in terms of its natural and historical characteristics; and (3) to evaluate the need for completing additional cultural resources investigations.

As discussed in the *Cultural Resources Review of the Project Region Associated with the Greater Hartford Connecticut Reliability Project, Hartford, Newington, and Berlin Connecticut* (Heritage Consultants, LLC: May 2015), the southwestern portion of Hartford and the Newington/West Hartford area contained a well-established transportation network consisting of several main roads, numerous secondary streets, and a rail line by the middle of the nineteenth century. Further, while the main building types in the area historically consisted principally of residences, there were a few commercial enterprises in the region, including a carriage shop, potter's shops, and a woolen yarn factory. In addition, a review of a series of aerial images dating from 1934 to 2014 documents that the project area in Hartford, West Hartford, and Newington has undergone substantial changes over the last century. The large open spaces seen in the nineteenth century became increasingly smaller through time as settlement of the area increased. This is especially true during the middle of the twentieth century when several new housing developments were constructed in the region. The other large addition to the area was Interstate 84, which extends from east-to-west through the northern portion of the study area. The construction of Interstate 84, which also occurred in the 1950s, resulted in the demolition of dozens of former residences and commercial buildings. It effectively cut off the Parkville neighborhood from those areas to the south. The only areas that had not suffered large scale impacts were the southwestern most and southern most areas, both of which consisted of open land traversed by the Eversource distribution line ROW that extends out of the Newington Substation to the east. Today, the project region is home to a large populace and numerous commercial and industrial enterprises, and almost all of the open spaces are gone.

Heritage Consultants, LLC presented a review of previously recorded cultural resources on file with the Connecticut SHPO in the May 2015 report concerning GHCCRP. This review revealed that no previously identified archaeological sites were known in the project study area as of 2015. As seen in Appendix A, Figure 3; Sheets 1 through 3), that finding also applies to the areas studied for the 2016 route options presented in this Addendum.

The May 2015 cultural resources review also resulted in the identification of four NRHP historic districts in the immediate vicinity of the project area. These include the Parkville Historic District, the Newington Junction North Historic District, the Newington Junction West Historic District, and the Newington Junction Railroad Depot Historic District. Of these, two are located within 152 m (500 feet) of Options 4 and 6 (as well as Options 1 through 3 and 5). These include the Parkville Historic District and the Newington Junction North Historic District (refer to Appendix A, Figure 4; Sheets 1 and 3). The Newington Junction West Historic District and the Newington Junction Railroad Depot Historic District are located to the south of the proposed routing options, outside of the project study area. Finally, two other National Register properties, the Newington Junction South Historic District and the Willard Homestead at 372 Willard Avenue, are located even further south of the project study area. Representative photographs of the GHCCRP area and the structures in the NRHP districts are provided in Appendix B.

The Parkville Historic District (Appendix A, Figure 4; Sheet 1), which was listed on the National Register in March of 2015, consists of a collection of nearly 400 mid-to-late-nineteenth and twentieth century buildings, the majority of which are contributing elements to its National Register of Historic Places significance. The district is architecturally significant as a working-class neighborhood that developed during the mid-to-late nineteenth and early twentieth centuries. Its period of significance spans from 1860 to the modern era, and its building resources represents the variety of the architectural styles and developmental trends that typify the era (see below for further discussion). Appendix B, Photo 1 represents an overview of the area encompassing the southern portion of the Parkville Historic district, facing south towards the proposed project corridor.

The Newington Junction North Historic District, which was listed on the National Register on June 2, 1987, is situated along Willard Avenue to the north of its intersection with West Hill Road (Appendix A, Figure 4; Sheet 3). This historic district is comprised of 13 contributing and three non-contributing properties that are situated throughout an area of more than 10 acres of land. The residences in the district consist of examples of Colonial Revival, Late Victorian, and Queen Anne styles, all of which typify the architecture dating from 1850-1949. The Newington Junction North Historic District currently consists of a mixed use area divided by Willard Avenue and is discussed further below.

In addition to researching historic mapping, aerial imagery, and previously identified cultural resources, representatives from Heritage Consultants, LLC also completed a pedestrian survey and photo-documentation of the areas encompassed by the various route options (Appendix B; Photos 1 through 18). The visual reconnaissance effort revealed that the vast majority of the project study area consists of paved streets and/or previously disturbed areas associated with the Amtrak corridor. These areas already contain a wide variety of buried utilities, including sewer lines, water lines, natural gas lines, and electrical utilities associated with traffic signals. As a result, these areas have been heavily disturbed, which has led to the classification of the soils in these areas as Urban Land or Udorthents (see Appendix A, Figure 5; Sheets 1 through 3). These soils have undergone massive disturbance through cutting, grading, and filling episodes associated with previous construction projects. Consequently, Urban land and Udorthent soils retain no potential to yield intact cultural deposits. Thus, the previously disturbed portions of the route options have been assessed as no/low sensitivity areas, and no archaeological testing of these areas is recommended prior to construction (refer to Appendix A, Figure 6; Sheets 1 through 3).

There are, however, several level, dry areas with good drainage characteristics along Eversource's distribution line ROW between Newington Substation and Willard Avenue that appear to have been only impacted in a localized way (see Appendix A, Figure 6; Sheets 3). Should Eversource propose to align the new 115-kV line along this distribution line ROW in either an overhead or underground configuration, Heritage Consultants, LLC recommends that any proposed impacts (e.g., work pads, access roads, cable trench, splice vaults) to the moderate/high sensitivity areas shown in green in Appendix A, Figure 6; Sheet 3 be subjected to Phase IB subsurface testing prior to construction. Proposed field methods to accomplish these surveys would differ slightly depending on whether overhead or underground transmission line configurations are planned. The recommended Phase IB survey methods are outline briefly below.

4. PROPOSED ARCHAEOLOGICAL TESTING ALONG EVERSOURCE DISTRIBUTION LINE ROW

Route Option 4: Underground along Eversource ROW to Shephard Street. The Areas of Potential Effect for archaeological testing associated with the alignment of the proposed 115-kV line in an all-underground configuration along the Eversource ROW will include approximately 1,310 m (4,300 ft) of underground line from Newington Substation to Willard Avenue. To install this underground cable the excavation of a trench measuring ca., 1.2 m (4 ft) in width will be necessary. This trench will be positioned adjacent to a 4.87 to 6.09 m (16 to 20 ft) wide access road constructed of a combination of gravel and timber mats. The latter will be temporary in nature and will be removed at the end of construction. In addition, several splice vaults also will be required. Each splice vault typically would require an excavation area of approximately 12 feet wide, 12 feet deep, and 28 feet long.

For this option, subsurface testing will be limited to areas that have previously been identified as having a moderate/high potential for containing intact cultural deposits. This encompasses approximately 1,012 m (3,340 ft) of the underground route option. The subsurface testing regime within proposed work areas associated with the installation of the underground line will consist of the excavation of shovel tests located at 15 m (49.2 ft) intervals along a single survey transect that will extend from east to west along the length of the Area of Potential Effect. This survey transect will clear an area that measures 49.2 m (50 ft) in width for cultural resources. Using this approach, it is anticipated that no more than 95 shovel tests will be required to complete the survey along this route option.

Route Option 6: Overhead along Eversource ROW and Underground along Shepard Street. The Areas of Potential Effect associated with the use of both underground and overhead transmission line configurations along the Eversource ROW includes approximately 365.7 m (1,200 ft) of underground line within the existing distribution line ROW, and nine overhead structures that will be constructed using 30 x 30 m (100 x 100 ft) gravel work pads. As was the case with Option 4, the cable trench will measure ca., 1.2 m (4 ft) in width and be positioned adjacent to a 4.87 to 6.09 m (16 to 20 ft) wide access road constructed of a combination of gravel and timber mats. This option also will include the use of two transition structures that will be required where the line changes from underground to overhead configurations (and vice versa). These transition structures also would require 100 x 100 ft gravel work pads. During survey of this option, subsurface testing will be confined to the underground trench location, as well as the 11 proposed work pads and the single access road.

For this route option, subsurface testing will be limited to areas that have previously been identified as having a moderate/high potential for containing intact cultural deposits. This encompasses approximately 365.7 m (1,200 ft) of the proposed underground route and nine of the 11 proposed structures. The two remaining structure areas fall within wetlands areas and are considered to possess a no/low probability for yielding intact archaeological deposits. The subsurface testing regime within proposed work areas will consist of the excavation of shovel tests located at 15 m (49.2 ft) intervals along a single survey transect

within the underground cable area, and along two parallel survey transects spaced 15 m (49.2 ft) apart within the proposed work pad areas. A single shovel test also will be placed at the location of the proposed new structures. Using this approach, it is anticipated that no more 75 shovel tests would be needed to complete this survey along this route option. Finally, up to 20 additional shovel tests may be excavated in order to determine the spatial limits of any archaeological resources identified during the survey of either Option 4 or Option 6. This testing regime is in keeping with all rules and restrictions governing cultural resources investigations put forth by the Connecticut State Historic Preservation Office.

During the survey, each shovel test will measure 50 cm (19.7 in) in size and will be excavated to 50 cm (19.7 in) below surface or until sterile subsoil is penetrated by at least 20 cm (9.8 in). Stratigraphic soil profiles for all shovel tests will be recorded and all shovel test fill will be screened through 0.64 cm (0.25 in) hardware cloth and examined visually for cultural material. Munsell Soil Color Charts will be used to record soil color; texture and other identifiable characteristics will be documented using standard soils nomenclature. All shovel tests will be backfilled completely following completion of recordation. In addition, the Phase IB cultural resource reconnaissance survey will entail mapping of the Areas of Potential Effect, with the locations of all shovel tests plotted, natural landscape features, and man-made structures depicted. The resultant maps will be digitized and included in the Final Report of Investigations. Finally, the proposed project areas will be subjected to photo-documentation using color digital media.

5. ABOVE-GROUND CULTURAL RESOURCES REVIEW

Representatives of Eversource, Burns & McDonnell (Eversource's engineering consultant), and Heritage Consultants, LLC met with Mr. Todd Levine of the Connecticut SHPO on Friday, May 20, 2016 to discuss the GHCCRP project, particularly the overhead transmission line design along the Amtrak corridor and the potential overhead line design along the Eversource distribution line ROW, and to solicit Mr. Levine's opinions regarding various construction techniques and potential impacts to above-ground cultural resources situated within the Newington Junction Railroad, Newington Junction North, Newington Junction West, and Parkville Historic Districts. Mr. Levine indicated that with respect to all routing options, avoidance was always the SHPO's preferred path forward; and he indicated that that in a conversation with SHPO staff archaeologist Catherine Labadia, underground routes, in roads and along the Eversource distribution ROW, would not be a concern as they would effectively avoid potential adverse visual effects on the historic districts. However, it was also acknowledged that there are other variables that need to be considered and balanced, so if avoidance was not possible, options that minimized impacts to cultural resources should be considered and presented by Eversource.

To minimize visual effects on the Newington Junction North NRHP of installing a portion of the new line overhead along the Eversource distribution line ROW, Eversource indicated to Mr. Levine that a non-standard three-pole structure measuring 65 ft in height could be used to transition the proposed transmission line from above grade to below ground at a point three stanchions to the west of Willard Avenue. Mr. Levine agreed that this could be an effective minimization strategy and indicated if that construction approach was implemented there may not be an adverse impact on nearby built resources associated with an overhead option. Since this meeting further engineering studies identified two options for the design of a transition structure. The first is a single pole, vertically configured 75-foot tall structure. The other is 3-pole, horizontally configured 55-foot tall structure.

To assess the potential visual effects of utilizing this construction approach, Eversource performed visual simulations to illustrate two potential transition structure types that would be installed within the Eversource distribution line ROW and could be seen from Willard Avenue, as well as certain contributing elements of the Newington Junction North NRHP. These photosimulations are included in Appendix E. Heritage's analyses of the photosimulations are provided after the balloon test discussion in this section.

It was further explained to Mr. Levine that from the transition structure on the west side of Willard Avenue, the transmission line would proceed underground to the Amtrak corridor, where it would transition above ground using a 100-foot tall monopole to be located on the west side of the Amtrak corridor. After crossing over the Amtrak corridor, the transmission line would be aligned along the east side of the corridor on a series of 100-foot tall monopole structures. Mr. Levine was also informed that the transmission line would once again transition to an underground route from a point adjacent to the Bowtie Cinema at the Palace and continue to the Southwest Hartford Substation.

Due to the 100-foot height of the transmission line structures proposed along the Amtrak corridor, Mr. Levine expressed concern for possible impacts to the surrounding historic districts outlined above. As a result, he requested that Eversource conduct balloon float tests to measure the visibility of the structures from the above-referenced historic districts and determine the type and scope of effects on the districts, if any.

As a result of the request by Mr. Levine, Heritage studied the possible visual effects of the proposed project on nearby National Register of Historic Places properties. This was accomplished by floating large red weather balloons at the locations where the proposed 115-kV transmission line would:

(1) Transition, via a 100-foot-tall monopole, from overhead to underground just north of the Bowtie Theater at the Palace cinema in Hartford; and

(2) Transition from underground to overhead at the eastern end of Shepard Street and cross over the Amtrak corridor via a 100-foot tall monopole structure.

The details and results of the two balloon floats are described below.

5.1 Results of Balloon Tests

Balloon Test #1: Hartford

The first balloon test was designed to determine visibility of the northernmost portion of a potential overhead transmission line structure located along the Amtrak corridor near the Parkville Historic District. The balloon, which was red and measured approximately 4 feet in diameter, was tethered to the ground to the north of a parking lot associated with the Bowtie Theater at the Palace and south of the Interstate 84 overpass. The balloon was positioned at 100 feet above ground level and left in place while personnel from Heritage Consultants, LLC investigated visibility from the Parkville Historic District. Heritage Consultants, LLC took representative photos towards various contributing elements within the district and back toward the balloon (Appendix C; Photos 1 through 15). The latter were undertaken to determine the level of visibility of the balloon from the historic district.

As mentioned above, the Parkville Historic District was listed in the NRHP in March 2015, and it contains 397 contributing and 46 non-contributing resources built between 1860 and 1964. The district is centered around the Parkville neighborhood, which is located at the far southwestern end of Hartford. The district is historically and architecturally significant as an example of mid- nineteenth-to early twentieth-century residential, industrial, and neighborhood commercial development within the City of Hartford (Criterion A). In addition, the district's building stock represents many of the significant industrial and residential architectural forms of the mid-nineteenth to the early twentieth century, ranging from Gothic Revival to Art Deco (Criterion C).

Balloon Test #1 was evaluated from various contributing buildings and streets located near the southern extent of the district. After investigating various viewsheds throughout this area, it was found that the

balloon was not visible from a majority of the contributing properties in the district; and although seemingly close in proximity, the balloon was not visible from any of the industrial buildings along Bartholomew Avenue (Appendix C; Photo 2), and was instead only visible from two locations. The first location was along Francis Avenue, one of the district's north to south thoroughfares and a residential and commercial block. The balloon was visible at the south end of Francis Avenue at a point approximately 0.45 miles to the northwest of the proposed structure to the southernmost extent of the street (Appendix C; Photos 4 through 6). The primary viewsheds from each of the contributing residences along Francis Avenue are of the houses located across from one another. They are tightly spaced and therefore provide dense cover at ground level. Mature trees line the street as well, providing additional visual interruptions in the area. While the balloon was visible at the southern end of the street, the viewshed south on Francis Avenue has already been obstructed by the massive cement block walls of the Stop and Shop building located at 150 Francis Avenue. This shopping center was built on the site of the former Royal Typewriter building, which was demolished in 1992. The balloon was visible above the roofline of the new building; however, the area contains numerous visual intrusions including, various utility poles, wires and light poles located in the Stop and Shop parking area.

The second site from which the balloon was visible within the Parkville Historic District is the M.S. Little Manufacturing Company, which is located at 151 New Park Avenue (Appendix C; Photo 12). This single-story Colonial Revival-style brick industrial building was built in 1917, with additions in 1922 and 1929. It was designed by Hartford architects Ford, Buck and Sheldon and has since been converted to offices. The balloon was visible from the façade (east elevation) and southern elevation of the building. The existing viewsheds south from this building contains a number of extant visual intrusions including light poles in the parking lot of the Stop and Shop at 150 New Park Avenue as well as lights, billboards and elevated ramps of Interstate 84.

Due to the existing conditions in the area, no adverse effect on any of the historic resources in the Parkville District is expected as a result of the construction project, and no additional architectural recordation of this area is recommended.

Balloon Test #2: West Hartford / Newington

The second balloon test was designed to determine whether the proposed structures located furthest south along the Amtrak corridor would be visible from the properties within the Newington Junction Multiple Resource Area (MRA). The Newington Junction MRA is a neighborhood centered at the intersection of Willard Avenue (State Route 173) and West Hill Road in the northwest portion of Newington, south of the Town of West Hartford boundary. The MRA includes the following resources: Newington Junction North Historic District (listed 1987 and encompassing 55-100 Willard Avenue), Newington Junction South Historic District (listed 1987 and encompassing 268-319 Willard Avenue), Newington Junction West Historic District (listed 1987 and encompassing 175 and 181-183 Willard Avenue, 269-303 West Hill Road, and 2-4 Chapman Street), the Newington Junction Railroad Depot (listed 1986 and encompassing 160 Willard and 200 Francis avenues), and the Willard Homestead at 372 Willard Avenue (listed in 1986). The area is significant as the historic junction of the Hartford to New Haven line (1839) and the Hartford, Providence and Fishkill Railroad (1850), which ran from Waterbury and Bristol to Hartford. The development of the Depot brought about economic growth and subsequent residential development in the community, and it played an important role in the establishment of Newington as a town independent from Wethersfield; thus, it is significant under Criterion A. The area also is architecturally significant for the wide range of architectural styles dating from the late eighteenth to the early twentieth century – including New England Colonial and Italianate (Criterion C).

The second balloon, which also was red and measured approximately 4 feet in diameter, was tethered to the ground by a stake situated within the southern portion of a gravel parking area associated with the

Shepard Steel Company, Inc. (Appendix D: Photos 1 through 27). The stake was located approximately 6 feet from the western fence line of the Amtrak corridor. The second balloon also was positioned at 100 feet above the ground surface and left in place while personnel from Heritage Consultants, LLC proceeded to the above-referenced historic districts to take representative photos toward the contributing elements of the districts and back toward the balloon. This was undertaken to determine the level of visibility of the balloon from the historic districts, as well as show the contributing elements of the historic districts.

The balloon was only slightly visible from one contributing resource located in the Newington Junction North Historic District, the residence at 82 Willard Avenue. The house at 82 Willard Avenue is an Italianate-style residence that dates from ca., 1860 and features projecting eaves with heavy, paired brackets, paired arched windows and wrap-around porch with molded, chamfered posts. The balloon was minimally visible from the street/front yard of the house at a distance of approximately 0.22-miles northeast and through deciduous tree growth (Appendix D; center of Photo 21). This level of visibility is extremely minor and does not pose any significant intrusion into the viewshed of or from the residence, nor does it detract from the significance of the residence in any way. The balloon was not visible from any of the other resources within this district. It also was not visible from the Newington Junction West and South Historic District or the Willard Homestead.

The balloon was visible from a second point looking northeast at a distance of approximately 0.42 mile from the intersection of Francis Avenue and the southern boundary of Newington Depot (Appendix D; Photo 8). This area is devoid of tree cover and elevated; therefore, the viewshed from this point toward the proposed transmission line structure is fairly unobstructed. However, the view from the actual depot buildings is extremely limited and the level of extant visual disturbances surrounding the area is high and includes several modern industrial and commercial properties. The additional presence of the proposed transmission line structure will not detract from the significance of the Newington Depot property in any way.

Given the above evaluation, it is the opinion of Heritage Consultants, LLC that the proposed project, as designed in an overhead configuration along the Amtrak corridor, will not introduce any significant visual disturbances into the viewsheds of the Parkville Historic District and/or properties associated with the Newington Junction MRA. Therefore, no adverse effect on any of the historic resources in this area is expected as a result of the construction project and no additional architectural recordation is recommended.

5.2 Visual Simulations: Alternative Overhead Line Configurations along Eversource Distribution Line ROW, Town of Newington

In addition to the above-referenced balloon float tests, Heritage also reviewed photo-simulations of alternative configurations for the transition structure(s) that would be required to switch the new 115-kV transmission line from overhead structures to an underground cable configuration within Eversource's distribution line ROW in the vicinity of the Newington Junction North NHRP district (see Appendix E). At the May 20, 2016 field meeting, Eversource indicated to SHPO that the eastern most portion of the new 115-kV line (i.e., the 0.08-mile portion of the line near Willard Avenue) would be installed underground within the existing Eversource distribution line ROW to avoid or limit indirect visual effects on the NRHP district.

Such transition structures would be required for either Route Option 5 or Route Option 6, as described in Section 2 of this Addendum. Two alternative transition structure configurations were discussed:

- A 75-foot-tall vertical monopole transition structure; or

- A 55-foot-tall three-pole horizontal transition structure.

The photo-simulations, which were prepared by Trinity Animation and provided to Heritage for analysis, were developed in an effort to determine whether Route Options 5 and 6, including the transition structures, would result in any visual impacts to the Newington Junction North NRHP district or any of its contributing resources. The photo-simulations are shown in Appendix E; Photos 1 through 3; these figures depict the existing views along the Eversource distribution line ROW looking west from Willard Avenue, as well as simulations of the views of the ROW that would be associated with Route Options 5 and 6 using the two different transition structure configurations. The photo-simulations illustrate the transition structures, as well as views along the ROW from Willard Avenue in general, after vegetation removal for the new 115-kV line.

A review of the available data indicates that the only two contributing resources within the Newington Junction North NRHP district that are visible from the proposed transition structure(s) are the residential structures located at 64-66 and 74 Willard Avenue. These structures are located on the east side of Willard Avenue. The existing westerly viewshed from the fronts of these historic homes currently includes Eversource's distribution line ROW and the above-ground utility facilities located within the fenced, distribution line switching station that abuts the west side of Willard Avenue. As Appendix E; Photo1 illustrates, despite landscaping, the existing switching station is prominently visible to passersby and from structures on the east side of Willard Avenue.

The transition structures, in either alternative configuration, would be located approximately 0.08 mile to the west of the switching station and thus would be in the visual background behind this existing utility facility. The single 75-foot-tall vertical transition structure would be located behind the existing switching station and, while visible, would not introduce any significant visual modifications into the viewshed from the historic homes (Appendix E; Photo 2). The 55-foot-tall, three-pole transmission structure would be similarly located approximately 0.08 mile west of Willard Avenue and would be visible in the background behind the switching station (Appendix E; Photo 3). However, compared to the vertical monopole alternative, this transition structure configuration option would create a comparatively greater visual intrusion into the landscape because of the horizontal massing of the three poles.

However, because the existing westerly views from the nearby historic properties are already influenced by the Eversource distribution line ROW and switching station, the overall integrity of the setting will not be diminished in any significant way by either of the alternative transition structure configurations. In sum, construction of either of the transition structure alternatives would not result in an adverse impact to the Newington Junction North NRHP district or its contributing elements.

6. SUMMARY

In sum, Heritage Consultants, LLC completed a cultural resources review of the proposed GHCCRP in Newington, West Hartford, and Hartford Connecticut. This review took into consideration potential impacts by the proposed construction on both archaeological and architectural resources. The results of the archaeological portion of the study are that no impacts to archaeological deposits are expected anywhere to the east of Willard Avenue. This area, which contains the Amtrak corridor, has been heavily disturbed in the past and no longer contains intact soils. In contrast, there are archaeologically sensitive areas located along the existing Eversource distribution line ROW between Newington Substation and Willard Avenue. If construction (either through the use of a linear trench, individual work pads, or a combination of both) in these areas cannot be avoided, then Phase IB survey of the moderate/high probability areas is recommended.

In addition, the current study also considered the visual effects the proposed construction may have on nearby NRHP properties. This was completed using two balloon float tests and visual simulations to assess any potential visibility issues in the areas around the Parkville Historic District and the Newington Junction Multiple Resource Area. While the balloons were visible from a few areas within the nearby historic districts, it is not anticipated that construction of the proposed structures will result any significant visual disturbances into the viewsheds of these historic properties. As a result, no adverse effect on above-ground historic resources is expected as a result of the GHCCRP project, and no additional architectural recordation is recommended.

Finally, construction within the existing footprints of the Newington and Hartford Southwest substations will not impact any cultural resources since these areas have been disturbed extensively in the past. Similarly, construction within a proposed 0.3-acre expansion area immediately to the south of the Newington substation, as well as the Newington Tap interconnection, also will not impact any cultural resources. These areas also have been disturbed in the past.

If you have any questions regarding this Addendum, or if we may be of additional assistance with this or any other projects you may have, please do not hesitate to call us at 860-667-3001 or email me at dgeorge@heritage-consultants.com. We are at your service.

Sincerely,

David R. George

David R. George, M.A., R.P.A. Archaeologist

Stacey Vairo

Stacey Vairo Architectural Historian

References Cited

Heritage Consultants, LLC
2015 *Cultural Resources Review of the Project Region Associated with the Greater Hartford Connecticut Reliability Project, Hartford, Newington, and Berlin Connecticut.* Report submitted to Eversource Energy, Berlin, Connecticut

Attachments

Appendix A: GHCCRP Proposed Project Route Options: USGS Maps, Figures, Aerial Maps, Locations of Previously-Identified Archaeological Sites, NRHP Areas, Soil Types

Appendix B: Representative Photographs of the Project Area and Route Options

Appendix C: Parkville NRHP District: Photo Log and Photographs of Balloon Test Results

Appendix D: Newington Junction North and Other Newington NRHP Districts: Photo Log and Photographs of Balloon Test Results

Appendix E: Photosimulations of Potential Transition Structures along Eversource Distribution Line ROW near Newington Junction North NRHP District

APPENDIX A

GHCCRP Proposed Project Route Options: USGS Maps, Figures, Aerial Maps, Locations of Previously Identified Archaeological Sites, NRHP Areas, Soil Types

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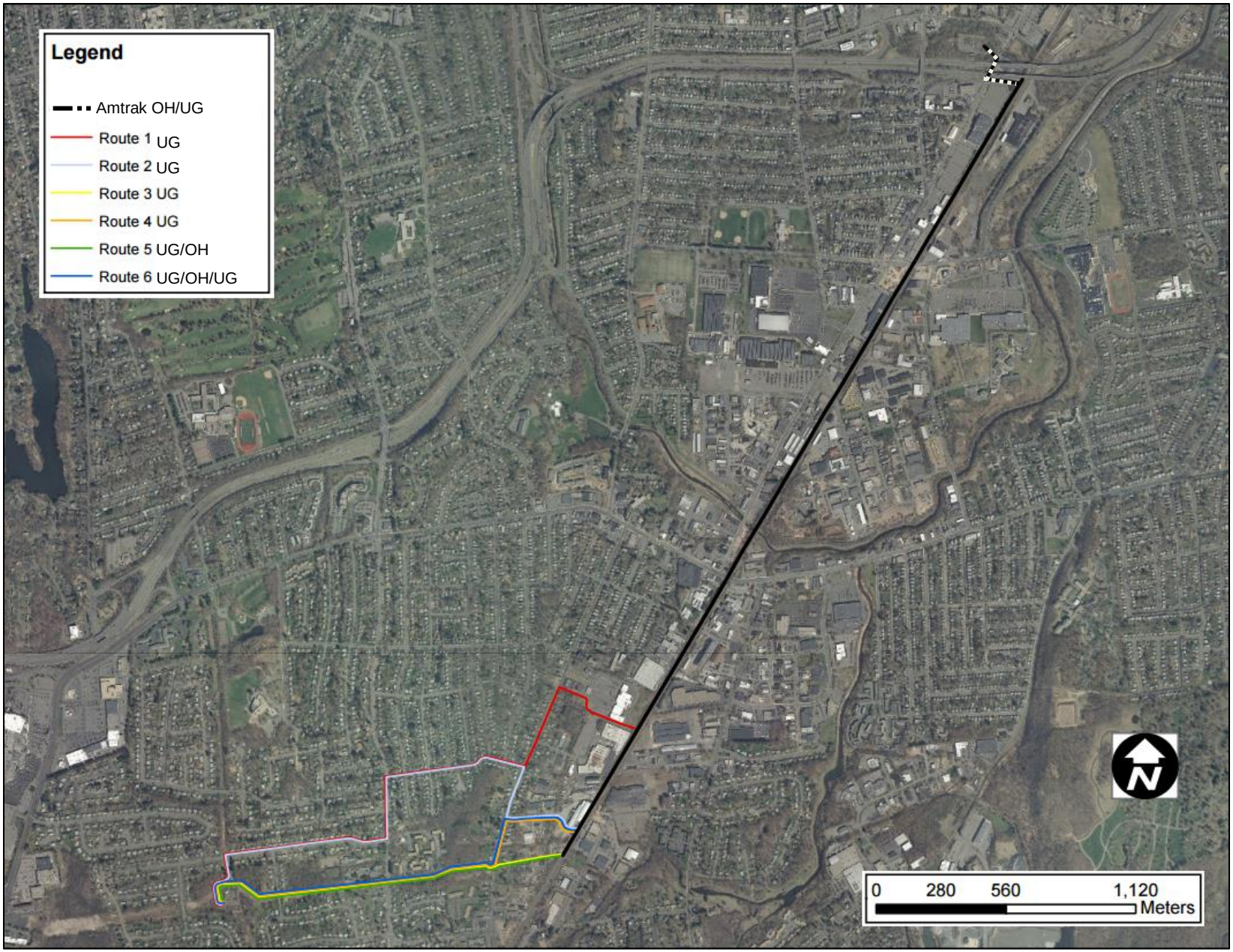


Figure 1. Excerpt from a current aerial image showing the six proposed routing options in Newington and West Hartford, Connecticut.

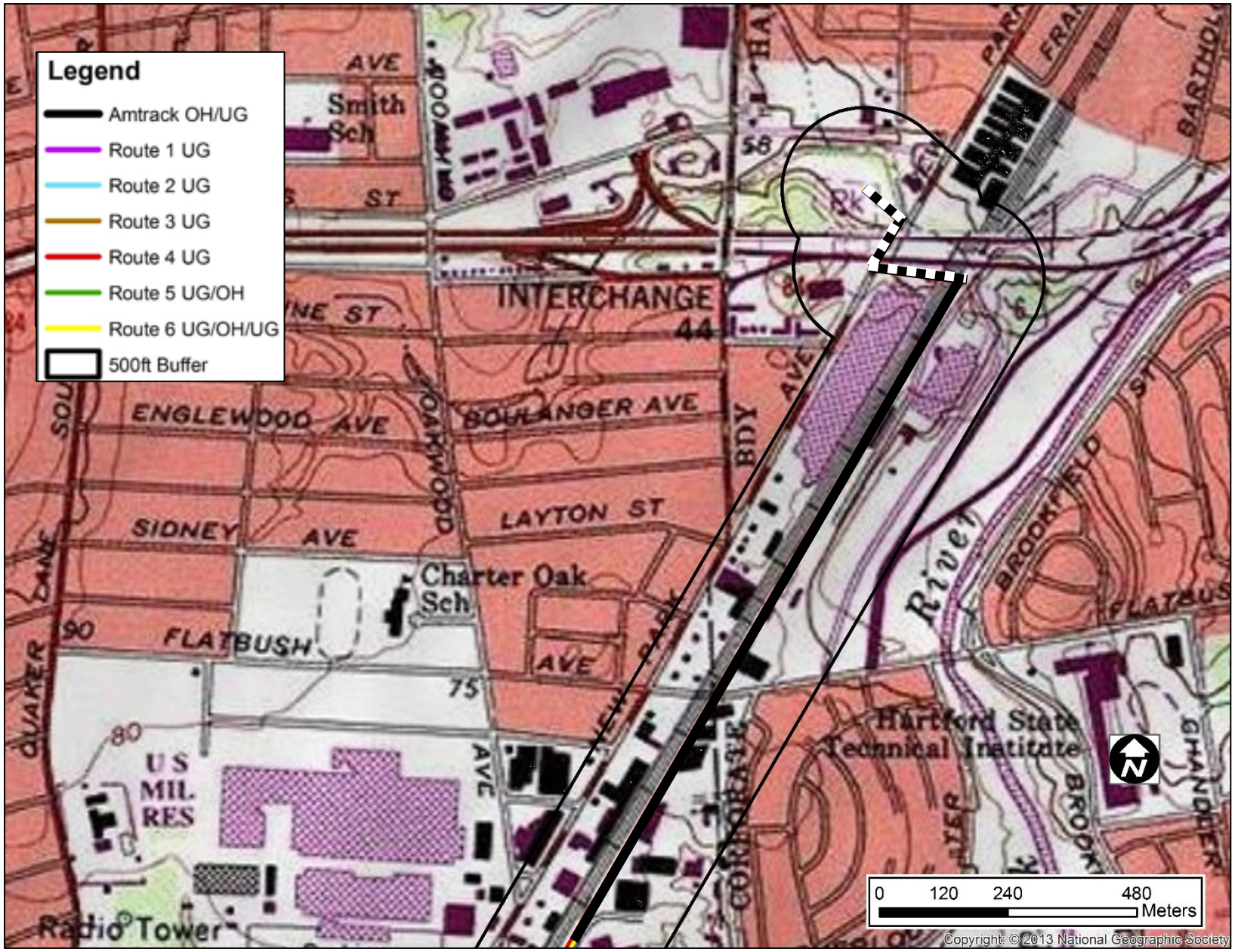


Figure 2; Sheet 1. Excerpt from a USGS 7.5' series topographic quadrangle image showing the route of the proposed routing options Newington and West Hartford, Connecticut.

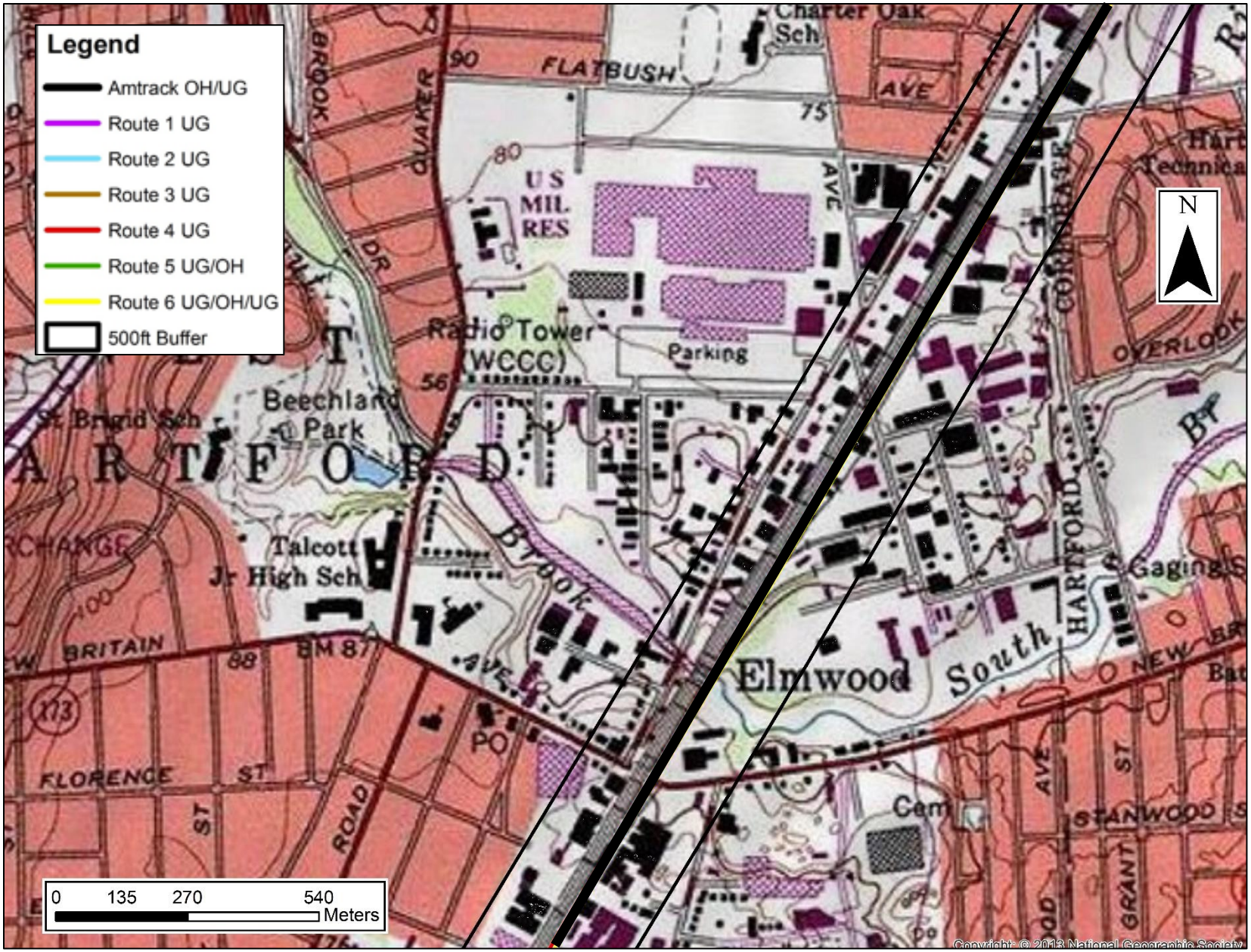


Figure 2; Sheet 2. Excerpt from a USGS 7.5' series topographic quadrangle image showing the route of the proposed routing options in Newington and West Hartford, Connecticut.

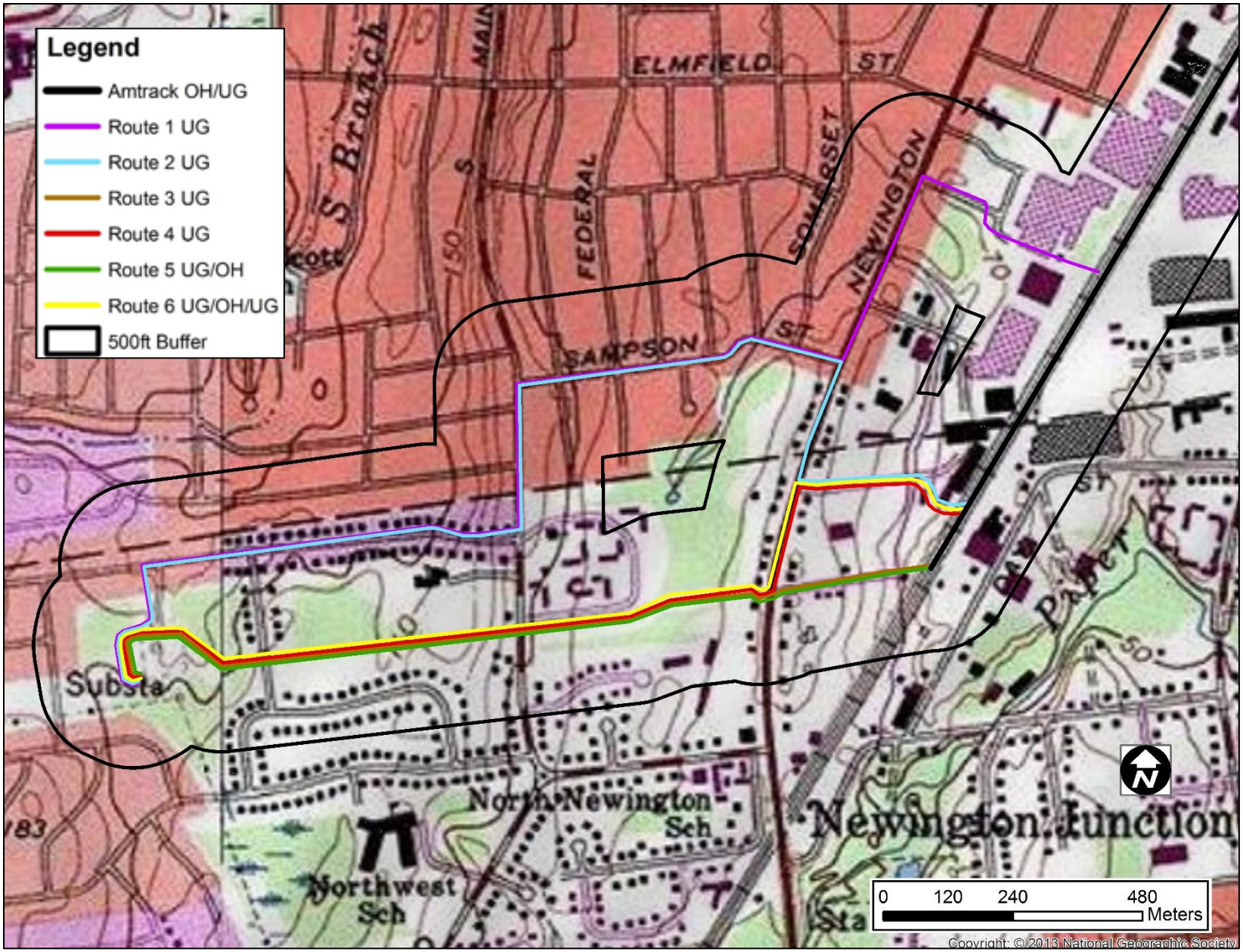


Figure 2; Sheet 3. Excerpt from a USGS 7.5' series topographic quadrangle image showing the route of the proposed routing options in Newington and West Hartford, Connecticut.

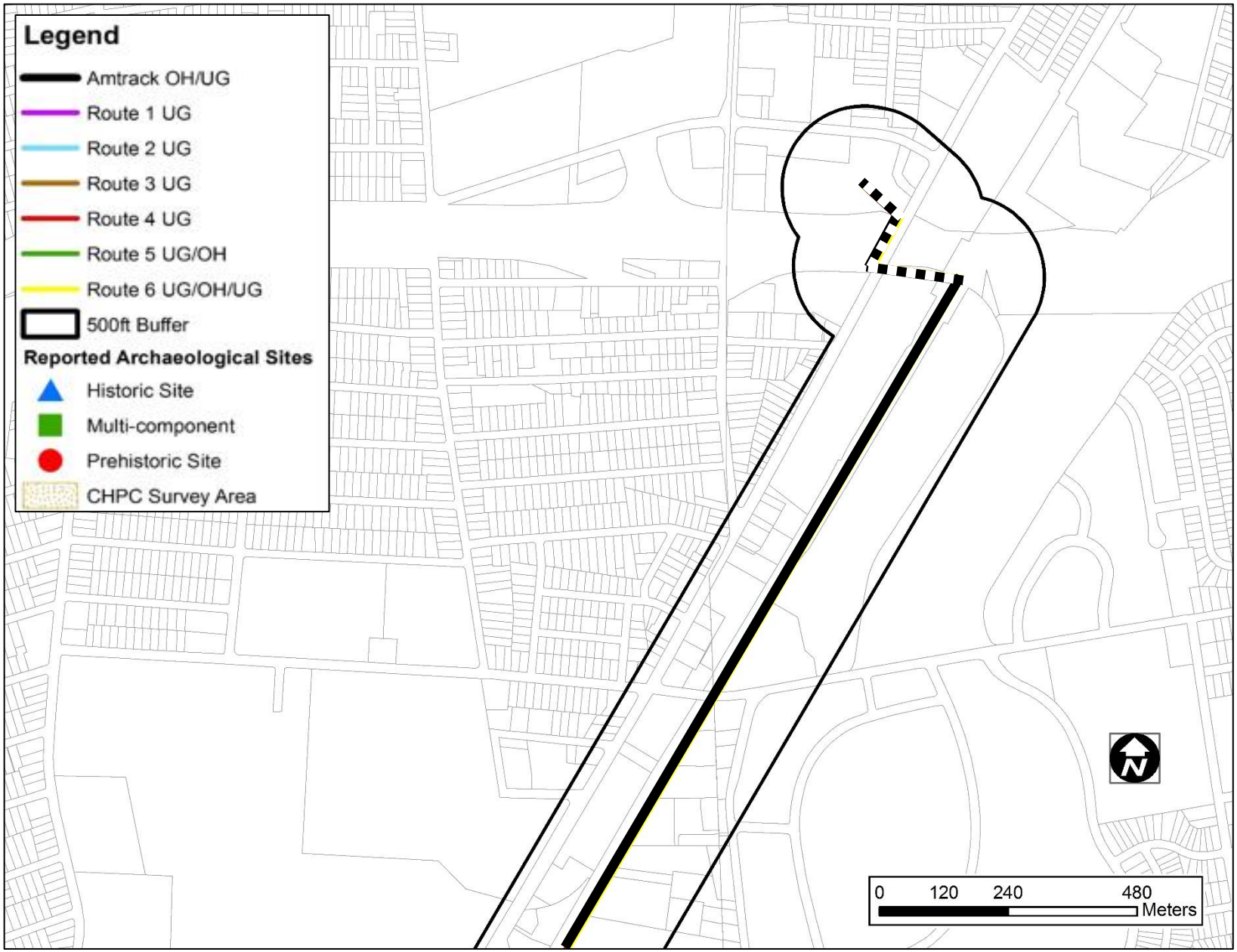


Figure 3; Sheet 1. Digital map showing the location of previously identified archaeological sites in the vicinity of the proposed routing options in Newington and West Hartford, Connecticut.

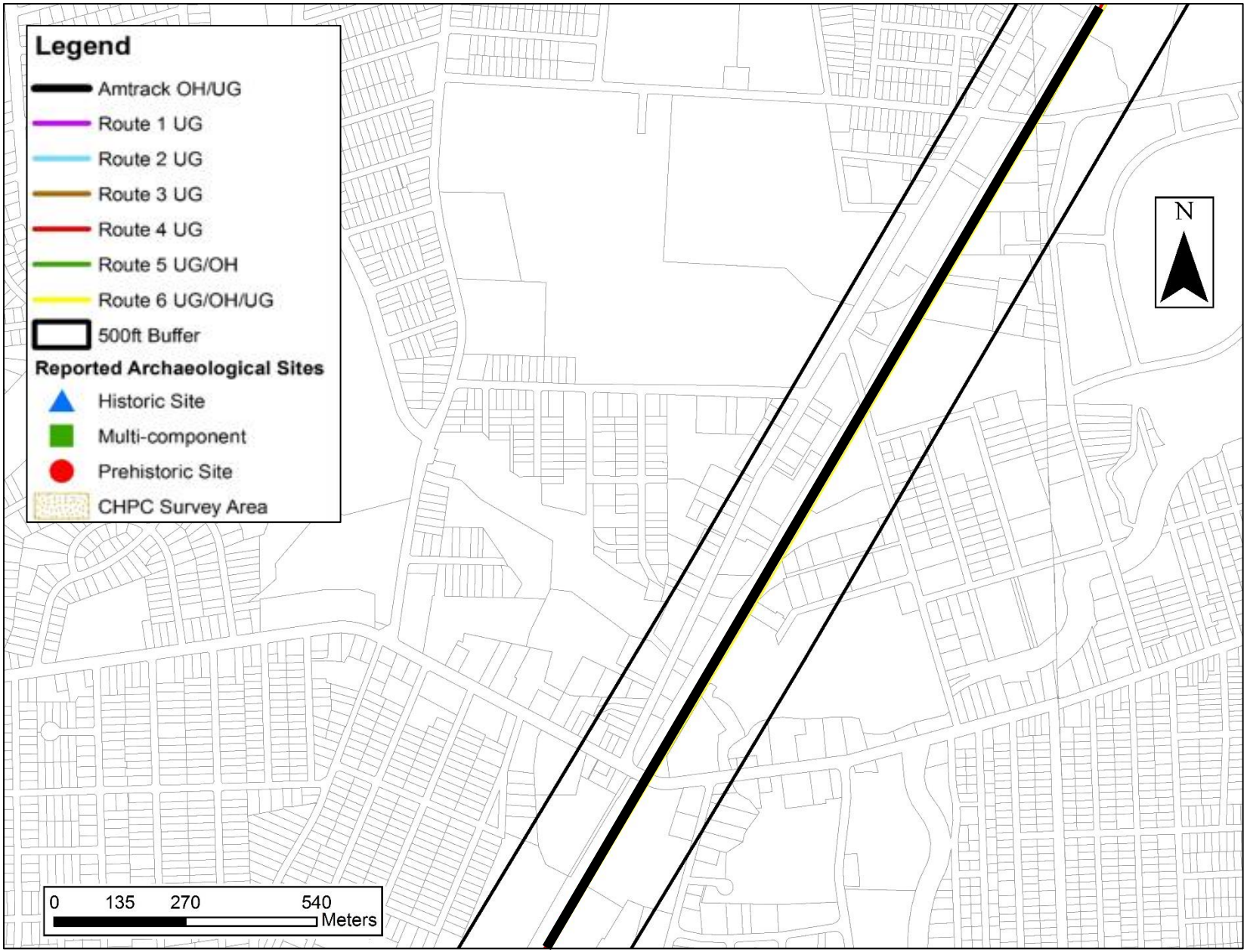


Figure 3; Sheet 2. Digital map showing the location of previously identified archaeological sites in the vicinity of the proposed routing options in Newington and West Hartford, Connecticut.

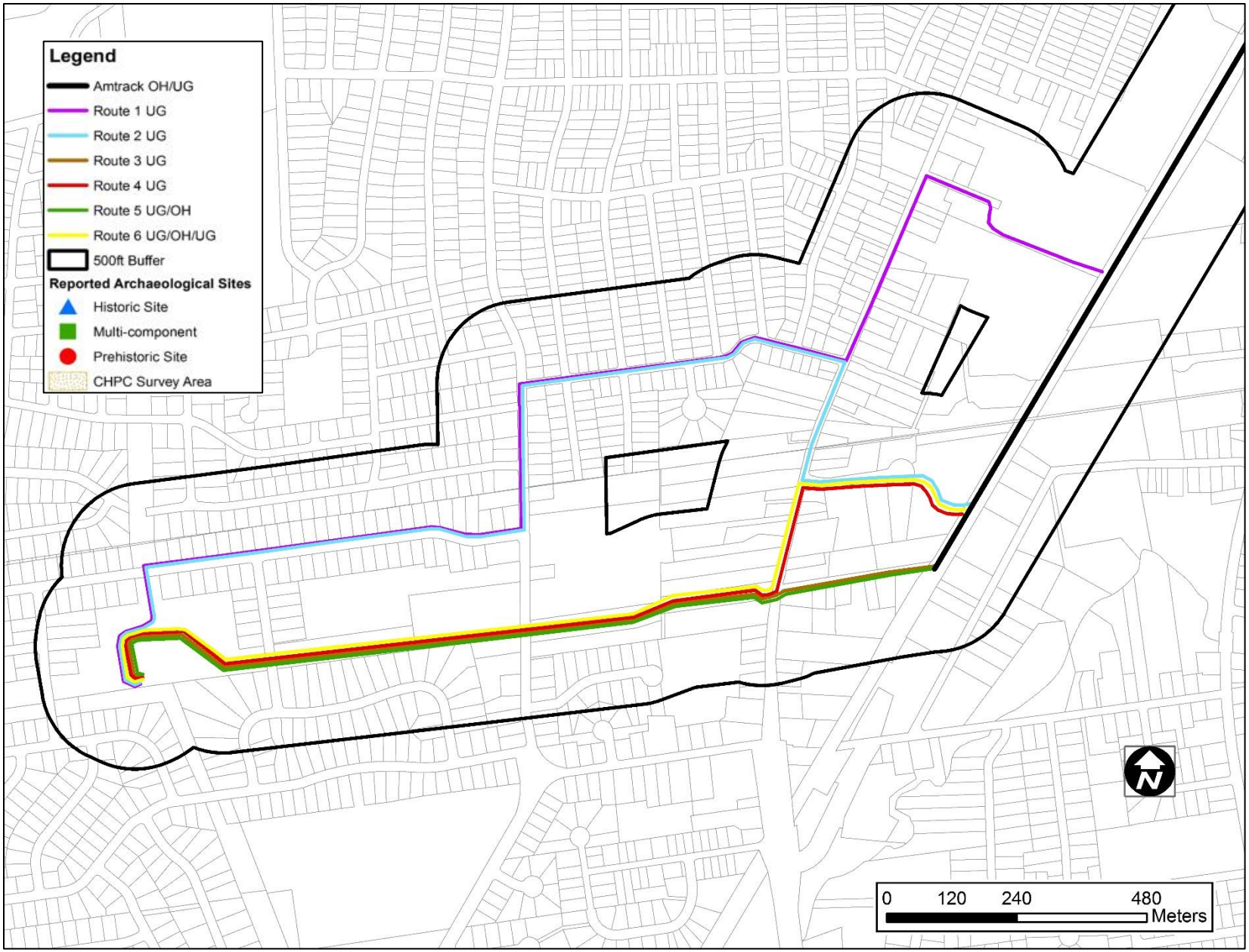


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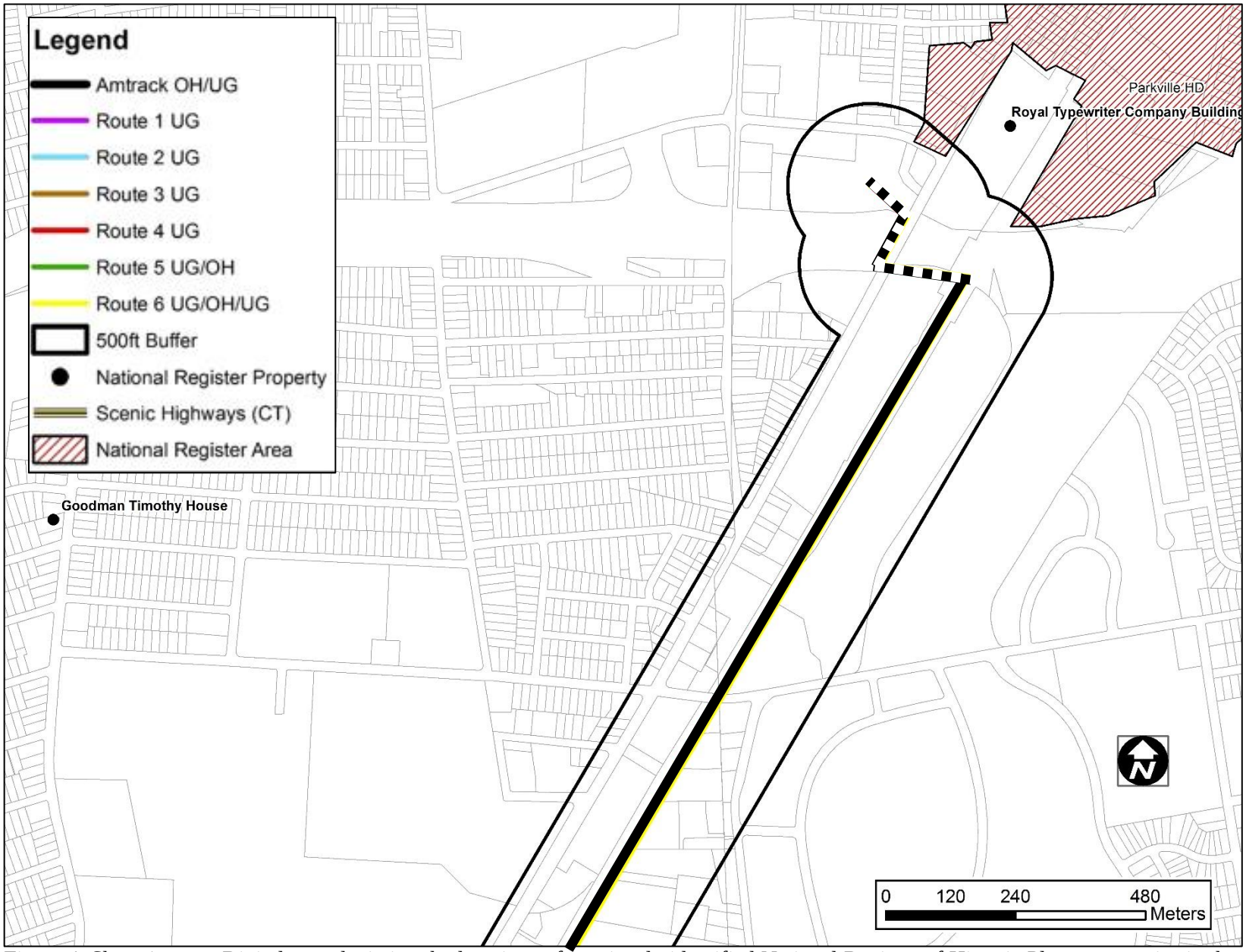


Figure 4; Sheet 1. Digital map depicting the locations of previously identified National Register of Historic Places properties in the vicinity of the proposed routing options in Newington and West Hartford, Connecticut.

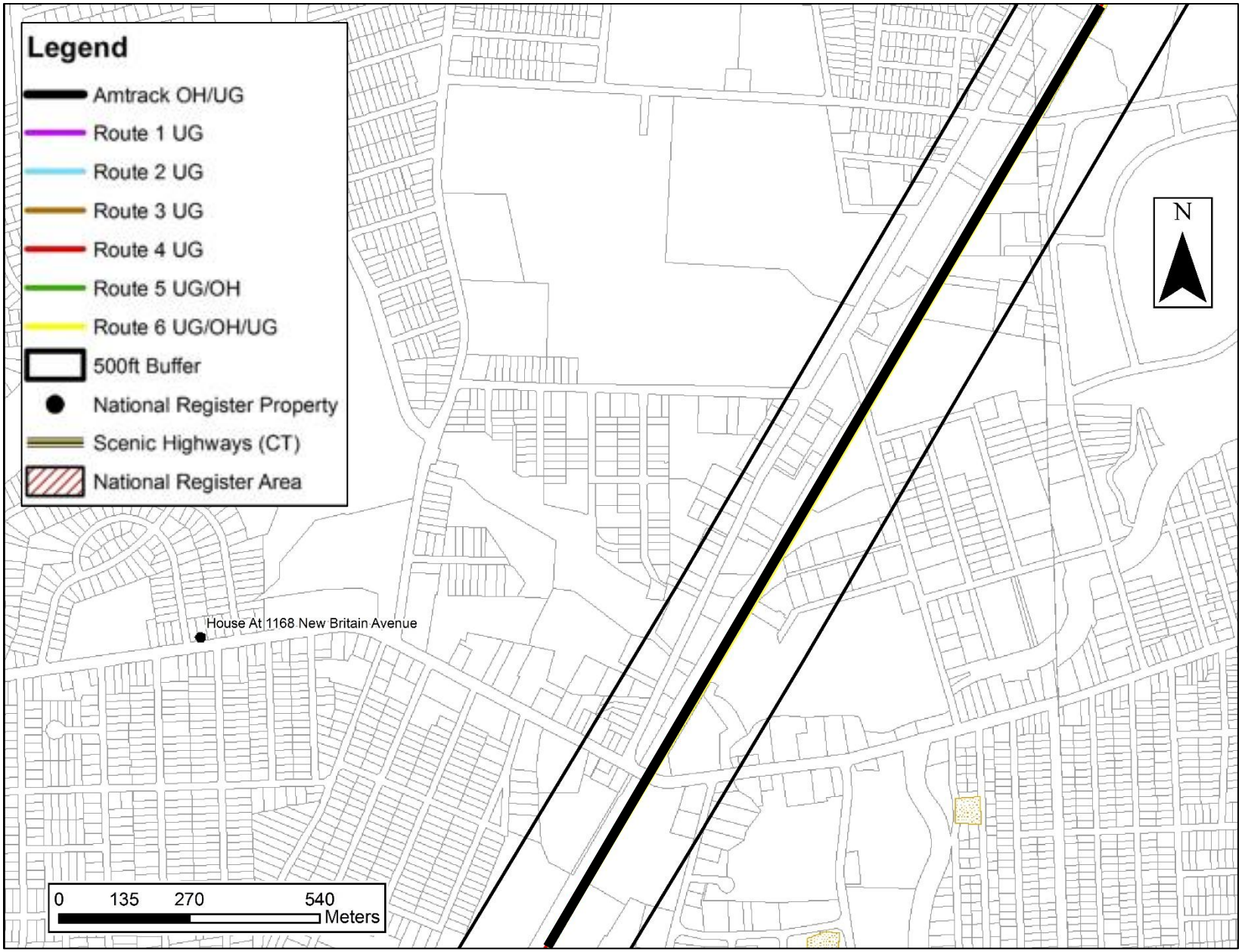


Figure 4; Sheet 2. Digital map depicting the locations of previously identified National Register of Historic Places properties in the vicinity of the proposed routing options in Newington and West Hartford, Connecticut.

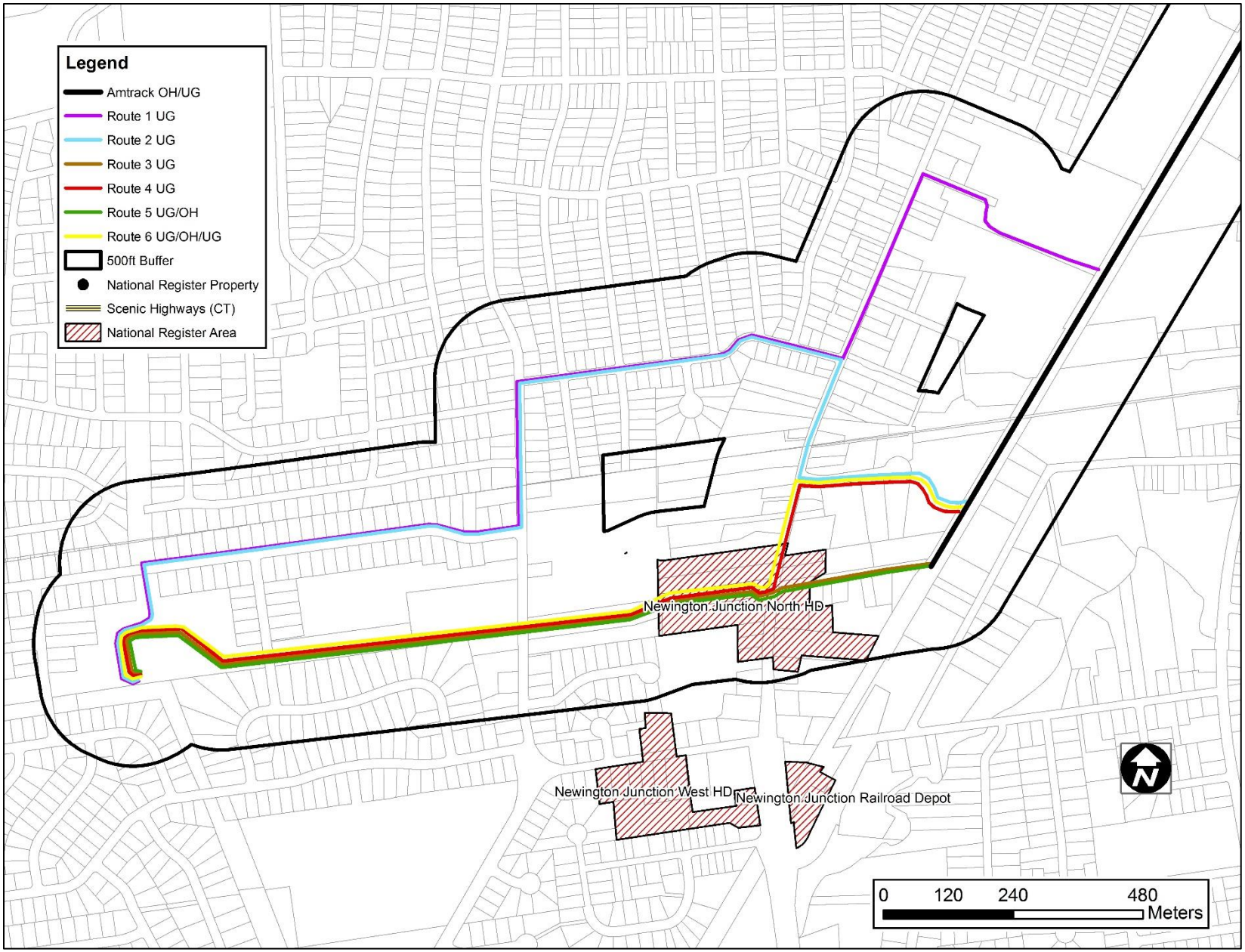


Figure 4; Sheet 3. Digital map depicting the locations of previously identified National Register of Historic Places properties in the vicinity of the proposed routing options in Newington and West Hartford, Connecticut.

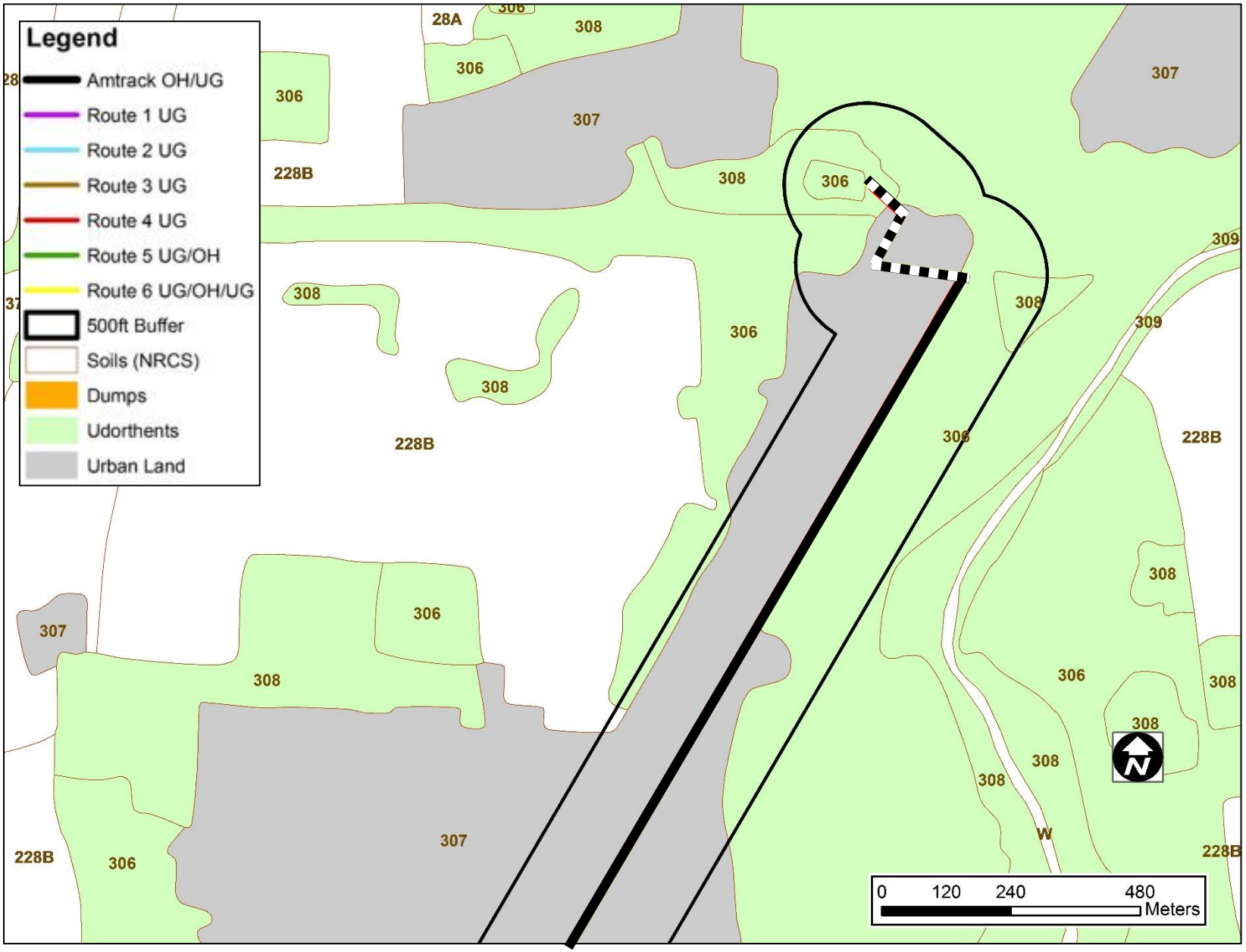


Figure 5; Sheet 1. Digital map showing the various soil types along the route of the proposed routing options in Newington and West Hartford, Connecticut.

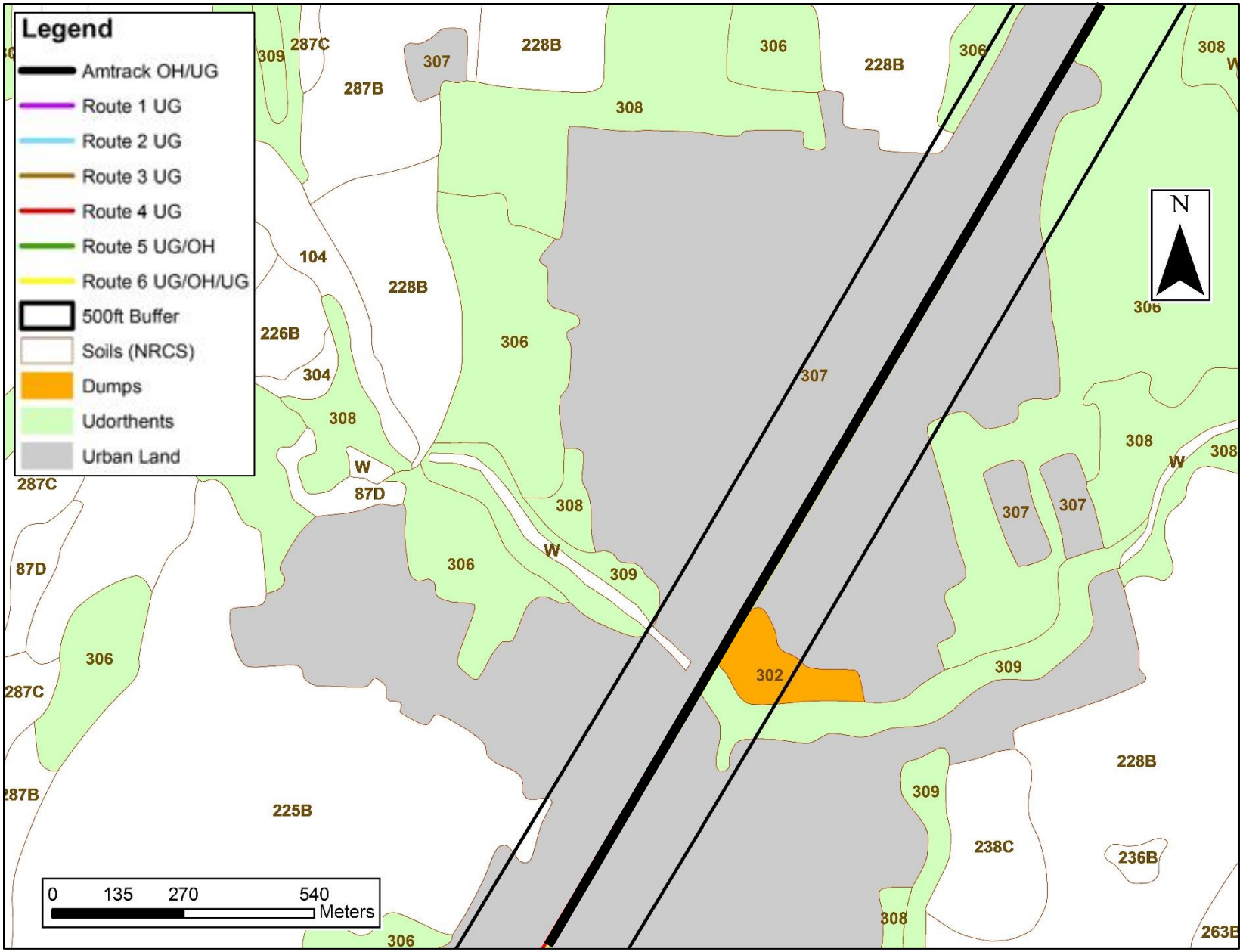


Figure 5; Sheet 2. Digital map showing the various soil types along the route of the proposed routing options in Newington and West Hartford, Connecticut.

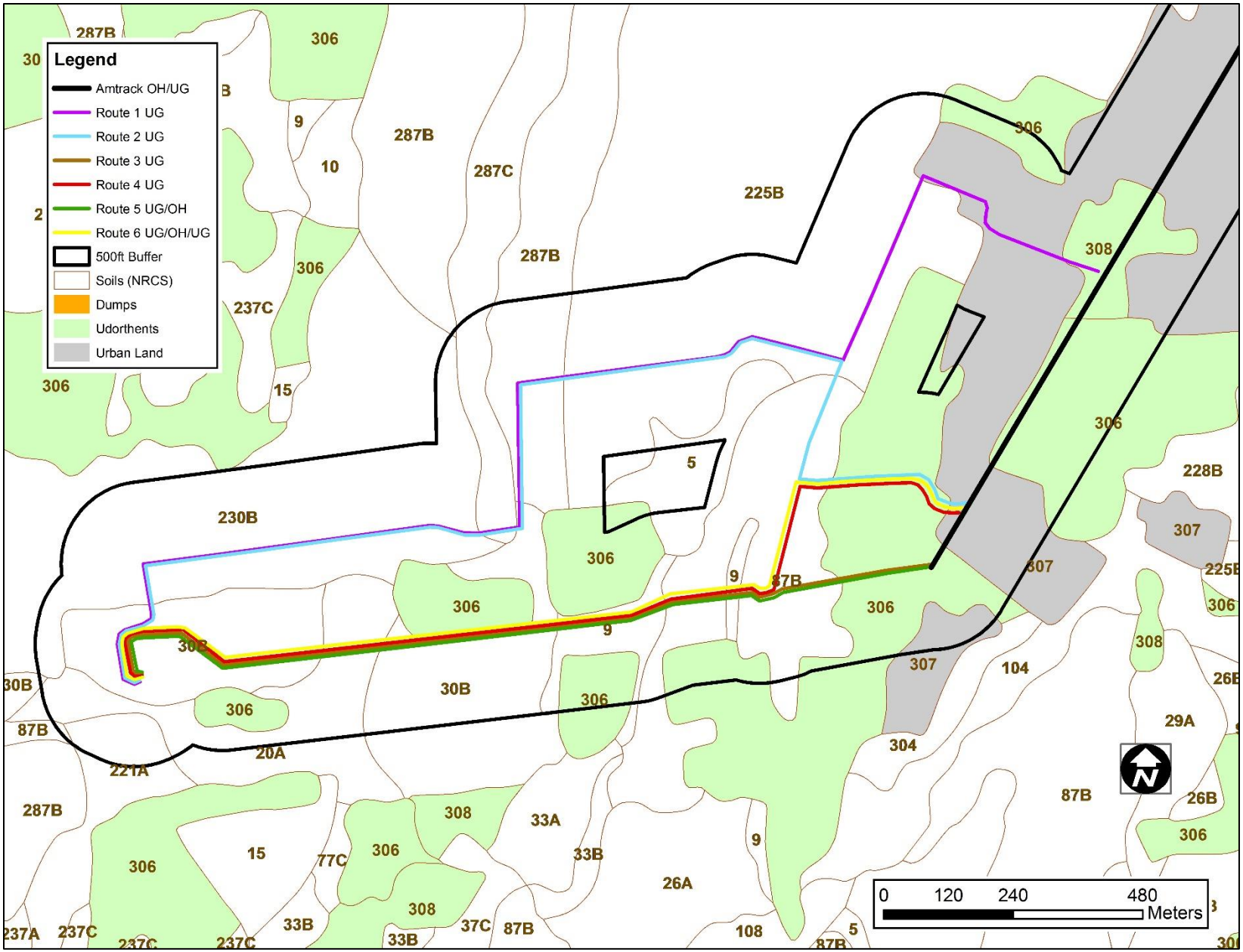


Figure 5; Sheet 3. Digital map showing the various soil types along the route of the proposed routing options in Newington and West Hartford, Connecticut.

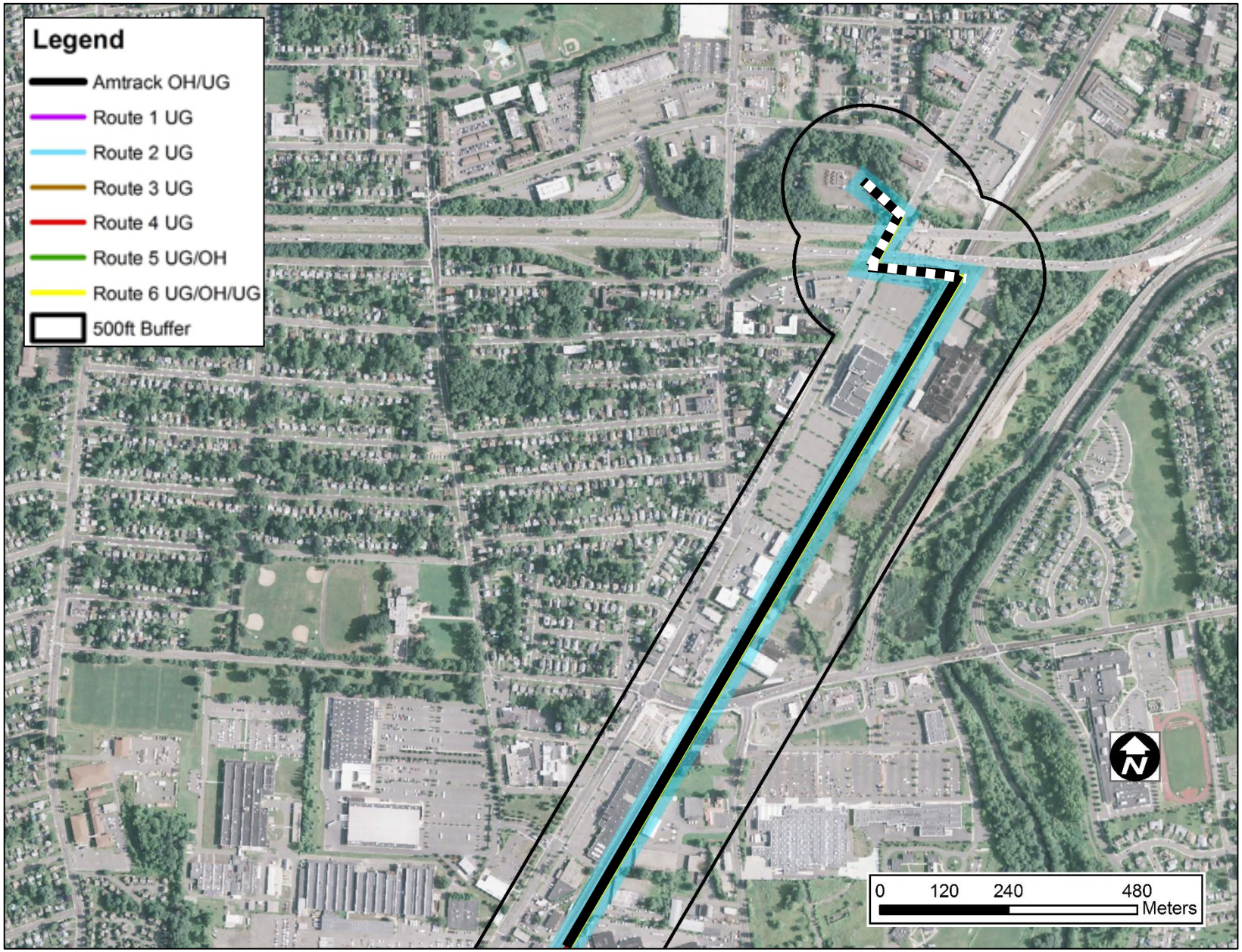


Figure 6, Sheet 1. Excerpt from a 2014 aerial image showing the route of the proposed routing options in Newington and West Hartford, Connecticut and archaeological sensitivity levels (blue = no/low potential; green = moderate/high potential).

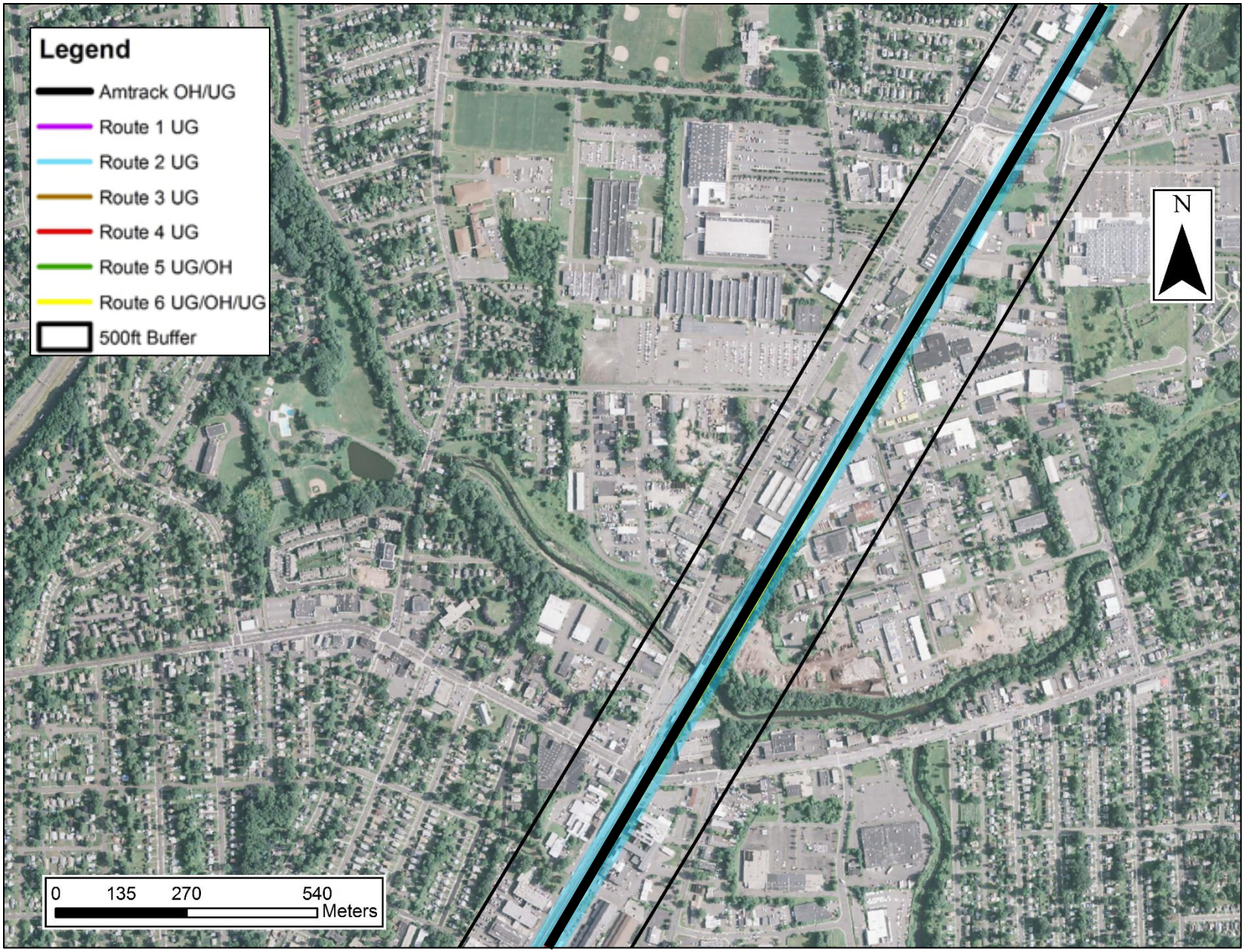


Figure 6, Sheet 2. Excerpt from a 2014 aerial image showing the route of the proposed routing options in Newington and West Hartford, Connecticut and archaeological sensitivity levels (blue = no/low potential; green = moderate/high potential).

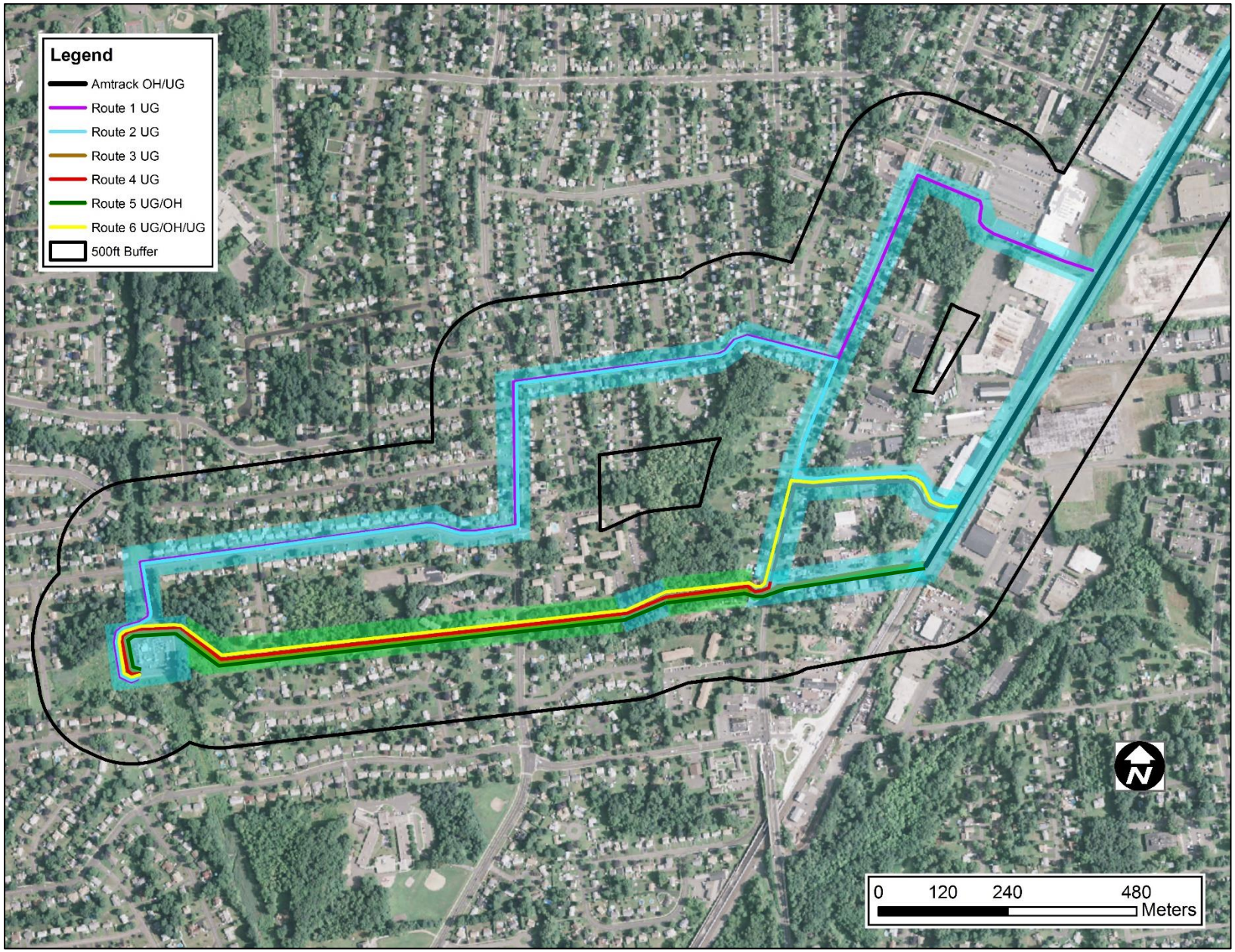


Figure 6, Sheet 3. Excerpt from a 2014 aerial image showing the route of the proposed routing options in Newington and West Hartford, Connecticut and archaeological sensitivity levels (blue = no/low potential; green = moderate/high potential).

APPENDIX B

Representative Photographs of the Project Area and Route Options

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Photo 1. Overview photo toward the proposed project corridor from the Parkville Historic District facing south.



Photo 2. Overview photo of the Southwest Hartford Substation facing west.



Photo 3. Overview photo of the proposed project corridor facing southeast along New Park Avenue (note the transmission cable will be buried underground in this location).



Photo 4. Overview photo of the proposed project corridor facing south behind the Bowtie Cinema at the Palace (note that the transmission line transitions from overhead to below ground in this area).



Photo 5. Overview photo of the proposed project corridor facing south from Flatbush Avenue (note the transmission line will be above ground and to the east of the Amtrak railroad corridor in this area).



Photo 6. Overview photo of the proposed project corridor facing north from Flatbush Avenue (note the transmission line will be above ground and to the east of the Amtrak railroad corridor in this area).



Photo 7. Overview photo of the proposed project corridor facing south from Oakwood Avenue (note the transmission line will be above ground and to the east of the Amtrak railroad corridor in this area).



Photo 8. Overview photo of the proposed project corridor facing south Fastrak station at New Park Avenue (note the transmission line will be above ground and to the east of the Amtrak railroad corridor in this area).



Photo 9. Overview photo of the proposed project corridor facing south (note the transmission line will be above ground and to the east of the Amtrak railroad corridor in this area).



Photo 10. Overview photo of the industrial area at the eastern end of Shepard Drive facing northwest.



Photo 11. Overview photo of proposed project corridor facing west along Shepard Drive (note the transmission line will be buried below ground in this area).



Photo 12. Overview photo of proposed project corridor facing south along Willard Avenue (note the transmission line will be buried below ground in this area, which is part of the Newington Junction North Historic District).



Photo 13. Overview photo of proposed project corridor facing north along Willard Avenue (note the transmission line will be buried below ground in this area, which is part of the Newington Junction North Historic District).



Photo 14. Overview photo of proposed project corridor facing west from Willard Avenue (This area is located in the southern portion of the Newington Junction North Historic District, and depending upon which construction option is chosen, the proposed transmission line may either be buried or overhead from this point west to the Newington Substation).



Photo 15. Overview photo of proposed project corridor facing south from Willard Avenue (This area is located in the southern portion of the Newington Junction North Historic District).



Photo 16. Overview photo of proposed project corridor facing west toward the Newington Substation (Depending upon which construction option is chosen, the proposed tranmission line may either be buried or overhead from this point west to the Newington Substation.



Photo 17. Overview photo of proposed project corridor facing southeast from the Newington Substation.



Photo 18. Overview photo of proposed Newington Substation facing south

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APPENDIX C

Parkville NRHP District: Photo Log and Photographs of Balloon Test Results

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BARTHOLOMEW AVENUE LOOKING NORTH

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
1	**BARTHOLOMEW AVENUE**	**SOUTHWEST**	**+/- 0.34 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



BARTHOLOMEW AVENUE LOOKING NORTH

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
2	**BARTHOLOMEW AVENUE**	**SOUTHWEST**	**+/- 0.46 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



GRACE EPISCOPAL CHURCH

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
3	**NEW PARK AVENUE**	**SOUTHWEST**	**+/- 0.46 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
4	**FRANCIS AVENUE**	**SOUTHWEST**	**+/- 0.45 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
5	**FRANCIS AVENUE**	**SOUTHWEST**	**+/- 0.40 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



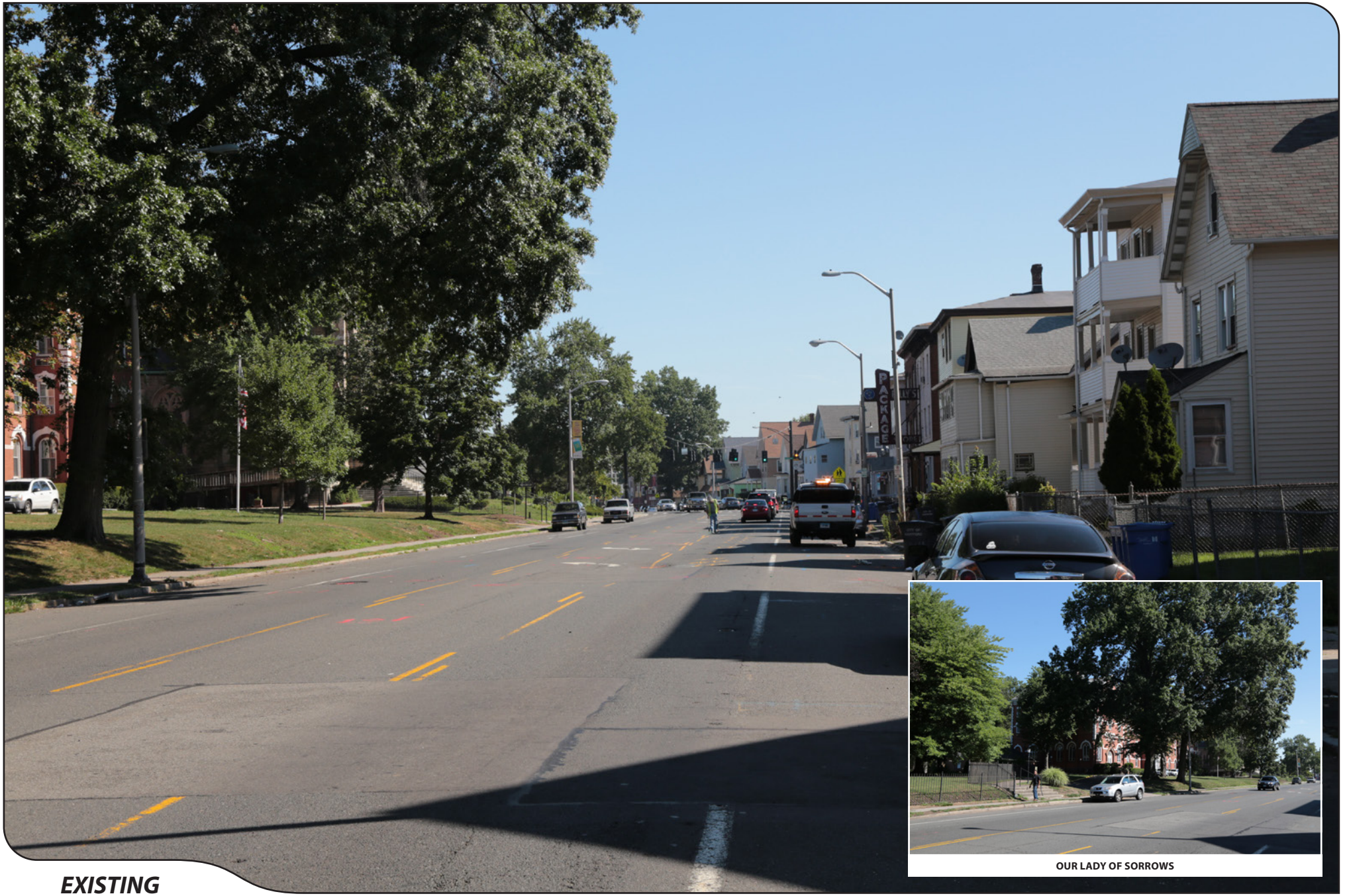
EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
6	**FRANCIS AVENUE**	**SOUTHWEST**	**+/- 0.34 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



OUR LADY OF SORROWS

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
7	**NEW PARK AVENUE**	**SOUTHWEST**	**+/- 0.34 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
8	**GREENWOOD STREET**	**SOUTH**	**+/- 0.46 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



MADISON AVENUE LOOKING NORTH

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
9	**MADISON AVENUE**	**SOUTHEAST**	**+/- 0.41 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



MADISON AVENUE LOOKING NORTH

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
10	**MADISON AVENUE**	**SOUTHEAST**	**+/- 0.30 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



OUR LADY OF FATIMA CHURCH - LOOKING NORTH

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
11	**OUR LADY OF FATIMA CHURCH**	**SOUTHEAST**	**+/- 0.19 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



M.S. LITTLE BUILDING

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
12	**NEW PARK AVENUE**	**SOUTH**	**+/- 0.24 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
13	**NEW PARK AVENUE**	**NORTHEAST**	**+/- 0.13 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
14	**NEW PARK AVENUE**	**NORTHEAST**	**+/- 0.39 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
15	**BROOKFIELD STREET**	**NORTHWEST**	**+/- 0.27 MILE**	**YEAR ROUND**

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APPENDIX D

Newington Junction North and Other Newington NRHP Districts: Photo Log and Photographs of Balloon Test Results

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372 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
1	**372 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.81 MILE**	**NOT VISIBLE**

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EVERSOURCE ENERGY

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319 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
2	**319 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.67 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



294 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
3	**294 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.63 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



293 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
4	**293 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.62 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

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282-284 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
5	282-284 WILLARD AVENUE	NORTHEAST	+/- 0.60 MILE	NOT VISIBLE

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



277 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
6	**277 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.58 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



268 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
7	268 WILLARD AVENUE	NORTHEAST	+/- 0.57 MILE	NOT VISIBLE

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EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
8	**268 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.42 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



200 FRANCIS AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
9	**200 FRANCIS AVENUE**	**NORTHEAST**	**+/- 0.34 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

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4 CHAPMAN STREET

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
10	**4 CHAPMAN STREET**	**NORTHEAST**	**+/- 0.39 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



2 CHAPMAN STREET

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
11	**2 CHAPMAN STREET**	**NORTHEAST**	**+/- 0.38 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



160 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
12	**160 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.30 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



269 WEST HILL ROAD

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
13	**269 WEST HILL ROAD**	**NORTHEAST**	**+/- 0.42 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



272 WEST HILL ROAD

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
14	**272 WEST HILL ROAD**	**NORTHEAST**	**+/- 0.43 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



275 WEST HILL ROAD

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
15	**275 WEST HILL ROAD**	**NORTHEAST**	**+/- 0.44 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



285-287 WEST HILL ROAD

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
16	**285-287 WEST HILL ROAD**	**NORTHEAST**	**+/- 0.46 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



295-297 WEST HILL ROAD

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
17	**295-297 WEST HILL ROAD**	**NORTHEAST**	**+/- 0.47 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



301-303 WEST HILL ROAD

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
18	**301-303 WEST HILL ROAD**	**NORTHEAST**	**+/- 0.48 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



108 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
19	**108 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.26 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



97 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
20	**97 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.25 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



97 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
21	**82 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.22 MILE**	**YEAR ROUND**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



79 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
22	**79 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.22 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



74 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
23	**74 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.21 MILE**	**NOT VISIBLE**

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EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
24	**SPRING STREET**	**NORTHEAST**	**+/- 0.14 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



64-66 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
25	**64-66 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.20 MILE**	**NOT VISIBLE**

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EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



55 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
26	**55 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.19 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

HERITAGE CONSULTANTS, LLC



56 WILLARD AVENUE

EXISTING

PHOTO	LOCATION	ORIENTATION	DISTANCE TO SITE	VISIBILITY
27	**56 WILLARD AVENUE**	**NORTHEAST**	**+/- 0.19 MILE**	**NOT VISIBLE**

ALL-POINTS TECHNOLOGY CORPORATION

EVERSOURCE ENERGY

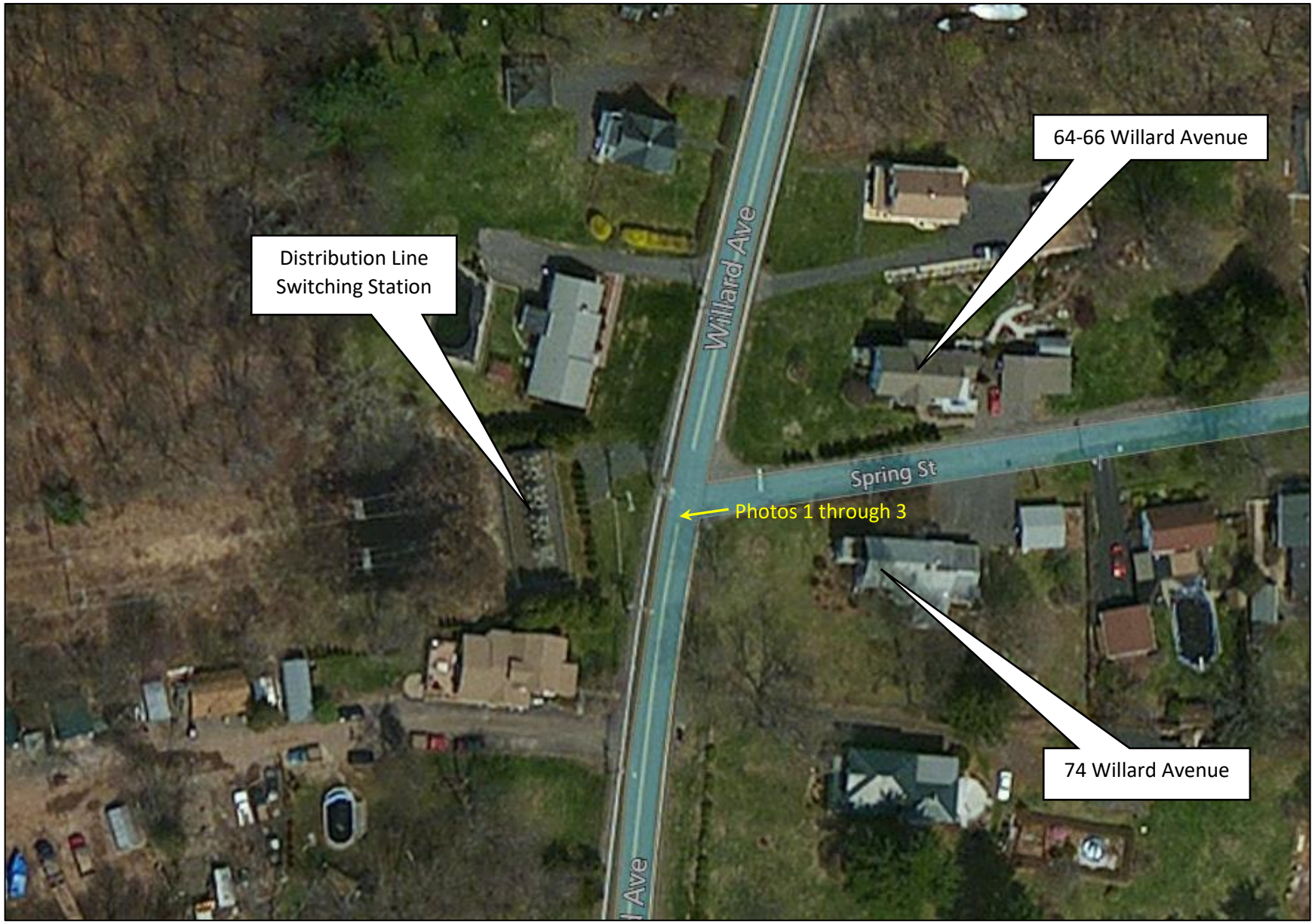
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APPENDIX E

Photosimulations of Potential Transition Structures along Eversource Distribution Line ROW near Newington Junction North NRHP District

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Aerial image. Excerpt from a 2016 aerial image showing the locations of the existing switching station, 64-66 Willard Avenue, 74 Willard Avenue and the directions from which the photos for the viewshed simulations were taken.



Photo 1. View of existing right-of-way facing west from Willard Avenue.

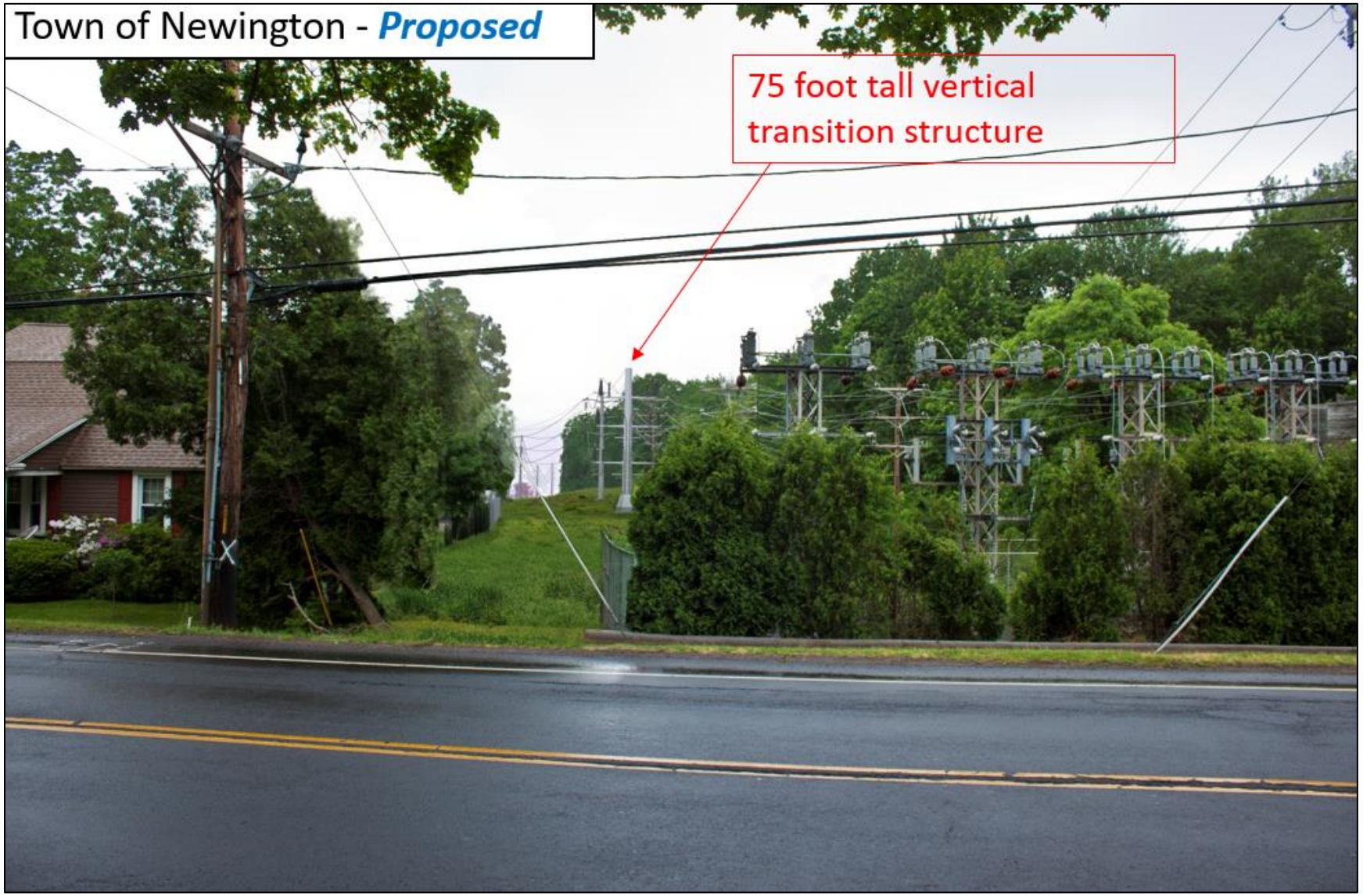


Photo 2. View of right-of-way with proposed 75-foot tall vertical transition structure facing west from Willard Avenue.



Photo 3. View of right-of-way with proposed 55-foot tall, 3-pole horizontal transition structure facing west from Willard Avenue.

APPENDIX II

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HISTORIC RESOURCES INVENTORY
PREHISTORIC ARCHAEOLOGICAL SITES
HIST-7 NEW 9/77

STATE OF CONNECTICUT
CONNECTICUT HISTORICAL COMMISSION
59 SOUTH PROSPECT STREET, HARTFORD, CONNECTICUT, 06106

FOR OFFICE USE ONLY															
Town No.:94							**Site no.**:1								
UTM:	1	8	6	8	7	1	7	1	4	6	2	0	7	4	8
QUAD:														**DISTRICT** ☐YES ☒NO	
NR: ☐ACT ☐ELIG. ☒NO															
SR: ☐ACT ☐ELIG. ☒NO															

IDENTIFICATION

1. SITE NAME
Newington Substation Site

STATE SITE NO.

CAS NO.

2. TOWN/CITY
Newington

VILLAGE

COUNTY

3. STREET AND NUMBER (and/or location)
Cherry Hill Drive

4. OWNER(S)
Eversource Energy Right-of-Way Corridor
☐ PUBLIC ☒ PRIVATE

5. ATTITUDE TOWARD EXCAVATION

6. USE *(Present)*
Electrical corridor

(Historic)
agricultural field

DESCRIPTION

7. PERIOD
☐Paleo ☐Early Archaic ☐Middle Archaic ☒Late Archaic ☐Early Woodland ☐Middle Woodland ☐Late Woodland ☐Contact ☐Unknown ☒Other*(specify)* historic

8. DATING METHOD
C-14 ☐ Intuition ☐Other*(specify)*
Comparative Materials projectile point, ceramics

9. SITE TYPE
☐Quarry ☐Camp ☐Rockshelter ☐Shell Midden ☐Cemetery ☐Village ☒Other*(specify)*task=specific

10. APPROXIMATE SIZE AND BOUNDARIES
10x15 meters

11. STRATIGRAPHY
☐Surface finds ☒Plowed ☐Not Stratified ☐Stratified ☐Major Disturbance ☐Other*(specify)*

ENVIRONMENT

12. SOIL
USDA SOIL SERIES: Branford Silt Loam
CONTOUR ELEVATION: 150 ft
SLOPE %: ☒ 0-5 ☐ 5-15 ☐ 15-25 ☐ over 25
TEXTURE: ☐Sand ☐Clay ☒Silt ☐Other *(specify)*
ACIDITY: ☐ less than 4.5 ☐ 4.5-5.5 ☐ 5.6-6.5 ☐ 6.6-7.3 ☐ 7.4-8.4

13. WATER
NEAREST WATER SOURCE: Unnamed Wetlands
SIZE AND SPEED:
DISTANCE FROM SITE: 100 m
SEASONAL AVAILABILITY:

14. VEGETATION
PRESENT: grasses/shrubs
PAST: agricultural field

CONDITION

15. SITE INTEGRITY
☐ Undisturbed ☐ Good ☐ Fair ☒ Destroyed

16. THREATS TO SITE
☐ None Known ☐ Highways ☐ Vandalism ☐ Developers ☐ Other *(specify)* ☐ Renewal ☐ Private ☐ Deterioration ☐ Zoning ☐ Unknown

17. SURROUNDING ENVIRONMENT
☒ Open Land ☐ Woodland ☒ Residential ☐ Scattered Buildings visible from site ☐ Commercial ☐ Industrial ☐ Rural ☒ High Building Density ☐ Coastal ☐ Isolated

18. ACCESSIBILITY TO PUBLIC – VISIBLE FROM PUBLIC ROAD
☒ Yes ☐ No

RESEARCH POTENTIAL

19. PREVIOUS EXCAVATIONS

	BY WHOM/AFFILIATION	*DATE*
☐ SURFACE COLLECTED		
☐ POT HUNTED	*BY WHOM/AFFILIATION*	*DATE*
☒ TESTED	*BY WHOM/AFFILIATION* Heritage Consultants, LLC	*DATE* 1/17/2-17
☐ EXCAVATION	*BY WHOM/AFFILIATION*	*DATE*

20. PRESENT LOCATION OF MATERIALS

To be curated with the Connecticut State Archaeologist

21. PUBLISHED REFERENCES

22. RECOVERED DATA *(Identify in DETAIL, including features, burials, faunal material, etc.)*

Site 94-1 was identified during survey to the east of the Newington Substation. It measures approximately 10 x 15 m (32.8 x 29.2 ft) in size; it was not delineated outside of the project area to the north due to the presence of a large disturbed area. The prehistoric component of Site 94-1 yielded single quartz secondary thinning flake and 1 quartz Brewerton side-notched projectile point from the plowzone. The latter dates from the Late Archaic period. The prehistoric use of the area most likely represents a very short-term occupation or perhaps even a single tool sharpening event. The prehistoric component of Site 94-1 lacks evidence of intact cultural deposits and/or cultural features. As a result, it was determined that the prehistoric component of Site 94-1 does not possess research potential and/or the qualities of significance as defined by the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]). No additional testing of the prehistoric component of Site 94-1 is recommended.

SIGNIFICANCE

23. ARCHAEOLOGICAL OR HISTORICAL IMPORTANCE

The historic component produced plain white ware sherds, a single whiteware handle fragment, 1 whiteware basal sherds, 1 quahog shell fragment, and 2 pieces of large mammal long bones. The latter are representative of cow (Bos taurus). A review of the project area, as well as historic maps and aerial images failed to reveal any evidence of historic cultural features (i.e., houses, barns, outbuildings, etc.) in this area. As a result, the historic component of Site 94-1 was interpreted as a light field scatter of artifacts that cannot be associated with any particular occupation of the area. The recovered historic artifacts are common nineteenth/early twentieth century artifacts found in the archaeological record of Connecticut. Consequently, the historic component of Site 94-1 also does not possess research potential and/or the qualities of significance defined by the National Register of Historic Places criteria for evaluation (36 CFR 60.4 [a-d]). No additional testing of the historic component is recommended.

PHOTOGRAPH

PHOTOGRAPHER	**Place 35 mm contact print here**
DATE	
VIEW	
NEGATIVE ON FILE	

ADDITIONAL INFORMATION

REPORTED BY

NAME David George	**ADDRESS** PO Box 310249, Newington, CT
ORGANIZATION Heritage Consultants, LLC	**DATE** 1/6/2017

FOR OFFICE USE ONLY

FIELD EVALUATION

COMMENTS

2.B.2 *Cultural Resources Review of the Project Region Associated with the Greater Hartford Connecticut Reliability Project* (Heritage Consultants, LLC, May 19, 2015)

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HERITAGE
CONSULTANTS, LLC

INTEGRATED HISTORIC PRESERVATION PLANNING

Mr. Justin Adams
Senior Licensing and Permitting Specialist
Eversource Energy
107 Selden Street
Berlin, CT 06037

RE: Cultural Resources Review of the Project Region Associated with the Greater Hartford Connecticut Reliability Project, Hartford, Newington, and Berlin Connecticut

Mr. Adams:

Heritage Consultants, LLC, is pleased to have this opportunity to provide Eversource Energy with the following cultural resources review of the proposed project referred to as the Greater Hartford Central Connecticut Reliability Project (GHCCRP) in Hartford, West Hartford, Newington, and Berlin Connecticut. To improve the reliability of the electric transmission system in the Greater Hartford, Connecticut area, Eversource Energy (Eversource) proposes to construct and operate a new underground transmission line and to modify three existing substations in central Connecticut. The new underground electric transmission cable system is planned to extend for approximately 3.6 miles between Eversource's existing Newington Substation in the Town of Newington to its Southwest Hartford Substation in the City of Hartford. To interconnect the new 115-kV cable to the transmission grid, Eversource proposes to expand and make related improvements to both substations. In addition, Eversource proposes to modify its existing Berlin Substation, located in the Town of Berlin. As shown in Figure 1; Sheets 1 through 3, the Hartford and Newington portions of the project will be confined mainly to existing streets wherein the proposed transmission line will be buried. The Berlin Substation portion of the project will be confined to the existing substation area.

The cultural resources review entailed the completion of an existing conditions cultural resources summary based on the examination of cultural resources data obtained from the Connecticut State Historic Preservation Office, as well as historic maps, aerial photographs, and topographic quadrangles maintained by Heritage Consultants, LLC. This study also included a pedestrian survey of the proposed project corridors and parcels during which photos of the areas were taken and an archaeological assessment of the project items was completed. This investigation did not consider the effects of the proposed construction upon built resources per se, and it is based upon project location information provided to Heritage Consultants, LLC by AECOM Environment. The objectives of this study were: 1) to gather and present data regarding previously identified cultural resources situated within the vicinity of the proposed project items; 2) to investigate the proposed project region in terms of its natural and historical characteristics; and 3) to evaluate the need for completing additional cultural resources investigations.

The Hartford and Newington Portions of the GHCCRP

As seen in Figure 2; Sheets 1 through 3, which depict excerpts from an 1855 map of the proposed project region, the southwestern portion of Hartford and the northern portion of Newington contained a well-

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Email: info@heritage-consultants.com

established transportation network consisting a several mains roads, numerous secondary streets, and a rail line in the middle of the nineteenth century. Nevertheless, the areas of densest settlement were positioned to the north, west, and south of the project area. Further, while the main building types in the area at that time consisted of residences, there were a few commercial enterprises in the region, including a carriage shop, potters shops, and a woolen yarn factory. Thus, the area was of a mixed use during the mid-nineteenth century. Figure 3; Sheets 1 through 3, which consist of map excerpts dating from 1869, show that after the Civil War there was additional in-filling of the proposed project region. However, this area remained of a mixed use character and dense settlement was not found there. It is likely that some portions of the proposed project area were still being farmed at that time rather than being dominated by settlement.

A review of Figure 4; Sheets 1 through 3, reveal that by 1934, the project area in Hartford and Newington had undergone substantial changes. The large open spaces depicted in the 1855 and 1869 maps appear to have been much diminished. The region now contained many more streets and buildings, especially in the northern and southeastern areas. Much of the southwestern portion of the project region, as it passes through Newington, remained open land however, with much of it under cultivation in the early part of the twentieth century. Finally, one prominent landscape feature that appears in the 1934 aerial image shown in Figure 4; Sheets 1 and 2, is what appears to be a large oval track. This may be the former location of the Charter Oak Race Track, which featured harness racing events in the early twentieth century.

The next aerial image in the sequence dates from 1951, and it shows dramatic changes to the Hartford and Newington portions of the GHCCRP area (Figure 5; Sheets 1 through 3). The site of the former race track and the area to the north has been developed to a massive degree, with hundreds of homes erected and a large industrial facility on the former race track location. This large facility is the site of the Colt Firearms factory, which remains in operation to this day. The southern portion of the GHCCRP still retained open land; however, several housing subdivisions were beginning to creep into the region as a result of the suburbanization process that took place after the close of World War II. At this time, only the southwestern portion of the project region retained any appreciable open space, much of which remained under cultivation.

As seen in Figure 6; Sheets 1 through 3, almost the entirety of the Hartford and Newington portions of the GHCCRP project region had been impacted by large scale development by 1990, including the construction of several more large housing subdivisions, additional industrial facilities, and a multitude of small commercial enterprises. The other large addition to the area was the construction of Interstate 84, which extends from east to west. The construction of Interstate 84, which occurred in the 1950s, resulted in the demolition of dozens of former residences and commercial buildings. By this time, the only areas that had not suffered large scale impacts were the southwestern most and southern most areas, both of which consist of open land traversed by an existing power line corridor. Impacts to these areas appear to have been limited to the immediate areas around where utility poles were installed.

Finally, Figure 7; Sheets 1 through 3, which contain excerpts from a 2014 aerial image, shows the GHCCRP project region in its modern state. Today this area is home to a large populace and numerous commercial and industrial enterprises. Again, the only portions of the project region that appear to be only minimally disturbed are the southwestern and southern areas where the existing power line corridor traverses the region.

In addition to the examination of historic maps and aerial images of the GHCCRP region, Heritage Consultants, LLC completed a review of previously recorded cultural resources on file with the

Connecticut State Historic Preservation Office. This review revealed that no previously identified archaeological sites are known in the project region (Figure 8; Sheets 1 through 3); however, this may be the result of under-sampling since no professional cultural resources surveys have been completed in the area. The review of previously identified cultural resources did result in the identification of four structures individually listed on the National Register of Historic Places and two National Register historic districts. The individually listed buildings consist of the Sarah Whitman Hooker House, which was built c. 1720 and is notable as the site where of Andrew Skene, a Loyalist, who was taken prisoner early in the American Revolutionary War (Figure 9; Sheet 3 and Photo 43); the Charles E. Beach House, a prominent shingle style house built in 1900 (Figure 9; Sheet 3 and Photo 44); the Royal Typewriter Company Building, a large Victorian type factory building erected in 1907 (Figure 9; Sheet 1); and a two-and-a-half story Greek Revival house located at 1168 New Britain Avenue (Figure 9; Sheet 3 and Photo 38).

The two historic districts noted in the vicinity of the proposed project corridors include the Parkville Historic District in the north and the Newington Junction North Historic District in the south (Figure 9; Sheet 1 and 3). The Parkville Historic District is a collection of mid-to-late-nineteenth and twentieth-century resources composed of 340 primary buildings, of which 294 are contributing elements to its National Register of Historic Places significance. The district is architecturally significant as a working-class neighborhood that developed during the mid-to-late nineteenth and early twentieth centuries. Its period of significance spans from 1860 to the modern era, and its building resources represents the variety of the architectural styles and developmental trends that typify the era (Photos 3 and 5). The Newington Junction North Historic District is situated along Willard Avenue and to the north of its intersection with West Hill Road. This historic district is comprised of 13 contributing and three non-contributing properties that are situated throughout an area of more than 10 acres of land. The residences in the district consist of examples of Colonial Revival, Late Victorian, and Queen Anne styles, all of which typify the architecture dating from 1850-1949 (Figure 9; Sheet 3 and Photos 55 and 56). While the purpose of this investigation was primarily to assess the archaeological potential of the proposed project items, historic built resources were mapped and streetscape photos of the areas where taken. Through this process, it was determined that any potential affects to the above-referenced historic districts and/or individually listed National Register of Historic Places properties would be temporary in nature and would only occur during construction of the underground portion of the proposed power transmission line. These potential impacts would be removed once the construction was completed and the areas were repaved.

In addition to researching historic mapping, aerial imagery, and previously identified cultural resources, representatives from Heritage Consultants, LLC also completed a pedestrian survey and photo-documentation of the proposed project corridors associated with the GHCCRP as it extends through Hartford and Newington. The results of this effort are captured in Photos 1 through 56 below (Figure 10 Sheets 1 through 3). The visual reconnaissance and the photographic effort revealed that the vast majority of the proposed project corridors consist of paved streets. These areas already contain a wide variety of buried utilities, including sewer lines, water lines, natural gas lines, and electrical utilities associated with traffic signals. As a result, these areas have been heavily disturbed, which has led to the classification of the soils in these areas as “urban land” or Udorthents (see Figure 11 Sheets 1 through 3). These soils type have undergone massive disturbance through cutting, grading, and filling episodes associated with previous construction projects. Both urban land and Udorthent soils types retain little, if any, potential to yield intact cultural deposits. Consequently, the paved portions of the GHCCRP have been assessed as no/low sensitivity areas, and no archaeological testing of these areas is recommended prior to construction of the GHCCRP.

There are several areas level, dry areas with good drainage characteristics along the existing power line corridor that appear to have been only impacted in a localized way (Figure 12). If a route is eventually selected where the proposed transmission line (above ground or underground) will follow the existing power line corridor in the southwestern and southern portion of the proposed GHCRP region, Heritage Consultants, LLC recommends that these areas be subjected to Phase IB subsurface testing prior to construction of the GHCCRP. It is further recommended that the existing power line corridor be cleared of vegetation to facilitate the archaeological survey effort should this route variation be chosen.

The Berlin Substation

As mentioned in the opening paragraph of this document, the GHCCRP also will entail the reorganization of the Berlin Substation situated along the eastern edge of Beckley Road in Berlin, Connecticut. As Figure 13 shows, the existing substation is located to the northeast of the Berlin Fairgrounds and it occupies a fairly level parcel of land. Figure 14, an excerpt from an 1855 map of the region containing the substation, shows that this portion of Berlin was rural in nature. The main areas of settlement were situated to the north, west, and south of the proposed project parcel. The 1869 map shown in Figure 15 shows that not much had changed in the vicinity of the Berlin Substation toward the end of the nineteenth century. The area remained rural and was accessible only by Beckley Road. It is likely that the substation area was used for agricultural production during the nineteenth century. This interpretation is confirmed by Figure 16, an aerial image dating from 1934. It is clear in Figure 16 that the substation area was at that time a large open field that appears as part of a local farm.

The aerial image shown in Figure 17, which dates from 1951, also confirms the presence of a farm and agricultural fields in the region encompassing the current location of the Berlin Substation. This area contained two or three buildings and cleared areas used for agricultural production. The next aerial image in the sequence, which is depicted in Figure 18 and dates from 1990, shows that by the closing decades of the twentieth century, the previously existing farm had been demolished and replaced with the current substation area. In addition this image shows power lines that run from east to west and north to south into and out of the Berlin Substation. Finally, Figure 19, an aerial image dating from 2014, shows the substation area in its modern state. It is clear that a large parcel of land has been cleared and graded for the construction of this electrical facility.

In addition to the examination of historic maps and aerial images of the Berlin Substation, Heritage Consultants, LLC completed a review of previously recorded cultural resources on file with the Connecticut State Historic Preservation Office. This review revealed that while no previously identified archaeological sites are known in the vicinity of the Berlin Substation parcel (Figure 20), a single National Register of Historic Places property has been recorded to the south of the substation parcel (Figure 21) Listed on the National Register of Historic Places in 1977, this property is known as the Ezekial Kelsey House (Photo 60). The Ezekial Kelsey House dates from the middle of the 18th century and is of the "saltbox" form. It is two-and-a-half stories high and it is one room deep with a lean-to that extends across the rear of the building. The home was constructed ca. 1760 by Mr. Kelsey and it is a significant architectural resource, as it is an excellent example of the saltbox form. Since the Berlin Substation is already in place, any reorganization of its internal structure will not constitute an impact to the Ezekial Kelsey House.

In addition to researching historic mapping, aerial imagery, and previously identified cultural resources, representatives from Heritage Consultants, LLC also completed a pedestrian survey and photo-documentation of the area containing the Berlin Substation (see Figure 22 and Photos 56 through 59). Visual reconnaissance of this area resulted in the determination that proposed project parcel has been

massively disturbed by heavy equipment in the past. This was confirmed by an investigation of the soil types comprising the substation property. As seen in Figure 23, the soil type encompassing the substation area is described as urban land. This soil type is described as having been heavily modified through cutting, filling, and grading. Thus, this parcel of land was assessed as having little, if any, potential to yield intact cultural deposits. As a result, no additional archaeological testing of the Berlin Substation is recommended prior to construction.

If you have any questions regarding this Technical Memorandum, or if we may be of additional assistance with this or any other projects you may have, please do not hesitate to call us at 860-667-3001 or email me dgeorge@heritage-consultants.com. We are at your service.

Sincerely,

David R. George

David R. George, M.A., R.P.A.
Heritage Consultants, LLC

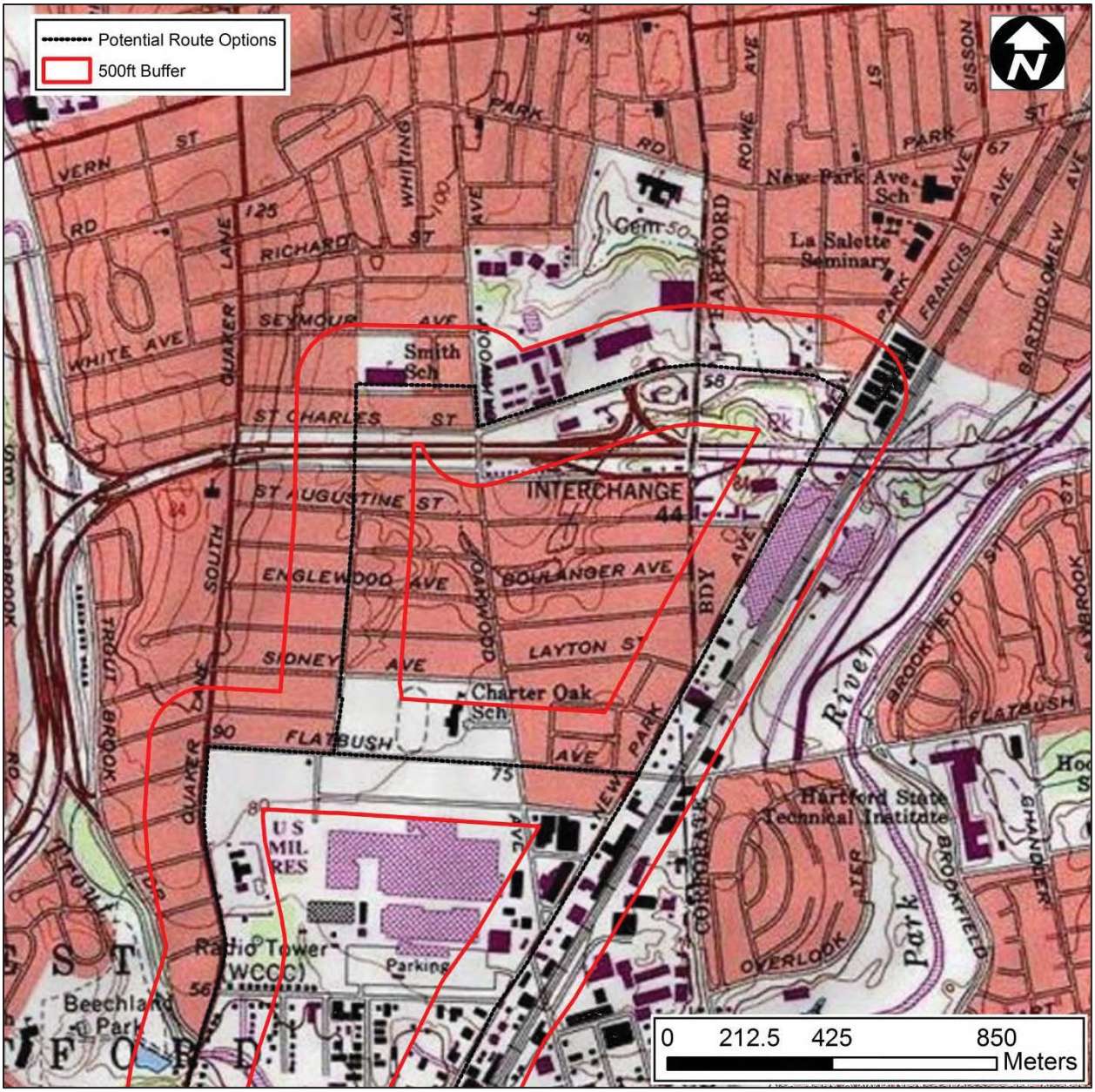
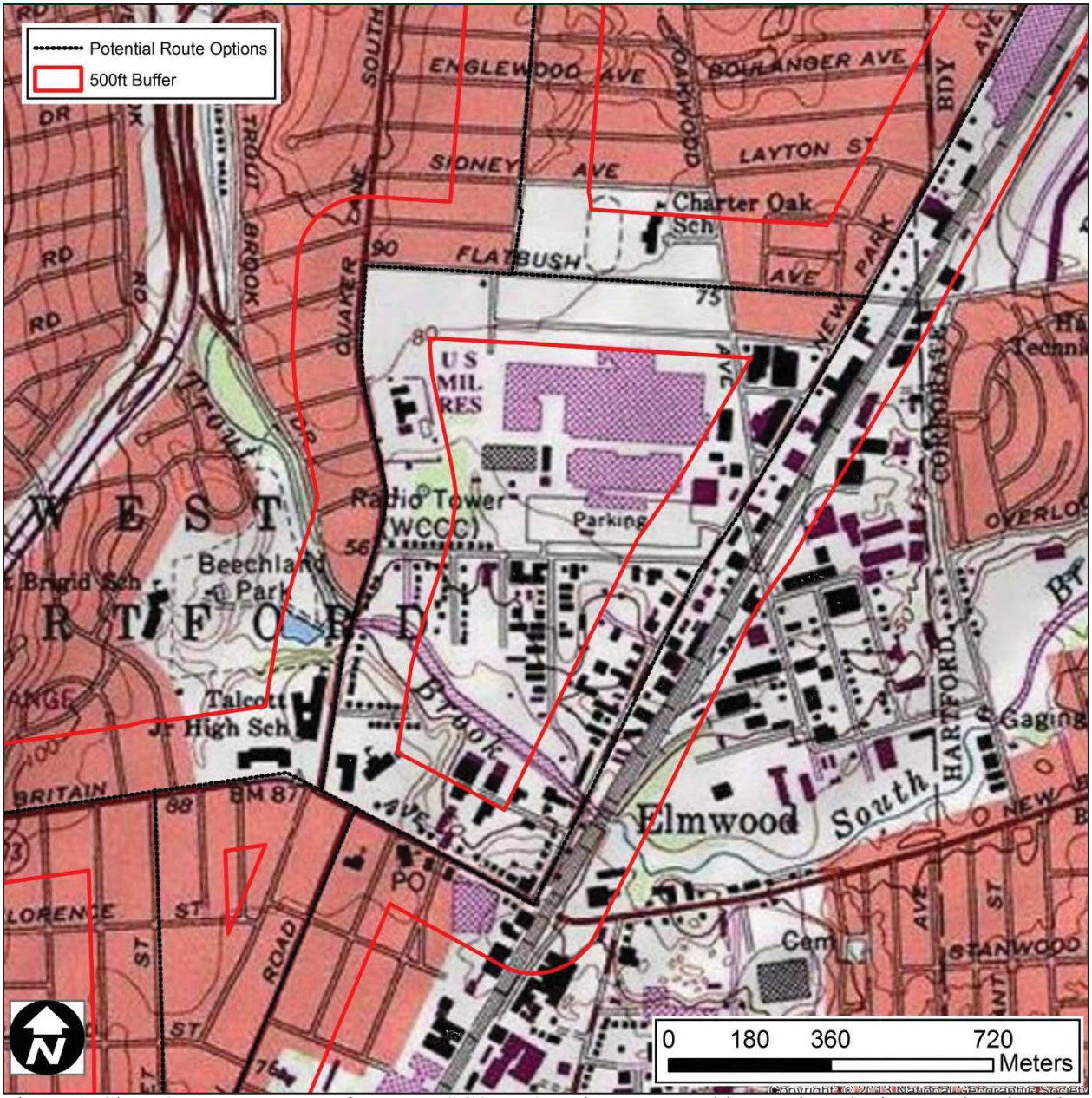


Figure 1, Sheet 1. Excerpt from a USGS 7.5' series topographic quadrangle image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.



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Figure 1, Sheet 2. Excerpt from a USGS 7.5' series topographic quadrangle image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

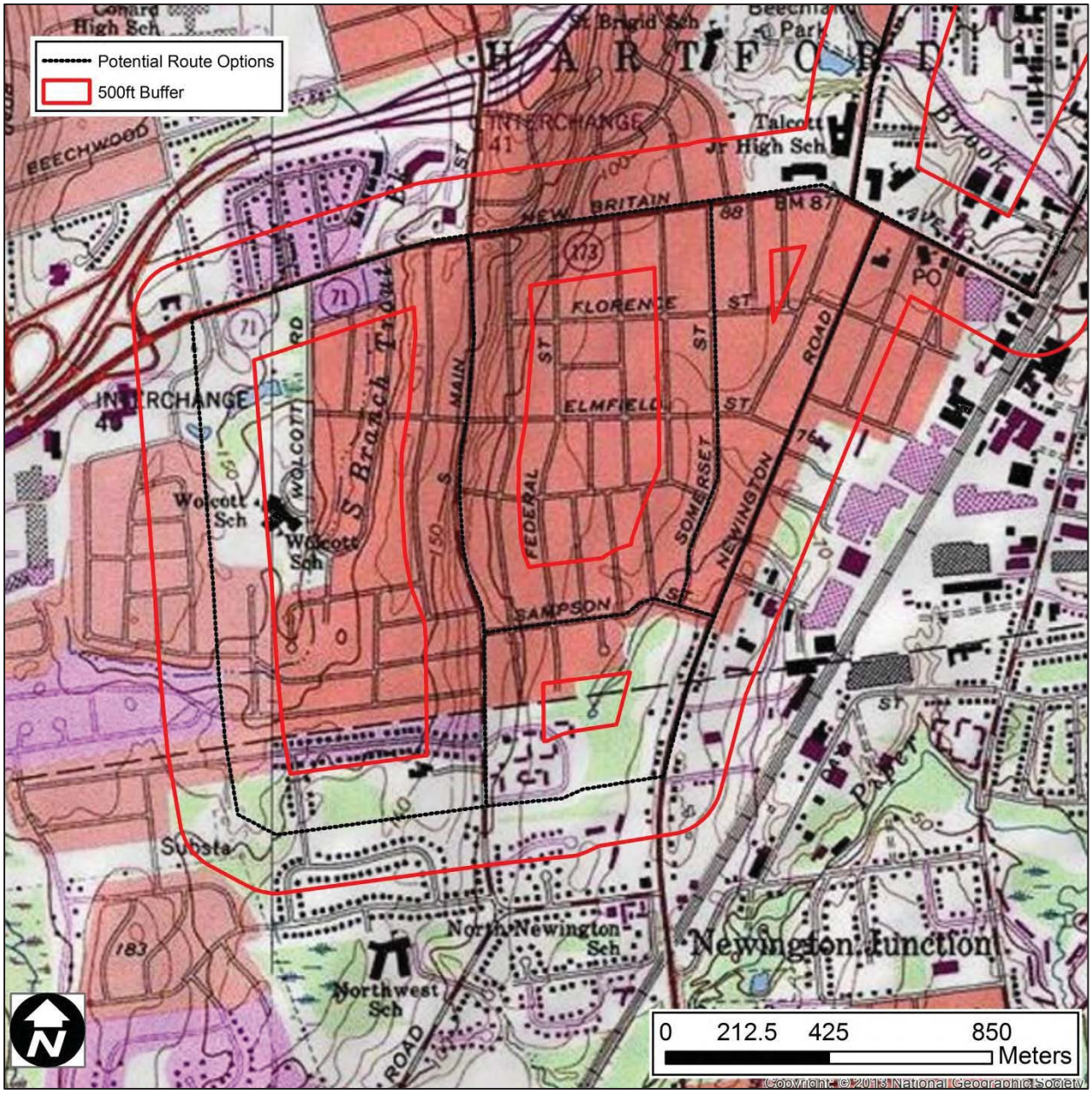


Figure 1, Sheet 3. Excerpt from a USGS 7.5' series topographic quadrangle image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

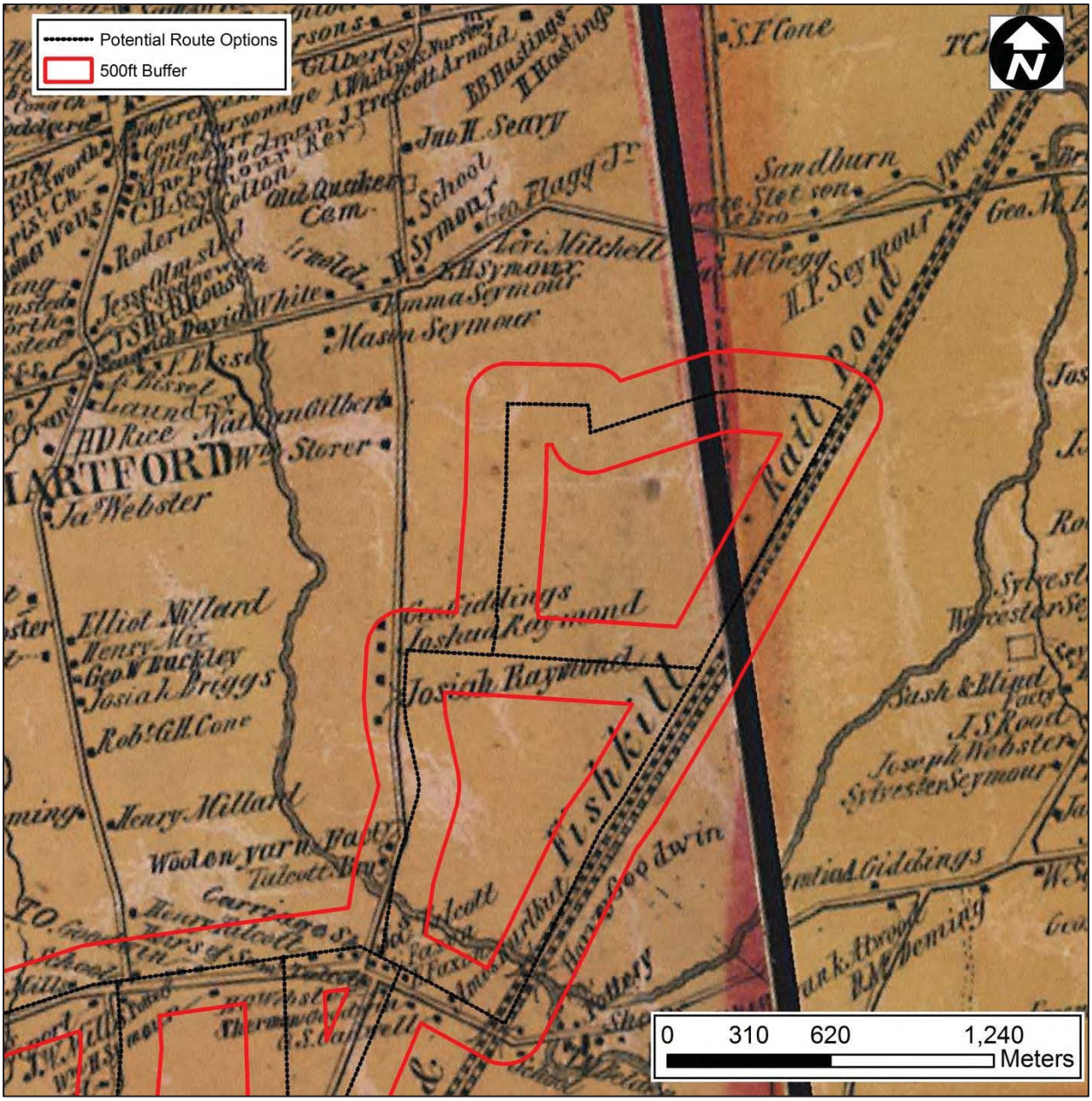


Figure 2, Sheet 1. Excerpt from an 1855 historic map showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.



Figure 2, Sheet 2. Excerpt from an 1855 historic map showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

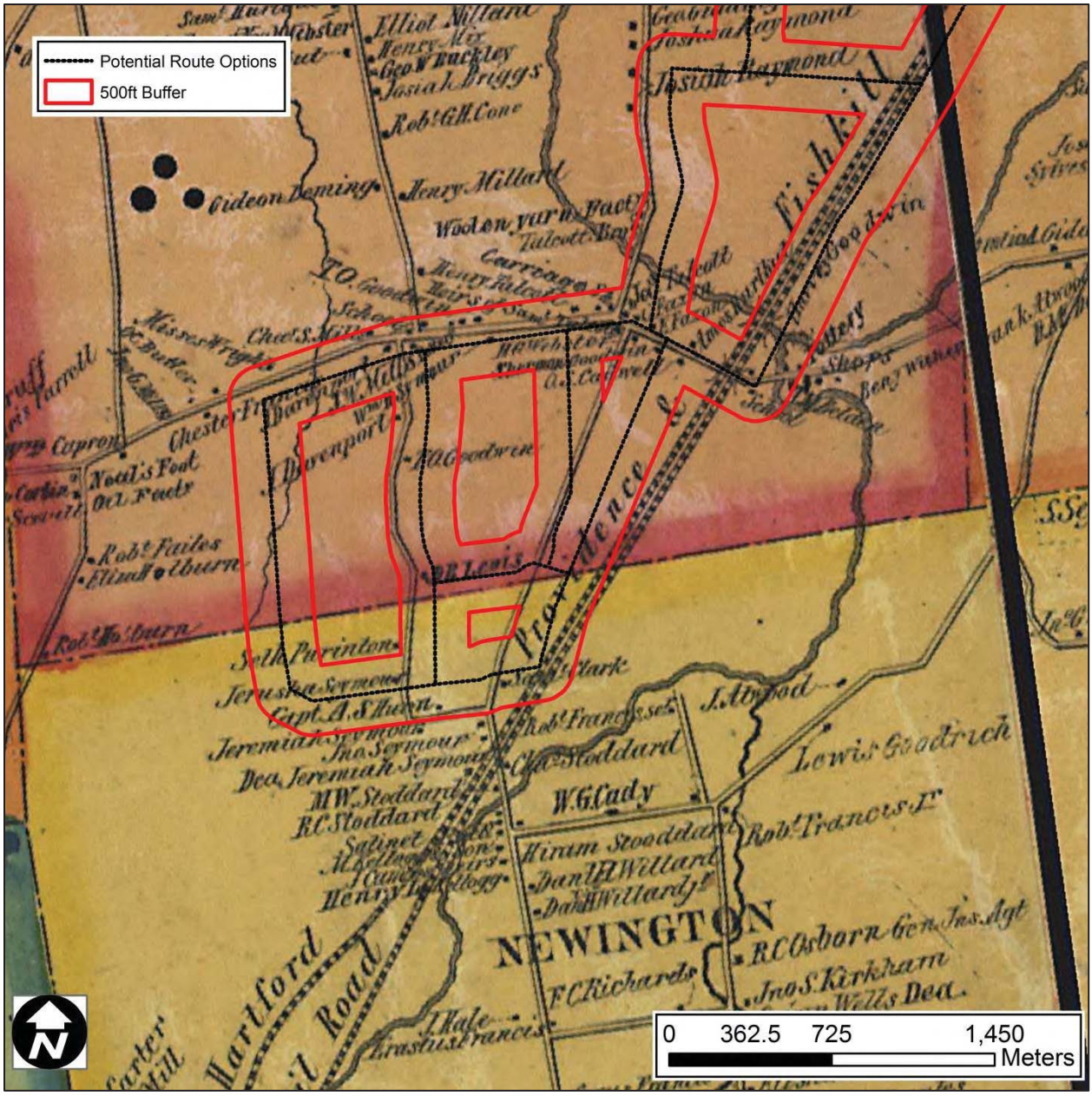


Figure 2, Sheet 3. Excerpt from an 1855 historic map showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

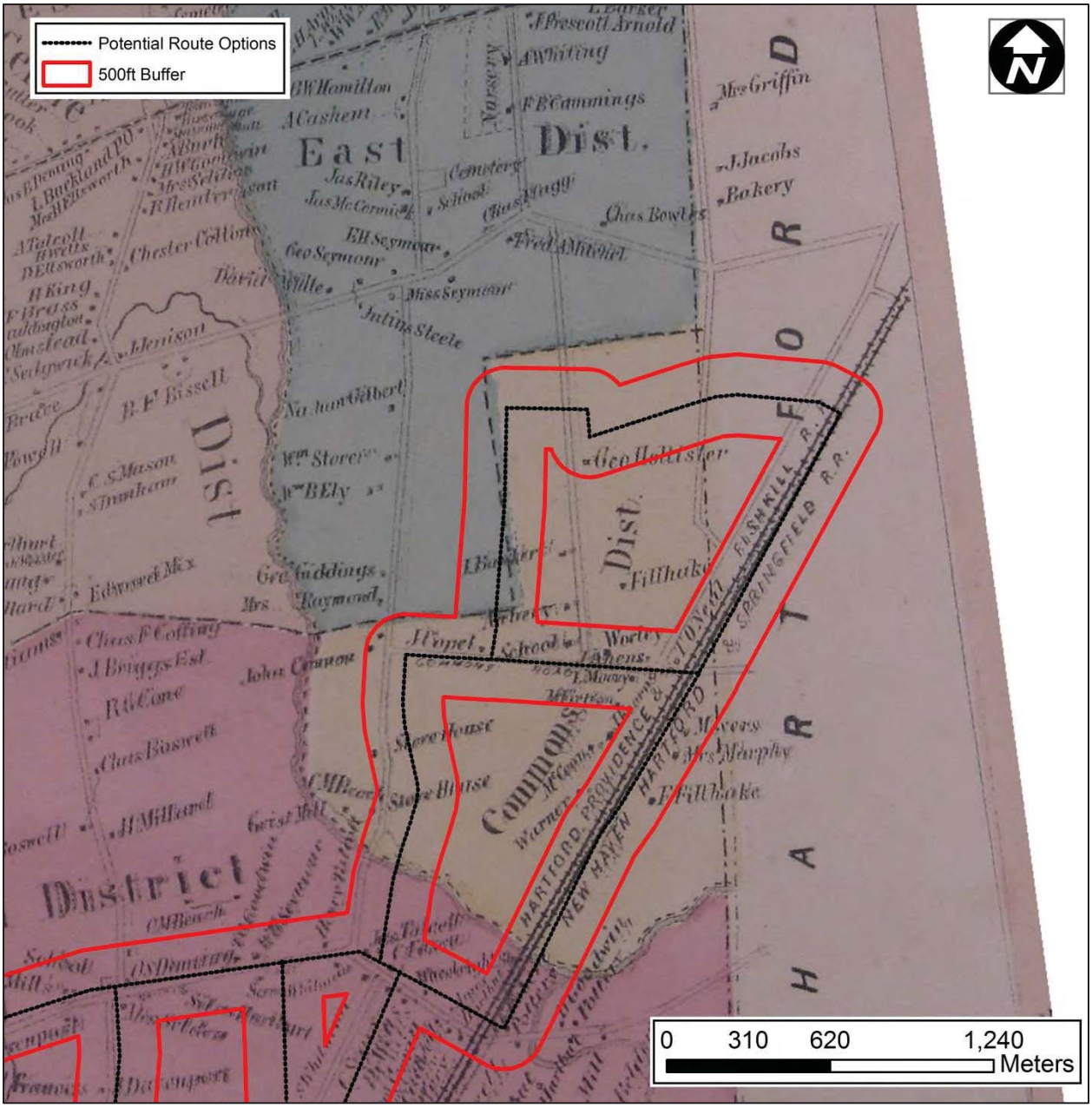


Figure 3, Sheet 1. Excerpt from an 1869 historic map showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

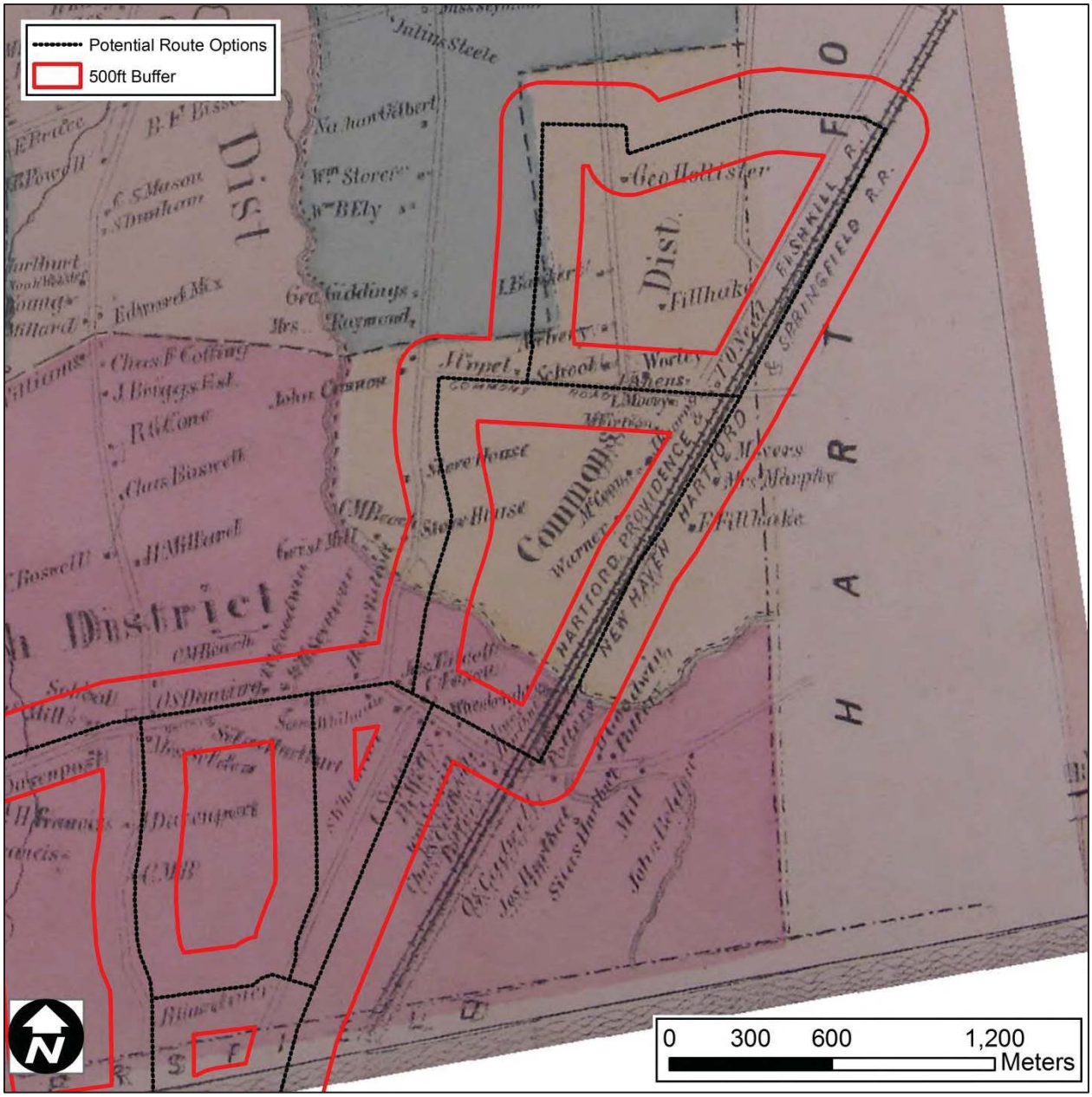


Figure 3, Sheet 2. Excerpt from an 1869 historic map showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

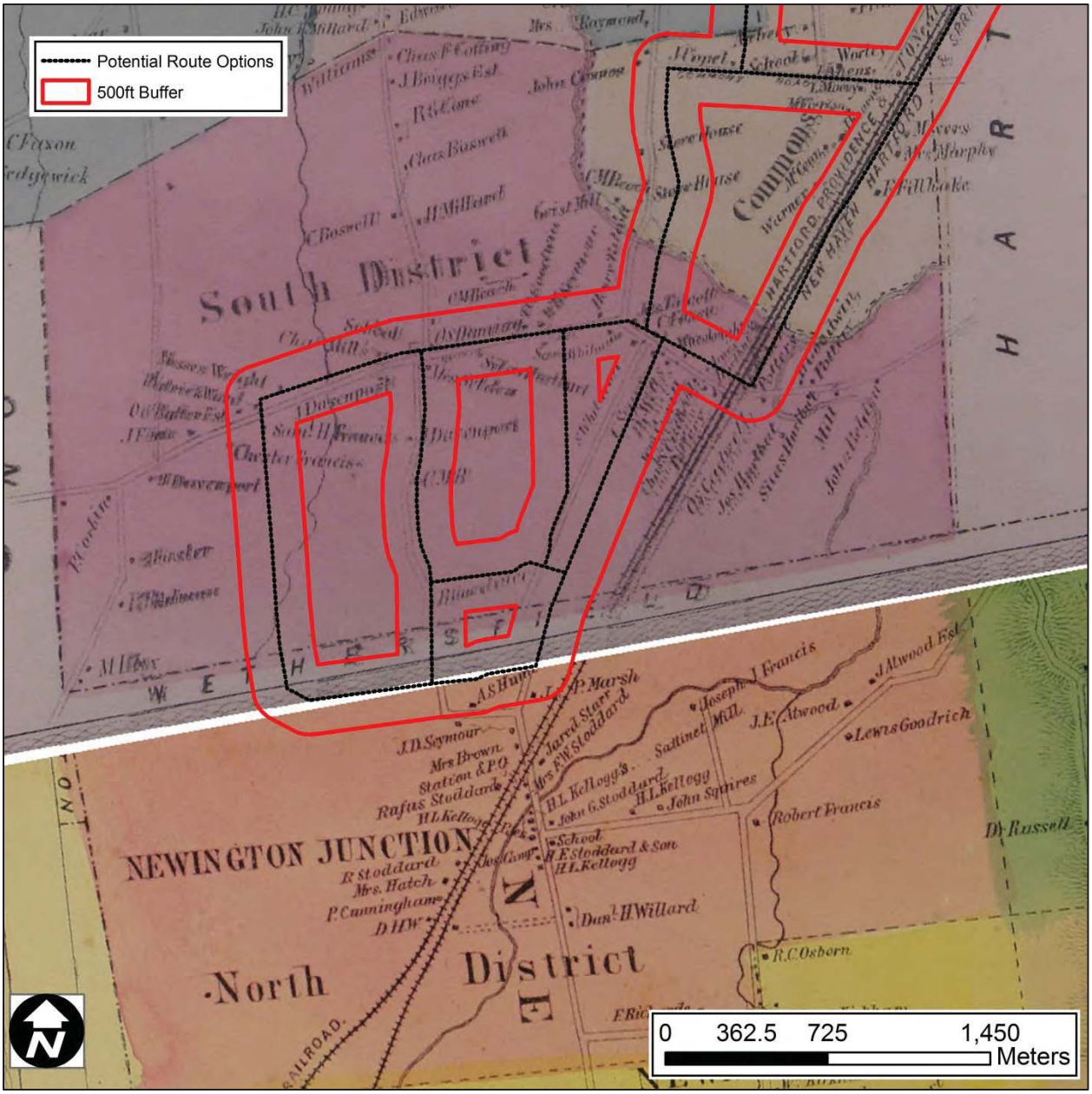


Figure 3, Sheet 3. Excerpt from an 1869 historic map showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.



Figure 4, Sheet 1. Excerpt from a 1934 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

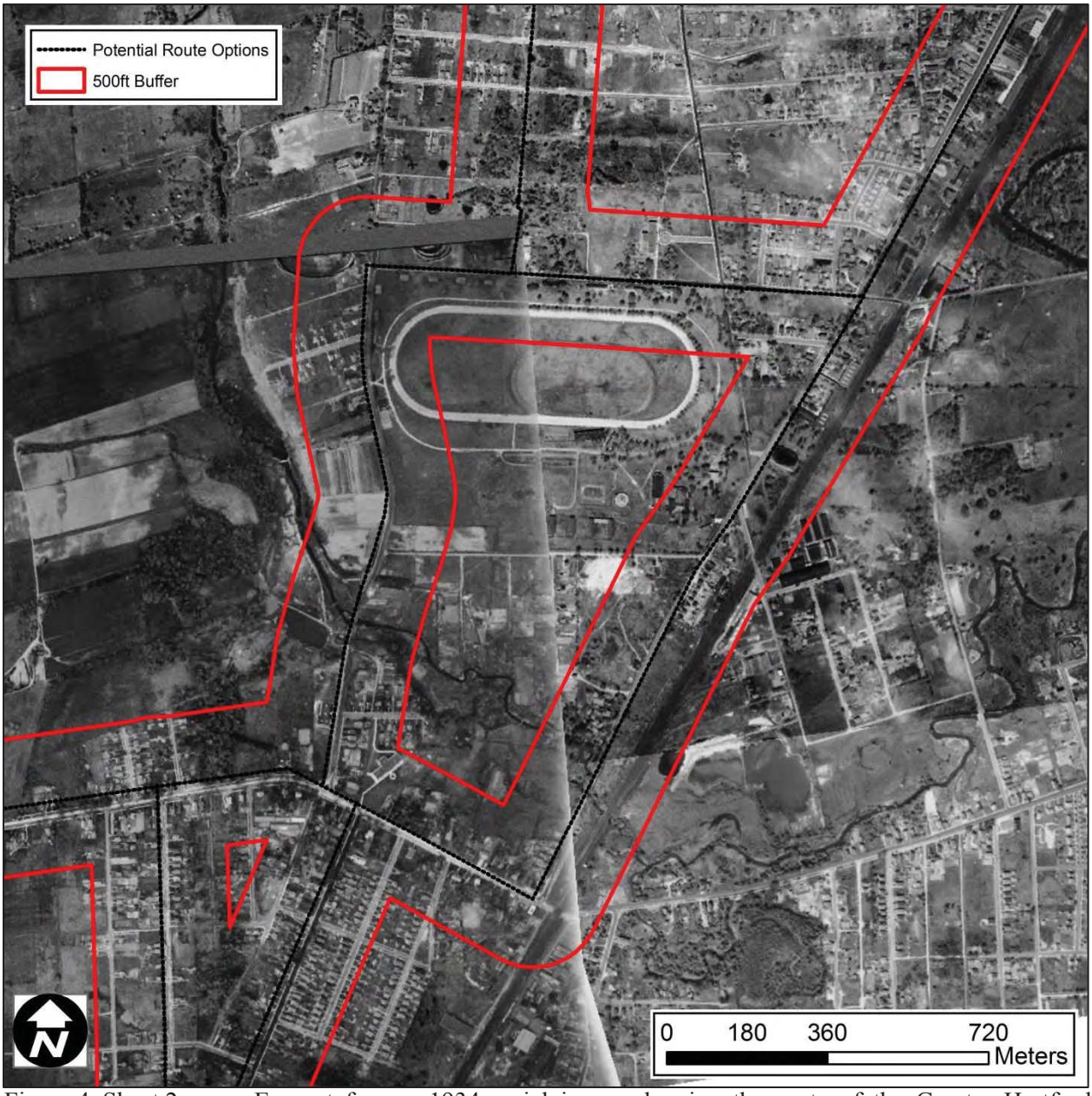


Figure 4, Sheet 2. Excerpt from a 1934 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

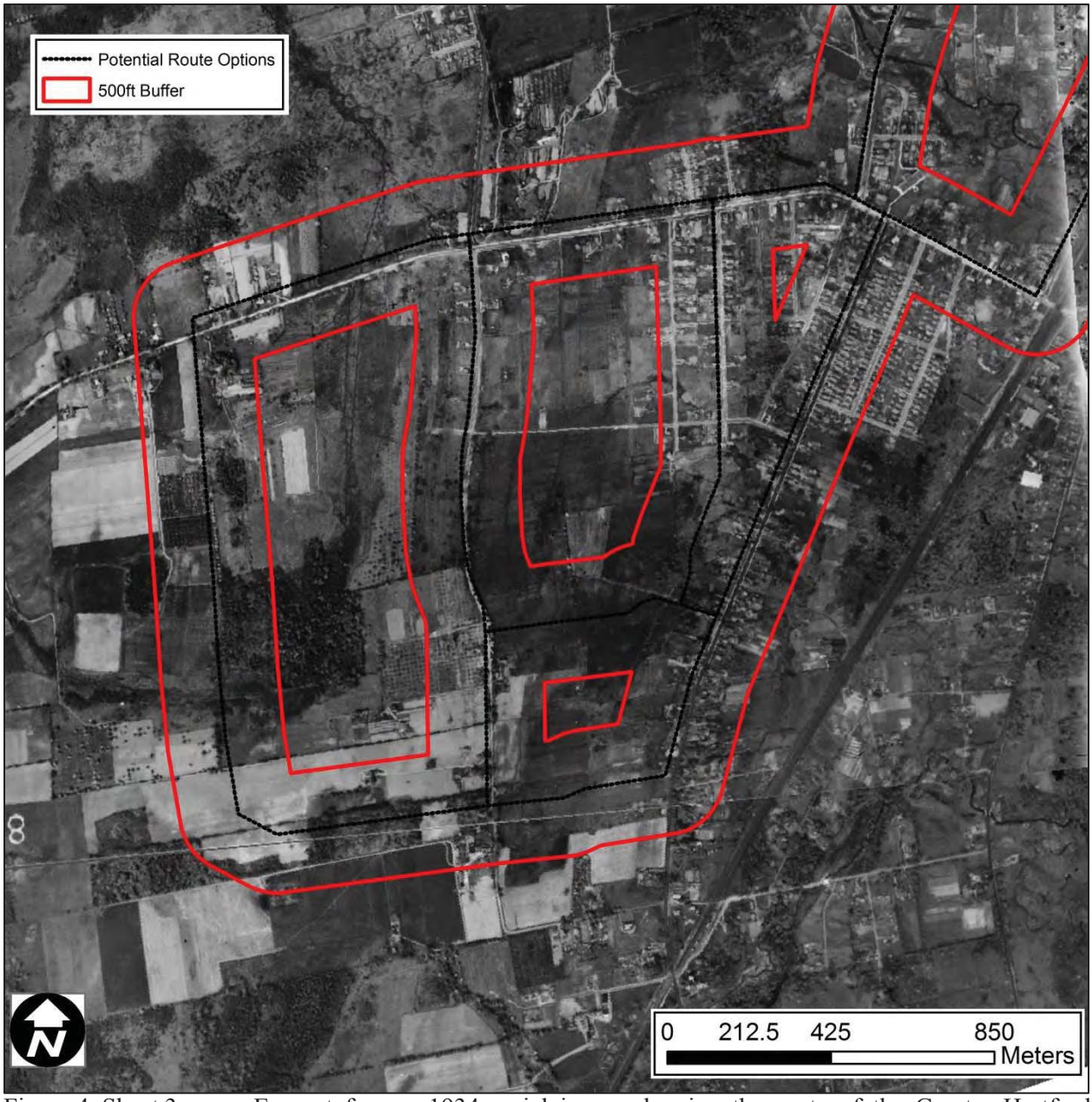


Figure 4, Sheet 3. Excerpt from a 1934 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.



Figure 5, Sheet 1. Excerpt from a 1951 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.



Figure 5, Sheet 2. Excerpt from a 1951 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.



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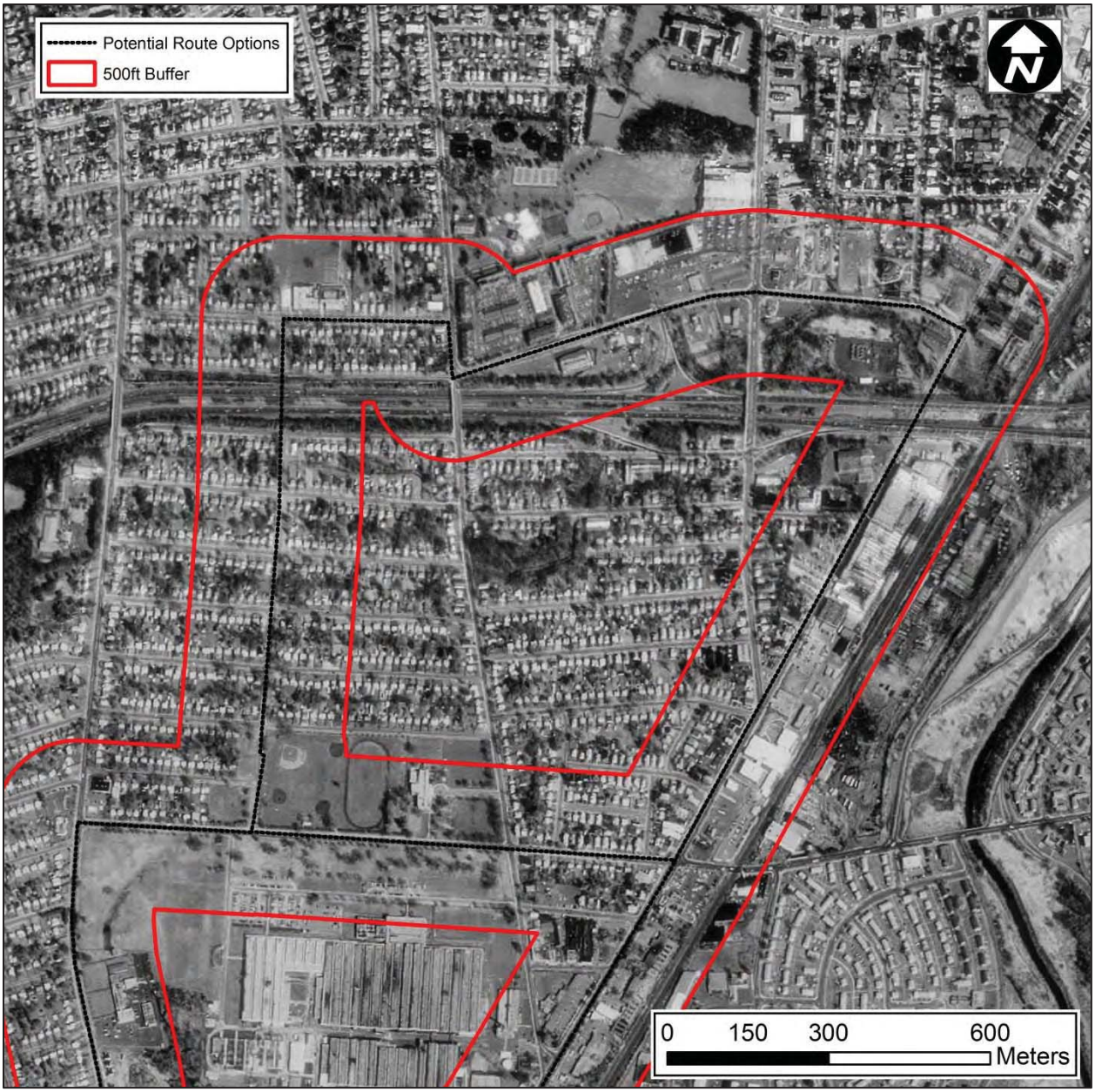


Figure 6, Sheet 1. Excerpt from a 1990 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

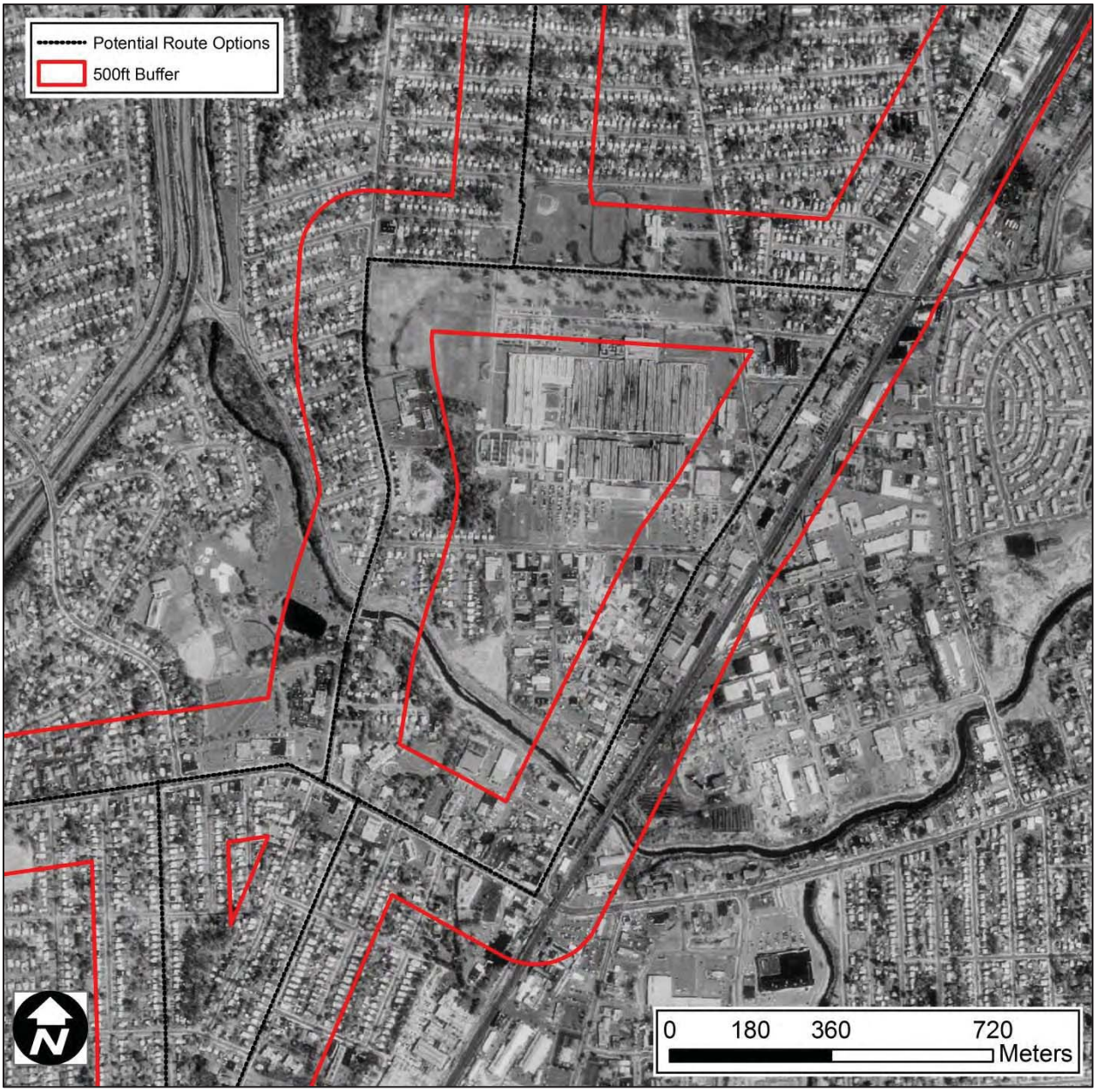


Figure 6, Sheet 2. Excerpt from a 1990 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

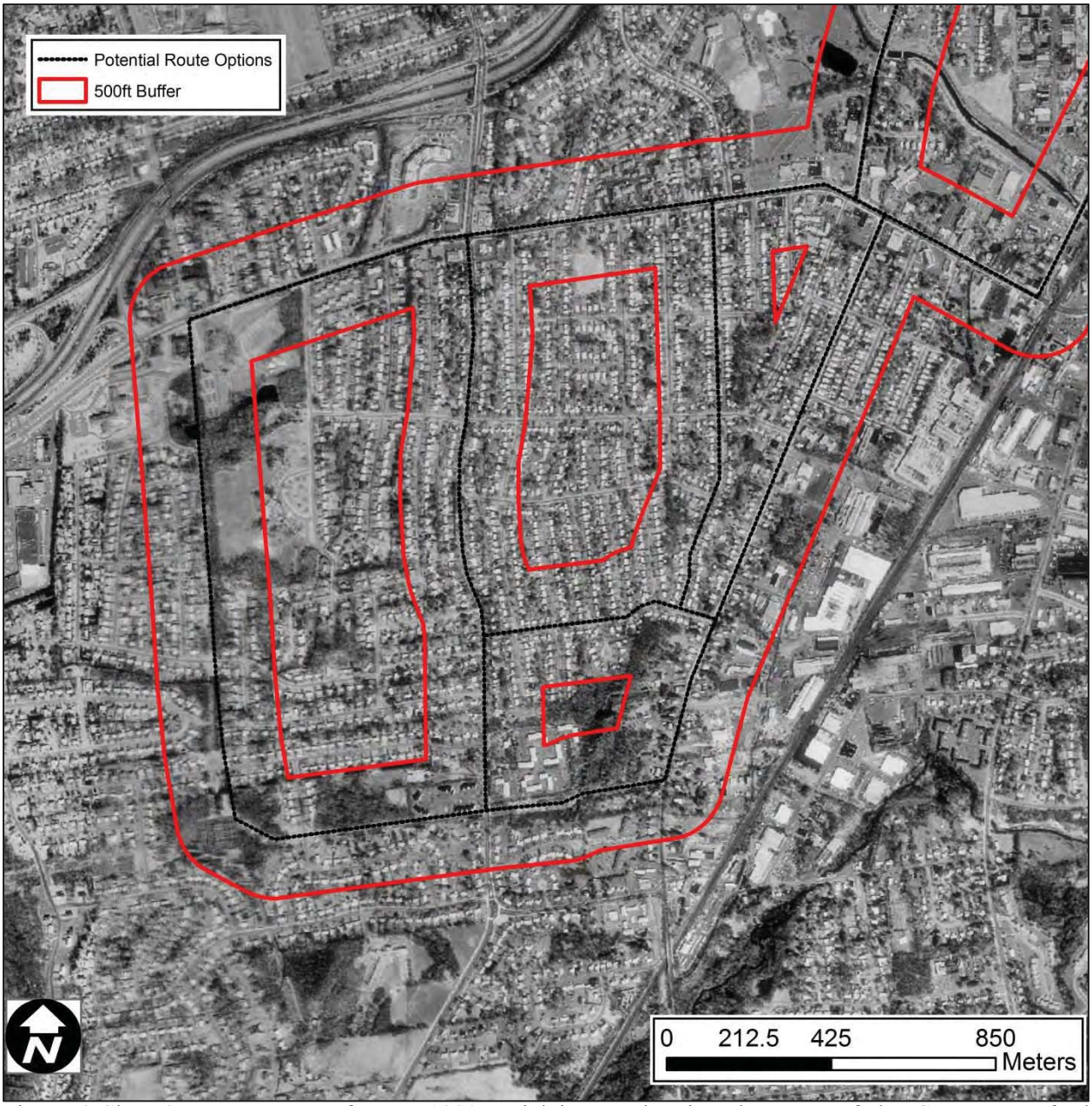


Figure 6, Sheet 3. Excerpt from a 1990 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

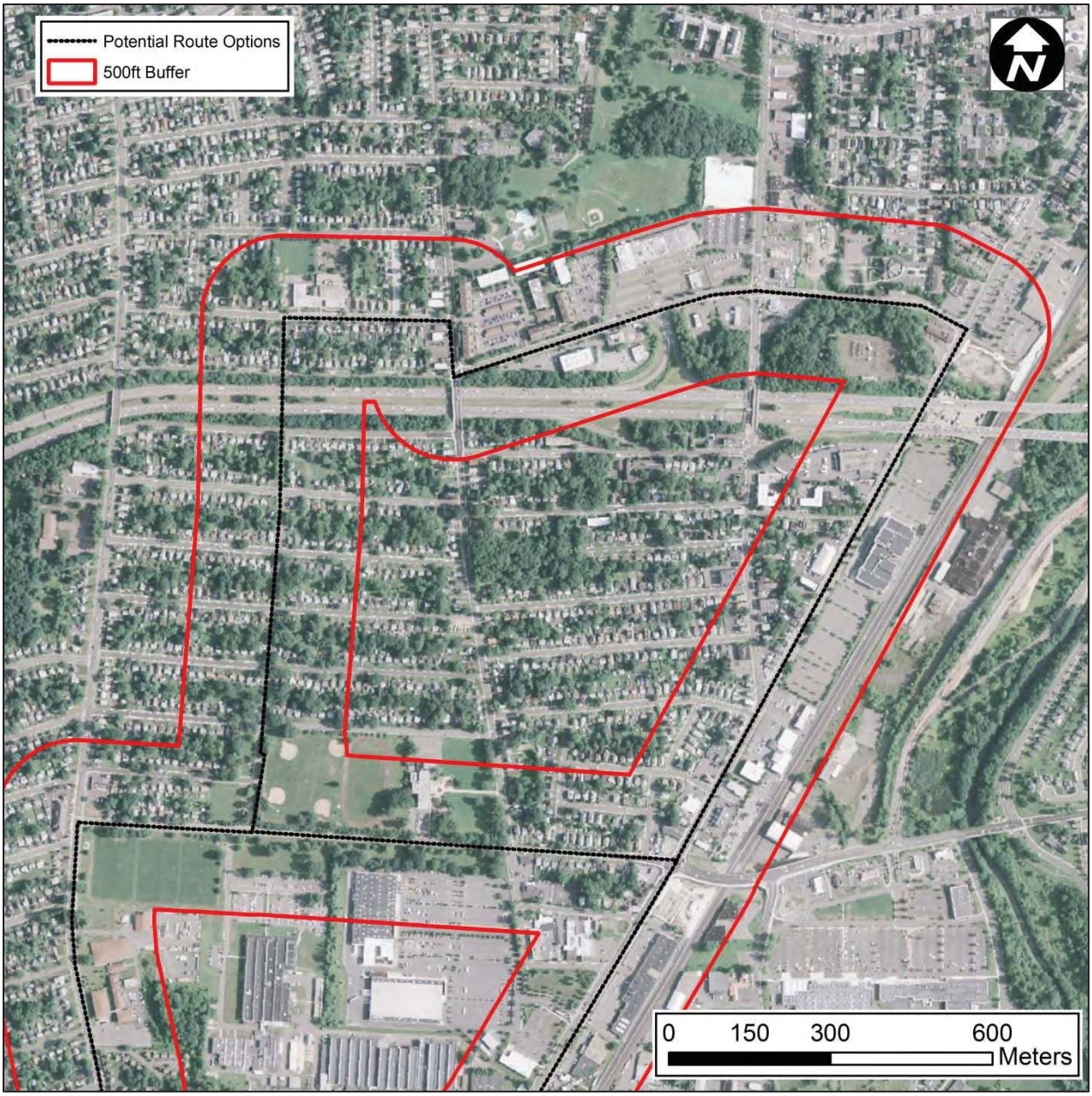


Figure 7, Sheet 1. Excerpt from a 2014 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.



Figure 7, Sheet 2. Excerpt from a 2014 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

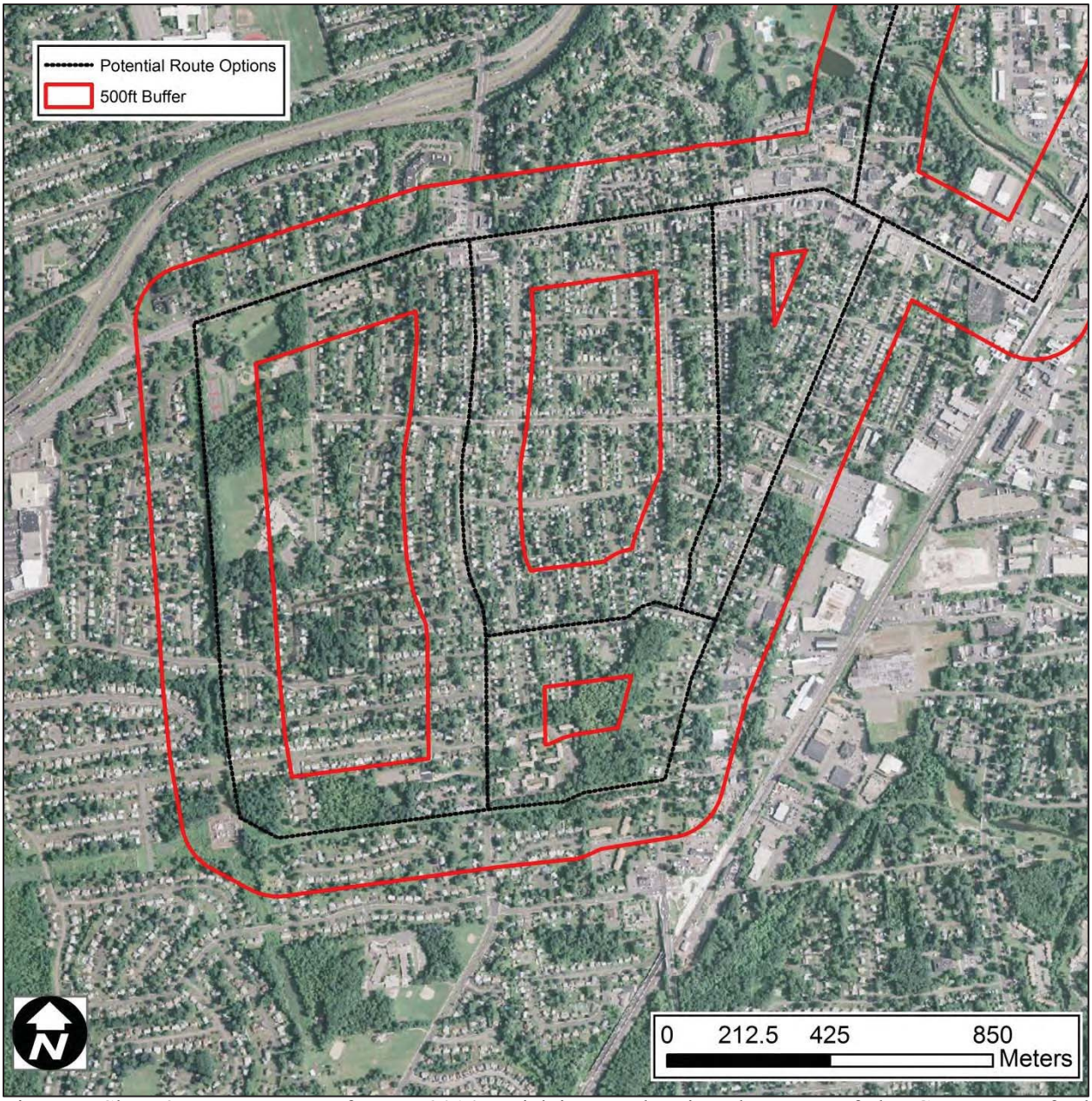


Figure 7, Sheet 3. Excerpt from a 2014 aerial image showing the route of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

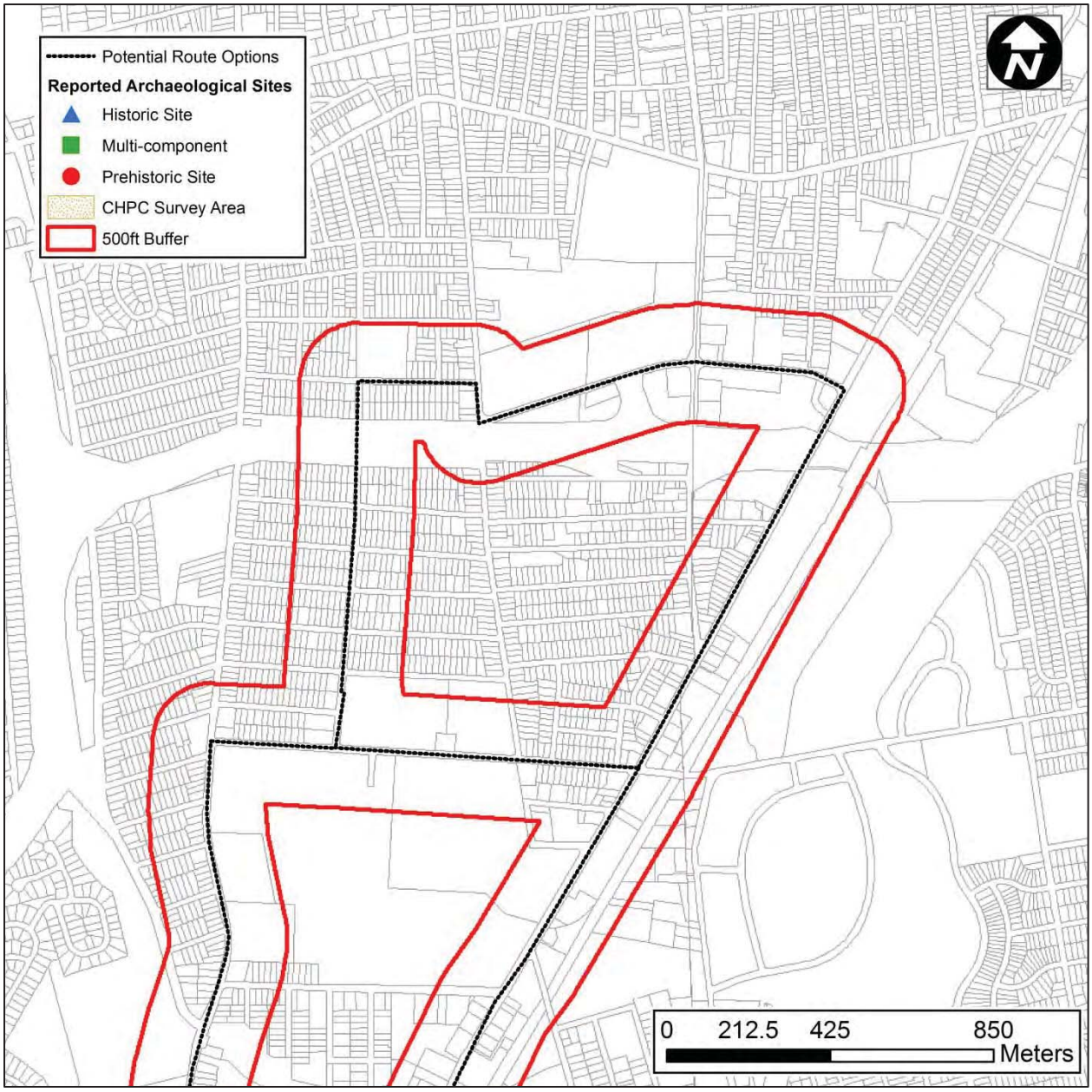


Figure 8, Sheet 1. Digital map depicting the locations of previously identified archaeological sites in the vicinity of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

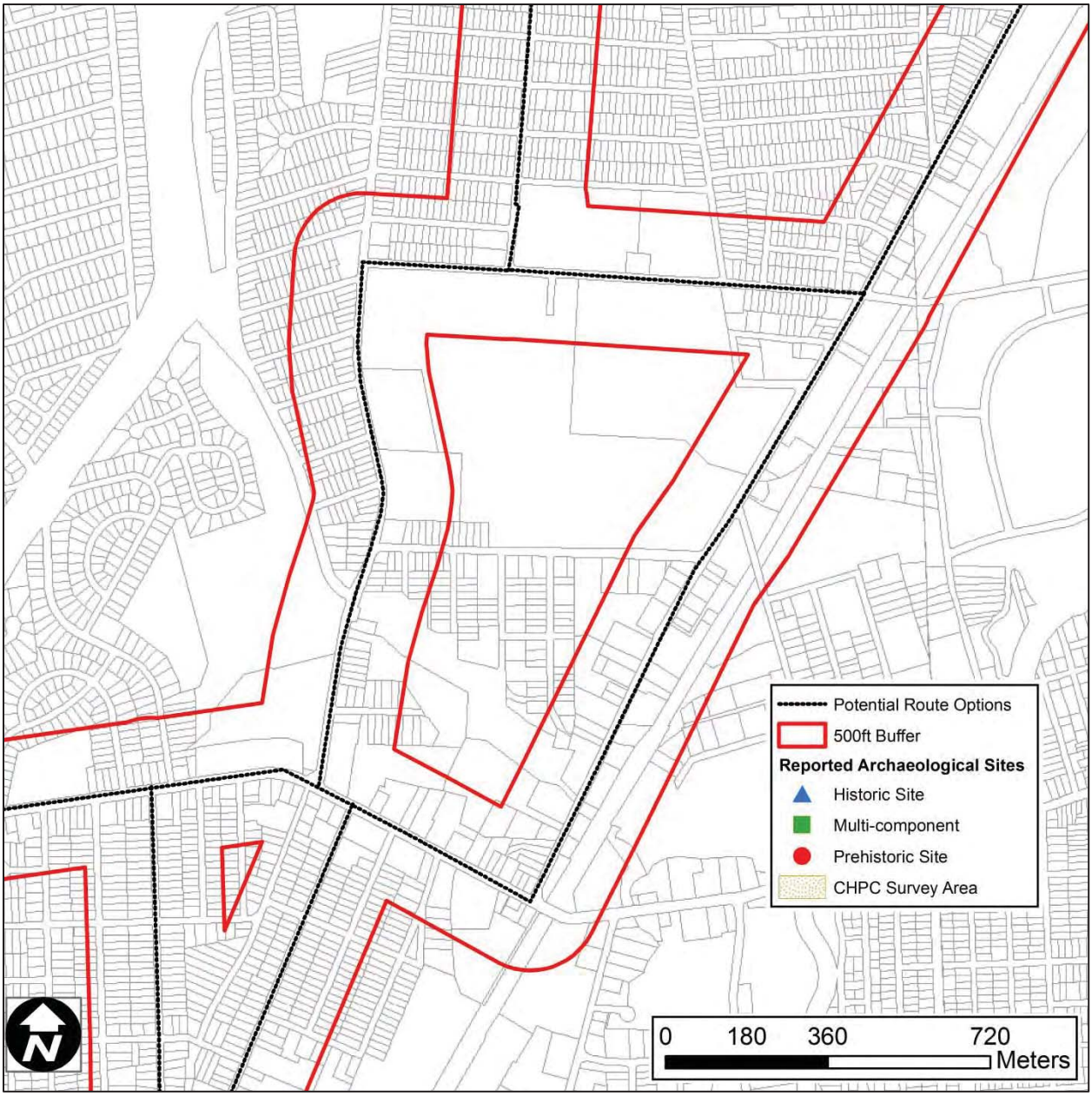


Figure 8, Sheet 2. Digital map depicting the locations of previously identified archaeological sites in the vicinity of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

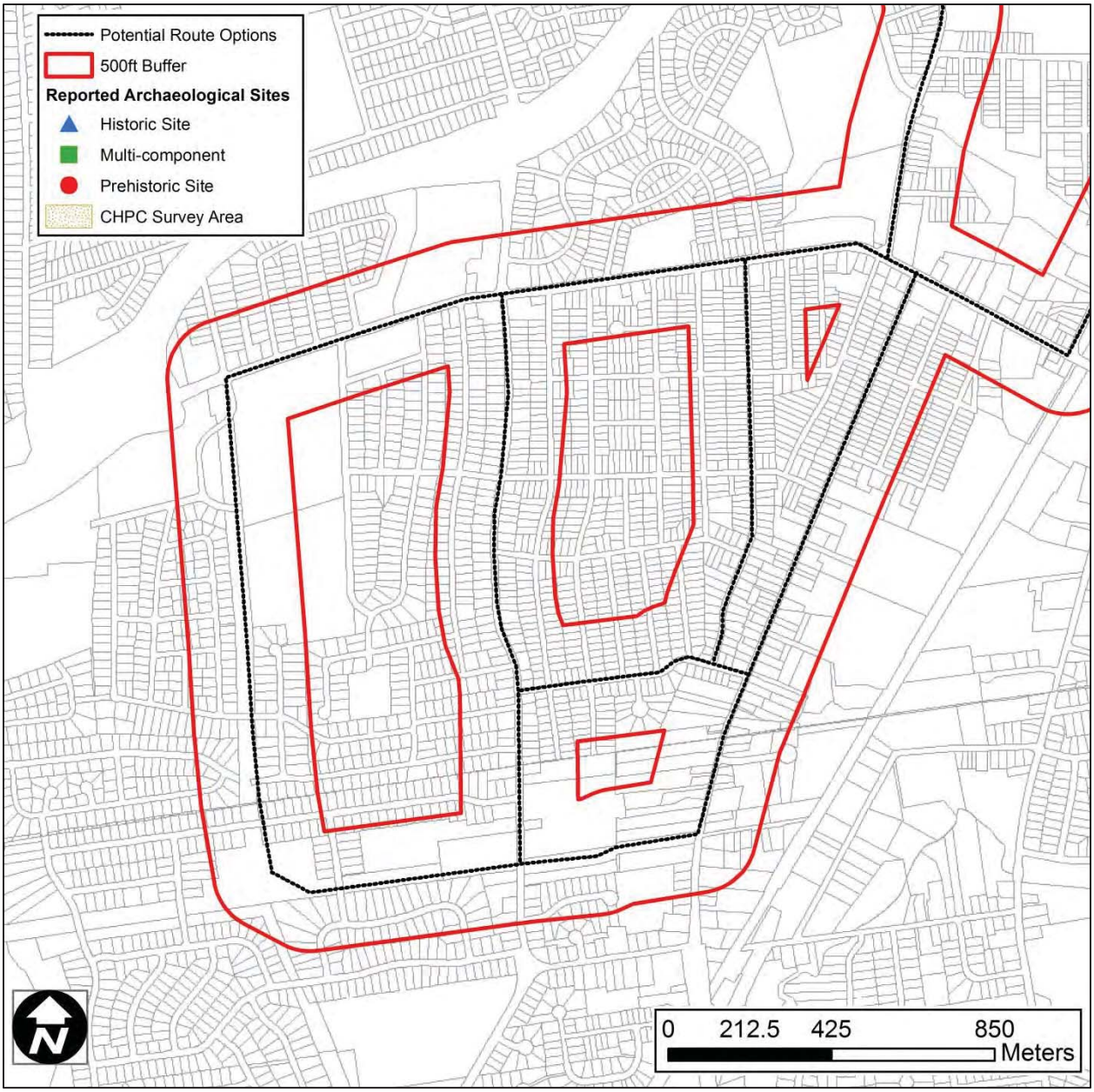


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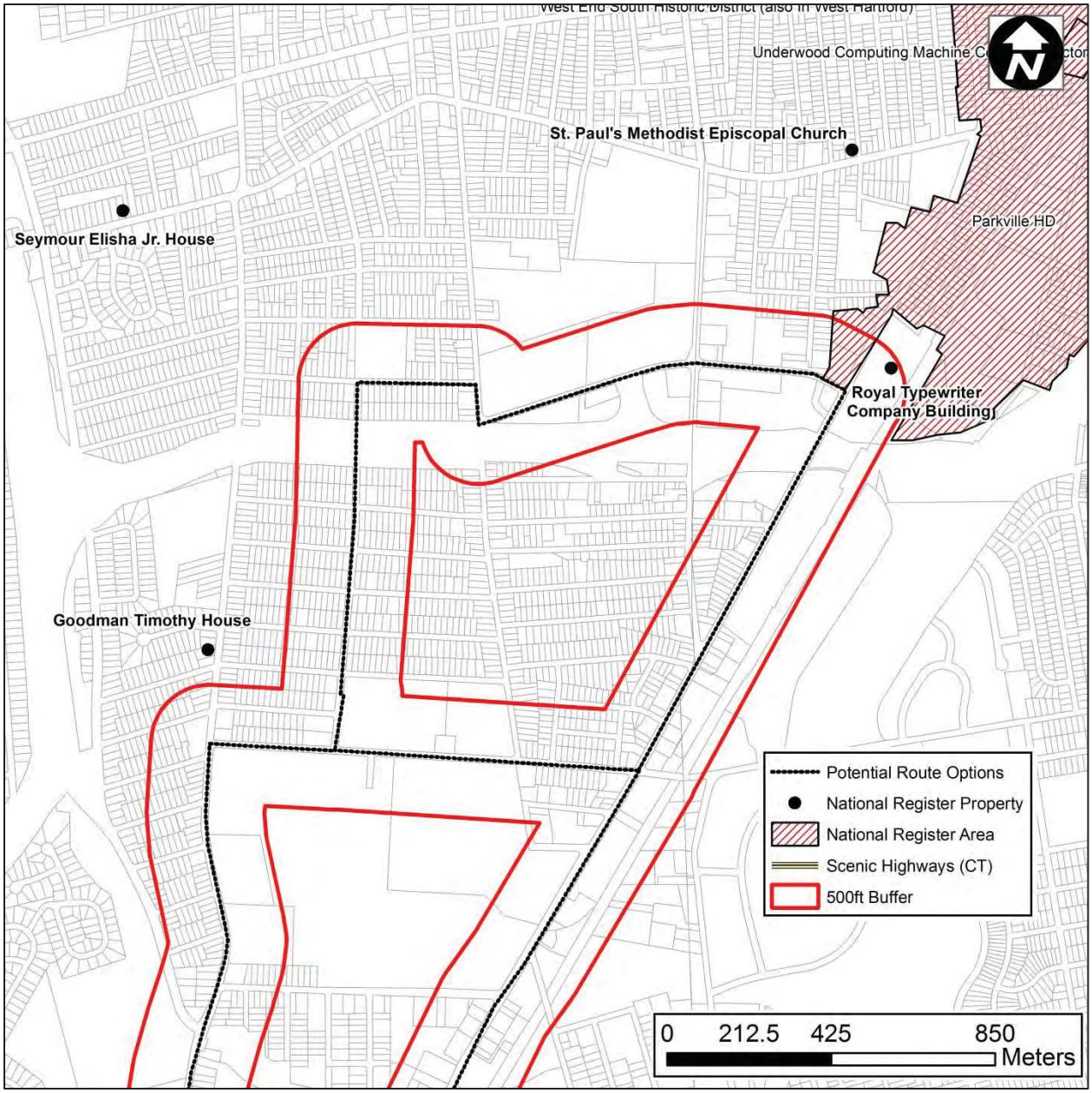


Figure 9, Sheet 1. Digital map depicting the locations of previously identified National Register of Historic Places properties in the vicinity of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

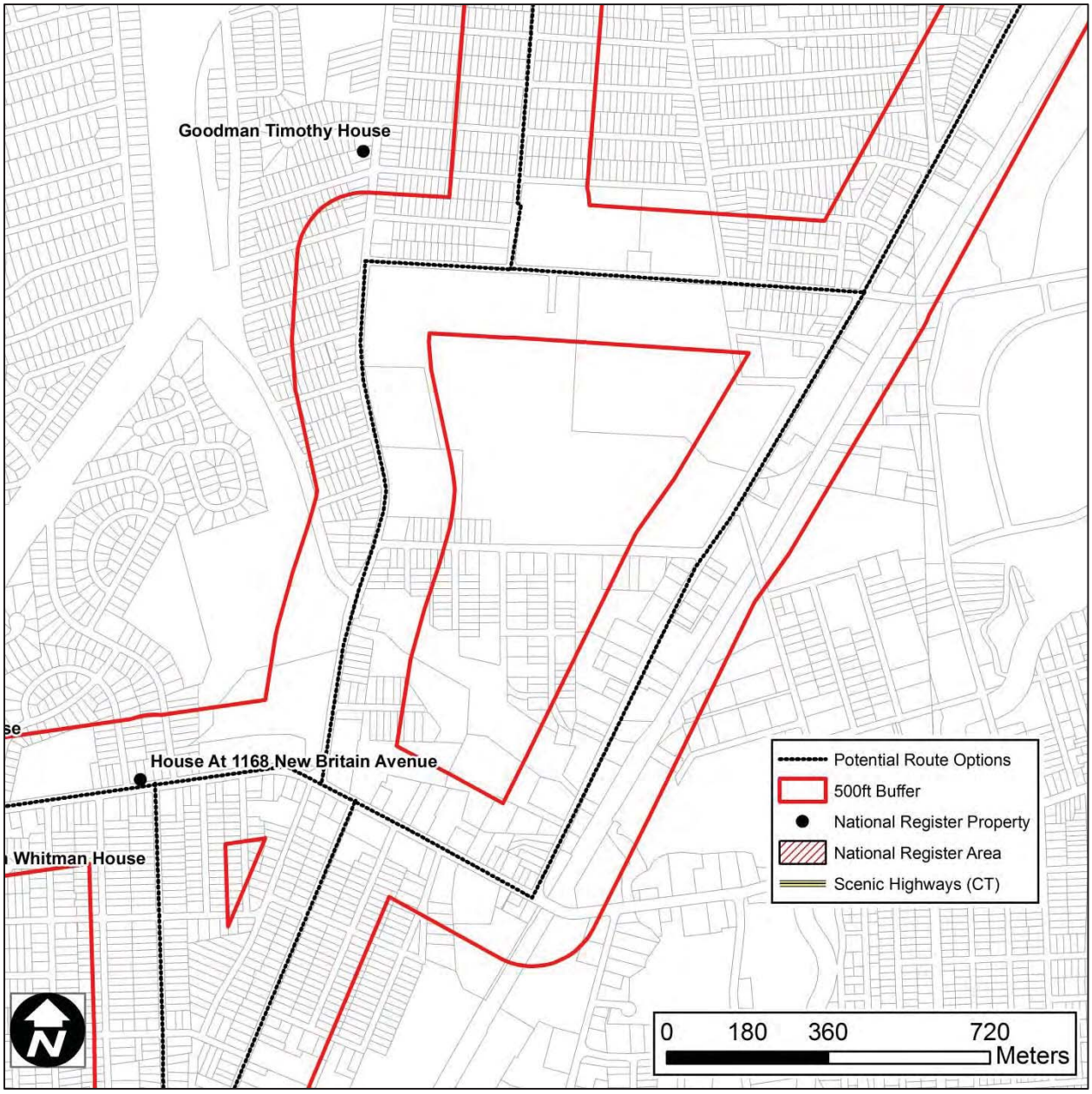


Figure 9, Sheet 2. Digital map depicting the locations of previously identified National Register of Historic Places properties in the vicinity of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

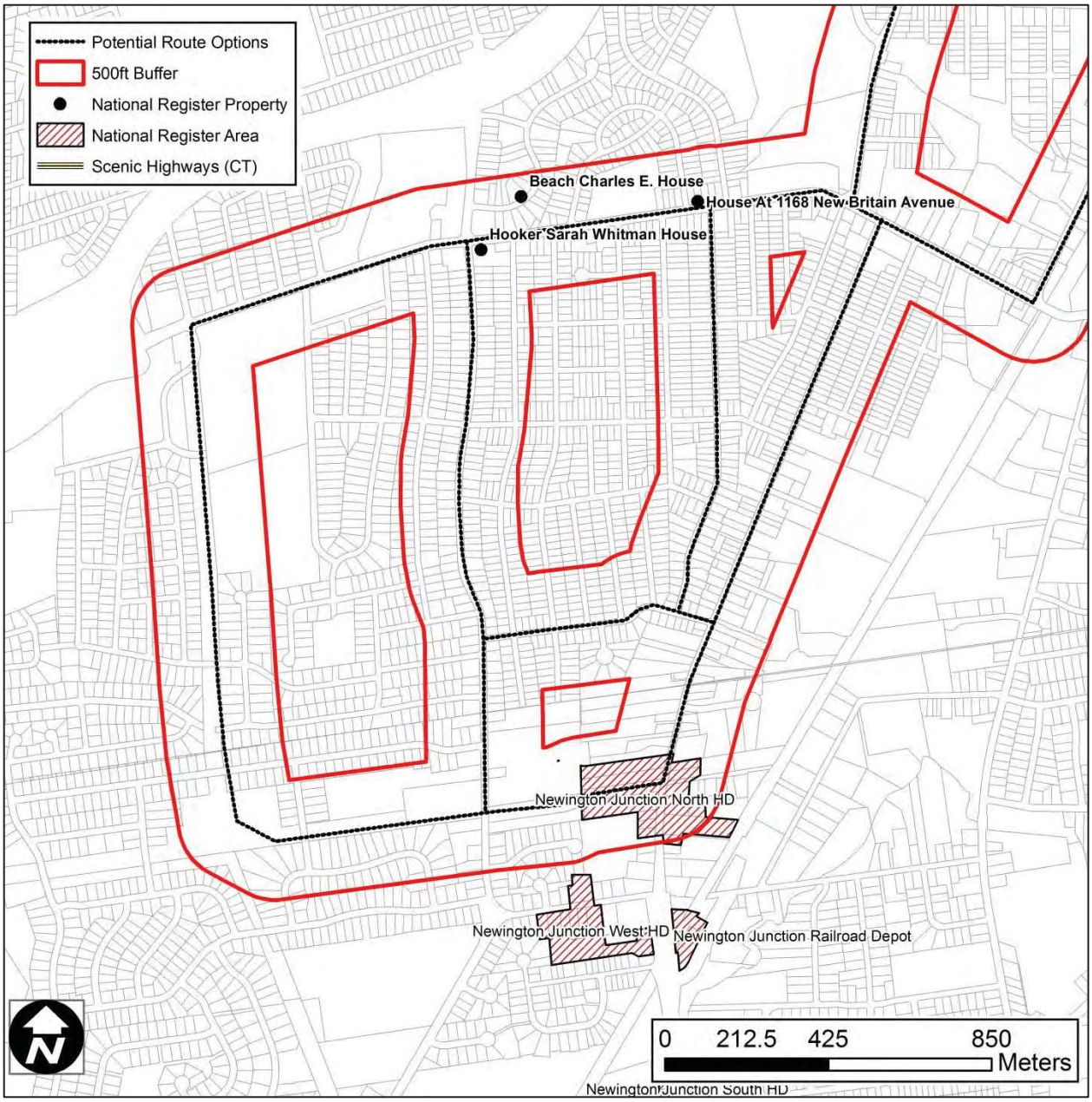


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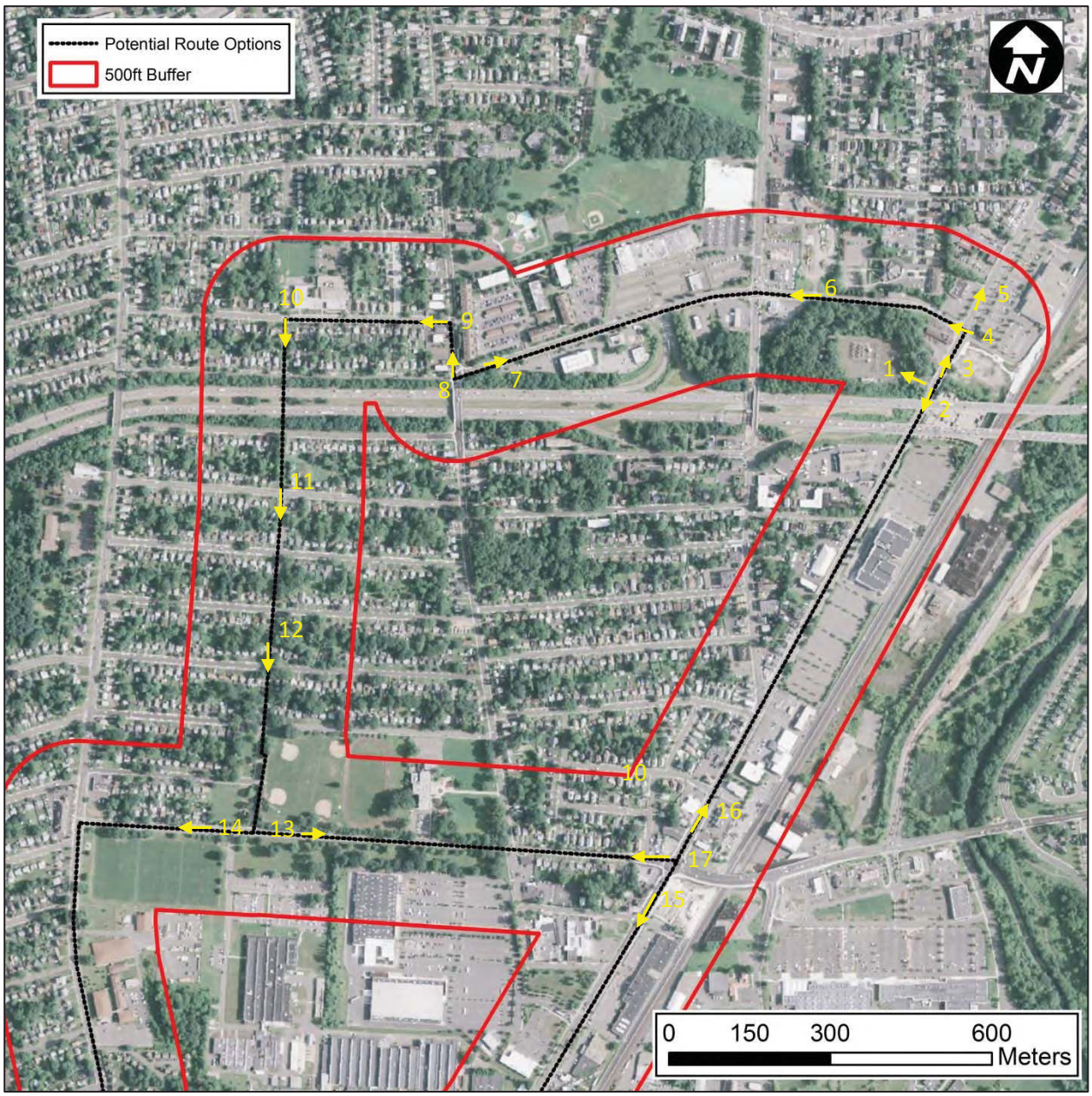


Figure 10, Sheet 1. Excerpt from a modern aerial image showing the proposed project corridors in Hartford and Newington, Connecticut and the directions from which photos were taken during pedestrian survey.

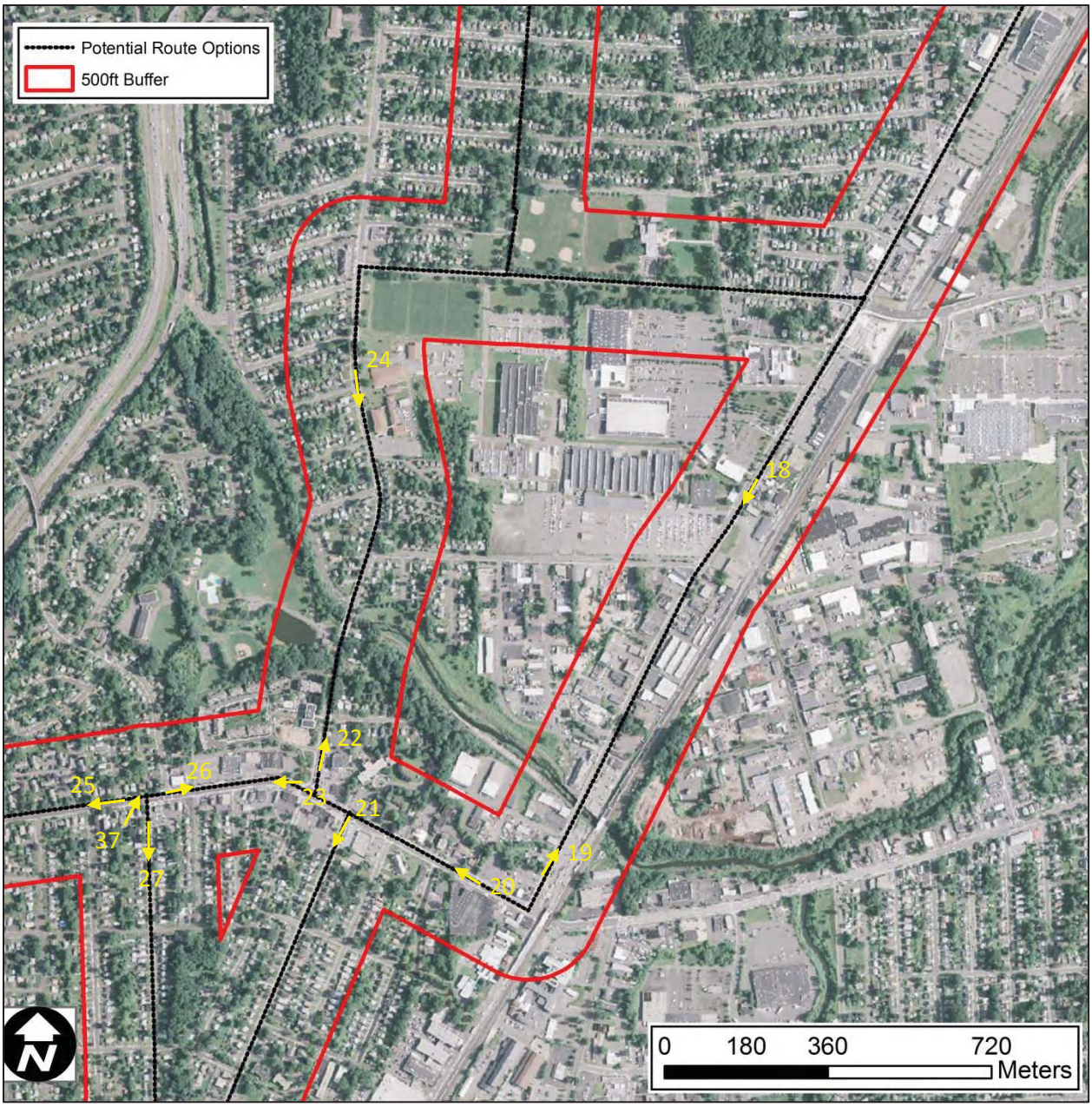


Figure 10, Sheet 2. Excerpt from a modern aerial image showing the proposed project corridors in Hartford and Newington, Connecticut and the directions from which photos were taken during pedestrian survey.

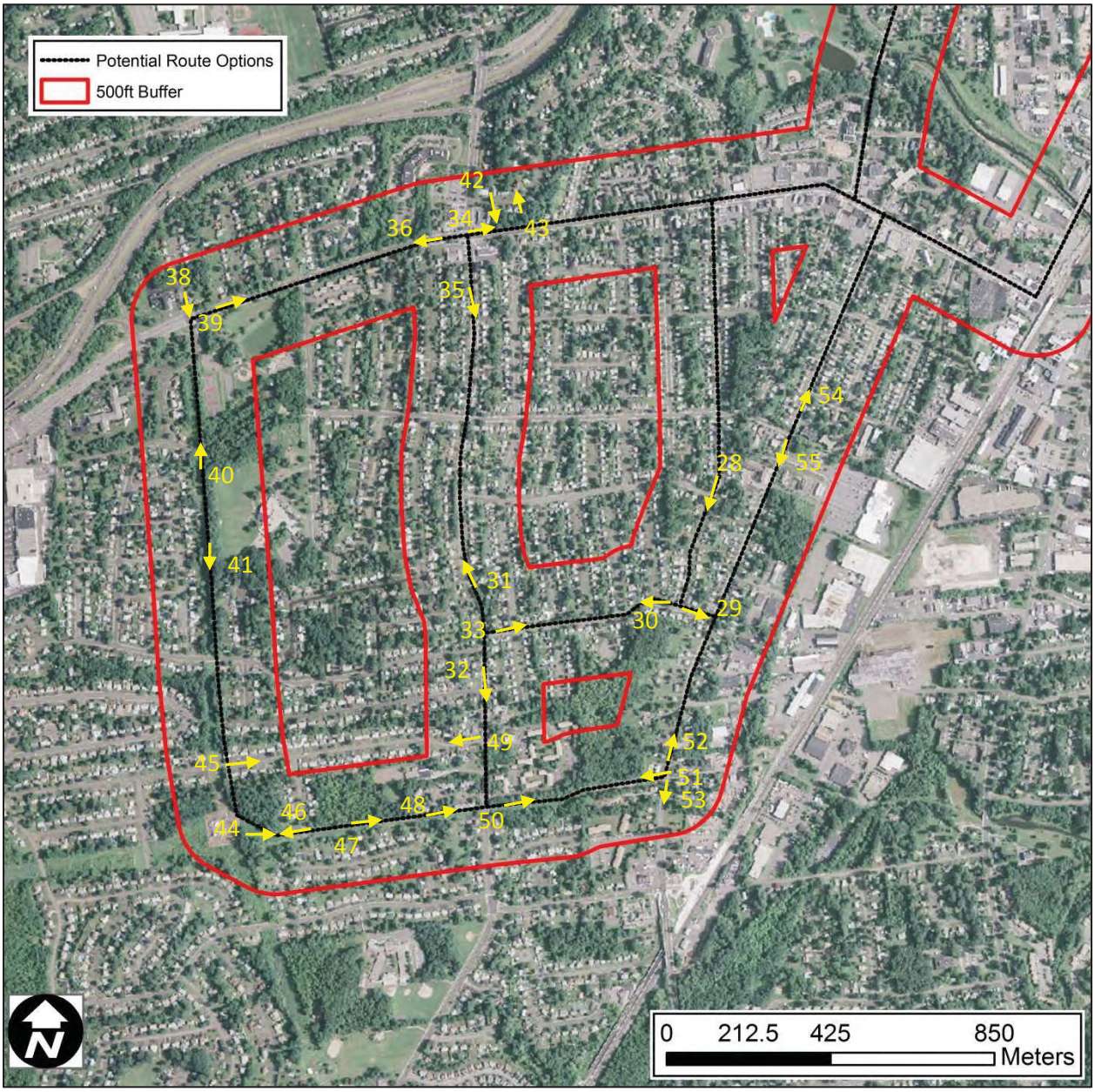


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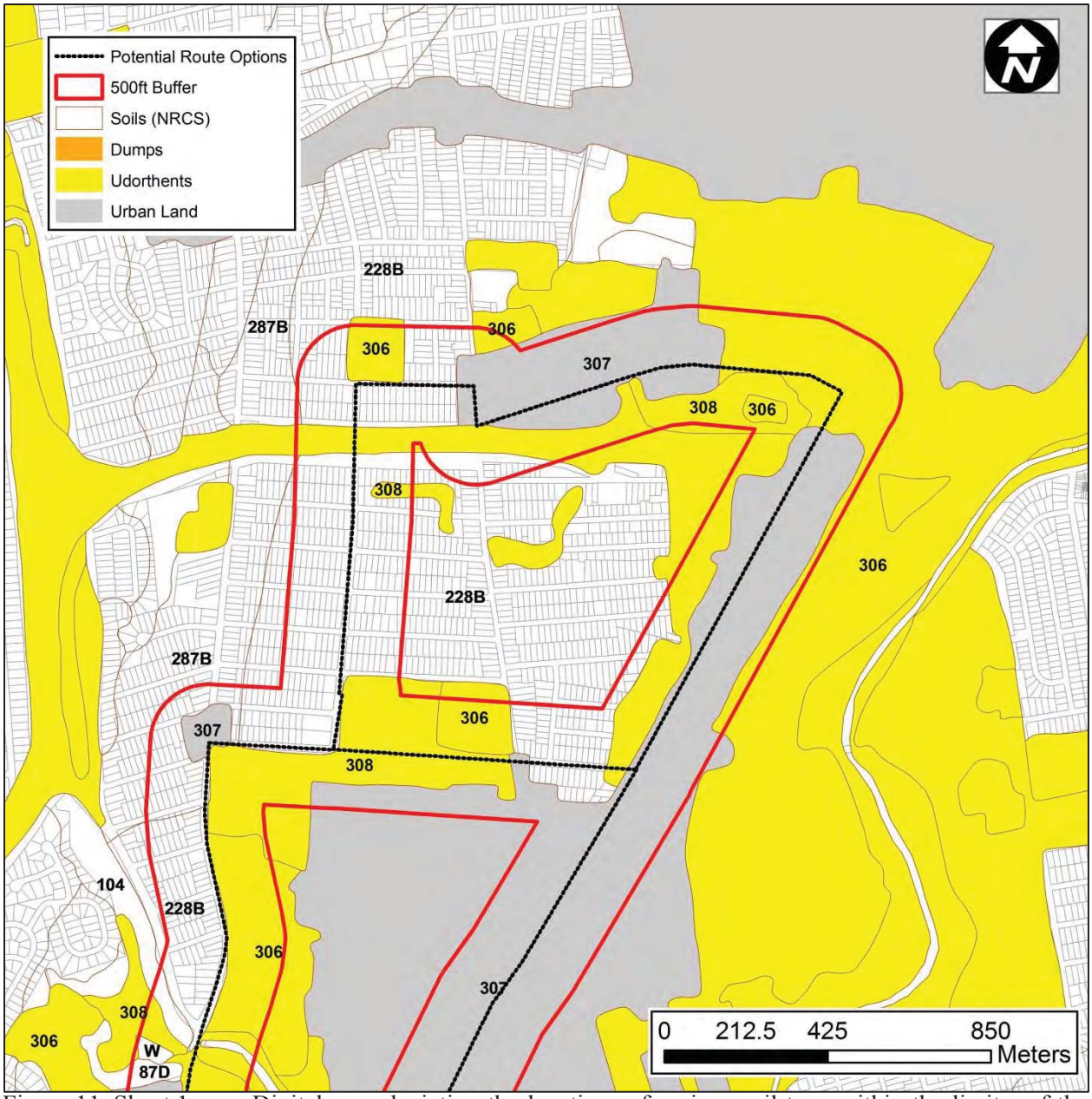


Figure 11, Sheet 1. Digital map depicting the locations of various soil type within the limits of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

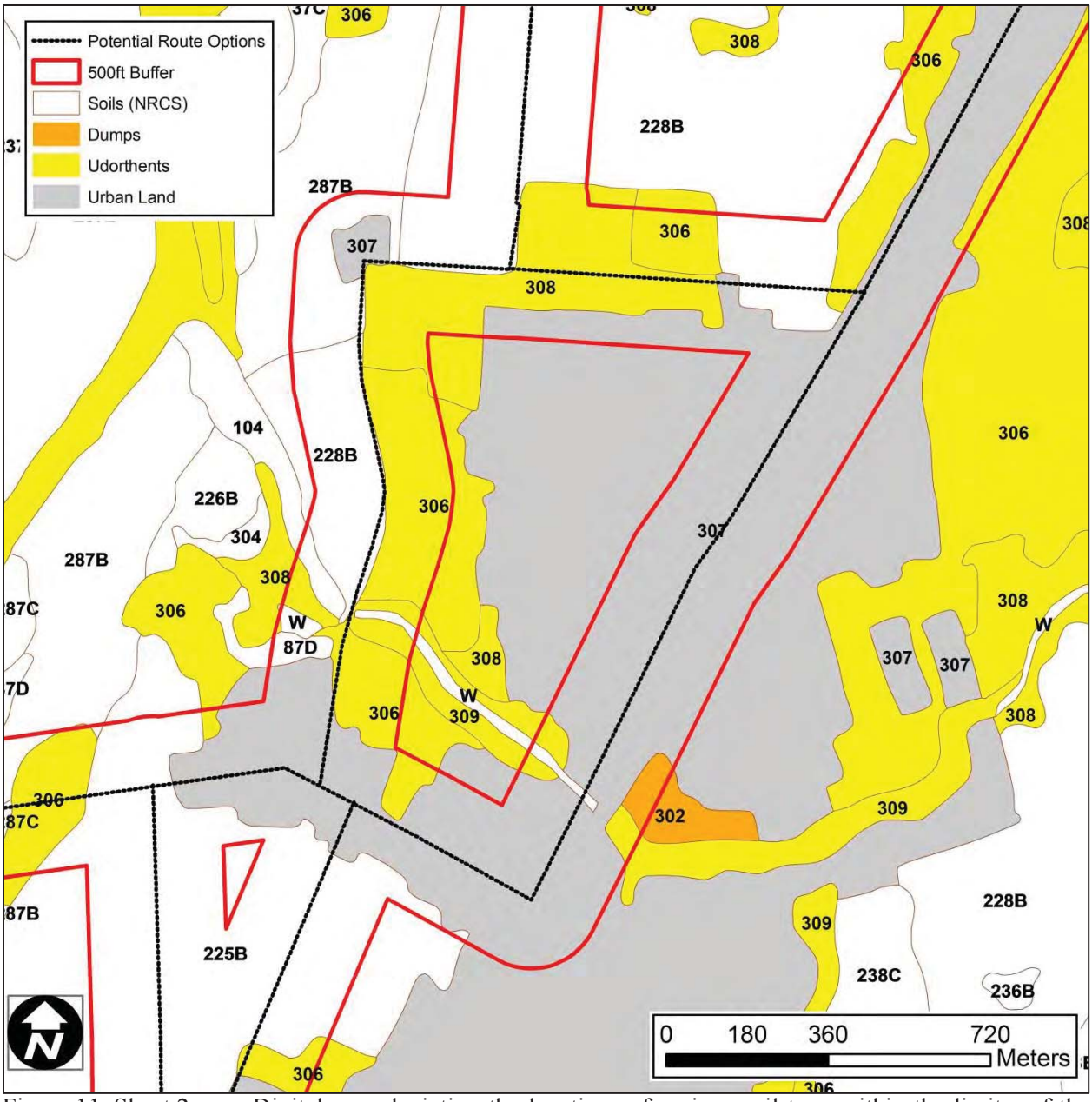


Figure 11, Sheet 2. Digital map depicting the locations of various soil type within the limits of the Greater Hartford Reliability Project Corridor in Newington and Hartford, Connecticut.

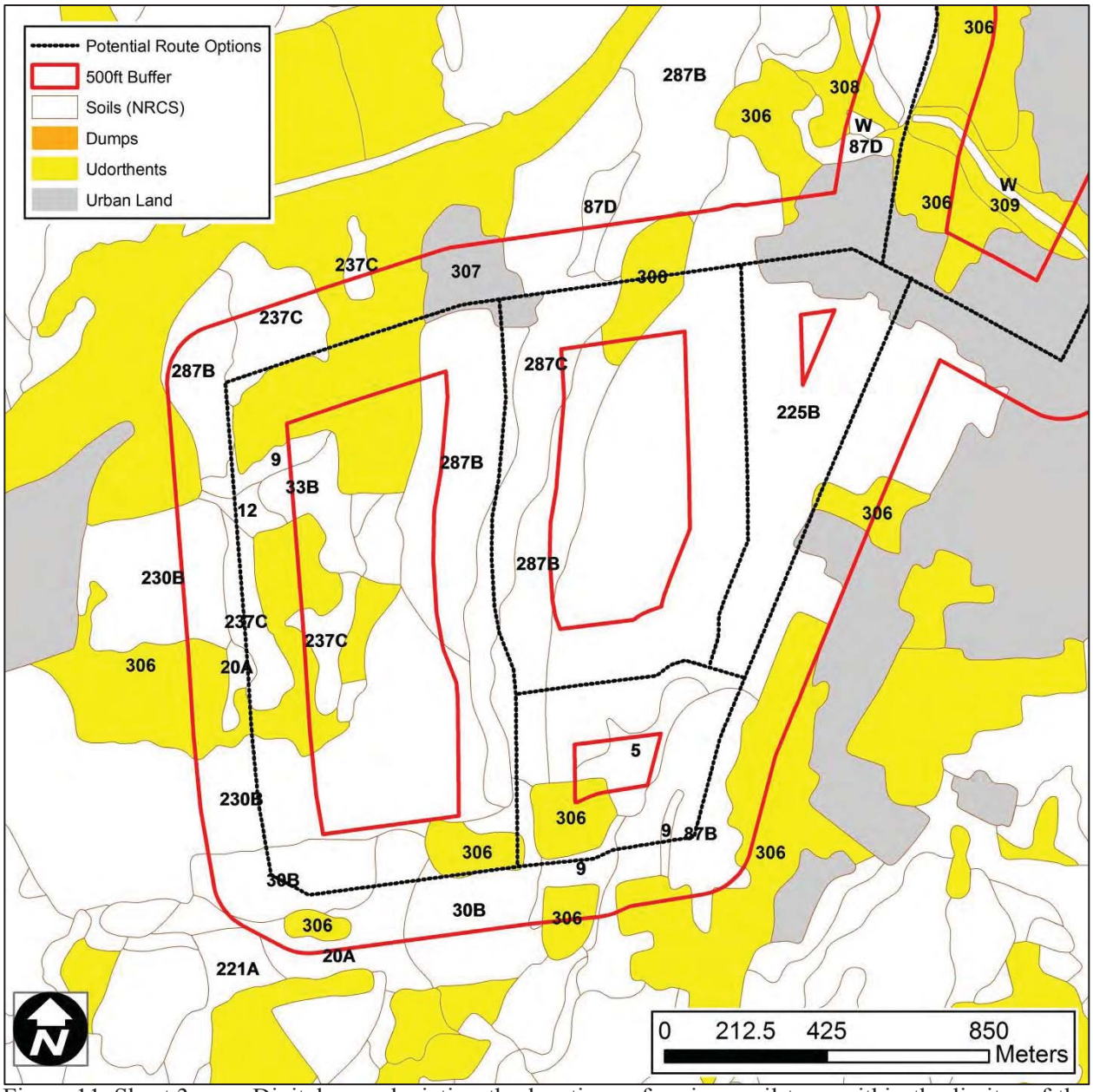


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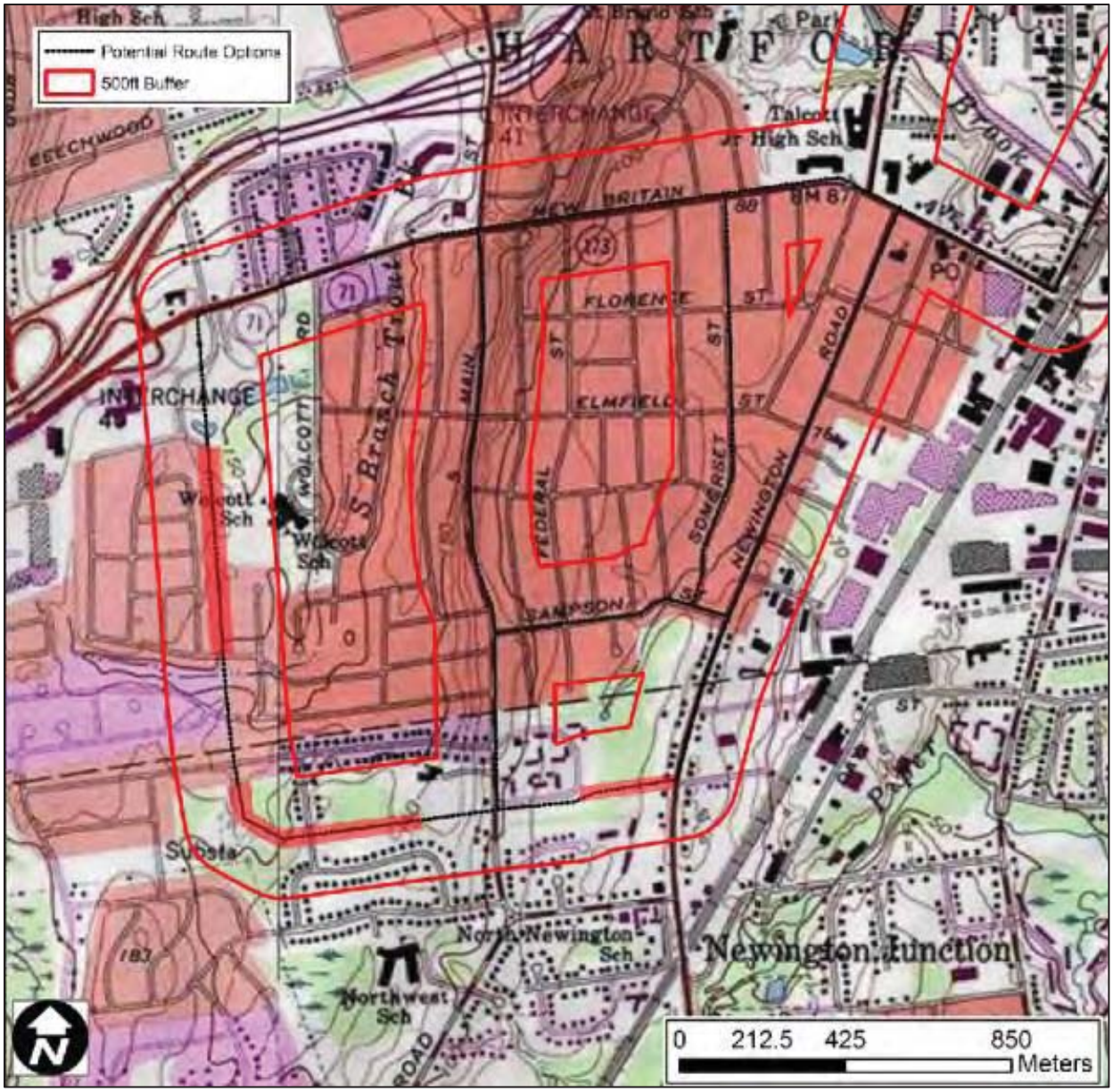


Figure 12. Excerpt for a modern USGS 7.5' series topographic quadrangle depicting the locations of areas of moderate/hihgh archaeological sensitivity within the Greater Hartford Reliability Project Corridor in Newington Connecticut (note the red polygons dnote moderate/high areas. The remainder of the region consists of areas of no/low archaeolgocial sensitivity).

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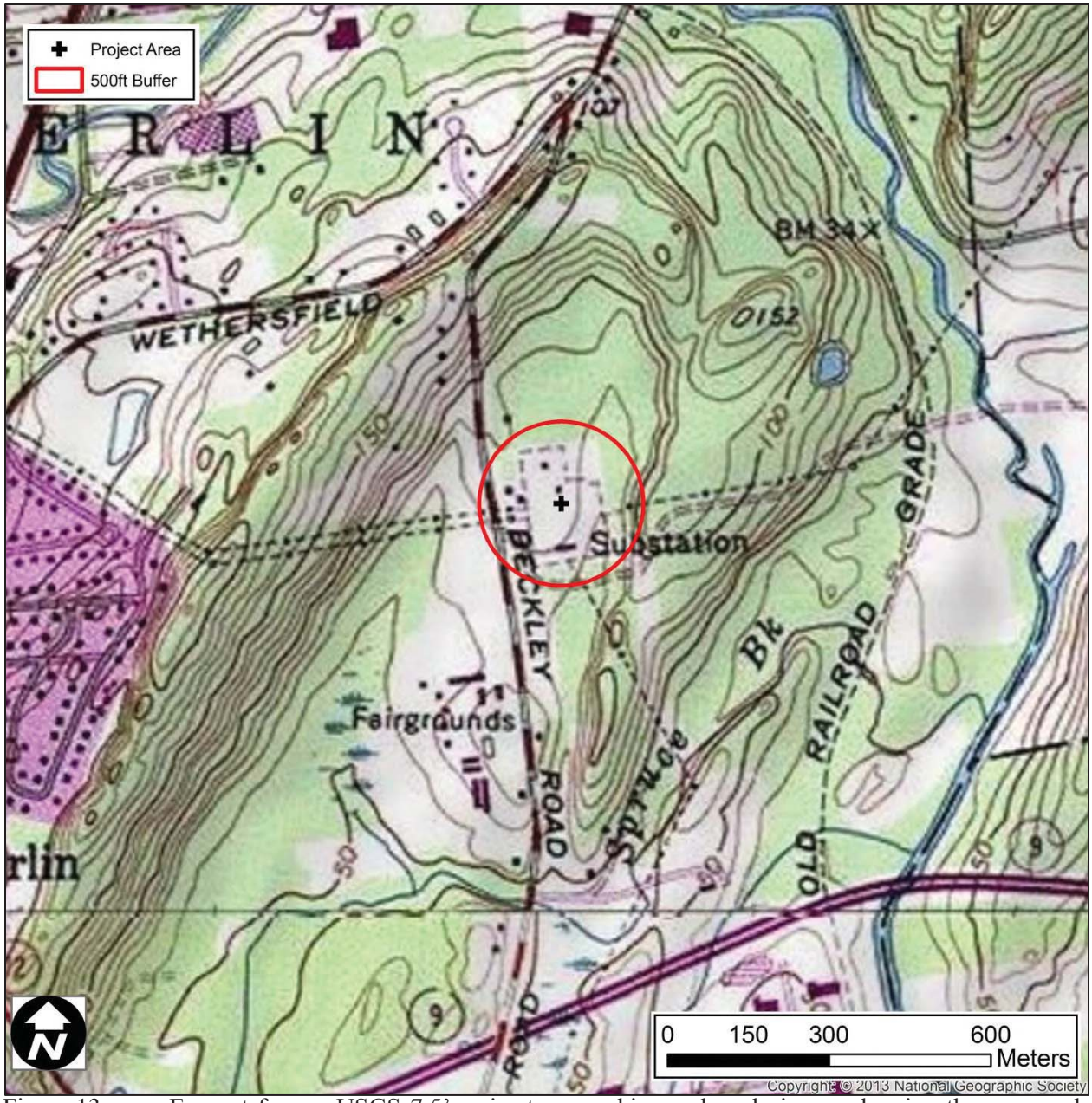


Figure 13. Excerpt from a USGS 7.5' series topographic quadrangle image showing the proposed substation expansion area in Berlin, Connecticut.

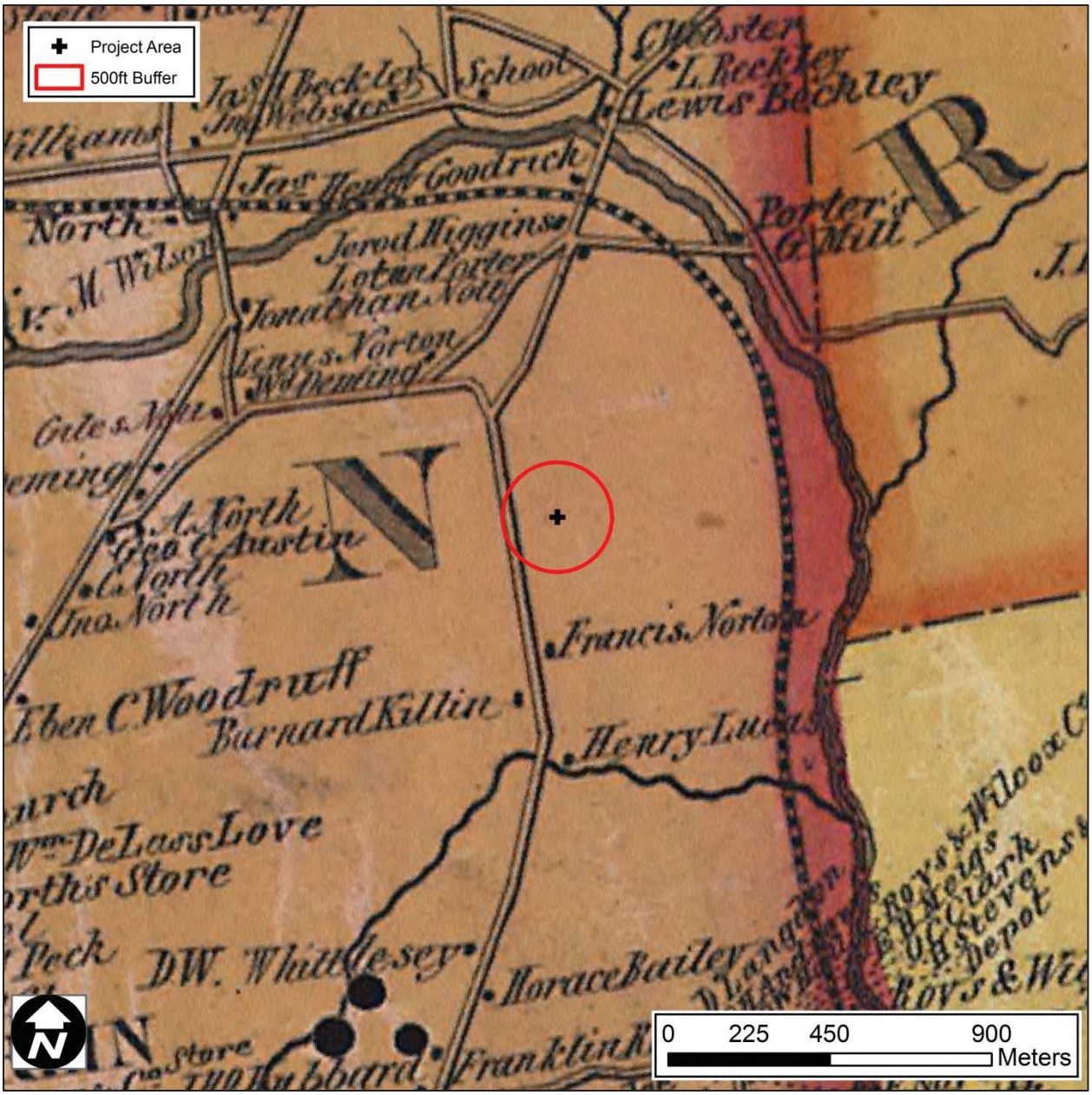


Figure 14. Excerpt from an 1855 historic map showing the proposed substation expansion area in Berlin, Connecticut.

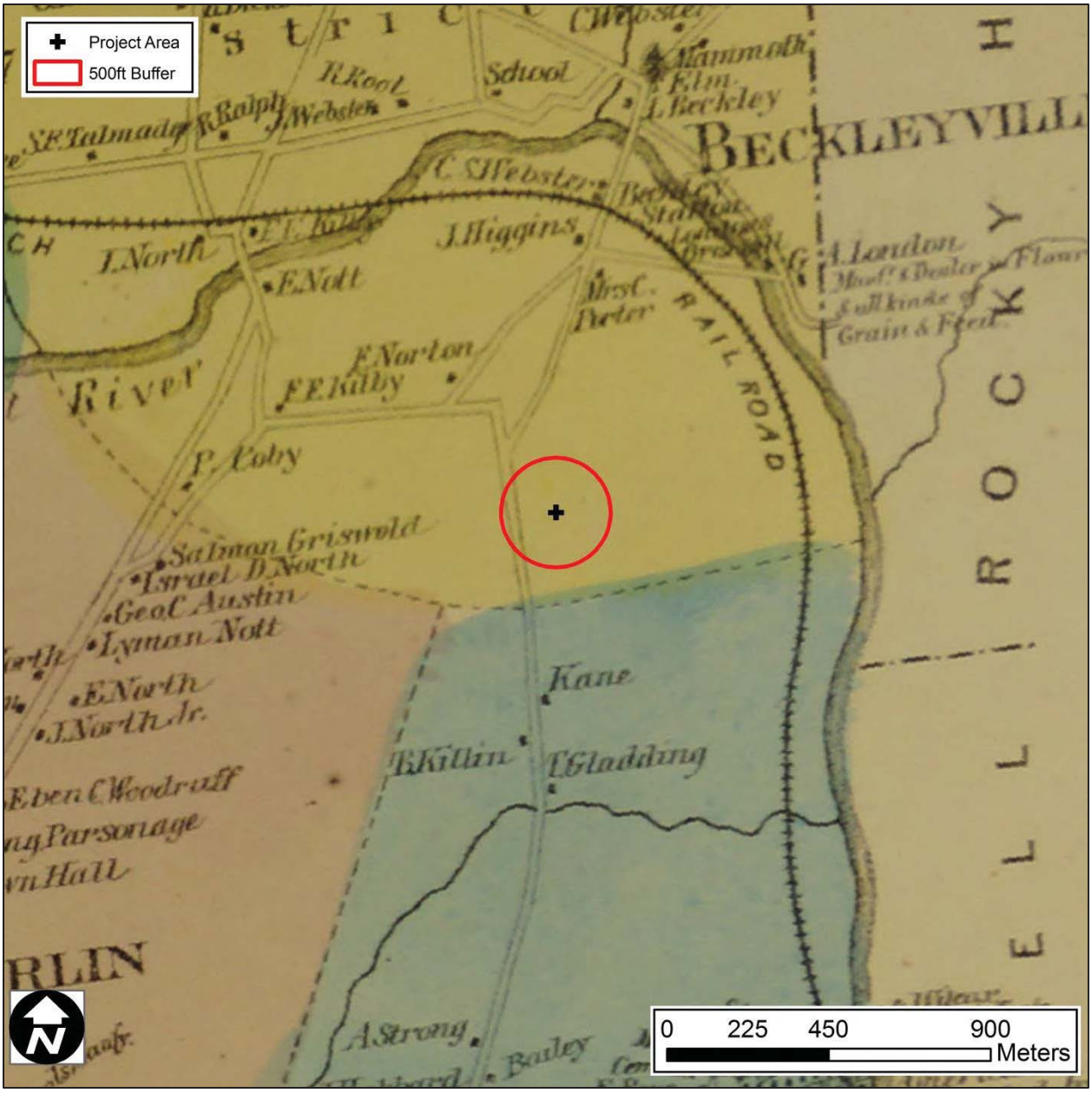


Figure 15. Excerpt from an 1869 historic map showing the proposed substation expansion area in Berlin, Connecticut.



Figure 16. Excerpt from a 1934 aerial image showing the proposed substation expansion area in Berlin, Connecticut.



Figure 17. Excerpt from a 1951 aerial image showing the proposed substation expansion area in Berlin, Connecticut.

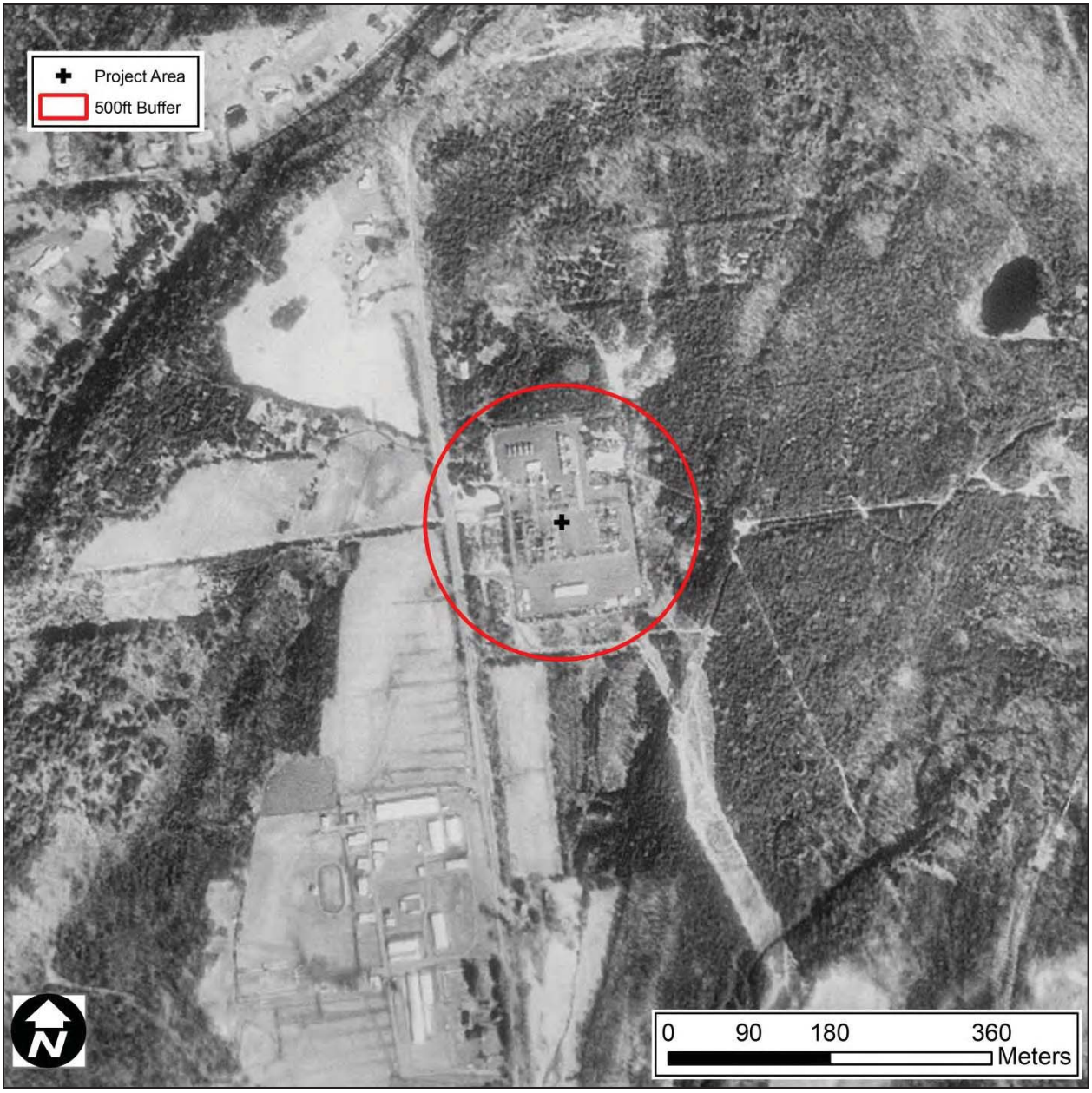


Figure 18. Excerpt from a 1990 aerial image showing the proposed substation expansion area in Berlin, Connecticut.

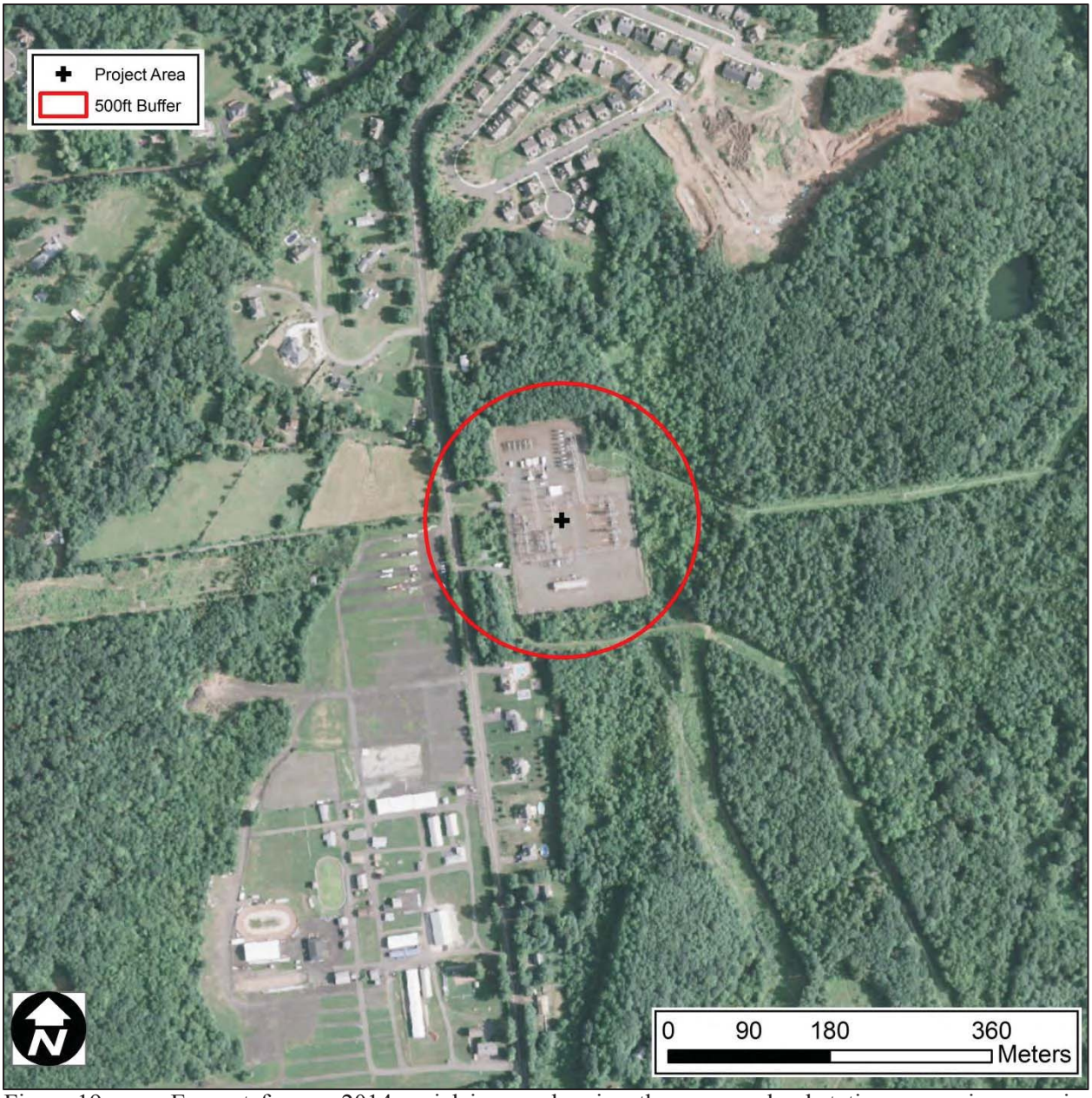


Figure 19. Excerpt from a 2014 aerial image showing the proposed substation expansion area in Berlin, Connecticut.

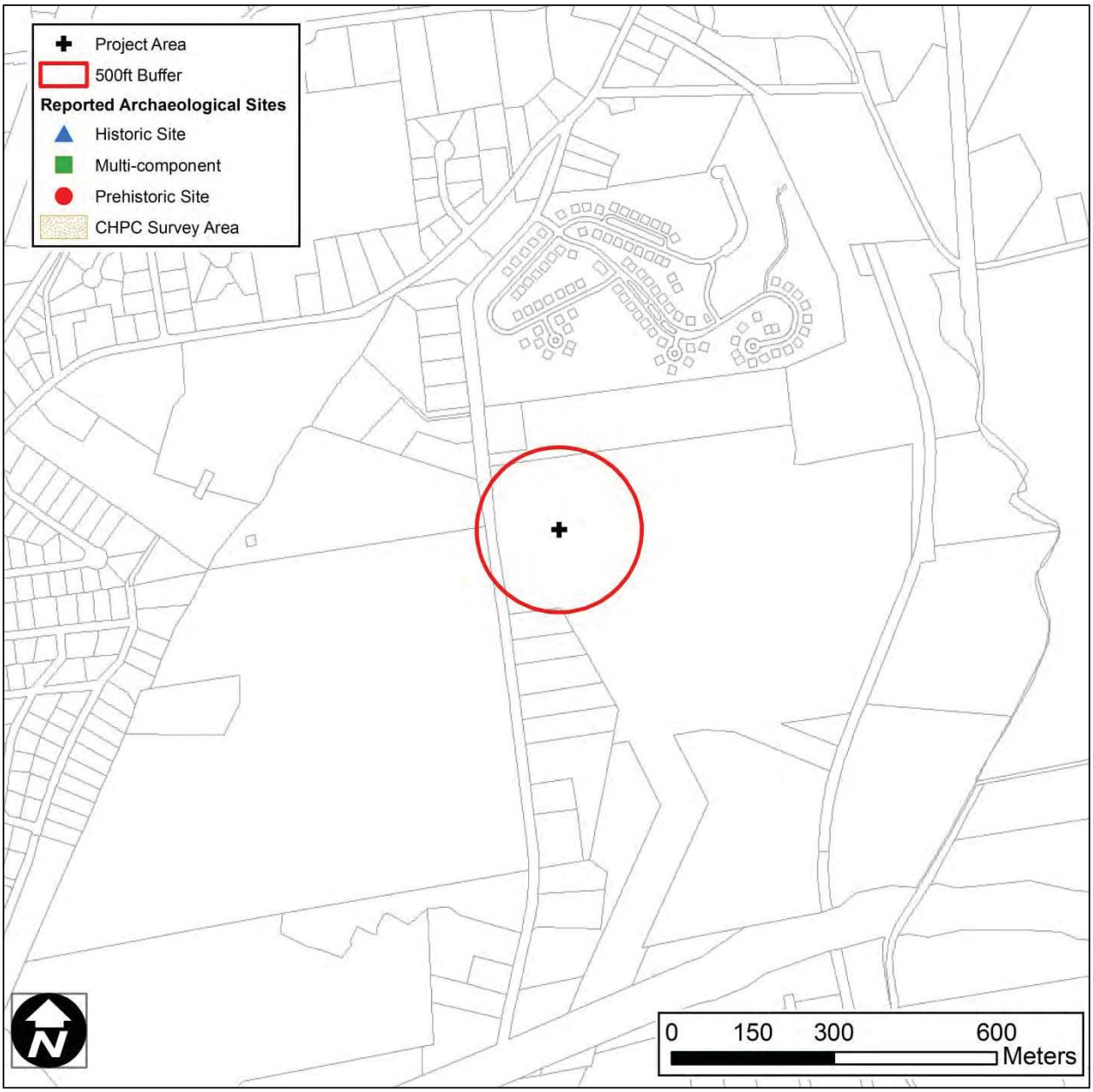


Figure 20. Digital map showing the location of previously identified archaeological sites in the vicinity og the proposed substation expansion area in Berlin, Connecticut.

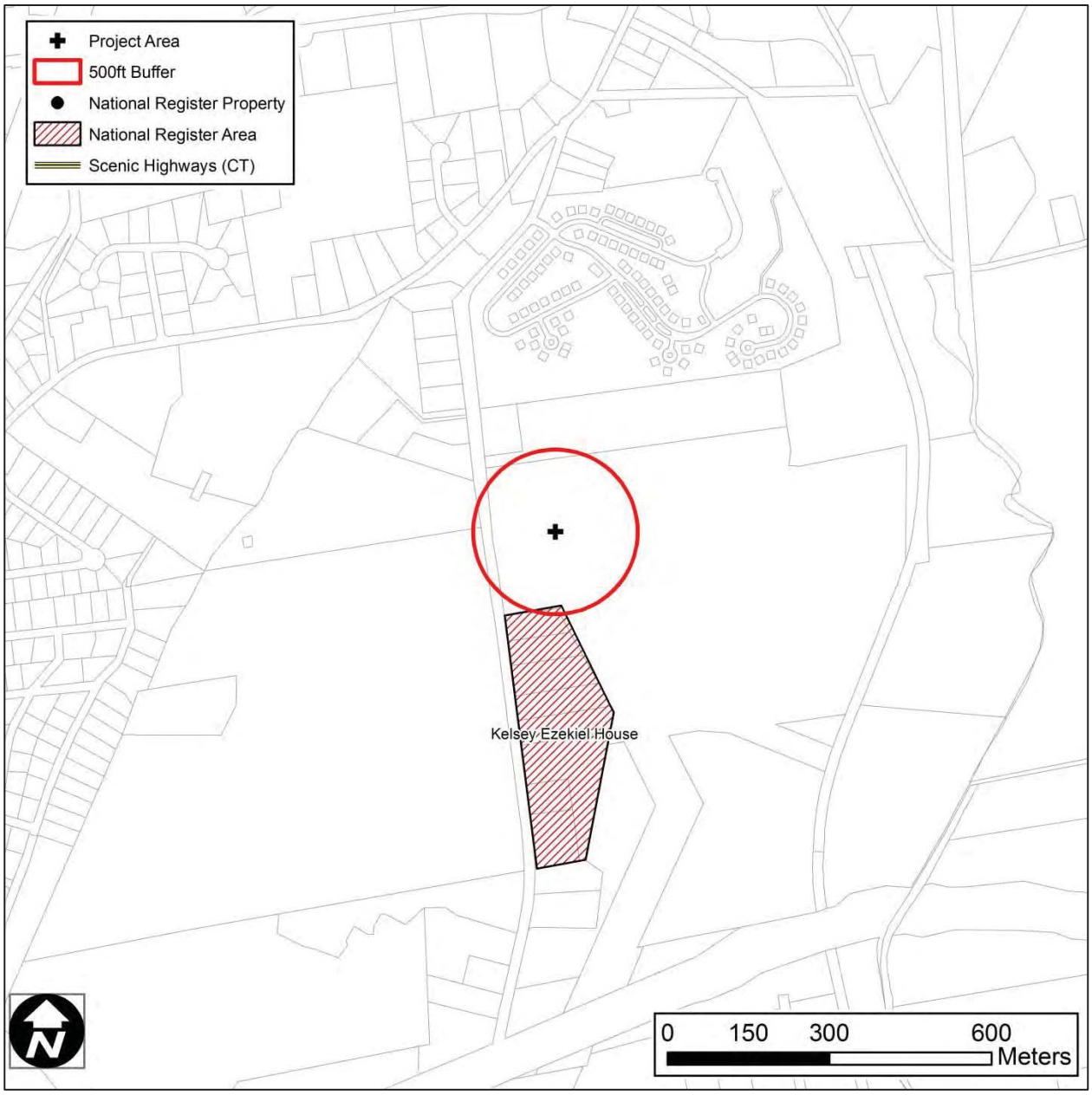


Figure 21. Digital map showing the location of previously identified National Register of Historic Places properties in the vicinity of the proposed substation expansion area in Berlin, Connecticut.

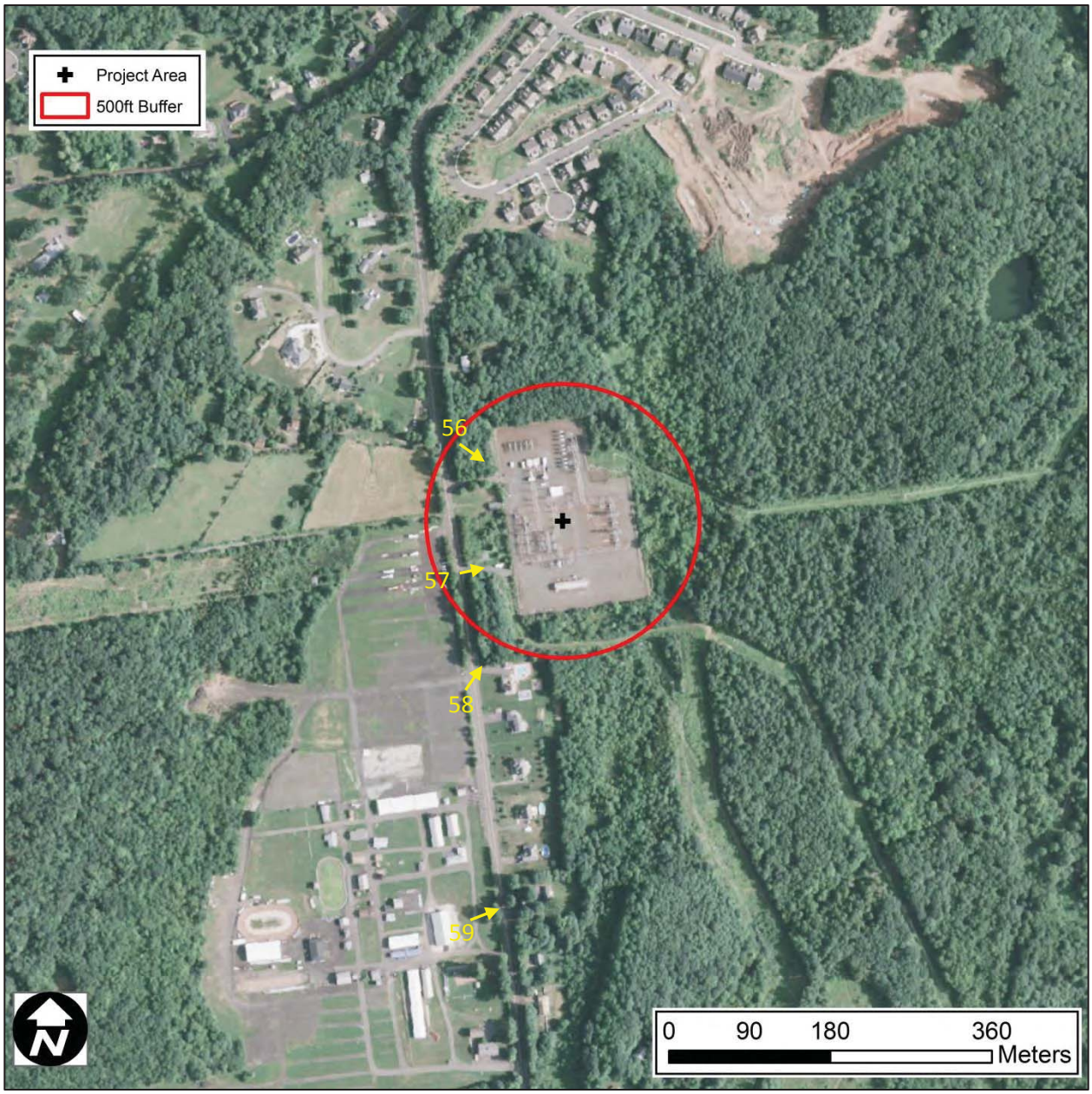


Figure 22. Excerpt from a modern aerial image showing the substation expansion area in Berlin, Connecticut and the directions from which photos were taken during pedestrian survey.

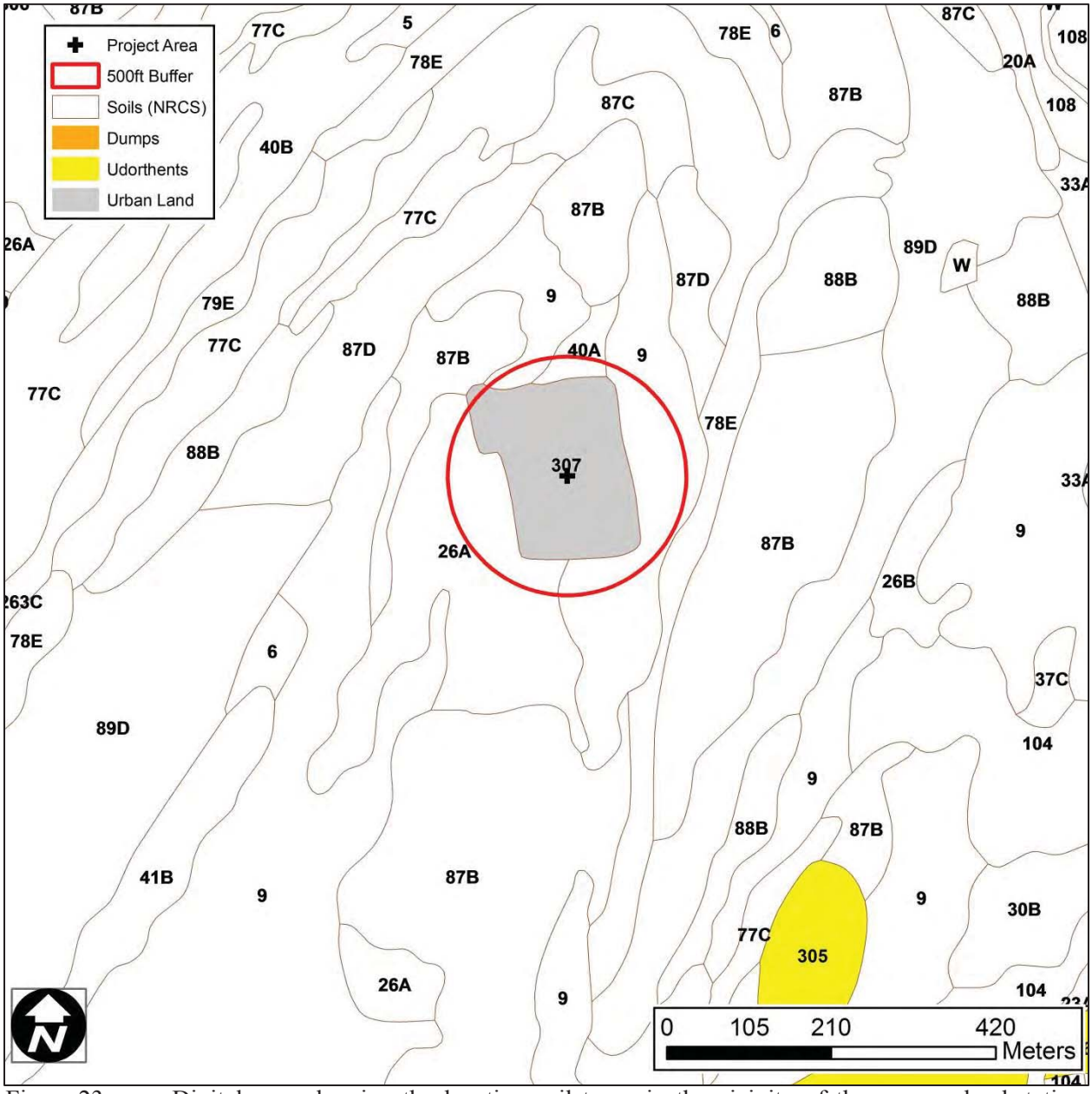


Figure 23. Digital map showing the location soil types in the vicinity of the proposed substation expansion area in Berlin, Connecticut.



Photo 1. Overview photo of the Southwest Hartford Substation facing northwest.



Photo 2. Overview photo of the proposed project corridor facing south along New Park Avenue.



Photo 3. Overview photo of the proposed project corridor facing north along New Park Avenue.



Photo 4. Overview photo of the proposed project corridor facing north along Kane Street.



Photo 5. Overview photo facing northeast from the proposed project corridor and toward the Parkville Historic District and the Royal Typewrite Company Building.



Photo 6. Overview photo of proposed project corridor facing west along Kane Street.



Photo 7. Overview photo of proposed project corridor facing northeast along Kane Street.



Photo 8. Overview photo of proposed project corridor facing north along Oakwood Avenue.



Photo 9. Overview photo of proposed project corridor facing west along Saint James Street.



Photo 10. Overview photo of proposed project corridor facing south along a dead end lane.



Photo 11. Overview photo of proposed project corridor facing south along Price Boulevard.



Photo 12. Overview photo of proposed project corridor facing south along Price Boulevard.



Photo 13. Overview photo of proposed project corridor facing east along Flatbush Avenue.



Photo 14. Overview photo of proposed project corridor facing west along Flatbush Avenue



Photo 15. Overview photo of proposed project corridor facing south along New Park Avenue.



Photo 16. Overview photo of proposed project corridor facing north along New Park Avenue.



Photo 17. Overview photo of proposed project corridor facing west along Flatbush Avenue


Photo 18. Overview photo of proposed project corridor facing north along New Park Avenue



Photo 19. Overview photo of proposed project corridor facing north along New Park Avenue



Photo 20. Overview photo of proposed project corridor facing west along New Britain Avenue.



Photo 21. Overview photo of proposed project corridor facing southwest along Newington Road.



Photo 22. Overview photo of proposed project corridor facing north along South Quaker Lane.



Photo 23. Overview photo of proposed project corridor facing west along New Britain Avenue.



Photo 24. Overview photo of proposed project corridor facing south along South Quaker Lane.

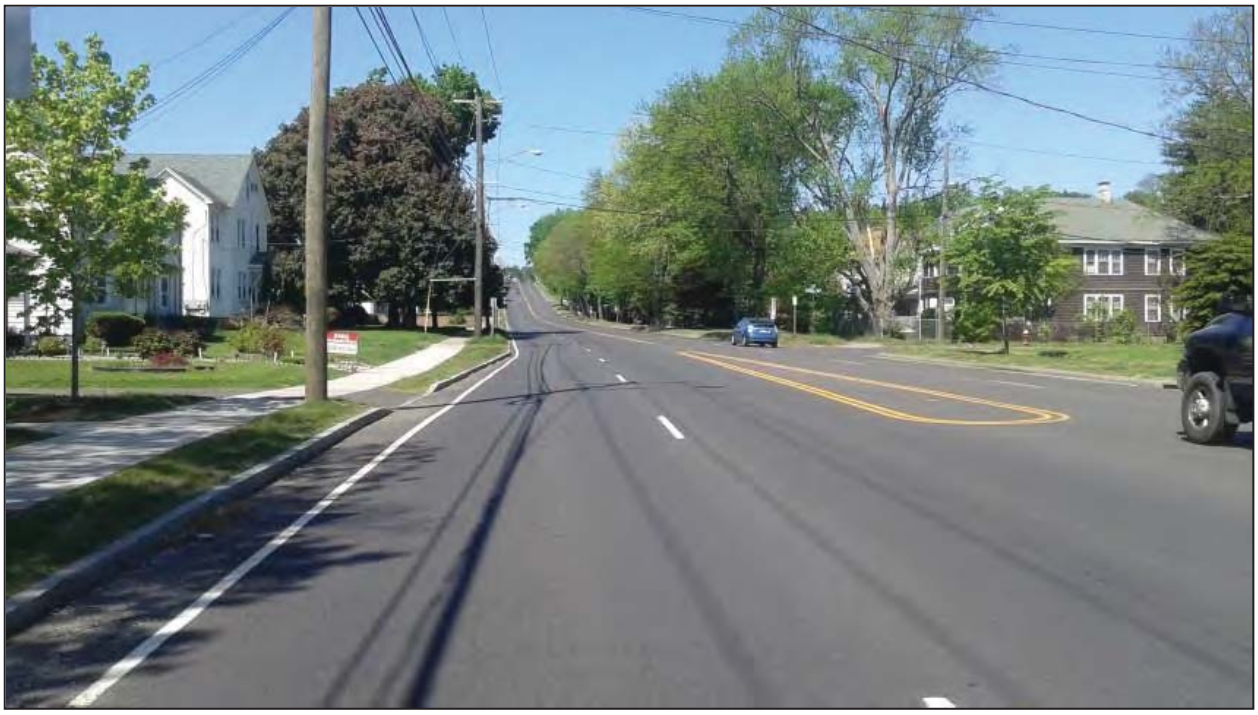


Photo 25. Overview photo of proposed project corridor facing west along New Britain Avenue.



Photo 26. Overview photo of proposed project corridor facing east along New Britain Avenue.



Photo 27. Overview photo of proposed project corridor facing south along Somerset Street.



Photo 28. Overview photo of proposed project corridor facing south along Somerset Street.



Photo 29. Overview photo of proposed project corridor facing east along Samspon Street.



Photo 30. Overview photo of proposed project corridor facing west along Samspon Street.



Photo 31. Overview photo of proposed project corridor facing north along South Main Street.

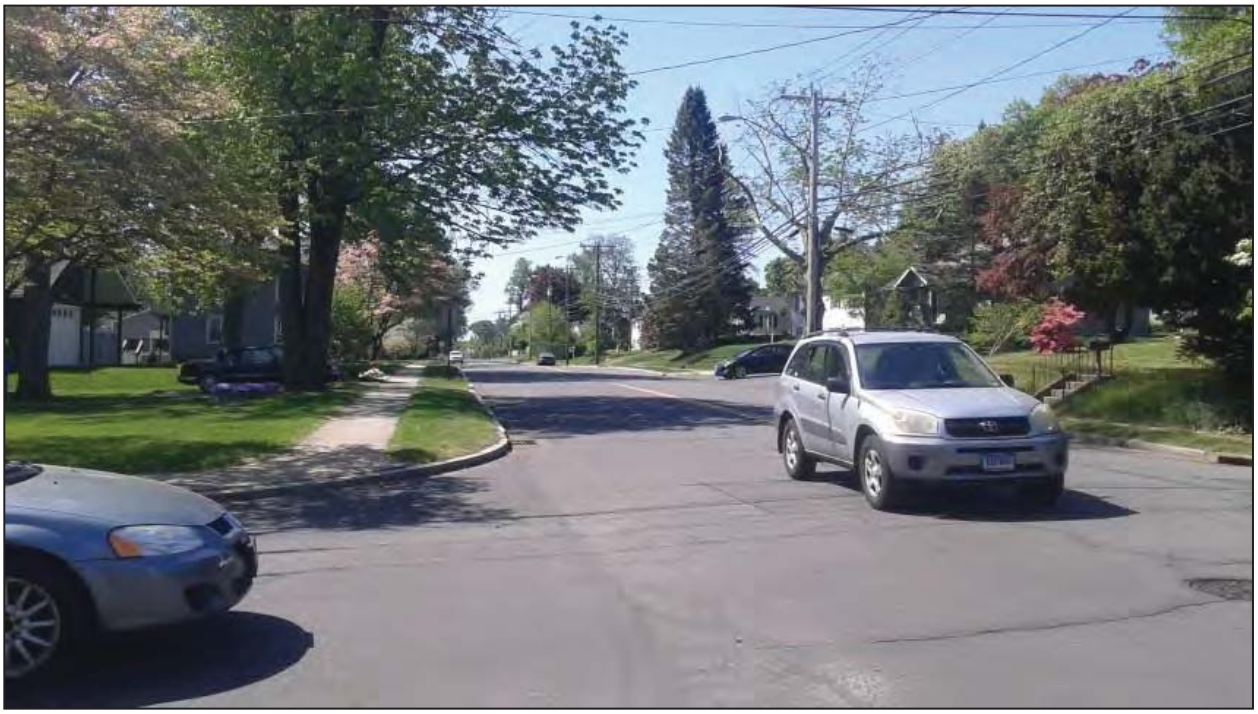


Photo 32. Overview photo of proposed project corridor facing south along South Main Street.



Photo 33. Overview photo of proposed project corridor facing east along Sampson Street.



Photo 34. Overview photo of proposed project corridor facing east along New Britain Avenue.



Photo 35. Overview photo of proposed project corridor facing south along South Main Street.



Photo 36. Overview photo of proposed project corridor facing west along New Britain Avenue.



Photo 37. Overview photo of 1168 New Britain Avenue facing northeast (this house is listed on the National Register of Historic Places).



Photo 38. Overview photo of proposed project corridor facing east along New Britain Avenue.

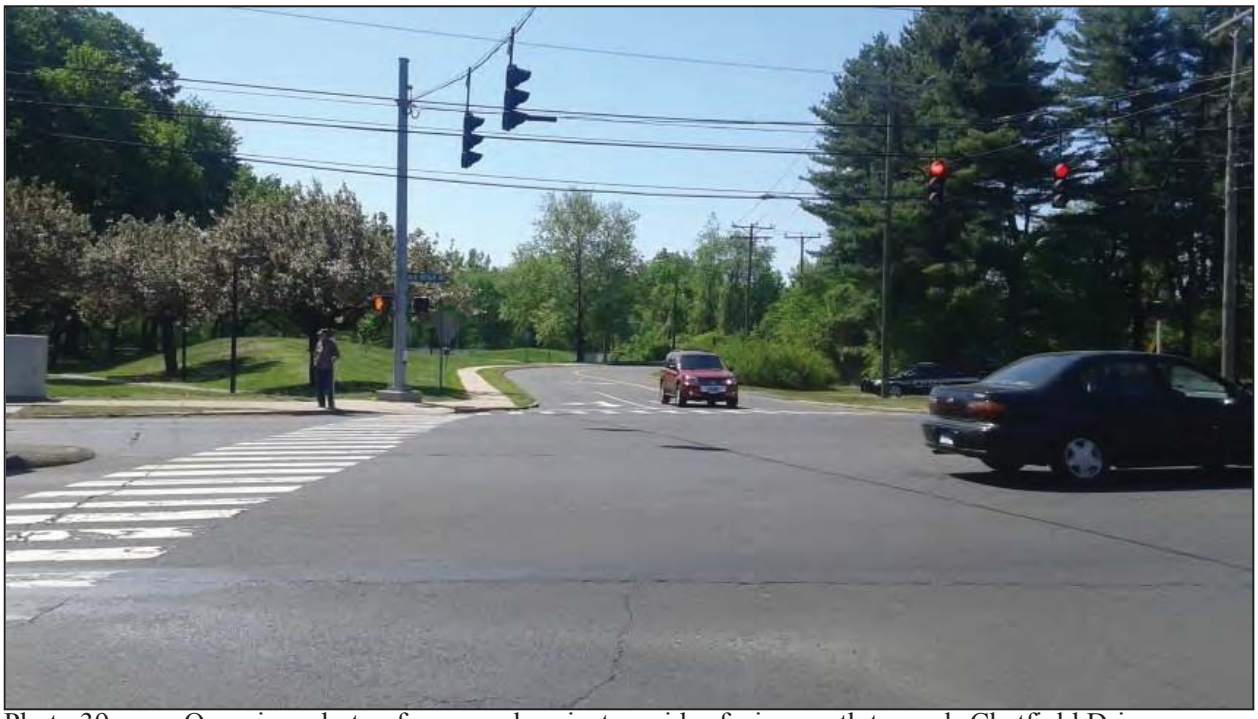


Photo 39. Overview photo of proposed project corridor facing south towards Chatfield Drive.



Photo 40. Overview photo of proposed project corridor facing north along an existing transmission line corridor.



Photo 41. Overview photo of proposed project corridor facing south along an existing transmission line corridor.



Photo 42. Overview photo of the Sarah Whitman Hooker House on the southern edge of the proposed project corridor facing south (this property is listed on the National Register of Historic Places).



Photo 43. Overview photo of the Charles E. Beacher House facing north (this house is located to the north of the proposed project corridor and it is listed on the National Register of Historic Places).



Photo 44. Overview photo of proposed project corridor facing east along an existing transmission line corridor.



Photo 45. Overview photo of proposed project corridor facing east along Cherry Hill Drive.



Photo 46. Overview photo of proposed project corridor facing west along an existing transmission line corridor.



Photo 47. Overview photo of the Newington Substation facing east.



Photo 48. Overview photo of the Newington Substation facing east.



Photo 49. Overview photo of proposed project corridor facing west along Cherry Hill Road.



Figure 50. Overview photo of proposed project corridor facing east along an existing transmission line corridor.



Photo 51. Overview photo of proposed project corridor facing west along an existing transmission line corridor.



Photo 52. Overview photo of proposed project corridor facing north along Newington Road (this area is part of the Newington Junction North Historic District).



Photo 53. Overview photo of proposed project corridor facing south along Newington Road (this area is part of the Newington Junction North Historic District).



Photo 54. Overview photo of proposed project corridor facing north along Newington Road.



Photo 55. Overview photo of proposed project corridor facing north along Newington Road.



Photo 56. Overview photo of the Berlin Substation area facing southeast.



Photo 57. Overview photo of the Berlin Substation area facing east.



Photo 58. Overview photo of the Berlin Substation area facing northeast.



Photo 59. Overview photo of the Ezekial Kelsey House facing northeast (this National Register of Historic Places property is located to the south of the Berlin Substation area).

Exhibit 2.C Electric and Magnetic Field Supporting Information

2.C.1 *Electric and Magnetic Fields Best Management Practices for the Construction of Electric Transmission Lines in Connecticut* (Connecticut Siting Council, February 20, 2014)

2.C.2 *Research on Extremely Low Frequency Electric and Magnetic Fields and Health* (Exponent, August 1, 2012 – August 31, 2016)

2.C.3 *Tabulated Calculations of Electric and Magnetic Fields*

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2.C.1 *Electric and Magnetic Fields Best Management Practices for the Construction of Electric Transmission Lines in Connecticut* (Connecticut Siting Council, February 20, 2014)

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CONNECTICUT SITING COUNCIL
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February 21, 2014

TO: Parties and Intervenors

FROM: Melanie Bachman, Acting Executive Director

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. §16-50l(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.

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2.C.2 *Research on Extremely Low Frequency Electric and Magnetic Fields and Health* (Exponent, August 1, 2012 – August 31, 2016)

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Health Sciences Practice

Exponent®

Research on Extremely Low Frequency Electric and Magnetic Fields and Health

August 1, 2012 – August 31, 2016

Research on Extremely Low Frequency Electric and Magnetic Fields and Health

August 1, 2012 – August 31, 2016

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April 11, 2017

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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 update the Connecticut Siting Council (CSC) on current health research relating to extremely low frequency (ELF) electric and magnetic fields (EMF) at the request of Eversource Energy. This supports the CSC policy to consider and review evidence of any new developments in scientific research addressing magnetic fields and public health effects or changes in scientific consensus group positions regarding magnetic during the public hearing process for new transmission line projects proposed by Eversource Energy.

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 the electricity network 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). Section 5 of 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 August 31, 2016. Finally, the report also provides a brief overview of reviews conducted on EMF health research by scientific organizations since the WHO evaluation (Section 6).

[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, 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, 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, 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, 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 August 31, 2016, 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 August 31, 2016.

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, including those near electric power lines, 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 long-term 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.

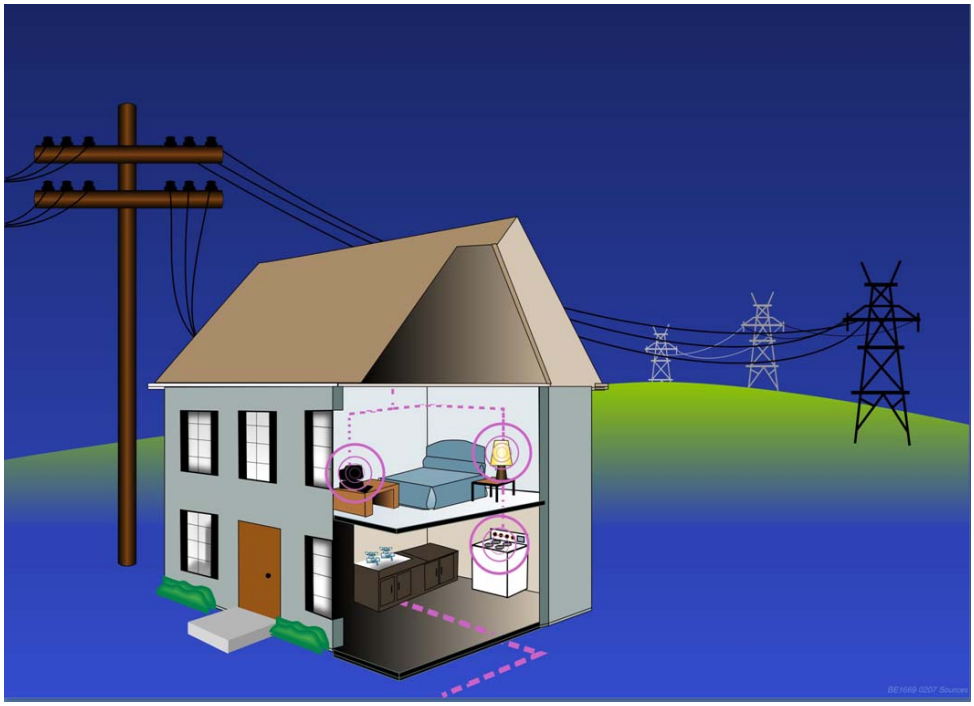


Figure 1. Common sources of ELF EMF in the home (appliances, wiring, currents running on water pipes, and nearby distribution and transmission lines).

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 long-term 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.

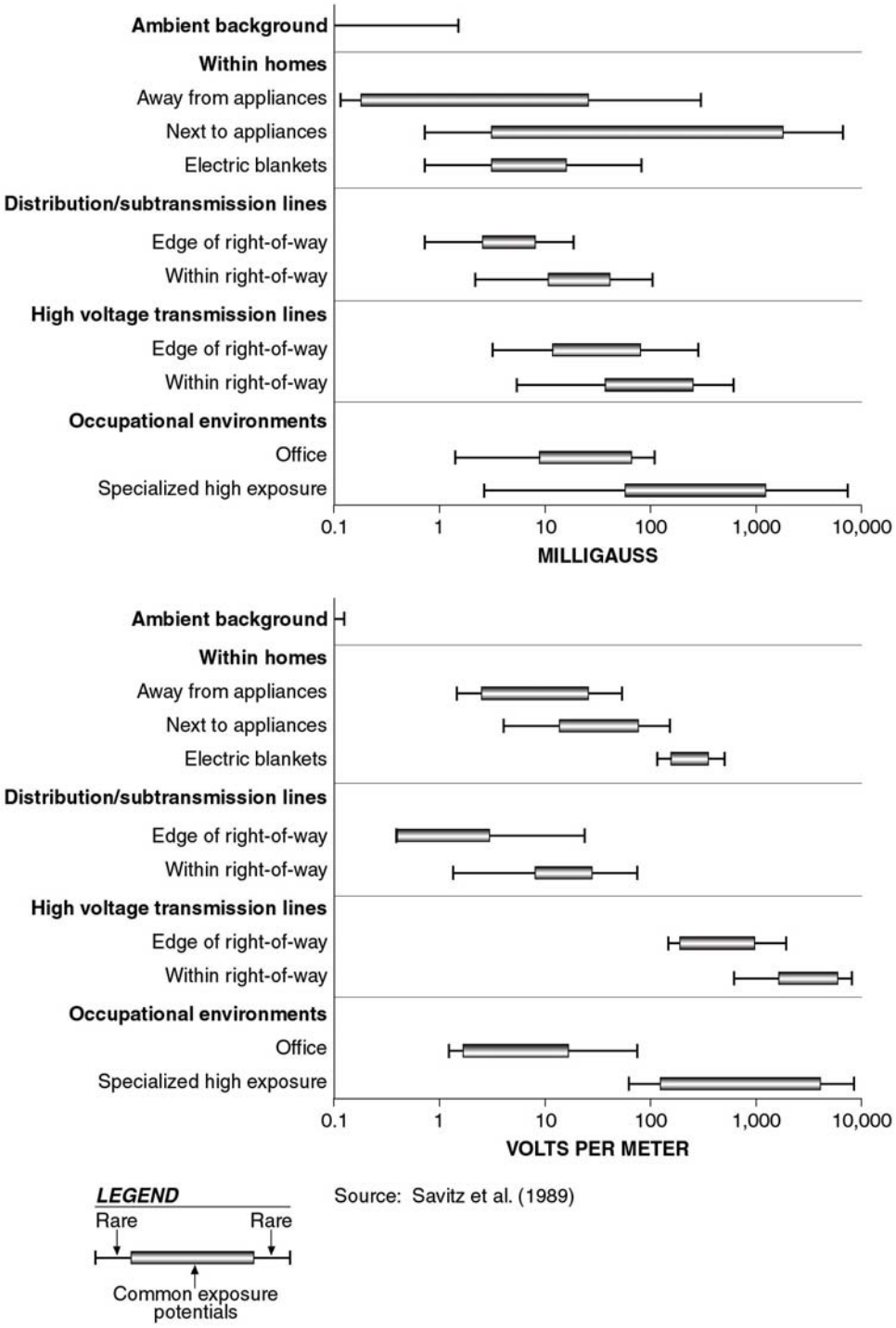


Figure 2. ELF magnetic field (upper panel) and electric field (lower panel) levels in various environments.

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-kilovots (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 (Korpinen and Pääkkönen, 2015, 2016) and the Ukraine (Okun et al., 2014), and in four power plants in Greece (Christopoulou et al., 2015). The highest measured field levels were 2,500 mG in the first Finnish study, 510 mG in the second Finnish study, 4,200 mG in the Ukranian study, and 4,700 mG in the Greek study 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 calculated induced current density in the central nervous system did not exceed the ICNIRP's 1998 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.

[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 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 chance, bias, or confounding cannot be ruled out as an explanation for the observed epidemiologic association; 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.

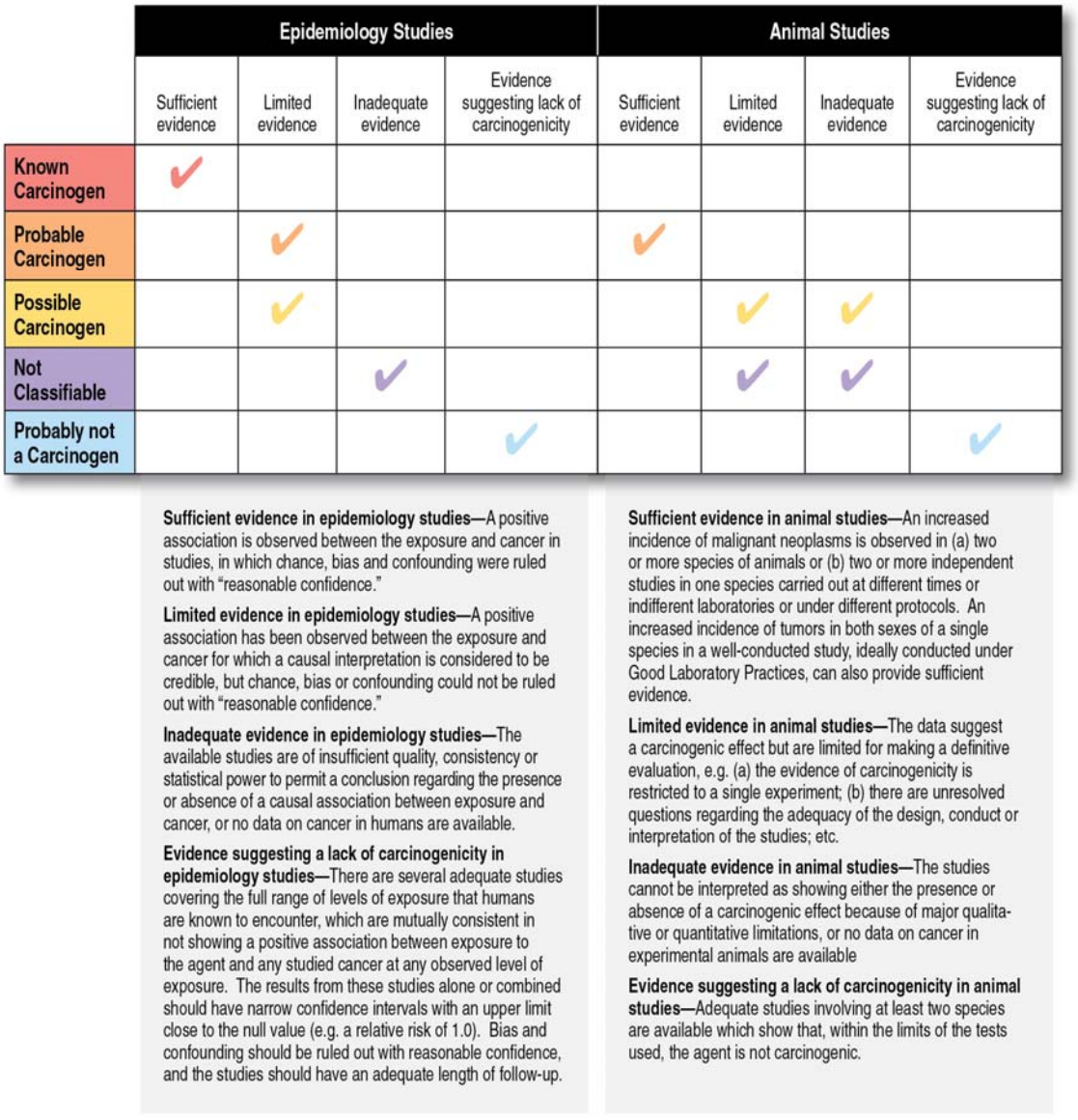


Figure 3. Basic IARC method for classifying exposures based on potential carcinogenicity.

[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 2016, 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 of 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:

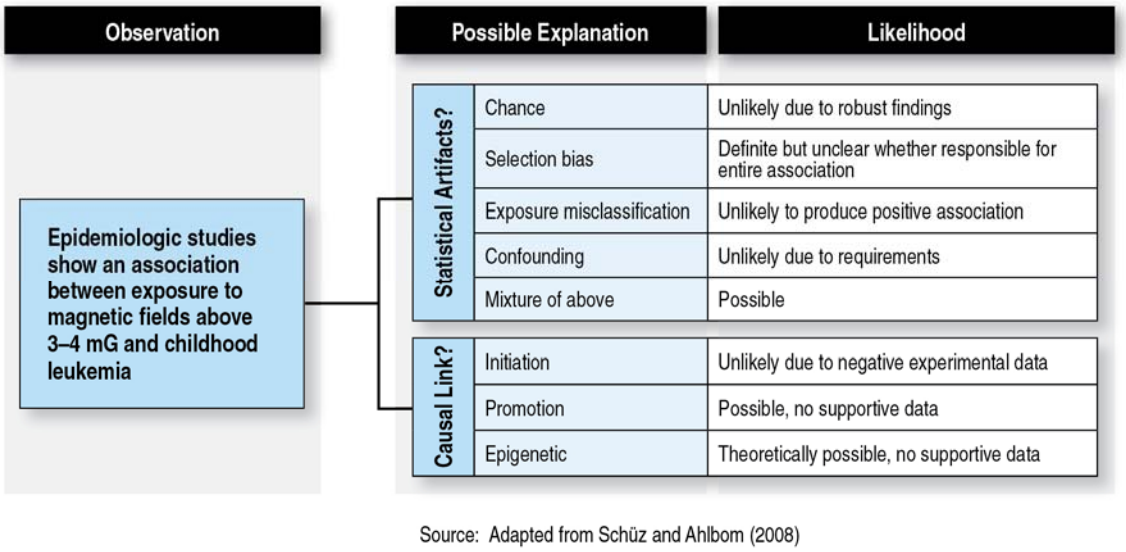
> New human, animal, and *in vitro* studies published since the 2002 IARC Monograph, 2002 [*sic*] do not change the overall classification of ELF as a possible human carcinogen (WHO, 2007, p. 347).
>
> Acute biological effects [i.e., short-term, transient health effects such as a small shock] have been 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 estimates of TWA exposure to relatively high average 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 apparent discrepancy between 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. It is worth noting here that a recommendation for further research is not an indication of the likelihood of causality, rather further research is recommended to reduce scientific uncertainty and to make sure that even small potential effects are not missed. 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, even 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 studies and *in vivo* studies of carcinogenesis related to ELF EMF exposure published from August 1, 2012 through August 31, 2016. 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 26 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 August 31, 2016.[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 23,000 publications on EMF at all frequencies and close to 6,000 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. No recent epidemiologic studies have assessed exposure to electric fields, thus, all EMF epidemiologic studies discussed below are magnetic field studies.

Childhood leukemia

In 2002, the IARC 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, approximately 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 – 2016)

Childhood leukemia continues to be the main focus of ELF EMF epidemiologic research. In recent years, several large case-control studies from France, Denmark, the United Kingdom, and California 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, 2016; Pedersen et al., 2014a, 2014b, 2015; Crespi et al., 2016). 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 to 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. In 2015, Pedersen et al., reported results of another case-control study that included all children diagnosed with a first primary leukemia

(n=1536), central nervous system (CNS) tumor (n=1324), or malignant lymphoma (n=417) in Denmark before the age of 15 years between 1968 and 2003. The study population of this paper mostly overlaps with the previously described papers. Cases were identified from the Danish Cancer Registry. Two to five controls (n=9129) for each case were selected randomly from the Danish childhood population. Controls were matched to cases based on their sex and year of birth. For all study subjects, average magnetic-field exposure levels were calculated from overhead 50- to 400- kV power lines based on their residential addresses from 9 months before birth until the diagnosis. The authors reported statistically non-significant associations between cancers combined and three types of cancers separately and estimated exposures ≥0.4 microtesla (μT) compared to <0.1 μT. The large number of cases and controls in the study, the inclusion of residential history and exposure assessment throughout their children's entire lifetime, control for some potential confounders (including radon exposure, traffic related air pollution, socioeconomic status) and the reliance on reliable population-based cancer and population registries in Denmark are among the strengths of the study. Reliance on calculated magnetic-field levels for exposure assessment and lack of details on the accuracy of the input data to these calculations, including historical line loading and distance to residence are among the limitations of the paper.

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 separate 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.

Based on additional analyses of the data, Bunch et al. (2016) reported that the risk increases observed in the earlier years, which were more pronounced among older children (aged 10-14 years), and for myeloid leukemia, were linked to calendar year of birth or year of cancer diagnosis, rather than the age of the power lines. This finding implies that whatever factors

might have resulted in the apparent risk increase in the earlier years of the study are less likely to be linked to the newly built or existing power lines, and more likely to be related to a yet to be identified characteristic of the population (or chance variation) in those years. Analyses by regions of the country did not suggest any clear pattern. The authors concluded that their findings, overall, do not provide support for the etiologic role of magnetic fields in the reported associations.

Crespi et al. (2016) reported results of a large, record-based case-control study of childhood leukemia (n=5,788) and CNS tumors (n= 3,308) diagnosed between 1986 and 2008 and residential proximity to high-voltage overhead power lines (60 kV to 500 kV) in California. Additional details on methods were presented in a previous publication (Kheifets et al., 2015). Cases were identified from the California Cancer Registry and age and sex matched controls were selected from the California Birth Registry. Birth record was also obtained for cases. For all subjects, distance of the address at birth to the nearest power line was estimated using geographic information systems, aerial imaging from Google Earth, and, for a subset of subjects, site visits. The authors reported no consistent overall associations between risk of leukemia or CNS tumor and residential distance to power lines with voltage 200 kV and above. A statistically non-significant increase was reported for childhood leukemia among subjects with addresses closer than 50 meters to 200+ kV power lines. Analyses that also included lower voltage lines revealed no associations for either leukemia or CNS tumors. In a separate publication, details of magnetic-field calculations for the same study populations also were presented (Vergara et al., 2015); thus, it may be anticipated that associations between cases and controls based calculated field levels will be investigated in the future.

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. An apparent duplication of the study with near identical results and limitations was also published (Tabrizi and Hossein, 2015). A letter to the editor that highlighted major flaws in the study also pointed out the apparent duplication and suggested retraction of the second publication (Dechent and Driessen, 2016).

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.

Several meta-analyses have been published by Chinese researchers in recent years. 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. Su et al. (2016) conducted a meta-analysis of 11 case-control studies and 1 cohort study that investigated the association between parental exposure to EMF and risk of childhood leukemia in the offspring. Overall, neither maternal nor paternal occupational EMF exposure was associated with childhood leukemia risk. The authors noted, however, that they observed an association when they combined small and low-quality studies, but not when they combined larger and high-quality studies. Zhang et al. (2016) combined epidemiologic studies of all types of cancer in their meta-analyses, including studies of adult and childhood cancers. Since various adult and childhood cancers have very different etiologies and biological mechanisms, it is scientifically not defensible to expect that any specific exposure will have an identical effect on the risk of all types of cancers, which renders the study's main results mostly meaningless, or difficult to interpret at best.

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. While some (Jeffers, 2015) questioned the validity of the employed modeling in the study claiming that corona ions may travel farther than 600 meters from the line, the authors responded that if corona ions were to explain the association reported up to 600 meters by Draper et al. (2005), exposure beyond that distance has no relevance in the context of the study because that would not contribute to the reported association (Swanson et al., 2015).

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; Schüz et al., 2016). In contrast, Leitgeb (2014, 2015) 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 this analysis.

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). A recent evaluation by a European Union funded research consortium concluded that recent research results have not provided new evidence that would change the overall conclusion reached by IARC in 2001, and the current evidence is consistent with the possibly carcinogenic classification (Schüz et al., 2016). 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 of residential exposure to EMF among children also continues to be of interest. While not linked to any specific health outcomes, EMF exposure assessment studies of children have recently been reported from Australia, Italy, Spain, and Switzerland (Karipidis, 2015; Struchen et al., 2015; Liorni et al., 2016; Gallastegi et al., 2016).

Assessment

In summary, while most of the recently published large and methodologically advanced studies showed no statistically significant associations (e.g., Bunch et al., 2014, Pedersen et al., 2014a, 2014b, Pedersen et al., 2015; Crespi et al., 2016), the association between childhood leukemia and magnetic fields observed in some earlier 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]

[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.

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; Rudant et al., 2015).

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
Bunch et al.	2016	Epidemiological study of power lines and childhood cancer in the UK: further analyses
Chang et al.	2014	Validity of geographically modeled environmental exposure estimates
Crespi et al.	2016	Childhood leukaemia and distance from power lines in California: a population-based case-control study
Dechent and Driessen	2016	Re: Role of Electromagnetic Field Exposure in Childhood Acute Lymphoblastic Leukemia and No Impact of Urinary Alpha- Amylase - a Case Control Study in Tehran, Iran
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
Leitgeb	2015	Synoptic analysis clarifies childhood leukemia risk from ELF magnetic field exposure
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
Pedersen et al.	2015	Residential exposure to extremely low-frequency magnetic fields and risk of childhood leukaemia, CNS tumour and lymphoma in Denmark
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
Schüz et al.	2016	Extremely low-frequency magnetic fields and risk of childhood leukemia: A risk assessment by the ARIMMORA consortium
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
Su et al.	2016	Associations of parental occupational exposure to extremely low-frequency magnetic fields with childhood leukemia risk

Author	Year	Study Title
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.
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
Tabrizi and Hosseini	2015	Role of Electromagnetic Field Exposure in Childhood Acute Lymphoblastic Leukemia and No Impact of Urinary Alpha- Amylase--a Case Control Study in Tehran, Iran
Teepen and van Dijck	2012	Impact of high electromagnetic field levels on childhood leukemia incidence
Vergara et al.	2015	Case-control study of occupational exposure to electric shocks and magnetic fields and mortality from amyotrophic lateral sclerosis in the US, 1991-1999
Zhao et al.	2014a	Magnetic fields exposure and childhood leukemia risk: a meta-analysis based on 11,699 cases and 13,194 controls
Zhang et al.	2016	Meta-analysis of extremely low frequency electromagnetic fields and cancer risk: a pooled analysis of epidemiologic studies
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?
†Comments and Replies on Swanson et al. 2014b		
Jeffers	2015	Comment on: Childhood cancer and exposure to corona ions from power lines: an epidemiological study
Swanson et al.	2015	Reply to 'Comment on: Childhood cancer and exposure to corona ions from power lines: an epidemiological study'.

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 – 2016)

The potential relationship between residential proximity to overhead and underground transmission lines and childhood brain cancer also has been investigated in some of the epidemiologic studies discussed in the childhood leukemia section (Bunch et al., 2014; Bunch et al., 2015; Bunch et al., 2016; Pedersen et al., 2015; Crespi et al., 2016). 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 follow up analyses that investigated the occurrence of cancer separately among younger and older children (Bunch et al., 2016), no clear pattern was identified. 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.

As described above in the childhood leukemia section, the childhood cancer epidemiologic studies conducted in Denmark and California also included cases of CNS tumors (Pedersen et al., 2015; Crespi et al., 2016). Neither of the two studies reported any consistent association between residential proximity to power lines and childhood brain cancer risk regardless of investigated time periods and voltage of the included transmission lines.

Assessment

The studies published between 2012 and 2016 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
Bunch et al.	2016	Epidemiological study of power lines and childhood cancer in the UK: further analyses
Crespi et al.	2016	Childhood leukaemia and distance from power lines in California: a population-based case-control study
Pedersen et al.	2015	Residential exposure to extremely low-frequency magnetic fields and risk of childhood leukaemia, CNS tumour and lymphoma in Denmark

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 – 2016)

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).

Gundy et al. (2016) reported results of their population-based case-control study of male breast cancer and occupational exposure to magnetic fields. Cases (n=115) were identified from eight Canadian provinces through the provincial cancer registries between 1994 and 1998. Controls (n=570), matched on age and sex, were selected from provincial health insurance plans or using random digit dialing. Information on demographic characteristics and occupational history was obtained through self-administered questionnaires. Exposure to magnetic fields was assessed by expert review of the jobs held by the study subjects, and classified into three categories (<0.3, 0.3 to <0.6 and ≥0.6 μT). The authors reported statistically non-significant risk increases with highest average exposure ≥0.6 μT compared to exposure <0.3 μT, and with having an exposed job (≥0.3 μT) for at least 30 years compared to never having an exposed job.

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. As mentioned earlier, Zhang et al. (2016) combined epidemiologic studies of all types of cancer in their meta-analysis, including studies of adult and childhood cancers, which renders their main conclusions mostly meaningless, or difficult to interpret at best. Based on a sub-analysis that included 23 epidemiologic studies, the authors reported no statistically significant associations for breast cancer.

Assessment

The recent large case-control and cohort studies, which report no statistically significant associations with female or male breast cancer, add to the 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!
Grudy et al.	2016	Occupational exposure to magnetic fields and breast cancer among Canadian men
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
Zhang et al.	2016	Meta-analysis of extremely low frequency electromagnetic fields and cancer risk: a pooled analysis of epidemiologic 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 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 – 2016)

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, and provide no overall 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. Kheifets et al. (2008) updated meta-analyses they had published in 1995 and 1997. Their updated meta-analysis indicated that pooled risk estimates from more recent studies were lower than in past meta-analyses, and no consistent pattern was seen by leukemia subtypes. Thus the combined results were not in support of a causal association between occupational EMF exposure and adult leukemia.

Recent studies (2012 – 2016)

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 – 2016)

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-

[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).

field insensitive) following 2 weeks of continuous exposure to 1,000 mG, 50-Hz magnetic fields. Control rats were sham exposed and analyses conducted in a blinded manner. Using a 2.5-fold change as the cut-off for establishing an exposure-related response, only 22 of 31,100 gene transcripts were altered with magnetic-field exposure in the two rat strains combined. Genes with the greatest change in response to magnetic-field exposure in F344 rats (with no change in expression 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 tissues collected in 2005 through 2006, magnetic-field exposure was associated with increased α-amylase activity in cranial, but not caudal, mammary tissues of both F344 and Lewis rats. Thus, the response did not correlate with the observed rat strain susceptibility to magnetic-field exposure. In 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 Lewis rats). 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.

Because of the potential significance of chronic exposure studies, two publications by Soffritti et al. are discussed in detail below. Soffritti et al. (2016a) conducted two experiments at the same time. The first involved exposures of over 5,000 rats to 50-Hz magnetic fields at intensities of 0, 20, 200, 1,000, and 10,000 mG for 19 hours per day starting before birth and continuing over their lifetime. In the second experiment, only 600+ rats were administered a single dose of high-energy x-rays (0.1 Gray), a known cause of cancer, at 6 weeks of age and then exposed to either 0 mG, 200 mG, or a 10,000 mG 50-Hz magnetic field for 19 hours per day starting before birth and continuing over the life span. These authors had included some data from both experiments in a book chapter and reported that among female rats there was no significant effect of either magnetic-field treatment (10,000 mG) alone, 0.1 Gray of high-energy x-rays, or combined exposure to 20 or 10,000 mG + radiation (Soffritti et al., 2010). Soffritti et al. (2016a), however, does not include the results from groups exposed to magnetic fields alone. Although sharing the same room with exposed rats, there was no evidence that the control group for these studies was housed in the same way as the rats exposed to magnetic fields (i.e., a sham exposure). The number of animals per treatment group was >100 per sex per group in the treated groups and ≥500 per sex in the unexposed group; therefore, statistical variation is probably the smallest source of uncertainty in this study compared to that from other factors. The design of the study, however, has severe limitations including: 1) the reported absence of sham controls, which would have had all conditions of housing, light, handling, etc., the same as the exposed groups (with the exception of exposure); 2) the allocation of individual rats to groups was not random and no account of within-litter effects was made in the statistical analysis; and 3) the histologic analyses were not reported to have been performed without *a priori* knowledge of the exposure condition that would to prevent bias in the scoring of the tissues.

Soffritti et al. (2016a) reported no effects of radiation + magnetic field treatment on the body weights or survival rates of male or female rats. The incidence of benign mammary fibroadenomas was statistically increased in the males, but not females, exposed to 10,000 mG + radiation compared to the unexposed control group. Atypical hyperplasia within the glands was reported to be increased in females in groups exposed to 200 and 10,000 mG + radiation (although not in a dose-related manner) and males only at 10,000 mG + radiation. The percent of animals with actual cancers of the gland was greater in female rats exposed to radiation alone (7.6 %) than radiation + 20 mG (7.5%), but was less than in females exposed to radiation + 10,000 mG (16.1%).[17] In contrast, male rats exposed to radiation + 20 mG had a higher incidence of cancers (2.9 %) than rats exposed to radiation + 10,000 mG (0.9%) or unexposed controls/radiation only groups (0% and 0.2%, respectively). Additionally, males exhibited a statistically significant increased incidence of malignant schwannomas in the heart at both magnetic-field strengths and greater at 10,000 mG than 20 mG, but fewer than three rats in any group developed such tumors; thus, a larger study would be needed to resolve the relation to treatment for this finding. Finally, hemolymphoreticular neoplasms (lymphomas and leukemias) were grouped altogether for the analysis and an increased incidence in males was reported for the radiation +10,000 mG. These data are difficult to interpret because of the differences between the housing of the controls and the animals exposed to magnetic fields. Additionally, some tumor types were grouped for analysis, the time to tumors was not reported, the study was carried out for the lifetime of the animals rather than the standard two years more commonly used in cancer studies, and at least some of the increased tumor types were associated with the extreme end of life at which the size of the study groups is diminished and subject to greater variability.

Additional serious concerns have been raised about the quality of the chronic exposure implemented in this and other studies performed at the Ramazzini Institute where Dr. Soffritti has served as Scientific Director. Based on concerns about the ability of Ramazzini scientists to properly distinguish between leukemias and lymphomas in certain tissues, the U.S. Environmental Protection Agency (EPA) has "decided not to rely on RI [Ramazzini Institute] data on lymphomas and leukemias in IRIS [Integrated Risk Information System] assessments" (EPA, 2013). Furthermore, scientists from EPA and the National Institute for Environmental Health Sciences have taken an unprecedented step to warn risk assessors about problems with cancer bioassays conducted by the Ramazzini Institute, including: the accuracy of cancer diagnoses; the categorization of tumors; errors in identifying cellular changes as leukemia/lymphoma in certain tissues that appear to be due to infections (lung) and tissue inflammation; a unexplained significant rise in the incidence of leukemia/lymphomas over time in control groups unrelated to the exposure under study; lack of complete reporting of analytical specifications and documentation; failure to control or analyze for potential genetic similarities associated with the breeding litters; and the use of common controls for multiple studies (Gift et al., 2013). Such factors probably account for the more than two-fold difference in the incidence of mammary cancers in unexposed controls in the Soffritti et al. (2016a) and Sofritti et al. (2014) studies and a similar difference in the incidence of mammary cancers upon exposure to 0.1 Gray of high-energy X-ray radiation between these studies.

[17] The exact same results for female rats exposed to radiation + 10,000 mG are reported in Soffritti et al (2010) and Soffritti et al. (2016a). However, only in the latter published paper is the difference from controls identified as statistically significant.

The investigators from the Ramazzini Institute used the same exposure apparatus and general methods to examine the effects of 10,000 mG, 50-Hz exposure in rats alone or in combination with oral exposure to 50 mg/L formaldehyde, a known cause of cancer, in drinking water for two years (Soffritti et al., 2016b). Controls were either unexposed (the same control group as reported in the previous study) or treated with formaldehyde in drinking water only. Again, sham exposures and blinded analyses were not described. The numbers of animals per treatment group were larger (≥200 per sex per group in the treated groups) than in the previously discussed study. Groups exposed or not exposed to magnetic fields did not differ in body weight or survival. Exposure to either magnetic fields alone or formaldehyde alone did not increase the incidence of total benign or malignant tumor above that observed in the control group but the contribution of different tissues, including the mammary gland, to this total was not disclosed. Malignant tumors, including C-cell carcinomas of the thyroid, and lymphatic tumors, were increased in the males exposed to both magnetic fields and formaldehyde compared to the unexposed control but the reported incidences were not significantly different than those seen with formaldehyde treatment alone. No effects were seen in females, except for an increase in thyroid adenomas and carcinomas with formaldehyde alone. These results were confounded by the substantially reduced water intake levels over the first year of the study in males receiving formaldehyde in the drinking water with or without magnetic-field exposure. Again, some of the reported increases were based on limited numbers of affected animals, time to tumor development was not reported, and the study was carried out for the lifetime of the animals. Unfortunately, the consistency of the background incidence rates in the two studies cannot be compared as each one reports on different tissues. Further, these results conflict with those of the investigators' other study in that they do not support a co-carcinogenic effect of 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 *in utero* 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 control for potential confounding variables (e.g., light, vibration, noise) were not described. Exposed offspring exhibited significantly reduced body weights compared to controls. Tumors were not increased in males, but chronic myeloid leukemias were significantly higher 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 blinded analyses were not reported. Both magnetic-field exposure and cisplatin treatment, alone or in combination, were associated with reduced tumor volume; the strongest response was observed with combination treatment. In another study (Mahna et al., 2014), female mice were injected with mouse mammary tumor cells,

then exposed to 150,000 mG, 50-Hz magnetic fields (10 minutes per day for 12 days). Other animal groups were exposed to magnetic fields and electrochemotherapy (a combination of chemotherapy with pulsed electric current applied to the skin in an attempt to increase permeability of cancers cells to the drugs). A sham-exposed control group was included, but analyses were not 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, and it is possible that the observed responses were 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. Brain astrocytes were then examined in culture for the presence of micronuclei (i.e., small nucleus-like structures containing DNA indicative of a chromosomal break). In other experiments, the animals were treated as described, but also administered tempol, an antioxidant. Magnetic-field exposure alone or in combination with 5 mg/kg bleomycin had no effect on micronuclei formation, but increased 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 or 24 hours later. The striatum, hippocampus, and cerebellum were evaluated in a blinded manner for DNA damage using the Comet assay. Control mice were sham-exposed and X-irradiated mice served as DNA-damage positive controls. 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 to 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 served as positive controls and analyses were conducted blind. The authors reported an increase in micronuclei 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 to 3,000 mG, 50-Hz magnetic fields for 2 or 15 hours on the gene mutation frequency in the sperm and blood cells of mice. Sham-exposed mice were included as negative controls; X-irradiated mice served as positive controls. Mutation frequencies in blood cells of 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 mouse embryonic neuronal stem cells with in vivo exposure to 1,000 mG, 50-Hz magnetic fields for 2 hours or with continuous or

intermittent exposure (5 minutes on, 10 minutes off) to a 3,000 mG magnetic field for 15 hours. The study included sham-exposed controls, multiple positive control groups exposed to X-irradiation, and appropriate statistical methods to account for litter effects. No increase in double-strand breaks was seen in groups exposed to magnetic fields. In a follow-on study (Woodbine et al., 2015), the same group of researchers using the same experimental system assessed whether concomitant exposure to magnetic fields and X-rays would have an effect. The mouse embryos were exposed to 3,000 mG, 50-Hz for 3 hours before and up to 9 hours after X-irradiation. Controls were X-irradiated and sham-exposed to magnetic fields. Additional controls were unexposed, sham-exposed, X-irradiated only (with or without sham-exposure), or magnetic-field exposed only. X-irradiation significantly increased DNA double-strand breaks at 1 hour post-exposure; levels decreased to control by 6 to 11 hours post-exposure with DNA repair. Magnetic-field exposure had no effect on the response to X-irradiation, indicating that magnetic fields did not affect the DNA repair process. One weakness of these studies is that 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. 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. A slight reduction in mitochondrial DNA synthesis was observed in 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 brain choroid plexus and the kidney collecting duct, but again, there was no effect on DNA single-strand breaks. Although controls were not sham exposed, the analyses were conducted in a blinded manner.

Three recent studies examined DNA damage in human subjects exposed to EMF. Tiwari et al. (2015) investigated DNA damage in peripheral blood lymphocytes among 293 subjects in a cross-sectional analysis. (In a cross-sectional study, the investigators determine the study subjects' exposure and outcome status at the same time, thus, these types of studies are not suitable to draw any conclusion on a potential causal association.) The authors considered 142 subjects as "exposed to EMFs emitted from high-voltage (132-kV) substations for more than 2 years of occupational exposure." No further details were provided on how exposure status was determined. The exposed subjects were compared to 151 non-exposed individuals of similar socioeconomic status. How these control subjects were selected was not reported in the paper. The analyses did not consider or control for the potential confounding effect of other occupational exposures. DNA damage was assessed 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, there was no significant difference between the two groups in the degree of DNA damage observed.

In another cross-sectional study of human subjects (Villarini et al., 2015), DNA damage was assessed using the alkaline Comet assay in 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 (healthy blood donors) of similar age, residence, and smoking status. Magnetic-field exposure was measured in exposed individuals using personal dosimeters 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 lengths were similar in both groups; 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. The authors suggested that this unexpected finding may be related to the type of DNA damage that might occur with exposure to various metal fumes, including chromium and nickel; both may induce DNA-protein cross-links that would migrate to a lesser degree than non-cross-linked DNA in the assay.

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; the other was either sham-exposed (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 unexposed. On the next day, the exposures were reversed for the pair of subjects. 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 immediate early genes involved in stress, inflammatory, and proliferative and apoptotic responses. Samples collected just prior to exposure were used as reference samples. Any positive findings were verified using the second set of collected blood samples. No genes showed a consistent response to magnetic-field exposure.

In a similarly well-conducted study, Kabacik et al. (2013) looked for changes in gene expression 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 leukemias are derived from cells in the bone marrow; thus, changes in bone marrow gene expression may be related to this process. Control mice were sham-exposed, the experiment was repeated in multiple groups of exposed and unexposed mice, and replicate samples were 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 (Qi et al., 2015). 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.

Two additional studies by a single research group examined the possible co-carcinogenic effects of lifetime magnetic-field exposure, with conflicting findings. These studies also suffer from substantial methodological and reporting flaws. At least some of the reported findings from Soffritti et al. (2016a, 2016b) are based on a limited number of affected animals and the occurrence of tumors that typically occur only at the extreme end of life. Additionally, serious concerns have been raised by others in the scientific community regarding tumor findings reported by this research group. Further investigations to assess the source of the species differences in susceptibility for mammary tumors generally have been unfruitful.

In addition to these studies, 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. The research on whether magnetic-field exposure can enhance tumor development in combination with known carcinogens remains inadequate.

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.
Soffritti et al.	2014	Life-span carcinogenicity studies on Sprague-Dawley rats exposed to γ-radiation: design of the project and report on the tumor occurrence after post-natal radiation exposure (6 weeks of age) delivered in a single acute exposure
Soffritti et al.	2016a	Life-span exposure to sinusoidal-50 Hz magnetic field and acute low-dose γ radiation induce gacinogenic effects in Spargue-Dawley rats
Soffritti et al.	2016b	Synergism between sinusoidal-50 Hz magnetic field and formaldehyde in triggering carcinogenic effects in male Sprague-Dawley Rats
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
Villarini et al.	2015	Primary DNA damage in welders occupational exposed to extremely-low-frequency magnetic fields (ELF-MF)
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 apparent 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 (2012-2016)

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, if any, 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 study reported a statistically significant increase in measured magnetic-field levels 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.

Three 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.

Finnish scientists examined the potential association between residential exposure to magnetic fields and time to pregnancy, low birth weight, and being small for gestational age (SGA) among 373 mothers who gave birth between 1990 and 1994 in Kuopio University Hospital (Eskelinen et al., 2016). The study group was selected from the birth register of the hospital. To increase the prevalence of high exposure to EMF and the exposure contrast in the study, the scientists selected mothers with residences in close proximity to nearby sources (e.g., transmission lines, transformers). Exposure to magnetic fields was assessed through spot measurements in the home and using a questionnaire that requested information on occupational and residential sources of EMF (e.g., electrical appliances and equipment). None of the exposure metrics used to assess EMF exposure was statistically associated with measures of fetal growth or time to pregnancy in the study. Consideration of various metrics, including residential measurements, and availability of personal level information on potential confounders were among the strengths of the study, while the relatively low number of highly-exposed subjects limited the study's statistical precision.

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.

An assessment of the scientific literature on ELF EMF exposure and measures of infertility and adverse pregnancy outcomes reviewed the strength and limitations of recently published studies and concluded that design limitations in most studies may explain their inconsistent findings (Lewis et al., 2016). The authors' recommendations for future studies included, among others,

the selection of appropriate study populations, the assessment and control for potential confounding by the mothers' physical activity, the careful characterization of exposure, and the analysis of various exposure metrics in the study.

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
Eskelinen et al.	2016	Maternal exposure to extremely low frequency magnetic fields: Association with time to pregnancy and foetal growth
Lewis et al.	2016	Exposure to Power-Frequency Magnetic Fields and the Risk of Infertility and Adverse Pregnancy Outcomes: Update on the Human Evidence and Recommendations for Future Study Designs
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 – 2016)

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, which include the cross-sectional study 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.

Vergara et al. (2015) conducted a mortality case-control study of occupational exposure to electric shock and magnetic fields and ALS in the United States. A total of 5,886 deaths due to ALS were identified between 1991 and 1999. For each ALS death, 10 controls, matched on sex, age, year of death, and region, were selected from among other deaths. The occupation reported on the death certificates were linked to job exposure matrices for electric shocks and magnetic fields, and classified as high, medium, and low. Occupations classified as "electric occupations" were moderately associated with ALS (OR 1.23, 95% CI, 1.04-1.47). ALS, however, was inversely associated with electric shocks (OR 0.73, 95% CI, 0.67-0.79 in high exposure, and OR 0.90, 95% CI, 0.84-0.97 in medium exposure compared to low exposure) and not statistically associated with EMF (OR 1.09, 95% CI, 1.00-1.19 in high exposure, and OR 1.09, 95% CI, 0.96-1.23 in medium exposure compared to low exposure). The authors conclude that their findings do not support that either electric shock or magnetic fields explain the observed association of ALS with "electric occupations."

Fischer et al. (2015) conducted a population-based case-control study of occupational exposure to electric shocks and magnetic fields and ALS in Sweden. The base population of the study included all individuals born in Sweden between 1901 and 1970 who were enumerated during the 1990 Swedish Census. All cases of ALS in the study population, newly diagnosed between 1990 and 2010, were identified by record linkages to the Swedish patient and death registries. Five controls, individually matched to cases on birth year and sex, were selected for each case

from the study base. Census-based information on occupations was linked to multiple previously developed job-exposure matrices to classify exposure to EMF and electric shocks for cases and controls. A total of 4,709 cases and 23,335 controls were included in the study. Overall, neither EMF nor electric shocks were related to ALS. Among subjects aged < 65 years, statistically significant increases in ALS risk were reported with exposure to electric shocks. A statistically non-significant decrease, however, was also observed among subjects 65 years and older. The study has a number of strengths, which include its large sample size, population-based design, inclusion of incidence cases, and the reliance on multiple job-exposure matrices (three for EMF and two for electric shocks) for exposure assessment.

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; van der Mark et al., 2014; Vergara et al., 2015; Fischer et al., 2015).

Assessment

In recent years, a number of studies have been published that examined the potential relationship between EMF, electric shocks, and neurodegenerative diseases. Many of these studies represented methodological improvements (e.g., increased sample size, improved exposure assessment, inclusion of incidence cases) compared to previous studies. In spite of these methodological improvements, the overall evidence from these studies provided no further support for a causal association. 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

Authors	Year	Study
Davanipour	2014	Severe cognitive dysfunction and occupational extremely low frequency magnetic field exposure among elderly Mexican Americans
Fischer et al.	2015	Occupational Exposure to Electric Shocks and Magnetic Fields and Amyotrophic Lateral Sclerosis in Sweden
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
Vergara et al.	2015	Case-control study of occupational exposure to electric shocks and magnetic fields and mortality from amyotrophic lateral sclerosis in the US, 1991-1999
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 – 2016)

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; Hall et al., 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; Hall et al., 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 association between magnetic fields and neurodegenerative diseases, including Alzheimer's disease and ALS.

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.

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2.C.3 *Tabulated Calculations of Electric and Magnetic Fields*

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Calculated Magnetic Fields During Average Annual Loads (mG)																								
Distance from Transmission Line (feet)	-300	-275	-250	-225	-200	-175	-150	-125	-100	-75	-50	-25	0	25	50	75	100	125	150	175	200	225	250	275	300
UG Transmission Line (Trench)	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.6	1.3	4.7	63.0	4.7	1.2	0.6	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0
UG Splice Vault	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.7	1.2	2.6	10.2	433.1	10.2	2.6	1.2	0.7	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1
OH Transmission Line (Along RR)	0.6	0.7	0.8	1.0	1.2	1.5	2.0	2.7	3.7	5.4	8.1	11.6	13.6	11.6	8.1	5.4	3.7	2.7	2.0	1.5	1.2	1.0	0.8	0.7	0.6
Calculated Magnetic Fields During Peak Day Average Loads (mG)																									
Distance from Transmission Line (feet)	-300	-275	-250	-225	-200	-175	-150	-125	-100	-75	-50	-25	0	25	50	75	100	125	150	175	200	225	250	275	300
UG Transmission Line (Trench)	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.7	1.6	6.0	80.0	5.9	1.6	0.7	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.0
UG Splice Vault	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.8	1.5	3.3	13.0	549.5	13.0	3.3	1.5	0.8	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1
OH Transmission Line (Along RR)	0.7	0.8	1.0	1.2	1.5	1.9	2.5	3.4	4.8	6.9	10.3	14.7	17.2	14.7	10.3	6.9	4.8	3.4	2.5	1.9	1.5	1.2	1.0	0.8	0.7
Calculated Magnetic Fields During Annual Peak Loads (mG)																									
Distance from Transmission Line (feet)	-300	-275	-250	-225	-200	-175	-150	-125	-100	-75	-50	-25	0	25	50	75	100	125	150	175	200	225	250	275	300
UG Transmission Line (Trench)	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.6	1.0	2.3	8.7	115.6	8.6	2.3	1.0	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1
UG Splice Vault	0.1	0.2	0.2	0.2	0.3	0.4	0.5	0.8	1.2	2.1	4.8	18.8	794.5	18.8	4.8	2.1	1.2	0.8	0.5	0.4	0.3	0.2	0.2	0.2	0.1
OH Transmission Line (Along RR)	1.0	1.2	1.5	1.8	2.2	2.8	3.6	4.9	6.9	10.0	14.9	21.2	24.9	21.2	14.9	10.0	6.9	4.9	3.6	2.8	2.2	1.8	1.5	1.2	1.0
Calculated Electric Fields (kV/m)																									
Distance from Transmission Line (feet)	-300	-275	-250	-225	-200	-175	-150	-125	-100	-75	-50	-25	0	25	50	75	100	125	150	175	200	225	250	275	300
OH Transmission Line (Along RR)	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.03	0.03	0.10	0.30	0.44	0.30	0.10	0.03	0.03	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01

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Exhibit 2.D Planning Documentation

2.D.1 *Analysis of the Feasibility and Practicality of Non-Transmission Alternatives (NTAs) to the Greater Hartford/Central Connecticut Reliability Project (GHCCRP)* (London Economics International LLC, August 31, 2015)

2.D.2 *Transmission Planning Technical Guide* (ISO-NE, December 2014)

2.D.3 *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment* (ISO-NE, May 2014), Redacted to secure Confidential Energy Infrastructure Information (CEII)

2.D.4 *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Solutions Study* (ISO-NE, February 2015), Redacted to secure Confidential Energy Infrastructure Information (CEII)

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2.D.1 *Analysis of the Feasibility and Practicality of Non-Transmission Alternatives (NTAs) to the Greater Hartford/Central Connecticut Reliability Project (GHCCRP)* (London Economics International LLC, August 31, 2015)

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ANALYSIS OF THE FEASIBILITY AND PRACTICALITY OF NON-TRANSMISSION ALTERNATIVES ("NTAS") TO THE GREATER HARTFORD / CENTRAL CONNECTICUT RELIABILITY PROJECT ("GHCCRP")

August 31st, 2015

prepared for Eversource Energy

by



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Synopsis

Eversource Energy ("Eversource") retained London Economics International LLC ("LEI") to provide independent expert analysis on the feasibility and practicality of relying on non-transmission alternatives ("NTAs") in lieu of a transmission project proposed to fix reliability violations in the Greater Hartford ("GH") electrical subarea. This report is intended to be filed with Eversource's application for the 115 kV Greater Hartford / Central Connecticut Reliability Project ("GHCCRP") before the Connecticut Siting Council ("CSC").

As part of the process of the needs assessment and identification of the preferred transmission solution for GHCC, ISO-NE conducted an analysis of market resource alternative ("MRA"[1]) for the various subareas of GHCC. ISO-NE identified the quantity and location of NTAs that would alleviate the thermal system overloads. Although the NTA study was conducted in late 2012, the violations are the same or worsening in light of the evolving market conditions. Indeed, the GHCC transmission solution study noted that a solution was needed as soon as possible, because the thermal loads could occur at peak loads consistent with 2013 levels. Eversource's planning staff confirmed the reasonableness of the ISO-NE's identified quantities of NTAs. Therefore, LEI relied upon the quantities and locations of NTAs specified in ISO-NE's study. ISO-NE determined that 196 MW of energy injection is required to resolve reliability problems in the GH subarea. LEI then examined what actual supply-side and demand-side resources could fulfill the need and selected hypothetical technically feasible NTA technologies for cost analysis, based on the location, costs and other practical factors of consideration. We define technically "feasible" technologies as technologies that could be hypothetically 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.

LEI identified peaker aeroderivative,[2] Combined Cycle Gas Turbines ("CCGT"), and passive demand response (energy efficiency) as technically feasible NTA technologies at the Northwest Hartford ("NW Hartford") substation. Although we explored the technical feasibility of solar photovoltaic ("PV") as NTA at the considered location, such technology was however dismissed over its cost, the volume of nameplate capacity needed, and the associated acreage requirements.

Next, LEI 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 they 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 least cost NTA technology by deducting expected average annual market-related revenues from levelized annual gross costs. The total net direct cost to ratepayers of the least cost technically feasible NTA solution for GH was estimated to range from $21 million to $33 million a year, which is significantly higher than the $4.6 million per year that Eversource estimates as the share of the revenue requirement associated with the GHCCRP transmission solution that would be allocated to Connecticut ratepayers. A host of factors – including

[1] MRA and NTA refer to the same concept of resources used as alternative to transmission projects.

[2] The term "Aeroderivative" is defined later in the document.

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land availability, enabling infrastructure, and technology durability – will bear on the practicality of least cost technically feasible NTA technologies. Gas-fired units (CCGT and peakers) were the resources associated with the least cost NTA solution in the GH subarea. However, no such facilities are currently operating or have been proposed for development at the NW Hartford substation. Furthermore, the considered substation is located some distance (4 miles) away from the nearest gas pipeline. Therefore, a new gas lateral would need to be constructed if the selected NTA is a gas-fired generator, which would further increase the cost for Connecticut end-users.

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Acronyms

AC	Alternating Current
ACP	Alternative Compliance Payment
CCGT	Combined Cycle Gas Turbine
CLL	Critical Load Level
CSC	Connecticut Siting Council
DALRP	Day Ahead Load Response Program
DG	Distributed Generation
DR	Demand Response
EPRI	Electric Power Research Institute
FCA	Forward Capacity Auction
FCM	Forward Capacity Market
FO&M	Fixed Operating & Maintenance
GH	Greater Hartford
GHCC	Greater Hartford Central Connecticut
HVDC	High Voltage Direct Current
IEA	International Energy Agency
ISO	Independent System Operator
ISO-NE	Independent System Operator- New England
kW	Kilowatt
LCOE	Levelized Cost of Entry
LEI	London Economics International
MRA	market resource alternative
NERC	North American Electric Reliability Corporation
NPCC	Northeast Power Coordinating Council
NREL	National Renewable Energy Laboratory
NTA	Non-Transmission Alternative
NWCT	Northwestern Connecticut
O&M	Operating & Maintenance
PNNL	Pacific Northwest National Laboratory
PV	Photovoltaic
REC	Renewable Energy Credit
RTDR	Real-Time Active DR
RTEG	Real-Time Emergency Generation
RTO	Regional Transmission Organization
VOLL	Value of Lost Load
VOM	Variable Operating and Maintenance

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1 Executive Summary

Over the course of the year 2012 through to 2014, the reliability aspects of the bulk power system in the GHCC areas were studied by ISO-New England ("ISO-NE"). This study, referred to as the *Greater Hartford Central Connecticut Area Transmission 2022 Needs Assessment Report* ("GHCC Needs Assessment") and issued in August 2012, analyzed a geographic area spanning the central and western part of Connecticut (essentially to the west of the Connecticut East-West interface and north of the Southwest Connecticut Import interface). For purposes of its analysis, ISO-NE analyzed four subareas within the GHCC Needs Assessment (some of which were themselves composed of further detailed subareas), namely the Manchester-Barbour Hill Area, Middleton Area, Northwest Connecticut Area, and Greater Hartford Area. Two components of the GHCC transmission solution will require transmission siting approval from the Connecticut Siting Council ("CSC"): the Northwestern Connecticut Reliability project ("NWCT") and the GHCCRP, which is the subject of this report. The principal component of the GHCCRP is the construction of a 4 mile, 115 kV line from the Newington Substation in Newington to the Southwest Hartford Substation in Hartford. The full scope of the project is summarized in the table below.

Figure 1. GH solution components

ID	Solution Component
1	Add a new 4 mile 115 kV underground cable from Newington to Southwest Hartford and associated terminal equipment including a 2% series reactor
2	Loop the 1779 line between South Meadow and Bloomfield into the Rood Avenue substation and reconfigure the Rood Avenue substation
3	Reconfigure the Berlin 115 kV substation including the addition of two 115 kV breakers and the relocation of a capacitor bank
4	Add a 115 kV 25.2 MVAR capacitor at Westside 115 kV substation
5	Reconductor the 115 kV line between Newington and Newington Tap (1783) – 0.01 mile
6	Separation of 115 kV DCT corresponding to the Bloomfield to South Meadow (1779) line and the Bloomfield to North Bloomfield (1777) line and add a breaker at Bloomfield 115 kV substation
7	Install a 115 kV 3% reactor on the underground cable between South Meadow and Southwest Hartford(1704)
8	Separation of 115 kV DCT corresponding to the Bloomfield to North Bloomfield (1777) line and the North Bloomfield – Rood Avenue – Northwest Hartford (1751) line and add a breaker at North Bloomfield 115 kV substation

Source: Eversource

LEI was engaged by Eversource to analyze the potential for technically-feasible, cost-effective and practical NTAs to replace the GHCCRP. LEI describes in detail the methodology and approach used to conduct its analysis in sections 4 and 5.

A Non-Transmission Alternative is a solution (or group of solutions) to an identified electric system need that does not involve the construction of traditional transmission infrastructure. NTA technologies may include supply-side resources (e.g. conventional generation, distributed generation or advanced generation technologies such as energy storage technologies), demand-side resources (e.g. demand response or energy efficiency), or a combination of both.

How to choose between a transmission solution and an NTA?

In theory, if an NTA can satisfactorily meet the technical requirements of the system that are driving the need for the transmission solution, it can then delay the timing of needed transmission investment. Consumers would pay for the transmission solution and may need to pay for the costs of deploying the NTA. Therefore, it is important to compare the costs of the transmission solution against the NTA. However, it is also important to recognize that NTAs and transmission may also have different characteristics that affect other aspects of electricity service. Even if an NTA has a lower cost and can fulfill the technical requirements of the system (e.g., the reliability need), there may also be other services and benefits that transmission can provide versus NTAs. Only if an NTA can fulfill all the same technical requirements and generate benefits at comparable or lower costs than those associated with transmission projects, should an NTA be pursued.

LEI was asked to determine whether there is a technically feasible combination of NTA technologies that could be more cost-effective than the GHCCRP in addressing the load serving concerns in the Greater Hartford subarea.[3]

As part of the process for the needs assessment for the Greater Hartford / Central Connecticut area and identification of preferred transmission solutions, ISO-NE conducted two NTA studies[4] in late 2012 that identified the smallest aggregate quantity of injections (as measured in MW terms) in the entire area (composed of four subareas including GH, grouped together) that would alleviate the thermal system overloads. The assumptions underpinning the NTA studies are based on the initial Needs Assessment study (2012). ISO-NE performed separate and distinct hypothetical analyses for either a 100% demand-

[3] In addition to addressing local load-serving concerns, the GHCCRP was designed to increase transfer capability across the Western Connecticut Import Interface. LEI was not tasked to determine if a feasible NTA that would resolve the load serving issues in the sub-area would also perform the "double duty" of increasing transfer capability across the interface or eliminating the need for such an increase.

[4] According to ISO-NE, the two analyses were conducted separately consistently with ISO-NE's protocol at the time. One study focused on demand-side NTAs only, while the other focused on supply-side NTAs. The demand-side study was not realistic as it required demand reductions at many locations that would not be practically achievable (such as 100% load reductions). Since the time of these studies, ISO-NE has moved to a hybrid approach considering both supply-side and demand-side resources under the same analysis, and employing more realistic assumptions on demand-side load reductions. LEI therefore has not relied on ISO-NE's demand-side NTA study. Rather, LEI has used the required injection values and the location for those values developed in the revised ISO-NE Supply-side MRA Study as the basis for developing supply, demand, or hybrid solutions.

side solution or a 100% supply-side solution. Both analyses were done under a number of different dispatch conditions, with the objective being to identify a minimum amount of total MWs (dispersed across the "best" locations) associated with either net load reduction or/and additional supply that would resolve all overloads and thermal violations under N-1-1 contingency events.[5] A single injection point was identified for an NTA solution in the GH subarea by ISO-NE: the NW Hartford bus (or injection point). According to ISO-NE, the quantity of energy injection or load reduction required to resolve the target reliability criteria violations totaled 196 MW for the GH subarea. Eversource's engineers confirmed that the injection location and the associated NTA requirement were not likely to have significantly changed as a result of increasing load in the GH subarea, or evolving market conditions.

LEI evaluated technically feasible NTA resources at the NW Hartford bus that fulfill the 196 MW of requirement, as determined by ISO-NE. LEI's analysis started with identifying a list of technically feasible NTA technologies that possess the operating characteristics required to meet the criteria of the NTA injections (either in terms of size, location, or operating profile) at the NW Hartford substation. We then compared the costs of implementing each of the prospective NTA technologies, in order to select the least cost one. The least cost NTA technology was then compared to the cost of the proposed transmission project. We also examined practical challenges related to the development and commercialization of an NTA technology. We concluded that the least cost technically feasible NTA solution is likely to be more difficult to implement than a transmission solution, and would be five times more costly on average for Connecticut ratepayers.

1.1 Background on LEI

LEI is a global economic and financial consultancy specializing in energy and infrastructure. The firm combines a detailed understanding of specific network and commodity industries, such as electricity generation and distribution, with sophisticated analysis and a suite of proprietary quantitative models to produce reliable and comprehensible results. LEI benefits from a balance of private sector and government clients, which enables the firm to effectively advise both regarding the impact of regulatory initiatives on private investment, as well as regulatory responses to activities undertaken by individual firms. LEI has extensive experience working with both renewable and conventional generation technologies, as well as transmission infrastructure in the New England and Connecticut region. LEI has also undertaken economic cost-benefit analysis, market price forecasting and asset valuation as well as presented expert witness testimony in front of various regulators in North America, including the Connecticut Siting Council, the Connecticut Department of Public Utility Control ("DPUC"), a predecessor entity to today's Public Utilities Regulatory Authority ("PURA"). A detailed description of LEI's experience is presented in Appendix A.

[5] Market Resource alternative Analysis – Demand-side Results, *GHCC Area*, PAC Meeting – Revised November 14, 2012, page 7 and Market Resource alternative Analysis - Final Demand-side Results, *GHCC Area*, PAC Meeting, December 13, 2012, page 8.

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1.2 What NTA technologies were considered?

The analysis presented in this report was designed around a mix of supply-side and demand-side technologies initially identified by both LEI and the Eversource:

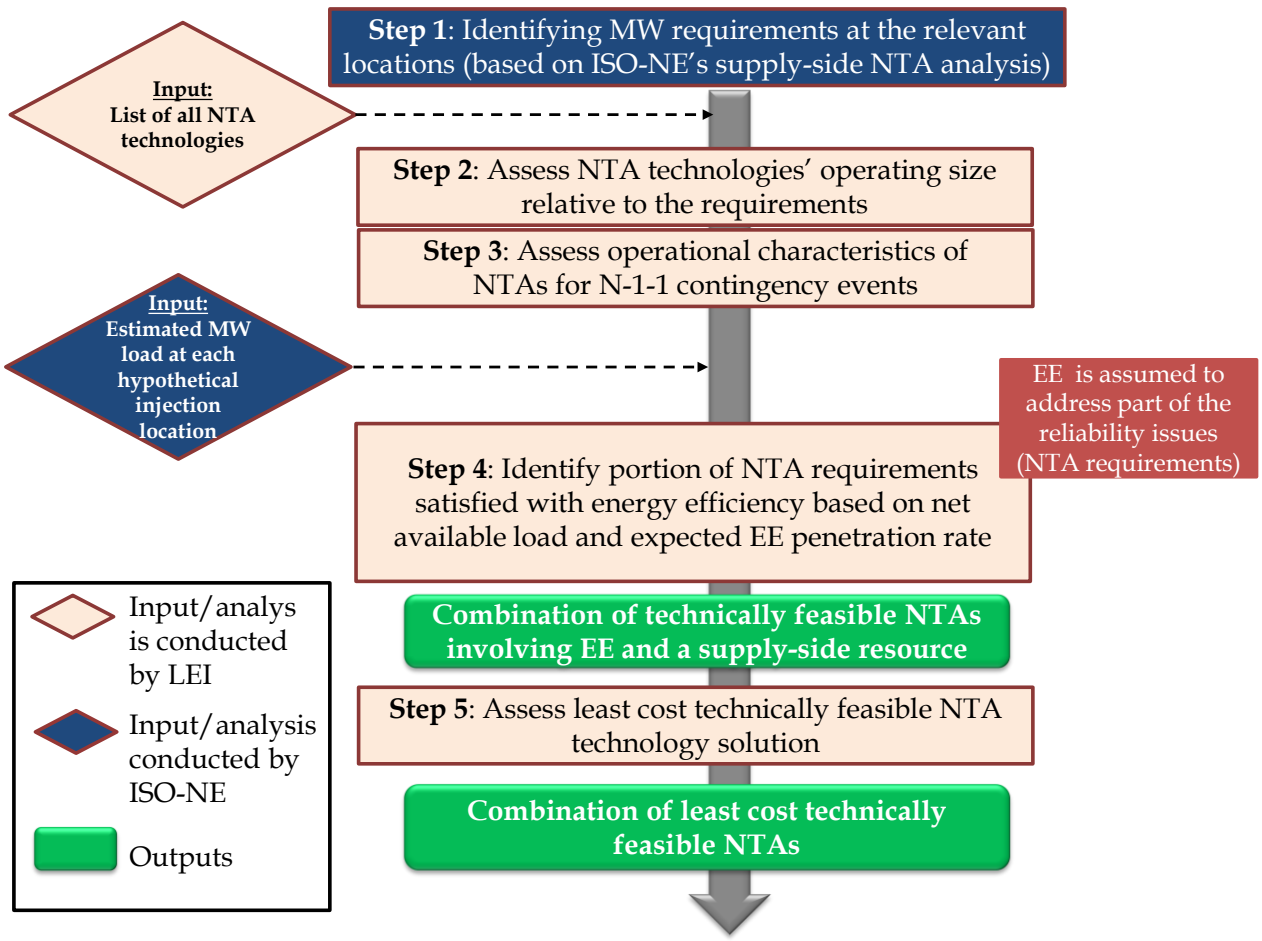
1. conventional fossil fuel fired generation (natural gas-fired peaking and combined cycle technologies);
2. large scale renewable generation (solar, wind and fuel cells);
3. distributed generation (solar);
4. active demand response (such as real-time demand response and real-time emergency generation);
5. passive demand response (such as energy efficiency programs); and
6. energy storage technologies (such as utility-scale battery technology and flywheels).

In undertaking the technology identification and cost analysis, LEI relied primarily on real world operating experience with such technologies in New England, as well as research documents and market information made publicly available by ISO-NE and the State of Connecticut related to technologies' operational data and statistics. Understanding of local market conditions was enhanced by Eversource's proprietary information. Where necessary, information from actual operational experience was supplemented with engineering–related data and generic technology information, including data on capital and operating costs, as well as operating parameters. Such generic information was collected from reputable sources, such as the US Department of Energy and affiliated national laboratories, manufacturers, and engineering procurement companies that work with such technologies. A detailed bibliography list is provided in Appendix D.

1.3 Overview of methodological approach

In order to identify technically feasible NTA technologies that can feasibly, cost-effectively and practically satisfy the reliability issues being addressed by GHCCRP transmission solution, a five-step methodology was designed. These steps are shown in Figure 2 below and are detailed in Section 4 of this report.

Figure 2. Methodological Approach



LEI undertook a technology mapping process in order to identify and associate a technically feasible NTA technology with the hypothetical NTA requirements for the designated location and injection amount (i.e., capability to produce energy, measured in MW terms). LEI used decision tree techniques to sequentially filter and narrow down the available list of technologies according to the requirements at each location.

While LEI recognizes that there may be multiple NTA technologies that are feasible with each injection point/amount, the purpose of this analysis is to identify technically feasible NTA technologies that possess the operating characteristics required to meet the criteria of the hypothetical NTA injections (either in terms of size, location, or operating profile). The details of LEI's methodology are presented in Section 4.3 of this report.

The next step in LEI's analysis employs a levelized cost methodology in order to evaluate the direct costs to ratepayers of implementing NTA technologies. The direct costs were calculated by aggregating the total cost of implementing least cost technically feasible NTA technologies by location. LEI first assessed the costs of technically feasible NTA solutions by evaluating the total costs of investment and operations (based on gross Levelized Cost of Entry ("LCOE") per kW year). Then, LEI considered the

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net costs of investment and operations that ratepayers would bear after accounting for possible market revenues.

1.4 Key Findings on technically feasible NTA technologies

CCGTs (small plant) and peaker aeroderivative units are the most suitable NTA technologies at the NW Hartford substation due to the size of the requirement (196 MW is required at that bus).

LEI ran a hybrid analysis assuming that a portion of the NTA requirement will be filled out by demand-side resources (limited by net load availability and expected load reduction rate), while supply-side resources will be used to address the residual NTA requirement. In other words, the technically feasible technologies identified through LEI's analysis consist of energy efficiency ("EE") and a supply-side resource. Based on Eversource's experience with existing EE programs, we assumed that any incremental energy efficiency programs (above and beyond existing and planned programs) could reduce peak load by up to 15% at the NW Hartford substation.[6]

At the target substation, CCGTs and peaker aeroderivative (likely multiple units) appear as technically feasible NTA technologies due to the size of the requirement (196 MW). In Figure 3, we present the NTA requirements at the NW Hartford substation, and summarize all the possible NTA technologies based on size and operational criteria.

Figure 3. Range of feasible NTA technologies for location in the GH subarea

Requirement at the NW Hartford substation (MW)		196
Technically feasible technologies		Capacity (MW)
EE	EE	23
Supply-side resources	Peaker Aeroderivative*	182
	CCGT	182

Each of the supply-side resources (peaker and CCGT) should be considered in combination with the EE

Notes: All capacity numbers are nameplate.
* "Peaker aeroderivative" would consist of multiple units of peaker aeroderivative technology
As can be seen at the NW Hartford substation, both peaker aeroderivative units, and CCGT (in combination with EE) meet the cumulative NTA resource needs. The final choice of which of these NTA technologies will be selected is determined on the basis of each technology's net levelized costs and the associated nameplate capacity (MWs).

The NTA requirements are presented under N-1-1 contingency events in Figure 3. Based on standard planning protocols as provided for in ISO-NE procedures, an N-1-1 contingency event is defined as follows:

- an N-1-1 contingency event refers to a situation when an additional single element of transmission or generation system fails, and a technically feasible NTA technology must be able

[6] The 15% assumption is discussed in detail in Section 3.2 of the report.

to provide energy within 30 minutes and continue to operate until the failed elements are repaired or as long as deemed necessary by the ISO-NE. Typically, ISO-NE can resolve contingency events within a 12 to 24 hour cycle, and LEI has conservatively assumed a 12 hours duration to resolve the contingency in its analysis.

One of the primary criteria to qualify as an N-1-1 NTA is the ability to operate whenever load in the region of study exceeds the critical load limit ("CLL"). According to the ISO New England, the CLL is defined as the load level at which violation could occur, and therefore a solution would be needed.[7] In the GHCC Needs Assessment, ISO-NE performed a CLL study and determined the level of load for the entire Connecticut area, at which the overloads and thermal violations would be resolved within the GH subarea. LEI compared the estimated CLL number (4,225 MW) to forecasted hourly load in Connecticut in 2022[8], in order to estimate the period of the year (shoulder, summer or winter), as well as the time of the day (daytime or nighttime) when the load is most likely to reach the CLL. The results of our CLL analysis indicate that a prospective NTA solution would likely need to be available round-the clock (all seasons, daytime and nighttime).[9]

Given the hypothetical NTA requirements, some technologies are not technically viable, mainly due to their operational characteristics. For example, fast discharge energy storage resources (such as flywheels) are not technically feasible on a standalone basis because they cannot inject power continuously for 12 hours as required by an N-1-1 contingency event.

Other small scale NTA technologies, such as solar DG, cannot effectively meet the technical requirements of the contingencies and the sizing required of hypothetical NTA requirements at the NW Hartford substation. In addition, solar DG resources have an operating profile that does not provide for the sustained performance required under N-1-1 contingencies. Even if solar DG were to be paired with energy storage technologies (such as batteries) to overcome the intermittency of operation, DG units would not provide a technically feasible NTA technology because of the very small amount of energy generated by a typical 5 MW[10] solar DG unit. Therefore, a large combination of units would be required, which would be cost prohibitive. LEI's examination of utility-scale solar PV installations is a sufficient proxy for solar technology in general.

Finally, it bears noting that Real-Time Active DR ("RTDR"), which is typically associated with industrial or large commercial customer sites (such as manufacturing facilities or processing factories), were not directly taken into consideration in the analysis, although LEI still considered them as potential NTA technologies. There is a lack of publicly available information on RTDR's operational

[7] Section 5.5: Information on Critical Load Level. Regional System Plan 2013. Available at: http://iso-ne.com/static-assets/documents/trans/rsp/2013/rsp13_final.docx.

[8] Source: ISO-NE.

[9] In our CLL/Load analysis, violations occur 39% of the time in the Winter, 45% of the time in the Summer and 7% of the time in the shoulder season.

[10] According to the ISO New England Transmission, Markets And Services Tariff, General Terms and Conditions Section I.2.2, solar distributed generation are limited in size at 5 MW.

mode (such parameters will vary with equipment type and size), timing and duration of operation, as well as response/performance rates and opportunity costs, which does not allow us to model these technologies with confidence. Furthermore, under ISO-NE's rules, RTDR and real-time emergency generation ("RTEG") are not typically operable at any given time of the day, which would be a stumbling block to their technical feasibility under N-1-1 contingency events.[11]

Technically, peaker frame units can also operate in the size range of between 20 and 250 MW, but these units do not qualify as a technically feasible NTA technology due to technical and market economics-related reasons. Under N-1-1 contingency events, we have assumed that a technically feasible NTA technology would be required to be capable of injecting power within 30 minutes. In order for peaker frame units to fulfill these timing requirements, and given the source of fuel (i.e., pipeline gas) and nominations required for such fuel, such units would need to be effectively committed day-ahead in order to be capable of operating in real-time, as they would not be able to ramp up from a cold start given the advance notice required for fuel supply and also the speed of ramping. Although the ISO-NE has the authority to commit resources "out-of-merit" on a day ahead basis, bringing online a gas-fired frame peaker and having it running essentially "out-of-merit" in order to be prepared for contingencies may be expensive and potentially distort market price signals. The ISO-NE may have more economic resources available for such purposes, such as other types of peakers (including dual fuel aeroderivative units and jet engines) if and when such a contingency occurs. Due to these operational considerations, LEI did not qualify peaker frame units as technically feasible NTA technologies for N-1-1 contingency events.

1.5 Key Findings from cost analysis

LEI employed industry-standard levelized costing principles to the identified pool of technically feasible NTA technologies in order to estimate the total cost of implementing the least cost NTA technologies. For each selected technology, LEI estimated a gross LCOE which, represents a resource' all-in-costs, annualized and levelized over its life cycle. The gross LCOE is reported in annual and per kilowatt terms ($/kW-year) and embodies all investment and operating costs, including capital costs (equity and debt), fixed operating and maintenance ("FOM") costs, fuel costs (where relevant), and variable operating and maintenance ("VOM") costs. The net LCOE for each NTA technology is derived by deducting from gross LCOE a bundle of potential revenues and income streams associated with each NTA technology. The net LCOE is used to reflect the fact that total direct cost to ratepayers of implementing an NTA could be reduced through revenues earned by the resource from other sources, such as wholesale energy and capacity markets, ancillary services or other income streams.[12]

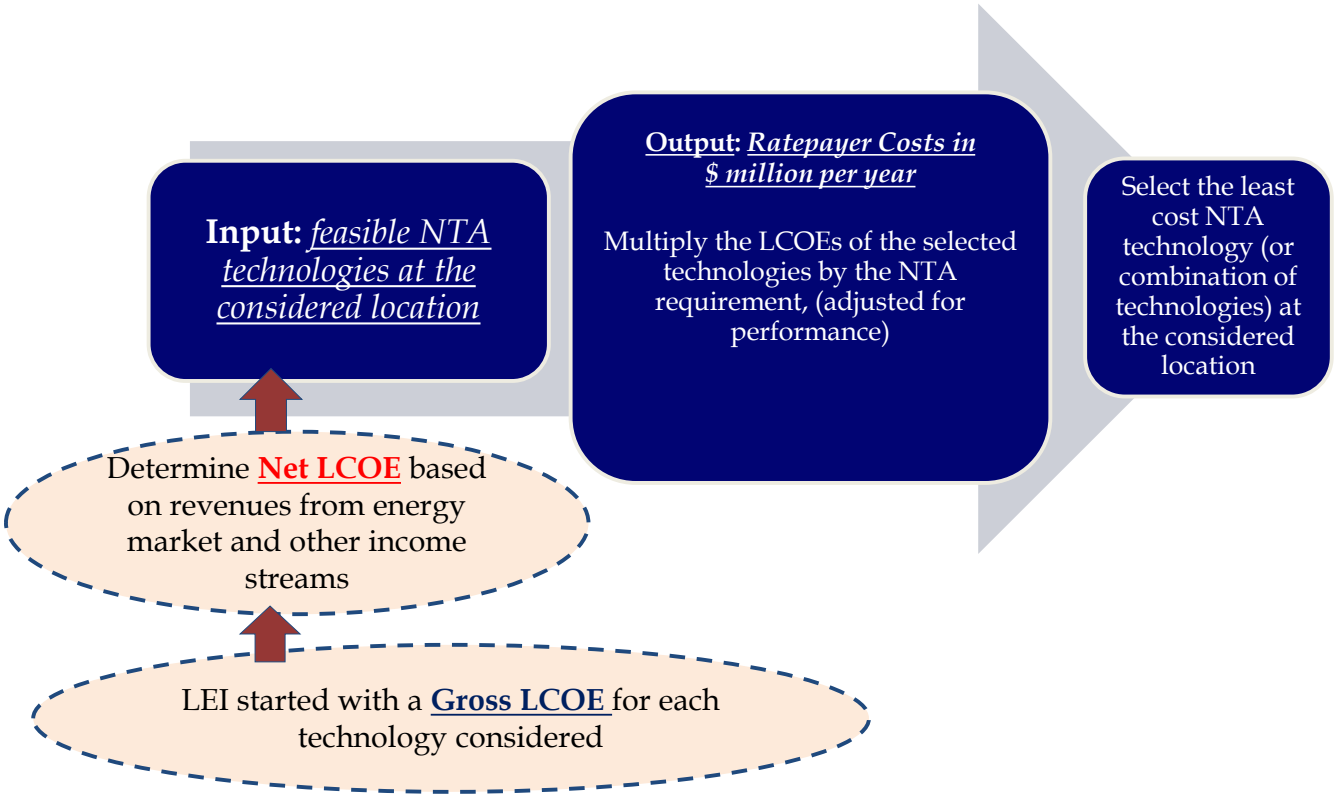
At the NW Hartford injection location, LEI calculated the total costs for the identified technically feasible NTA technologies based on the combination of their respective gross LCOE (or net LCOE) and

[11] "ISO New England Operating Procedure No. 14 - Technical Requirements for Generators, Demand Resources, Asset Related Demands and Alternative Technology Regulation Resources." *ISO-NE, November 7, 2014* http://www.iso-ne.com/rules_proceds/operating/isone/op14/op14_rto_final.pdf.

[12] These revenues were estimated notionally based on current market intelligence and are discussed further in Section 5.1.2.

total capacity needs (at the injection location), with adjustment for operating factors.[13] LEI selected the least costly combination[14] by comparing the resulting costs for all technically feasible NTA technologies (presented in Figure 3) at the substation. The least cost combination is then used to derive the overall direct cost for Connecticut's ratepayers in $ million terms per year.

Figure 4. Methodology for estimating net direct costs of technically feasible NTA technologies ($/kW-year)



Under the base line gross LCOE, gross cost for ratepayers is estimated at $88 million a year. When adding a +/- 20% sensitivity, the resulting gross direct cost falls within a range of $70 million to $105 million a year. LEI recognizes that total costs of NTA technologies can be defrayed by revenues from ISO-NE wholesale markets as well as other sources. In order to capture an accurate estimate of net direct cost to Connecticut ratepayers from technically feasible NTA solutions, LEI deducted these revenues from the gross costs (to derive net LCOE). Nonetheless, there is a significant amount of uncertainty regarding the magnitude and sustainability of these revenue offsets. To account for this uncertainty, LEI also conducted a scenario analysis on the net LCOEs.

[13] Operating factors include capacity factor, availability factor (which is defined as 1-forced outage rate), and ramping rates, which describe how "fast" a power plant can increase or decrease output - it is usually defined in MW per minute.

[14] Combination of EE and a supply-side resource.

LEI considered the uncertainty of all new generating resources such as CCGTs or peakers clearing forward capacity auctions ("FCAs"). Some of the uncertainty is based upon the fact that the auctions for the next three years have already been completed; there are also some question marks on the needs of such new resources in future FCAs; in which case new resources – as represented by these NTA technologies – may not be able to get capacity revenues for some time. Securing these resources in a timely fashion in order to meet the reliability requirements of the GH subarea, will need to be done outside the Forward Capacity Market ("FCM") timetables, given that new capacity has already been procured for the 2018-2019 delivery period in the Forward Capacity Auction #9 ("FCA#9") of February 2015. Therefore, it will necessitate out-of market solicitation, exposing Connecticut ratepayers to greater cost. LEI calculated the net direct costs to ratepayers under two scenarios: (i) feasible resources would not be able to clear all FCAs but would receive capacity payments over half[15] of the years of their life span; and (ii) feasible resources do not clear any FCA and consequently do not earn any capacity revenues over their life cycle. Figure 5 provides a summary of the two scenarios.

Figure 5. Summary of LEI's scenarios

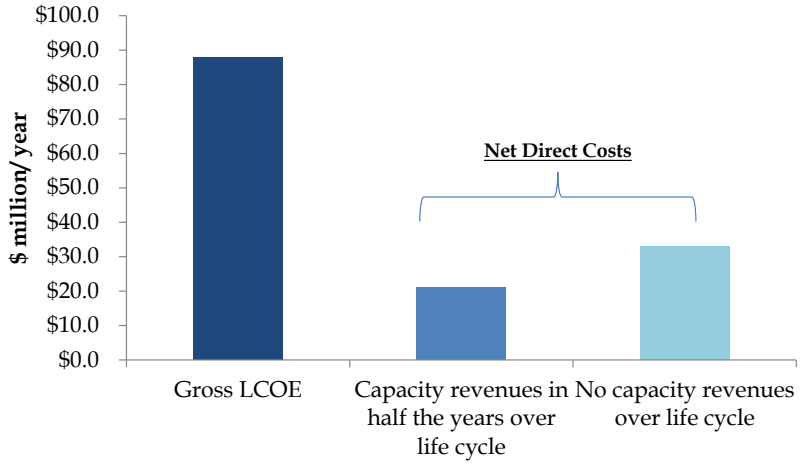
Scenario	Methodology	Key assumptions for net LCOE
Scenario 1 (Capacity revenues in half the years over life cycle)	Net LCOE used to select the least cost technologies	We assumed that new resources such as CCGT and peakers would receive capacity payments over half the years of their life cycle
Scenario 2 (No capacity revenues in years over life cycle)	Net LCOE used to select the least cost technologies	We assumed that none of the new resources would receive capacity payments over their respective life cycle

The total net direct cost (gross costs net of revenues offsets) for ratepayers was determined to range between $21 million and $33 million a year across the two scenarios.[16] The lowest annual net direct costs estimated for Connecticut ratepayers, ($21 million per year under Scenario 1) is more than five-fold higher than the share of the estimated annual revenue requirement for the GHCCRP transmission solution that would be borne by Connecticut ratepayers ($4.6 million a year).

[15] There is also uncertainty in the future price of capacity, which we indirectly reflect with this 50% variable in the capacity revenue formula.

[16] Net LCOEs were derived from mid-range gross LCOE values.

Figure 6. Estimated net direct costs of NTA solution in GH subarea



Greater Hartford	Scenario 1	Scenario 2	GHCCRP
Scenarios	**Capacity revenues in half the years over life cycle**	**No capacity revenues over life cycle**	**Cost of the transmission solution shouldered by end-users**
Total cost ($ million/ year)	$21.2	$33.0	$4.6

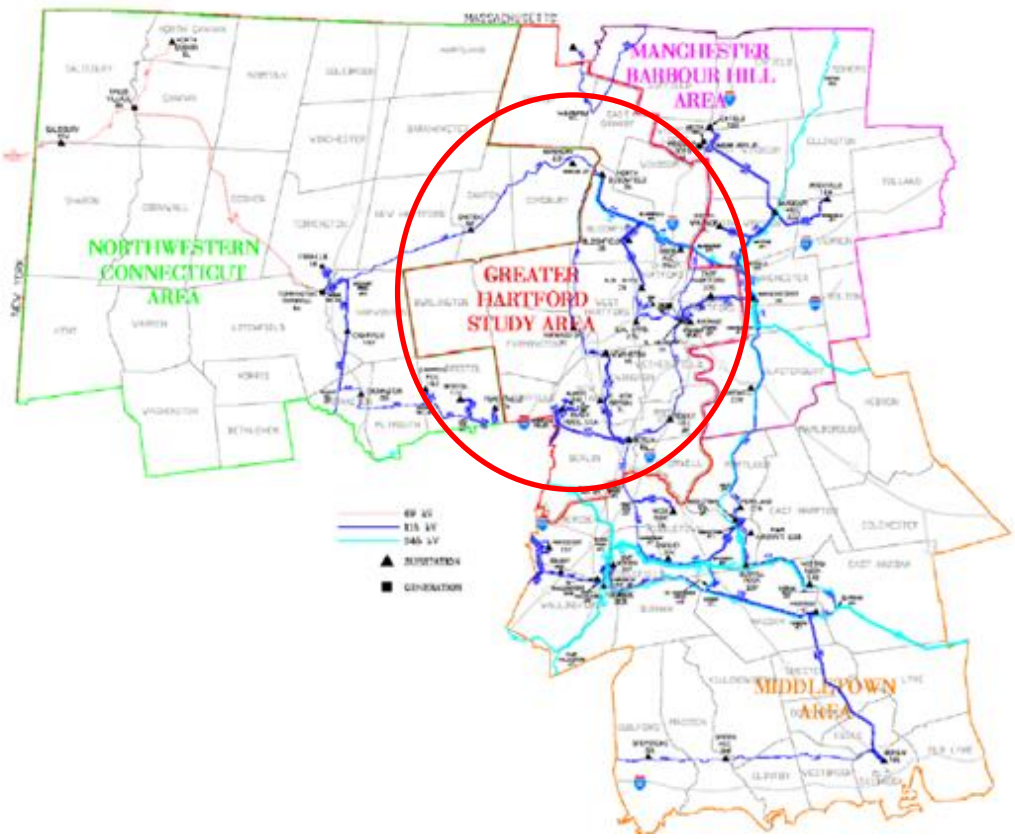
Connecticut ratepayers are expected to shoulder 27% of the GHCCRP transmission solution annual revenue requirements based on current load projections published by ISO-NE and current rules with respect to transmission cost allocation. The total estimated revenue requirement is $17.1 million for the GHCCRP transmission solution. Therefore, Connecticut ratepayers would be responsible for $4.6 million a year. However 100% of the NTA technologies costs will be borne by Connecticut end-users.

2 Background on the Greater Hartford Central Connecticut Solution and the GHCCRP transmission solution

2.1 Greater Hartford Central Connecticut Transmission Reinforcement Projects

Over the course of the 2012-2014 period, the reliability aspects of the bulk power system in the GHCC areas were studied by ISO-New England ("ISO-NE"). This study, the *Greater Hartford Central Connecticut Area Transmission 2022 Needs Assessment Report* ("GHCC Needs Assessment"), was released in August 2012 and analyzed a geographic area spanning the central and western part of Connecticut (essentially to the west of the East-West interface and north of the Southwest Connecticut Import interface). For purposes of its analysis, ISO-NE analyzed four subareas within the GHCC Needs Assessment, namely the Manchester-Barbour Hill subarea, Middleton subarea, Northwest Connecticut subarea, and Greater Hartford subarea as illustrated in Figure 7.

Figure 7. Mapping of the GHCC area



Circled in red is the GH subarea

Source: Market Resource Alternative – *Demand-side results* - GHCC, PAC, November 14, 2012

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LEI understands that among the numerous components to the preferred transmission solution, two components of the GHCC solution will require transmission siting approval from the Connecticut Siting Council: the NWCT Reliability project and the GHCCRP subarea which is the area of study in this report.

2.2 The Northwestern Connecticut transmission solution

What we refer to in this report as "The GHCCRP transmission solution" consists of the construction of a 4 mile, 115 kV line from Newington to Southwest Hartford combined with multiple upgrades and equipment addition - as summarized in the table below.

Figure 8. GHCCRP solution components

ID	Solution Component
1	Add a new 4 mile 115 kV underground cable from Newington to Southwest Hartford and associated terminal equipment including a 2% series reactor
2	Loop the 1779 line between South Meadow and Bloomfield into the Rood Avenue substation and reconfigure the Rood Avenue substation
3	Reconfigure the Berlin 115 kV substation including the addition of two 115 kV breakers and the relocation of a capacitor bank
4	Add a 115 kV 25.2 MVAR capacitor at Westside 115 kV substation
5	Reconductor the 115 kV line between Newington and Newington Tap (1783) – 0.01 mile
6	Separation of 115 kV DCT corresponding to the Bloomfield to South Meadow (1779) line and the Bloomfield to North Bloomfield (1777) line and add a breaker at Bloomfield 115 kV substation
7	Install a 115 kV 3% reactor on the underground cable between South Meadow and Southwest Hartford(1704)
8	Separation of 115 kV DCT corresponding to the Bloomfield to North Bloomfield (1777) line and the North Bloomfield – Rood Avenue – Northwest Hartford (1751) line and add a breaker at North Bloomfield 115 kV substation

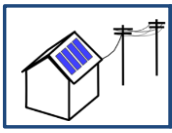
Source: Eversource

3 What is an NTA?

An NTA is a solution (or a group of solutions) to an identified electric system need that does not involve the construction of traditional transmission infrastructure. NTAs may include supply-side resources (e.g. conventional generation, distributed generation, and advanced generation-like technologies such as batteries and storage), demand-side resources (e.g. demand response and energy efficiency), or a combination of the two. More recently, the term "NTAs" has been expanded to include smart grid distribution technologies.

Discussions of NTAs occurring in wholesale power markets and at state regulatory bodies generally focus on six categories of NTA technologies as described further in Figure 9 below: energy efficiency; demand response; utility-scale generation; distributed generation; energy storage; and smart grid technology.

Figure 9. NTA Technology Categories

 **Energy Efficiency**	improvements that result in the ability to use less energy to provide end-use customers with the same (or a better) level of service in an economically efficient way
 **Demand Response**	changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time or to incentive payments
 **Utility-scale Generation**	relatively large generators that connect to the grid at the transmission (high voltage) level
 **Distributed Generation**	small generation systems located at a customer site
 **Energy Storage**	technologies that allow electricity generated at one time to be used at another time
 **Smart Grid**	technologies that enable a more efficient use of the electric power grid through computer-based remote control and automation

Note: LEI was not asked to consider SmartGrid as a technology category in this analysis because it is relatively untested and there is limited data available to model it as an NTA technology with confidence.

Consistent with the general categories of NTA technologies and adjusted for what is reasonable in New England (and specifically in Connecticut), the analysis presented in this report was designed around a list of six types of NTA technologies as follows:

1. conventional fossil fuel fired generation (natural gas-fired peaking and combined cycle technologies);
2. large scale renewable generation (solar and wind);
3. distributed generation (solar and fuel cells);
4. active demand response (such as real-time demand response and real-time emergency generation);
5. passive demand response (such as energy efficiency programs); and
6. energy storage technologies (such as utility-scale battery technology and flywheels).

The six types of NTA technologies listed above include both supply-side and demand-side resources. Supply-side technologies include conventional fossil fuel-fired generation, large-scale renewable generation, distributed generation, and energy storage technologies. Supply-side technologies can also include applications with energy storage technologies. Demand-side technologies include various forms of demand response.

Each of these NTA technologies has inherent operating characteristics that may determine their applicability as a technically feasible NTA technology vis-à-vis the reliability-driven requirements for a solution. When evaluating the practical feasibility of NTA technologies (ability for the NTA technologies-based solution to be implemented in real life) versus a transmission solution, the analysis must be done in a way that would make NTAs and transmission comparable in terms of both technical characteristics (reliability) and economic attributes (costs and benefits), as we discuss further below.

3.1 Evaluation of an NTA

As part of its ongoing work with the energy industry, LEI has proposed a set of tools and analytical techniques to allow for a comprehensive evaluation of NTAs and transmission solutions.[17] Although the specific steps and analytical tools can differ, subject to the specific context of a given investment need and system operator's planning process, there are a number of guiding principles that must be considered.

First and foremost, a rigorous analysis should acknowledge that NTA technologies and transmission will provide different services and therefore could generate different levels of benefits for consumers. Furthermore, a rigorous analysis needs to ensure that NTAs meet the technical needs underpinning the transmission solution. Finally, LEI recommends that a comparative analysis is conducted within the discipline of cost-benefit framework, where benefits and costs are considered as comprehensively as possible. Economic cost-benefit analysis should consider the dynamic evolution of the system, rational market response to NTAs and/or transmission, and consideration of the operational uncertainties of each over time.[18]

[17] *Market Resource Alternatives – an examination of new technologies in the Electric Transmission Planning Progress*, WIRES Group, September 2014.

[18] A comprehensive benefit analysis was outside the scope of work in this engagement, given that the levelized cost analysis demonstrated such a wide disparity between the costs (and associated practical challenges) related to implementing NTAs versus the costs linked to the development of the proposed transmission project.

LEI has applied these principles in this NTA analysis. The study begins with the simulation-based supply-side NTA analysis performed by ISO-NE, where the reliability requirements for the GH subarea were determined in the form of location-specific NTA requirements for one bus: NW Hartford. LEI then assigned technologies to the specified NTA requirements using a logical decision tree process to sequentially filter and narrow down the available list of technologies that meet the technical needs underpinning the solutions. Next, LEI employed a levelized cost methodology in order to evaluate the direct costs per annum to ratepayers of implementing NTA technologies. LEI's cost analysis was designed to be as comprehensive as possible. For each NTA technology, LEI developed an all-in cost (gross LCOE) inclusive of development and operation costs (capital cost, fixed and variable operating and maintenance cost, and fuel cost). The net LCOE values were then derived by adjusting gross LCOE values from potential revenues yielded by the NTA technologies.

3.2 Prospective NTA technologies

Thirteen selected prospective NTA technologies have been short-listed based on their ability to operate in the GH subarea. The considered technologies have unique operating characteristics which are compared against NTA injection requirements to determine their feasibility. Figure 10 lists the technologies under consideration for technically feasible NTAs. In addition, the figure also outlines typical capacity ranges, operating profiles and performance rates associated with these technologies, which are detailed in Appendix B. In addition to stand-alone NTAs, the analysis also includes various practical combinations such as solar PV with storage, which are also included in the Figure 10.

In undertaking the technology identification and cost analysis, and for developing the technical assumptions in Figure 10, LEI relied primarily on real world operating experience with such technologies in New England, as well as research documents and market information made publicly available by ISO-NE, and the state of Connecticut related to technologies' operational data and statistics. The understanding of local market conditions was facilitated through Eversource's proprietary market information; where necessary, technologies' operational data were supplemented with engineering–related data and generic information on technologies, including generic information on levelized costs. Such generic information was collected from reputable sources, such as the US Department of Energy and affiliated national laboratories, manufacturers, and engineering procurement companies that work with such technologies. A detailed bibliography list is provided in Appendix D.

Figure 10. Descriptive summary of NTA technologies

MRA Resource	Installed Capacity range	Operations profile	Performance Rate
Combined Cycle Gas Turbine (CCGT)	100 to 800 MW range in CT	Baseload	95% availability factor
Peaker Aeroderivative Unit	1 to 125 MW range	Peaking load	85% availability factor
Peaker Frame Unit	20 to 250 MW range	Peaking load	83% availability factor
Dual-fuel Jet Engine	<1 to 50 MW	Peaking load	85% availability factor
Solar Utility Scale (with storage)	5 to 250 MW	Potential baseload depending on storage capacity	15% efficiency ratio
Solar Utility Scale	5 to 250 MW	Daytime peaking load during sunny days	15% efficiency ratio
Solar DG (with storage)	<1 to 5 MW	Potential peaking load depending on storage	15% efficiency ratio
Solar DG	<1 to 5 MW	Daytime peaking load during sunny days	15% efficiency ratio
Fast Discharge Battery	<1 to 10 MW	Can provide instantaneous power for short periods	Variable, depending on efficiency, charging time and storage capacity
Slow Discharge Battery	10 to 20 MW	Can provide steady supply of power for short periods	Variable, depending on efficiency, charging time and storage capacity
Active DR - Emergency Generation	Variable (based on type of equipment and load)	Peaking load	Assume 15% of peak load becomes available to respond
Passive DR (Energy Efficiency)	Variable (based on type of equipment and load)	Intermittent	Assume 15% of peak load becomes available to respond
Fuel Cells	2.8 MW to 63 MW	Baseload	95% availability factor

Note 1: Wind was not considered as a technically feasible NTA due to the lack of potential for sizeable wind capacity development in the Connecticut.

Note 2: Installed capacity range for utility scale fast and slow discharge batteries depends on the number of individual batteries connected together at a given site. The range indicated in the figure above is indicative, and LEI used variable sizes depending on requirements in order to ascertain the technical feasibility of using batteries as NTA technologies.

Note 3: Performance rates for CCGTs, Peaker Aeroderivative units, Peaker frame units and dual-fuel jet engines calculated based on the ISO New England EFORd Class Averages, sourced from: http://www.iso-ne.com/static-assets/documents/genrtion_resrcs/gads/class_ave_2010.pdf

Note 4: Active DR emergency profile is sourced from ISO New England Operating Procedure No. 14 - Technical Requirements for Generators, Demand Resources, Asset Related Demands and Alternative Technology Regulation Resources." ISO-NE, November 7, 2014 http://www.iso-ne.com/rules_proceds/operating/isone/op14/op14_rto_final.pdf.

Note 5: Size of fuel cells based on DFC3000 units from FuelCell Energy. The maximum size was based on the anticipated 63 MW fuel cells plant to be built in Connecticut (the largest yet in the world). Fuel Cells technology is baseload and can run 24/7 pending fuel availability. Given the limited information on availability factor, we assumed the same availability factor as a CCGT.

More details on the methodology and sources are provided in Appendix B.

In analyzing the potential for new energy efficiency as a technically feasible NTA technology, LEI assumed that at most 15% of the net peak load can be reduced using new energy efficiency measures. According to Eversource, achieving peak load reductions of 15% with passive energy efficiency resources over and above current levels is an aggressive assumption as it would represent approximately a two-fold increase in projected peak reduction currently expected from Eversource's energy efficiency programs. This level of peak reduction through passive energy efficiency resources would be unprecedented in Connecticut and the wider New England region, especially given that the more cost effective energy efficiency measures have been implemented. Achieving demand reduction will become (and has become) increasingly challenging and costly. In addition, successful geo-targeting energy efficiency to small geographic areas can be challenging as it relies upon customers willingness to participate in programs. For example, Eversource's Marshfield Distribution Relief Pilot (a targeted attempt to reduce 2 MW of demand on key circuits/substations through a combination of energy efficiency, direct load control, and solar PV installation) resulted in actual kW reductions of approximately 715 kW – less than 3% of peak day afternoon loads of 25,000 – 30,000 kW on the affected lines. Energy efficiency contributed only 320 kW to this achieved load reduction.

Operations profiles for each NTA technology are used to determine when a given technology can operate during a 24 hour period. N-1-1 contingency events require that a technically feasible NTA technology can operate for 12 hours. For each NTA technology listed in the figure above, its operations profile determines if it can meet the requirements posed by the contingency events. For example, while a peaker frame unit can operate for 24 hours, it may not be operating during off-peak night-time hours, which prevents it from a technically feasible NTA technology.

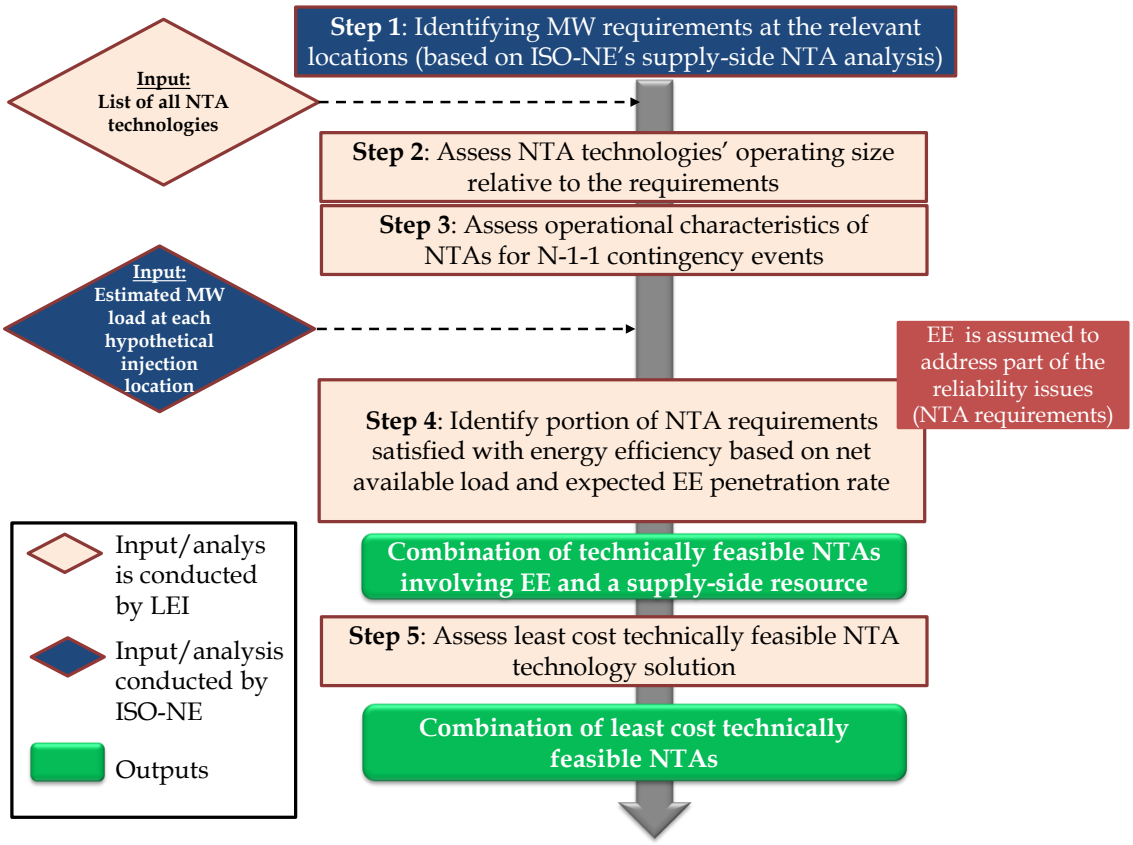
It bears noting that RTDR, which is typically associated with industrial or large commercial customer sites (such as manufacturing facilities or processing factories), was not directly taken into consideration in the analysis, although it could theoretically be considered as a potential NTA technology. There is limited publicly available information on RTDR's operational mode. Operation characteristics would vary from one resource to the other due to a host of parameters including equipment activity type, timing and duration of operation, response/performance rates and opportunity costs, which does not allow us to model these technologies with confidence. Furthermore, under ISO-NE's rules, RTDR and RTEG are not typically operable at any given time of the day, which would be a stumbling block to their technical feasibility under N-1-1 contingency events.[19] For reference purposes, LEI nevertheless estimated gross and net LCOE figures associated with both RTDR and RTEG in Appendix C.

[19] " ISO New England Operating Procedure No. 14 - Technical Requirements for Generators, Demand Resources, Asset Related Demands and Alternative Technology Regulation Resources." *ISO-NE, November 7, 2014* <http://www.iso-ne.com/rules_proceds/operating/isone/op14/op14_rto_final.pdf>.

4 Overview of Methodological Approach

In order to identify technically feasible NTA technologies that can satisfy the reliability issues being addressed by the GHCCRP, a five-phase methodology was designed as illustrated in Figure 11 below.

Figure 11. Methodological Approach



The overarching objective of LEI's methodology from Step 1 through Step 4 is to: i) identify the portion of NTA requirements covered by energy efficiency programs at a given location; and ii) determine both volume (MW) and type of supply-side NTA technologies required to address the remainder of the capacity needs at the injection point. The methodology uses decision tree analytics to sequentially filter and narrow down the available list of technologies according to the requirements at each location. In summary, the five steps for selecting a technically-feasible NTA technology are as follows:

- Step 1: determine capacity needs (in MW) at the NW Hartford substation (completed by ISO-NE) to solve for reliability issues;
- Step 2: screen prospective technologies based on their size and the capacity needs at the injection point. This is analytically straightforward and effectively narrows the list of technically feasible NTA technologies for the subsequent steps;
- Step 3: evaluate the successfully screened NTA technologies based on their technical parameters and select the ones that conform to the contingency event requirements; and

- Step 4: evaluate the feasibility of addressing the reliability requirements with a combination of energy efficiency programs and supply-side NTA resources. The amount of EE relied upon is determined based on net available load and expected EE's penetration rate at the injection point.

While LEI recognizes that there may be multiple NTA technologies (or combination of NTA technologies) that are technically feasible at a substation, the purpose of this analysis is to only identify all possible technically feasible NTA technologies that individually meet the criteria of the hypothetical NTA injections (either in terms of size, location, or operating profile).

In the last step (Step 5), the levelized cost methodology evaluates the direct cost of implementing the combination of technically feasible NTA technologies for Connecticut ratepayers. Since no merchant sponsor is proposing to build an NTA and our analysis shows that it would not yield a sufficient return to attract private investment, we assume that it would be built only if its costs were borne by electric ratepayers. Those direct costs are then compared to the costs of building and servicing the components of the GHCCRP transmission solution. The direct cost to Connecticut customers is calculated by aggregating, net direct costs to consumers associated with constructing and operating the least cost technically feasible NTA technologies identified for the NW Hartford substation. The full cost of the NTA technologies would be passed through to Connecticut ratepayers. On the other hand, for the proposed transmission solution, the costs of the transmission solution will be rolled into regional network service and recovered through the Pooled Transmission Facilities rates. Therefore Connecticut ratepayers would only pay a share of those costs based on current ISO-NE rules for transmission cost allocation (i.e., 27% of the total costs to construct and operate, based on current load projections).

4.1 Determination of hypothetical NTA solutions

As part of the process for the needs assessment for the GHCC and identification of preferred transmission solutions, ISO-NE conducted two NTAs studies[20] in late 2012 that identified the smallest aggregate quantity of injections (as measured in MW terms) across the four subareas (the entire GHCC area) that would alleviate the thermal system overloads. The assumptions underpinning the NTA studies are based on the initial Needs Assessment study (2012). ISO-NE performed separate and distinct hypothetical analyses for either a 100% demand-side solution or a 100% supply-side solution – both analyses were done under a number of different dispatch conditions, with the objective being to identify a minimum amount of total MWs (dispersed across the "best" locations) associated with either net load reduction or additional supply that would resolve all overloads and thermal violations under N-1-1 contingency events. The analyses were performed for the GHCC area as a whole, instead of at subarea level. Figure 12 summarizes the assumptions relied upon for the Needs Assessment and therefore for the NTA studies.

[20] According to ISO-NE, the two analyses were conducted separately consistently with ISO-NE's protocol at the time. Since then, ISO-NE has moved to a hybrid approach considering both supply-side and demand-side resources under the same analysis.

Figure 12. Summary of modeling assumptions used in the NTA studies

Items	Description	Sources
Horizon	10 years (2013-2022) with a focus on the year 2022	ISO-NE
Power Flow study	ISO-NE's Model on demand system to reflect system conditions in 2022	ISO-NE
Topology	Included transmission projects with proposed plan application approved as of April 2011 as well as new projects as of October 2013.	April 2011 RSP Project Listing, and ISO-NE
Supply	Generation projects with a FCM Capacity Supply Obligation as of Forward Capacity Auction 7 (FCA #7) were included in the study base case. This includes the Cape wind project which materialization is in jeopardy. It does not include Bridgeport Harbor 2 and Norwalk Harbor.	GHCC Needs Assessments
Load	Used year 2022, 90/10 summer peak load level from the CELT: 34,105 MW for New England and 8,825 MW for Connecticut. The CELT load forecast includes both system demand and losses (transmission and distribution) from the power system.	CELT report issued in May 2013
Energy efficiency (Passive DR)	Includes 100% passive demand response cleared in FCA (#1 to #6); Assume 100% of EE forecast for the remaining years 2016-2022. EE resources were modeled via a load reduction spread across their respective load zones.	FCA (#1 to #6); Final 2013 Energy-Efficiency Forecast 2016-2022 (March 2013)
Active demand response ("DR")	Based on active demand response cleared in FCA (#1 to #6) to which it is a plied a 75% performance factor based on historical performance of similar resource. Active DR were modeled via a load reduction spread across their respective dispatch zones.	FCA (#1 to #6)

The ISO-NE's supply-side analysis estimated that approximately 936 MW would be needed to solve overloads and thermal violations in the GHCC area (and 196 MW in the GH subarea), versus 1,350 MW for the demand-side analysis. There were three fundamental aspects of the ISO-NE's analyses that needed to be considered in deciding on the pertinence and the usability of ISO-NE's study results:

i) ***The choice of NTA study***: should LEI use the demand-side or the supply-side NTA study or both?

ii) ***The independence of the NTA requirements for the various subareas***: can the NTA requirements for each subarea be evaluated without consideration of the NTA needs in another subarea?

iii) ***The staleness of the NTA studies***: is it reasonable for LEI to rely on NTA requirements based on a study performed in late 2012?

Further details on the consideration of these three issues is provided below. However, in summary, based on discussion with ISO-NE staff that authored the NTA studies and discussions with Eversource's system planners, LEI concluded that the demand-side NTA study did not need to be

evaluated. LEI also concluded that the NTA requirements for each subarea can be analyzed individually, and that the requirements themselves as estimated by ISO-NE in late 2012 were still valid.

4.1.1 Choice of NTA study

The NTA demand-side analysis has unrealistic demand reduction assumptions.[21] This NTA study was one of the first ever done by ISO-NE and the ISO has since then modified its approach. LEI's understanding was confirmed by a discussion with ISO-NE staff,[22] who recommended not developing any analysis based upon these results. ISO-NE staff suggested testing the feasibility of both supply-side and demand-side technologies at the NW Hartford substation based on the total requirement identified under the NTA supply-side analysis (as summarized in the figure below, and totaling 196 MW).

Figure 13. Summary of injection requirements for the hypothetical NTA solution for the GH subarea

Project Subarea	Substation	MRA requirements
Greater Hartford	NW Hartford	196 MW

4.1.2 Independence of NTA requirements across subareas

When ISO-NE expanded the scope of its GHCC Needs Assessment in 2011 to cover all of the Greater Hartford, Manchester/Barbour Hill, Middletown, and Northwest Connecticut subareas, it expected, based on earlier, preliminary study results, that the needs and solutions in the four subareas would be "interdependent."[23] This was still the case when the ISO-NE performed its initial GHCC Needs Assessment, which was presented in August, 2012 (Needs Assessment I), and its NTA studies,[24] which were presented to the PAC in November and December 2012.

The NTA studies "used the same conditions and study criteria used in the [initial] GHCC Transmission Needs Assessment."[25] In the studies, ISO-NE cautioned that each subarea's NTAs "work only if applied simultaneously with other subareas."

Subsequently, as work progressed on the preferred transmission solutions for the GHCC area, through a "Working Group" that was led by ISO-NE planners (and included representatives of the planning staffs of the Northeast Utilities Service Company and The United Illumination Company), it became

[21] For instance 64% of demand reduction was assumed for the Northwestern CT subarea, Source: NTA Demand side results GHCC, PAC meeting, November 14, 2012.

[22] Discussion with Justice Ansah and Dwarakesh Nallan on May 14, 2015.

[23] Planning Advisory Committee Presentation, "Greater Hartford and Central Connecticut Area (GHCC) Needs Assessment Scope of Work, March 16, 2011, at page 3

[24] Demand-side and supply-side NTA studies.

[25] Supply-side MRA analysis, at page 7.

clear that previous assumptions on interdependence were not relevant. As the Working Group developed transmission solutions to address criteria violations in the four subareas, they realized that the needs of each subarea could be resolved independently. As stated in their final Solutions Report, published in February, 2015, the Working Group ultimately determined that the solutions for different subareas within the greater GHCC area could be analyzed independently of one another since the needs for the area were largely driven by load serving issues following the loss of critical 115 kV sources into each area. Thus, in the final Solutions Report, the Working Group analyzed separate "local solution alternatives" for the Northwestern Connecticut subarea, the Middletown subarea, and for the GH subarea.

Eversource planners who were part of the ISO-NE GHCC Working Group have advised LEI that it is reasonable to assume that, since each subarea was ultimately determined to be an independent local transmission solution, each subarea could also be considered as independent local non-transmission solution. In a memo submitted to LEI on the topic, Eversource stated that "to determine if there is a practical NTA for the GH subarea, an NTA consisting of the quantities (MW) of injections or load reductions at the busses specified in the ISO-NE study for each of these subareas may be analyzed without considering the solutions that would need to be implemented to address issues in other subareas." Further, "if a conceptual NTA identified by ISO-NE's NTA analysis is determined to be practical, based on cost, technical, environmental and siting considerations, then additional system modeling can be performed to confirm that it will provide the expected performance on its own, or what additional transmission or non-transmission improvements would be required."[26]

4.1.3 Staleness of the NTA studies

ISO-NE's supply-side NTA analysis was performed based on the assumptions in the GHCC Needs Assessment presented to the PAC meeting in December 2012. Thereafter, in light of significant changes in predicted resources in the study area, ISO-NE revised[27] its Needs Assessment to reflect increases in the predicted Connecticut net load for 2022 and changes in the distribution of that load. As a result, the modeled net load for the GH subarea changed from 1,203 MW to 1,222 MW, an increase of 19 MW or 1.5%. While it is possible that these changes might result in a change to the NTA requirements identified in the 2012 supply-side NTA study, the change, if any, would be an increase in the required MW according to Eversource planners. In other words, for the purposes of assessing the technical feasibility of NTA technologies to the proposed transmission improvements, it is reasonable to consider the NTA requirements identified in ISO-NE's analysis (without consideration for additional MW) to conduct our independent analysis. Should an NTA be found to be the least cost solution based on economic, environmental, and siting considerations, supplemental load flow studies would need to be performed to assess the performance of the NTA and whether any changes to the NTA quantity are required.

Figure 14 shows the geographical location of the NW Hartford substation (bus) in relation to the interstate natural gas pipelines that supply Connecticut. The injection amount or requirement is in

[26] Analysis of Non Transmission Alternatives to Transmission Improvements in Greater Hartford and Northwest Connecticut Subareas, Robert Russo and Joseph Adadjo, Eversource Energy Service Company, Planning, June 8, 2015.

[27] Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment, May 2014.

capacity (MW terms) but also effectively represents an amount of energy that would be needed to be injected into the system at a given moment in time, in order to ensure reliable operations during contingency events.

Figure 14. NTA requirements at the NW Hartford substation



The closest (large) cities are demarcated with red dot, and the injection point is labeled with a blue marker

4.2 Methodology for identifying technically feasible NTA technologies

As summarized in the previous section, LEI used a five-step methodology for selecting the least cost technically feasible NTA technologies at the NW Hartford substation. The first four steps are dedicated to the selection of all the technologies that would be technically feasible at the relevant location, whereas the last step is used to select the least cost of this group of resources.

A technically feasible NTA technology is defined as one that can independently fulfill to all the requirements at the specific location. In other words, if at a location, two different technologies are required to work together (e.g. solar PV during the day and a CCGT at night) to meet the requirements,

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then neither of these technologies is determined to be technically feasible for this location on their own.[28]

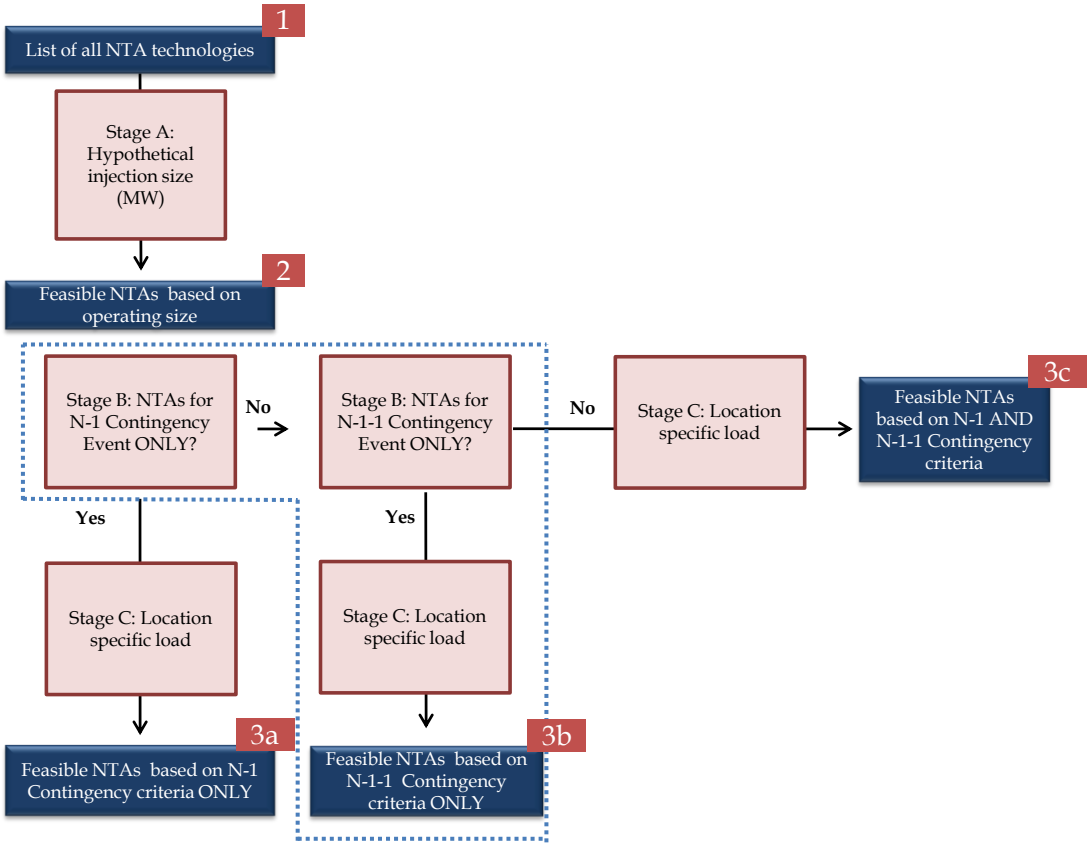
However, a given location can have multiple NTA technologies that can each independently meet the NTA requirement. In such cases, the final selection from among the technically feasible NTA technologies is based on their levelized costs (multiplied by the NTA requirement), as discussed further in Section 5.1 below.

When we use the term, "technically feasible", we are reflecting on a specific technology's ability to meet requirements set out by system planning criteria, and therefore in the case of this analysis, "feasibility" is not to be interpreted in the more connotative sense of the word (and the technologies may still be deemed to be impractical or commercially infeasible, as discussed in Section 5 of this report). System planning criteria refers to requirements such as the maximum allowable time for an NTA technology to respond to N-1-1 contingency events (response time) and the minimum duration of time for which an NTA technology must remain operational after being called into service. In contrast, physical considerations, which are not a part of this methodology, refer to the amount of land required for a given NTA technology to be located at a substation and the time required for siting and construction, as well as the anticipated market need for the NTA technology in the future. These physical constraints and commercial development considerations are presented in Section 5.2. The cost implications of technically feasible NTA technologies are also discussed in detail in Section 5.1.

Figure 15 depicts in a flow chart the decision process followed to arrive at a selection of technically feasible technologies that clears both the size and the operational criteria commanded by n-1-1 contingency events. The decision process is another interpretation of Steps 1 through 4 of Figure 11.

[28] The exception to this philosophy relates to solar PV technologies and energy storage. We do combine these two separate NTA technologies in order to form a third unique technology; energy storage enables the solar PV unit to qualify as a technically feasible NTA technology (if some of the production from day-time hours is stored so that it can be injected into the grid at night).

Figure 15. Methodology for identifying technically feasible NTA technologies (supply-side resources)



Note: Circled in dotted line is the process followed for selecting technically feasible NTA technologies based on operating size, operational characteristics and n-1-1 contingency criteria.

Stage A: Size

The first step focuses on the level or size of injection required by location or node. Upon reviewing commercial information provided by manufacturers (such as General Electric ("GE"), SIEMENS or FuelCell Energy) on technologies, and comparing the typical size of the prospective resources in operation in Connecticut against the size of injection requirements at each location, it is possible to eliminate NTA technologies that are not suitable to the size of the injection. The maximum and minimum sizes considered for each NTA technology are summarized in Figure 10.

Stage B: Operational

We then move to consider the operating characteristics of the list of technically feasible NTA technologies from Stage A, relative to the requirements of the NTA injection amounts. These operating characteristics refer to N-1-1 contingency events. LEI understands that as part of the NTA studies, ISO-NE modeled the N-1-1 contingencies, as those were more severe than the N-1 contingencies.

N-1 and N-1-1 contingency events have associated operational considerations that must be met by a technology in order to be considered a technically feasible NTA technology. Although LEI's selection process was designed to be fully inclusive and solve multiple situations, including those where NTA requirements would emerge under both N-1 and N-1-1 contingency events, this analysis only considered N-1-1 events' criteria with respect to technologies' operational characteristics – as highlighted in dotted line on Figure 15. An N-1 contingency event refers to a situation when a single element of the generation or transmission system fails. An N-1-1 contingency event refers to a situation where an additional single element of the generation or transmission system fails within 30 minutes of the N-1 contingency event. Under these circumstances, a qualified NTA technology must be able to provide energy within 30 minutes and must continue to do so until the elements are repaired or as long as deemed necessary by the ISO-NE (typically, ISO-NE can resolve contingency events within a 12 to 24 hour cycle; LEI has assumed a 12 hour duration to resolve the N-1-1 contingency events in its analysis.

Stage C: Locational

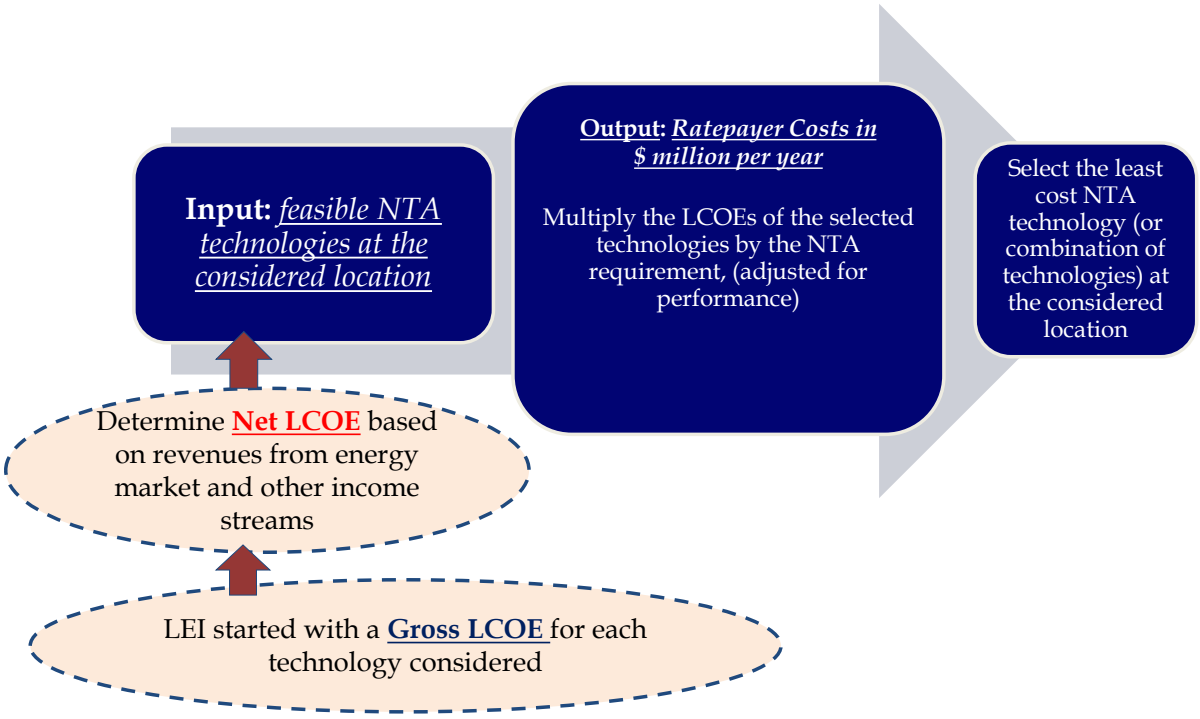
The last stage further refines this list of technically feasible NTA technologies by using locational considerations at the NW Hartford substation. This stage of the methodology evaluates the potential for implementing incremental EE measures based on the net load (MW demand) at each injection location. We assumed that energy efficiency programs will be part of any NTA solution deemed feasible to address reliability requirements. The underlying assumption is that the level of peak reduction achieved through passive energy efficiency resources would not exceed 15% at the relevant location, lowering consequently the associated NTA requirements. Achieving incremental peak load reductions from energy efficiency of 15% above levels achieved through state-mandated programs would be unprecedented as such a target reduction goes well beyond utility geo-targeting experiences to date.

The sample of NTA technologies resulting from LEI's selection process were then used as direct inputs into the cost analysis.

4.3 Methodology for estimating cost of technically feasible NTA technologies

LEI applied industry-standard levelized costing principles to the identified pool of technically feasible NTA technologies from Stage 3B (Figure 15) above in order to estimate the total cost of implementing the least cost technically feasible NTA technologies. For each selected technology, LEI estimated a gross LCOE, which represents a resource' all-in-costs, levelized over its life cycle. The gross LCOE is a per kilowatt per year figure ($/kW-year) that embodies all costs including capital costs, going-forward FOM costs, as well as fuel and VOM costs. The gross LCOE represents a long term timeframe that is consistent with the requirements identified at the NW Hartford substation. As a next step, LEI derived Net LCOE for each technology by deducting from gross LCOE a bundle of potential revenue streams associated with each NTA technology. The analysis then consisted of multiplying at the considered injection point the net LCOEs of all feasible technologies by the NTA capacity requirements (adjusted for performance and availability). The least cost technically feasible NTA solution for NW Hartford was selected by comparing the products of net LCOEs and NTA capacity requirements for all feasible technologies. Finally, we aggregated the total costs associated with the identified least cost technically feasible NTA technologies at NW Hartford in order to determine net direct cost for the Connecticut ratepayers. Figure 16 provides an illustration of this methodology.

Figure 16. Methodology for estimating net direct costs of technically feasible NTA technologies ($/kW-year)



Gross and Net LCOE are expressed in dollars per kW-year unless otherwise specified.

4.3.1 Determining gross LCOE for technically feasible NTA technologies

Gross LCOE represents the total fixed cost of NTA technologies levelized over the lifetime of the relevant technologies. As discussed previously, gross LCOE includes capital costs, fuel costs, as well as both FOM and VOM. Gross LCOE is denominated in $/kW per year and then multiplied by the installed capacity of the technically feasible NTA technologies to derive an annual gross cost. Figure 17 provides a summary of calculated gross LCOE for all technologies deemed technically feasible. For cost information, LEI relied primarily on data made publicly available by ISO-NE and the state of Connecticut. We then cross-compared and supplemented this data with information collected from reputable sources, such as the US Department of Energy and affiliated national laboratories, manufacturers and engineering procurement companies that work with such technologies, as well as actual operating data from similar installations across New England.

Appendix C provides a detailed description of assumptions and sources used for determining the ranges of gross LCOEs. LEI defined a +/- 20% range of gross LCOE to take into consideration the uncertainty associated with cost assumptions. In fact, in real life, development and operation costs of facilities can vary significantly and deviate from a generic assumption due to a variety of reasons including plant location, financing structure and market conditions, technology types, labor cost, environmental cost, site preparation, fuel supply, etc. The cost range was suggested in an attempt to

crystallize this uncertainty. The +/-20% cost range was used to measure the impact of this uncertainty on the net direct costs of technically feasible NTA solutions.

Figure 17. Summary of Gross LCOE per year for each technology

Feasible Technologies (all numbers in $/kW - year unless specified otherwise)	Gross LCOE ($/kW-year)	Range ($/kW-year) -/+20%	
CCGT	$ 418.0	$ 334.4	$ 501.6
Peaker Aeroderivative	$ 323.4	$ 258.7	$ 388.1
Dual fuel jet engine	$ 362.9	$ 290.3	$ 435.5
Slow Discharge Batteries	$ 181.4	$ 145.1	$ 217.7
Solar Utility Scale (with storage)	$ 415.9	$ 332.7	$ 499.1
Passive DR (Energy Efficiency)	$ 513.0	$ 410.4	$ 615.6
Fuel Cells	$ 382.7	$ 306.1	$ 459.2

Gross LCOE for CCGT was adjusted to reflect smaller than standard size of the required plant. The size of generic CCGT considered in ISO-NE's analysis ranges between 500 and 700 MW. CCGTs needed to meet the NTA requirements in this analysis are much smaller and therefore, they are likely to be more expensive in dollar per kW terms. The opportunity cost of inefficient scale for CCGTs is reflected in the numbers above by application of a 12% increase to the gross LCOE figure, based on the overnight cost difference between 400 MW and a 600 MW CCGT power plant (Source: EIA).

Sources: ISO-NE (ISO New England Inc. and New England Power Pool, Docket No. ER14) 000, Demand Curve Changes, Paril 2014), National Renewable Energy Laboratory ("NREL"), Pacific Northwest National Laboratory ("PNNL"), International Energy Agency, Electric Power Research Institute ("EPRI"), Department of Energy, FuelCell Energy and LEI

4.3.2 Determining Net LCOE for technically feasible NTA technologies

The total gross cost of NTA technologies can be defrayed by market revenues and other sources of income received by these resources when they begin operations, which in turn would reduce the cost of the NTA to ratepayers. Therefore we deduct these revenues from the gross LCOEs, so as to isolate the net direct costs to ratepayers for a technically feasible NTA solution. In this respect, LEI adjusted the gross LCOE analysis by incorporating a number of potential market revenue streams associated with each feasible technology. The resulting calculation is the net LCOE which is relied upon to evaluate net direct cost of implementing technically feasible NTA technologies for ratepayers. The revenue streams considered in this analysis include revenues from the energy and capacity markets, Local Forward Reserve Market ("LFRM") and Regulation Market revenues, income associated with avoided retail rate costs (for solar DG and energy efficiency resources), as well as Renewable Energy Credits. However, we did not integrate in the analysis any additional charges (such as Net Commitment Period Compensation ("NCPC") associated with operating the technologies out of merit.[29] Figure 18 depicts

[29] NCPC is the additional compensation received by a resource that is committed for reliability purposes but not dispatched above its economic minimum output level.

the revenue streams considered and provides a summary of calculated Net LCOE by feasible technology. Appendix C summarizes the sources relied upon to estimate the revenue offsets.

Figure 18. Components of the net LCOE calculations for each technically feasible NTA technology ($/kW-year)

In $/kW-year	CCGT	Aero Peaker	Passive DR (EE)	Fuel Cell
Gross LCOE	418.0	323.4	513.0	382.7
Energy*	283.3	117.8	-	54.0
FCM	57.3	57.3	61.9	-
LFRM	-	-	-	-
Regulation	-	-	-	-
Avoided retailed cost	-	-	143.3	-
Net LCOE	77.4	148.3	307.8	328.7

Notes: This table illustrates net LCOEs for a scenario assuming half of FCM payments are received by the resources Rows highlighted in pink represent revenue offsets, while the bottom blue row contains the net LCOE results from the realization of all of these revenue offsets.

FCM price based on FCA#9 results ($9.55/kW-month) (before adjustment for derating factor and scenario)
**Energy revenues inclusive of VOM and fuel cost recovery*
LFRM ($/MW-month) for summer 2013: $2,996; LFRM ($/MW-month) for winter (2013/2014): $5,501
Annual average regulation price (without performance payment in 2013):$18/MWh
Avoided retail cost: (based on average residential retail rate) $21.9/MWh
Charging costs for battery have not been taken into account

Sources: ISO-NE, NREL, PNNL, IEA, EPRI, DOE and LEI

5 Analysis and results

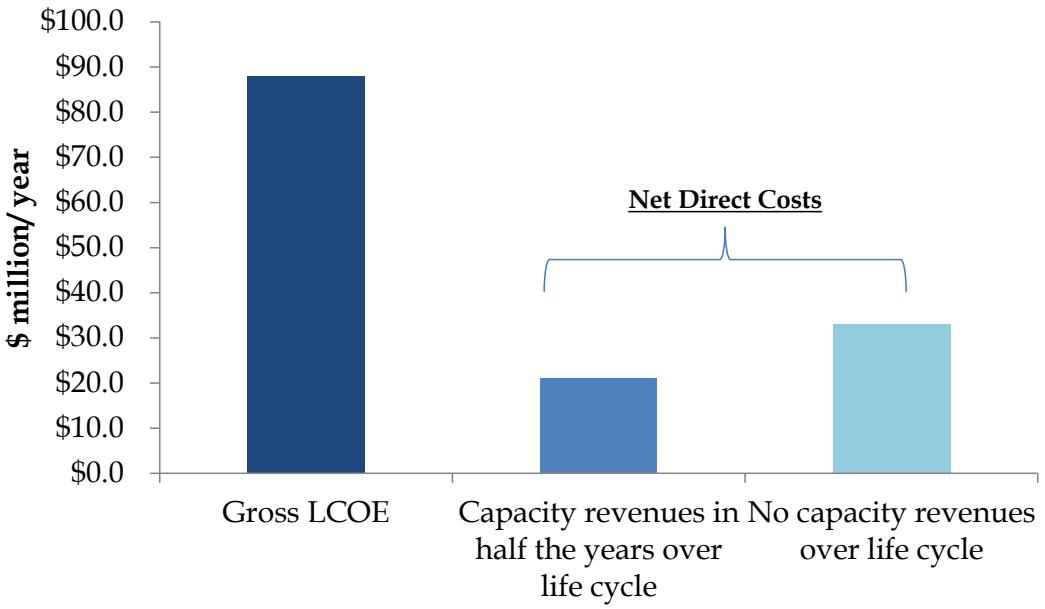
Of the total thirteen NTA technologies under consideration, two technologies qualify as technically feasible for the GH subarea. At the NW Hartford substation (196 MW of requirement), the technically feasible NTA technologies include: (i)CCGT and (ii) peaker aeroderivative (multiple units). And, based on our hybrid approach, some of the requirements can be fulfilled by EE. We believe that no more than 23 MW of load reduction via EE should be expected given the assumed 15% threshold of demand reduction. Fast discharge batteries, solar PV (DG and utility scale) without storage, and peaker frame units are among the technologies that never qualify as technically feasible NTA technologies owing to their various technical characteristics (i.e., limitations on performance duration, and/or time of performance).

The injection amounts associated with these technologies need to be converted into an installed capacity figure using the performance rates of each individual technology (e.g., availability factor for thermal technologies, conversion efficiency for solar units and batteries). For instance, a requirement of 1 MW may actually require installed capacity that exceeds 1 MW. Furthermore, since more than one NTA technology can be technically feasible for a given location, the installed capacity of all the technically feasible technologies can be significantly larger than the NTA requirement at that location, as there are multiple feasible technologies that are possible at many locations. For example, the 196 MW of NTA requirements at NH Hartford translate into 206 MW of CCGT installed capacity after accounting for expected performance (without taking EE into consideration).

The cost analysis begins with the evaluation of total cost of technically feasible technologies based on gross LCOE and estimated required nameplate capacity. Under the baseline gross LCOE, gross costs for a technically feasible NTA to the GHCCRP that involve a small portion of EE and CCGT resources, are estimated at $88 million per year. When adding a +/- 20% sensitivity on gross LCOEs, the resulting gross costs range from $70 million to $105 million a year.

LEI recognizes that total costs of NTA technologies can be defrayed by revenues from markets as well as other sources. Therefore, in estimating the cost of a feasible NTA solution that would be payable by Connecticut ratepayers, LEI elected to deduct expected notional market revenues from the gross costs in order to derive a net LCOE. The net LCOE multiplied by the required nameplate capacity for the technically feasible NTA technologies completes the process of estimating the net direct cost to ratepayers.

Figure 19. Illustration of gross and net direct cost



The primary uncertainty in estimating the net LCOE is the revenue forecast for each technology. Running a full blown simulation for each technology and forecasting year by year revenues was outside the scope of this study. Therefore, projected revenue offsets were estimated using existing market information and general market expectations for the future.[30] For example, for capacity revenue, LEI assumed an average price over time consistent with FCA#9. Energy market revenues were forecast based on information relied upon by ISO-NE to establish net CONE for various technologies, and other rules within the FCM. In summary, the net direct cost was estimated to range between $21 million and $33 million per year across the two scenarios. The two scenarios vary according to the level of capacity revenues attributable to NTA resources during the technologies' lifecycle. The scenario that produces the lowest net direct cost to ratepayers is Scenario 1, where the technically feasible NTA technologies are assumed to receive capacity payments over half the years of their lifecycle. Under this scenario, the net direct cost to ratepayers is estimated at $21 million a year, which is significantly more than the portion of the annual revenue requirements of the GHCCRP transmission solution, supported by Connecticut ratepayers (approximately $4.6 million). In addition, it is important to keep in mind that 100% of the NTA technologies' costs would be shouldered by Connecticut ratepayers; whereas only 27% of the projected annual revenue requirement (27% of $17.1 million a year) for the transmission solution is expected to be borne by Connecticut end-users.[31]

[30] A detailed modeling analysis would be required to further refine these revenue estimates and factor in the resources' year on year impacts on market conditions and how that, in turn, affects market prices; such an analysis is beyond the scope of this report.

[31] Transmission solution costs provided by Eversource

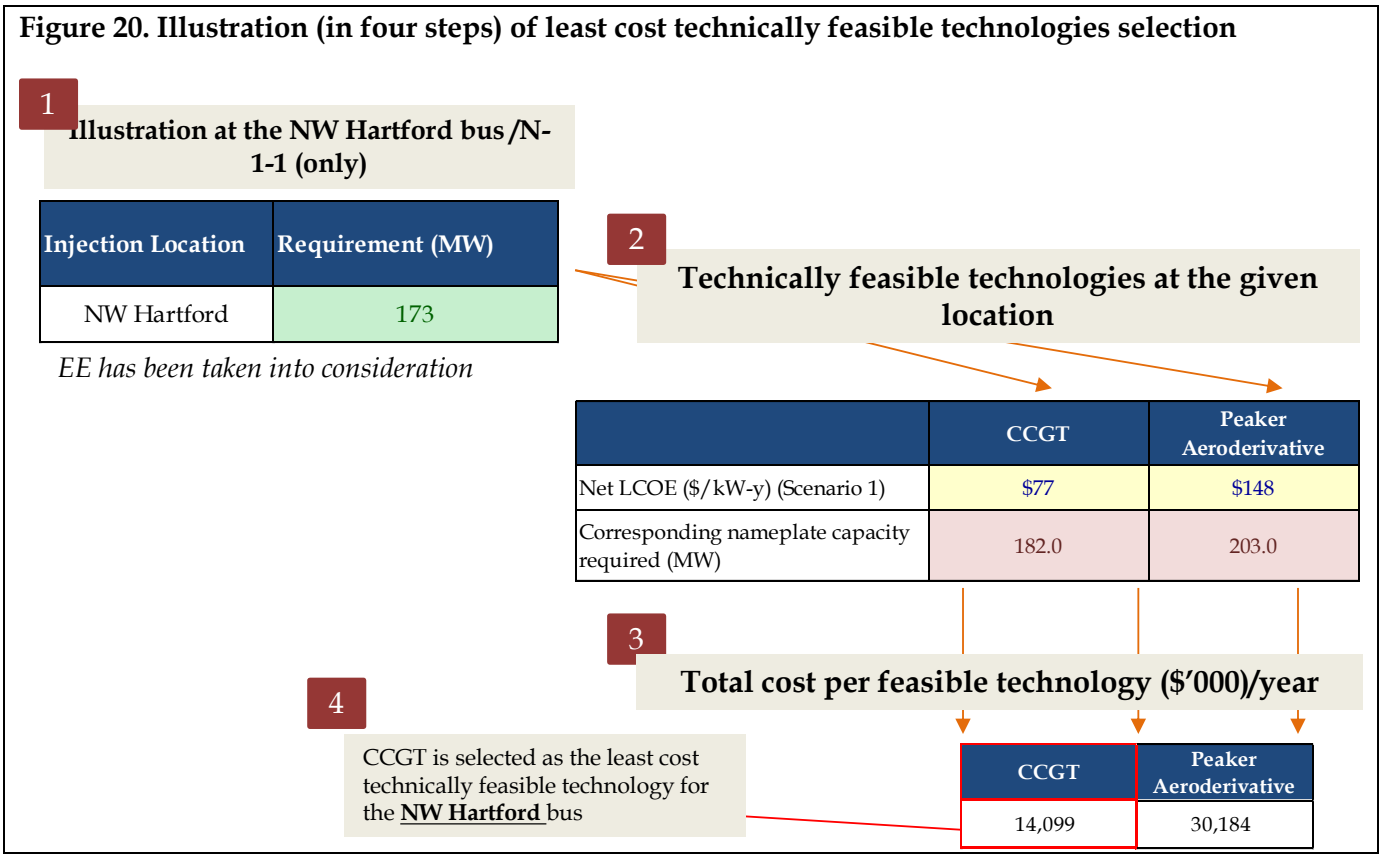
5.1 Cost estimates

The goal of the cost analysis is to evaluate the net direct cost of implementing NTA technologies for Connecticut ratepayers as opposed to building the components of the GHCCRP transmission solution. The analysis begins with the evaluation of total cost of technically feasible technologies based on gross LCOE and nameplate capacity, followed by a net LCOE analysis which leads to an estimate of the net direct costs to ratepayers.

5.1.1 Gross cost estimates for ratepayers

Under the base line gross LCOE, gross cost for ratepayers is estimated at $88 million a year for a hybrid NTA solution at the NW Hartford bus. This gross cost reflects 23 MW of EE, along with 182 MW of CCGT technology. When adding a +/- 20% sensitivity, the resulting gross direct cost falls within a range of $70 million to $105 million a year. The cost analysis was done for all identified technically feasible NTA technologies based on the combination of their respective gross LCOE and total nameplate capacity requirements - adjusted for operating factors.[32] At the NW Hartford bus, we compared the resulting costs for all technically feasible NTA technologies to derive the least cost NTA technology LEI then tested both higher (+20%) and lower (-20%) gross LCOEs.

Figure 20. Illustration (in four steps) of least cost technically feasible technologies selection



[32] Operating factors include capacity factor, availability factor and ramping rates.

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At the NW Hartford substation, EE in combination with a CCGT is the least cost technically feasible NTA technology.

It is worth noting that the successful development of 182 MW of gas-fired generation in NW Hartford might be challenged by a host of physical constraints such as land and fuel supply availability, access to cooling water and other factors, as discussed in Section 5.2. Therefore, the gross LCOE analysis of technically-feasible NTA technologies is not sufficient to determine whether a NTA solution is practical.

5.1.2 Net direct cost estimates of NTA solutions for ratepayers

As discussed in Section 4.3.1, the major revenue offsets for NTA technologies include energy and capacity revenues. However, capacity revenues are not certain for these NTAs. First of all, the capacity auction occurs three years in advance and new resources must apply to qualify a year in advance. Therefore, an NTA that is aiming to go into service in 2016 would not be able to secure capacity revenues until May 2021 at the earliest (assuming it has not yet applied in the Show of Interest window for the next FCA for the 2019-2020 deliverability period). In fact, if there is surplus capacity supply, a new resource may not clear, even if it qualified to participate in the capacity auction. Based on LEI's analysis of market developments and ISO-NE's load projections for the future, there may not be "room" in the near term future auctions for additional resources to clear. So NTA resources brought to market in order to serve as part of an NTA solution for GHCCRP would likely not get revenues from capacity sales for some of its operating years.[33] In fact, in the most recent auction (FCA#9), there was enough capacity to meet the system wide Installed Capacity Requirement ("ICR"). Going forward, we do not see an immediate need for new capacity resources as future capacity needs are expected to be met by other resources, including energy efficiency and other announced resources. As such, there will be no "room" in the capacity market for significant new gas-fired generation, unless existing resources decide to exit the market (i.e., delist and retire). Moreover, for a new generating resource to be accepted and qualified to participate in the FCM, it would not be able to use out-of-market funding (by customers) to gain a competitive advantage on other capacity suppliers. ISO-NE requires that all new resources offer into the FCA consistently with their fundamental costs of investment. Based on ISO-NE's published offer review trigger price ("ORTP") data, the minimum acceptable offer price for a generic gas-fired CCGT is $9.170/kW-month and minimum acceptable offer price for a generic gas-fired peaker is $13.820/kW-month.[34] Therefore, if the capacity price is lower than this minimum offer price, neither the new CCGT nor the new peaker would be able to compete with existing generation and therefore would not clear the FCA.

In addition, there is uncertainty regarding future capacity prices. Over time, when the ISO-NE capacity market is balanced, then capacity clearing prices in the FCA will tend to the net CONE. However, there may be years where prices are significantly below that price level. And if all the resources in an NTA

[33] None of the technically feasible NTA technologies are currently being considered by investors for development at the NW Hartford substation in the GH subarea. Should gas-fired generation be built and interconnected with the NW Hartford substation, it would likely require out-of-market compensation, especially given the timetables of the Forward Capacity Market vis-à-vis the timing of the required solution.

[34] Parameters for the Tenth Forward Capacity Auction (FCA #10), Capacity Commitment Period 2019-2020. www.iso-ne.com/static-assets/documents/2015/05/parameters_for_the_tenth_forward_capacity_auction.pdf.

solution were to clear the FCA, that would reduce the clearing price in the FCA (and the capacity revenue offsets in the net LCOE), which would then raise the net direct costs of the NTA solution to ratepayers. In light of these capacity market timing and pricing uncertainties, LEI calculated the net direct costs to ratepayers under two scenarios: (i) technically feasible resources would be able to clear FCAs for half the years % of their life span (or alternatively, one can view this scenario as one where capacity prices are depressed below net CONE levels); and (ii) technically feasible resources do not clear any FCA and consequently do not earn any capacity revenues throughout their life-cycle, to defray NTA direct costs to Connecticut ratepayers. Figure 21 summarizes the two scenarios considered by LEI.

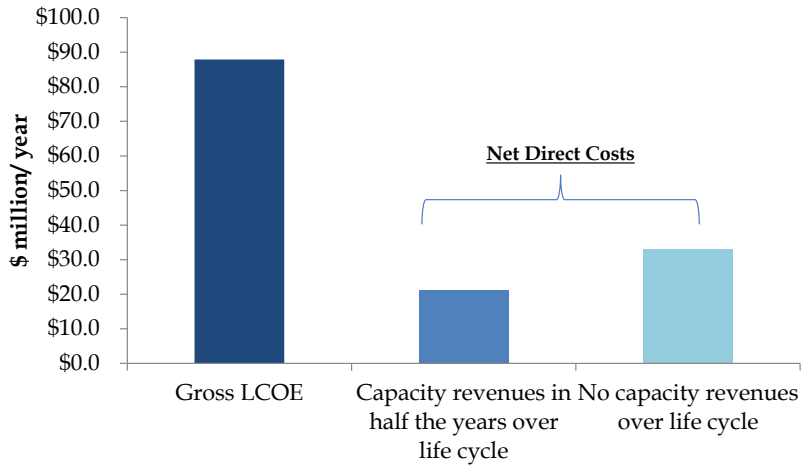
The total net direct cost (gross costs net of revenues offsets) of an NTA solution for the GH subarea payable by Connecticut ratepayers was determined to range between $21 million and $33 million a year. This cost range was based on the following combination of technically feasible NTA technologies: 23 MW of EE and 182 MW of CCGT.[35] The lowest net direct costs ($21 million per year) to ratepayers materialize under Scenario 1, where we assume some capacity revenues over the lifetime of the NTA technology.

Figure 21. Summary of LEI's scenarios

Scenario	Methodology	Key assumptions for net LCOE
Scenario 1 (Capacity revenues in half the years over life cycle)	Net LCOE used to select the least cost technologies	We assumed that new resources such as CCGT and peakers would receive capacity payments over half the years of their life cycle
Scenario 2 (No capacity revenues in years over life cycle)	Net LCOE used to select the least cost technologies	We assumed that none of the new resources would receive capacity payments over their respective life cycle

[35] Net LCOEs were derived from mid-range gross LCOE values.

Figure 22. Estimated net direct costs of NTA solution for GHCCRP per annum based on varying assumptions regarding offsetting revenues and subsidies



Greater Hartford	Scenario 1	Scenario 2	Newington to Southwest Hartford
Scenarios	Capacity revenues in half the years over life cycle	No capacity revenues over life cycle	Cost of the transmission solution shouldered by end-users
Total cost ($ million/ year)	$21.2	$33.0	$4.6

5.2 Qualitative discussion on feasibility of NTA solution in the GH subarea

There are several factors associated with each NTA technology that will have further bearing on its practical feasibility at the required interconnection point or node. The scope of this analysis does not presume to identify and evaluate all criteria for successful development of technically feasible, least cost NTA technologies at the NW Hartford bus. However, we have considered general development requirements associated with each NTA technology and a macro-level assessment of feasibility of the necessary NTAs in the GH subarea.

A community's enthusiasm towards a project is usually a key determinant to a project success. Some of the community's major concerns relate to the project's impact on the environment (emission of pollutants), and the impact on life quality (potential for noise disturbance or irreversible changes in the landscape). Moreover, the costs associated with developing accompanying infrastructure are prone to increase the financial burden for the community. All of these concerns can weight on a project's permitting process, as well as eventual completion. Some of the important practical considerations for all the technologies reviewed (including those not considered technically feasible) are summarized in Figure 23 below. The discussion of these considerations in the following paragraph is however focused on the technically feasible NTA technologies identified in LEI's analysis.

Figure 23. Qualitative review of NTA technologies

NTA Resource	Land requirement	Enabling infrastructure	Pollution
Combined Cycle Gas Turbine (CCGT)	Sizeable footprint	Gas lateral/pipeline; access to water; interconnection costs	Noise; pollutants
Peaker Aeroderivative Unit	Small footprint	Gas lateral/pipeline; interconnection costs	Noise; pollutants
Peaker Frame Unit	Sizeable footprint	Gas lateral/pipeline; interconnection costs	Noise; pollutants
Dual-fuel Jet Engine	Small footprint	Gas lateral/pipeline; on-site fuel storage	Noise; pollutants
Solar Utility Scale (with storage)	Sizeable footprint	Interconnection costs	N/A
Solar DG (with storage)	Sizeable footprint	Interconnection costs	N/A
Slow Discharge Battery	Small footprint	Interconnection costs	N/A
Active DR - Emergency Generation	Small footprint	N/A	Noise; pollutants
Passive DR (Energy Efficiency)	N/A	N/A	N/A
Fuel Cells	Small footprint	Gas lateral/pipeline; interconnection costs	N/A

Market limitations

No gas-fired unit is currently operating or has been proposed in the ISO-NE's interconnection queue for development at the NW Hartford substation. ISO-NE's load growth projections coupled with LEI's analysis of market developments suggest there is not likely to be sufficient "room" in the capacity market or a market need for additional gas-fired generation in the next few upcoming capacity markets auctions. Therefore, securing these resources without sustained capacity revenues will require out-of market funding, exposing Connecticut ratepayers to greater cost.

End-use customers mix

In our analysis we conservatively assumed a load reduction rate not greater than 15% for all EE programs above and beyond existing and planned programs. This penetration rate depends a great deal on the mix of customer types in the region. A zone dominated by industrial facilities is likely to feature the best load reduction rates; whereas zones dominated by residential customers could achieve load reduction rates as low as 1 to 2%, in which case, demand resources would not be effective as NTA.

Land requirements

The development of NTA technologies such as CCGTs and peakers is contingent upon the availability of buildable space (measured in acres) at or near the proposed hypothetical injection point in order to

be a practically feasible solution. The least cost technically feasible NTA technologies for the GH subarea is a 182 MW CCGT plant to be built in at the NW Hartford substation. The area surrounding the NW Hartford substation is heavily developed and zoned for residential use.

Enabling infrastructure

In addition to land, some NTA technologies also need other enabling infrastructure to be practically feasible at a given hypothetical injection point. For example, a CCGT would require access to water (for cooling). There needs to be sufficient transmission infrastructure to interconnect a generation unit and provide for the delivery of the energy into the bulk power system.[36] In addition, gas-fired resources will require access to fuel supply through pipeline infrastructure, while dual-fuel jet engines would also require a reliable supply of fuel oil (and permits to allow for oil storage on-site). Some CCGTs and peaking units can be co-located alongside existing generation facilities (if there are sufficient land resources for zoning and permitting) or on-site of retired generation or other former industrial facilities, which could reduce the costs of installation. The NW Hartford substation is not situated immediately next to a major gas pipeline.[37] The closest pipelines are located approximately 4 miles away from NW Hartford substation. As such, any gas-fired technology in this location will require building additional gas pipelines (laterals) to secure access to gas supply. This would result in more than $12 million[38] in additional costs.

[36] No interconnection study was performed to determine whether there may be transmission upgrade costs associated with interconnection and/or deliverability.

[37] Furthermore, there are no gas-fired plants currently in operation near the considered substation.

[38] We assumed a $2.9 million per mile pipeline cost based on the average of $/mile of natural gas lateral projects built in New England over the past years (Source: EIA Natural gas pipelines projects).

6 Conclusion

The least cost alternative to the GHCCRP transmission solution requires a total of 182 MW of additional new CCGT capacity and 23 MW of incremental demand response (in addition to what is currently planned to be built pursuant to ISO-NE's FCM, and above and beyond what is known publicly based on the current ISO-NE interconnection queue) by 2022 in the GH subarea. Although energy efficiency was considered a feasible NTA technology, it remains a marginal contributor to the overall NTA solution, because of the inherent load at the NW Hartford substation and reasoned expectations regarding incremental penetration rates (beyond the level of EE already funded and planned for). Many NTA technologies are simply not technically feasible from a planning perspective. Certain NTA technologies such as solar DG do not possess the operating characteristics required to meet the reliability needs under N-1-1 contingencies and therefore could not provide the same reliable service as the preferred GHCCRP transmission solution. Other technologies, like utility scale solar, could not be developed in these particular geographical areas in sufficient quantities to meet the NTA requirement amount.

Although there are technically feasible NTA technologies that could meet the reliability needs in the GHCCRP subarea at the specific nodes identified by ISO-NE in their supply-side NTA study, these NTA solutions are estimated to be more costly than the preferred transmission solution. In fact, the least cost technically feasible NTA solution was estimated to cost Connecticut ratepayers more than five times the annual cost of the transmission solution payable by Connecticut end-use customers. Furthermore there are a host of practical impediments to developing and bringing to fruition an NTA solution. Such practical hurdles include the siting challenges related to land availability, and build out of the requisite fuel supply infrastructure (as well as negotiating fuel supply contracts). There are also questions related to the development process itself, as no private developer to date has shown interest in bring to market an NTA that would fit the technological requirements and geographical requirements of the necessary NTA solution.

7 Appendix A: LEI's Qualifications

London Economics International LLC ("LEI") is a global economic, financial, and strategic advisory professional services firm specializing in energy and infrastructure. The firm combines detailed understanding of specific network and commodity industries, such as electricity generation, transmission and distribution, with a suite of proprietary quantitative models to produce reliable and comprehensible results. The firm has its roots in advising on the initial round of privatization of electricity, gas, and water companies in the UK. Since then, LEI has advised private sector clients, market institutions, and governments on privatization, asset valuation, deregulation, tariff design, market power, and strategy in virtually all deregulating markets worldwide.

LEI's areas of expertise straddle both the deregulated/market environments (including for example, price forecasting and asset valuation; wholesale power market analysis; market design (ISO market rules); and competitive procurement) and application of regulatory economics (such as regulated tariff design; cost of service ratemaking and performance based ratemaking; productivity analysis; policy design for incentivizing renewable energy and new technologies; and transmission and distribution network analysis). Provided below is a sample of previous LEI work showcasing its considerable experience, notably in the analysis of transmission projects and Non-Transmission Alternatives.

Sample of projects relating to Non-transmission alternatives, cost-benefit analysis of transmission projects

Non-transmission Alternatives analysis for the Greater Boston area: LEI was engaged by National Grid and Eversource Energy ("the Utilities") to determine the economic viability of non-transmission alternatives ("NTAs") to replace a combination of three transmission solutions designed to address reliability and performance issues in the Greater Boston area starting in 2018. More specifically, LEI's scope of work consisted of determining the least cost combination of technologies that could be integrated to the New England transmission system and provide the same reliability benefits as the proposed transmission lines. A combination of supply-side and demand-side resources were considered for the study, this included: distributed solar PV, utility-scale solar PV, energy efficiency and active demand response, conventional generation (gas CCGT and peakers), as well as energy storage devices. LEI started the analysis by screening prospective NTA technologies based on their technical characteristics, their relevance in the New England market and their technical applicability with regards to the operational criteria required by the grid to address contingency events (i.e volume of available capacity/energy, time of response, duration of response, flexibility etc…). Next, LEI conducted a comparative cost analysis to estimate the levelized cost per kW-month over the economic life of each of the technologies. Through his selection process, we retained technically feasible NTAs that are materially less expensive than other comparable options at the same locations (substations). Finally the most probable combinations of NTA technologies identified in the selection process were further evaluated based on their probability of materialization taking into account a spectrum of criteria including physical constraints such as land availability, siting issue, financing hurdle, etc…

White paper on Non-transmission Alternatives (NTAs): London Economics International LLC ("LEI") was engaged by WIRES to prepare a White Paper on Market Resource Alternatives ("MRAs") which provides external parties with a clear understanding of MRAs and a concise description of how MRAs

can work effectively alongside transmission investment in US power markets to support market development, reliability, and cost-effective supply. The structure of the White Paper specifically has the goal of "education" in mind. It started with the definition of MRAs, and then LEI presented case studies and lessons learned from several regional markets. The White Paper also recommended a conceptual analytical framework for proper and effective consideration of MRAs in transmission planning processes.

Cost-benefit analysis of a proposed transmission line: For a utility in the northeastern US, LEI prepared a cost-benefit analysis of a proposed transmission line with the potential to change existing market arrangements. In the analysis, LEI developed a base case and multiple project cases based on different configurations of the transmission project. Using its proprietary modeling tool, POOLMod, LEI simulated energy and capacity prices in each configuration over a 15-year timeframe, and compared the price differences against various cost allocation scenarios for the transmission line's construction. LEI also tested the statistical significance of the project case results against the base case results, and conducted further analysis on the economic effects of additional renewable generation projects that construction of the transmission line would make possible.

CHPE application for siting - Julia Frayer led LEI's team regarding the detailed cost-benefit analysis and macroeconomic impact analysis in support of the Champlain Hudson Power Express ("CHPE") application for siting approval at the New York Department of Public Service ("DPS"). LEI's analysis on economic effects was the cornerstone of the settlement agreement reached between Transmission Developers, Inc. ("TDI") and a number of New York agencies. Julia acted as independent expert on behalf of TDI and prepared updated study results on energy market impacts, capacity market impacts and also macroeconomic benefits stemming from the operation of the CHPE project. Julia's testimony was used in the DPS proceeding in the summer of 2012.

Lake Erie HVDC transmission project – cost /benefit analysis: LEI was hired by a private developer to assess the economics of the proposed Lake Erie HVDC transmission project and determining the additional revenue streams or value adders of the Lake Erie HVDC transmission project ("LEP") from the perspective of third-party shippers. The LEP is a 100-km long 1,000 MW bi-directional HVDC transmission line that will connect the Ontario energy market with the PJM market. LEI prepared a comprehensive report that includes a review of the Ontario and PJM markets, a 20-year (2017 to 2036) market outlook and prices for electricity, capacity and renewable energy credits in Ontario and the relevant zone/s in PJM; the total gross arbitrage value for the energy congestion rents, the capacity revenue potentials for PJM, and the renewable energy credits revenue potential in PJM.

Forecast the impact of a 1,000 MW DC transmission line on New England market prices: LEI prepared a 10-year energy market price outlook for the New England wholesale power market and forecast the impact of a proposed project on New England market prices. The project proposes to build a 1,000 MW DC-based transmission line that between Quebec and Vermont and import energy into Vermont. LEI modeled the long-term price forecast for Vermont and the rest of ISO-NE over the 2019-2028 period, and examined the price differentials. Two cases were modeled: a Base Case (without the HVDC project), and the Project Case (with the HVDC project). Analysis was done under the assumption that the transmission capacity on the project will accommodate low-cost hydro imports from Quebec. LEI also determined the benefits of the proposed transmission project on employment, economic activity,

and tax revenues in New England. LEI utilized the dynamic input-output ("I/O") economic model developed by Regional Economic Models, Inc. ("REMI") to measure the economic benefits to Vermont and other New England states from the project on employment, economic activity, and tax revenues. LEI separated the economic impact caused by the construction of the project, and the impact caused by the reduction in energy prices due to the commercial operation of the project, taking into account issues such as usage of electricity in residential, commercial, and industrial sectors in the region, and also existing long-term energy contracts that would limit the impact of the project.

Assess the potential economic benefits of a New England transmission project: LEI was commissioned by Northeast Utilities to determine the potential economic benefits of the proposed NEEWS transmission project. Using detailed hourly simulation modeling of future power market conditions, LEI studied the potential market implications of NEEWS for ten years from a notional expected date of commercial operation of 2014. LEI reached the following conclusions: New England ratepayers could expect cumulative energy cost savings attributable to NEEWS over ten years under normal operating conditions; NEEWS would create regional energy market impacts; each phase of NEEWS would create energy market benefits over the ten-year modeling horizon; NEEWS would reduce LFRM costs each year; NEEWS would provide an insurance hedge against stressed system events; and NEEWS would offer market access to renewable resources in Northern New England/Canada.

Forecast the impact of a proposed transmission interconnection on Maine customers: LEI was engaged by a US power utility to perform a 15-year simulation analysis to estimate the market impacts resulting from a new transmission interconnection (covering the timeframe 2015-2029) and project the impact on Maine customers (including Northern Maine customers). LEI evaluated the market evolution with and without the interconnection and described the potential ramifications for purchasing electricity for Northern Maine customers. The analysis also estimated the potential impact on ratepayers from the re-allocation of the ISO-NE Pool Transmission Facility rate to incorporate the Northern Maine load and franchise area under a pro forma 10-year transitional agreement. LEI performed the modeling using our up-to-date ISO-NE simulation model (which covers the energy and capacity markets), extended to represent in detail the Maritimes control area.

Analysis of congestion rents and forecasted impact on energy and capacity prices due to a proposed transmission line: In connection with a proposed transmission line from Hydro Quebec to New York City, LEI Managing Director Julia Frayer led a team that forecasted 10-year energy and capacity prices of the New York market using POOLMod. The team also conducted analysis on congestion rents to support the client's negotiation with potential shippers. In support of the client's filing at the NYPSC, the LEI team conducted analyses on generation and production cost savings, emission reductions and sensitivities.

MA Energy Facilities Siting Board ("EFSB"): in response to NU retaining LEI, New England wholesale electricity markets were simulated in order to determine whether the Greater Springfield Reliability Project ("GSRP") would produce economic benefits to the New England region. In order to ensure that economic benefits were not subject to the forced outage and availability schedule of the simulated energy markets, LEI simulated the energy market with 30 different random forced outage and availability schedules. Using these simulations, a distribution of results was used to calculate confidence intervals and hypothesis tests run on the results, hence increasing the robustness of our

findings. The study results introduced as testimony to the EFSB, which is scheduled to be presented in October. (2009) **[MA EFSB, EFSB 08-2/DPU 08-105/DPU 08-106].**

Assess the economic value of a proposed transmission project: LEI was hired by a transmission developer to conduct an independent rigorous modeling exercise to determine the potential revenues for the proposed transmission project wheeling power from western MISO to East MISO (and eventually PJM). LEI evaluated both the revenue opportunities to the investors (e.g., private benefits of the line based on market price differences and the market value of the transmission) as well as social benefits to the MISO system (i.e., wholesale price reductions and capacity market price differences); and evaluated the incremental value of the business strategy of selling the energy (and capacity) out of East MISO to third parties who will serve customers ultimately in PJM. LEI's modeling exercise entailed evaluating intrinsic revenues (originating from power markets), extrinsic revenue (originating from price volatility), along with the green value of the Project (originating from the purchase of low cost renewable energy). LEI's overall analysis was comprehensive and included a series of sensitivity scenarios testing key value drivers.

Sample of projects in Connecticut

Connecticut

Connecticut Siting Council ("CSC") – NU/GSRP: LEI simulated the New England wholesale electricity markets in order to compare the economic benefits between Greater Springfield Reliability Project ("GSRP") and responses to the Connecticut Energy Advisory Boards' ("CEAB") RFP for a non-transmission alternative ("NTA") to GSRP. The NTA consisted of modeling a new CCGT plant to be placed in Southwestern Connecticut. In order to ensure that economic benefits were not subject to the forced outage and availability schedule of the simulated energy markets, LEI simulated the energy market with 30 different random forced outage and availability schedules. In effect these 30 different simulations added further robustness to our results because it captured the flexibility of the New England energy market under several different normal operating conditions. Furthermore the simulations created a distribution of results which was used to calculate confidence intervals and hypothesis tests, hence further increasing the robustness of our findings. The study results were used to produce written testimony to the CSC, oral testimony was provided in late August and early September 2009. (2008-2009) [CSC, Docket 370].

NU-NSTAR merger: in support of a client's opposition of a proposed NU-NSTAR merger, LEI analyzed the potential competitive market effects on a vertical scale and considered the extent of buyer market power for the purchase of standard service (full requirements) products. The testimony was submitted to the Public Utility Regulatory Authority (PURA). In a later submission, LEI also analyzed the settlements reached or proposed in a number of recent utility mergers. (2012) [PURA Docket No. 12-01-07].

Impact analysis of transmission project: LEI advised a major transmission company on financial implications of proposed new 400kV transmission line to New York City and Connecticut. LEI analyzed the impact of new transmission, assuming it delivered 100% carbon-free energy, on electricity prices and emissions levels in New York and New England.

2006 "All Source" RFP: LEI served as the economic advisor to the Connecticut Department of Public Utility Control (DPUC), helping them design and implement an "all source" RFP for new capacity in the state in order to mitigate the exposure to ratepayers from Federally Mandated Congestion Costs. As economic advisor and RFP Coordinator, LEI was responsible for managing all aspects of the RFP, including design of innovative financial contracts for capacity, administration of RFP process, and evaluation of bids submitted by project sponsors, and recommendation to the DPUC for selection of winning projects. The selection of projects is based on a proprietary set of models that LEI staff designed to estimate the cost-benefit to ratepayers from long term contracts with new capacity, based on reduction in wholesale market costs across three different ISO New England power markets. LEI also submitted significant written testimony during the 18 months of this engagement, and LEI staff also testified orally on numerous occasions. (2006-2007) **[DPUC, Docket No. 05-07-14PH02; FERC, ER03-563-000**].

DPUC auction oversight: the DPUC retained the services of LEI to assist it in monitoring the power procurement processes for Connecticut Light & Power's (CL&P) Transitional Standard Offer auction in November 2004 for services in 2005 and 2006, and in September 2005 to monitor the November 2005 auction for services in 2006. LEI 's mandate included providing advisory services to the DPUC, including guidance on communications protocols, design of sales contract agreement (between CL&P and winning bidders), and also valuation of final bids vis-à-vis the forward market alternatives available to the utility. LEI filed affidavits after the completion of each auction process which the Commissioners used to approve the process and the contracts between CL&P and the winning bidders. (2004 and 2005) **[DPUC, Docket No. 03-07-18PH02].**

Sample of projects in New England

Projection of retail rates for commercial customers in New England: LEI performed a market study reviewing historical electric rates (and projecting forward electric rates) for large commercial customers in the New England market. The electric rates analysis was composed of a number of components, such as the commodity costs of electricity, compliance costs for certain state programs (like RPS), delivery charge for delivering electricity, and ancillary services and administrative supply charges. LEI created projections for each of these components and considered state retail sales requirements for renewables and other factors.

New England energy price outlook and economic impacts: LEI prepared a 10-year energy market price outlook for the New England wholesale power market and forecast the impact of a proposed transmission project on New England market prices. LEI also determined the benefits of the proposed transmission project on employment, economic activity, and tax revenues in New England. LEI utilized the dynamic input-output ("I/O") economic model developed by Regional Economic Models, Inc. ("REMI") to measure the economic benefits to various New England states from the project on employment, economic activity, and tax revenues. LEI took into account issues such as usage of electricity in residential, commercial, and industrial sectors in the region, and also existing long-term energy contracts that would limit the impact of the project.

Review of NESCOE study: LEI conducted a comprehensive review of the NESCOE Gas Electric Phase Three study in order to ensure that the appropriate economic models and techniques were being used to accurately model the hydro and gas solutions. LEI also aided the client in identifying any

assumptions and modeling approaches which may be suboptimal, and communicated how these issues can be addressed and improved in future studies.

Maine

Advisory to Maine Public Utilities Commission on RPS: LEI presented a written report on the state of renewable portfolio standard (RPS) requirements in Maine and regionally across New England. LEI also testified at the Maine legislature. The report was commissioned by the Maine Public Utility Commission to fulfill a statutory requirement to provide research on the issue of RPS and its impact on generators and consumers.

Advisory to Maine Public Utilities Commission on transmission cost allocation: LEI advised Maine Public Utilities Commission on methodologies for transmission cost allocation by comparing and contrasting alternative planning approaches and pricing models employed within the US and one international jurisdiction, the United Kingdom. The final report will provide a 'strawman' recommendation for an effective cost allocation methodology. (2010) **[Docket No. RM10-23-000].**

Advisory to the Maine Public Utilities Commission on RFP: LEI assisted the Commission on the RFP related to the procurement of electricity in response to statutory mandates and state policy preferences. LEI provided economic analyses of bid proposals by estimating the benefits and costs to the ratepayers, and is currently supporting Commission staff in negotiations with short-listed bidders. (2009).

Development of an Electric Resource Adequacy Plan in Maine: in Docket No. 2008-104, LEI assisted the Maine Public Utilities Commission in developing an electric resource adequacy plan to aid MPUC in the development of a strategy for the pursuit of the long-term contracts. LEI submitted a report that builds up a set of recommendations for a long-term investment strategy based on an analysis of the current supply-demand situation, a review of the existing wholesale market rules for energy and the Forward Capacity Market, an examination of historical price trends, and review of the investment needs assessments prepared by the utilities and ISO-NE, as well as relevant sub-regional planning studies. (2008) **[Maine PUC, Docket No. 2008-104].**

Maine renewable portfolio requirement: LEI was engaged by the Maine Public Utilities Commission to conduct an in-depth analysis of the renewable portfolio standards ("RPS") required by a legislative Act. This analysis supported a Commission study and report to the Legislature. Julia led the team in preparation of the report, which was submitted to the Commission and later testified at the state legislature on the key findings of that report.

New Hampshire

Testimony describing wholesale market dynamics and benefits of Northern Pass in averting supply risks associated with generation "at risk" for retirement: On behalf of Public Service of New Hampshire, LEI testified in front of the new Hampshire Senate Committee on issue of eminent domain generally and more specifically, on the power market context and near term outlook for the New England power market and reasons for the development of a new proposed transmission project known as Northern Pass.

Vermont

Testimony on proposed merger between Central Vermont Public Service and Green Mountain Power: for a small independent power producer, LEI prepared a testimony on the potential harms of the proposed merger to the client and proposed certain conditions for the Vermont Public Service Board to consider. (2012) **[PSB Docket No. 7770].**

ISO-NE tariff design: LEI submitted testimony on behalf of ISO New England to the FERC to help defend ISO New England's self-funding tariff. LEI first defined the basic underlying economic principles for specifying the tariff, and then undertook to show how the tariff should be applied to various system users. The engagement involved an intensive financial modeling effort, and frequent interaction with stakeholders. (2000) **[ER01-316-000].**

Commercial litigation in New England

PPA contract dispute: LEI provided expert witness service for a private equity investor in matter related to a contractual dispute regarding a long term power purchase agreement between a municipal utility located in New England and a landfill gas generator. LEI analyzed the key contractual terms of the PPA and providing an expert's review of how those terms compared to the industry norm when the contract was signed and became effective. LEI will also be providing an independent estimate of potential contractual damages. (2010-2011) **[Commonwealth of Massachusetts Superior Court Department, Civil Action No. PLCV2006-00651-B].**

Updated market power analysis: prepared for a US utility's triennial review of market-based rate authorizations for certain subsidiaries in the northeast region. LEI analyzed the company's market power in PJM and ISO-NE. (2010) **[ER98-4159, et al.].**

Section 203 and 205 analysis in support of NRG's acquisition of certain Dynegy assets in CAISO and ISO-NE: LEI was engaged to provide testimony in support of a proposed acquisition. LEI performed a Delivered Price Test (DPT) for CAISO and ISO-NE energy markets as well as a standalone Herfindahl-Hirschman Index (HHI) analysis for the capacity markets. In addition, LEI discussed the impact of the acquisition of the ancillary services markets. (2010) **[EC10-88-000]**

Confidential FERC investigation in 2009-2010 of market manipulation in New England: Julia and her team assisted the client with certain matters pertaining FERC investigation. Specifically, the scope of this retention included economic and market analysis in support of a market participant in ISO New England's day ahead load response program ("DALRP"). Julia also provided affidavits and deposed in connection with FERC investigation of behind-the-fence industrial generator and participation in a wholesale power market in New England. Julia helped the client to respond to assertions of market manipulation and estimate market benefit provided through its participation in demand response program.

8 Appendix B: Technical and operational characteristics of various NTA technologies

Operating size and capacity factor

Each injection point has a specified amount of MW requirement that must be met by an eligible NTA. Each NTA under consideration has been selected based on whether previous examples of its successful operations have been documented in Connecticut. In addition, the minimum and maximum operating size for the short-listed NTAs were determined by evaluating typical operating size of similar technologies in New England, Connecticut and where available in the GH subarea. In addition, each NTA has a representative capacity factor which is based on actual data relevant to installations of that technology in Connecticut. Together these parameters help determine if a particular NTA can meet the injection requirements at a specific injection point.

NTA Performance Parameters

Response time is an important criterion to determine eligible technologies under N-1-1 contingency events. Under an N-1-1 contingency event, eligible NTAs must be able to inject power in less than 30 minutes. In addition to response time and ramp rate, the duration for which a given NTA can inject power after it has been called into service during a contingency event is also a vital criterion. Based on its understanding of ISO-NE rules,[39] LEI modeled uses a conservative estimate of 12 hours as the minimum duration for which an NTA must remain online for N-1-1 contingency event in order to qualify as a technically feasible NTA.

Specific values for each of these criteria defined above are summarized in Figure 24. The second and third columns indicate the minimum and maximum MW size for each NTA. The column labeled ramp rates specifies how fast the corresponding NTA can ramp up to start producing at its maximum capacity. For example, a 14.3% of total size per minute ramp rate for dual-fuel jet engines implies that these units can start producing at their maximum capacity in about 7 minutes. Finally, the last column, duration refers to the length of time these NTAs can produce power without interruption. For fossil fuel powered NTAs, the underlying assumption is that the availability of fuel is not a constraint. For NTAs with storage technologies such as solar PV, we assume that the storage capacity is long enough to support the NTA for during nighttime hours.

[39] Subsection III of Part III – Procedure of ISO New England Operating Procedure No. 8 Operating Reserve and Regulation. May 2, 2014. Available at http://www.iso-ne.com/rules_proceds/operating/isone/op8/op8_rto_final.pdf.

Figure 24. Technical characteristics of NTA technologies

MRA Resource	Installed Capacity range	Operations profile	Performance Rate	Duration (Hr.)
Combined Cycle Gas Turbine (CCGT)	100 to 700 MW range in CT	Baseload	95% availability factor	24
Peaker Aeroderivative Unit	1 to 125 MW range	Peaking load	85% availability factor	24
Peaker Frame Unit	20 to 250 MW range	Peaking load	83% availability factor	24
Dual-fuel Jet Engine	<1 to 50 MW	Peaking load	85% availability factor	24
Solar Utility Scale (with storage)	5 to 250 MW	Potential baseload depending on storage capacity	15% efficiency ratio	24
Solar Utility Scale	5 to 250 MW	Daytime peaking load during sunny days	15% efficiency ratio	12
Solar DG (with storage)	<1 to 5 MW	Potential peaking load depending on storage	15% efficiency ratio	12
Solar DG	<1 to 5 MW	Daytime peaking load during sunny days	15% efficiency ratio	8
Fast Discharge Battery	<1 to 10 MW	Can provide instantaneous power for short periods	Variable, depending on efficiency, charging time and storage capacity	2
Slow Discharge Battery	10 to 20 MW	Can provide steady supply of power for short periods	Variable, depending on efficiency, charging time and storage capacity	12
Active DR - Emergency Generation	Variable (based on type of equipment and load)	Peaking load	Assume 15% of peak load becomes available to respond	24
Passive DR (Energy Efficiency)	Variable (based on type of equipment and load)	Intermittent	Assume 15% of peak load becomes available to respond	24
Fuel Cells	2.8 MW to 63 MW	Baseload	95% availability factor	24

Note 1: Wind was not considered as a technically feasible NTA due to the lack of potential for sizeable wind capacity development in the Connecticut.

Note 2: Installed capacity range for utility scale fast and slow discharge batteries depends on the number of individual batteries connected together at a given site. The range indicated in the figure above is indicative, and LEI used variable sizes depending on requirements in order to ascertain the technical feasibility of using batteries as NTA technologies.

Note 3: Performance rates for CCGTs, Peaker Aeroderivative units, Peaker frame units and dual-fuel jet engines calculated based on the ISO New England EFORd Class Averages, sourced from: http://www.iso-ne.com/static-assets/documents/genrtion_resrcs/gads/class_ave_2010.pdf

Note 4: Active DR emergency profile is sourced from ISO New England Operating Procedure No. 14 - Technical Requirements for Generators, Demand Resources, Asset Related Demands and Alternative Technology Regulation Resources." ISO-NE, November 7, 2014 http://www.iso-ne.com/rules_proceds/operating/isone/op14/op14_rto_final.pdf.

Note 5: Size of fuel cells based on DFC3000 units from FuelCell Energy. The maximum size was based on the anticipated 63 MW fuel cells plant to be built in Connecticut (the largest yet in the world). Fuel Cells technology is baseload and can run 24/7 pending fuel availability. Given the limited information on availability factor, we assumed the same availability factor as a CCGT.

Figure 25. Technology parameter determination assumptions

	Parameter	Methodology	Source
CCGT	**Minimum/Maximum Size**	Based on typical observed installed capacities, capped at the maximum value of CCGT unit in Connecticut	Review of information provided by manufacturers (SIEMENS and GE) and actual data of operation in ISO-NE (based on new construction over the past 20 years)
	Ramp Rate	CCGTs are assumed already committed	Not applicable
	Performance Rate	CCGTs are assumed to have 95% availability factor	Based on ISO-NE EFORd Class Averages
	Duration	CCGTs are not energy limited resources	Not applicable
Peaker Frame Unit	**Minimum/Maximum Size**	Based on typical observed installed capacities	Review of information provided by manufacturers (SIEMENS and GE) and actual data of operation in ISO-NE
	Ramp Rate	Industry-standard ramp rates	Review of information provided by manufacturers and plants' operational data in ISO-NE
	Performance Rate	Peaker Aeroderivative units are assumed to have 85% availability factor	Based on ISO-NE EFORd Class Averages
	Duration	Frame units are not energy limited resources	Not applicable
Peaker Aeroderivative Unit	**Minimum/Maximum Size**	Based on typical observed installed capacities, with the assumption that several units can be installed together (capped at the value for which a peaker aeroderivative unit becomes a feasible technology	Review of information provided by manufacturers (SIEMENS and GE) and actual data of operation in ISO-NE (based on new construction over the past 20 years)
	Ramp Rate	Industry-standard ramp rates	Review of information provided by manufacturers and plants' operational data in ISO-NE
	Performance Rate	Peaker Frame units are assumed to have 83% availability factor	Based on ISO-NE EFORd Class Averages
	Duration	Aeroderivative units are not energy limited resources	Not applicable
Dual-Fuel Jet Engines	**Minimum/Maximum Size**	Based on typical observed installed capacities	Review of information provided by manufacturers (Wärtsilä) and actual data of operation in ISO-NE
	Ramp Rate	Industry-standard ramp rates	Review of information provided by manufacturers and plants' operational

	Parameter	Methodology	Source
			data in ISO-NE
	Performance factor	Dual fuel jet engines are assumed to have 85% availability factor	Based on ISO-NE EFORd Class Averages
	Duration	Jet Engines are not energy limited resources	Not applicable
Solar Utility-Scale	**Minimum/Maximum Size**	Based on typical observed installed capacities and ISO's definition	Review of utilities' new installations in CT and external sources such as "Utility-Scale Concentrating Solar Power and Photovoltaic Projects: A Technology and Market Overview." (National Renewable Energy Laboratory)
	Ramp Rate	Not applicable	Not applicable
	Performance factor	Utility scale solar units have a conversion efficiency comparable to standard solar PV unit in CT	System Advisory Model ("SAM)" from National Renewable Energy Laboratory ("NREL") for Connecticut
	Duration	Limited to daytime	Not applicable
Solar Utility-Scale with storage	**Minimum/Maximum Size**	Based on typical observed installed capacities and ISO's definition	Similar assumptions as for "utility scale solar"
	Ramp Rate	Not applicable	Not applicable
	Performance factor	Utility scale solar units have a conversion efficiency comparable to standard solar PV unit in CT	System Advisory Model ("SAM)" from National Renewable Energy Laboratory ("NREL") for Connecticut
	Duration	Storage capacity assumed sufficient to deliver energy equivalent to solar capacity factor at night [needed for a minimum of 12 hours to last through a contingency]	Not applicable
Solar DG	**Minimum/Maximum Size**	Based on typical observed installed capacities and ISO's definition	Connecticut and external sources such as "Utility-Scale Concentrating Solar Power and Photovoltaic Projects: A Technology and Market Overview." National Renewable Energy Laboratory. April 2012. http://www.nrel.gov/docs/fy12osti/51137.pdf
	Ramp Rate	Not applicable	Not applicable
	Performance factor	Utility scale solar units have a conversion efficiency comparable to standard solar PV unit in New England	System Advisory Model ("SAM)" from National Renewable Energy Laboratory ("NREL") for Connecticut
	Duration	Limited to daytime	Not applicable

	Parameter	Methodology	Source
Fast-Discharge Batteries	**Minimum/Maximum Size**	Based on typical observed installed capacities, with the assumption that batteries can be installed in banks (capped in the model to total installed capacity in the US in 2015)	Review of information provided by manufacturers (Flywheel (Beacon Power, NaS Batteries (NJK)) & Energy Storage Association
	Ramp Rate	Not applicable	Not applicable
	Performance factor	Based on typical charging-discharging cycle efficiency	Review of information provided by manufacturers, and Electric Power Research Institute
	Duration	Typical value for available technologies	Review of information provided by manufacturers , and Electric Power Research Institute ("EPRI"),
Slow-Discharge Batteries	**Minimum/Maximum Size**	Based on typical observed installed capacities, with the assumption that batteries can be installed in banks (capped in the model to total installed capacity in the US in 2015)	Review of information provided by manufacturers (Flywheel (Beacon Power, sodium sulfur (NaS) Batteries (NJK)) & Energy Storage Association
	Ramp Rate	Not applicable	Not applicable
	Performance factor	Based on typical charging-discharging cycle efficiency	Review of information provided by manufacturers, and Electric Power Research Institute
	Duration	Typical value for available technologies	Electric Power Research Institute ("EPRI")
Fuel Cells	**Minimum/Maximum Size**	Based on DFC3000 unit size	FuelCell Energy (manufacturer)
	Ramp Rate	(baseload/running at all time)	Not applicable
	Performance factor	Assumed same as CCGT 95%	Not applicable
	Duration	Available at all times pending fuel availability	FuelCell Energy and EIA

9 Appendix C: Derivation of cost estimates for various NTA technologies

In this appendix we disclose gross and Net LCOE of all considered technologies (feasible and infeasible) and provide detailed information on all sources used. A summary of the sources utilized is documented in the following Figures.

Figure 26. Gross and net LCOE per technology ($/kW-year)

	CCGT	Frame Peaker	Aero Peaker	Slow discharge batteries	Fast response energy storage	Utility-scale solar (with storage)	Soalr DG (with storage	Passive DR (EE)	Fuel Cell	Active DR (RTEG)	Active DR (RTDR)
Gross LCOE	418.0	231.2	323.4	181.4	154.3	415.9	523.3	513.0	382.7	371.0	480.0
Energy*	283.3	129.9	117.8	-	-	66.4	-	-	54.0	-	-
FCM	57.3	57.3	57.3	-	-	20.1	-	61.9	-	28.7	28.7
LFRM	-	-	-	12.5	-	-	-	-	-	-	-
Regulation	-	-	-	33.0	33.0	-	-	-	-	-	-
Avoided retailed cost	-	-	-	-	-	-	21.5	143.3	-	0.2	0.2
Net LCOE	77.4	44.0	148.3	135.9	121.2	7.6	179.9	307.8	328.7	342.1	451.1

** Includes fuel and variable operating and maintenance costs*

Figure 27. Overnight cost per technology ($/kW-year)

	CCGT	Aero Peaker	Slow discharge batteries	Fast response energy storage	Utility-scale solar (with storage)	Solar DG (with storage	Passive DR (EE)	Fuel Cell	Active DR (RTEG)	Active DR (RTDR)
Overnight capital cost ($/kW-year)	$1,146	$1,486	$1,330	$1,277	$3,697	$5,830	N/A	$7,475	N/A	N/A

Sources: Summarized in Figure 28 below.

London Economics International LLC
717 Atlantic Avenue, Suite 1A
Boston, MA 02111
www.londoneconomics.com

Figure 28. Assumptions and sources on gross LCOE

Technologies	Methodology	Sources
Peaker (aeroderivative and frame units) and CCGT technologies	Gross LCOE based on ISO-NE's estimates adjusted for O&M and fuel cost. Gross LCOE for CCGT was adjusted to reflect smaller than standard size of the required plant. The generic CCGT considered by ISO-NE it is analysis has a size ranging between 500 and 700 MW. CCGT qualified as smaller than usual will likely be more expensive due to the lack of scale. This is reflected by a 12% increase in gross LCOE based on the overnight cost difference between 400 MW and a 600 MW power plant	ISO New England's demand curve assumptions for the Forward Capacity Auction # 9 EIA http://www.iso-ne.com/regulatory/ferc/filings/2014/apr/er14-1639-000_demand_curve_c
Energy storage (slow discharge and fast operating response)	Gross LCOE was estimated through LEI's proprietary LCOE model. Key inputs such as overnight capital cost and VOM and FOM were sourced from NREL and PNNL. Results were then cross-checked against industry's estimates (IEA)	National Assessment of Energy Storage for Grid Balancing and Arbitrage", Pacific Northwest National Laboratory http://energyenvironment.pnnl.gov/pdf/National_Assessment_Storage_PHASE_II_vol_2_ International Energy Agency http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergystorage.pdf and LEI
Utility -scale solar	Gross LCOE was estimated through LEI's proprietary LCOE model. Key inputs to such as overnight capital costs and O&M sourced from NREL, EIA and DOE. Results were then cross-checked against industry's estimates.	National Renewable Energy Laboratory ("NREL") http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html Sun Shot Initiative (US Department of Energy), SEIA - http://www.seia.org/research-resources/solar-market-insight-report-2014-q1; and LEI
Solar DG	Gross LCOE was estimated through LEI's proprietary LCOE model and industry's estimates -(from NREL and DOE)	NREL (PV system pricing trends, 2014 - http://www.nrel.gov/docs/fy14osti/62558.pdf and LEI
Dual fuel jet engine	Key inputs to LEI's proprietary LCOE model such as overnight capital costs and O&M sourced from NYISO's estimates (technologies reviewed to established cost of new entry) sand Wärtsilä	Wärtsilä, NYISO Demand curves filing http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_icapwg/meeting_materials/2013-08-22/2013%20NYISO%20Demand%20Curve%20Recommendation_draft_8-18-13.pdf
Active DR (RTEG and RTDR)	Key inputs to LEI's proprietary LCOE model such as overnight capital costs and O&M sourced from EPRI (RTEG); Cost estimates for RTDR determined based on VOLL for a 12 hour requirement (N-1 and N-1-1 criteria)	EPRI- http://www.publicpower.org/files/deed/finalreportcostsofutilitydistributedgenerators.pdf LEI and ISO-NE http://www.iso-ne.com/markets-operations/system-forecast-status/current-system-status/op4-archiv
Fuel Cell	Gross LCOE was estimated through LEI's proprietary LCOE model. Key inputs to LEI's proprietary LCOE model such as overnight capital costs and O&M sourced from FuelCell Energy	FuelCell Energy http://www.fuelcellenergy.com/assets/PID000218_FCE_BFCP_Open-House-Spotlight_r2_HIRES.pdf

For market revenue information, we relied primarily on documents and market information made publicly available by ISO-NE and as relevant for the state of Connecticut. For technical and cost information, sources relied upon include mainly independent engineering reports and market research performed by US government sponsored laboratories and research institutes as well as US Government agencies and manufacturing companies when relevant.

Figure 29. Assumptions and sources of revenue streams

Technologies	Methodology	Source
Energy	Determined average annual revenue on the energy markets for a generic technology based on LEI's outlook of market prices	Based on LEI's ISO-NE wholesale price forecasts
FCM	Revenues calculated based on FCA#9 results	Based on FCA#9 - http://www.iso-ne.com/markets-operations/markets/forward-capacity-market
LFRM	Revenues calculated using most recent clearing price (winter and summer) adjusted for participation time	Based on 2014 summer and winter results (net of capacity payments) http://www.iso-ne.com/markets/mkt_anlys_rpts/annl_mkt_rpts/2013/2013_amr_final_050614.pdf
Regulation	Revenue calculated based on regulation price adjusted for estimated market share	Based on 2013 clearing prices (ISO NE)
Avoided retailed cost	Avoided cost calculated based on average annual retail costs	EIA's statistics on CT's retail costs ; http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

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System Planning
December 2, 2014

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Section 1
Introduction

This guide describes the current standards, criteria and assumptions used in various transmission planning studies in New England.

Section 1 of this guide describes its purpose and the source of the standards, criteria and assumptions used in transmission planning studies. Section 2 describes the various types of transmission planning studies that use these standards, criteria and assumptions. Sections 3 and 4 discuss thermal and voltage ratings used in planning studies.

The remaining sections each describe the different assumptions that are utilized in transmission planning studies and the basis for these assumptions. The assumptions are presented in an order that is useful to a planner performing a transmission planning study.

Sections 5, 6 and 7 discuss modeling load in different types of transmission planning studies. Section 8 discusses the topology, transmission system and generators, used in different types of transmission planning studies. Sections 9-11 describe assumptions associated with generators. Section 12 discusses contingencies and Section 13 discusses interface stresses.

Sections 14- 20 discuss modeling of specific types of equipment. The remaining sections describe specific parts of planning studies.

Capitalized terms in this guide are defined in Section I of the Tariff or in Section 2 or Appendix A of this guide.

The provisions in this document are intended to be consistent with ISO New England's Tariff. If, however, the provisions in this planning document conflict with the Tariff in any way, the Tariff takes precedence as the ISO is bound to operate in accordance with the ISO New England Tariff.

1.1 Purpose

The purpose of this guide is to clearly articulate the current assumptions used in planning studies of the transmission system consisting of New England Pool Transmission Facilities ("PTF"). Pursuant to Attachment K, ISO New England ("the ISO" or "ISO-NE") is responsible for the planning of the PTF portion of New England's transmission system. Pool Transmission Facilities are the transmission facilities owned by Participating Transmission Owners ("PTOs"), over which the ISO exercises Operating Authority in accordance with the terms set forth in the Transmission Operating Agreement, rated at 69 kV and above, except for lines and associated facilities that contribute little or no parallel capability to the PTF. The scope of PTF facilities is defined in Section II.49 of the ISO New England Open Access Transmission Tariff ("OATT" or "Tariff").

The PTO's are responsible for planning of the Non-PTF and coordinating such planning efforts with the ISO. The planning assumptions in this guide apply to the non-PTF transmission system when studying upgrades to the non-PTF transmission system which will result in new or modified PTF transmission facilities. The PTO's establish the planning assumptions for planning of the Non-PTF which does not impact the PTF. Section 6 of Attachment K to the OATT describes the responsibilities for planning the PTF and non-PTF transmission systems.

The planning assumptions in this guide also apply to studies of the impacts of system changes on the PTF transmission system, the Highgate Transmission System, Other Transmission Facilities, and Merchant Transmission Facilities. This includes studies of the impacts of Elective Transmission Upgrades and generator interconnections, regardless of the point of interconnection.

1.2 Reliability Standards

ISO New England establishes reliability standards for the six-state New England region on the basis of authority granted to the ISO by the Federal Energy Regulatory Commission. Because New England is part of a much larger power system, the region also is subject to reliability standards established for the northeast and the entire United States by the Northeast Power Coordinating Council and the North American Electric Reliability Corporation.

The standards, criteria and assumptions used in planning studies are guided by a series of reliability standards and criteria:

- North American Electric Reliability Corporation ("NERC") Reliability Standards for Transmission Planning ("TPLs") which apply to North America. These standards can be found on the NERC website at http://www.nerc.com/page.php?cid=2|20

- Northeast Power Coordinating Council ("NPCC") Design and Operation of the Bulk Power Systems (Directory #1) which describes criteria applicable to Ontario, Quebec, Canadian Maritimes, New York and New England. These criteria can be found at the NPCC website at https://www.npcc.org/Standards/Directories/Forms/Public%20List.aspx

- ISO New England Planning and Operating Procedures which apply to New England except for the northern section of Maine that is not directly interconnected to the rest of the United States but is interconnected to New Brunswick. These standards can be found at the ISO-NE website at http://www.iso-ne.com/rules_proceds/index.html

NERC, NPCC and ISO-NE describe the purpose of their reliability standards and criteria as:

- NERC describes the intent of Transmission Planning Standards, its TPLs, as providing for system simulations and associated assessments that are needed periodically to ensure that reliable systems are developed that meet specified performance requirements with sufficient lead time, and that continue to be modified or upgraded as necessary to meet present and future system needs.

- NPCC describes the intent of its criteria as providing a "design-based approach" to ensure the Bulk Power System is designed and operated to a level of reliability such that the loss of a major portion of the system, or unintentional separation of a major portion of the system, will not result from any design contingencies.

- ISO-NE, in its Planning Procedure No. 3 ("PP-3"), describes that the purpose of the New England Reliability Standards is to assure the reliability and efficiency of the New England bulk power supply system through coordination of system planning, design and operation.

The ISO-NE planning standards and criteria, which are explained in this guide, are based on the NERC, NPCC and ISO-NE specific standards and criteria, and are set out for application in the region in ISO-NE Planning and Operation procedures. As the NERC registered Planning Authority, ISO-NE has the responsibility to establish procedures and assumptions that satisfy the intent of the NERC and NPCC standards.

Section 2
Types of Transmission Planning Studies

There are a number of different types of planning studies conducted in New England which assess or reflect the capability of the transmission system, including Market Efficiency upgrade studies, operational studies and reliability studies. The focus of this guide is on reliability studies.

The major types of studies addressed in this guide are:

- Proposed Plan Application ("PPA") Study-a study done to determine if any addition or change to the system has a significant adverse effect on stability, reliability or operating characteristics of the PTF or Non-PTF transmission system.(See Section I.3.9 of the OATT). Note that this does not need to be an independent study but can be submission or supplementation of another study such as a System Impact Study or Transmission Solutions Study as long as appropriate system conditions were included in that study.

- System Impact ("SIS") Study-a study done to determine the system upgrades required to interconnect a new or modified generating facility (See Schedule 22 of the OATT, Section 7 and Schedule 23 of the OATT, Section 3.4), to determine the system upgrades required to interconnect an Elective Transmission Upgrade, or to determine the system upgrades required to provide transmission service pursuant to the OATT. A Feasibility Study is often the first step in the interconnection study process and may be done as part of the System Impact Study or separately.

- Transmission Needs Assessment-a study done to assess the adequacy of the PTF system (See OATT Section II, Attachment K, Section 4)

- Transmission Solutions Studies-a study done to develop regulated solutions to issues identified in a Transmission Needs Assessment of the PTF system (See OATT Section II, Attachment K, Section 4.2 (b))

- NPCC Area Review Analyses-a study to assess Bulk Power System reliability (See NPCC Directory #1, Appendix B)

- Bulk Power System ("BPS") Testing-a study done to determine if Elements should be classified as part of the Bulk Power System (See NPCC Document A-10, Classification of Bulk Power System Elements)

- Transfer Limit Study-a study done to determine the range of megawatts that can be transferred across an interface under a variety of system conditions

- Interregional Study-a study involving two or more adjacent regions, for example New York and New England

- Overlapping Impact Study-the optional study that an Interconnection Customer may select as part of its interconnection studies. This study provides information on the potential upgrades required for the generation project to qualify as a capacity resource in the Forward Capacity Market. (See Schedule 22 of the OATT, Section 6.2 or 7.3)

- FCM New Resource Qualification Network Capacity Interconnection Standard Analyses-a study of the transmission system done to determine a list of potential Element or interface loading problems caused by a resource seeking to obtain a new or increased capacity supply obligation. This study is done if a System Impact Study for a generator interconnection is not complete. (See Planning Procedure 10, section 5.6)

- FCM New Resource Qualification Overlapping Impact Analyses-a study of the transmission system done to determine the deliverability of a resource seeking to obtain a new or increased capacity supply obligation. (See Planning Procedure 10, section 5.7)

- FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals-a study of the transmission system done to determine the deliverability of a resource seeking to obtain a new or increased capacity supply obligation. (See Planning Procedure 10, section 5.8)

- FCM Delist/Non-Price Retirement Analyses-a study of the transmission system done to determine the reliability impacts of delists and retirements. (See Planning Procedure 10, section 7)

- Transmission Security Analyses-a deterministic study done to determine the capacity requirements of import constrained load zones. (See Planning Procedure 10, section 6)

Section 3
Transmission Element Ratings

Planning utilizes the following thermal capacity ratings for transmission facilities, as described in ISO-NE Operating Procedure No. 16 Transmission System Data - Appendix A - Explanation of Terms and Instructions for Data Preparation of NX-9A (OP-16A):

- Normal
  Normal is a continuous 24 hour rating

- Long Time Emergency ("LTE")
  LTE is a 12 hour rating in Summer and a 4 hour rating in Winter

- Short Time Emergency ("STE")
  STE is a 15 minute rating

Summer equipment ratings (April 1 through October 31) and Winter equipment ratings (November 1 through March 31) are applied as defined in ISO-NE Operating Procedure 16. The twelve hour and four hour durations are based on the load shape for Summer and Winter peak load days.

The transmission Element ratings used in planning studies are described in ISO New England Planning Procedure 5-3 and in ISO New England Planning Procedure 7: Procedures for Determining and Implementing Transmission Facility Ratings in New England. In general, Element loadings up to normal ratings are acceptable for "All lines in" conditions. Element loadings up to LTE ratings are acceptable for up to the durations described above. Element loadings up to the STE ratings may be used following a contingency for up to fifteen minutes. STE ratings may only be used in limited situations such as in export areas where the Element loading can be reduced below the LTE ratings within fifteen minutes by operator or automatic corrective action.

There is also a Drastic Action Limit that is only used as a last resort during actual system operations where preplanned immediate post-contingency actions can reduce loadings below LTE within five minutes. Drastic Action Limits are not used in testing the system adequacy in planning studies or for planning the transmission system.

Element ratings are calculated per ISO New England Planning Procedure 7, and are submitted to ISO New England per ISO New England Operating Procedure 16: Transmission System Data.

Section 4
Voltage Criteria

4.1 Overview

The voltage standards used for transmission planning have been established to satisfy three constraints: maintaining voltages on the distribution system and experienced by the ultimate customer within required limits, maintaining the voltages experienced by transmission equipment and equipment connected to the transmission system within that equipment's rating, and avoiding voltage collapse. Generally the maximum voltages are limited by equipment and the minimum voltages are limited by customer requirements and voltage collapse. Note: This Transmission Planning Technical Guide does not address voltage flicker or harmonics.

The voltage standards prior to equipment operation apply to voltages at a location that last for seconds or minutes, such as voltages that occur prior to transformer load tap changer ("LTC") operation or capacitor switching. The voltage standards prior to equipment operation do not apply to transient voltage excursions such as switching surges, or voltage excursions during a fault or during disconnection of faulted equipment.

The voltage standards apply to PTF facilities operated at a nominal voltage of 69 kV or above.

4.2 Pre-Contingency Voltages

The voltages at all PTF buses must be in the range of 0.95-1.05 per unit with all lines in service.

There are two exceptions to this standard. The first is voltage limits at nuclear units, which are described in Section 4.9. The second exception is that higher voltages are permitted at buses where the Transmission Owner has determined that all equipment at those buses is rated to operate at the higher voltage. Often the limiting equipment under steady-state high voltage conditions is a circuit breaker. IEEE standard C37.06 lists the maximum voltage for 345 kV circuit breakers as 362 kV, the maximum voltage for 230 kV circuit breakers as 245 kV, the maximum voltage for 138 kV circuit breakers as145 kV, the maximum voltage for 115 kV circuit breakers as 123 kV and the maximum voltage for 69 kV circuit breakers as 72.5 kV. Older 115 kV circuit breakers may have a different maximum voltage.

For testing N-1 contingencies, shunt VAR devices are modeled in or out of service pre-contingency, to prepare for high or low voltage caused by the contingency, as long as the pre-contingency voltage standard is satisfied. For testing of an N-1-1 contingency, shunt VAR devices are switched between the first and second contingencies to prepare for the second contingency as long as the post contingency voltage standard is satisfied following the first contingency and prior to the second contingency.

4.3 Post-Contingency Low Voltages Prior to Equipment Operation

The lowest post-contingency voltages at all PTF buses must be equal to or higher than 0.90 per unit prior to the automatic or manual switching of shunt or series capacitors and reactors, and operation of tap changers on transformers, autotransformers, phase-shifting transformers and shunt reactors. Dynamic devices such as generator voltage regulators, STATCOMs, SVCs, DVARs, and HVDC equipment are assumed to have operated properly to provide voltage support when calculating these voltages.

Also capacitor banks that switch automatically with no intentional time delay (switching time is the time for the sensing relay and the control scheme to operate, usually a few cycles up to a second) may be assumed to have operated when calculating these voltages.

No contingency defined in Section 12.4 or 12.5 is allowed to cause a voltage collapse.

4.4 Post-Contingency Low Voltages After Equipment Operation

The lowest voltages at all PTF buses must be equal to or higher than 0.95 per unit after the switching of shunt or series capacitors and reactors, and operation of tap changers on transformers, autotransformers, phase-shifting transformers and shunt reactors.

There are two exceptions to this standard. The first is voltage limits at nuclear units. The other exception is that voltages as low as 0.90 per unit are allowed at a limited number of PTF buses where the associated lower voltage system has been designed to accept these lower voltages and where the change in voltage pre-contingency to post-contingency is not greater than 0.1 per unit. The planner should consult with the Transmission Owner and ISO-NE to determine if the second exception applies to any buses in the study area.

4.5 Post-Contingency High Voltages Prior to Equipment Operation

The standard for high voltages prior to corrective action is under development.

4.6 Post-Contingency High Voltages After Equipment Operation

The highest voltages at all PTF buses must be equal to or lower than 1.05 per unit.

The only exception is that higher voltages are permitted where the Transmission Owner has determined that all equipment at those buses is rated to operate at the higher voltage. The planner should consult with the Transmission Owner and ISO-NE to determine if the exception applies to any buses in the study area.

4.7 Voltage Limits for Line End Open Contingencies

There is no minimum voltage limit for the open end of a line if there is no load connected to the line section with the open end. If there is load connected the above standards for post-contingency low voltage apply.

The maximum voltage limit for the open end of a line is under development.

4.8 Transient Voltage Response

NERC is revising its transmission planning procedures to establish the requirement for transient voltage response criteria. This section will address those criteria once it is final.

4.9 Voltage Limits at Buses Associated with Nuclear Units

The minimum voltage limits at the following buses serving nuclear units, both for pre-contingency and for post-contingency after the switching of capacitors and operation of transformer load tap changers, are listed below. These limits apply whether or not the generation is dispatched in the study.

Table 4-1
Nuclear Unit Minimum Voltages

Critical Bus	Minimum Bus Voltage
Millstone 345 kV bus	345 kV
Pilgrim 345 kV bus	343.5 kV
Seabrook 345 kV bus	345 kV
Vermont Yankee 115 kV bus	112 kV (1)

(1) Due to the retirement of Vermont Yankee, the unique minimum voltage limit at Vermont Yankee 345 kV will be eliminated. The unique voltage limit at Vermont Yankee 115 kV will temporarily be 112 kV and will be eliminated within about three years dependent on NRC approval.

The minimum voltage requirements at buses serving nuclear units are provided in accordance with NERC Standard NUC-001 and documented in the appendices to Master Local Control Center Procedure MLCC 1.

Section 5
Assumptions Concerning Load

Load data is included in the power flow cases provided by ISO-NE. The following describes the make-up of the load data in those cases.

ISO New England's Planning Procedure 5-3: Guidelines for Conducting and Evaluating Proposed Plan Application Analyses states:

- Disturbances are typically studied at peak load levels in steady-state analysis since peak load levels usually promote more pronounced thermal and voltage responses within the New England Control Area than at other load levels. However, other load levels may be of interest in a particular analysis and, as appropriate, additional studies are conducted.

The following load levels are used in planning studies:

- Peak Load
- Intermediate Load
- Light Load
- Minimum Load

The Report of Capacity, Energy, Loads, and Transmission (CELT) is the primary source of assumptions for use in electric planning and reliability studies for the ISO New England Reliability Coordinator area. The CELT includes generators at their net output and customers with behind the meter generation at their net load or generation. In many planning studies, this generation is modeled at its gross output. When this is done, it is necessary to add generating station service loads and certain manufacturing loads, predominately mill load in Maine, to the CELT load forecast. These loads add approximately 1,464 megawatts of load that is not included in the CELT load forecast. About 1,100 megawatts of this is station service load and 364 MW is associated with the manufacturing loads. The amount of station service represented will be dependent on the generation that is in service. Station service should be turned off if the generation it is associated with is out of service, with the exception of station service to nuclear plants. Also specific large new loads, such as data centers and large green house facilities, are not generally included in the CELT load forecast, and may be included in the study depending on the degree of certainty that the large new load will come to fruition.

When assessing peak load conditions, 100% of the projected 90/10 summer peak load for the New England Control Area is used. The New England system experiences its peak load in the summer. The 90/10 Peak Load represents a load level that has a 10% probability of being exceeded due to variations in weather. Summer peak load values are generally obtained from the CELT report. This forecast includes losses of about 8% of the total load, 2.5% for transmission and large transformer losses and 5.5% for distribution losses. Thus the amount of customer load served is typically slightly less than the forecast. The peak load level is adjusted for modeling of Demand Resources as discussed in Section 11.8. The target load level for Peak Load is achieved by requesting a case with the 90/10 CELT forecast year and the study year being evaluated.

The Intermediate Load, Light Load and Minimum Load levels were derived from actual measured load, which is total generation plus net flows on external tie lines. These load levels include transmission losses and manufacturing loads. The loads in the base cases provided by ISO-NE are adjusted to account for these factors. Since actual measured load includes the impacts of distributed resources and distributed generation, no adjustments to ISO-NE bases cases are needed to address these impacts. The Intermediate Load, Light Load and Minimum Load will be reviewed periodically and may be adjusted in the future based on actual load levels.

The Intermediate Load level, also called the shoulder load level, represents both loads in off peak hours during the summer and loads during peak hours in the Spring and Fall. The Intermediate Load level was developed by

reviewing actual system loads for the three years (2011-2013) and approximating a value system loads were at or below 90% of the time (7884 hours.) The load level analysis used 500 MW increments and the current value was rounded down to account for the anticipated impact of continuing energy efficiency programs. The target load level of 18,000 MW for Intermediate Load is adjusted to 17,636 MW C to properly account for the manufacturing loads.

The Light Load level was developed by reviewing actual system loads for the last ten years and approximating a value system loads were at or below for 2000 hours. The load level analysis used 500 MW increments and the current value was rounded down to account for the anticipated impact of continuing energy efficiency programs. The target load level of 12,500 MW for Light Load is adjusted to 12,136 MW to properly account for the manufacturing loads.

In a similar fashion, the Minimum Load level was developed by reviewing actual minimum system loads, excluding data associated with significant outages such as after a hurricane. The original intent was to base the load level used on 500 MW increments and the value was rounded down to account for the anticipated impact of continuing energy efficiency programs. The original intent was to model 8,500 MW as the total of CELT load and manufacturing loads. However, the concept was never clearly documented and most studies have been based on a CELT load of 8,500 MW with the additional 364 MW of manufacturing load also reflected. This has been reviewed and is acceptable and therefore will be carried forward until such time that historic data shows that this value needs revision

Steady-state testing is done at summer load levels because equipment ratings are lower in the summer and loads are generally higher. Stability testing is always done at the Light Load level to simulate stressed conditions due to lower inertia resulting from fewer generators being dispatched and reduced damping resulting from reduced load. Except where experience has shown it is not necessary, stability testing is also done at peak loads to bound potential operating conditions and test for low voltages. Testing at the Minimum Load level is done to test for potential high voltages when line reactive losses may be low and fewer generators are dispatched resulting in lower availability of reactive resources.

The following table lists the load levels generally used in different planning studies:

Table 5-1
Load Levels Tested in Planning Studies

Study	Peak Load	Intermediate Load	Light Load	Minimum Load
System Impact Study (Steady State)	Yes	Yes	(6)	(1)
System Impact Study (Stability)	Yes	No	Yes	No
PPA Study of Transmission (Steady State)	Yes	(2)	No	(1)
PPA Study of Transmission (Stability)	Yes	No	Yes	No
Transmission Needs Assessment (Steady State)	Yes	(2)	No	Yes
Transmission Needs Assessment (Stability)	Yes	No	Yes	No
Transmission Solutions Study (Steady State)	Yes	(2)	No	Yes
Transmission Solutions Study (Stability)	Yes	No	Yes	No
NPCC Area Review Analyses (Steady State)	Yes	No	No	No
NPCC Area Review Analyses (Stability)	Yes	No	Yes	No
BPS Testing (Steady State)	Yes	No	No	No
BPS Testing (Stability)	Yes	No	Yes	No
Transfer Limit Studies (Steady State)	Yes	(3)	No	No
Transfer Limit Studies (Stability)	Yes	No	Yes	No

Study	Peak Load	Intermediate Load	Light Load	Minimum Load
Interregional Studies	Yes	No	No	No
FCM New Resource Qualification Overlapping Impact Analyses (4)	Yes	No	No	No
FCM New Resource Qualification NCIS Analyses (4)	Yes	No	No	No
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals (4) (5)	Yes	No	No	No
FCM Delist/Non-Price Retirement Analyses (4)	Yes	No	No	No
Transmission Security Analyses (4) (5)	Yes	No	No	No

(1) Testing at a Minimum Load level is done for projects that add a significant amount of transmission (charging current) to the system or where there is significant generation that does not provide voltage regulation.

(2) It may be appropriate to explicitly analyze intermediate load levels to assess the consequences of generator and transmission maintenance.

Critical outages and limiting facilities may sometimes change at load levels other than peak, thereby occasionally requiring transfer limit analysis at intermediate loads.

(3) These studies are described in ISO New England Planning Procedure No. 10, Planning Procedure to Support the Forward Capacity Market.

Sensitivity analyses at load levels lower than peak are considered when such lower load levels might result in high voltage conditions, system instability or other unreliable conditions per ISO New England Planning Procedure No. 10.

Testing at Light Load is done when generation may be limited due to Light Load export limits

Section 6
Load Power Factor Assumptions

The power factor of the load is important in planning studies because it impacts the current flow in each transmission Element. For example, a 100 megawatt load causes about 500 amps to flow in a 115 kV line if it is at unity power factor and about 560 amps to flow if it is at 0.90 power factor. The larger current flow resulting from a lower power factor causes increased real power and reactive power losses and causes poorer transmission voltages. This may result in the need for replacing transmission Elements to increase their ratings, in the need for additional shunt devices such as capacitors or reactors to control voltages, or in a decrease in the ability to transfer power from one area to another.

Each transmission owner in New England uses a process that is specific and appropriate to their particular service area to determine the load power factor to be assumed for loads in its service territory. The following summarizes the methods used by transmission owners within the New England area to set the load power factor values to be used in modeling their systems at the 90/10 Peak Load:

Table 6-1
Power Factor Assumptions

Company	Base Modeling Assumption
BHE	Uses Historical Power Factor (PF) values
CMP	Historical metered PF values (Long term studies use 0.955 lagging)
Municipal Utilities	Uses Historical PF values
National Grid	1.00 PF at Distribution Bus
NSTAR North	Individual Station 3 Year Average PF at Distribution Bus
NSTAR South	0.985 lagging PF at Distribution Bus
NU	0.990 lagging PF at Distribution Bus
UI	0.995 lagging PF at Distribution Bus
VELCO	Historical PF at Distribution Bus provided by Distribution Companies

The above power factor assumptions are also used in Intermediate Load and Light Load cases. The power factor at the Minimum Load level is set at 0.998 leading at the distribution bus for all scaling load in New England with the exception of:

1. Boston downtown load fed by NSTAR that is set to a power factor of 0.978 lagging at the distribution bus
2. Boston suburban load fed by NSTAR this is set to unity power factor at the distribution bus

The non-scaling load includes mill loads in Maine, MBTA loads in Boston, railroad loads in Connecticut and other similar loads.

ISO-NE Operating Procedure 17, Load Power Factor Correction, discusses load power factor and describes the annual survey done to measure compliance with acceptable load power factors.

Section 7
Load Models

7.1 Load Model for Steady-State Analysis

In steady-state studies, loads are modeled as constant MVA loads, comprised of active ("real") P and reactive ("imaginary") Q loads. They are modeled by the Transmission Owners based on historical and projected data at individual buses, modeling equivalent loads that represent line or transformer flows. These loads may be modeled at distribution, sub-transmission, or transmission voltages.

7.2 Load Model for Stability Analysis

Loads (including generator station service) are assumed to be uniformly modeled as constant impedances throughout New England and New York. The constant impedances are calculated using the P and Q values of the load. This representation is based on extensive simulation testing using various load models to derive the appropriate model from an angular stability point of view, as described in the 1981 NEPOOL report, "Effect of Various Load Models on System Transient Response."

For under frequency load shedding analysis, other load models are sometimes used, such as either a polynomial combination of constant impedance, constant current and constant load; or a complex load model, including modeling of motors. The alternate modeling is based on the end use composition of the load.

Voltage stability analysis is sometimes done using a complex load model, including modeling of motors.

Section 8
Base Case Topology

8.1 Summary of Base Case Topology

Base case topology refers to how system Elements are represented and linked together for the year(s) to be studied. System Elements modeled in base cases include, but are not limited to transmission lines, transformers, and other series and shunt Elements in New England, generators on the New England transmission system, generators on the New England distribution system, merchant transmission facilities in New England, and similar topology for adjacent systems.

There are a number of Tariff and practical considerations that determine the topology used for various types of planning studies. For example, Needs Assessments and Solutions Studies need to include the facilities that have a commitment to be available (e.g. an obligation in the Forward Capacity Market, a reliability upgrade with an approved PPA or a merchant facility with an approved PPA and an associated binding contract) and need to exclude projects that are not committed to be available. For System Impact Studies for generation the studies need to include all active generators in the FERC section of the ISO-NE queue that have earlier (higher) queue positions. The starting point for the development of a base case is ISO-NE's Model on Demand database which includes a model of the external system from the Multi-regional Modeling Working Group ("MMWG"). This Model on Demand data base is used to create ISO-NE's portion of the MMWG base case. However the Model on Demand data base is updated periodically to include updated ratings, updated impedances and newly approved projects. The following table summarizes the topology used is planning studies:

Table 8-1
Base Case Topology

Study	Transmission in New England	Generation in New England (7,8)	Merchant Facilities	Transmission outside New England	Generation outside New England
PPA Study of transmission project (Steady State and Stability)	In-Service, Under Construction, and Planned (1)	In-Service, Under Construction or has an approved PPA (1)	In-Service, Under Construction or has an approved PPA	Models from recent Multiregional Modeling Working Group ("MMWG") base case	Models from recent MMWG base case
System Impact Study (Steady State and Stability)	In-Service, Under Construction, and Planned (1)	In-Service, Under Construction, or has an approved PPA or is included in FERC section of the ISO-NE queue (1)	In-Service, Under Construction or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
Transmission Needs Assessment (Steady State)	In-Service, Under Construction, Planned, and Proposed (6)	Has a capacity supply obligation or a binding contract (4)	In-Service, Under Construction, or has an approved PPA; and delivers an import with a capacity supply obligation or a binding contract (4); and has a certain ISD	Models from recent MMWG base case	Models from recent MMWG base case

Study	Transmission in New England	Generation in New England (7,8)	Merchant Facilities	Transmission outside New England	Generation outside New England
Transmission Solutions Study (Steady State and Stability)	In-Service, Under Construction, Planned, and Proposed (6)	Has a capacity supply obligation or a binding contract (4)	In-Service, Under Construction, or has an approved PPA: and delivers an import with a capacity supply obligation or a binding contract (4); and has a certain ISD	Models from recent MMWG base case	Models from recent MMWG base case
Area Review Analyses (Steady State and Stability)	In-Service, Under Construction, and Planned	In-Service, Under Construction, or has an approved PPA	In-Service, Under Construction, or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
BPS Testing Analyses (Steady State and Stability)	In-Service, Under Construction, and Planned	In-Service, Under Construction, or has an approved PPA	In-Service, Under Construction, or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
Transfer Limit Studies (Steady State and Stability)	In-Service, Under Construction, and Planned	In-Service, Under Construction or has an approved PPA	In-Service, Under Construction or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
Interregional Studies	In-Service, Under Construction, and Planned (2)	In-Service, Under Construction or has an approved PPA	In-Service, Under Construction or has an approved PPA	Models from recent MMWG base case	Models from recent MMWG base case
FCM New Resource Qualification Overlapping Impact Analyses (3) (4)	In-Service, or Under Construction, Planned, or Proposed with an In Service Date (ISD) certified by the Transmission Owner ("TO")	Existing resources and resources that have a capacity supply obligation	In-Service, Under Construction , Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas
FCM New Resource Qualification Network Resource Interconnection Standard Analyses (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the TO	Existing resources and resources that have a capacity supply obligation	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas

Study	Transmission in New England	Generation in New England (7,8)	Merchant Facilities	Transmission outside New England	Generation outside New England
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the TO	Existing resources and resources that have a capacity supply obligation	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas
FCM Delist/Non-Price Retirement Analyses (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the TO	Existing resources and resources that have a capacity supply obligation	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	Models from recent MMWG base case	Models from recent MMWG base case and generators which represent flows to/from external areas
Transmission Security Analyses (5)	In-Service or Under Construction, Planned, or Proposed with an ISD certified by the TO	Existing resources and resources that have a capacity supply obligation	In-Service, Under Construction, Planned, or Proposed with an ISD certified by the Owner	N/A	N/A

(1) Projects with a nearly completed PPA Study and that have an impact on this study are also considered in the base case. This includes transmission projects and generation interconnections to the PTF or non-PTF transmission system. Also generators without capacity supply obligations in the Forward Capacity Market are included in PPA Studies.
(2) Some interregional studies may include facilities that do not have approved Proposed Plan Applications.
(3) Base Cases for preliminary, non-binding overlapping impact analysis done as part of a generation Feasibility Study or generation System Impact Study are developed with input from the Interconnection Customer.
(4) Section 4.2 of Attachment K describes that resources that are bound by a state-sponsored RFP or financially binding contract are represented in base cases.
(5) These studies are described in ISO New England Planning Procedure No. 10, Planning Procedure to Support the Forward Capacity Market.
(6) Sensitivity analysis may also be done to confirm the Proposed Projects in the Study Area continue to be needed.
(7) Generators that have submitted a Non-Price Retirement Request are considered to be retired in the year associated with their Non-Price Retirement Request and in subsequent years.
(8) In Transmission Needs Assessments and Transmission Solutions Studies, additional generators are often considered unavailable. Generators that have a rejected Permanent De-list bid are considered unavailable (See Attachment K 4.1.c). Also, generators that have delisted in the two most recent FCM auctions are considered unavailable. In addition, the ISO may consider generators unavailable because of circumstances such as denial of license extensions or being physically unable to operate.

8.2 Modeling Existing and Proposed Generation

Generating facilities 5 megawatts and greater are listed in the CELT report and are explicitly modeled in planning study base cases. The current exception to this is generators 5 MW and greater that are "behind the meter" and do not individually participate in the ISO New England energy market. Some of these generators are netted to load. However, as these generators could have an impact on system performance, future efforts will be made to model these resources in greater detail. The ISO is collecting load flow, stability and short circuit models for generators 5 MW and greater that are new or being modified. Additional models such as PSCAD models are collected as necessary. For example a PSCAD model is often required for solar and wind generation connecting to the transmission system.

Generators less than 5 MW are modeled explicitly, either as individual units or as the equivalent of multiple units, or are netted to load. Generators connected to the distribution system are generally modeled at a low voltage bus connected to the transmission system through a load serving transformer.

8.3 Base Cases for PPA Studies and System Impact Studies

Similar topology is used in base cases for PPA Studies for transmission projects and System Impact Studies. Both types of studies include projects in the Planned status in their base cases. However, projects with a nearly completed PPA Study and that have an impact on a study area are also considered in the base case.

Section 2.3 of Schedule 22 of the OATT states that base cases for generation interconnection Feasibility and System Impact Studies shall include all generation projects and transmission projects, including merchant transmission projects that are proposed for the New England Transmission System for which a transmission expansion plan has been submitted and approved by the ISO. This provision has been interpreted that a project is approved when it is approved under Section I.3.9 of the Tariff.

Sections 6.2 and 7.3 of Schedule 22 of the OATT further state that on the date the Interconnection Study is commenced, the base cases for generation interconnection studies shall also include generators that have a pending earlier-queued Interconnection Request to interconnect to the New England Transmission System or are directly interconnected to the New England Transmission System.

8.4 Coordinating Ongoing Studies

At any point in time there are numerous active studies of the New England transmission system. The New England planning process requires study teams to communicate with other study teams to ascertain if the different teams have identified issues which 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. It is appropriate for a Needs Assessment, a Solutions Study or a Generator Interconnection Study to consider relevant projects that have nearly completed their PPA analyses. For example, a study of New Hampshire might consider a 345 kV line from New Hampshire to Boston that is a preferred solution in a Solutions Study of the Boston area, or, when issues in both areas are considered, may suggest a benefit of modifying a solution that has already progressed to the Proposed or the Planned stage.

8.5 Base Case Sensitivities

Often in transmission planning studies, there is uncertainty surrounding the inclusion of a resource, a transmission facility, or a large new load in the base case for a study. These uncertainties are handled by doing sensitivity analysis to determine the impact the inclusion or exclusion of a particular resource, transmission project or load has on the study results. Sensitivity studies are done to determine the impact of changes that are somewhat likely to occur within the planning horizon and may influence the magnitude of the need or the choice of the solution. Typically, stakeholder input is solicited at PAC meetings in determining the manner in which sensitivity results are factored into studies. Examples are resources that may be retired or added, and transmission projects that may be added, modified, or delayed. Sensitivity analysis usually analyzes a limited number of conditions for a limited number of contingencies.

8.6 Modeling Projects with Different In-Service Dates

In some situations it is necessary to do a study where the year of study is earlier than the in service dates of all the projects that need to be considered in the base case. In such situations it is necessary to also include a year of study that is after the in-service-dates of all relevant projects.

As an example, consider two generation projects in the ISO's queue. The first project has queue position 1000 and a Commercial Operation Date of 2018. The second project has queue position 1001 and a Commercial Operation Date of 2015. Sections 6.2 and 7.3 of Schedule 22 of the OATT require that the study of the project with queue position 1001 to include the project with queue position 1000. To accomplish this, the study of the project with queue position 1001would be done with 2015 base case without the project with queue position 1000 and also with a 2018 base case that includes the project with queue position 1000 and any transmission upgrades associated with queue position 1000.

Section 9
Generator Ratings

9.1 Overview of Generator Real Power Ratings

Within New England, a number of different real power (megawatt) ratings for generators connected to the grid are published. Examples of the different generator ratings are summarized in the table below. The detailed definitions of these ratings are included in Appendix A. CNRC and NRC values for New England generators are published each year in the CELT (Capacity, Energy, Loads, & Transmission) Report.[1] QC values are calculated based on recent demonstrated capability for each generator. The Capacity Supply Obligation value and QC values are published for each Forward Capacity Auction in the informational results filings to FERC.[2]

Table 9-1
Generator Real Power Ratings

Capacity Network Resource Capability ("CNRC") – Summer- (maximum output at or above 90 degrees Fahrenheit)	CNRC Summer is the maximum amount of capacity that a generator has interconnection rights to provide in Summer. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 90 degrees Fahrenheit
Capacity Network Resource Capability ("CNRC") - Winter (maximum output at or above 20 degrees Fahrenheit)	CNRC Winter is the maximum amount of capacity that a generator has interconnection rights to provide in Winter. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 20 degrees Fahrenheit
Capacity Supply Obligation ("CSO")	A requirement of a resource to supply capacity. This requirement can vary over time based on the resource's participation in the Forward Capacity Market.
Network Resource Capability ("NRC") -Summer (maximum output at or above 50 degrees Fahrenheit)	NRC Summer is the maximum amount of electrical output that a generator has interconnection rights to provide in Summer. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 50 degrees Fahrenheit
Network Resource Capability ("NRC") –Winter (maximum output at or above 0 degrees Fahrenheit)	NRC Winter is the maximum amount of electrical output that a generator has interconnection rights to provide in Winter. It is measured as the net output at the Point of Interconnection and cannot exceed the generator's maximum output at or above 0 degrees Fahrenheit
Qualified Capacity ("QC")	QC is the amount of capacity a resource may provide in the Summer or Winter in a Capacity Commitment Period, as determined in the Forward Capacity Market qualification processes

In New England planning studies, except for the FCM studies, generators connected to the transmission system are generally modeled as a generator with its gross output, its station service load and its generator step-up transformer ("GSU"). In FCM studies, except for Network Capacity Interconnection Standard studies, generation is generally modeled net of station service load at the low voltage side of the GSU and station service load is set to zero. This is done because the CSO, QC and CNRC values are net values. One exception is

[1] http://www.iso-ne.com/trans/celt/index.html

[2] http://www.iso-ne.com/regulatory/ferc/filings/index.html

made in FCM-related studies for nuclear resources, where the generator is modeled at its gross output, in order to capture the need to maintain supply to the generator's station service load if the generator is out of service. Another exception is generating facilities composed of multiple smaller generators such as wind farms, solar and small hydro units. These facilities are often modeled as a single equivalent generator on the low voltage side of the transformer that interconnects the facility with the transmission system.

The ratings and impedances for an existing GSU are documented on the NX-9 form for that transformer. The existing generator's station service load is documented on the NX-12 form for that generator. Similar data is available from the Interconnection Requests for proposed generators. The generator's gross output is calculated by adding its appropriate net output to its station service load associated with that net output. GSU losses are generally ignored in calculating the gross output of a generator. This data is used by the ISO-NE to help create the base cases for planning studies.

In New England planning studies, generators connected to the distribution system are generally modeled as connected to a low voltage bus that is connected to a transformer that steps up to transmission voltage or netted to distribution load. Multiple generators connected to the same low voltage bus may be modeled individually or as an equivalent generator.

9.2 Generator Ratings in Steady-State Needs Assessments, Solutions Studies, and NPCC Area Review Analyses

The Summer Qualified Capacity value is used to represent a machine's maximum real power output (megawatt) for all load levels studied except for Light Load (when applicable) and Minimum Load Studies. QC is used in these studies because QC represents the recently demonstrated capability of the generation. The QC value is the maximum Capacity Supply Obligation that a resource may obtain in the Forward Capacity Market. Any requested reduction in obligation from a resource's QC is subject to a reliability review and may be rejected for reliability reasons. The Capacity Network Resource Capability acts as an approved interconnection capability cap within the Forward Capacity Market that limits how much a resource could increase its QC without an Interconnection Request. In other words, QC cannot exceed CNRC. Because QC corresponds to the recently demonstrated capability, as opposed to CNRC which is the upper limit of the capacity capability of a resource, using QC instead of CNRC does not overstate the amount of capacity that could potentially be obligated to provide capacity to the system.

For reliability analysis conducted at Light Load and Minimum Load Levels, the generator's Summer NRC value (maximum megawatt output at or above 50 degrees) is used. Some generators have higher individual resource capabilities at 50 degree ratings compared with 90 degrees. Therefore, using 50 degree ratings allows a smaller number of resources to be online to serve load. The fewer the number of resources online, the less overall reactive capability on the system to mitigate high voltage concerns. This value is also consistent with the expected ratings of machines at the temperatures that are typically experienced during lighter load periods in the summer rating period.

9.3 Generator Ratings in PPA Studies and System Impact Studies

The generator's Summer NRC value is used to represent a machine's maximum real power output (megawatts) for all load levels. For generator System Impact Studies, using this value ensures that studies match up with the level of service being provided. Studying Elective Transmission Upgrades and transmission projects with machines at these ratings also ensures equal treatment when trying to determine the adverse impact to the system due to a project.

9.4 Generator Ratings in Stability Studies

The generator's Winter NRC value is used to represent a machine's maximum real power output (megawatts) for all load levels in all stability studies. Using the Winter NRC values ensures that stressed dispatches (in terms of

limited inertia on the system and internal generator rotor angles) are studied and addressed, therefore ensuring reliable operation of the system in real-time. This operability is required because real-time power system analysis is unable to identify stability concerns or determine stability limits that may exist on the system. These limits are determined in offline operational studies performed in a manner that ensures that they are applicable over a wide range of system conditions, including various ambient temperatures and load levels.

9.5 Generator Ratings in Forward Capacity Market Studies

The generator's Summer CNRC value is used to represent a machine's maximum real power output (megawatts) for FCM New Resource Qualification Overlapping Impact Analyses. This output represents the level of interconnection service that a generator has obtained for providing capacity.

The generator's Summer NRC value is used to represent a machine's maximum real power output (megawatts) for FCM New Resource Qualification NCIS Analyses. This output represents the level of interconnection service that a generator has obtained for providing energy.

The generator's Summer QC value is used to represent a machine's maximum real power output (megawatts) for FCM Delist/Non-Price Retirement Analyses and Transmission Security Analyses. This output represents the expected output of a generator during Summer peak periods.

The lower of a generator's Summer QC value or Summer Capacity Supply Obligation is used to represent a machine's maximum real power output (megawatts) for FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals. This output represents the expected capacity capability of a generator during Summer peak periods.

9.6 Generator Reactive Ratings

This section is under development.

Section 10
Generators Out of Service in Base Case

In Transmission Needs Assessments and Transmission Solutions Studies, generally two generation resources are considered out of service in the study area. These resources can be individual generators or interdependent generating facilities such as combined-cycle units (see section 11.9). The most impactful generators, those whose outage creates the greatest stress on the portion of transmission system under study, are considered out of service. Identifying the most impactful generators may in itself require some analysis. Additional generators could be considered to be out of service if the area under study has a large population of generators or if examining Intermediate, Light or Minimum Load maintenance conditions. Often multiple base cases are required to assess the impact of different combinations of generators being out of service. In general, having several generators out 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

In some of the other transmission planning studies listed in Section 2, the most impactful single generators are considered out of service in the base cases and other generators may be turned off in order to create system stresses. For example, in FCM overlapping impact studies, the system is stressed by assuming that the most impactful helper is out of service. The most impactful helper is the generator that, when placed in service at its full output, will result in the most significant reduction in the flow on the limiting element.

Section 11
Determination of Generation Dispatch in Base Case

11.1 Overview

Different types of studies are conducted to achieve different transmission planning objectives. Therefore, it is necessary to consider the different range of anticipated generator capabilities which are appropriate to the objectives of study and the specific conditions which are being examined.

11.2 Treatment of Different Types of Generation

The following table lists the maximum generation levels generally used in different planning studies. Generators, when dispatched, are usually dispatched up to their maximum output in a study.

Table 11-1
Generator Maximum Power Output in Planning Studies

Study	Conventional Generation	Fast Start Generation	Hydro (1) Generation	Wind Generation	Solar Generation
System Impact Study (Steady State)	Summer NRC	Summer NRC	Summer NRC	Summer NRC	Summer NRC
System Impact (Stability)	Winter NRC	Winter NRC	Winter NRC	Winter NRC	Winter NRC
PPA Study of Transmission (Steady State)	Summer NRC	Summer NRC	Summer NRC	Summer NRC	Summer NRC
PPA Study of Transmission (Stability)	Winter NRC	Winter NRC	Winter NRC	Winter NRC	Winter NRC
Transmission Needs Assessment (Steady State)	Summer QC	Summer QC	Historical Level	5% of nameplate for on-shore wind (2)	Summer QC
Transmission Solutions Study (Steady State)	Summer QC	Summer QC	Historical Level	5% of nameplate for on-shore wind (2)	Summer QC
Transmission Solutions Study (Stability)	Winter NRC	Winter NRC	Winter NRC	Winter NRC	Winter NRC
Area Review Analyses (Steady State)	Summer NRC	Summer NRC	Summer NRC	Summer NRC	Summer NRC
Area Review Analyses (Stability)	Winter NRC	Winter NRC	Winter NRC	Winter NRC	Winter NRC
BPS Testing Analyses (Steady State)	Summer NRC	Summer NRC	Summer NRC	Summer NRC	Summer NRC
BPS Testing Analyses(Stability)	Winter NRC	Winter NRC	Winter NRC	Winter NRC	Winter NRC
Transfer Limit Studies (Steady State)	Summer NRC	Summer NRC	Summer NRC	Summer NRC	Summer NRC
Transfer Limit Studies (Stability)	Winter NRC	Winter NRC	Winter NRC	Winter NRC	Winter NRC

(1) Table lists treatment on conventional hydro. The treatment of pumped storage hydro is described in Section 11.5.
(2) 20% of the nameplate for off-shore wind

Study	Conventional Generation	Fast Start Generation	Hydro (1) Generation	Wind Generation	Solar Generation
Interregional Studies	Summer NRC	Summer NRC	Summer NRC	Summer NRC	Summer NRC
FCM New Resource Qualification Overlapping Impact Analysis	Summer CNRC	Summer CNRC	Summer CNRC	Summer CNRC	Summer CNRC
FCM New Resource Qualification Network Capacity Interconnection Standard Analyses	Summer NRC	Summer NRC	Summer NRC	Summer NRC	Summer NRC
FCM Delist/Non-Price Retirement Analyses	Summer QC	Summer QC	Summer QC	Summer QC	Summer QC
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals	Lower of Summer QC or CSO	Lower of Summer QC or CSO	Lower of Summer QC or CSO	Lower of Summer QC or CSO	Lower of Summer QC or CSO
Transmission Security Analyses	Summer QC	Summer QC	Summer QC	Summer QC	Summer QC

(1) Table lists treatment on conventional hydro. The treatment of pumped storage hydro is described in Section 11.5.

11.3 Treatment of Wind Generation

Studies of wind generation in New England reveal that the output of on-shore (land-based) wind generation can be very low during Summer peak load hours.[3] In general, when it is needed to support area transmission requirements, on-shore wind generation is modeled at 5% of nameplate and off-shore wind is modeled at 20% of nameplate for Needs Assessment and Solutions Studies. If a wind farm's Qualified Capacity is lower than the above value, the Qualified Capacity will be used in Needs Assessments and Solutions Studies.

The above percentages are estimates of the level of wind generation output that can be counted on during Summer peak for reliability analysis. To ensure that the interconnection rights of wind resources are preserved, wind generation is modeled at its NRC value in PPA studies.

11.4 Treatment of Conventional Hydro Generation

There are two classifications of conventional hydro, those hydro facilities that have no control over water flow, for example no capability to store water, and those hydro facilities that can control water flow, for example those facilities with a reservoir or river bed that can store water. For the purpose of planning studies, hydro facilities listed as "hydro (weekly cycle)" or "hydro (daily cycle-pondage)" in the CELT report are considered to be able to control water flow. Hydro facilities listed as "hydro (daily cycle-run of river)" in the CELT report, are assumed to have no ability to control water flow and are classified as intermittent resources. Hydro facilities that can control water flow are classified as non- intermittent resources. For both classifications the output of the hydro generation is set at its historic capability that can be relied on for reliability purposes or at 10% of nameplate, which is an estimate of that historic capability, in the base cases for Needs Assessments and Solutions Studies. Post contingency, conventional hydro that has the capability to control water flow and has sufficient water storage capability is dispatched up to 100% of its nameplate to relieve criteria violations in Needs and Solutions Analysis. Hydro facilities that have no control over water flow or limited water storage capability are dispatched at the same output pre and post contingency.

[3] This was discussed at the Planning Advisory Committee meetings on September 21, 2011 and October 22, 2014.

11.5 Treatment of Pumped Storage Hydro

There are three pumped storage-hydro plants connected to the New England Transmission System: Northfield Mountain and J. Cockwell (also known as Bear Swamp) in Massachusetts and Rocky River in Connecticut. Records indicate that these facilities historically have had limited stored energy during prolonged heat waves because limited time and resources are available to allow these units to refill their reservoirs during off-peak periods. Additionally J. Cockwell and Northfield are often used to provide reserve capacity. Based on this, the following generation levels are generally used in Needs Assessments and Solutions Studies.

Table 11-2
Pumped Storage Hydro Generation Levels

Generating Facility	Megawatt Output
J. Cockwell	50% of Summer QC
Northfield Mountain	50% of Summer QC
Rocky River	Treated as conventional hydro with ponding capability

In Needs Assessments and Solutions Studies addressing the area that includes a pumped storage-hydro facility, the pumped storage-hydro facility in that area may also be dispatched at their maximum and/or minimum values to ensure that they can be utilized to serve load when they are available since they are often utilized in operations to provide reserve. In PPA studies, pumped storage-hydro plants are dispatched at their full output when necessary to show that their ability to supply load is maintained.

11.6 Treatment of Fast Start Generation

Fast start units are generally used as reserve for generation that has tripped off line, for peak load conditions, and to mitigate overloads or unacceptable voltage following a contingency, N-1 or N-1-1. Based on operating experience and analysis, 80% of fast start units in the study area are assumed to be available. However it is not appropriate to rely on any one specific fast start unit as the solution to an overload.

For the purpose of transmission planning studies, fast start units are those combustion turbines or diesel generators that can go from being off line to their full Seasonal Claimed Capability in 10 minutes. A list of fast start units has been developed by reviewing market information such as notification times, start times and ramp rates. The list is included as Appendix B in the guide. The capacity included in the list is from Forward Capacity Auction 8. The capacity of any generator may have changed and needs to be confirmed. The unit does not need to participate in the 10-minute reserve market to be considered a fast start unit in planning studies.

For the steady-state portion of Transmission Needs Assessments and Solutions Studies at peak load, the fast start units can be turned on in the base cases. When using this approach, criteria violations that can be mitigated by turning off fast start generation can be disregarded.

For Transmission Needs Assessments and Solutions Studies at Intermediate or Light load level, fast start units are turned off in the base cases and turned on to mitigate post-contingency criteria violations.

One exception to the above is that fast start generation in Vermont is not dispatched in the base case in Needs Assessments and Solutions Studies due to their past poor performance, but they are may be turned on between the first and second contingency.

11.7 Treatment of Solar Generation

Solar generation will be represented in the power flow base cases that are provided by ISO-NE. Solar generation with has a nameplates capacity of 5 MW or greater will be modeled explicitly as generators in all

base cases. Solar generation which is less than 5 MW will be modeled explicitly as a reduction to load in base cases representing peak loads. Solar generation less than 5 MW will not be modeled explicitly in the fixed load level cases representing shoulder, light and minimum loads, because the impact of solar generation was considered in the establishment of the fixed load levels (see Section 5, "Assumptions Concerning Load").

The amount of solar generation represented in peak load base cases is based on the forecast developed by the Distributed Generation Forecast Working Group. This working group annually develops a forecast of the amount of solar generation expected to be connected in New England in future years. The amount of solar generation connected to the system that is represented in the models is derived by multiplying the nameplate capability by an adjustment factor of 26% which represents the output of solar generation during the peak load period between 4 p.m. and 6 p.m. in the summer. This is the time period when solar output begins to go down due the angle of the sun and when loads are still at or near the peak level. Solar generation is distributed among distribution buses using information on the location of solar generation provided by distribution companies and based on the location of solar generators over one MW that submit information as required by Planning Procedure PP 5-1.

Solar generation will be represented in peak power flow cases such that it does not affect the net power factor of the load. It is assumed that distribution companies will adjust their power factor correction programs to account for solar generation. At peak load levels, solar generation generally should reduce distribution VAR losses, therefore modeling solar power such that it does not impact net load power factor should be a slightly conservative approach.

11.8 Treatment of Demand Resources

Through the Forward Capacity Market, Demand Resources ("DR") can be procured to provide capacity and have future commitments similar to that of a generator. There are currently two categories of DR in the FCM: Passive Demand Resources ("Passive DR") and Active Demand Resources ("Active DR"). Passive DR consists of two types of Resources: On-Peak and Seasonal Peak. Active DR reduces load based on ISO-NE instructions under real-time system conditions. Active DR consists of Real-Time Demand Response resources ("RTDR") and Real-Time Emergency Generation resources ("RTEG"). After June 2017, RTDR will be replaced with Demand Response Capacity Resources (DRCR). In addition to the demand resources mentioned above that are procured through the FCM, the ISO forecasts Energy Efficiency as a part of the annual CELT forecast. This Energy Efficiency is a form of passive DR but is treated separately as it is forecasted beyond the FCM horizon. This DR is included for studies that analyze time periods beyond the FCM horizon.

The modeling of Demand Resources in planning studies varies with the type of study and the load level being studied. Demand Resources and their modeling are described fully in Appendix C, "Guidelines for Treatment of Demand Resources in System Planning Analyses".

Demand Resources will not be modeled explicitly in the fixed load level cases representing shoulder, light and minimum loads, because the impact of Demand Resources was included in the actual measured load used to establish the fixed load levels (see Section 5, "Assumptions Concerning Load").

11.9 Treatment of Combined Cycle Generation

For the purposes of modeling generating units in a base case and in generator contingencies, all generators of a combined cycle unit are considered to be in-service at the same time or out-of-service together. The basis for this assumption is that many of the combustion and steam generators that make up combined cycle units cannot operate independently because they share a common shaft, they have air permit or cooling restrictions, or they do not have a separate source of steam. Other combined cycle units share a GSU or other interconnection facilities such that a fault on those facilities causes the outage of the entire facility. ISO New England's operating history with combined cycle units has shown that even for units that claim to be able to operate in modes where one portion of the facility is out of service, they rarely operate in this partial mode.

11.10 Generator Dispatch in Stability Studies

At both Peak and Light load levels, generators are modeled at highest gross (maximum) MW output at 0^0 F or higher. Generators are generally dispatched either "full-on" at maximum capability, or "full-off." If transmission transfers need to be adjusted, then the following is done:

- First, generators are re-dispatched by simulating them "full on" or "off"
- Second, adjust generators, if necessary, least critical to study results to obtain desired transfers ("off" or as close to "full on" as possible).

This is done to obtain generators' maximum stressed internal angles in order to establish a stability limit under worst-case conditions. Generator reactive dispatch must also be considered for generators being evaluated for stability performance. Pre-fault reactive output is based on the Light Load voltage schedule in Operating Procedure OP-12.

Section 12
Contingencies

12.1 Basis for Contingencies Used in Planning Studies

The contingencies that are tested in planning studies of the New England transmission system are defined in NERC, NPCC and ISO New England reliability standards and criteria. These standards and criteria form deterministic planning criteria. The application of this deterministic criteria results in a transmission system that is robust enough to operate reliably for the myriad of operating conditions that occur on the transmission system.

These standards and criteria identify certain contingencies that must be tested and the power flow in each Element in the system must remain under the Element's emergency limits following any specified contingency. In most of New England, the Long Time Emergency Rating is used as the emergency thermal limit. The Short Time Emergency Rating may be used as the emergency thermal limit when an area is exporting if generation can be dispatched lower to mitigate overloads. The Short Time Emergency Rating may be used as the emergency thermal limit in areas where phase-shifting transformers can be used to mitigate overloads. Voltage limits are discussed earlier in this guide.

Contingencies used for the design of the transmission system can be classified as:

- N-1, those Normal Contingencies("NCs") with a single initiating cause (a N-1 contingency may disconnect one or more transmission Elements)
- N-1-1, those NCs with two separate initiating causes and where timely system adjustments are permitted between initiating causes
- Extreme contingencies

Planning criteria allow certain adjustments to the transmission system between the two initiating causes resulting in N-1-1 contingencies as described in Section 12.5.

Steady-state analysis focuses on the conditions that exist following the contingencies. Stability analysis focuses on the conditions during and shortly after the contingency, but before a new steady-state condition has been reached.

12.2 Contingencies in Steady-State Analysis

NERC and/or NPCC require that the New England Bulk Power System shall maintain equipment loadings and voltages within normal limits for pre-disturbance conditions and within applicable emergency limits for the system conditions following the contingencies described in Sections 12.4 and 12.5.

12.3 Contingencies in Stability Analysis

NERC and NPCC require that the New England Bulk Power System shall remain stable and damped and the Nuclear Plant Interface Coordinating Standard (NUC-001-2 approved August 5, 2009) shall be met. This requirement must be met during and following the most severe of the contingencies stated below "With Due Regard to Reclosing", and before making any manual system adjustments. For each of the contingencies below that involves a fault, stability and damping shall be maintained when the simulation is based on fault clearing initiated by the "system A" Protection Group, and also shall be maintained when the simulation is based on fault clearing initiated by the "system B" Protection Group where such protection group is required or where there would otherwise be a significant adverse impact outside the local area.

New England's planning criteria defines a unit as maintaining stability when it meets the damping criteria in Appendix C of ISO-NE Planning Procedure No. 3 (also included as Appendix D to this guide). New England also uses the voltage sag guideline, which is included as Appendix E to this guide, to determine if it may be necessary to mitigate voltage sags.

Consistent with Operating Procedure OP-19, New England's planning procedures require generator unit stability for all Normal Design Contingencies as defined in Planning Procedure PP-3. This criterion applies when the fastest protection scheme is unavailable at any BPS substation involved in the fault clearing. This criterion applies if the fastest protection scheme is available at any non-BPS substation involved in the fault clearing. If the fastest protection scheme is unavailable at a non-BPS substation, unit instability is permitted as long as the net source loss resulting from the Normal Design Contingency is not more than 1,200 MW, and the net source loss is confined to the local area (i.e. no generator instability or system separation can occur outside the local area).

The 1,200 MW limit derives from the NPCC Directory 1 criteria which require that a Normal Design Contingency have no significant adverse impact outside the local area. The maximum loss of source for a Normal Design Contingency has been jointly agreed upon by NYISO (formerly NYPP), ISO-NE (formerly NEPEX) and PJM to be between 1,200 MW and 2,200 MW depending on system conditions within NYISO and PJM. This practice is observed pursuant to a joint, FERC-approved protocol, which is Attachment G to the ISO-NE Tariff. The low limit of 1,200 MW has historically been used for Design Contingencies in New England.

Table 12-1
Protection Modeling in Stability Studies

Station Type	Fastest Protection System Modeling for Normal Design Contingencies	
	Fastest Protection System In-Service	Fastest Protection System Out-of-Service
BPS	Not Tested	Tested
Non-BPS	Tested	Not Tested

12.4 N-1 Contingencies

NERC and/or NPCC require that the following N-1 contingencies be tested:

a. A permanent three-phase fault with Normal Fault Clearing on any:
   - Generator
   - Transmission circuit
   - Transformer
   - Bus section
   - Series or shunt compensating device

b. Simultaneous permanent phase-to-ground faults on:
   - Different phases of each of two adjacent transmission circuits on a multiple circuit transmission tower, with Normal Fault Clearing. If multiple circuit towers are used only for station entrance and exit purposes, and if they do not exceed five towers at each station, then this condition and other similar situations can be excluded from ISO-NE testing on the basis of acceptable risk, provided that the ISO approves the request for an exclusion. For exclusions of more than five towers, the ISO and the NPCC Reliability Coordinating Committee need to specifically approve each request for exclusion.
   - Any two circuits on a multiple circuit tower

c. A permanent phase-to-ground fault, with Delayed Fault Clearing, on any:
   - Transmission circuit
   - Transformer
   - Bus section

   This Delayed Fault Clearing could be due to malfunction of any of the following:
   - Circuit breaker
   - Relay system
   - Signal channel

d. Loss of any Element without a fault (See Section 12.7)

e. A permanent phase-to-ground fault in a circuit breaker, with Normal Fault Clearing. (Normal Fault Clearing time for this condition may not be high speed.)

f. Simultaneous permanent loss of both poles of a direct current bipolar facility without an ac fault

g. The failure of any Special Protection System which is not functionally redundant to operate properly when required following the contingencies listed in "a" through "f" above.

h. The failure of a circuit breaker to operate when initiated by an SPS following: loss of any Element without a fault: or a permanent phase to ground with Normal Clearing, on any transmission circuit, transformer or bus section.

12.5 N-1-1 Contingencies

NERC and/or NPCC require that the N-1-1 contingencies be tested. These are events that have two initiating events that occur close together in time. The list of first initiating events tested must include events from all of the following possible categories of events:

a. Loss of a generator

b. Loss of a series or shunt compensating device

c. Loss of one pole of a direct current bipolar facility

d. Loss of a transmission circuit

e. Loss of a transformer

Following the first initiating event, generation and power flows are adjusted in preparation for the next initiating event using units capable of ten-minute reserve, generator runback, generator tripping, phase angle regulators and high-voltage direct-current controls, transformer load tap changers, and switching series and shunt capacitors and reactors. Generator adjustments must not exceed 1,200 MW. The second events tested must include all of the contingencies in Section 12.4.

12.6 Extreme Contingencies

Consistent with NERC and NPCC requirements, New England tests extreme contingencies. This assessment recognizes that the New England transmission system can be subjected to events that exceed in severity the contingencies listed in Section 12.4 and 12.5. Planning studies are conducted to determine the effect of the following extreme contingencies on New England bulk power supply system performance as a measure of system strength. Plans or operating procedures are developed, where appropriate, to reduce the probability of

occurrence of such contingencies, or to mitigate the consequences that are indicated as a result of the simulation of such contingencies.

a. Loss of the entire capability of a generating station.

b. Loss of all transmission circuits emanating from a:
   - Generating station
   - Switching station
   - DC terminal
   - Substation (either all circuits at a single voltage level, or all circuits at any voltage level)

c. Loss of all transmission circuits on a common right-of-way.

d. Permanent three-phase fault on any:
   - Generator
   - Transmission circuit
   - Transformer or bus section
     with Delayed Fault Clearing and with due regard to reclosing

   This Delayed Fault Clearing could be due to malfunction of:
   - Circuit breaker
   - Relay system
   - Signal channel

e. The sudden dropping of a large load or major load center

f. The effect of severe power swings arising from disturbances outside of New England

g. Failure of a Special Protection System to operate when required following the normal contingencies listed in "a" through "f"

h. The operation or partial operation of a Special Protection System for an event or condition for which it was not intended to operate

i. Common mode failure of the fuel delivery system that would result in the sudden loss of multiple plants (i.e., gas pipeline contingencies, including both gas transmission lines and gas mains)

The following responses are considered unacceptable responses to an extreme contingency involving a three phase fault with Delayed Clearing and should be mitigated:

- Transiently unstable response resulting in wide spread system collapse

- Transiently stable response with undamped or sustained power system oscillations

- A net loss of source within New England in excess of 2,200 MW resulting from any combination of the loss of synchronism of one or more generating units, generation rejection initiated by a Special Protection System, tripping of the New Brunswick-New England tie, or any other system separation. The loss of source is net of any load that is interrupted as a result of the contingency.

The following response can be considered acceptable to an extreme contingency involving a three phase fault with Delayed Clearing:

- A net loss of source above 1,400 MW and up to 2,200 MW, resulting from any combination of the loss of synchronism of one or more generating units, generation rejection initiated by a Special Protection System,

or any other defined system separation, if supported by studies, on the basis of acceptable likelihood of occurrence, limited exposure to the pre-contingent operating conditions required to create the scenario, or efforts to minimize the likelihood of occurrence or to mitigate against the consequence of the contingency. The loss of source is net of any load that is interrupted as a result of the contingency. The 1,400 MW and 2,200 MW levels are documented in a NEPOOL Stability Task Force presentation to the NEPOOL Reliability Committee on September 9, 2000. This presentation is included as Appendix F to this guide.

12.7 Line Open Testing

The requirement to evaluate a no-fault contingency (often thought of as the opening of one terminal of a line) as a contingency event in transmission studies has been a topic for discussion over the years. The following describes how that requirement is addressed in New England. Additional detail is provided in the white paper that is included as Attachment H to this guide.

The following is a summary of the line open testing requirements:

1. NERC BES facilities:
    a. Single contingency testing (N-1) - Evaluate the opening of the terminal of a line, independent of the design of the termination facilities.

    b. First or Second contingency in N-1-1 testing – Not required

2. NPCC BPS and New England PTF facilities:
    a. Single contingency testing (N-1) – Evaluate the opening of a single circuit breaker.

    b. Second contingency in N-1-1 testing – Evaluate the opening of a single circuit breaker as the second contingency, not as the first contingency in the pair

When evaluating the no-fault contingencies pursuant to implementation of NERC, NPCC, and ISO New England criteria, the following will be used to establish the acceptability of post-contingency results and potential corrective actions:

a. If voltage is within acceptance criteria and power flows are within the applicable emergency rating, operator action can be assumed as a mitigating measure.

b. If voltage is outside of acceptance criteria or power flows are above the applicable emergency rating, operator action cannot be assumed as a mitigating measure. Mitigating measures may include, but are not limited to, transfer trip schemes detecting an open circuit breaker(s) or open disconnect switch(es), or, special protection systems (SPS) designed to trigger for specific system conditions that include the no fault opening of a transmission line.

Special consideration must be given to the design and operation of SPSs when evaluating this no fault contingency. An SPS may not operate for a line end open condition if its triggers are not satisfied, or may operate inappropriately if its triggers are satisfied but only one terminal of a line is open.

Generally, in New England, opening one end of a two terminal line is not a concern. However, in instances of long lines, high voltages may be a concern due to the charging associated with an unloaded line.

Section 13
Interfaces/Transfer Levels To Be Modeled

13.1 Overview

Reliability studies begin with development of system models which must include definition of the initial or base conditions that are assumed to exist in the study area over the study horizon. These assumed initial conditions must be based on requirements as described within the applicable reliability standards and criteria as well as supplemental information that describe system operating conditions likely to exist.

It is important to note that study assumptions used for interface transfer level analysis must always be coordinated with generator outage assumptions. Specifically, unit unavailability is only relevant to generation inside the boundaries of a specific local study area. On the other hand, interface transfer levels are adjusted to target levels by only varying generation resources outside the boundaries of the local study area. This approach ensures interface transfer levels are tested at appropriate levels while maintaining a disciplined approach to unit unavailability consideration.

13.2 Methodology to Determine Transfer Limits

In response to NERC standards, the ISO is documenting the methodology used to determine transfer limits. Once that methodology is finalized, it will be inserted into this guide.

13.3 Modeling Assumptions – System Conditions

NPCC's Basic Criteria for Design and Operation of Interconnected Power Systems requires in Section 2.1 - Design Criteria, that planning entities include modeling of conditions that "stress" the system when conducting reliability assessments:

> "Design studies shall assume power flow conditions utilizing transfers, load and generation conditions that stress the system. Transfer capability studies shall be based on the load and generation conditions expected to exist for the period under study. All reclosing facilities shall be assumed in service unless it is known that such facilities will be rendered inoperative."

ISO-NE's Reliability Standards for the New England Area Bulk Power Supply System also states in Section 3 - Area Transmission Requirements, that studies be conducted assuming conditions that "reasonably stress" the system:

> "With due allowance for generator maintenance and forced outages, design studies will assume power flow conditions with applicable transfers, load, and resource conditions that reasonably stress the system. Transfers of power to and from another Area, as well as within New England, shall be considered in the design of inter-Area and intra-Area transmission facilities."

In each case, an assumption that considers stressed system conditions with respect to transfer levels must be included in reliability studies. ISO-NE has the primary responsibility for interpreting these general descriptions.

Additionally, these requirements are confirmed by ISO-NE's PP5-3, "Guidelines for Conducting and Evaluating Proposed Plan Application Analysis," which sets forth the testing parameters for the required PPA approval under Section I.3.9 of ISO-NE's Tariff. PP5-3 requires that "intra-area transfers will be simulated at or near their established limits (in the direction to produce 'worst cases' results)." Given the reliability standard obligations as well as the requirements for the PPA approval of any transmission upgrade, reasonably stressed transfer conditions that simulate interfaces at or near their defined limits are used in determining the transmission system needs.

13.4 Stressed Transfer Level Assumptions

The system is designed to preserve existing range of transfer capabilities. This is a requirement defined in ISO-NE Planning Procedure PP 5-3, the Reliability Standards for the New England Area Bulk Power Supply System and is a fundamental objective of the minimum interconnection standard. In order to meet this requirement, interfaces that may affect the area under study are modeled with transfer levels that cover the full range of existing capabilities. The review of interface stresses includes an evaluation of each interface internal to New England as well as interfaces between New England and adjacent control areas to determine the set of interfaces that may have a significant impact on the results of studies for the study area. Interfaces that are not directly connected to a study area but may have a significant effect on the study area interface are considered "coincident interfaces". The procedures for selecting transfer levels for study area interfaces and coincident interfaces are provided below.

There may be a need to increase transfer capabilities as generation patterns shift across the system. General system trends in the direction of flow and magnitude may change dramatically over time. Some examples of conditions in which transfer capabilities requirements have changed include:

- The Connecticut area used to export across the Connecticut interface to eastern New England over many hours, but significant load growth and the outage of the nuclear units changed this to an import
- Whether the New Brunswick control area is an exporter to New England or an importer from New England can vary and depends on many factors including the availability of generation in New Brunswick.
- There has been an increase of "in-merit" natural gas generation being sited adjacent to existing gas pipelines in southern New England.
- Studies associated with the New England East West Solution have in the past been focused on the need to move power from across New England from east to west. The most recent update of these studies now shows the need to move power from west to east, even prior to consideration of the retirement of Salem Harbor station in 2014.

13.5 Transfer Level Modeling Procedures

Interfaces associated with a study area must be considered individually as well as in combination with each other when more than one interface is involved. Transfer levels for defined interfaces are tested based on the defined capability for the specific system conditions and system configurations to be studied.
Transfer levels are also adjusted as appropriate for the load levels that are to be studied. Transfer level testing may require thermal, voltage and/or stability testing to confirm no adverse impact on transfer limits.

Interface transfer levels are tested up to their capability in order to sustain the economic efficiency of the electric system and reliable operation and transmission service obligations of the New England transmission system.

The following procedure is used when conducting system reliability assessments:

For the steady-state studies, the relevant interface transfer levels need to be determined up front for each dispatch in Needs Assessment studies. Solutions Study transfer levels are tested with the same transfer levels as tested in any associated Needs Assessment study as well as additional variations in transfer levels as determined to be appropriate to demonstrate that solution alternatives have not adversely affected any existing interface transfer capabilities.

In the past, Needs Assessments supported by ISO New England included base case conditions that simulated local generation outages simultaneously with power exports from New England to other Areas, such as New York. Simulation results that failed to meet system performance criteria (typically steady state thermal and voltage) would identify base case and contingency related system needs to be addressed.

In November, 2013, the ISO revised its practice with respect to Needs Assessments and Solutions Studies. Needs Assessments (steady state and dynamics) no longer model power exports to other Areas (New York, New Brunswick, and Quebec) in the base case conditions and N-1 contingency analysis when evaluating transmission system needs. As a result, reliability based needs and their related backstop transmission solutions will not be identified and developed to support power exports out of New England. The only exception to this policy change would be long term power exports realized through the Forward Capacity Market, such as certain power exports across the Cross Sound Cable, which will be modeled with 100 MW from New England to Long Island due to the Administrative Export De-list bid associated with Bear Swamp.

However testing required by NPCC Document A-10, Classification of Bulk Power System elements, as part of a Needs Assessment must consider the full range of potential operating conditions and therefore will continue to consider conditions where New England is exporting to other Areas.

Even with this decision by the ISO, planned system changes still need to respect Section I.3.9 of the Tariff, generally referred to as the PPA process. As part of the I.3.9 evaluation, the applicant must demonstrate that any proposed system changes do not have a significant adverse effect upon the reliability or operating characteristics of the Transmission Owner's transmission facilities, the transmission facilities of another Transmission Owner, or the system of a Market Participant, the Market Participant or Transmission Owner. In carrying out these responsibilities, testing must demonstrate that the project has not reduced transfer capability from pre-project levels.

Transfer level modeling when conducting a Needs Assessment are based on the dispatch conditions within the study area such that the transfer level = local load – local generation. The local area generation dispatch assumptions are consistent with stressed system modeling unit availability assumptions and provide the basis for the transfer level expected to exist for the area under study.

Transfer level modeling for Solutions Studies, in addition to modeling conditions as studied in any associated Needs Assessments, also includes modeling of system conditions that evaluate the ability to dispatch units with a capacity supply obligation within an area under heavy load conditions. ISO-NE may also determine that additional transfer level variations need to be tested in order to demonstrate that there is no adverse impact to existing interface transfer capabilities associated with any proposed solution alternatives.

Transfer level modeling for those cases in which more than one coincident interface (i.e. surrounding interfaces rather than an interface internal to the study area) can impact a study area is based on a set of transfer level combinations that includes the maximum and minimum values for each interface. This includes situations where the interface limits are not independent and for which simultaneous limits have been identified. For example, study of the Greater Boston area would consider the Boston Import interface as internal to the study and the North-South, SEMA/RI and East-West as coincident interfaces. Modeling of the Boston interface would be based on the procedures as described above. Modeling of the North-South, SEMA/RI and East-West interfaces would include those levels as shown in the table below.

Testing of coincident interfaces includes interface transfers modeled at high as well as low transfer levels. High transfer levels are modeled as close as possible to the defined maximum for an interface and low values are modeled as close as possible to the defined minimum for an interface. For example, if three interfaces can all affect a study area there will be eight variations in interface levels such that all combinations are tested:

Table 13-1
Example of Modeling Interface Flows in Planning Studies

Interface 1	Interface 2	Interface 3
High	High	High
High	High	Low
High	Low	High
High	Low	Low
Low	Low	High
Low	High	Low
Low	High	High
Low	Low	Low

If specific transfer level combinations cannot be achieved due to load and/or dispatch constraints an explanation of the conditions that prevented testing of the combination is provided.

Section 14
Modeling Phase Angle Regulators

The modeling of each Phase Shifting Transformers (Phase Angle Regulators) is described in ISO New England's ***Reference Document for Base Modeling of Transmission System Elements in New England.*** This document is located in the ISO New England Planning Procedures subdirectory of the Rules & Procedures directory, on the ISO New England web site and is included as Appendix G to this guide. Modeling of phase shifting transformers in power flow studies is also addressed in Section 26.

Phase Shifting Transformers are used by system operators in the following locations within New England to control active (real) power flows on the transmission system within operating limits.

- The Saco Valley / Y138 Phase Shifter is located along the New Hampshire – Maine border, and is used to control 115 kV tie flow along the Y138 line into central New Hampshire
- The Sandbar Phase Shifter is located along the Vermont – New York border, and is used to control power flow into the northwest Vermont load pocket from northeast New York
- The Blissville Phase Shifter is located along the Vermont – New York border, and is mainly used to prevent overloads on the New York side
- The Granite Phase Shifters are located in Vermont and are mainly used to control flow on the 230 kV line between New Hampshire and Vermont
- The three Waltham Phase Shifters and the two Baker Street Phase Shifters are located in the Boston, Massachusetts area. They are adjusted manually to regulate the amount of flow into and through Boston.
- The Sackett Phase Shifter is located in southwest Connecticut and will be replaced by a series reactor in late 2017. It is run in manual mode mainly to draw power from Grand Avenue towards Mix Avenue Substation.
- The Northport / 1385 Phase Shifter, located at LILCO's Northport station (controlled by Long Island Power Authority) is used to control the power flow on the Norwalk Harbor – Northport 601, 602, and 603 submarine cables

Section 15
Modeling Load Tap Changers

Many transformers connected to the New England Transmission system have the capability of automatic load tap changing. This allows the transformer to automatically adjust the turns' ratio of its windings to control the voltage on the regulated side of the transformer. In transmission planning studies, load tap changers are allowed to operate when determining the voltages and flows after a contingency.

Modeling the operation of load tap changers on transformers that connect load to the transmission system generally produces conservative results because raising the voltage on the distribution system will reduce the voltage on the transmission system. Operation of load taps changers on autotransformers raises the voltage on the lower voltage transmission system (typically 115 kV) and reduces the voltage on the higher voltage transmission system (typically 230 kV or 345 kV).

In areas of the transmission system where there are known voltage concerns that occur prior to load tap changer operation, it is necessary to do sensitivity testing to determine if voltage criteria violations occur prior to load tap changer operation. This is further discussed in the voltage criteria section. Modeling of transformer load tap changers in load flow studies is also addressed in Section 26.

Section 16
Modeling Switchable Shunt Devices

In transmission planning studies, switchable shunt devices are allowed to operate when determining the voltages and flows after a contingency.

In areas of the transmission system where there are known high or low voltage concerns that occur prior to operation of switchable shunt devices, it is necessary to do testing to determine if voltage criteria violations occur prior to operation of switchable shunt devices. This is further discussed in the voltage criteria section 4. Modeling of switchable shunt devices in load flow studies is also addressed in Section 26.

Section 17
Modeling Series Reactors

There are 17 series reactors on the New England transmission system. Some of these are permanently in service to limit short circuit duty, others may be switched to control flows on specific transmission Elements. The following table lists these devices and briefly describes their purpose and operation in planning studies.

Table 17-1
Modeling Series Reactors in Planning Studies

Device	Ohms	State	Normal Operation	Purpose
Breckwood series reactor in 1322 line	5.55 ohms	MA	Out of Service (Shorted)	Inserted to limit short circuit duty at Breckwood when 1T circuit breaker is closed
Cadwell Series Reactor in 1556 line	3.97 ohms	MA	In Service	Limits short circuit duty at 115 kV East Springfield substation, not to be switched in planning studies
Cadwell Series Reactor in 1645 line	3.97 ohms	MA	In Service	Limits short circuit duty at 115 kV East Springfield substation, not to be switched in planning studies
East Devon series reactor in 1497 line	1.32 ohms	CT	In Service	Limits short circuit duty on 115 kV system, not to be switched in planning studies
East Devon series reactor in 1776 line	1.32 ohms	CT	In Service	Limits fault duty on 115 kV systems, not to be switched in planning studies
Greggs series reactor in F162 line	10 ohms	NH	Out of Service (Shorted)	Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
Hawthorne series reactor in 1222 line	5 ohms	CT	Out of Service (Shorted)	Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
Mix Avenue series reactor in 1610	7.5 ohms	CT	In Service	Will be installed in late 2017 to control flows on the 115 kV system, not to be switched in planning studies
North Bloomfield series reactor in 1784 line	2.65 ohms	CT	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads
North Cambridge series reactor in 329-530 line	2.75 ohms	MA	In Service	Limit flows and short circuit duty on 115 kV cables, not to be switched in planning studies
North Cambridge series reactor in 329-531 line	2.75 ohms	MA	In Service	Limit flows and short circuit duty on 115 kV cables, not to be switched in planning studies
Norwalk series reactor in 1637 line	5 ohms	CT	Out of Service (Shorted)	Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
Potter series reactor in115-10-16 line	3 ohms	MA	In Service	Limit flows on 115 kV cables, not to be switched in planning studies
Sandbar Overload Mitigation Series reactor in PV-20 line	30 ohms	VT	Out of Service (Shorted)	Controls flows on the 115 kV system, can be switched in to mitigate thermal overloads
Southington series reactor in 1910 line	3.97 ohms	CT	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads
Southington series reactor in 1950 line	3.97 ohms	CT	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate thermal overloads
Woburn series reactor in 211-514 line	2.75 ohms	MA	In Service	Limit flows and short circuit duty on 115 kV cables, not to be switched in planning studies

Section 18
Modeling High Voltage Direct Current Lines

There are three existing high voltage direct current facilities on the New England Transmission System, Highgate, Hydro Quebec Phase 2 and the Cross Sound Cable and one future high voltage direct current facility with an approved PPA, Northern Pass Transmission. The following tables lists the flows on these facilities generally used in the base cases for different planning studies:

Table 18-1
Modeling Existing DC Lines in Planning Studies

Study (1)	Highgate	Phase 2	Cross Sound Cable
PPA Study (I.3.9) of transmission project (Steady State and Stability)	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	-330 to 346 MW towards Long Island
System Impact Study (Steady State and Stability)	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	-330 to 346 MW towards Long Island
Transmission Needs Assessment (Steady State)	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	0 to 346 MW towards Long Island
Transmission Solutions Study (Steady State and Stability)	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	0 to 346 MW towards Long Island
Area Review Analyses (Steady State and Stability)	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	0 to 346 MW towards Long Island
BPS Testing Analyses (Steady State and Stability)	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	0 to 346 MW towards Long Island
Transfer Limit Studies (Steady State and Stability)	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	-330 to 346 MW towards Long Island
Interregional Studies	0 to 225 MW towards Vermont at border	0 to 2000 MW towards New England	-330 to 346 MW towards Long Island
FCM New Resource Qualification Overlapping Impact Analyses	0 to 225 towards Vermont at border	0 to 1400 MW towards New England	0 MW
FCM New Resource Qualification NCIS Analyses	0 to 225 towards Vermont at border	0 MW towards New England	0 MW
FCM Delist/ Non-price Retirement Analyses	0 to qualified existing imports	0 to qualified existing imports	Qualified Administrative export to 0 MW
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals	0 to cleared imports	0 to cleared imports	Cleared Administrative export to 0 MW
Transmission Security Analyses	Qualified existing imports	Qualified existing imports	0 MW

(1) Imports on these facilities are considered Resources as discussed in Planning Procedure PP5-6.

Table 18-2
Modeling Future DC Lines in Planning Studies

Study (1)	Northern Pass
PPA Study (I.3.9) of transmission project (Steady State and Stability)	0 to1200 MW towards New Hampshire
System Impact Study (Steady State and Stability)	0 to1200 MW towards New Hampshire
Transmission Needs Assessment (Steady State)	0 MW
Transmission Solutions Study (Steady State and Stability)	0 MW
Area Review Analyses (Steady State and Stability)	0 to1200 MW towards New Hampshire
BPS Testing Analyses (Steady State and Stability)	0 to1200 MW towards New Hampshire
Transfer Limit Studies (Steady State and Stability)	0 to1200 MW towards New Hampshire
Interregional Studies	0 to1200 MW towards New Hampshire
FCM New Resource Qualification Overlapping Impact Analyses	0 MW
FCM New Resource Qualification NCIS Analyses	0 MW
FCM Delist/ Non-price Retirement Analyses	0 MW
FCM Study for Annual Reconfiguration Auctions and Annual CSO Bilaterals	0 MW
Transmission Security Analyses	0 MW

(1) Imports on this facility are considered Resources as discussed in Planning Procedure PP5-6

Modeling of high voltage direct current lines in load flow studies is also addressed in Section 26.

Section 19
Modeling Dynamic Reactive Devices

This section is under development

Section 20
Special Protection Systems (Remedial Action Schemes)

Special Protection Systems ("SPSs") may be employed in the design of the interconnected power system subject to the guidelines in the ISO New England Planning Procedure 5-6 "Special Protection Systems Application Guidelines." All SPSs proposed for use on the New England system must be reviewed by the Reliability Committee and NPCC and approved by the ISO. Some SPSs may also require approval by NPCC. The requirements for the design of SPSs are defined in the NPCC Directory #4 "Bulk Power System Protection Criteria" and the NPCC Directory #7 "Special Protection Systems".

The owner of the SPS must provide sufficient documentation and modeling information such that the SPS can be modeled by the ISO, and other planning entities, in steady-state and stability analyses. The studies that support the SPS must examine, among other things:

- System impact should the SPS fail to operate when needed
- System impact when the SPS acts when not needed
- Will the SPS function properly and acceptably during facility out conditions

Once a SPS is approved, its operation should be considered in all transmission planning studies.

Section 21
Load Interruption Guidelines

This section is under development.

Guidelines, which describe the amount of load that may be interrupted and the circumstances where load may be interrupted, were presented to the Reliability Committee ("RC") on November 17, 2010. At the request of stakeholders, ISO-NE retransmitted this material to the RC on November 17, 2011 for comment and to the Planning Advisory Committee on November 21, 2011. ISO-NE has received comments on the guideline and is reviewing those comments.

Section 22
Short Circuit Studies

This section is under development.

NPCC requires that the transmission system be designed such that equipment capabilities are adequate for fault levels with all transmission and generating facilities in service. In New England, the base case for short circuit studies include transmission projects that are In-Service, Under Construction, and Planned and generators that are In-Service, Under Construction, are included in FERC section of the ISO-NE queue at the time the study begins, or have an approved Proposed Plan Applications. Projects with a nearly completed PPA Study and that have an impact on this study are also considered in the base case.

The voltage values that are used in short circuit studies are:

BHE-1.05 per unit
CMP -1.05 per unit
NGRID - 1.03 per unit
NU (NSTAR) -1.03 per unit
NU (CT, W. MA, NH) -1.04 per unit
UI - 1.04 per unit
Vermont- 1.05 per unit

Section 23
Critical Load Level Analysis

The Critical Load Level is the lowest load level at which the criteria violation occurs. One technique used to estimate Critical Load Level ("CLL") for overloads is linear extrapolation. Other methods are also acceptable.

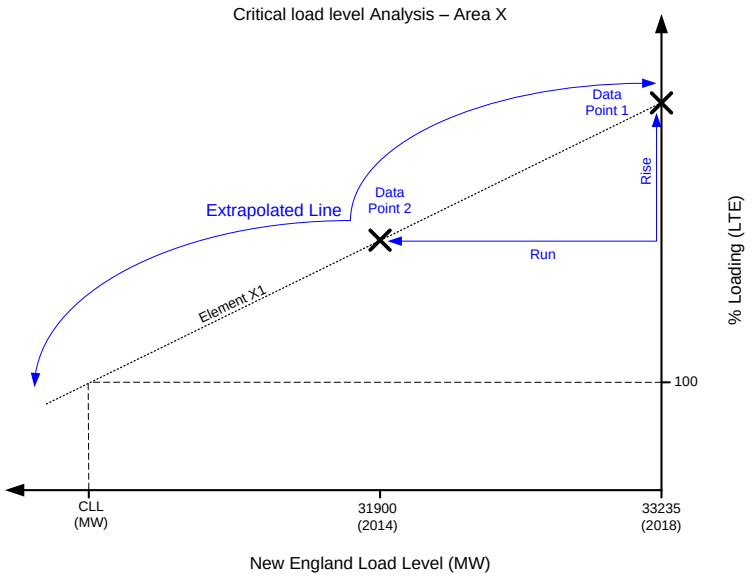
The linear extrapolation method is an approximation and provides a reasonable estimate with a minimum of additional analyses. The method requires that level of the loading on a transmission Element be determined at two load levels for the contingency or contingencies that have the largest impact on that transmission Element. This is done for each transmission Element that is overloaded. The load level in each base case is plotted on the x axis of a graph and percentage of the overload is plotted on y-axis. A straight line is drawn to connect these two points. The critical load level is the load level (x axis value) associated with 100 percent on the y axis.

An example of the use of linear extrapolation from a study of southwest Connecticut follows:

The initial base case was a 2018 base case. A second base case was developed by adjusting loads in the first case to 2014 year load levels taking into account the following:

- Loads plus losses in ISO-NE adjusted to 2009 CELT year 2014 levels (31,900 MW)
- Generation outside of CT was used to adjust to the new 2014 load levels
- Connecticut loads scaled according to 2009 RSP to 2014 levels (8,455 MW)
- Loads adjusted to account for FCA 3 cleared DR

No transmission topology changes were made to the adjusted 2014 cases. The highest overload per Element was identified in 2018 and the same Element's loading was obtained from the 2014 case results. This was done for the same single contingency (N-1) or line-out plus contingency pair (N-1-1) for every case. That is, both N-1 and N-1-1 analysis were performed in order to obtain two data points (2018 and 2014). Using the two data points available, linear extrapolation was used to form a line loading equation (slope = rise / run, y = mx + b, etc.) for each monitored Element which can then provide the loading of a particular line for different New England load levels. As an example, below shows the extrapolated line for Element X1 in Area X for a thermal violation.



Section 24
Bulk Power System Testing

This section is under development.

Section 25
Treatment on Non-Transmission Alternatives

This section is under development.

Section 26
Power Flow Study Solution Settings

26.1 Area Interchange

Enabling area interchange models the normal operation of the power system in that it adjusts generation to maintain inter-area transfers at a pre-determined level. Each area defined in the power system model has one of its generators designated as the area-slack bus. Area interchange is implemented by setting an overall interchange with all neighboring areas and the power flow program adjusts the output of the area-slack machines to match that set point. The area-slack bus for the New England Area is generally Brayton Point 3. For studies of the area near Brayton Point 3, a remote generator such as Seabrook in New Hampshire or Yarmouth 4 in Maine (also referred to as Wyman 4) is typically chosen as the area-slack bus.

Annually the Multiregional Modeling Working Group ("MMWG") establishes the area interchange assumptions for different seasons, load levels, and years. These assumptions are included in base cases provided by the ISO. Requesting base cases from the ISO, which represent the scenarios that will be studied, ensures that area interchanges external to New England are appropriate.

In establishing a base case (N-0 or N-1) for a particular study, the planner selects the appropriate interchanges between New England and other areas. This should be done with area interchange enabled for tie lines and loads. This ensures that area interchanges external to New England are correct and that loads shared between New England and Quebec are accounted for properly. The planner should re-dispatch generation in New England to obtain the desired interchanges with areas external to New England. The area-slack bus will adjust its output for the change in losses resulting from this re-dispatch. The planner should verify that the generation at the area-slack bus is within the operating limits of that generator.

For contingency analysis, area interchange is generally disabled. This causes the system swing bus output in the power flow model to increase for any generation lost due to a contingency. Following a loss of generation, each generator in the Eastern Interconnection increases its output in proportion to its inertia. About 95% of the total inertia for the eastern interconnection is to the west of New England. The system swing bus in the New England base cases is Browns Ferry in TVA. Using the system swing bus to adjust for any lost generation appropriately approximates post-contingency conditions on the power system prior to system-wide governors reacting to the disturbance and readjusting output.

26.2 Phase-Angle Regulators

The modeling of each Phase Shifting Transformers (Phase Angle Regular) is described in ISO New England's ***Reference Document for Base Modeling of Transmission System Elements in New England.*** This document is located in the ISO New England Planning Procedures subdirectory of the Rules & Procedures directory, on the ISO New England web site and is included as Appendix G to this guide.

26.3 Transformer Load Tap Changers

Transformer load tap changers (LTC's) can exist on autotransformers, load serving transformers and transformers associated with generation (e.g. transformers associated with wind parks). LTC's allow the ratio of

the transformer to be adjusted while the transformer is carrying load so that voltage on low voltage side of the transformer can be maintained at a pre-determined level.

An LTC adjusts voltage in small steps at a rate of about 3-10 seconds per step. A typical LTC may be able to adjust its ratio by plus or minus ten percent may have sixteen 5/8% steps. Also the action of an LTC is delayed to prevent operations during temporary voltage excursions. For example, a 345 kV autotransformer might delay initiating tap changing by thirty seconds. A load-serving transformer, which is connected to the 115 kV system near the autotransformer, might delay changing its tap by forty-five seconds to coordinate with the autotransformer. The total time for an LTC to adjust voltage can be several minutes. For example, a LTC, which has thirty-two 5/8% steps, requires five seconds per step and has a thirty second initial delay, would require seventy seconds to adjust its ratio by five percent.

To model the actual operations of the system, LTC operation is typically enabled in the power system model to allow the LTC's to adjust after contingencies for Steady State analysis. This generally represents the most severe condition because contingencies typically result in lower voltages and operation of LTC's to maintain distribution voltages result in higher current flow and lower voltages on the transmission system. Similarly operation of LTC's on autotransformers typically results in lower voltage on the high voltage side of the autotransformer.

In some portions of the transmission system, the voltage immediately following a contingency may be problematic because voltage collapse may occur. When instantaneous voltage is a concern, sensitivity analysis should be done with LTC's locked (not permitted to adjust) in the power flow model due to the amount of time required for the taps to move.

26.4 Shunt Reactive Devices

This section is under development by the ISO/TO study coordination group and will be sent out at a later date.

26.5 Series Reactive Devices

Section 17 of this guide describes the series reactive devices in the New England transmission system. The following table lists those series reactive devices that can be switched to resolve criteria violations. Those devices that are out-of service in the base case can be switched into service. Those devices that are in-service in the base case can be switched out of service. The switching can be done post contingency if flows do not exceed STE ratings. When post contingency flows exceed STE ratings, switching must be done pre-contingency and analysis must be done to ensure that the switching does not create other problems.

Table 26-1
Modeling Series Reactors in Planning Studies

Device	Base Case	Adjustments
Greggs series reactor in F162 line	Out of Service (Shorted)	Controls flows on the 115 kV system, can be switched in to mitigate criteria violations
Hawthorne series reactor in 1222 line	Out of Service (Shorted)	Controls flows on the 115 kV system, can be switched in to mitigate criteria violations
North Bloomfield series reactor in 1784 line	In Service	Controls flows on the 115 kV system, can be bypassed to mitigate criteria violations
Norwalk series reactor in 1637 line	In Service	Controls flows on the 115 kV system, can be bypassed to mitigate criteria violations
Sandbar Overload Mitigation Series reactor in PV-20 line	Out of Service (Shorted)	Controls flows on the 115 kV system, can be switched in to mitigate criteria violations. This reactor is controlled by a Special Protection System
South Agawam series reactor in 1821 line	In Service	Controls flows on the 115 kV system, can be bypassed to mitigate criteria violations
South Agawam series reactor in 1836 line	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate criteria violations
Southington series reactor in 1910 line	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate criteria violations
Southington series reactor in 1950 line	In Service	Controls flows on the 115 kV system, can be by-passed to mitigate criteria violations

26.6 High Voltage Direct Current Lines

The flows in higher voltage direct current lines are not automatically adjusted after a contingency except where an adjustment is triggered by a Special Protection System.

Appendix A – Definitions

50/50 PEAK LOAD
A peak load with a 50% chance of being exceeded because of weather conditions, expected to occur in New England at a temperature of 90.4°F.

90/10 PEAK LOAD
A peak load with a 10% chance of being exceeded because of weather conditions, expected to occur in New England at a temperature of 94.2°F.

ADVERSE IMPACT
See Significant Adverse Impact

APPLICABLE EMERGENCY LIMIT
- These Emergency limits depend on the duration of the occurrence, and are subject to New England standards.
- Emergency limits are those which can be utilized for the time required to take corrective action, but in no case less than five minutes.
- The limiting condition for voltages should recognize that voltages should not drop below that required for suitable system stability performance, meet the Nuclear Plant Interface Requirements and should not adversely affect the operation of the New England Bulk Power Supply System.
- The limiting condition for equipment loadings should be such that cascading outages will not occur due to operation of protective devices upon the failure of facilities.

AREA
An Area (when capitalized) refers to one of the following: New England, New York, Ontario, Quebec or the Maritimes (New Brunswick, Nova Scotia and Prince Edward Island); or, as the situation requires, area (lower case) may mean a part of a system or more than a single system.

AREA REVIEW ANALYSIS (see NPCC Directory #1, Appendix B)
A study to assess bulk power system reliability

BULK ELECTRIC POWER SYSTEM (as defined in the NERC Glossary of Terms Used in Reliability Standards)
As defined by the Regional Reliability Organization, the electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, generally operated at voltages of 100 kV or higher. Radial transmission facilities serving only load with one transmission source are generally not included in this definition.

BULK POWER SUPPLY SYSTEM
The New England interconnected bulk power supply system is comprised of generation and transmission facilities on which faults or disturbances can have a significant effect outside of the local area.

BULK POWER SYSTEM TESTING (see NPCC Document A-10, Classification of Bulk Power System Elements)
A study done to determine if Elements are classified as part of the Bulk Power System

BULK POWER SYSTEM (as defined in NPCC Glossary of Terms Used in Directories)
The interconnected electrical system within northeastern North America comprised of system elements on which faults or disturbances can have significant adverse impact outside the local area

CAPACITY SUPPLY OBLIGATION (as defined in Section I of the Tariff)
This is an obligation to provide capacity from a resource, or a portion thereof, to satisfy a portion of the Installed Capacity Requirement that is acquired through a Forward Capacity Auction in accordance with Section III.13.2, a reconfiguration auction in accordance with Section III.13.4, or a Capacity Supply Obligation Bilateral in accordance with Section III.13.5.1 of Market Rule 1.

CONTINGENCY (as defined in NPCC Document A-7)
An event, usually involving the loss of one or more Elements, which affects the power system at least momentarily

CAPACITY NETWORK RESOURCE CAPABILITY (as defined in Schedule 22 of the OATT)
Capacity Network Resource Capability ("CNR Capability") is defined in Schedule 22 of the Tariff and means (i) in the case of a Generating Facility that is a New Generating Capacity Resource pursuant to Section III.13.1 of the Tariff or an Existing Generating Capacity Resource that is increasing its capability pursuant to Section III.13.1.2.2.5 of the Tariff, the highest megawatt amount of the Capacity Supply Obligation obtained by the Generating Facility in accordance with Section III.13 of the Tariff, and, if applicable, as specified in a filing by the System Operator with the Commission in accordance with Section III.13.8.2 of the Tariff, or (ii) in the case of a Generating Facility that meets the criteria under Section 5.2.3 of this LGIP, the total megawatt amount determined pursuant to the hierarchy established in Section 5.2.3. The CNR Capability shall not exceed the maximum net megawatt electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 90 F. degrees for Summer and at or above 20 degrees F. for Winter. Where the Generating Facility includes multiple production devices, the CNR Capability shall not exceed the aggregate maximum net megawatt electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 90 degrees F. for Summer and at or above 20 degrees F. for Winter. The CNR Capability of a generating facility can be found in the Forecast Report of Capacity, Energy, Loads and Transmission (CELT Report) which is produces annually by ISO New England.

DELAYED FAULT CLEARING (as defined in NPCC Document A-7)
Fault clearing consistent with correct operation of a breaker failure protection group and its associated breakers, or of a backup protection group with an intentional time delay.

ELEMENT (as defined in NPCC Document A-7)
Any electric device with terminals which may be connected to other electric devices, usually limited to a generator, transformer, circuit, circuit breaker, or bus section.

FCM STUDY FOR ANNUAL RECONFIGURATION AUCTIONS AND ANNUAL BILATERALS
The FCM study as part of the annual reconfiguration auction or annual evaluation of Capacity Supply Obligations as described in Sections 13.4 and 13.5 of Market Rule 1.

FCM DELIST/NON-PRICE RETIREMENT ANALYSES
The FCM Delist/Non-Price Retirement Analyses is the analysis of de-list bids, demand bids and non-price retirement requests as described in Section 7.0 of Planning Procedure PP-10.

FCM NEW RESOURCE QUALIFICATION OVERLAPPING IMPACT ANALYSES
The FCM New Resource Qualification Overlapping Analyses is the analysis of overlapping interconnection impacts as described in Section 5.7 of Planning Procedure PP-10. This study is similar in scope as the thermal analyses performed in a System Impact Study associated with a generator interconnection request.

FCM NEW RESOURCE QUALIFICATION NCIS ANALYSES

The FCM New Resource Qualification NCIS Analyses is the initial interconnection analysis under the Network Capability Interconnection Standard as described in Section 5.6 of Planning Procedure PP-10. This study is similar in scope as the thermal analyses performed in a System Impact Study associated with a generator interconnection request.

NORMAL FAULT CLEARING (as defined in NPCC Document A-7)
Fault clearing consistent with correct operation of the protection system and with the correct operation of all circuit breakers or other automatic switching devices intended to operate in conjunction with that protection system

NR CAPABILITY
Network Resource Capability ("NR Capability") is defined in Schedule 22 of the Tariff and means the maximum gross and net megawatt electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 50 degrees Fahrenheit for Summer and at or above 0 degrees Fahrenheit for Winter. Where the Generating Facility includes multiple energy production devices, the NR Capability shall be the aggregate maximum gross and net megawatt electrical output of the Generating Facility at the Point of Interconnection at an ambient temperature at or above 50 degrees Fahrenheit for Summer and at or above 0 degrees Fahrenheit for Winter. The NR Capability shall be equal to or greater than the CNR Capability. The NR Capability of a generating facility can be found in the Forecast Report of Capacity, Energy, Loads and Transmission (CELT Report) which is produces annually by ISO New England.

NUCLEAR PLANT INTERFACE REQUIREMENTS (as defined in the NERC Glossary of Terms Used in Reliability Standards)
The requirements based on Nuclear Plant Licensing Requirements (NPLRs) and Bulk Electric System requirements that have been mutually agreed to by the Nuclear Plant Generator Operator and the applicable Transmission Entities.

NUCLEAR PLANT LICENSING REQUIREMENTS (NPLRs) (as defined in the NERC Glossary of Terms Used in Reliability Standards)
Requirements included in the design basis of the nuclear plant and statutorily mandated for the operation of the plant, including nuclear power plant licensing requirements for:
1. Off-site power supply to enable safe shutdown of the plant during an electric system or plant event; and
2. Avoiding preventable challenges to nuclear safety as a result of an electric system disturbance, transient, or condition.

PLANNED (as defined in Attachment K of Section II of the ISO-NE Tariff)
A transmission upgrade the ISO has approved under Section I.3.9 of the tariff. (Both a Needs Assessment and a Solutions Study have been completed for planned projects.)

PROPOSED (as defined in Attachment K of Section II of the ISO-NE Tariff)
A regulated transmission solution that (1) has been proposed in response to a specific identified needs in a needs assessment or the RSP and (2) has been evaluated or further defined and developed in a Solutions Study, as specified in the OATT, Attachment K, Section 4.2(b) but has not received ISO-NE approval under Section I.3.9 of the tariff. The regulated transmission solution must include analysis sufficient to support a determination by the ISO, as communicated to the PAC, that it would likely meet the identified need included in the needs assessment or the RSP, but has not received approval by the ISO under Section I.3.9 of the Tariff.

PROTECTION GROUP (as defined in NPCC Document A-7)
A fully integrated assembly of protective relays and associated equipment that is designed to perform the specified protective functions for a power system Element, independent of other groups.

Notes:
1. Variously identified as Main Protection, Primary Protection, Breaker Failure Protection, Back-Up Protection, Alternate Protection, Secondary Protection, A Protection, B Protection, Group A, Group B, System 1 or System 2.
2. Pilot protection is considered to be one protection group.

PROTECTION SYSTEM (as defined in NPCC Document A-7)
Element Basis: One or more protection groups; including all equipment such as instrument transformers, station wiring, circuit breakers and associated trip/close modules, and communication facilities; installed at all terminals of a power system Element to provide the complete protection of that Element.

Terminal Basis: One or more protection groups, as above, installed at one terminal of a power system Element, typically a transmission line.

QUALIFIED CAPACITY (as defined in Section I of the ISO-NE Tariff)
Qualified Capacity is the amount of capacity a resource may provide in the Summer or Winter in a Capacity Commitment Period, as determined in the Forward Capacity Market qualification processes.

RESOURCE (as defined in Section I of the ISO-NE Tariff)
Resource means a generating unit, a Dispatchable Asset Related Demand, an External Resource or an External Transaction.

SIGNIFICANT ADVERSE IMPACT (Based on Section I.3.9 of the Tariff and Planning Procedure 5-3)
A change to the transmission system that increases the flow in an Element by at least two percent of the Element's rating and that causes that flow to exceed that Element's appropriate thermal rating by more than two percent. The appropriate thermal rating is the normal rating with all lines in service and the long time emergency or short time emergency rating after a contingency (See Section 3).

A change to the transmission system that causes at least a one percent change in a voltage and causes a voltage level that is higher or lower than the appropriate rating by more than one percent (See Section 4).

A change to the transmission system that causes at least a one percent change in the short circuit current experienced by an Element and that causes a short circuit stress that is higher than an Element's interrupting or withstand capability. (See Section 22)

With due regard for the maximum operating capability of the affected systems, one or more of the following conditions arising from faults or disturbances, shall be deemed as having significant adverse impact:

A fault or a disturbance that cause:

- any loss of synchronism or tripping of a generator
- unacceptable system dynamic response as described in Planning Procedure PP-3
- unacceptable equipment tripping: tripping of an un-faulted bulk power system element (element that has already been classified as bulk power system) under planned system configuration due to operation of a protection system in response to a stable power swing or operation of a Type I or Type II Special Protection System in response to a condition for which its operation is not required

SPECIAL PROTECTION SYSTEM (SPS) (as defined in NPCC Document A-7)
A protection system designed to detect abnormal system conditions, and take corrective action other than the isolation of faulted Elements. Such action may include changes in load, generation, or system configuration to maintain system stability, acceptable voltages or power flows. Automatic under frequency load shedding, as defined in NPCC Emergency Operation Criteria A-3, is not considered an SPS. Conventionally switched, locally controlled shunt devices are not SPSs.

STEADY STATE (as defined in ANSI/IEEE Standard 100)
The state in which some specified characteristic of a condition such as value, rate, periodicity, or amplitude exhibits only negligible change over an arbitrary long period of time (In this guide, the term steady state refers to sixty hertz currents and voltages after current and voltages deviations caused by abnormal conditions such as faults, load rejections and the like are dissipated)

SUMMER (as defined in ISO-NE OP-16 Appendix A)
The Summer period is April 1 to October 31.

TEN-MINUTE RESERVE (as defined in NPCC Document A-7)
The sum of synchronized and non-synchronized reserve that is fully available in ten minutes.

VOLTAGE COLLAPSE
The situation which results in a progressive decrease in voltage to unacceptable low levels, levels at which power transfers become infeasible. Voltage collapse usually leads to a black-out.

WINTER (as defined in ISO-NE OP-16 Appendix A)
The Winter period is November 1 to March 31.

WITH DUE REGARD TO RECLOSING (as defined in NPCC Document A-7)
This phrase means that before any manual system adjustments, recognition will be given to the type of reclosing (i.e., manual or automatic) and the kind of protection.

Appendix B – Fast Start Units

The list of fast start units referenced in Section 11.6 is listed separately on the ISO-NE website at:

http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/plan_guides/plan_tech_guide/technical_planning_guide_appendix_b_reference_document.pdf

Appendix C – Guidelines for Treatment of Demand Resources in System Planning Analysis

This document referenced in Section 11.8 is listed separately on the ISO-NE website at:

http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/plan_guides/plan_tech_guide/technical_planning_guide_appendix_c_guidelines_for_treatment_of_demand_resources_in_system_planning_analysis.pdf

Appendix D – Dynamic Stability Simulation Damping Criteria

The damping criteria referenced in Section 12.3 is listed separately on the ISO-NE website at:

http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/plan_guides/plan_tech_guide/technical_planning_guide_appendix_d_damping_criteria.pdf

Appendix E – Dynamic Stability Simulation Voltage Sag Criteria

This document referenced in Section 12.3 is listed separately on the ISO-NE website at:

http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/plan_guides/plan_tech_guide/technical_planning_guide_appendix_e_voltage_sag_guideline.pdf

Appendix F – Stability Task Force Presentation to Reliability Committee-September 9, 2000

This document referenced in Section 12.6 is listed separately on the ISO-NE website at:

http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/plan_guides/plan_tech_guide/technical_planning_guide_appendix_f_stabiliy_task_force_presentation.pdf

Appendix G – Reference Document for Base Modeling of Transmission System Elements in New England

This document, referenced in Sections 14 and 26.2, is listed separately on the ISO-NE website at:

http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/plan_guides/plan_tech_guide/technical_planning_guide_appendix_g_reference_document.pdf

Appendix H – Position Paper on the Simulation of No-Fault Contingencies

This document, referenced in Section 12.7, is listed separately on the ISO-NE website at:

http://www.iso-ne.com/static-assets/documents/2014/12/technical_planning_guide_appendix_h_reference_document.pdf

2.D.3 *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment* (ISO-NE, May 2014), Redacted to secure Confidential Energy Infrastructure Information (CEII)

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Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment

Greater Hartford and Central Connecticut Working Group
(ISO New England, Northeast Utilities, and United Illuminating)

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May 2014

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Section 1
Executive Summary

1.1 Objective

The objective of the GHCC study was to evaluate the system needs in the Greater Hartford and Central Connecticut (GHCC) study area and to reassess the needs which drove the Central Connecticut Reliability Project (CCRP), while considering the following:

- Future load growth
- Reliability over a range of generation patterns and transfer levels
- All applicable North American Electric Reliability Corporation (NERC), Northeast Power Coordinating Corporation (NPCC) and ISO New England transmission planning reliability standards
- Regional and local reliability issues
- New England East-West Solution (NEEWS) project, and
- Existing and planned supply resources and demand resources

The scope of the Needs Assessment study performed for the GHCC area included evaluation of the reliability performance of the transmission system serving this area of New England for the year 2022 projected system conditions. The system was tested with all elements in-service i.e. N-0 and under N-1 and N-1-1 contingency conditions for a number of possible operating conditions with respect to related interface transfer levels and generating unit availability conditions.

As described in this report, the Needs Assessment identified certain areas of the system that failed to meet North American Electric Reliability Corporation (NERC), Northeast Power Coordinating Council (NPCC), Independent System Operator of New England Inc. (ISO-NE), and Transmission Owner standards and criteria.

This Needs Assessment was the first step in the study process defined in accordance with the Regional Planning Process as outlined in Attachment K to the ISO-NE Open Access Transmission Tariff (OATT). In accordance with Attachment K, a Solutions Study will be conducted to develop and analyze potential transmission solutions for the needs identified in this analysis.

A working group led by ISO-NE, and consisting of members from ISO-NE, Northeast Utilities (NU), and United Illuminating (UI), was formed to study the Greater Hartford and Central Connecticut transmission system. As part of the Planning Advisory Committee (PAC) process, stakeholders, which include generator owners, suppliers, load serving entities, energy efficiency entities, state regulators, and transmission owners, also provided input throughout the study process.

1.2 Method and Criteria

The Needs Assessment was performed in accordance with NERC TPL-001, TPL-002 and TPL-003 Transmission System Standards, NPCC Directory1, "Design and Operation of the Bulk Power System," the ISO New England Planning Procedure 3, "Reliability Standards for the New England

Area Bulk Power Supply System," the ISO New England Planning Procedure 5-3, "Guidelines for Conducting and Evaluating Proposed Plan Application Analyses".

1.3 Study Assumptions

A long-term (ten-year) planning horizon was used for this study based on the most recently available Capacity, Energy, Loads, and Transmission (CELT) forecast data (2013) at the time the study began. This study was focused on the projected 2022 peak demand load levels for the ten-year horizon. The models reflected the following peak load conditions:

Loads:

The summer peak 90/10 load level forecast is 34,105 MW for all of New England and 8,825 MW (which represents 26% of the New England load) for the state of Connecticut

Transmission Topology:

All relevant transmission projects with Proposed Plan Application (PPA) approval have been included in the study base case. Section 3.1.3 includes a full listing and description of all projects included.

Generation:

All generation projects with a Capacity Supply Obligation as of Forward Capacity Auction 7 (FCA #7) were included in the study base case. Section 3.1.4 of this report includes a full listing and description of generation included in the base case. Due to the submission of Non-Price Retirement (NPR) Requests for the Bridgeport Harbor 2 and Norwalk Harbor units for FCA #8, these units have been taken out-of-service (OOS) in the base case.

Demand Resource Assumptions:

Demand Resources (active and passive) were modeled based on the Demand Resources (DR) cleared in FCA #7. In addition, any accepted NPR requests for DR and any DR terminations in Connecticut for FCA #8 were also taken into account. Finally, the energy efficiency forecast for the years corresponding to FCA #8 and beyond until 2022 were also modeled based on the 2013 energy efficiency (EE) forecast. Section 3.1.6 includes the details of the demand resources considered for this study.

Section 3 of this report contains more details of all assumptions used to complete this study.

The following types of analyses were performed as part of this study:

- **Steady-State Thermal and Voltage Analysis** – steady-state analysis was performed to determine the level of steady-state power flows on transmission circuits and voltage levels and performance on transmission buses for a variety of one and two-unit-out generation dispatches and inter-regional stresses, for N-0 (All-facilities-in) conditions as well as following contingency events for N-1 (all-facilities-in, first contingency) and N-1-1 (facility-out, first contingency) conditions.
- **Extreme Contingency Analysis** – limited steady-state analysis was performed to evaluate the severity of the impact of NERC Category D Transmission Planning System Standard 004 (TPL-

004)[1] extreme contingencies on transmission system performance. A thermal or voltage violation arising from this analysis may not necessarily demonstrate a reliability need in the study area; as such, this analysis was performed for informational purposes only.

- **Short Circuit Analysis** – a study to determine the ability of substation equipment to withstand and interrupt fault current was also conducted.

1.4 Design Case Specific Areas of Concern

While the results of the short circuit analysis indicated that there were no over-dutied substation breakers in the GHCC area, the results of the steady state thermal and voltage analysis indicated that many thermal and voltage issues exist on facilities in each of the subareas comprising the GHCC study area. The results for each study subarea are summarized in the following sub-sections. Each subsection summarizes the number of thermal and voltage violations observed and provides the Connecticut load level at which these violations would be resolved. The Connecticut load numbers provided exclude transmission losses, and include the impact of demand resources. Details on how the net Connecticut loads were obtained are provided in Appendix J: Net Load in Connecticut Calculation.

1.4.1 Greater Hartford Subarea Thermal and Voltage Needs

The Greater Hartford subarea net load for 2022 after demand resources are subtracted is about 1,227 MW. This subarea is a net importer of energy and relies on the surrounding areas to serve local load.

The Greater Hartford subarea had four transmission elements with N-1 thermal violations and four 115 kV buses with N-1 low-voltage violations. Under N-1-1 conditions, there were 27 elements with thermal violations and ten 115 kV PTF buses with low-voltage violations. Two 115 kV non-PTF buses also had low voltages. There were no N-0 violations.

The N-1-1 violations have been grouped into the following three areas:

- South Meadow – Berlin – Southington Area
- North Bloomfield – Manchester Area
- Southington Area

[redacted] See Sections 5.1.1 and 5.2.1 for a full discussion of this subarea and its load pockets.

The majority of the worst-case violations in the Greater Hartford subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load at which all thermal violations would be resolved is 4,756 MW and the net Connecticut load at which all voltage violations would be resolved is 4,319 MW. The details of the critical load level analysis are available in Section 6.4.1.

[1] Transmission Planning (TPL) System Standard 004: System Performance Following Extreme Events Resulting in the Loss of Two or More Bulk Electric System Elements (Category D), published February 2005; available at http://www.nerc.com/files/TPL-004-0.pdf.

1.4.2 Manchester – Barbour Hill Subarea Thermal and Voltage Needs

The Manchester-Barbour Hill subarea net load for 2022 after demand resources are subtracted is about 452 MW. This sub-area is a net importer of energy and relies on the surrounding areas to serve local load.

Within the Manchester-Barbour Hill subarea, there is a smaller Barbour Hill load pocket that consists of five 115 kV substations with net load of about 326 MW.

The Manchester and Barbour Hill Area had five transmission elements with N-1-1 thermal violations and two 115 kV PTF buses with N-1-1 low voltage violations. Additionally, there were four non-PTF buses with N-1-1 voltage violations. There were no N-0 or N-1 steady-state criteria violations.

[redacted]

See Sections 5.1.2 and 5.2.2 for a full discussion of this subarea.

The majority of the worst-case violations in the Manchester-Barbour Hill subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load at which all thermal violations would be resolved is 5,616 MW and the net Connecticut load at which all the PTF voltage violations would be resolved is 5,069 MW. The details of the critical load level analysis are available in Section 6.4.2.

1.4.3 Middletown Subarea Thermal and Voltage Needs

The Middletown subarea net load for 2022 after demand resources are subtracted is about 656 MW. This subarea depends on the surrounding areas to serve the local load, but unlike the other subareas does have significant local generation that reduces the need for import capability when all units are available.

The Middletown subarea had no N-1 thermal violations and three 115 kV buses with N-1 low voltage violations. Under N-1-1 conditions, there were 11 elements with thermal violations and fourteen 115 kV buses with low voltage violations. There were no N-0 violations.

[redacted]

See Sections 5.1.3 and 5.2.3 for a full discussion of this subarea.

The majority of the worst-case violations in the Middletown subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load at which all thermal violations would be resolved is 3,444 MW and the net Connecticut load at which all voltage violations would be resolved is 3,694 MW. The details of the critical load level analysis are available in Section 6.4.3.

1.4.4 Northwestern Connecticut Subarea Thermal and Voltage Needs

The Northwestern Connecticut (NWCT) subarea net load for 2022 after demand resources are subtracted is about 511 MW. This subarea is a net importer of energy and relies on the surrounding areas to serve local load.

The NWCT subarea had no N-0 thermal violations, but one 69 kV non-PTF bus had an N-0 basecase voltage violation. There were three transmission elements with N-1 thermal violations and five PTF buses with N-1 low-voltage violations. Two non-PTF buses had N-1 voltage violations. Under N-1-1 conditions, there were ten elements with thermal violations and twelve PTF buses with low voltage violations. Two non-PTF buses had N-1-1 voltage violations. See Sections 5.1.4 and 5.2.4 for a full discussion of this subarea.

The majority of the worst-case violations in the Northwestern Connecticut subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load at which all thermal violations would be resolved is 4,225 MW and the net Connecticut load at which all voltage violations would be resolved is 5,694 MW. The details of the critical load level analysis are available in Section 6.4.4.

1.5 Statements of Need

All the criteria violations observed in the Greater Hartford and Central Connecticut (GHCC) area were based on steady state thermal and voltage testing. The following summarizes the needs for each subarea:

Greater Hartford Subarea

- Need to resolve N-1 and N-1-1 criteria violations observed in the Greater Hartford area
- Thermal and voltage violations observed in the following areas:
  - North Bloomfield to Manchester area
  - South Meadow – Berlin – Southington area
  - Southington area
- [redacted]

Middletown Subarea:

- Need to resolve the N-1 and N-1-1 criteria violations observed in the Middletown area
- [redacted]

Manchester – Barbour Hill Subarea

- Need to resolve the N-1-1 criteria violations observed in serving load in the Manchester-Barbour Hill area
- [redacted]

Northwestern Connecticut Subarea:

- Need to resolve N-1 and N-1-1 criteria violations observed in serving load in the Northwest Connecticut area
- [redacted]

Western Connecticut Interface:

- Need to resolve N-1-1 criteria violations observed [redacted]
- The needs are interrelated with the needs in the four subareas listed above

Section 2
Introduction and Background Information

2.1 Study Objective

The objective of the GHCC study was to evaluate the system needs in the Greater Hartford and Central Connecticut (GHCC) study area and to reassess the needs which drove the Central Connecticut Reliability Project (CCRP), while considering the following:

- Future load growth
- Reliability over a range of generation patterns and transfer levels
- All NERC, NPCC and ISO New England applicable transmission planning reliability standards
- Regional and local reliability issues
- New England East-West Solution (NEEWS) project, and
- Existing and planned supply resources and demand resources

The scope of the Needs Assessment study performed for the GHCC area included evaluation of the reliability performance of the transmission system serving this area of New England for the year 2022 projected system conditions. The system was tested with all elements in-service i.e. N-0 and under N-1 and N-1-1 contingency conditions for a number of possible operating conditions with respect to related interface transfer levels and generating unit availability conditions.

This Needs Assessment was the first step in the study process defined in accordance with the Regional Planning Process as outlined in Attachment K to the ISO-NE Open Access Transmission Tariff (OATT). In accordance with Attachment K, a Solutions Study will be conducted to develop and analyze potential transmission solutions for the needs identified in this analysis.

A working group led by ISO-NE, and consisting of members from ISO-NE, Northeast Utilities (NU), and United Illuminating (UI), was formed to study the Greater Hartford and Central Connecticut transmission system. As part of the Planning Advisory Committee (PAC) process, stakeholders, which include generator owners, suppliers, load serving entities, energy efficiency entities, state regulators, and transmission owners, also provided input throughout the study process.

2.2 Areas Studied

In this study, the GHCC area has been divided into the following four subareas:

1. Greater Hartford
2. Northwest Connecticut
3. Middletown, and
4. Manchester - Barbour Hill

Table 2-1 summarizes the towns included in each of the subareas:

Table 2-1:
Towns Included in Study Area

Subarea	Towns in the Subarea (*Note: Location of towns may not dictate where load is served*)
Greater Hartford	Avon, Berlin, Bloomfield, Burlington, Cromwell, East Granby, East Hartford, Farmington, Granby, Hartford, New Britain, Newington, Plainville, Rocky Hill, West Hartford, Wethersfield, Windsor
Northwest Connecticut	Barkhamsted, Bethlehem, Bristol, Canaan, Canton, Colebrook, Cornwall, Goshen, Hartland, Harwinton, Kent, Litchfield, Morris, New Hartford, Norfolk, North Canaan, Plymouth, Salisbury, Sharon, Simsbury, Thomaston, Torrington, Warren, Washington, Winchester
Middletown	Chester, Clinton, Colchester, Deep River, Durham, East Haddam, East Hampton, Essex, Guilford, Haddam, Hebron, Killingworth, Lyme, Madison, Marlborough, Meriden, Middlefield, Middletown, Old Lyme, Old Saybrook, Portland, Wallingford, Westbrook
Manchester - Barbour Hill	Bolton, East Windsor, Ellington, Enfield, Glastonbury, Manchester, Somers, South Windsor, Suffield, Tolland, Vernon, Windsor Locks

Figure 2-1 shows the geographic map of the study area and Figure 2-2 shows the one-line diagram for the study area. Each of the figures has the four study subareas delineated.

It should be noted that the Scitico substation, while geographically located within the state of CT and in the Manchester/Barbour Hill area, is fed by 115 kV lines from the Springfield area. Since the Scitico substation is not fed from the Manchester/Barbour Hill area transmission facilities the study of the transmission system around the Scitico substation is excluded from the study area.

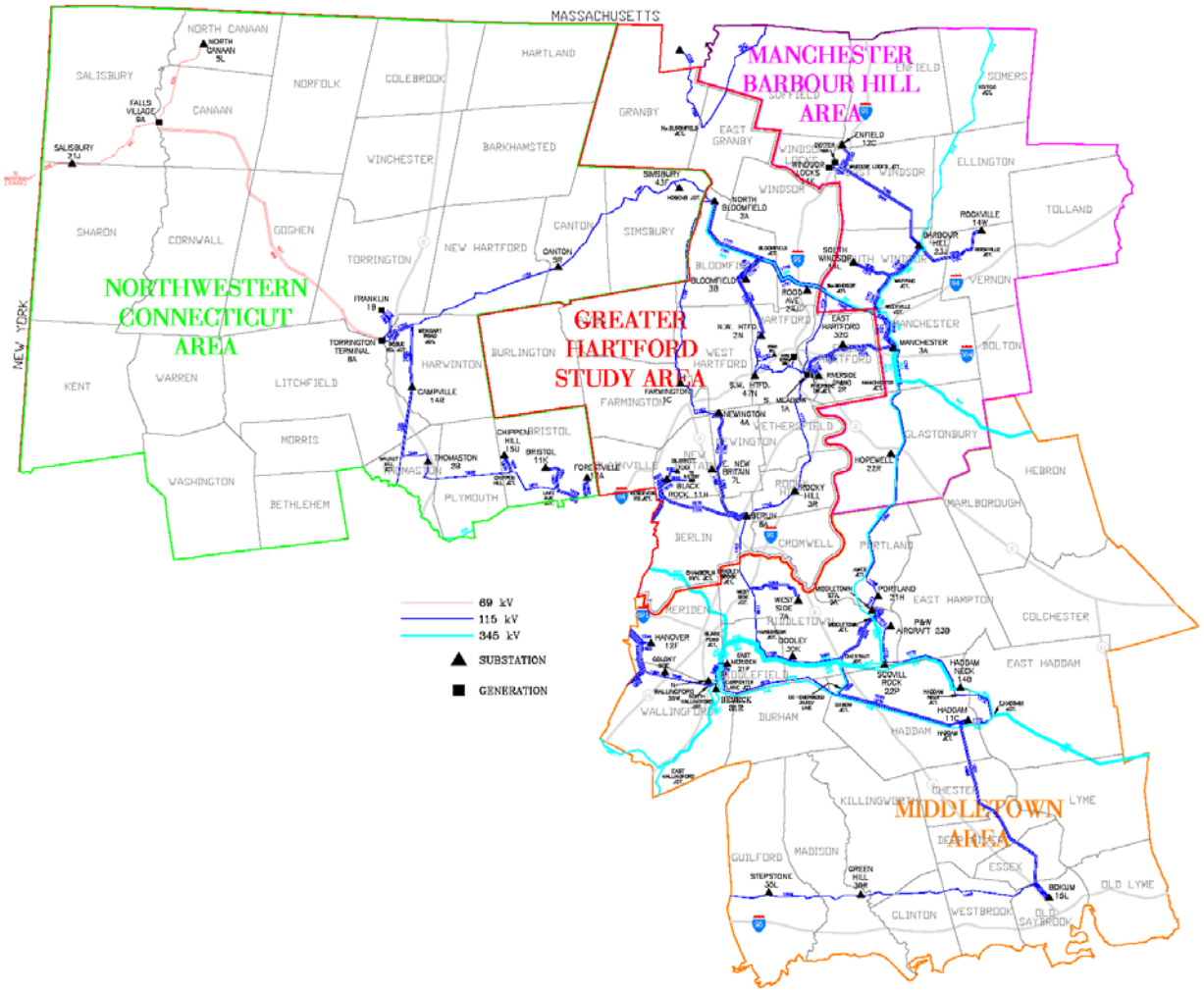


Figure 2-1: GHCC Study Area Map[2]

[2] The diagram is for illustrative purposes to show the study area. In the Manchester – Barbour Hill area, the Scitico substation is supplied from western Massachusetts but serves load in Connecticut. The Scitico station and the load fed from it has been excluded from the study



Figure 2-2: GHCC Study Area One Line Diagram

The GHCC study area is located between the Connecticut Import interface and the Southwest Connecticut (SWCT) import interface, while only parts of the study area are within the Western Connecticut import area. In addition to the above interfaces the export/import levels to/from New York through the AC ties, the Cross Sound Cable (CSC), and the Norwalk Northport Cable (NNC) also affect the study area. Figure 2-3 shows the interfaces impacting the study area.

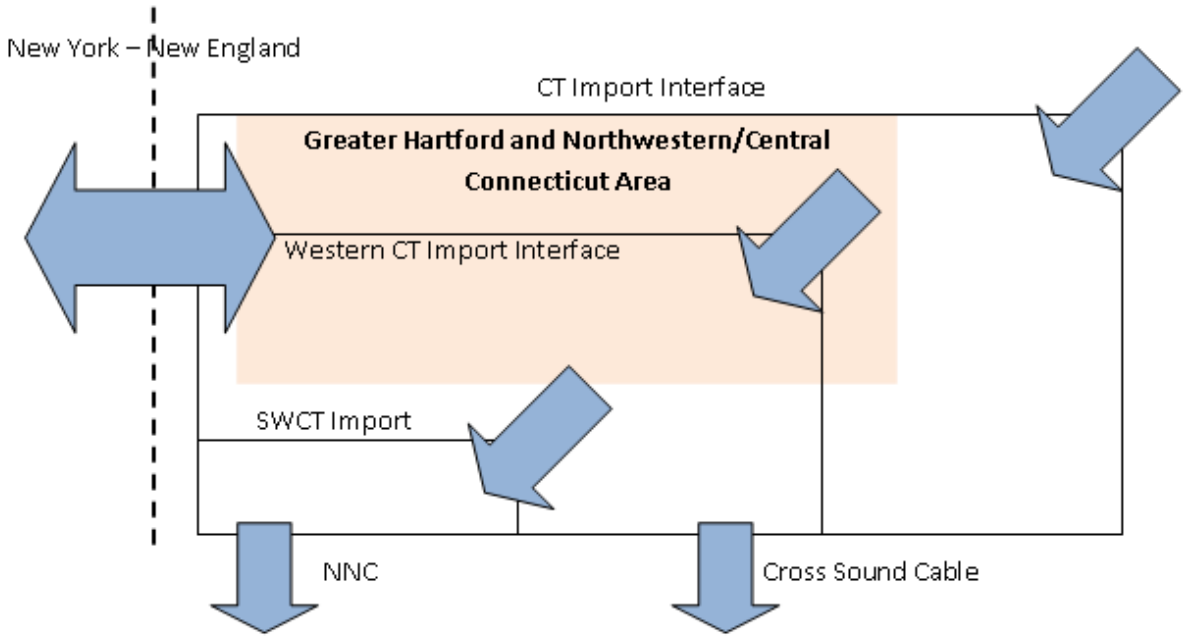


Figure 2-3: Interfaces of Interest for the GHCC Study Area

The New England East-West Solution (NEEWS) project received its Proposed Plan Application (PPA) approval in 2008 and was revised and re-approved in 2012. Since the first approval, a significant amount of new resources have been procured in Connecticut via the Forward Capacity Market (FCM). With the addition of these new resources an updated transmission-based needs analysis for the NEEWS transmission project was required. Three of the four components of NEEWS, Greater Springfield Reliability Project (GSRP), the Rhode Island Reliability Project (RIRP), and the Interstate Reliability Project (IRP) have had their needs re-affirmed. In 2010, it was determined that an updated Needs Assessment of the fourth major component of NEEWS – the Central Connecticut Reliability Project would be conducted as part of the GHCC study. CCRP, as originally designed, would add a new 345 kV line to the Western CT import interface, which lies entirely within the GHCC study area.

Some of the highest criteria violations that were seen on 115 kV lines in the Greater Hartford area in preliminary analyses were also observed in the western Connecticut import analysis as part of the preliminary CCRP reassessment. Accordingly, the GHCC analysis was expanded to identify needs for both local reliability issues and western Connecticut import requirements, with the expectation that both sets of needs could be addressed by a single integrated solution. This determination was based on the fact that recent changes in assumptions that included new generation and demand resources were expected to significantly reduce the need for increased western Connecticut import. This assessment considers both local load serving needs and the need for additional western Connecticut import capacity. However, the needs results are presented by geographic location of the element with a thermal or voltage violation and are not separated based on local load serving needs and the need for additional western Connecticut import capability.

2.3 Study Horizon

This study was initiated in 2012 with a 10-year look ahead at the projected 2022 peak demand load level. The loads are based on the most recent CELT report, issued in May 2013.

2.4 Analysis Description

The study included the evaluation of the reliability of the transmission system serving the GHCC study area, including the transmission facilities that are part of the Western Connecticut Import Interface for the projected system conditions in 2022. The system was tested under N-0 (all-facilities-in), N-1 (all-facilities-in, first contingency), and N-1-1 (facility-out, first contingency) conditions for a number of possible operating scenarios with respect to related interface transfer levels and generating unit unavailability conditions.

The following types of analysis were performed:

- **Thermal Analysis** – studies to determine the level of steady-state power flows on transmission circuits under base case conditions and following contingency events.
- **Voltage Analysis** – studies to determine steady-state voltage levels and performance under base case conditions and following contingency events.
- **Extreme Contingency** – limited steady-state studies to evaluate the severity of the impact of NERC Category D Transmission Planning System Standard 004 (TPL-004)[3] extreme contingencies on transmission system performance. A thermal or voltage violation arising from this analysis may not necessarily demonstrate a reliability need in the study area.
- **Short Circuit Analysis** – studies to determine the ability of substation equipment to withstand and interrupt fault current.

For the various elements having thermal violations and for buses with voltage violations, a critical load level assessment was performed to determine the Connecticut load level at which these violations would be eliminated.

The following analyses may be performed during the solutions study phase:

- **Stability Analysis** – detailed studies to determine if any substations would be classified as BPS[4] (Bulk Power System) elements with the addition of the proposed solutions.

The Needs Assessment was performed in accordance with relevant NERC, NPCC, ISO-NE criteria as described in Section 4.2.1.

The thermal and voltage analysis was performed using Siemens PTI PSS/E version 32 and PowerGEM TARA version 710. The short circuit analysis was performed using ASPEN.

[3] Transmission Planning (TPL) System Standard 004: System Performance Following Extreme Events Resulting in the Loss of Two or More Bulk Electric System Elements (Category D), published February 2005; available at http://www.nerc.com/files/TPL-004-0.pdf.

[4] In accordance with NPCC document A-10: Classification of Bulk Power System Elements (https://www.npcc.org/Standards/Criteria/A-10-Revised%20Full%20Member%20Approved%20December%2001,%202009%20GJD.pdf)

Section 3 Study Assumptions

3.1 Steady State Model Assumptions

3.1.1 Study Assumptions

The regional steady-state model was developed to be representative of the 10-year projection of the 90/10 summer peak system demand levels to assess reliability performance under stressed system conditions. The assumptions included consideration of area generation unit unavailability conditions as well as variations in surrounding area regional interface transfer levels. These study assumptions are consistent with ISO-NE Planning Procedure No. 3 (PP 3), "Reliability Standards for the New England Area Bulk Power Supply System".

3.1.2 Source of Power Flow Models

The power flow study cases used in this study were obtained from the ISO-NE Model on Demand system with selected upgrades to reflect the system conditions in 2022. A detailed description of the system upgrades included is provided in later sections of this report.

3.1.3 Transmission Topology Changes

Transmission projects with Proposed Plan Application (PPA) approval in accordance with Section I.3.9 of the Tariff, as of the April 2011 RSP Project Listing, have been included in the study base case. New projects in Connecticut that were relevant to the study area were added to the base cases as of the October 2013 project listing. Projects outside of Connecticut that were added to the project listing were deemed to not have a significant impact on the study area and were excluded. Therefore, no updates were made to the base cases since the April 2011 update outside of Connecticut. A listing of the major projects is included below.

Maine

- Maine Power Reliability Program (MPRP) (RSP ID: 905-909, 1025-1030, 1158)
- Down East Reliability Improvement (RSP ID: 143)

New Hampshire

- Second Deerfield 345/115 kV Autotransformer Project (RSP ID: 277, 1137-1141)

Vermont

- Northwest Vermont Reliability Projects (RSP ID: 139)
- Vermont Southern Loop Project (RSP ID: 323, 1032-1035)

Massachusetts

- Auburn Area Transmission System Upgrades (RSP ID: 59, 887, 921, 919)
- Merrimack Valley / North Shore Reliability Project (RSP ID: 775-776, 782-783, 840)
- Long Term Lower SEMA Upgrades (RSP ID: 592, 1068, 1118)
- Central/Western Massachusetts Upgrades (RSP ID: 924- 929, 931-932, 934-935, 937- 950, 952- 955)
- NEEWS – Greater Springfield Reliability Project (RSP ID: 196, 259, 687-688, 818-820, 823, 826, 828-829, 1010, 1070-1075, 1078-1080, 1100-1105)
- NEEWS – Interstate Reliability Project (RSP ID: 1094,1202)

Rhode Island

- Greater Rhode Island Transmission Reinforcements (RSP ID: 484, 786, 788, 790-793, 913-918, 1098)
- NEEWS – Rhode Island Reliability Project (RSP ID: 795, 798-800, 1096-1097, 1099, 1106, 1109)
- NEEWS – Interstate Reliability Project (RSP ID: 190, 794, 1095, 1233-1234)

Connecticut

- NEEWS – Greater Springfield Reliability Project (RSP ID: 816, 1054, 1092)
- NEEWS – Interstate Reliability Project (RSP ID: 191, 802, 810, 1085, 1090-1091, 1235)
- Northeast Simsbury Substation 115 kV Circuit Breaker Project (RSP ID: 1230)
- Advanced NEEWS Projects – (RSP ID:1370,1235,1245)
- SWCT Minimum Load Project – Haddam Neck 150 MVAR Shunt Reactor (RSP ID:1400)

For the GSRP, RIRP and IRP components of NEEWS the model reflects the revised PPA that received ISO-NE approval in May 2012. An upgrade that would impact the GHCC study area is the re-conductoring of the 1784 line between North Bloomfield and Northeast Simsbury and the replacement of the 2% reactor on this line at North Bloomfield with a reactor of equal impedance but higher thermal rating.

Several upgrades in the SWCT area have received PPA approval since these basecases were created, but since the Southwest Connecticut working group is reassessing the needs and solutions for that area those upgrades were not included. The only upgrade from the SWCT area that is approved and not under reassessment that was included was the Haddam Neck shunt reactor.

The Central Connecticut Reliability Project (CCRP) component of the NEEWS projects was also excluded since as a part of the GHCC Needs Assessment the needs for these upgrades were reassessed.

In addition to the new transmission projects in Connecticut that were added during the Needs Assessment, any changes to element ratings or impedances as a part of the base case update process were captured on an ongoing basis. These upgrades may have varied some of the line ratings or impedances to reflect the most accurate future system condition. A significant change in this area was the replacement of the Torrington 115/69 kV autotransformer in December 2013.

Eight transmission substation buses in the GHCC study area are arranged as ring buses. Under contingency conditions, a large amount of power could flow through the bus and the traditional model of buses in the basecases would not capture these flows. The updated analysis completed in this Needs Assessment report accurately captured the modeling of these ring buses and reports violations on any of the bus elements that were seen under contingency conditions.

3.1.4 Generation Additions & Retirements

Generation projects with a FCM Capacity Supply Obligation as of Forward Capacity Auction 7 (FCA #7) were included in the study base case. A listing of the recent major new projects cleared in FCA #1 through FCA #7 is included below.

Maine

- QP 244 – Wind Project (FCA #4)

New Hampshire

- QP 251 – Biomass Project (FCA #4)

- QP 307 – Biomass Project (FCA #4)

Massachusetts

- QP 089 – Cape Wind Turbine Generators (FCA #7)
- QP 196 – Northfield Mountain Uprate 88 MW (FCA #4, #6 and #7)
- QP 387-2 – Combined Cycle Unit (FCA #7)

Rhode Island

- QP 332 – RISEP Increase (FCA #5)

Connecticut

- QP 155.6 – Fuel Cell Project in Fairfield, CT (FCA #4)
- QP 289 – Fuel Cell Project in New Haven County, CT (FCA #4)

In March 2012, the Ansonia generation unit (QP-193) withdrew its PPA. As a result the Ansonia generation has been removed from the case. The generator had previously cleared in FCA #2.

During FCA #4, FCA #5, FCA #6, and FCA #7, a dynamic delist was submitted for Bridgeport Harbor 2 for the commitment periods of June 2013 – May 2014, June 2014 – May 2015, June 2015 – May 2016, and June 2016 – May 2017. Subsequently, on September 16, 2013 a full Non-Price Retirement (NPR) Request for this resource was submitted for FCA #8. Following a reliability review by ISO-NE, the NPR request was accepted on October 16, 2013. As a result, for this study, the Bridgeport Harbor 2 unit was assumed OOS as a base case condition.

Additionally, during FCA #5 and FCA #6 a dynamic delist bid was submitted for the AES Thames unit for the commitment periods of June 2014 – May 2015 and June 2015 – May 2016. Subsequently, on September 18, 2012, a Non-Price Retirement Request was submitted for this resource; following a reliability review by ISO-NE, the Non-Price Retirement Request was accepted on November 13, 2012. For this study, the AES Thames unit was assumed OOS as a base case condition.

On September 30, 2013 a Non-Price Retirement request for Norwalk Station (Norwalk 1, 2 and 10) was submitted for the FCA #8 commitment period. The NPR request was accepted on December 20, 2013. As a result, the Norwalk Station was assumed out–of-service as a base condition.

Real Time Emergency Generation (RTEG) represents distributed generation facilities which have air permit restrictions that limit their operations to OP 4, Action 6 – an emergency action which also implements voltage reductions of five percent (5%) of normal operating voltage that require more than 10 minutes to implement. The impact of RTEG was not included in this analysis because in general, long-term analyses should not be performed such that the system must be in an emergency state as required for the implementation of OP 4, Action 6.

3.1.5 Explanation of Future Changes Not Included

The following projects were not added:

- Transmission projects that have not been fully developed and have not received PPA approval as of the April 2011 RSP Project Listing. These projects were not modeled in the study base case due to the uncertainty concerning their final development or lack of an impact on the GHCC study area.
- Transmission Projects that have been added to the project listing since the April 2011 project listing update, but do not have a significant impact on the study area

Additionally, the NEEWS – Central Connecticut Reliability Project component has PPA approval but was not included in the base case because the scope of this study includes the re-assessment of the transmission reliability needs for this component.

3.1.6 Forecasted Load

A ten-year planning horizon was used for this study based on the most recently available CELT report issued in May 2013. This study focused on the projected 2022 peak demand load levels for the ten-year horizon.

The 2022 summer peak 90/10 demand forecast for New England is 34,105 MW.

The CELT load forecast includes both system demand and losses (transmission and distribution) from the power system. The power flow modeling programs have the transmission system explicitly modeled and hence the losses on the transmission system are calculated by the software. Therefore, the actual system load modeled in the case was reduced to account for transmission system losses which are explicitly calculated in the system model. Load distributions in the case are based on the most recent 2013 MMWG case library data.

Demand Resources (DR) are treated as capacity resources in the Forward Capacity Auctions (FCA). DR is split into two major categories, Passive and Active DR. Passive DR is largely comprised of energy efficiency and is expected to lower the system demand during designated peak hours in the summer and winter. Active DR is commonly known as Demand Side Management (DSM) and can be dispatched on a zonal basis if a forecasted or real-time capacity shortage occurs on the system. Starting in 2012, forecasting passive DR has become part of the annual load forecasting process. This forecast takes into account additional electrical efficiency (EE) savings beyond FCM results across the ten-year planning horizon. This forecast is primarily based on forecasted financial investment in state-sponsored EE programs and its correlation with historical data on reduction in peak demand per dollar spent. This EE forecast was published in the annual CELT Report beginning in spring 2012. Active DR are modeled in the base case at the levels of the most recent Forward Capacity Auction (FCA #7), multiplied by a Performance Factor of 75% based on historical performance of similar resources. Passive DR are modeled at 2022 levels based on the passive DR cleared through FCA #7 (2010-2016) and the aforementioned EE forecast for the years until 2022 (2017-2022). In addition, Active and Passive DR levels in Connecticut were scaled down to account for the submission of several Non-Price Retirement Requests for FCA #8 and DR terminations post-FCA #7.

Starting in 2010, DR values are now published in the CELT Report. Because DR are modeled at the low-side of the distribution bus in the power-flow model, all DR values were increased by 5.5% to account for the reduction in losses on the local distribution network. Passive DR are modeled by load zone and Active DR are modeled by dispatch zone. The amounts modeled in the cases are listed in Table 3-1 and Table 3-2 and detailed reports can be seen in Table 8-3 in Appendix A: Load Forecast.

Table 3-1:
2022 Passive DR Values: DR through FCA #7 and EE Forecast

Load Zone	Passive DR (FCA-1-7) DRV[5] (MW)	Passive DR Terminations DRV[5] (MW)	Passive DR NPR DRV[5] (MW)	EE Forecast (2017-2022) DRV (MW)	Total Passive DR DRV (MW)
Maine	159	Not Included	Not Included	56	215
New Hampshire	80	Not Included	Not Included	53	133
Vermont	125	Not Included	Not Included	89	214
Northeast Massachusetts & Boston	341	Not Included	Not Included	276	617
Southeast Massachusetts	194	Not Included	Not Included	147	341
West Central Massachusetts	245	Not Included	Not Included	165	410
Rhode Island	142	Not Included	Not Included	114	256
Connecticut	417	-25	-8	139	523
New England Total	1,703	-25	-8	1,039	2,709

[5] DRV = Demand Reduction Value = the actual amount of load reduced measured at the customer meter; these totals are forecasted values for the commitment period beginning June 1, 2022. These values exclude transmission and distribution losses.

Table 3-2:
FCA #7: Active DR Values through FCA #7

Dispatch Zone	Active DR (FCA-1-7) DRV[6] (MW) (Includes DR terminations in CT)	Active DR NPR DRV[5] (MW)	Total Active DR DRV (MW)
Bangor Hydro	56	Not Included	56
Maine	207	Not Included	207
Portland, ME	32	Not Included	32
New Hampshire	49	Not Included	49
New Hampshire Seacoast	12	Not Included	12
Northwest Vermont	38	Not Included	38
Vermont	25	Not Included	25
Boston, MA	81	Not Included	81
North Shore Massachusetts	36	Not Included	36
Central Massachusetts	51	Not Included	51
Springfield, MA	33	Not Included	33
Western Massachusetts	78	Not Included	78
Lower Southeast Massachusetts	20	Not Included	20
Southeast Massachusetts	121	Not Included	121
Rhode Island	74	Not Included	74
Eastern Connecticut	49	-12	37
Northern Connecticut	100	-16	84
Norwalk-Stamford, Connecticut	37	-3	34
Western Connecticut	117	-13	104
New England Total	1,216	-44	1,171

3.1.7 Load Levels Studied

Consistent with ISO-NE planning practices, transmission planning studies utilize the ISO-NE extreme weather 90/10 forecast assumptions for modeling summer peak load profiles in New England. A state-by-state summary of the load modeled in the 2022 cases, taking into account transmission and distribution losses, is shown in Table 3-3. A more detailed report of the loads modeled and how the numbers were derived from the CELT values can be seen in Appendix A: Load Forecast in Table 8-2.

[6] DRV = Demand Reduction Value = the actual amount of load reduced measured at the customer meter; these totals are forecasted values for the commitment period beginning June 1, 2022. These values exclude transmission and distribution losses.

Table 3-3:
Load Levels to be studied

State	2022 CELT 90/10 Load (MW)
Maine	2,450
New Hampshire	3,150
Vermont	1,220
Massachusetts	16,055
Rhode Island	2,405
Connecticut	8,825
New England CELT Load	34,105

In addition to the CELT load described above there is about 365 MW of non-CELT load in Maine that is also in the base cases.

After taking into account the aforementioned transmission losses, the subtraction of demand response loads, and the addition of non-CELT loads, the net load level modeled in the base cases for this study was approximately 29,800 MW.

3.1.8 Load Power Factor Assumptions

Load power factors consistent with the local transmission owner's planning practices were applied uniformly at each substation. Demand resource power factors were set to match the power factor of the load at that bus in the model. A list of overall power factors by company territory can be found in the detailed load report in Appendix A: Load Forecast in Table 8-2.

3.1.9 Transfer Levels

In accordance with the reliability criteria of the NERC, NPCC and the ISO, the regional transmission power grid must be designed for reliable operation during stressed system conditions. A detailed list of all transfer levels can be found in Section 6. The following external transfers were utilized for the study:

- N-1 Analysis
  - New York to New England (AC ties) – 0 MW / 1,200 MW Import
  - Cross Sound Cable – 346 MW Export to Long Island[7]
  - Norwalk-Northport Cable – 200 MW Export to Long Island[8]
  - Highgate HVDC – 200 MW Import into New England
  - Phase II HVDC – 2,000 MW Import[9] into New England

[redacted]

[redacted]

[redacted]

    - New Brunswick to New England – 1,000 MW Import
- N-1-1 Analysis
    - New York to New England (AC Ties) – 0 MW Export
    - Cross Sound Cable – 0 MW Export
    - Norwalk-Northport Cable – 0 MW Export
    - Highgate HVDC – 200 MW Import into New England
    - Phase II HVDC – 2,000 MW Import into New England
    - New Brunswick to New England – 1,000 MW Import

For this Needs Assessment the generation dispatch dictated the internal transfer levels.

As a part of this Needs Assessment report the violations observed for the 1,200 MW export will be reported in the detailed results in Appendix E: Steady State Testing Results. However the ensuing solutions study will not resolve the violations identified for the 1,200 MW export to NY cases.

The NY dispatch was adjusted depending on the NY-NE stress that was being studied. The dispatches were set up such that:

1. For 1,200 MW import from NY cases – Increased generation in the southern part of NY and reduced generation in upstate NY to create a loop flow that would increase flow on the 398 and 690 lines from New York to New England.
2. For 1,200 MW export to NY cases – Increased generation in the upstate NY and reduced generation in the southern part of NY to create a loop flow that would increase flow on the 398 and 690 lines from New England to New York.

3.1.10 Generation Dispatch Scenarios

All generators in the base case are modeled with a maximum capacity corresponding to their qualified capacity as of FCA #7.

Table 3-4 shows the qualified capacities of the generating units in the study area.

Table 3-4:
Qualified Generating Capacities of Study Area Units

Area	Generating Unit	Qualified Capacity (MW)	Fast-Start [10] Unit
Two Largest Critical Units in Connecticut	Millstone 2	877	No
	Millstone 3	1225	No
Middletown Subarea	Middletown 2	117	No
	Middletown 3	236	No
	Middletown 10	17	Yes
	Branford Jet	19	Yes

Comprehensive Area Transmission Review of the New England Transmission System report, the Phase II facility was backed down by 450 MW to 1550 MW.

[10] "Fast-start" generators are those units that can go from being off-line to their full Seasonal Claimed Capability in 10 minutes. These units do not need to participate in the 10-minute reserve market to be considered a fast-start unit in planning studies.

Area	Generating Unit	Qualified Capacity (MW)	Fast-Start [10] Unit
Critical unit in Eastern CT	Kleen Energy	620	No
Greater Hartford Subarea	CDECCA	55	No
	South Meadow 5	23	No
	South Meadow 6	25	No
	South Meadow 11	36	Yes
	South Meadow 12	38	Yes
	South Meadow 13	38	Yes
	South Meadow 14	37	Yes
Northwest Connecticut Area	Bristol Refuse/ Forestville	13	No
	Falls Village	3	No
	Franklin Drive 10	15	Yes
	Torrington Terminal Jet	19	Yes
Manchester-Barbour Hill Subarea	Dexter	37	No
	Rainbow	8	No
Other Units in Western CT & outside SWCT	Middletown 4	400	No
	Middletown 12	47	Yes
	Middletown 13	47	Yes
	Middletown 14	47	Yes
	Middletown 15	47	Yes
	New Haven Harbor 1	448	No
	New Haven Harbor 2	43	Yes
	New Haven Harbor 3	43	Yes
	New Haven Harbor 4	43	Yes
Two Largest Units in Southwest CT	Bridgeport Harbor 3 (BH3)	383	No
	Bridgeport Energy (BE)	448	No

Twenty two dispatches were set up for the four study areas and for the western Connecticut import and Connecticut import needs assessment. The dispatches were set up by taking out one or two critical units in each subarea.

At all locations in the study area where a single fast-start unit was available, that unit was assumed OOS for each dispatch. For subareas where there were two single fast-start units, one of the two fast-start units was assumed online and available, if non-fast-start units were taken out of service in that subarea. For example, if the Middletown 3 unit is assumed OOS as a non-fast-start unit out of service then one of the two single fast-starts in the Middletown subarea, Branford Jet or Middletown 10, will be assumed to be in-service.

The Connecticut fast-start units were dispatched such that approximately 80% of the fast-start capability in Connecticut was online. The most up-to-date voltage schedules for area units were provided by Northeast Utilities and were utilized in this study. The fast-start dispatch assumptions detailed above were turned on in the base case and no adjustments were made to these fast start units post first contingency.

The performance of one of the hydroelectric units in the study area, Rainbow Hydro, was examined and it was determined that an availability of 10% of its nameplate capacity at summer peak was a reasonable assumption. This assumption was extended to all the Connecticut hydro units. This was acceptable since there are very few hydro units in Connecticut and just 2 of them are in the study area: Rainbow Hydro and Falls Village.

Table 3-5 provides the outputs assumed for the hydro units in Connecticut for units above 5 MW.

Table 3-5:
Dispatch of Hydro Units in Connecticut

Unit Name	Dispatched Amount (MW)	Name Plate (50 degree rating - MW)	Location
Rainbow Hydro	0.8	8.2	Manchester/ Barbour Hill
Stevenson Hydro	2.9	28.9	SWCT
Falls Village	1.0	9.8	NWCT
Rocky River	2.9	29.4	SWCT
Shepaug	4.3	42.9	SWCT
Bulls Bridge	0.8	8.4	SWCT
Derby Dam	0.7	7.1	SWCT

The dispatches for each subarea are defined in the following section:

- **Middletown Subarea**: There were two critical units in this subarea: Middletown 2 and 3; these units were assumed OOS as a base case condition for this area's two-units-out dispatch. Since these units are located on the same bus, only the largest of the two (Middletown 3) was taken OOS to create a one-unit-out dispatch. The Middletown study area has two single fast-start units, Middletown 10 and Branford Jet. For each case, one-unit-out case and two-unit-out case, two dispatches were created based on fast-start dispatch. Cases with the Middletown 10 off and Branford Jet on are called MIDD_01 (two units OOS) and MIDD_1A (one unit out). Alternately, cases with the Middletown 10 on and Branford Jet off are called MIDD_02 (two units OOS) and MIDD_2A (one unit out). This leads to a total of four dispatches for this subarea.
- **Manchester-Barbour Hill Subarea**: There were two critical units in this subarea: Dexter and Rainbow Hydro; these units were assumed OOS as a base case condition for this area's dispatch. Since the Rainbow Hydro unit is a small unit, only one single unit out dispatch was created with Dexter out-of-service. This leads to a total of two dispatches for this subarea.
- **Northwest Connecticut Subarea**: There were two critical units in this subarea: Falls Village Hydro and Forestville; these units were assumed OOS as a base case condition for this area's two-units-out dispatch. Since the Falls Village Hydro unit is a small unit, only one single unit out dispatch was created with the Forestville unit out of service. The Northwest Connecticut study area has two single fast-start units, Franklin Drive 10 and Torrington Terminal Jet. For each case, one-unit-out case and two-unit-out case, two dispatches were created based on fast-start dispatch. Cases with the Franklin Drive 10 on and Torrington Terminal Jet off are called NWCT_01 (two units OOS) and NWCT_1A (one unit out). Alternately, cases with the Franklin Drive 10 off and Torrington Terminal Jet on are called

NWCT_02 (two units OOS) and NWCT_2A (one unit out). This leads to a total of four dispatches for this subarea.

- **Hartford Subarea**: There were three critical units in this subarea: South Meadow 5, South Meadow 6 and Capitol District. There were two different two-units-out dispatches for this study area. The first has the two South Meadow units OOS and the other has one South Meadow unit (#6) and the Capitol District unit OOS. Two one-unit-out dispatches were also created, taking out the larger South Meadow unit (#6) and the Capitol District unit separately. This leads to a total of four dispatches for this subarea.
- **Western Connecticut Import Analysis**: Four dispatches were established to test the need for additional western Connecticut import capability.
    - **Dispatch 1** – High SWCT Import – Bridgeport Harbor 3 OOS and Bridgeport Energy OOS
    - **Dispatch 2** – Moderate western CT Import – New Haven Harbor and Kleen Energy OOS (Kleen is an eastern CT unit very close to the western CT import interface)
    - **Dispatch 3** – High Western CT Import – Bridgeport Harbor 3 and New Haven Harbor OOS (two largest 115 kV generators in western Connecticut)
    - **Dispatch 4** – High Western CT import – Bridgeport Energy and New Haven Harbor OOS (two largest generators in western Connecticut)

  Additionally, two one-unit out dispatches were created.

    - **Dispatch 3A** – High SWCT Import –Bridgeport Energy OOS
    - **Dispatch 4A** – High western CT Import – New Haven Harbor OOS

  This leads to a total of six dispatches for the western CT import analysis.
- **Connecticut Import Analysis**: As a part of the NEEWS Interstate analysis several line overloads were seen in the GHCC Study area. The overloads seen in the Interstate analysis were not resolved and were examined as a part of this analysis. The two-unit-out stress for this analysis was created by taking the two Millstone units out of service. Since these units are located on the same bus, only the largest of the two (Millstone 3) was taken OOS to create a one-unit-out dispatch. This leads to a total of two dispatches for this analysis.

The twenty-two dispatches just described are summarized in Table 3-6 and Table 3-7 on the following pages.

Table 3-6:
Two-Units–Out Generation Dispatches

Major Area Units	Dispatch Name / Number											
	Middletown #1	Middletown #2	Barbour Hill #1	NWCT #1	NWCT #2	HTFD #1	HTFD #2	CCRP #1	CCRP #2	CCRP # 3	CCRP #4	IRP #1[11]
Middletown 2	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 3	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 10[12]	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Branford Jet[12]	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Dexter	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON
Rainbow	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON
Falls Village	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	ON
Forestville	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	ON
Franklin Drive 10[12]	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Torrington Term. Jet[12]	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
South Meadow 5	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON
South Meadow 6	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON
CDECCA	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON
Bridgeport Energy	ON	ON	ON	ON	ON	ON	ON	OFF	ON	ON	OFF	ON
Bridgeport Harbor 3	ON	ON	ON	ON	ON	ON	ON	OFF	ON	OFF	ON	ON
Kleen Energy	ON	ON	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON
New Haven Harbor 1	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	ON
Millstone 2	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
Millstone 3	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF

[11] Interstate studies showed severe overloads in the Greater Hartford subarea for this dispatch; for that reason, this dispatch will also be tested in this Needs Assessment, even though the units OOS lie outside of the study area.

[12] Fast-Start unit

Table 3-7:
One-Unit-Out Generation Dispatches

Major Area Units	Dispatch Name/Number									
	Middletown #1A	Middletown #1B	Barbour Hill #1A	NWCT #1A	NWCT #2A	HTFD #1A	HTFD #2A	CCRP #3A	CCRP # 4A	IRP #1A[13]
Middletown 2	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 3	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 10[14]	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Branford Jet[14]	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Dexter	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON
Rainbow	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Falls Village	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Forestville	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON
Franklin Drive 10[14]	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
Torrington Term. Jet[14]	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF
South Meadow 5	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
South Meadow 6	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON
CDECCA	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON
Bridgeport Energy	ON	ON	ON	ON	ON	ON	ON	OFF	ON	ON
Bridgeport Harbor 3	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Kleen Energy	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
New Haven Harbor 1	ON	ON	ON	ON	ON	ON	ON	ON	OFF	ON
Millstone 2	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Millstone 3	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF

3.1.11 Reactive Dispatch Assumptions

All area shunt reactive resources were assumed available and dispatched when required. Reactive output of generating units was modeled to reflect defined limits. A summary of the reactive output of units and shunt devices connected to the transmission system that played a significant role in the study area can be found in the power flow case summaries included in Appendix B: Case Summaries.

3.1.12 Demand Resources

As stated in Section 3.1.6, passive demand resources as forecasted for the year 2022 and active demand resources that cleared as of FCA #7 in 2013 were modeled for this study, minus approximately 52 MW of demand resources in Connecticut that have accepted NPR Requests for

[13] Interstate studies showed severe overloads in the Greater Hartford subarea for this dispatch; for that reason, this dispatch was also tested in this Needs Assessment, even though the units OOS lie outside of the study area.

[14] Fast-Start unit

FCA #8. Passive demand resources were assumed to perform to 100% of their forecasted amount. The passive DR included the forecasted EE which was assumed to perform to 100% of the forecast. Active demand resources were assumed to perform to 75% of their cleared amount. Real Time Emergency Generation (RTEG) was not modeled, consistent with all needs and solutions planning analyses.

Table 3-8:
New England Demand Resource Performance Assumptions

Region	Passive DR	Energy Efficiency	Active DR	RTEGs
New England	100%	100%	75%	0%

3.1.13 Protection and Control System Devices Included in the Study Area

[redacted]



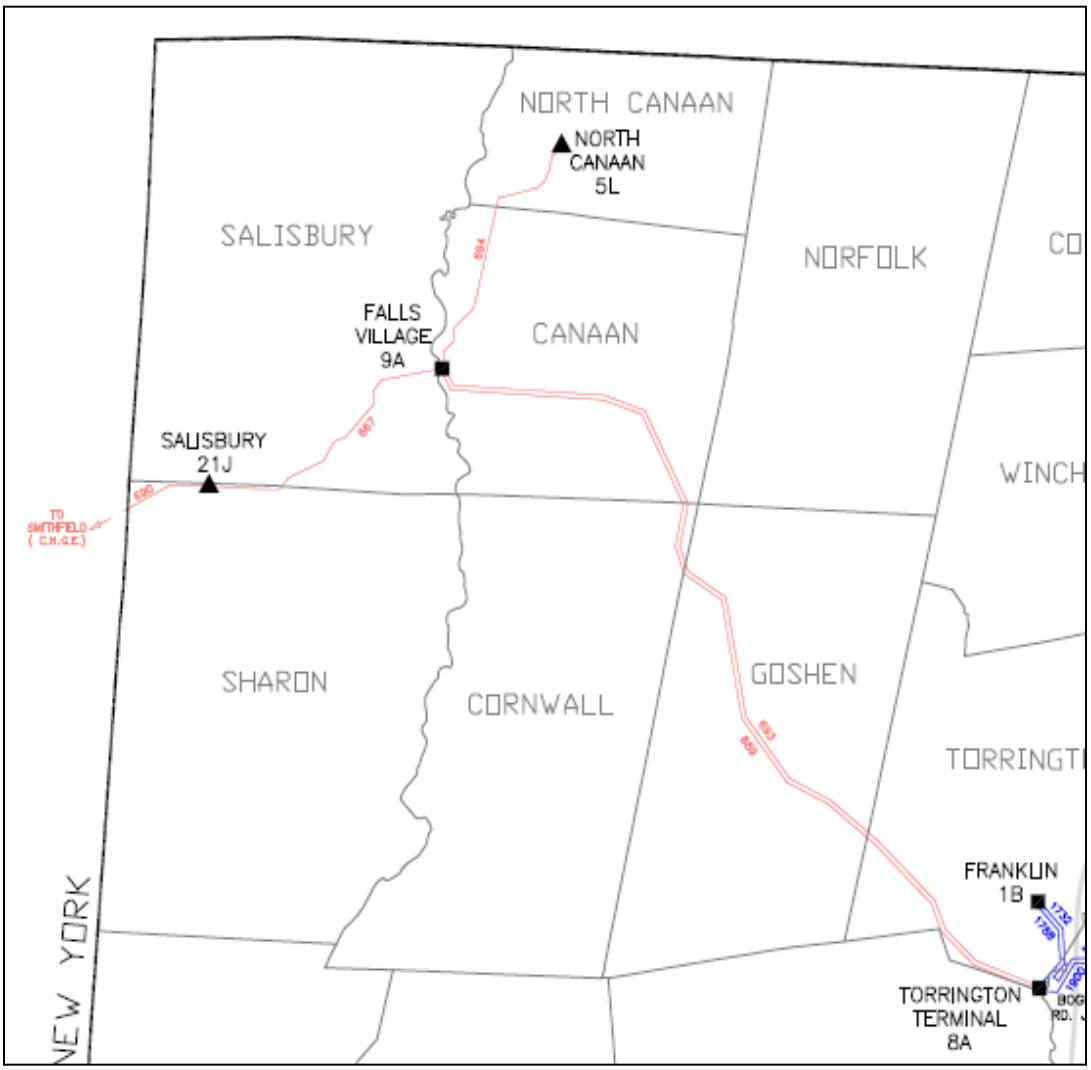


Figure 3-2: The 69 kV System in Northwestern Connecticut

3.2 Stability Modeling Assumptions

Not applicable for this study.

3.3 Short Circuit Model

3.3.1 Study Assumptions

The short circuit study evaluated the projected 2022 available fault current levels around the GHCC area. It also included the effects of area reliability project upgrades as well as selected proposed generation interconnection projects as outlined in Sections 3.3.3 and 3.3.4 of this study document.

3.3.2 Short Circuit Model

The ASPEN Circuit Breaker Rating Module software was used to calculate all circuit breaker duties. The case for the short circuit study was obtained from the 2011 short circuit base case library and all

PPA-approved projects, as discussed in Section 3.1.3 of this scope document, were added to that model. The Central Connecticut Reliability Project (CCRP) was excluded from the basecase, similar to the steady-state basecases.

3.3.3 Generation Additions and Retirements

The model included proposed generation interconnection projects that have PPA approval as well as those generator projects that have FCA Capacity Supply Obligations (CSOs).

The following relevant generation projects were modeled for this study:

- QP 095 – Kleen Energy (FCA #2)
- QP 125 – Cos Cob 13&14 (FCA #1)
- QP 140 – A.L. Pierce (FCA #1)
- QP 150 – Plainfield Renewable Energy Project (FCA #3)
- QP 155.6 – Fuel Cell Project in Fairfield, CT (FCA #4)
- QP 161 – Devon 15-18 (FCA #2)
- QP 161 – Middletown 12-15 (FCA #2)
- QP 199 – Waterbury Generation (FCA #1)
- QP 206 – Kimberly Clark Energy (FCA #2)
- QP 248 – New Haven Harbor 2-4 (FCA #3)
- QP 289 – Fuel Cell Project in New Haven County, CT (FCA #4)

The non-price retirements of Norwalk Harbor 1, 2, and 10 as well as Bridgeport Harbor 2 were reflected in the short circuit basecase.

3.3.4 Generation and Transmission System Configurations

NPCC Regional Reliability Reference Directory #1, "Design and Operation of the Bulk Power System" and PP 3 require short circuit testing to be conducted with all transmission and generation facilities in-service for all potential operating conditions.

3.3.5 Boundaries

This study included testing of all 69 kV, 115 kV and 345 kV substations and breakers in the GHCC study area.

3.3.6 Other Relevant Modeling Assumptions

Not applicable to this scope document.

Section 4
Analysis Methodology

4.1 Planning Standards and Criteria

The applicable NERC, NPCC and ISO-NE standards and criteria will be tested as part of this evaluation. Descriptions of each of the NERC, NPCC and ISO-NE standard tests that were used to assess system performance are discussed later in this section.

4.2 Performance Criteria

4.2.1 Steady-state Criteria

The Needs Assessment was performed in accordance with NERC TPL-001, TPL-002, TPL-003 and TPL-004 Transmission Planning System Standards, NPCC "Regional Reliability Reference Directory #1, Design and Operation of the Bulk Power System", dated 04/20/12, and the ISO Planning Procedure No. 3, "Reliability Standards for the New England Area Bulk Power Supply System", dated 03/01/13. The contingency analysis steady-state voltage and loading criteria, solution parameters and contingency specifications that were used in this analysis are consistent with these documents.

As a part of this needs analysis the robustness of the system with respect to limited extreme contingency events was evaluated.

4.2.1.1 Thermal and Voltage Limits

Loadings on all transmission facilities rated at 69 kV and above in the study area were monitored. The thermal violation screening criteria defined in Table 4-1 were applied.

Table 4-1:
Steady-State Thermal Criteria

System Condition	Maximum Allowable Facility Loading
Normal (all-lines-in) (Pre-Contingency)	Normal Rating
Post-Contingency	Long Time Emergency (LTE) Rating

Voltages were monitored at all buses with voltages 69 kV and above in the study area. System bus voltages outside of limits identified in Table 4-2 were identified for all normal (pre-contingency) and post-contingency conditions.

Table 4-2:
Steady-State Voltage Criteria

Transmission Owner	Voltage Level	Bus Voltage Limits (Per-Unit)	
		Normal Conditions (Pre-Contingency)	Emergency Conditions (Post-Contingency)
Northeast Utilities	69 kV & above	0.95 to 1.05	0.95 to 1.05
Millstone / Seabrook[15]	345 kV	1.00 to 1.05	1.00 to 1.05
Pilgrim[15]	345 kV	0.995 to 1.05	0.99 to 1.05
Vermont Yankee[15]	115 kV 345 kV	1.00 to 1.05 0.985 to 1.05	1.00 to 1.05 0.985 to 1.05

It must be noted that some of the facilities that are classified as non-Pool Transmission Facilities (PTF) were reported in this report and the appendices. These violations however will not be categorized as needs and the ensuing solutions study will not develop solutions to solely resolve these violations.

4.2.1.2 Solution Parameters

The steady-state analysis was performed with pre-contingency solution parameters that allow for adjustment of load tap-changing transformers (LTCs), static VAR devices (SVDs, including automatically-switched capacitors), and phase angle regulators (PARs). Table 4-3 displays these solution parameters.

Table 4-3:
Study Solution Parameters

Case	Area Interchange Control	Tap Adjustments	Adjust Phase Shift	Switched Shunt Adjustments
Base	Tie Lines and Loads Enabled	Stepping	Enabled	Enabled
Contingency	Disabled	Stepping	Not Enabled	Not Enabled

As a part of the scope it was stated that sensitivity testing would be conducted with area interchange enabled. However, a few cases were tested with both area interchange enabled and disabled and no significant difference was observed for the contingencies not involving a source loss. Since a majority of the critical contingencies in the area do not involve a source loss, the results with area interchange disabled were only considered for the remainder of this report.

4.2.2 Stability Performance Criteria

Not applicable for this study.

[15] This is in compliance with NUC-001-2, *"Nuclear Plant Interface Coordination Reliability Standard,"* adopted August 5, 2009.

4.2.3 Short Circuit Performance Criteria

This study was performed in accordance with appropriate IEEE C37 standards and specific design parameters of the circuit breakers. This includes specific considerations for total-current rated and symmetrical-current rated breakers as appropriate.

The circuit breakers were evaluated for short circuit adequacy based on the following criteria of Northeast Utilities (NU):

- *Acceptable-duty*: Circuit breaker fault interrupting duty less than 90% of the available fault current. No action required.
- *Marginal-duty*: Circuit Breaker Fault Interrupting Duty greater than or equal to 90% and less than 100%. This is an acceptable operating condition; however, potential solutions should begin to be developed to address solutions that would require a significant lead time to complete.
- *Over-duty Condition*: Circuit Breaker Fault Interrupting Duty greater than 100%. This is considered an unacceptable operating condition requiring a solution to be developed to eliminate the over-duty condition.

4.3 System Testing

4.3.1 System Conditions Tested

Testing of system conditions included the evaluation of system performance under a number of resource outage scenarios, variation of related transfer levels, and an extensive number of transmission equipment contingency events.

4.3.2 Steady-State Contingencies Tested

Each base case was subjected to single element contingencies such as the loss of a transmission circuit or an autotransformer. In addition, single contingencies which may cause the loss of multiple transmission circuit facilities, such as those on a common set of tower line structures were simulated. The steady-state contingency events in this study also included circuit breaker failures and substation bus fault conditions that could result in removing multiple transmission elements from service. A comprehensive set of contingency events, listed in Appendix D: Contingency Listings, were tested to monitor thermal and voltage performance of the GHCC study area transmission network. A listing of all contingency types that were tested is included in Table 4-4.

Additional analyses evaluated N-1-1 conditions with an initial outage of a key transmission element or generator followed by another contingency event. The N-1-1 analyses examined the summer peak load case with stressed conditions. For these N-1-1 cases, reliability standards, including ISO-NE Planning Procedure 3, allow specific manual system adjustments, such as fast-start generation redispatch, phase-angle regulator adjustment or HVDC adjustments between the first and second single contingency event. A summary listing of first element-out scenarios is provided in Table 4-5. A total of 113 element-out scenarios were tested. A detailed listing of all the element out scenarios tested is provided in Appendix C: Element Out for N-1-1 Analysis.

A class of contingencies not mentioned in the scope document is the loss of elements without a fault. A distinction was made in this assessment based on the nature of a no-fault contingency as follows:

- Type 1: No-fault contingencies involving the opening of a terminal of a line independent of the design of the terminating facility

- Type 2: A subset of the above contingencies that involves the opening of a single breaker

For N-1 testing, all Type 1 contingencies above were simulated. However, for N-1-1 testing only the Type 2 contingencies were simulated as 2nd contingencies.

Table 4-4:
Summary of NERC, NPCC and/or ISO-NE Category Contingencies to be Included

Contingency Type	NERC Type	NPCC D-1 Section	ISO PP 3 Section	Tested in This Study
All Facilities in-service	A	5.4.2.b	3.2.b	Yes
Generator (Single Unit)	B1	5.4.1.a	3.1.a	Yes
Transmission Circuit	B2	5.4.1.a	3.1.a	Yes
Transformers	B3	5.4.1.a	3.1.a	Yes
Element w/o Fault	B5	5.4.1.d	3.1.d	Yes
Bus Section	C1	5.4.1.a	3.1.a	Yes
Breaker Failure	C2	5.4.1.e	3.1.e	Yes
Double Circuit Tower	C5	5.4.1.b	3.1.b	Yes
Extreme Contingencies	D	5.6	6	Yes (Limited)

Table 4-5:
Summary of N-1-1 First Element-Out Scenarios

Contingency Type	Number of Element Out Scenarios
Overhead 345 kV lines	23
Autotransformers	14
Generators	6
Underground 115 kV cables	2
Overhead 115 kV lines	65
Overhead 69 kV Lines	3
Total Number of Scenarios	**113**

4.3.3 Use of Redispatch

When setting up the dispatches in Section 3.1.10, all the regular generators in Connecticut and 80% of the quick starts were dispatched to their qualified capacity with the exception of the critical generators out of service. However, prior to running the N-1 analysis, a generation redispatch was conducted to see if backing down any of these generators would resolve criteria violations. The back down did result in a few violations being eliminated. The tables in Section 5 only report the residual violations post redispatch. The details of the redispatch performed on the basecases can be found in Appendix E: Steady State Testing Results.

Additionally, as outlined in ISO Planning Procedure #3 (PP3), allowable actions after the first contingency event and prior to the second contingency event include redispatch of generation. During the analysis, available generation in the study area and its vicinity were allowed to reduce their output if online. Remote generation in Maine remote from the study area was used to replace the lost

generation within the area of study to simulate the redispatch of fast-start units within New England to keep load balance. A maximum limit of 1200 MW of redispatch was considered acceptable. Anything higher than 1200 MW could not be considered acceptable due to the amount of reserves typically available on the system.

To simulate these actions in power flow analysis, the Security Constrained Redispatch (SCRD[16]) tool in the TARA software package was used.

Additionally, since the shunt devices were assumed to be locked for post contingency conditions as indicated in Table 4-3, pre-contingency adjustment of capacitors were allowed to prevent post contingency voltage concerns. The adjustment was primarily performed to the Southington 115 kV and Frost Bridge 115 kV capacitors.

4.3.4 Stability Contingencies Tested

Not applicable to this study.

4.3.5 Short Circuit Faults Tested

The ASPEN circuit breaker rating module software was used to calculate all circuit breaker duties. The pre-fault operating voltage for all GHCC study area buses was set to be 1.04 per unit (p.u.). Figure 4-1shows the ASPEN options that were used in this study.

[16] TARA's SCRD tool does not consider economics in the objective function to solve violation constraints. It solely uses the most effective generation that will resolve a particular constraint on the system

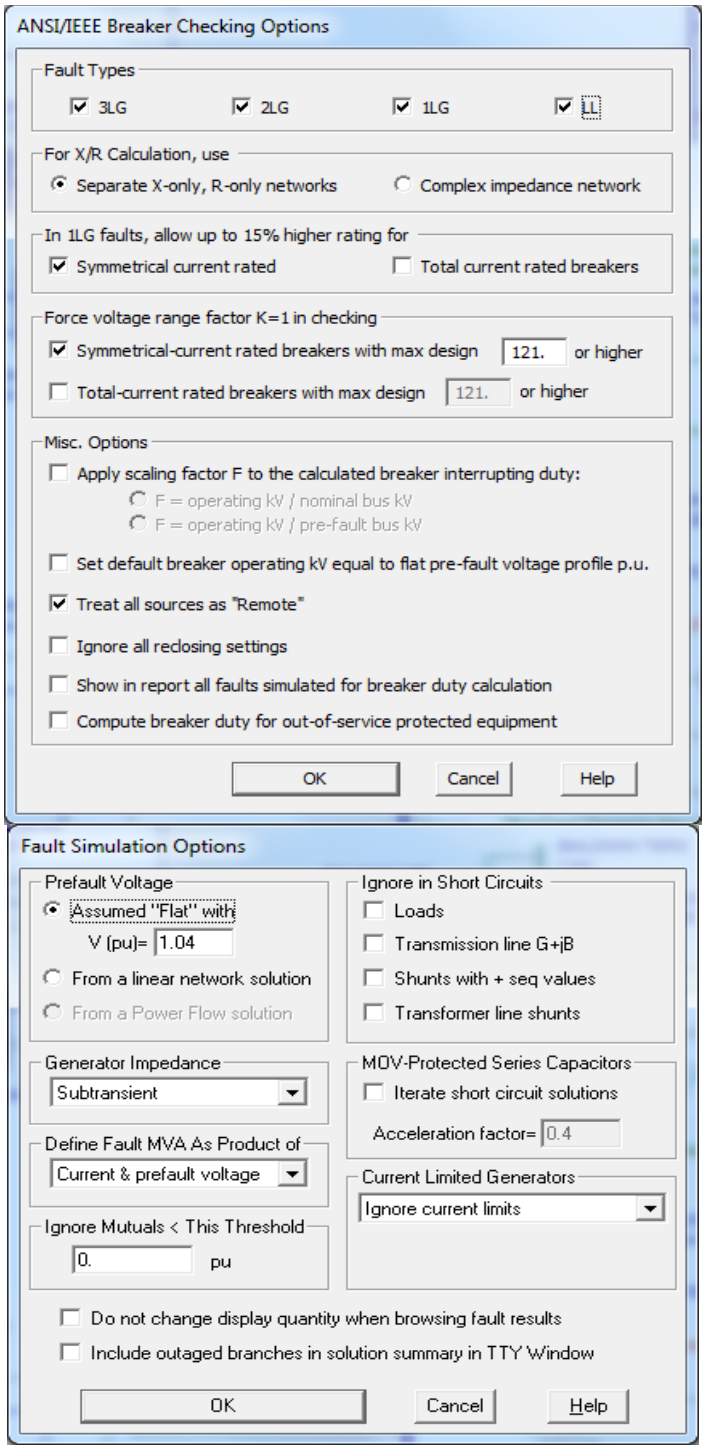


Figure 4-1: Circuit Breaker Testing Parameters

Section 5
Results of Analysis

5.1 Overview of Results

The GHCC study area load for 2022 was 2846 MW after demand resources are subtracted. The total generation in the area is less than 750 MW. The GHCC area is primarily an import area and depends on the transmission lines connecting the area to the rest of the system to serve load. A majority of the issues seen in the study area are load serving issues caused by the loss of key transmission elements OOS under N-1 and N-1-1 contingency conditions.

The criteria violations observed in the Needs Assessment indicate thermal and voltage violations in the four subareas seen mostly under generation deficiency conditions in each subarea. A number of issues are also seen when all the generation in a subarea is available thereby indicating that the issues are independent of generation dispatch.

As a part of the thermal and voltage analysis it was observed that criteria violations were seen to exist in both the one unit OOS and the two units OOS cases. In most cases there was very little difference in the extent of violation between the one unit OOS and the two units OOS cases. These results indicate that the violations are more a result of the local load and the contingencies applied rather than the specific generation dispatches.

The short circuit analysis indicated that all the study area breakers had acceptable fault duty, and the extreme contingency assessment indicated an acceptable response.

The following section provides a description of each subarea in terms of total load in the subarea and some of the general characteristics that were seen for each subarea. The sections intend to provide a high level overview of the thermal and voltage concerns in each subarea.

5.1.1 Greater Hartford Subarea Overview

The Greater Hartford subarea net load for 2022 after demand resources are subtracted is about 1,227 MW of load. The area has three generators totaling to about 103 MW that may be classified as regular units and four generators totaling to about 149 MW that are classified as fast-start units.

Looking at the load and generation it can be observed that the Greater Hartford area is a net importer of energy and relies on the surrounding areas to serve local load. The major 115 kV lines that feed this subarea are:

- Three 115 kV lines from North Bloomfield (Lines 1726, 1751, and 1777)
  - 1726: North Bloomfield – Farmington
  - 1751: North Bloomfield – Northwest Hartford – Rood Avenue
  - 1777: North Bloomfield – Bloomfield
- Three 115 kV lines from Manchester (Lines 1207, 1448 and 1775)
  - 1207: Manchester – East Hartford
  - 1448: Manchester – Rood Avenue
  - 1775: Manchester – Riverside Drive – South Meadow
- Two 115 kV lines from Southington (Lines 1670 and 1771)
  - 1670: Southington – Black Rock – Berlin

  - 1771: Southington – Berlin
- One 115 kV line from Middletown (Line 1765)
  - 1765: Westside – Berlin

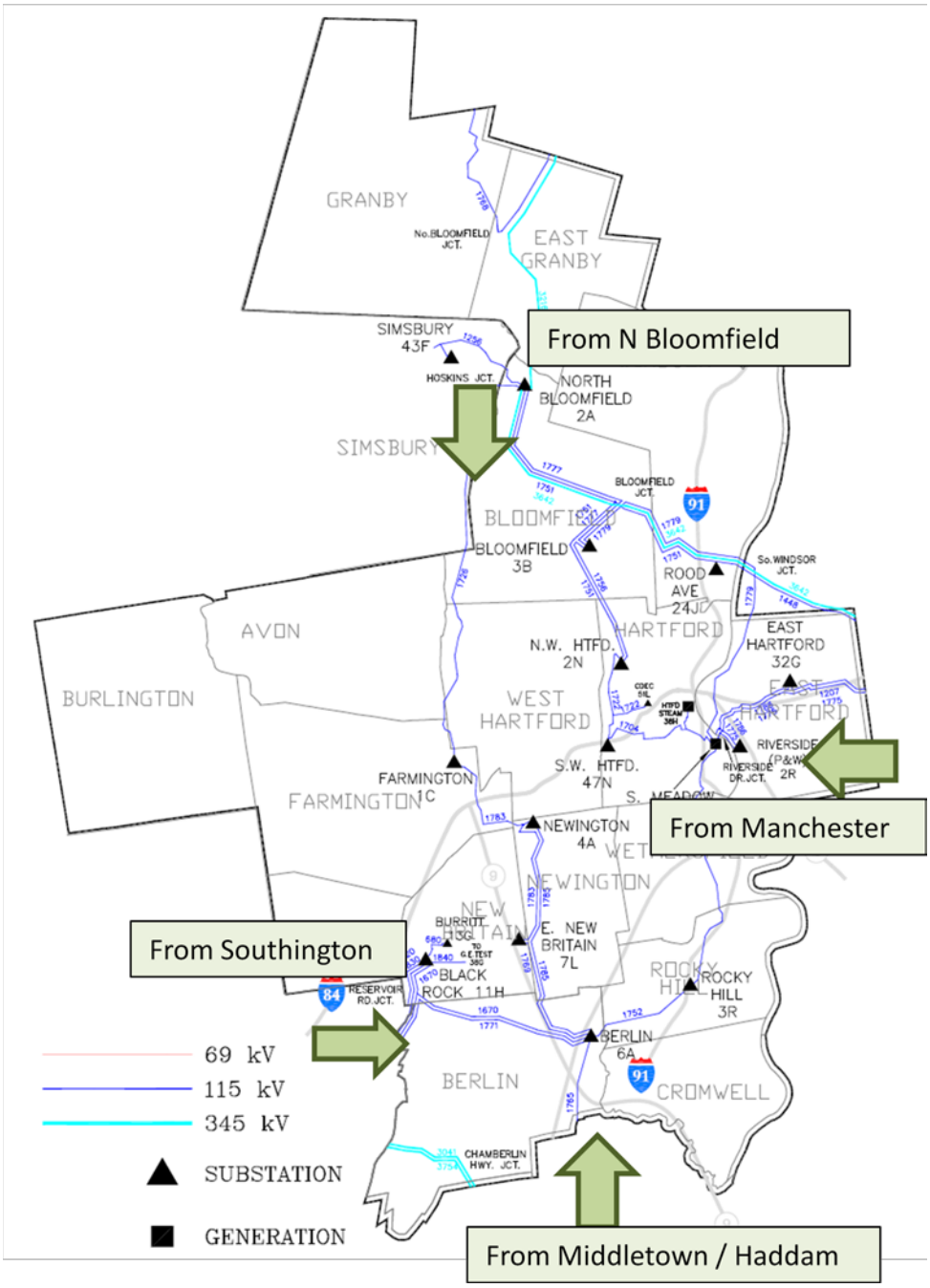


Figure 5-1: An Overview of the Greater Hartford Subarea

The N-1 violations in the subarea were few, but a majority of the violations were N-1-1 violations. The N-1-1 violations have been grouped into the following three areas:

- South Meadow – Berlin – Southington Area
- North Bloomfield – Manchester Area
- Southington Area

5.1.1.1 South Meadow, Berlin and Southington Area

- This area has a 2022 load of about 569 MW after DR loads are subtracted. The load is distributed across seven substations.
- This load pocket is served by five 115 kV lines:
  - Two 115 kV lines from Southington to Berlin (Line s 1670 and 1771)
  - A 115 kV line from North Bloomfield to Farmington (Line 1726)
  - A 115 kV line from South Meadow to Rocky Hill (Line 1773)
  - A 115 kV line from Westside towards Berlin (Line 1765)
- There is no generation located within this load pocket
  - Highest violations seen when adjacent Middletown generation is OOS

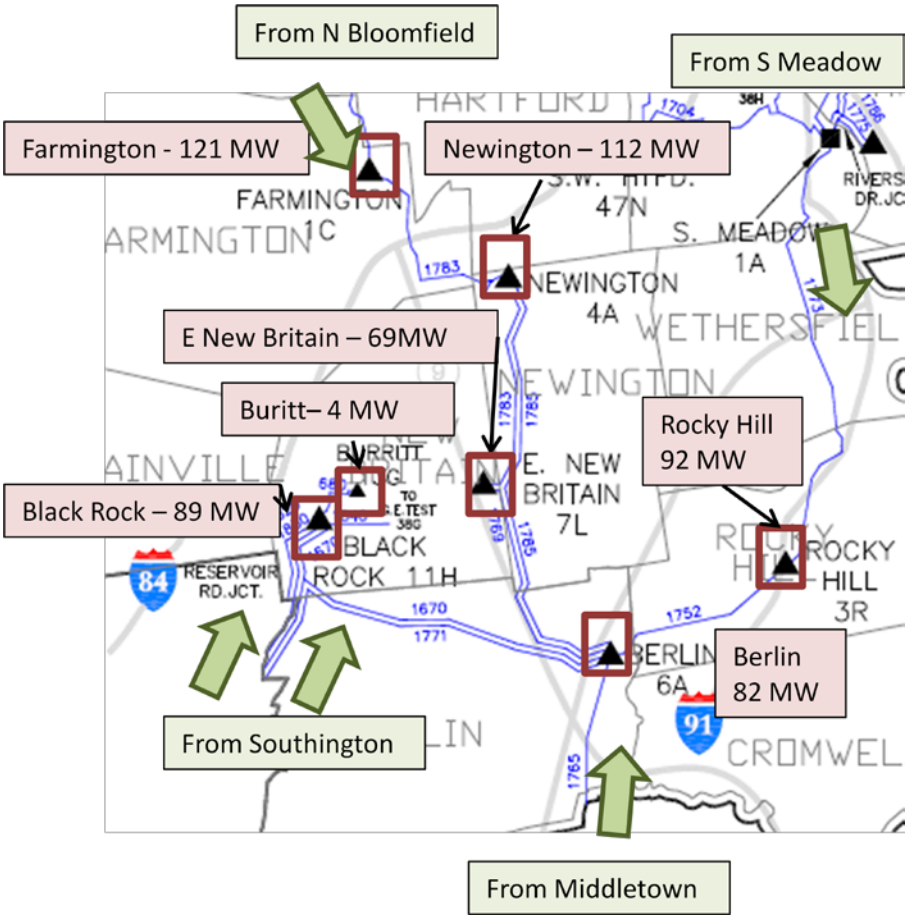


Figure 5-2: South Meadow, Berlin and Southington Load Area

Within this load area is the Farmington, Newington and East New Britain load pocket.

- This load pocket has a net load of 302 MW for 2022 after DR loads are subtracted. The load is distributed across three 115 kV substations.
- This load pocket served by three 115 kV lines:
  - A 115 kV line from North Bloomfield to Farmington (Line 1726)
  - A 115 kV line from Berlin to Newington (Line 1785)
  - A 115 kV line from Berlin to East New Britain (Line 1769)
- [redacted]
- [redacted]

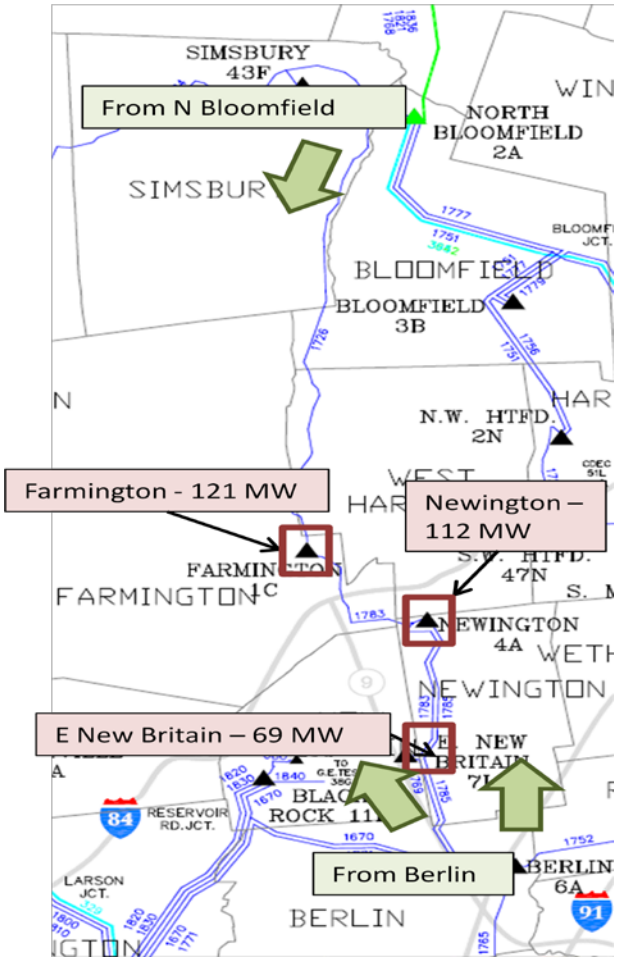


Figure 5-3: Farmington, Newington and East New Britain Load Pocket

5.1.1.2 North Bloomfield – Manchester Area

- This area is bound by feeds from North Bloomfield and Manchester.
- This area is served by five 115 kV lines:
  - A three-terminal 115 kV line from North Bloomfield to Northwest Hartford to Rood Avenue (Line 1751)
  - A 115 kV line from North Bloomfield to Bloomfield (Line 1777)

- A three terminal 115 kV line from Manchester – Riverside – South Meadow (Line 1775)
- A 115 kV line from Manchester – East Hartford (Line 1207)
- A 115 kV line from Manchester – Rood Avenue (Line 1448)

- CDECCA generation and South Meadow generation is located at the heart of this area [redacted]
- [redacted]

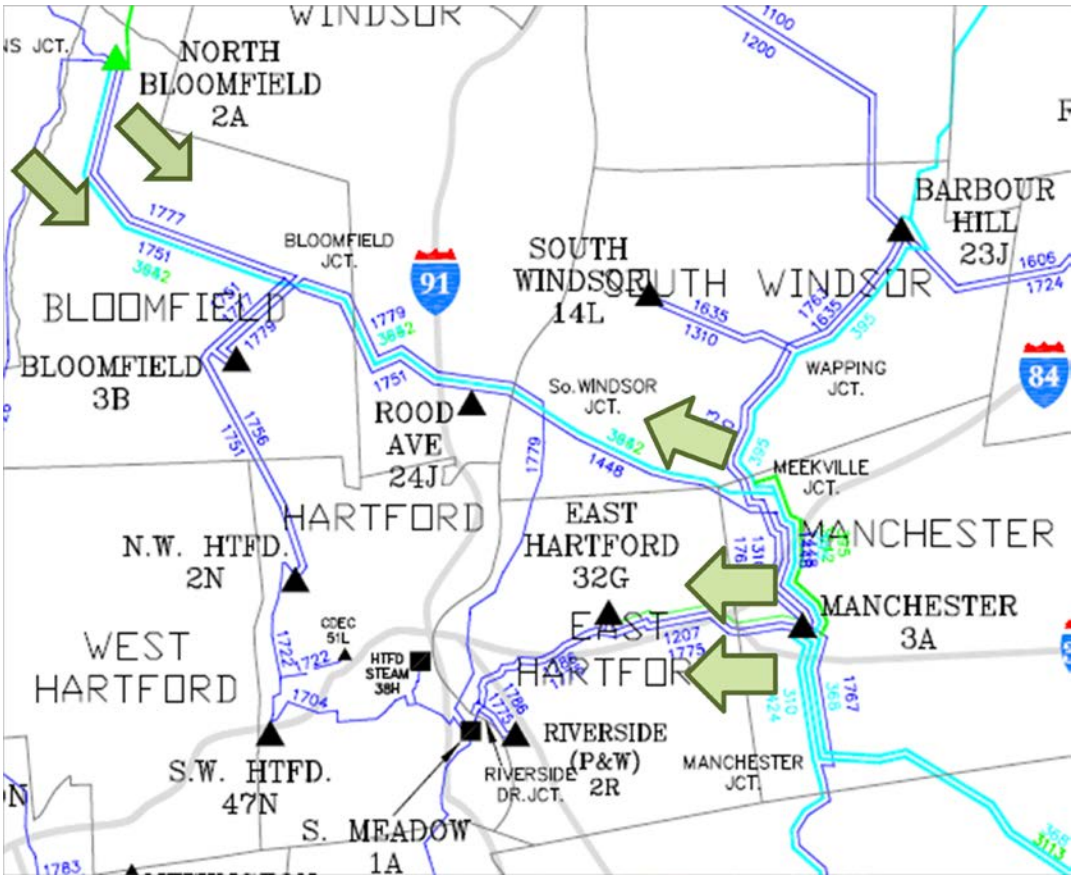


Figure 5-4: North Bloomfield - Manchester Area

5.1.1.3 Southington Area

The final set of violations was seen on elements at or emanating from the Southington substation. [redacted]

The Southington substation has five 115 kV facilities that are a part of the SWCT import interface. There are 4 autotransformers at Southington that feed into these SWCT import lines. The violations seen in this area are all thermal violations. [redacted]

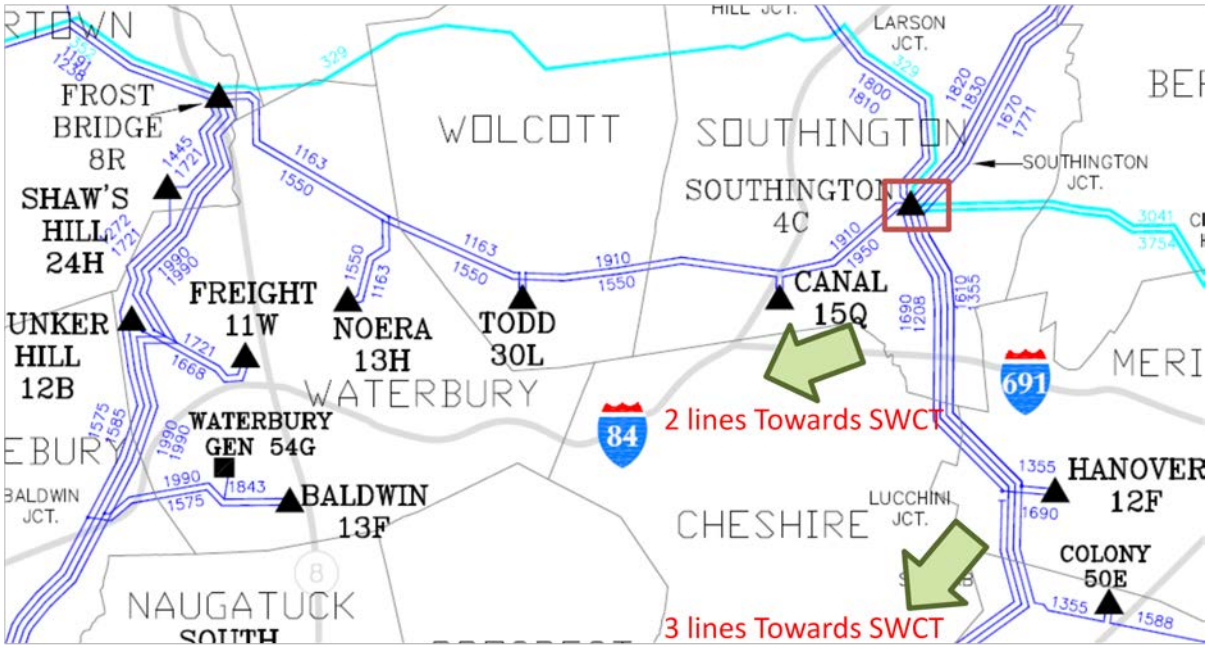


Figure 5-5: Southington substation and SWCT Import Interface

Additional details for the violations in the Greater Hartford subarea has been documented in Section 5.2.1.

5.1.2 Manchester - Barbour Hill Subarea Overview

The Manchester-Barbour Hill subarea consists of about 452 MW of load including demand resources in 2022. The area has one generator (Dexter) that has a qualified capacity of 37 MW and is considered a regular generator and one hydro station (Rainbow Hydro) that has a total qualified capacity of about 8 MW. The hydro station is dispatched to 10% of its nameplate capacity at 0.8 MW.

Looking at the load and generation it can be observed that the Manchester-Barbour Hill subarea is a net importer of energy and relies on the surrounding areas to serve local load. [redacted]

All criteria violations in this subarea are observed under N-1-1 conditions. The violations may be broadly divided into two categories:

- Barbour Hill Load Pocket
- Manchester Autotransformers

The Barbour Hill load pocket consists of five 115 kV substations and the details for this load pocket are shown in Figure 5-6. The total load within this load pocket is about 326MW including demand resources. The area is fed by the following three transmission elements:

- The 345/115 kV autotransformer at Barbour Hill (Barbour Hill Auto)
- A 115 kV line from Manchester to Barbour Hill (Line 1763)
- A 115 kV line from Manchester to South Windsor (Line 1310)

Both area units are located within this load pocket [redacted]

The criteria violations are only seen under N-1-1 conditions. [redacted]

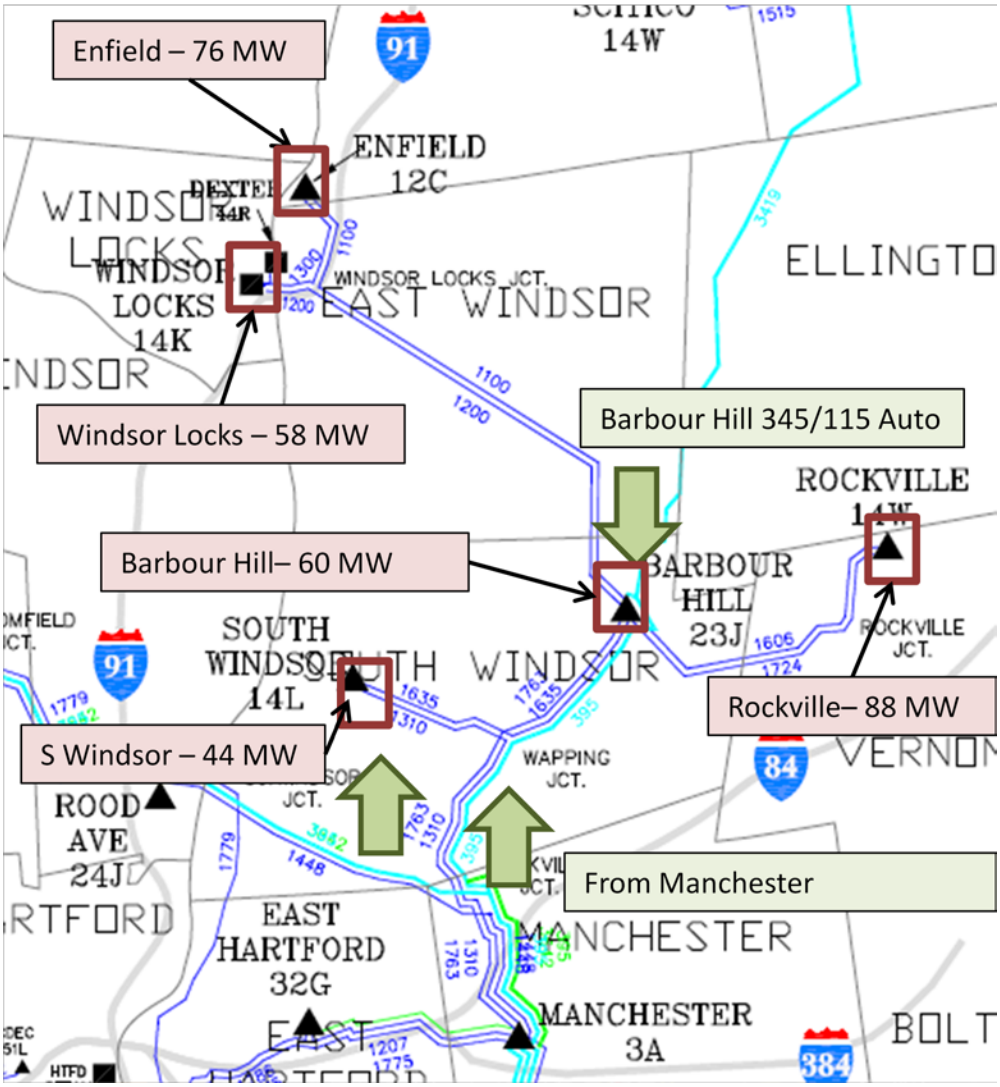


Figure 5-6: Barbour Hill Area Load Pocket

[redacted]

5.1.3 Middletown Subarea Overview

The Middletown subarea consists of about 656 MW of load including demand resources in 2022. The area has two generators totaling to about 353 MW (Middletown 2 and 3) that may be classified as regular generators and two generators (Middletown 10 and Branford 10) totaling to about 33 MW that are classified as fast-start units.

Looking at the load and generation it can be observed that the Middletown subarea does depend on the surrounding areas to serve the local load, but has a substantial amount of local generation which reduces the need for import capability when all units are available.

The major transmission elements that feed this subarea are:

- A 345/115 kV autotransformer at Haddam (Haddam 6X)
- A 115 kV line from Southington to Colony (Line 1355)
- A 115 kV line from Manchester to Hopewell (Line 1767)
- A 115 kV line from Branford to Stepstone (Line 1738)
- A 115 kV line from Berlin to Westside (Line 1765)

[redacted]

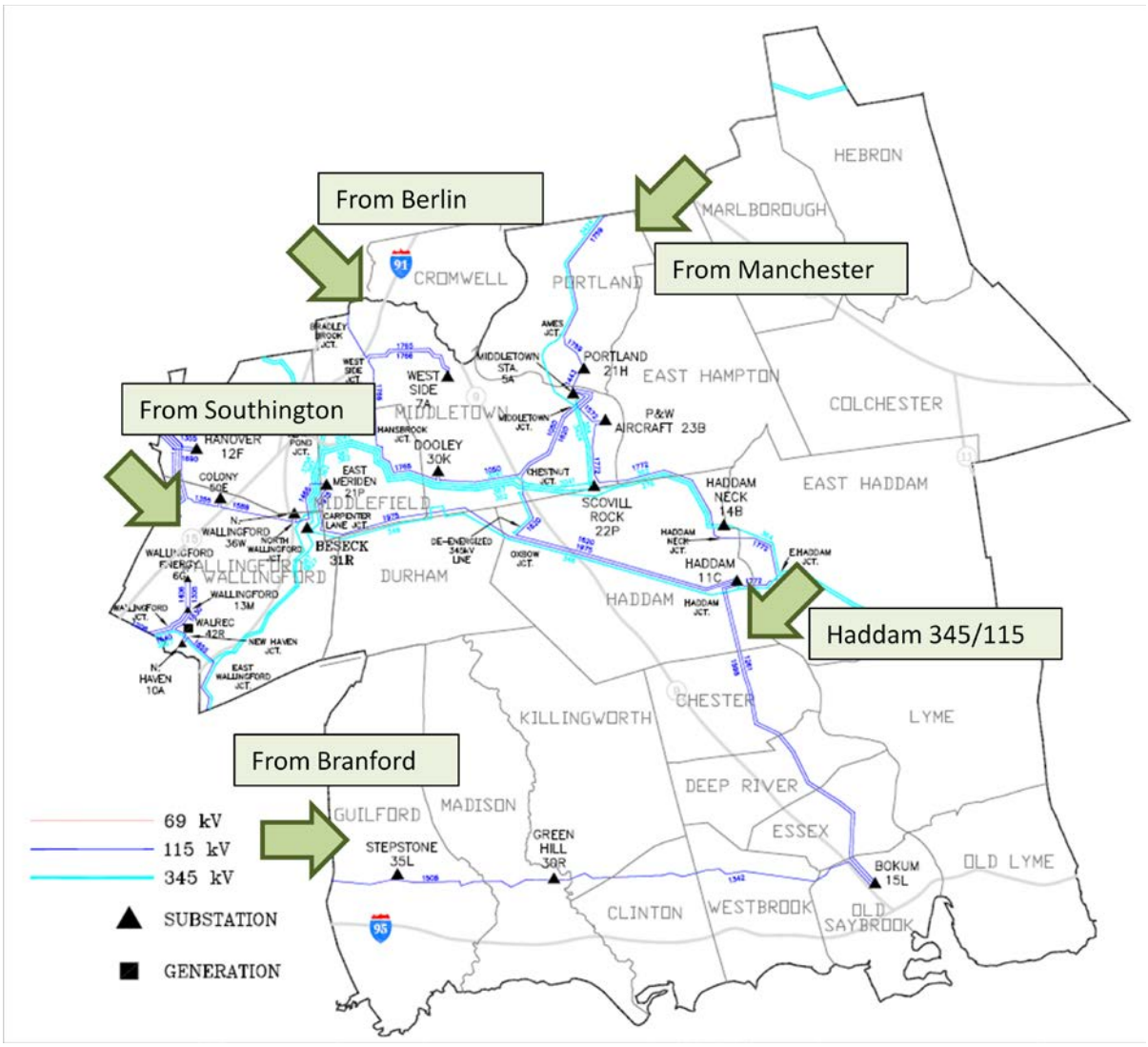


Figure 5-7: An Overview of the Middletown Subarea

A smaller load pocket between Haddam and Branford on the 115 kV network experiences some violations for all the dispatches. This load pocket consists of four substations totaling 180 MW of load including demand resources. The only unit in the subarea is the Branford 10 unit [redacted] The dispatch of other regular units has an insignificant impact on these violations.

This load pocket is fed by:

- Two 115 kV lines from Haddam to Bokum (Line 1261 and 1598)
- One 115 kV line from Branford - Stepstone (Line 1738)

Thermal and voltage violations are observed under N-1 and N-1-1 conditions [redacted].

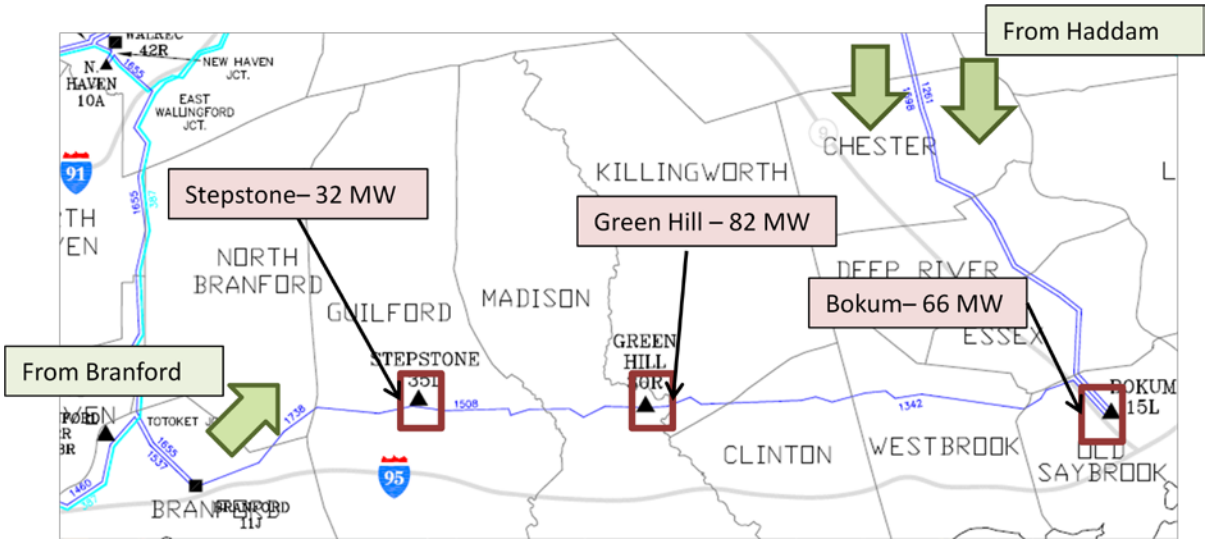


Figure 5-8: Branford - Haddam Load Pocket

In addition to the issues discussed above some other N-1 and N-1-1 criteria violations were also observed. The details of these violations are discussed in Section 5.2.3.

5.1.4 Northwestern Connecticut Subarea Overview

The Northwestern Connecticut (NWCT) subarea consists of about 511 MW of load including demand resources in 2022. The area has one generator at Forestville at 17 MW which is classified as a regular generator and a hydro station (Falls Village) that has a total qualified capacity of about 3MW. The hydro station is dispatched to 10% of its nameplate capacity (9 MW) at 0.9 MW, based on historical performance data for hydroelectric generation in the area during summer peak load conditions. The subarea also has two fast start generators at Franklin Drive and Torrington Terminal that total to 31 MW.

Looking at the load and generation it can be observed that the Northwestern Connecticut subarea is a net importer of energy and relies on the surrounding areas to serve local load. The major transmission elements that feed this subarea are:

- Two 115 kV lines from Southington (Line 1810 and 1800):
  - 1800: Southington – Forestville
  - 1810: Southington – Chippen Hill – Bristol
- A 115 kV line from N Bloomfield (Line 1256):
  - 1256: North Bloomfield – Northeast Simsbury
- A 115 kV line from Frost Bridge (Line 1191):
  - 1191: Frost Bridge – Chippen Hill
- A 69 kV line from New York (Line 690):
  - 690: Smithfield substation in NY to Salisbury substation in CT

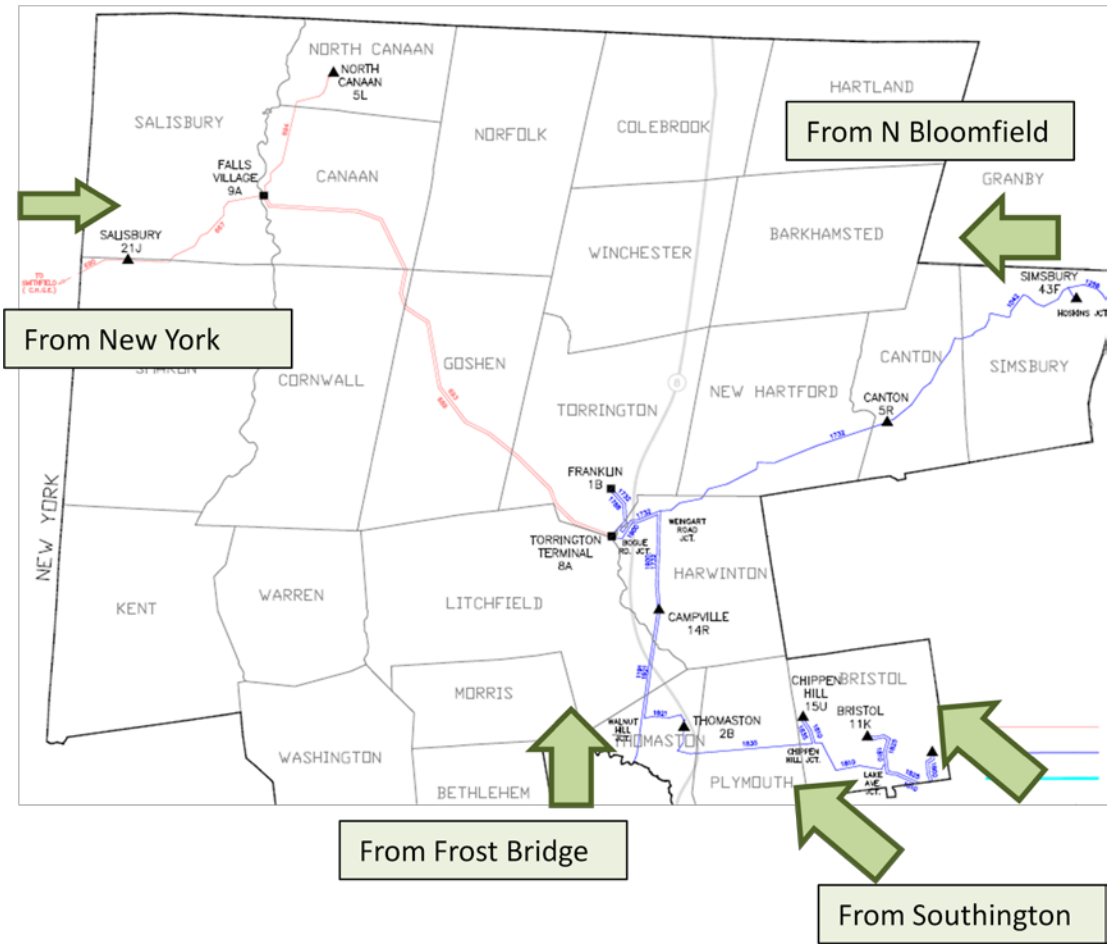


Figure 5-9: An Overview of the Northwestern Connecticut Subarea

[redacted]

The worst-case criteria violations are observed for the N-1-1 conditions [redacted] he criteria violations observed under N-1-1 conditions are almost identical with one or two units OOS.

In addition to the N-1-1 issues, some N-1 and N-0 criteria violations were also observed in the Northwestern Connecticut subarea. The details of these violations are discussed in Section 5.2.4.

5.2 Steady State Performance Criteria Compliance

The following sections provide the worst-case steady-state performance criteria violations for each of the four subareas studied. The information in the tables and the text captures the worst-case violations for each element that has at least one thermal or voltage violation. For a comprehensive list of all the base case conditions and contingencies for which overloads were observed, the tables provided in

Appendix E: Steady State Testing Results may be used. All thermal violations for N-1 and N-1-1 testing were based on the Long Term Emergency (LTE) rating of the different transmission facilities. Under N-0 conditions, the thermal overloads were based on the Normal rating of the transmission facilities.

For a number of contingency conditions the resultant voltages at some buses were very low. Under very low-voltage conditions there is a possibility that voltage collapse may occur since the load cannot be sustained at that low of a voltage magnitude. With the tools utilized in this study, the resultant voltage is obtained in many cases but the result may be misleading because instead of a low-voltage violation, a voltage collapse may occur. In reporting these results a threshold of 0.8 per unit of voltage was utilized, and if the resultant post contingency voltage was below 0.8 per unit, a footnote is added by an asterisk (*) indicating that a potential voltage collapse might occur.

In addition, when reviewing the results is that low voltages under post contingencies leads to higher current flow on the transmission elements. Hence, if a particular contingency causes thermal and low-voltage violations, the low voltage would typically aggravate the thermal loadings. If the voltage would be raised the thermal loadings on the line would be lower, thereby reducing the extent of the overload. If a voltage below 0.85 is observed in the vicinity of the overloaded element a footnote is added by a hashtag ($^{\#}$) indicting the low voltage is contributing to the thermal results.

5.2.1 Greater Hartford Subarea Steady-State Performance

The Greater Hartford subarea had four transmission elements with N-1 thermal violations and four 115 kV buses with N-1 low-voltage violations. Under N-1-1 conditions, there were 27 elements with thermal violations and ten 115 kV PTF buses with low-voltage violations. Two 115 kV non-PTF buses also had low voltages. There were no N-0 violations.

5.2.1.1 N-0 Thermal and Voltage Violation Summary

There were no N-0 violations in the Greater Hartford subarea.

5.2.1.2 N-1 Thermal and Voltage Violation Summary

The following Table 5-1 summarizes the worst-case 115 kV thermal violations seen in the Greater Hartford subarea. The corresponding violations are shown in Figure 5-10. The thermal violations can be classified into 3 categories:

- Dispatch independent violations (1726 and 1783-1)
- Thermal violations that are highest with low Hartford generation (1751)
- Thermal violations that are highest with high western CT import (Southington 2X)



Figure 5-10: N-1 Thermal Violations in the Greater Hartford Area

Table 5-1:
N-1 Thermal Violations in the Greater Hartford Area

Element ID	Overloading Element	Worst-case Contingency	Highest Loading (one unit OOS)	Highest Loading (two units OOS)	Comments
1726	North Bloomfield to Farmington		129%	129%	
1783-1	Farmington to Newington Tap		144%	144%	
1751-2	Bloomfield Junction to Northwest Hartford		104%	108%	
STGTN 2X	Southington 345/115 Autotransformer (2X)		103%	105%	

[redacted]

[redacted]

Table 5-2 summarizes the worst-case 115 kV voltage violations seen in the Greater Hartford subarea. The corresponding violations are shown in Figure 5-11. [redacted]

Table 5-2:
N-1 Voltage Violations in the Greater Hartford Subarea

Bus Name	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
East New Britain – 115 kV	[redacted]	0.85	0.85	[redacted]
Farmington – 115 kV	[redacted]	0.89	0.89	[redacted]
Newington – 115 kV	[redacted]	0.85	0.85	[redacted]
NW Hartford – 115 kV	[redacted]	0.94	0.94	[redacted]



Figure 5-11: N-1 Voltage Violations in the Greater Hartford Area

5.2.1.3 N-1-1 Thermal and Voltage Violation Summary

The following three tables summarize the worst-case thermal violations seen in the Greater Hartford subarea under N-1-1 conditions. The overloads are divided into three areas as discussed in Section 5.1.1.

Table 5-3 consists of the worst-case N-1-1 violations in the South Meadow, Berlin and Southington Load Area. The thermal violations are demonstrated in Figure 5-12. [redacted] The solution for this load pocket would need to be coordinated with the Middletown area solutions.



Figure 5-12: N-1 Thermal Violations in the Greater Hartford Area

Within this load area is a load pocket consisting of the Farmington, Newington and East New Britain stations. These violations are independent of generation dispatch and are seen in the last four entries in Table 5-3.

Table 5-3:
N-1-1 Thermal Violations in the South Meadow, Berlin and Southington Load Area

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
1670-1	Southington – Reservoir Rd Junction	[redacted]	[redacted]	102%	106%	[redacted]
1670-2	Reservoir Road Junction - Berlin	[redacted]	[redacted]	<100%	101%	[redacted]
1726	N Bloomfield to Farmington	[redacted]	[redacted]	158%#	167%#	[redacted]
1752	Rocky Hill- Berlin	[redacted]	[redacted]	101%#	108%#	[redacted]
1765	Berlin - Westside	[redacted]	[redacted]	<100%	147%#	[redacted]
1771	Southington - Berlin	[redacted]	[redacted]	<100%	105%	[redacted]

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
1773	South Meadow – Rocky Hill			150%#	158%#	
1783-1	Farmington to Newington Tap			190%#	205%#	
1769	Berlin to East New Britain			132%	132%	
1783-2	Newington Tap to Newington			149%#	149%#	
1783-3	East New Britain to Newington Tap			107%	107%	
1785	Berlin to Newington			189%#	189%#	

#Low Voltages Aggravate Thermal Loadings

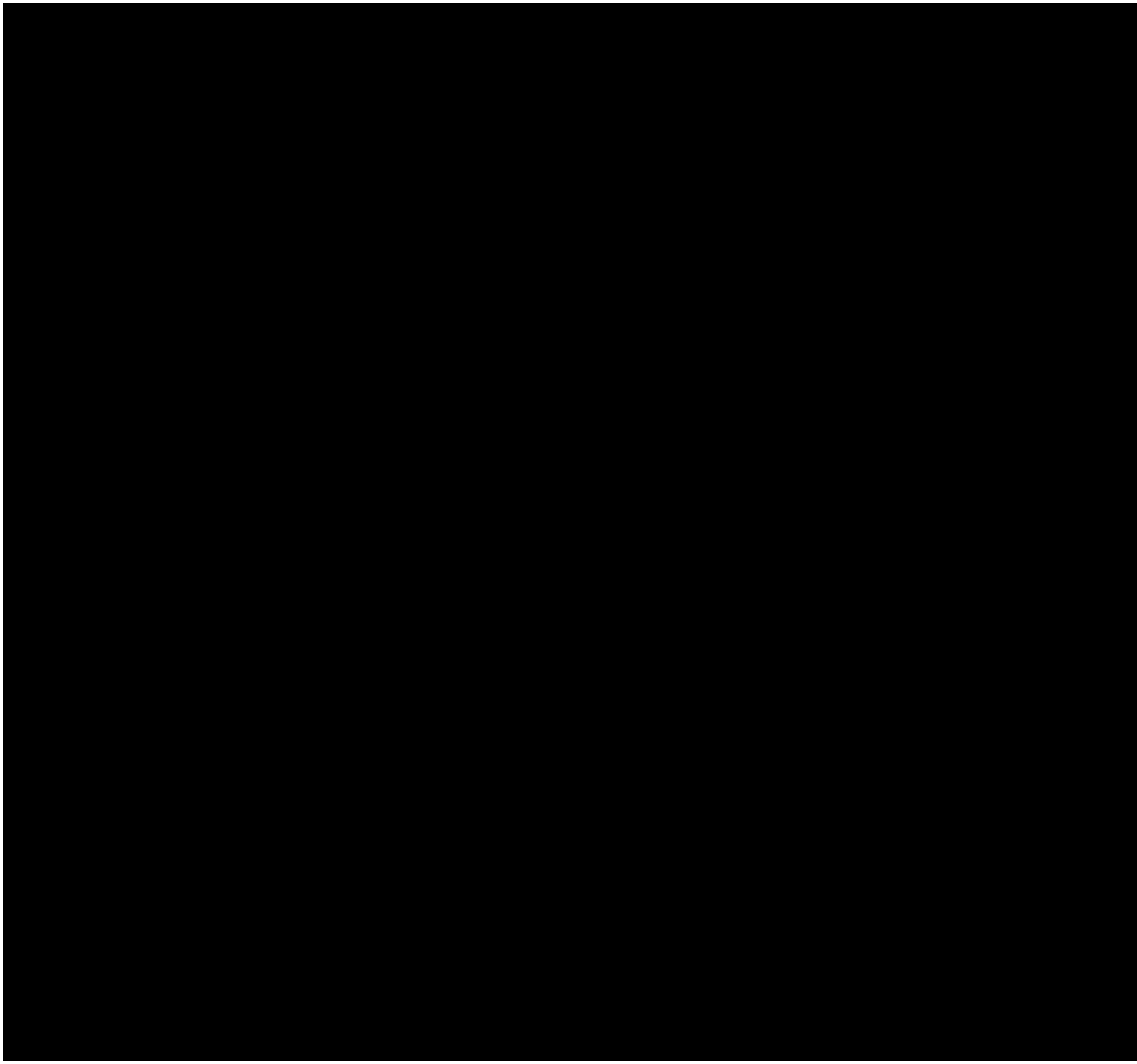


Figure 5-13: N-1-1 Thermal Violations in the South Meadow, Berlin and Southington Area

Table 5-4 consists of the N-1-1 thermal violations seen in the North Bloomfield to Manchester load area. The corresponding violations are shown in Figure 5-14.

Table 5-4:
N-1-1 Thermal Violations in the North Bloomfield – Manchester Load Area

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
1207	Manchester – East Hartford	[redacted]	[redacted]	119%	123%	[redacted]
1704	South Meadow to SW Hartford	[redacted]	[redacted]	131%	131%	[redacted]
1722-1	SW Hartford to Capitol District Tap	[redacted]	[redacted]	109%	109%	[redacted]
1722-2	Capitol District Tap to NW Hartford	[redacted]	[redacted]	116%	119%	[redacted]
1751-2	Bloomfield Junction to NW Hartford	[redacted]	[redacted]	165%	172%	[redacted]
1756	Bloomfield to NW Hartford	[redacted]	[redacted]	119%[#]	119%[#]	[redacted]
1777	N Bloomfield to Bloomfield	[redacted]	[redacted]	154%	160%	[redacted]
1775-1	Riverside Tap – South Meadow	[redacted]	[redacted]	111%	116%	[redacted]
1775-2	Manchester – Riverside Tap	[redacted]	[redacted]	117%	122%	[redacted]
1779	South Meadow to Bloomfield	[redacted]	[redacted]	174%[#]	174%[#]	[redacted]
1786	East Hartford – 1786 Tap	[redacted]	[redacted]	112%	117%	[redacted]
NWHTFD 32T	Breaker 32T Bus Segment	[redacted]	[redacted]	123%	127%	[redacted]

[#]Low Voltages Aggravate Thermal Loadings

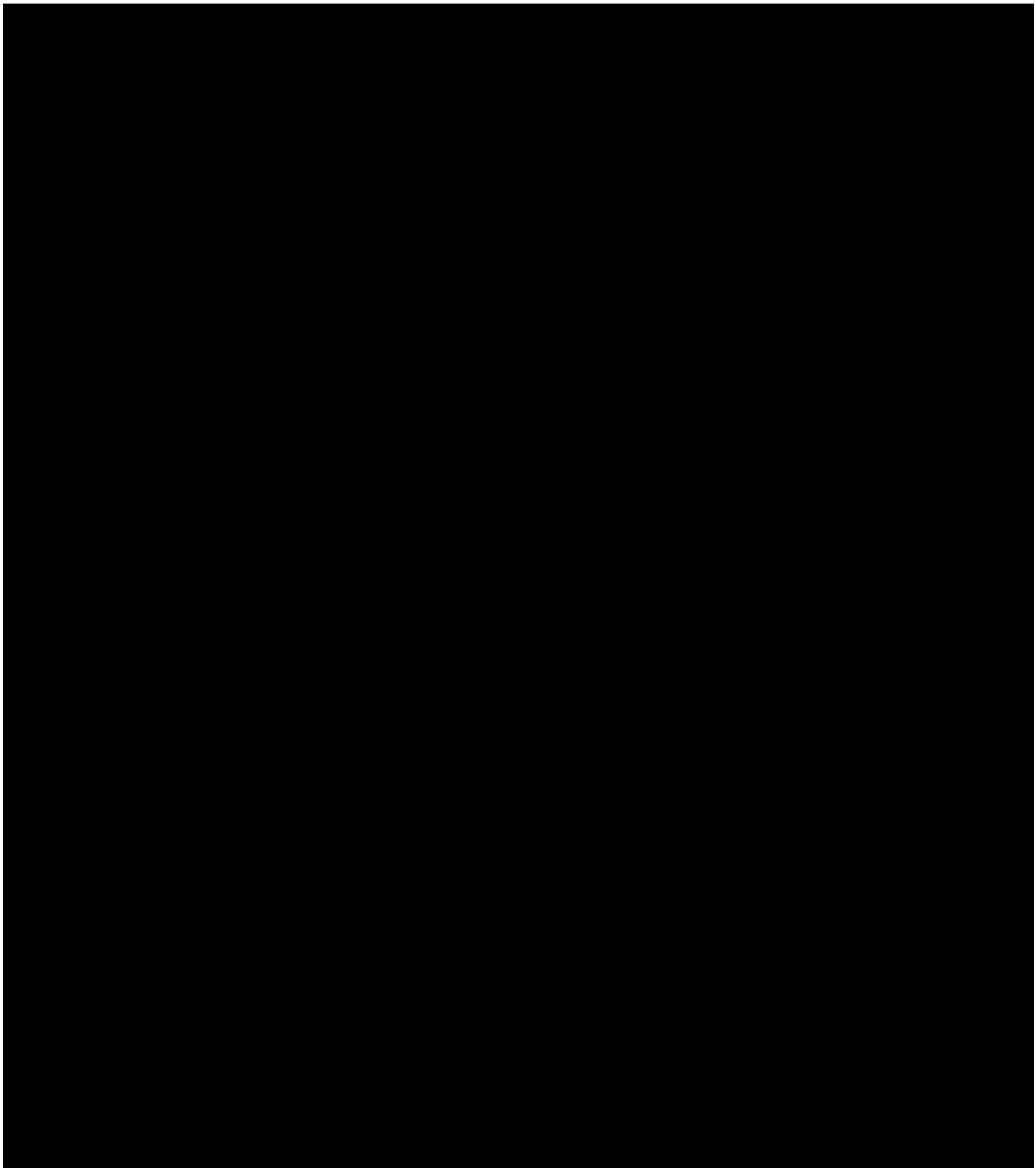


Figure 5-14: N-1-1 Thermal Violations in the North Bloomfield – Manchester Area

Finally, the last set of thermal violations in the Greater Hartford subarea under N-1-1 conditions are the two Southington 345/115 kV autotransformers (Southington 2X and Southington 3X) and a 115 kV lines between Southington and southwest Connecticut. These overloads are [redacted] shown in Table 5-5 and Figure 5-15 [redacted]

Table 5-5:
N-1-1 Thermal Violations in the Southington Area

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
STGTN 2X	Southington 345/115 Autotransformer	[redacted]	[redacted]	146%	148%	[redacted]
STGTN 2X	Southington 345/115 Autotransformer	[redacted]	[redacted]	114%	116%	
STGTN 3X	Southington 345/115 Autotransformer	[redacted]	[redacted]	114%	115%	
1950	Southington to Canal	[redacted]	[redacted]	N/A	101%	

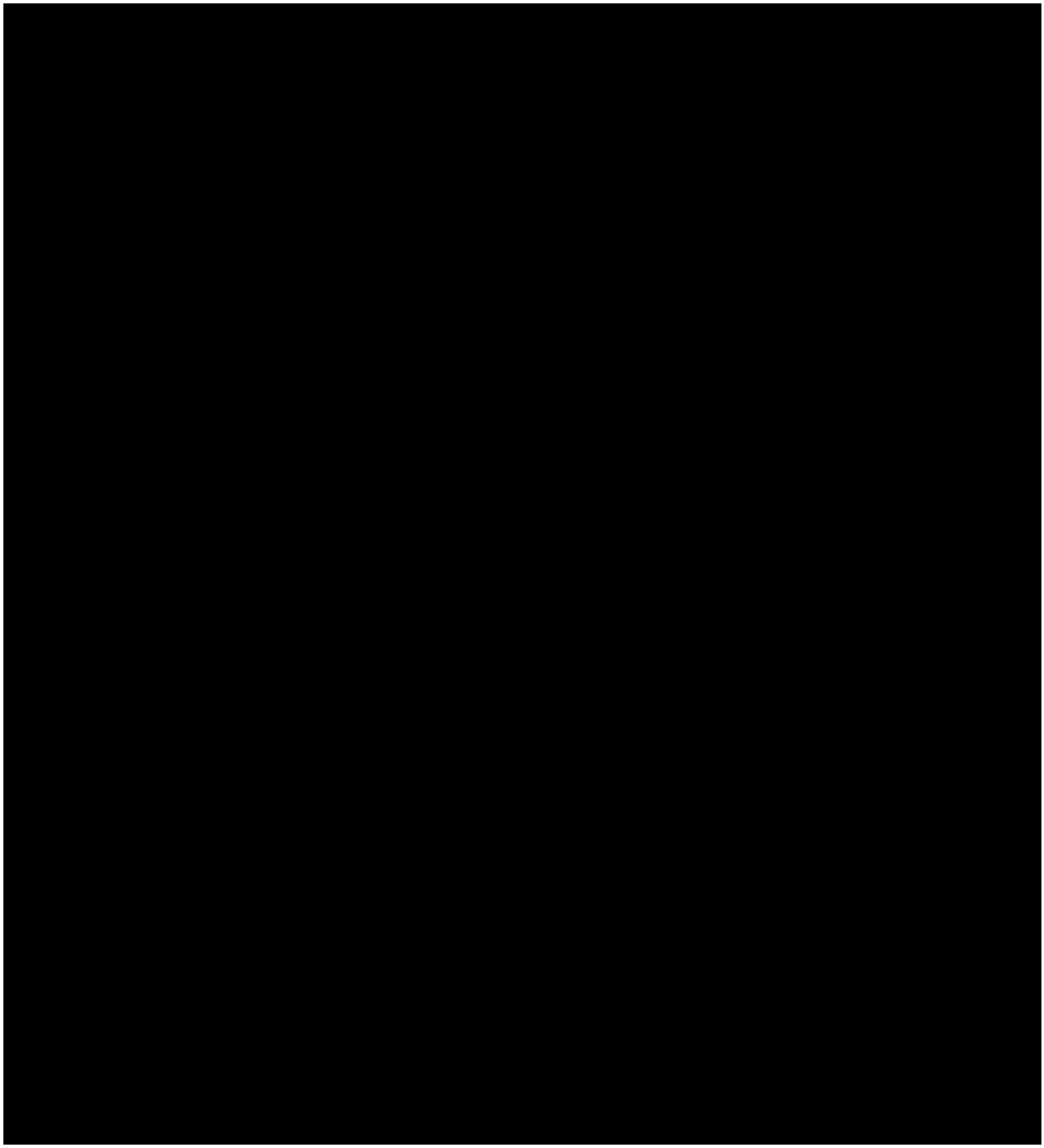


Figure 5-15: N-1-1 Thermal Violations in the Southington Area

The tables below summarize the worst-case voltage violations seen in the Greater Hartford subarea under N-1-1 conditions. Once again the violations are arranged with the three load areas. All violations observed were low-voltage violations.

Table 5-6 has the voltage violations seen in the South Meadow, Berlin and Southington Load Area

[redacted]

The last two entries in Table 5-6 are non-PTF buses in the Hartford subarea with voltage violations. The non-PTF violations will be recorded in this report but will not be specifically addressed in the solutions study report.

The voltage violations for the South Meadow, Berlin and Southington area are shown in Figure 5-16.

Table 5-6:
N-1-1 Voltage Violations in the South Meadow, Berlin and Southington Load Area

Bus Name	Initial Element OOS	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
East New Britain – 115 kV	[redacted]	[redacted]	0.82	0.82	[redacted]
Farmington – 115 kV	[redacted]	[redacted]	0.82	0.81	[redacted]
Newington – 115 kV	[redacted]	[redacted]	0.82	0.82	[redacted]
Berlin – 115 kV	[redacted]	[redacted]	0.84	0.83	[redacted]
Rocky Hill – 115 kV	[redacted]	[redacted]	0.83	0.82	[redacted]
Westside – 115 kV	[redacted]	[redacted]	0.93	0.81	[redacted]
Westside – 115 kV[17]	[redacted]	[redacted]	0.87	0.85	[redacted]
Black Rock – 115 kV (non-PTF)	[redacted]	[redacted]	0.83	0.82	[redacted]
GE – 115 kV (non-PTF)	[redacted]	[redacted]	0.84	0.82	[redacted]

[17] Additional entry to reflect worst-case One-unit out-of-service violation



Figure 5-16: N-1-1 Voltage Violations in the South Meadow, Berlin and Southington Load Area

Table 5-7 lists the voltage violations seen in the North Bloomfield - Manchester Load Area The voltage results for this area are shown in Figure 5-17.

Table 5-7:
N-1-1 Voltage Violations in the North Bloomfield – Manchester Load Area

Bus Name	Initial Element OOS	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
Bloomfield – 115 kV			0.83	0.82	
Capitol District – 115 kV			0.79*	0.79*	
NW Hartford – 115 kV			0.79*	0.79*	
SW Hartford – 115 kV			0.79*	0.79*	

*Indicates Potential Voltage Collapse



Figure 5-17: N-1-1 Voltage Violations in the North Bloomfield – Manchester Load Area

5.2.2 Manchester and Barbour Hill Area Steady-State Performance

The Manchester and Barbour Hill Area had five transmission elements with N-1-1 thermal violations and two 115 kV PTF buses with N-1-1 low voltage violations. Additionally, there were four non-PTF buses with N-1-1 voltage violations. There were no N-0 or N-1 steady-state criteria violations.

5.2.2.1 N-0 Thermal and Voltage Violation Summary

There were no N-0 violations in the Manchester and Barbour Hill subarea.

5.2.2.2 N-1 Thermal and Voltage Violation Summary

There were no N-1 violations in the Manchester and Barbour Hill subarea.

5.2.2.3 N-1-1 Thermal and Voltage Violation Summary

Table 5-8 lists the five transmission elements that have thermal violations in the Manchester-Barbour Hill area. The table also lists the worst-case contingency elements and conditions that lead to these violations.

[redacted]

All the worst-case thermal violations are demonstrated in Figure 5-18.

Table 5-8:
N-1-1 Thermal Violations in the Manchester and Barbour Hill Area

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
1310	Manchester – South Windsor	[redacted]	[redacted]	152%	153%	[redacted]
1635	South Windsor – Barbour Hill	[redacted]	[redacted]	134%	135%	[redacted]
1763	Manchester – Barbour Hill	[redacted]	[redacted]	146%	147%	[redacted]
MANCH 4X	Manchester 345/115 Autotransformer	[redacted]	[redacted]	119%	124%	[redacted]
MANCH 6X	Manchester 345/115 Autotransformer	[redacted]	[redacted]	122%	127%	[redacted]



Figure 5-18: N-1-1 Thermal Violations in the Manchester and Barbour Hill Area



Table 5-9 provides the worst-case N-1-1 low voltage violations in the Manchester and Barbour Hill area. [redacted] there is no significant difference in the extent of the voltage violation between the one and two units out of service cases.

The first two violations are observed at PTF buses whereas the last four buses are voltage violations at non-PTF buses.

The voltage violations for the Manchester-Barbour Hill area are demonstrated in Figure 5-19.

Table 5-9:
N-1-1 Voltage Violations in the Manchester and Barbour Hill Area

Bus Name	Initial Element OOS	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
Barbour Hill – 115 kV	[redacted]	[redacted]	0.87	0.87	[redacted]
South Windsor– 115 kV	[redacted]	[redacted]	0.92	0.92	[redacted]
Windsor Locks – 115 kV (Non-PTF)	[redacted]	[redacted]	0.85	0.85	[redacted]
Dexter– 115 kV (Non-PTF)	[redacted]	[redacted]	0.85	0.85	[redacted]
Enfield – 115 kV (Non-PTF)	[redacted]	[redacted]	0.85	0.85	[redacted]
Rockville – 115 kV (Non-PTF)	[redacted]	[redacted]	0.86	0.86	[redacted]



Figure 5-19: N-1-1 Voltage Violations in the Manchester and Barbour Hill Area

5.2.3 Middletown Subarea Steady-State Performance

The Middletown subarea had no N-1 thermal violations and three 115 kV buses with N-1 low voltage violations. Under N-1-1 conditions, there were 11 elements with thermal violations and fourteen 115 kV buses with low voltage violations. There were no N-0 violations.

5.2.3.1 N-0 Thermal and Voltage Violation Summary

There were no N-0 violations in the Middletown subarea.

5.2.3.2 N-1 Thermal and Voltage Violation Summary

There were no N-1 thermal violations observed in the Middletown area.
Table 5-10 summarizes the worst-case 115 kV voltage violations seen in the Middletown subarea.

The N-1 voltage violations in the Middletown subarea are shown in Figure 5-20.

Table 5-10:
N-1 Voltage Violations in the Middletown Subarea

Bus Name	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
Branford – 115 kV		0.92	0.92	
Green Hill – 115 kV		0.93	0.93	
Stepstone – 115 kV		0.92	0.92	



Figure 5-20: N-1 Voltage Violations in the Middletown Subarea

5.2.3.3 N-1-1 Thermal and Voltage Violation Summary

Table 5-11 summarizes the worst-case thermal violations seen in the Middletown subarea under N-1-1 conditions.

Table 5-11:
N-1-1 Thermal Violations in the Middletown Subarea

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
1355-1	Hanover Tap – Colony	[redacted]	[redacted]	126%#	148%#	[redacted]
1355-3	Southington – Hanover Tap	[redacted]	[redacted]	118%#	134%#	[redacted]
1443	Portland – Middletown	[redacted]	[redacted]	N/A	118%#	[redacted]
1588	Colony – N Wallingford	[redacted]	[redacted]	133%#	159%#	[redacted]
1759	Hopewell – Portland	[redacted]	[redacted]	N/A	132%#	[redacted]
1050	Middletown – Dooley	[redacted]	[redacted]	152%#	152%#	[redacted]
1766	Dooley - Westside	[redacted]	[redacted]	145%#	145%#	[redacted]
1261	Haddam - Bokum (Circuit 1)	[redacted]	[redacted]	107%#	107%#	[redacted]
1598	Haddam - Bokum (Circuit 2)	[redacted]	[redacted]	108%#	109%#	[redacted]
1620	Middletown – Haddam	[redacted]	[redacted]	111%	121%	[redacted]
362	Haddam Neck – Beseck	[redacted]	[redacted]	N/A	105%	[redacted]

#Low Voltages Aggravate Thermal Loadings

The thermal violations in the Middletown area are shown in the three diagrams that form Figure 5-21.

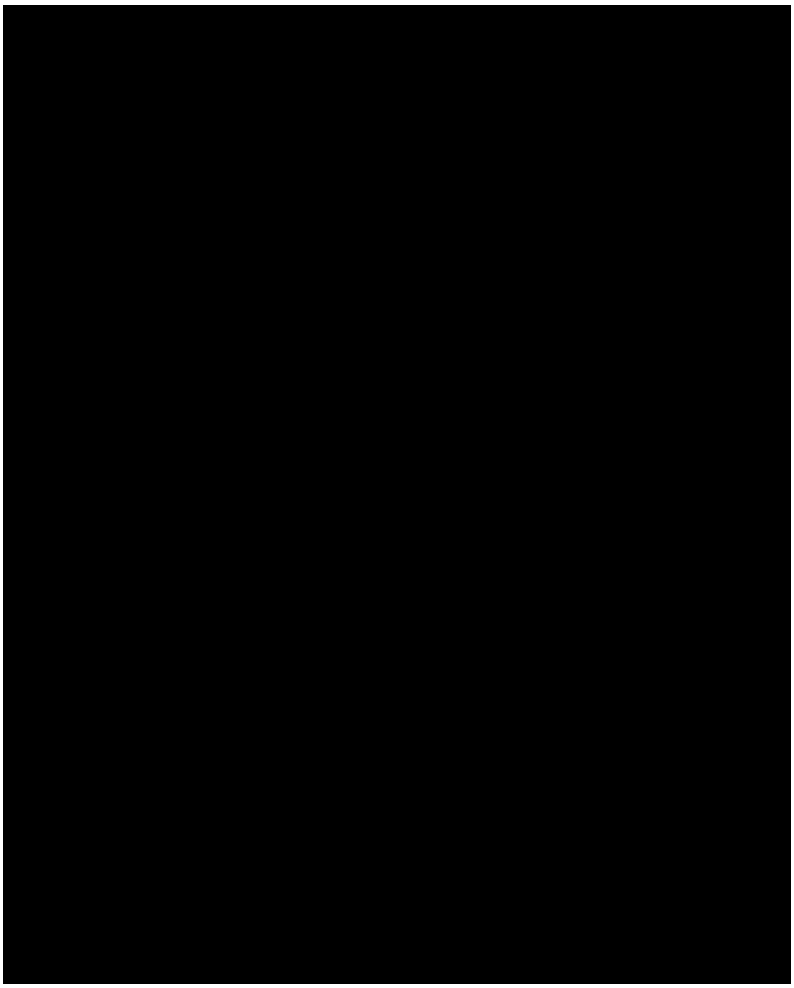




Figure 5-21: N-1-1 Thermal Violations in the Middletown Subarea

Table 5-12 summarizes the worst-case voltage violations seen in the Middletown subarea under N-1-1 conditions.

Table 5-12:
N-1-1 Voltage Violations in the Middletown Subarea

Bus Name	Initial Element OOS	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
Bokum – 115 kV	[redacted]	[redacted]	0.79*	0.74*	[redacted]
Branford – 115 kV	[redacted]	[redacted]	0.82	0.73*	[redacted]
Colony – 115 kV	[redacted]	[redacted]	0.88	0.84	[redacted]
Dooley – 115 kV	[redacted]	[redacted]	0.91	0.80	[redacted]
Dooley – 115 kV[18]	[redacted]	[redacted]	0.90	0.90	[redacted]
East Meriden – 115 kV	[redacted]	[redacted]	0.88	0.84	[redacted]
Green Hill – 115 kV	[redacted]	[redacted]	0.73*	0.68*	[redacted]
Haddam – 115 kV	[redacted]	[redacted]	0.84	0.78*	[redacted]
Hanover – 115 kV	[redacted]	[redacted]	0.91	0.87	[redacted]
Hopewell – 115 kV	[redacted]	[redacted]	0.85	0.72*	[redacted]
Middletown – 115 kV	[redacted]	[redacted]	0.90	0.77*	[redacted]
N-Wallingford – 115 kV	[redacted]	[redacted]	0.88	0.84	[redacted]
Portland – 115 kV	[redacted]	[redacted]	0.89	0.76*	[redacted]
Pratt & Whitney – 115 kV	[redacted]	[redacted]	0.91	0.82	[redacted]
Pratt & Whitney – 115 kV	[redacted]	[redacted]	0.89	0.83	[redacted]
Stepstone – 115 kV	[redacted]	[redacted]	0.73*	0.68*	[redacted]

*Indicates Potential Voltage Collapse

[18] Additional entry to reflect worst-case One-unit out-of-service violation

The voltage violations in the Middletown area are shown in the three diagrams that form Figure 5-22.







Figure 5-22: N-1-1 Voltage Violations in the Middletown Subarea

5.2.4 Northwestern Connecticut Subarea Steady-State Performance

The Northwestern Connecticut (NWCT) subarea had three transmission elements with N-1 thermal violations and five PTF buses with N-1 low-voltage violations. Two non-PTF buses had N-1 voltage violations. Under N-1-1 conditions, there were ten elements with thermal violations and twelve PTF buses with low voltage violations. Two non-PTF buses had N-1-1 voltage violations. There were no N-0 thermal violations, but one 69 kV non-PTF bus had N-0 basecase voltage violation.

5.2.4.1 N-0 Thermal and Voltage Violation Summary

There were no N-0 thermal violations in the NWCT subarea.

From a voltage violation perspective, there was one bus with base case low voltage violations on the 69 kV network in Northwestern CT. Table 5-13 summarizes the worst-case N-0 voltage violations in the NWCT subarea. The North Canaan 69 kV bus is a non-PTF bus and is radial out of the PTF bus at Torrington 69 kV.

Table 5-13:
N-0 Voltage Violations in the NWCT Subarea

Bus Name	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
North Canaan – 69 kV (non-PTF)	Basecase	N/A	0.94	Lowest voltages seen for NWCT Gen OOS

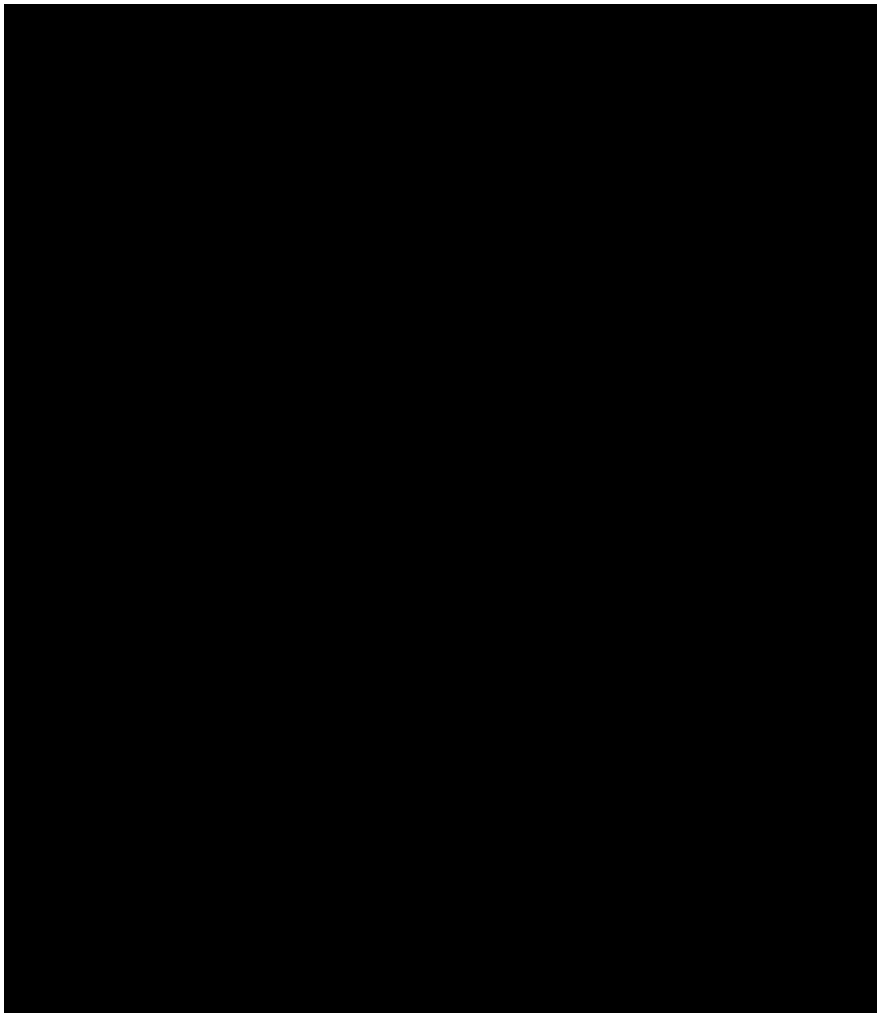


Figure 5-23 N-0 Voltage Violations in the NWCT Subarea

5.2.4.2 N-1 Thermal and Voltage Violation Summary

Table 5-14 summarizes the worst-case thermal violations under N-1 conditions in the Northwestern Connecticut subarea.

The N-1 thermal violations in the NWCT subarea are shown in Figure 5-24.

Table 5-14:
N-1 Thermal Violations in the NWCT Subarea

Element ID	Overloading Element	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
1191	Frost Bridge - Campville	[redacted]	N/A	101%	[redacted]
1810-1	Southington – Lake Ave Junction	[redacted]	100%	101%	[redacted]
1825	Bristol - Forestville	[redacted]	114%	114%	[redacted]

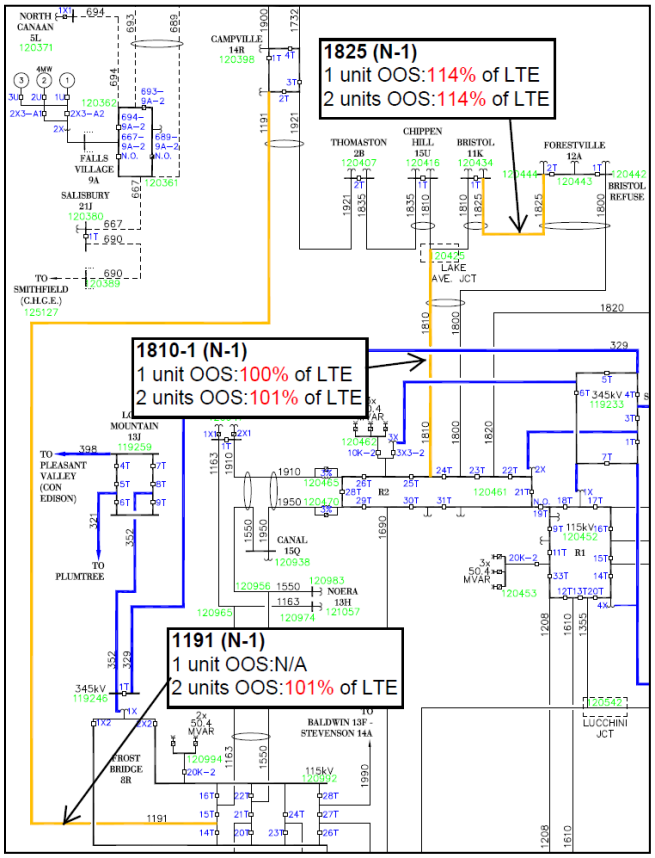


Figure 5-24: N-1 Thermal Violations in the NWCT Subarea

Table 5-15 summarizes the worst-case N-1 voltage violations in the NWCT subarea. [redacted]
The N-1 voltage violations in the NWCT subarea are shown in Figure 5-25.

Table 5-15:
N-1 Voltage Violations in the NWCT Subarea

Bus Name	Worst-case Contingency	Worst-case Voltage Violations (One unit OOS)	Worst-case Voltage Violations (Two units OOS)	Comments
Campville – 115 kV	[redacted]	0.90	0.89	[redacted]
Canton – 115 kV	[redacted]	0.87	0.87	[redacted]
Forestville – 115 kV	[redacted]	0.92	0.92	[redacted]
Franklin Drive – 115 kV	[redacted]	0.90	0.90	[redacted]
Torrington Terminal – 115 kV	[redacted]	0.90	0.90	[redacted]
Falls Village – 69 kV (non - PTF)	[redacted]	0.93	0.92	[redacted]
North Canaan– 69 kV (non - PTF)	[redacted]	0.91	0.91	[redacted]



Figure 5-25: N-1 Voltage Violations in the NWCT Subarea

5.2.4.3 N-1-1 Thermal and Voltage Violation Summary

Table 5-16 provides the worst-case N-1-1 thermal violations that were observed in the NWCT subarea. [redacted]

Table 5-16:
N-1-1 Thermal Violations in the NWCT Subarea

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Highest Loading (One unit OOS)	Highest Loading (Two units OOS)	Comments
1191	Frost Bridge - Campville	[redacted]	[redacted]	172%	172%	[redacted]
1256	NE Simsbury - Canton	[redacted]	[redacted]	142%#	142%#	[redacted]
1732	Weingarten Junction – Franklin Drive	[redacted]	[redacted]	N/A	119%#	[redacted]
1810-1	Southington – Lake Ave Junction	[redacted]	[redacted]	149%#	149%#	[redacted]
1810-3	Lake Ave Junction – Chippen Hill	[redacted]	[redacted]	228%#	229%#	[redacted]
1825	Bristol - Forestville	[redacted]	[redacted]	114%	114%	[redacted]
1835	Chippen Hill - Thomaston	[redacted]	[redacted]	210%#	210%#	[redacted]
1921	Thomaston - Campville	[redacted]	[redacted]	165%#	166%#	[redacted]
Campville 1T	Breaker 1T Bus Segment	[redacted]	[redacted]	107%	107%	[redacted]
Campville 3T	Breaker 3T Bus Segment	[redacted]	[redacted]	153%#	153%#	[redacted]

#Low Voltages Aggravate Thermal Loadings

The N-1-1 thermal violations in the NWCT subarea are highlighted in Figure 5-26.



Figure 5-26: N-1-1 Thermal Violations in the NWCT Subarea

Table 5-17 provides the worst-case voltage violations in the NWCT subarea. The violations have also been included in Figure 5-27.

Table 5-17:
N-1-1 Low-Voltage Violations in the NWCT Subarea

Bus Name	Initial Element OOS	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
Bristol – 115 kV	[redacted]	[redacted]	0.94	0.93	[redacted]
Campville – 115 kV	[redacted]	[redacted]	0.70*	0.70*	[redacted]
Canton – 115 kV	[redacted]	[redacted]	0.66*	0.66*	[redacted]
Chippen Hill – 115 kV	[redacted]	[redacted]	0.68*	0.68*	[redacted]
Forestville – 115 kV	[redacted]	[redacted]	0.90	0.90	[redacted]
Franklin Drive – 115 kV	[redacted]	[redacted]	0.69*	0.69*	[redacted]
NE Simsbury – 115 kV	[redacted]	[redacted]	0.66*	0.65*	[redacted]
Thomaston – 115 kV	[redacted]	[redacted]	0.69*	0.69*	[redacted]
Torrington Terminal – 115 kV	[redacted]	[redacted]	0.69*	0.69*	[redacted]
Falls Village – 69 kV (PTF)	[redacted]	[redacted]	0.71*	0.70*	[redacted]
Salisbury – 69 kV	[redacted]	[redacted]	0.69*	0.69*	[redacted]

Bus Name	Initial Element OOS	Worst-Case Contingency	Worst-Case Voltage Violations (One unit OOS)	Worst-Case Voltage Violations (Two units OOS)	Comments
					[redacted]
Torrington – 69 kV	[redacted]	[redacted]	0.74*	0.73*	[redacted]
Falls Village – 69 kV (non - PTF)	[redacted]	[redacted]	0.67*	0.66*	[redacted]
North Canaan– 69 kV (non - PTF)	[redacted]	[redacted]	0.65*	0.65*	[redacted]

*Indicates Potential Voltage Collapse

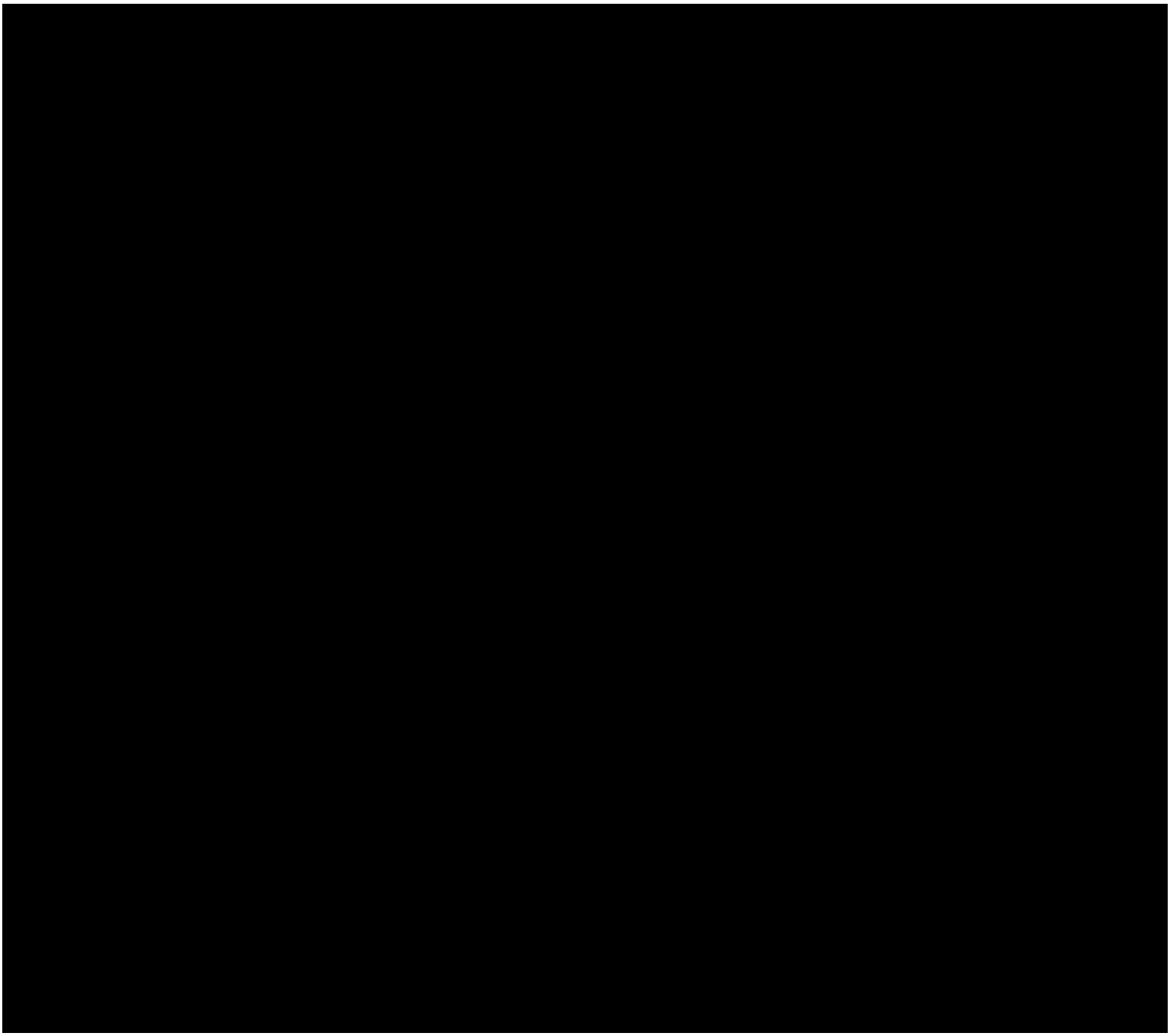


Figure 5-27: N-1-1 Low-Voltage Violations in the NWCT Subarea

Finally, Table 5-18 below provides the N-1-1 contingency conditions that led to potential voltage collapse

Table 5-18:
N-1-1 Non-Convergence in the NWCT Subarea – Pre 690 SPS

Line Out	Second Contingency	Comments
[redacted]	[redacted]	Independent of dispatch assumptions (SPS Action would isolate load)
[redacted]	[redacted]	Independent of dispatch assumptions (SPS Action would isolate load)

5.2.5 Discussion of the 690 SPS

[redacted]

[redacted]

[redacted]

The review of the 690 SPS and the future operation of the areas impacted by the SPS will not be conducted in the ensuing solutions study report. This matter will be dealt separately in coordination with NYISO.

5.2.6 Discussion of Western Connecticut Import

One of the objectives of this Needs Assessment was to reassess the need for the CCRP project which was one of the four components of the New England East West Solution (NEEWS) project. The need for the CCRP project was based on increasing the transfer capability across the western Connecticut import interface. The western Connecticut Import interface has three 345 kV lines that connect the generation rich eastern Connecticut with the load in western Connecticut (348, 364 and 3533). [redacted] The solution to that need was identified as a new 345 kV line that crosses the interface from North Bloomfield to Frost Bridge.

However, as detailed in Sections 5.2.1 through 5.2.4, with the exception of overloads on the 362 line from Haddam Neck to Beseck, there were no other 345 kV violations. This may be attributed to the new generation and demand resources that have been procured in western Connecticut in FCA #1 through FCA #7.

However, a number of 115 kV lines and 345/115 kV autotransformers have thermal overloads that are either seen for the high Western Connecticut Import dispatches, or are driven by the loss of two 345 kV lines that form the Western Connecticut Import interface. [redacted] The detailed contingency results in Appendix E: Steady State Testing Results reports these overloads. Therefore, it may be concluded that the original need for increased Western Connecticut Import has diminished but it has not been eliminated. Additionally, a majority of the elements that have violations in either high Western Connecticut Import dispatches or for contingencies involving loss of elements which form the Western Connecticut Import interface also have violations for local area contingencies.

5.2.7 Extreme Contingency Testing

As a part of this Needs Assessment, a number of extreme contingencies (NERC Category D contingencies) were tested. The full list of the extreme contingencies tested can be found in Appendix D: Contingency Listings. According to NERC, NPCC and ISO-NE standards, the extreme contingency testing is required to understand the risks and impacts to the system following an extreme event. NERC, NPCC and ISO-NE standards do not require that corrective plans be identified for the violations following these events but rather document the results of the assessment.

Therefore, as part of this study there will be no development of solutions to address violations that result from the extreme contingencies tested but the results may influence the selection of preferred solutions selected to address other violations. The results of the extreme contingency testing can be found in Appendix F: Extreme Contingency Testing Results.

5.3 Stability Performance Criteria Compliance

Not applicable for this study.

5.3.1 Stability Test Results Summary

Not applicable for this study.

5.4 Short Circuit Performance Criteria Compliance

5.4.1 Short Circuit Test Results Summary

[redacted]

Table 5-19:
Summary of Circuit Breakers with Duties Greater than 90% of Interrupting Rating

Substation & Voltage	Breaker Id	Breaker Rating	Breaker Duty (%)
[redacted]	[redacted]	[redacted]	[redacted]

Appendix G: Short Circuit Testing Results has the detailed results for all the substations analyzed.

Section 6
Critical Load Level Assessment

6.1 Critical Load Level Methodology

The critical load level assessment was conducted to determine the load levels at which the criteria violations would be first seen. Since the issues were driven by low voltages and high thermal loadings, reducing load in the study area should reduce the thermal loadings and raise the voltages. The analysis determines the critical load level at which the overloading elements are at or below 100% of their summer LTE rating and the buses with voltage violations have post-contingency voltages that are at or above 0.95 per unit.

Since Connecticut is located at one end of the New England system, the load outside of Connecticut would have a minimal impact on thermal loadings and voltage violations in Connecticut. Hence, as a part of the critical load level assessment, the only load that was scaled down was Connecticut load. The load in the remaining parts of New England was maintained at expected 2022 load levels. Additionally, the generation in Connecticut was kept constant in the critical load level assessment. As load in Connecticut was scaled down, the generation far away from Connecticut, in Southeastern Massachusetts, Boston, Maine, and New Hampshire was scaled down. Thus, as load decreased in Connecticut, Connecticut import decreased.

6.2 Critical Contingency Pairs and Dispatches

For each element with a thermal or voltage violation, the contingency pair and base case with the worst-case violation was included in the analysis. [redacted]

The details of the elements and the corresponding contingency pairs tested are provided in Appendix H: Critical Load Level Assessment Testing.

6.3 Comparison of Critical Load Levels with CT Forecasted loads

Table 6-1 provides the net load expected in Connecticut for the 2013-2022 timeframe. The loads exclude the transmission losses. The details for the net load calculation are provided in Appendix J: Net Load in Connecticut Calculation.

Hence a critical load level of 7,400 MW indicates that the need is expected to be seen in the 2015-2016 timeframe. For all loads below 7,055 MW, the year of need is prior to 2013. Note that that 2013 load in the table below is based on the 2013 summer peak load forecast in the 2013 CELT and is not the actual load for 2013.

Table 6-1: Projected Load in Connecticut 2013-2022 (Load – Available DR)

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CT Load – DR (MW): Excluding Transmission Losses	7,055	7,165	7,292	7,456	7,568	7,620	7,677	7,721	7,777	7,819

6.4 Results of Critical Load Level Assessment

The details of the critical load level assessment for each subarea are provided in Appendix I: Critical Load Level Assessment Results. The details include the following:

- Element for which the critical load level was developed – Transmission element or bus
- Critical contingency pair being analyzed
- Dispatch that was analyzed
- Critical load level – Connecticut load minus DR at which violations are expected to be eliminated. This load excludes transmission losses.
- Final thermal loading or bus voltage

The following sections summarize the results for each subarea. The lowest critical load level for each element has been identified in the tables below.

6.4.1 Greater Hartford Subarea

Table 6-2 summarizes the critical load levels for the subarea buses with thermal violations.

Table 6-2:
Greater Hartford Subarea Critical Load Levels for Thermal Violations

Element ID	Overloading Element	Critical Load Level (CT Load) - MW	Year of Need
1207	Manchester – E Hartford	6,959	Pre-2013
1670-1	Southington – Reservoir Rd Jct	7,195	2014-2015
1670-2	Reservoir Rd Jct - Berlin	7,287	2014-2015
1704	S Meadow - SW Hartford	6,412	Pre-2013
1722-1	SW Hartford – Capitol District Tap	7,334	2015-2016
1722-2	Capitol District Tap – NW Hartford	6,850	Pre-2013
1726	N Bloomfield - Farmington	5,787	Pre-2013
1751	Bloomfield Jct. – NW Hartford	5,959	Pre-2013
1752	Rocky Hill – Berlin	7,537	2016-2017
1756	Bloomfield – NW Hartford	7,194	2014-2015
1765	Berlin - Westside	5,522	Pre-2013
1769	Berlin – E New Britain	6,475	Pre-2013
1771	Southington - Berlin	7,256	2014-2015
1773	S Meadow – Rocky Hill	5,912	Pre-2013
1775-1	Riverside Tap – S Meadow	7,225	2014-2015

Element ID	Overloading Element	Critical Load Level (CT Load) - MW	Year of Need
1775-2	Manchester – Riverside Tap	7,006	Pre-2013
1777	N Bloomfield - Bloomfield	6,170	Pre-2013
1779	S Meadow - Bloomfield	5,600	Pre-2013
1785	Berlin - Newington	4,756	Pre-2013
1783-1	Farmington – Newington Tap	5,147	Pre-2013
1783-2	Newington Tap - Newington	5,756	Pre-2013
1783-3	E New Britain – Riverside Tap	7,342	2015-2016
1786	E Hartford – S Meadow	7,209	2014-2015
1950	Southington – Canal	7,287	2014-2015
NW HTFD 32T	NW Hartford 32T Bus Segment	6,553	Pre-2013
STGTN 2X	Southington 2X Auto	4,819	Pre-2013
STGTN 3X	Southington 3X Auto	6,600	Pre-2013

Table 6-3 summarizes the critical load levels for the subarea buses with voltage violations.

Table 6-3:
Greater Hartford Subarea Critical Load Levels for Voltage Violations

Bus Name – Voltage	Critical Load Level (CT Load) - MW	Year of Need
Berlin – 115 kV	6,194	Pre-2013
Bloomfield – 115 kV	5,569	Pre-2013
Capitol District – 115 kV	5,069	Pre-2013
E New Britain – 115 kV	4,319	Pre-2013
Farmington – 115 kV	5,819	Pre-2013
Newington – 115 kV	4,444	Pre-2013
NW Hartford – 115 kV	5,069	Pre-2013
Rocky Hill – 115 kV	6,069	Pre-2013
SW Hartford – 115 kV	5,069	Pre-2013
Westside – 115 kV	4,694	Pre-2013
Black Rock – 115 kV (Non-PTF)	6,069	Pre-2013
GE – 115 kV (Non-PTF)	6,131	Pre-2013

6.4.2 Manchester-Barbour Hill Subarea

Table 6-4 summarizes the critical load levels for the subarea buses with thermal violations.

Table 6-4:
Manchester-Barbour Hill Subarea Critical Load Levels for Thermal Violations

Element ID	Overloading Element	Critical Load Level (CT Load) - MW	Year of Need
1310	Manchester – South Windsor	5,631	Pre-2013
1635	South Windsor – Barbour Hill	6,256	Pre-2013
1763	Manchester – Barbour Hill	5,616	Pre-2013
MANCH 4X	Manchester 345/115 Autotransformer	6,944	Pre-2013
MANCH 6X	Manchester 345/115 Autotransformer	6,762	Pre-2013

Table 6-5 summarizes the critical load levels for the subarea buses with voltage violations.

Table 6-5:
Manchester-Barbour Hill Subarea Critical Load Levels for Voltage Violations

Bus Name	Critical Load Level (CT Load) - MW	Year of Need
Barbour Hill – 115 kV	5,069	Pre-2013
S Windsor – 115 kV	6,319	Pre-2013
Dexter – 115 kV (Non-PTF)	4,569	Pre-2013
Enfield – 115 kV (Non-PTF)	4,569	Pre-2013
Rockville – 115 kV (Non-PTF)	4,819	Pre-2013
Windsor Locks – 115 kV (Non-PTF)	4,569	Pre-2013

6.4.3 Middletown Subarea

Table 6-6 summarizes the critical load levels for the subarea buses with thermal violations.

Table 6-6:
Middletown Subarea Critical Load Levels for Thermal Violations

Element ID	Overloading Element	Critical Load Level (CT Load) - MW	Year of Need
362	Haddam Neck – Beseck	7,475	2016-2017
1050	Middletown – Dooley	3,819	Pre-2013
1261	Haddam - Bokum (Circuit 1)	7,545	2016-2017
1443	Portland – Middletown	6,850	Pre-2013
1588	Colony – N Wallingford	4,912	Pre-2013
1598	Haddam - Bokum (Circuit 2)	7,541	2016-2017

Element ID	Overloading Element	Critical Load Level (CT Load) - MW	Year of Need
1620	Middletown – Haddam	6,694	Pre-2013
1759	Hopewell – Portland	6,491	Pre-2013
1766	Dooley - Westside	3,444	Pre-2013
1355-1	Hanover Tap – Colony	5,444	Pre-2013
1355-3	Southington – Hanover Tap	6,100	Pre-2013

Table 6-7 below summarizes the critical load levels for the subarea buses with voltage violations.

Table 6-7:
Middletown Subarea Critical Load Levels for Voltage Violations

Bus Name	Critical Load Level (CT Load) - MW	Year of Need
Branford – 115 kV	6,194	Pre-2013
Bokum – 115 kV	4,694	Pre-2013
Colony – 115 kV	4,569	Pre-2013
Dooley – 115 kV	4,319	Pre-2013
East Meriden – 115 kV	4,694	Pre-2013
Green Hill – 115 kV	4,069	Pre-2013
Haddam – 115 kV	5,194	Pre-2013
Hanover – 115 kV	5,694	Pre-2013
Hopewell – 115 kV	3,694	Pre-2013
Middletown – 115 kV	4,069	Pre-2013
N Wallingford – 115 kV	4,694	Pre-2013
Portland – 115 kV	3,944	Pre-2013
Pratt and Whitney – 115 kV	5,319	Pre-2013
Stepstone – 115 kV	4,069	Pre-2013

6.4.4 Northwestern Connecticut Subarea

Table 6-8 summarizes the critical load levels for the subarea elements with thermal violations.

Table 6-8:
NWCT Subarea Critical Load Levels for Thermal Violations

Element ID	Overloading Element	Critical Load Level (CT Load) - MW	Year of Need
1191	Frost Bridge - Campville	4,600	Pre-2013
1256	NE Simsbury - Canton	6,944	Pre-2013
1732	Campville – Weingarten Jct.	7,616	2017-2018
1810-1	Southington – Lake Ave Junction	6,241	Pre-2013
1810-3	Lake Ave Junction – Chippen Hill	4,225	Pre-2013
1825	Bristol - Forestville	6,174	Pre-2013
1835	Chippen Hill - Thomaston	4,787	Pre-2013
1921	Thomaston - Campville	6,006	Pre-2013

Element ID	Overloading Element	Critical Load Level (CT Load) - MW	Year of Need
CAMP 1T	Campville 1T Breaker Bus Segment	7,444	2015-2016
CAMP 3T	Campville 3T Breaker Bus Segment	6,381	Pre-2013

Table 6-9 summarizes the critical load levels for the subarea buses with voltage violations.

Table 6-9:
NWCT Subarea Critical Load Levels for Voltage Violations

Bus Name	Critical Load Level (CT Load) - MW	Year of Need
Bristol – 115 kV	6,951	Pre-2013
Campville – 115 kV	5,819	Pre-2013
Canton – 115 kV	5,819	Pre-2013
Chippen Hill – 115 kV	5,819	Pre-2013
Forestville – 115 kV	5,694	Pre-2013
Franklin Drive – 115 kV	5,819	Pre-2013
NE Simsbury – 115 kV	5,787	Pre-2013
Thomaston – 115 kV	5,944	Pre-2013
Torrington – 115 kV	5,819	Pre-2013
Falls Village – 69 kV (PTF)	6,944	Pre-2013
Salisbury – 69 kV	6,951	Pre-2013
Torrington – 69 kV	6,881	Pre-2013
Falls Village – 69 kV (Non - PTF)	6,444	Pre-2013
North Canaan – 69 kV (Non - PTF)	6,381	Pre-2013

Section 7 Conclusions on Needs Analysis

7.1 Statement of Needs

All the criteria violations observed in the Greater Hartford and Central Connecticut (GHCC) area were based on steady state thermal and voltage testing. The following summarizes the needs for each subarea:

Greater Hartford Subarea

- Need to resolve N-1 and N-1-1 criteria violations observed in the Greater Hartford area
- Thermal and voltage violations observed in the following areas:
    - North Bloomfield to Manchester area
    - South Meadow – Berlin – Southington area
    - Southington area
- [redacted]

Middletown Subarea:

- Need to resolve the N-1 and N-1-1 criteria violations observed in the Middletown area
- [redacted]

Manchester – Barbour Hill Subarea

- Need to resolve the N-1-1 criteria violations observed in serving load in the Manchester/Barbour Hill area
- [redacted]

Northwestern Connecticut Subarea:

- Need to resolve N-1 and N-1-1 criteria violations observed in serving load in the Northwest Connecticut area
- [redacted]

Western Connecticut Interface:

- Need to resolve N-1-1 criteria violations observed [redacted]

The needs are interrelated with the needs in the four subareas listed above

7.2 Critical Load Levels

The following sections summarize the critical load levels for each subarea at which all thermal and voltage violations are expected to be resolved. The critical load levels are provided in terms of Connecticut load including demand resources and energy efficiency and the numbers exclude transmission losses.

7.2.1 Summary of Results for Greater Hartford Subarea

The majority of the worst-case violations in the Greater Hartford subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 4,756 MW and the net Connecticut load at which all voltage violations would be resolved is 4,319 MW.

7.2.2 Summary of Results for Manchester-Barbour Hill Subarea

The majority of the worst-case violations in the Manchester-Barbour Hill subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 5,616 MW and the net Connecticut load at which all the PTF voltage violations would be resolved is 5,069 MW. The non-PTF voltage violations would only be resolved at a net Connecticut load level of 4,569 MW.

7.2.3 Summary of Results for Middletown Subarea

The majority of the worst-case violations in the Middletown subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 3,444 MW and the net Connecticut load at which all voltage violations would be resolved is 3,694 MW.

7.2.4 Summary of Results for Northwestern CT Subarea

The majority of the worst-case violations in the Northwestern Connecticut subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 4,225 MW and the net Connecticut load at which all voltage violations would be resolved is 5,694 MW.

Section 8
Appendix A: Load Forecast

Table 8-1:
2013 CELT Seasonal Peak Load Forecast Distributions

		Peak Load Forecast at Milder Than Expected Weather				Reference Forecast at Expected Weather	Peak Load Forecast at More Extreme Than Expected Weather				
Summer (MW)	2013	26470	26715	27045	27420	27840	28285	28735	29385	30135	30790
	2014	26900	27150	27485	27865	28290	28740	29200	29860	30620	31280
	2015	27410	27665	28005	28390	28825	29285	29750	30425	31185	31860
	2016	27910	28165	28515	28910	29350	29815	30295	30980	31740	32420
	2017	28325	28590	28940	29340	29790	30265	30750	31445	32210	32900
	2018	28675	28940	29295	29700	30155	30635	31125	31830	32615	33315
	2019	29025	29295	29655	30065	30525	31010	31505	32220	33010	33720
	2020	29345	29615	29980	30395	30860	31350	31855	32575	33380	34095
	2021	29670	29950	30315	30735	31205	31700	32210	32935	33755	34480
	2022	29970	30250	30625	31045	31520	32020	32535	33270	34105	34840
WTHI (1)		**78.49**	**78.73**	**79.00**	**79.39**	**79.88**	**80.30**	**80.72**	**81.14**	**81.96**	**82.33**
Dry-Bulb Temperature (2)		**88.50**	**88.90**	**89.20**	**89.90**	**90.20**	**91.20**	**92.20**	**92.90**	**94.20**	**95.40**
Probability of Forecast Being Exceeded		**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**
Winter (MW)	2013/14	22025	22140	22235	22295	22445	22595	22765	22865	23080	23505
	2014/15	22205	22320	22420	22480	22630	22780	22955	23055	23255	23685
	2015/16	22385	22500	22595	22660	22810	22960	23135	23235	23440	23870
	2016/17	22540	22660	22755	22815	22970	23125	23295	23400	23620	24050
	2017/18	22680	22795	22895	22955	23110	23265	23440	23540	23780	24205
	2018/19	22800	22920	23020	23080	23235	23390	23565	23670	23920	24345
	2019/20	22915	23035	23130	23195	23350	23505	23685	23785	24045	24470
	2020/21	23030	23150	23250	23315	23470	23625	23805	23910	24160	24590
	2021/22	23145	23265	23365	23425	23585	23745	23920	24025	24280	24705
	2022/23	23255	23380	23480	23540	23700	23860	24040	24145	24395	24820
Dry-Bulb Temperature (3)		**10.72**	**9.66**	**8.84**	**8.30**	**7.03**	**5.77**	**4.40**	**3.58**	**1.61**	**(1.15)**

FOOTNOTES:

(1) WTHI - a three-day weighted temperature-humidity index for eight New England weather stations. It is the weather variable used in producing the summer peak load forecast. For more information on the weather variables see http://www.iso-ne.com/trans/celt/fsct_detail/.

(2) Dry-bulb temperature (in degrees Fahrenheit) shown in the summer season is for informational purposes only.

(3) Dry-bulb temperature (in degrees Fahrenheit) shown in the winter season is a weighted value from eight New England weather stations.

Table 8-2:
2022 Detailed Load Distributions by State and Company

ISO New England Basecase DB - Load File Report by Company

Study Date : 08/15/2022 **Study Name :** GHCC Revised

File Created : 2014-01-22 **CELT Forecast :** 2013 **Forecast Year :** 2022

Season : Summer Peak **Weather :** 90/10 **Load Distribution :** N+10_SUM

ISO-NE CELT : 34105 MW **% of Peak :** 100.000% **Tx Losses :** 2.50%

State CELT L&L		2.50% Tx Losses		Non-CELT Load		Station Service		Area 104 NE Load		Area 101 Load
34105 MW	-	852.6 MW	+	364.4 MW	+	0.0 MW	-	42.8 MW	=	33574.3 MW

1: State CELT L&L: This represents the sum of the 6 State CELT forecasts. This number can sometimes be 5-10 MW different than the ISO-NE CELT forecast number due to round-off error.
2: Non-CELT Load: This is the sum of all load modeled in the case that is not included in the CELT forecast. An example is the "behind the meter" paper mill load in Maine.
3: Station Service: This is the amount of generator station service modeled. If station service is off-line, the Area 101 report totals will be different since off-line load is not counted in totals.
4: Area 104 NE Load: This load is load modeled in northern VT that is electrically served from Hydro Quebec. To make Area Interchange load independent, this load is assigned Area 104.

Maine **State Load = 2450 MW - 2.50% Tx Losses = 2388.75 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CMP	85.42%	2040.39	655.06	0.952	332.06
BHE	14.59%	348.42	133.15	0.934	17.81

New Hampshire **State Load = 3150 MW - 2.50% Tx Losses = 3071.25 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
PSNH	78.73%	2418.00	344.54	0.990	
UNITIL	12.13%	372.58	53.09	0.990	
GSE	9.14%	280.68	6.42	1.000	1.85

Vermont **State Load = 1220 MW - 2.50% Tx Losses = 1189.5 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
VELCO	100.00%	1189.57	200.18	0.986	95.79

Massachusetts **State Load = 16055 MW - 2.50% Tx Losses = 15653.625 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
BECO	28.31%	4431.86	1146.57	0.968	37.79
COMEL	11.63%	1820.19	368.90	0.980	
MA-NGRID	39.34%	6157.37	355.79	0.998	38.49
WMECO	6.34%	992.13	141.36	0.990	
MUNI:BOST-NGR	3.40%	532.23	93.80	0.985	
MUNI:BOST-NST	1.21%	189.87	29.00	0.989	
MUNI:CNEMA-NGR	2.10%	328.38	33.68	0.995	
MUNI:RI-NGR	0.88%	137.44	16.67	0.993	
MUNI:SEMA-NGR	1.86%	290.39	30.91	0.994	
MUNI:SEMA-NST	1.74%	272.37	50.29	0.983	
MUNI:WMA-NGR	1.01%	157.79	15.67	0.995	
MUNI:WMA-NU	2.20%	343.77	48.98	0.990	

Rhode Island **State Load = 2405 MW - 2.50% Tx Losses = 2344.875 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
RI-NGRID	100.00%	2344.90	229.64	0.995	45.44

Connecticut **State Load = 8825 MW - 2.50% Tx Losses = 8604.375 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CLP	76.26%	6561.83	935.10	0.990	82.50
CMEEC	4.71%	405.62	57.80	0.990	
UI	19.02%	1636.87	163.66	0.995	10.00

Table 8-3:
Detailed Demand Response Distributions by Zone

ISO New England Basecase DB - Demand Resources File Report

Study Date : 08/15/2022 **Study Name :** GHCC Revised
File Created : 2014-01-22 **CCP :** 2016/2017 **Load Season :** 2022 - Summer Peak
Load Distrb : N+10_SUM **Distrb Losses :** 5.50% **DR Season :** SUM

	Demand Reduction Value (DRV)	X	Load Dependent Capability Assumption (LDCA)	X	Performance Assumption (PA)	+	Distribution Losses Gross-Up	-	Area 104 DR	=	Area 101 DR
Passive :	1670.15 MW		100.00%		100.00%		91.86 MW		4.77 MW		1757.05 MW
Forecast EE :	1038.85 MW		100.00%		100.00%		57.14 MW		3.37 MW		1092.68 MW
Active :	1171.84 MW		100.00%		75.00%		48.34 MW		1.72 MW		925.35 MW

Demand Reduction Value (DRV): Amount of DR measured at the customer meter without any gross-up values for transmission or distribution losses.
Load Dependent Capability Assumption (LDCA): De-rate factor applied based on % of CELT load. (i.e. Light load is 45% of 50/50 load, so the LDCA would be 45%.)
Performance Assumption (PA): De-rate factor applied based on expected performance of DR after a dispatch signal from Operations.
Area 104 DR: This load is modeled in northern VT and is electrically served from Hydro Quebec. To make Area Interchange load independent, this load is assigned Area 104.

Passive Demand Resources - (On-Peak and Seasonal Peak)

DR Modeled = (DRV_SUM * 100.00% LDCA * 100.00% PA) + 5.50% Distrb Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_P_ME	20	Load Zone - Maine	158.72	-167.44	-60.62
DR_P_NH	21	Load Zone - New Hampshire	79.75	-84.16	-11.66
DR_P_VT	22	Load Zone - Vermont	125.44	-132.24	-22.07
DR_P_NEMABOS	23	Load Zone - Northeast Massachusetts & Boston	341.18	-359.90	-79.19
DR_P_SEMA	24	Load Zone - Southeast Massachusetts	193.94	-204.59	-20.15
DR_P_WCMA	25	Load Zone - West Central Massachusetts	244.71	-258.17	-21.99
DR_P_RI	26	Load Zone - Rhode Island	141.90	-149.65	-14.66
DR_P_CT	27	Load Zone - Connecticut	384.51	-405.67	-54.52

Forecasted Energy Efficiency

DR Modeled = (DRV_EE * 100.00% LDCA * 100.00% PA) + 5.50% Distrb Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_P_ME	20	Load Zone - Maine	56.48	-59.57	-21.50
DR_P_NH	21	Load Zone - New Hampshire	52.78	-55.67	-7.69
DR_P_VT	22	Load Zone - Vermont	88.88	-93.88	-15.70
DR_P_NEMABOS	23	Load Zone - Northeast Massachusetts & Boston	276.34	-291.52	-64.14
DR_P_SEMA	24	Load Zone - Southeast Massachusetts	146.98	-155.05	-15.30
DR_P_WCMA	25	Load Zone - West Central Massachusetts	164.62	-173.68	-14.80
DR_P_RI	26	Load Zone - Rhode Island	113.89	-120.16	-11.81
DR_P_CT	27	Load Zone - Connecticut	138.88	-146.52	-19.68

Active Demand Resources - (Real-Time Demand Resource (RTDR), Excludes RTEG)

DR Modeled = (DRV_SUM * 100.00% LDCA * 75.00% PA) + 5.50% Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_A_ME_BHE	30	Dispatch Zone - ME - Bangor Hydro	56.40	-44.63	-23.28
DR_A_ME_MAIN	31	Dispatch Zone - ME - Maine	206.61	-163.53	-55.36
DR_A_ME_PORT	32	Dispatch Zone - ME - Portland Maine	31.49	-24.89	-8.12
DR_A_NH_NEWH	33	Dispatch Zone - NH - New Hampshire	48.62	-38.46	-5.28
DR_A_NH_SEAC	34	Dispatch Zone - NH - Seacoast	12.10	-9.58	-1.36
DR_A_VT_NWVT	35	Dispatch Zone - VT - Northwest Vermont	38.46	-30.40	-4.93
DR_A_VT_VERM	36	Dispatch Zone - VT - Vermont	24.83	-19.64	-3.51
DR_A_MA_BOST	37	Dispatch Zone - MA - Boston	81.06	-64.09	-16.39
DR_A_MA_NSHR	38	Dispatch Zone - MA - North Shore	35.48	-28.06	-3.39
DR_A_MA_CMA	39	Dispatch Zone - MA - Central Massachusetts	51.46	-40.67	-2.04
DR_A_MA_SPFD	40	Dispatch Zone - MA - Springfield	32.76	-25.91	-3.69
DR_A_MA_WMA	41	Dispatch Zone - MA - Western Massachusetts	78.27	-61.92	-5.86
DR_A_MA_LSM	42	Dispatch Zone - MA - Lower Southeast Massachusetts	20.01	-15.85	-2.60
DR_A_MA_SEMA	43	Dispatch Zone - MA - Southeast Massachusetts	121.48	-96.13	-6.76
DR_A_RI_RHOD	44	Dispatch Zone - RI - Rhode Island	73.75	-58.38	-5.69
DR_A_CT_EAST	45	Dispatch Zone - CT - Eastern Connecticut	36.55	-28.90	-4.12
DR_A_CT_NRTH	46	Dispatch Zone - CT - Northern Connecticut	84.10	-66.53	-9.48
DR_A_CT_NRST	47	Dispatch Zone - CT - Norwalk-Stamford	34.23	-27.08	-3.70
DR_A_CT_WEST	48	Dispatch Zone - CT - Western Connecticut	104.18	-82.42	-10.71

Section 9
Appendix B: Case Summaries

Quick links to case summaries for each of the dispatches described in Table 3-6 and Table 3-7 are provided below. Each file contains all of the case summaries for the portion of the study area or associated transmission upgrade project noted in the title.

Appendix B1_Barbour_Hill_Dispatches.pdf

Appendix B2_CCRP_Dispatches.pdf

Appendix B3_Greater_Hartford_Dispatches.pdf

Appendix B4_IRP_Dispatches.pdf

Appendix B5_Middletown_Dispatches.pdf

Appendix B6_NWCT_Dispatches.pdf

Section 10
Appendix C: Element Out for N-1-1 Analysis

Table 10-1:
N-1-1 First Element-Out Scenarios

Line/ Autotransformer	Station A	Station B	Station C	BPS Element
Underground cables				
1704	South Meadow 115 kV	Southwest Hartford 115 kV		Yes
1722	Southwest Hartford 115 kV	CDEC 115 kV	Northwest Hartford 115 kV	No
Overhead 345 kV lines				
310	Manchester 345 kV	Millstone 345 kV		Yes
329	Frost Bridge 345 kV	Southington 345 kV		Yes
330	Card 345 kV	Lake Road 345 kV		Yes
347	Killingly 345 kV	Sherman Road 345 kV		Yes
348	Millstone 345 kV	Haddam 345 kV	Beseck 345 kV	Yes
352	Frost Bridge 345 kV	Long Mountain 345 kV		Yes
352 (w/ Element Restored)[19]	Frost Bridge 345 kV	Long Mountain 345 kV		Yes
362	Beseck 345 kV	Haddam Neck 345 kV		Yes
364	Montville 345 kV	Haddam Neck 345 kV		Yes
368	Manchester 345 kV	Card 345 kV		Yes
371	Millstone 345 kV	Montville 345 kV		Yes
376	Scovill Rock 345 kV	Haddam Neck 345 kV		Yes
383	Millstone 345 kV	Card 345 kV		Yes
3041	Southington 345 kV	Scovill Rock 345 kV		Yes
3196	Agawam 345 kV	Ludlow 345 kV		Yes
3216	North Bloomfield 345 kV	Agawam 345 kV		Yes
3271	Lake Road 345 kV	Card 345 kV		Yes
3348	Killingly 345 kV	Lake Road 345 kV		Yes
3419	Barbour Hill 345 kV	Ludlow 345 kV		Yes
3424	Manchester 345 kV	Kleen Energy 345 kV		Yes
3557	Barbour Hill 345 kV	Manchester 345 kV		Yes
3642	North Bloomfield 345 kV	Manchester 345 kV		Yes
3827	Beseck 345 kV	East Devon 345 kV		Yes
Overhead 115 kV lines				
1042	North Bloomfield 115 kV	Northeast Simsbury 115 kV		Yes

[19] In some cases, the initial element-out scenario also disconnects another element connected to the same breaker position. In some cases the restoration of this additional element in the 30 minutes prior to the next contingency can have an impact on the results. For these conditions, two different initial line-out scenarios were analyzed, one in which the additional element remains offline and one in which the element is restored before the second contingency.

Line/ Autotransformer	Station A	Station B	Station C	BPS Element
1042 (w/ Element Restored)	North Bloomfield 115 kV	Northeast Simsbury 115 kV		No
1050	Middletown 115 kV	Dooley 115 kV		No
1100	Enfield 115 kV	Barbour Hill 115 kV		No
1191	Frost Bridge 115 kV	Campville 115 kV		Yes
1200	Windsor Locks 115 kV	Barbour Hill 115 kV		No
1207	Manchester 115 kV	East Hartford 115 kV		Yes
1208	Southington 115 kV	Wallingford 115 kV		Yes
1256	Canton 115 kV	Northeast Simsbury 115 kV		No
1261	Haddam 115 kV	Bokum 115 kV		Yes
1300	Windsor Locks 115 kV	Enfield 115 kV		No
1310	Manchester 115 kV	East Windsor 115 kV		Yes
1342	Bokum 115 kV	Green Hill 115 kV		No
1355	Southington 115 kV	Hanover 115 kV	Colony 115 kV	Yes
1443	Portland 115 kV	Middletown 115 kV		No
1448	Manchester 115 kV	Rood Avenue 115 kV		Yes
1448 (w/ Element Restored)	Manchester 115 kV	Rood Avenue 115 kV		Yes
1460	East Shore 115 kV	Branford RR 115 kV		Yes
1466	North Wallingford 115 kV	East Meriden 115 kV		No
1508	Stepstone 115 kV	Green Hill 115 kV		No
1508(w/ Element Restored)	Stepstone 115 kV	Green Hill 115 kV		No
1537	Branford 115 kV	Branford RR 115 kV		No
1572_1772	Middletown 115 kV	P&W Aircraft 115 kV	Haddam 115 kV	Yes
1588	North Wallingford 115 kV	Colony 115 kV		No
1598	Haddam 115 kV	Bokum 115 kV		Yes
1606	Barbour Hill 115 kV	Rockville 115 kV		No
1610				
1620	Haddam 115 kV	Middletown 115 kV		Yes
1635	Barbour Hill 345 kV	South Windsor 115 kV		Yes
1655	North Haven 115 kV	Branford 115 kV		No
1670	Berlin 115 kV	Southington 115 kV	Black Rock 115 kV	Yes
1690	Southington 115 kV	Hanover 115 kV		Yes
1724	Barbour Hill 115 kV	Rockville 115 kV		No
1726	Farmington 115 kV	North Bloomfield 115 kV		Yes
1732	Franklin Drive 115 kV	Campville 115 kV	Canton 115 kV	No
1738	Stepstone 115 kV	Branford 115 kV		No
1751	North Bloomfield 115 kV	Rood Avenue 115 kV	Northwest Hartford 115 kV	Yes
1752	Berlin 115 kV	Rocky Hill 115 kV		Yes

Line/ Autotransformer	Station A	Station B	Station C	BPS Element
1756	Bloomfield 115 kV	Northwest Hartford 115 kV		No
1759	Hopewell 115 kV	Portland 115 kV		No
1763	Manchester 115 kV	Barbour Hill 115 kV		Yes
1765	Berlin 115 kV	West Side 115 kV		Yes
1766	Dooley 115 kV	West Side 115 kV		No
1767	Manchester 115 kV	Hopewell 115 kV		Yes
1769	Berlin 115 kV	East New Britain 115 kV		Yes
1771	Berlin 115 kV	Southington 115 kV		Yes
1773	Rocky Hill 115 kV	South Meadow 115 kV		Yes
1775	South Meadow 115 kV	Riverside Drive 115 kV	Manchester 115 kV	Yes
1777	Bloomfield 115 kV	North Bloomfield 115 kV		Yes
1779	Bloomfield 115 kV	South Meadow 115 kV		Yes
1783	East New Britain 115 kV	Newington 115 kV	Farmington 115 kV	No
1785	Berlin 115 kV	Newington 115 kV		Yes
1786	South Meadow 115 kV	East Hartford 115 kV	Riverside Drive 115 kV	Yes
1788	Torrington Terminal 115 kV	Franklin Drive 115 kV		No
1788 (w/ Element Restored)	Torrington Terminal 115 kV	Franklin Drive 115 kV		No
1800	Southington 115 kV	Forestville 115 kV		Yes
1810	Southington 115 kV	Bristol 115 kV	Chippen Hill 115 kV	Yes
1820	Southington 115 kV	Black Rock 115 kV		Yes
1825	Bristol 115 kV	Forestville 115 kV		No
1830	Southington 115 kV	Black Rock 115 kV		Yes
1835	Thomaston 115 kV	Chippen Hill 115 kV		No
1900	Torrington Terminal 115 kV	Campville 115 kV		No
1900 (w/ Element Restored)	Torrington Terminal 115 kV	Campville 115 kV		No
1921	Campville 115 kV	Thomaston 115 kV		No
1975	Haddam 115 kV	East Meriden 115 kV		Yes
Overhead 69 kV Lines				
667_689	Salisbury 69 kV	Falls Village 69 kV	Torrington Terminal 69 kV	No
690	Salisbury 69 kV	Smithfield 69 kV		No
693_694	Torrington Terminal 69 kV	Falls Village 69 kV	North Canaan 69 kV	No
Autotransformers				
Barbour Hill 1X	Barbour Hill 345 kV	Barbour Hill 115 kV		Yes
Frost Bridge 1X	Frost Bridge 345 kV	Frost Bridge 115 kV		Yes
Frost Bridge 1X(w/	Frost Bridge 345 kV	Frost Bridge 115 kV		Yes

Line/ Autotransformer	Station A	Station B	Station C	BPS Element
Element Restored)				
Haddam 6X	Haddam 345 kV	Haddam 115 kV		Yes
North Bloomfield 5X	North Bloomfield 345 kV	North Bloomfield 115 kV		Yes
North Bloomfield 7X	North Bloomfield 345 kV	North Bloomfield 115 kV		Yes
Manchester 4X	Manchester 345 kV	Manchester 115 kV		Yes
Manchester 5X	Manchester 345 kV	Manchester 115 kV		Yes
Manchester 6X	Manchester 345 kV	Manchester 115 kV		Yes
Southington 1X	Southington 345 kV	Southington115 kV		Yes
Southington 2X	Southington 345 kV	Southington115 kV		Yes
Southington 3X	Southington 345 kV	Southington115 kV		Yes
Southington 4X	Southington 345 kV	Southington115 kV		Yes
Southington 4X (w/ Element Restored)	Southington 345 kV	Southington115 kV		Yes
Generators				
Bridgeport Energy	Bridgeport Energy 115 kV			Yes
Bridgeport Harbor 3	Pequonnock 115 kV			Yes
Middletown 4	Middletown 345kV			Yes
New Haven Harbor	New Haven 115 kV			Yes
South Meadow 6	South Meadow 115 kV			Yes
Capitol District	CDECCA 115 kV			No

Section 11
Appendix D: Contingency Listings

11.1 GHCC Area NERC Category B Contingencies

Generator Contingencies = 91 Total				
GN_11_10BE	GN_DEXT_2	GN_LRD1	GN_MON6	GN_SOM6
GN_12_10BE	GN_DV10	GN_LRD2	GN_NHHB	GN_STEV
GN_AETN_CC	GN_DV11	GN_LRD3	GN_NORWICH	GN_THAM
GN_ALP	GN_DV12	GN_MFD1	GN_NRW1	GN_TORR
GN_ANSONIA	GN_DV13	GN_MFD2	GN_NRW2	GN_TUNN
GN_BHR2	GN_DV14	GN_MI12	GN_NRW3	GN_UCONN_CC
GN_BHR3	GN_DV15	GN_MI13	GN_PLAINFLD	GN_WAL1
GN_BHR4	GN_DV16	GN_MI14	GN_QP248_2	GN_WAL2
GN_BPTR	GN_DV17	GN_MI15	GN_QP248_3	GN_WAL3
GN_BRAN	GN_DV18	GN_MIDLTWN10	GN_QP248_4	GN_WAL4
GN_BRF	GN_EXTR	GN_MIDLTWN2	GN_ROCK	GN_WAL5
GN_BULL	GN_FALS	GN_MIDLTWN3	GN_SECR	GN_WBRY
GN_CC10	GN_FOXWOOD_1	GN_MIDLTWN4	GN_SHEP	GN_WLRC
GN_CC11	GN_FOXWOOD_2	GN_MIL2	GN_SO11	GN_WTSD_1
GN_CC12	GN_FRDR	GN_MIL3	GN_SO12	GN_WTSD_2
GN_CC13	GN_KIMB_CC	GN_MO10	GN_SO13	GN_WTSD_3
GN_CC14	GN_KLEEN_CC	GN_MO11	GN_SO14	GN_YALE_DG_1
GN_DERB	GN_LISB	GN_MON5	GN_SOM5	GN_YALE_DG_2
GN_DEXT_1				

Line Contingencies = 271 Total				
LN_100	LN_1515S	LN_1751	LN_314	LN_364
LN_1000	LN_1522	LN_1752	LN_315	LN_3642
LN_1042	LN_1537	LN_1753	LN_316	LN_366
LN_1050	LN_1545	LN_1756	LN_3161	LN_368
LN_1070	LN_1550_1950	LN_1759	LN_3165	LN_370
LN_1080	LN_1555	LN_1760_1876	LN_3196	LN_371
LN_1090	LN_1560N	LN_1763	LN_321	LN_3754
LN_1100	LN_1560S	LN_1765	LN_3216	LN_376
LN_1120	LN_1565	LN_1766	LN_322	LN_381
LN_1130	LN_1570	LN_1767	LN_323	LN_3827
LN_1163	LN_1572_1772	LN_1769	LN_325	LN_383
LN_1165	LN_1575	LN_1770	LN_326	LN_384
LN_1191	LN_1580	LN_1771	LN_327	LN_387
LN_1200	LN_1585	LN_1773	LN_3271	LN_389
LN_1207	LN_1588	LN_1775	LN_328	LN_3921
LN_1208	LN_1594	LN_1776	LN_3280	LN_398
LN_1210	LN_1598	LN_1777	LN_329	LN_399

LN_1220	LN_1605	LN_1779	LN_330	LN_400
LN_1222	LN_1606	LN_1780	LN_331	LN_500
LN_1235	LN_1607	LN_1783	LN_332	LN_601
LN_1238_1813	LN_1610	LN_1785	LN_3320	LN_602
LN_1250	LN_1617	LN_1786	LN_3321	LN_603
LN_1256	LN_1618	LN_1788	LN_333	LN_667_689
LN_1261	LN_1620	LN_1790	LN_334	LN_690
LN_1270	LN_1621	LN_1792	LN_3340	LN_693_694
LN_1272	LN_1622	LN_1800	LN_3348	LN_800
LN_1280	LN_1630	LN_1810	LN_335	LN_8100
LN_1300	LN_1635	LN_1820	LN_336	LN_8200
LN_1310	LN_1637	LN_1825	LN_3361	LN_8300
LN_1319	LN_1640	LN_1830	LN_3381	LN_8301
LN_1337	LN_1650	LN_1835	LN_340	LN_8400
LN_1342	LN_1655	LN_1840	LN_3403	LN_84004
LN_1350	LN_1668	LN_1843	LN_341	LN_8500
LN_1355	LN_1670	LN_1867	LN_3419	LN_8600
LN_1363	LN_1675	LN_1870S	LN_342	LN_8700
LN_1365	LN_1682	LN_1880	LN_3424	LN_8702
LN_1389	LN_1685	LN_1887	LN_343	LN_88003A
LN_1394	LN_1690	LN_1890	LN_344	LN_88003A_UG
LN_1410	LN_1697	LN_1900	LN_347	LN_88005A
LN_1416	LN_1704	LN_1910	LN_348	LN_88006A
LN_1430	LN_1710	LN_1921	LN_350	LN_8804A
LN_1440	LN_1710_LS	LN_1943	LN_3512	LN_8809A
LN_1443	LN_1714	LN_1955	LN_352	LN_89003B
LN_1445	LN_1720	LN_1975	LN_3520	LN_89003B_UG
LN_1448	LN_1721	LN_1977	LN_3521	LN_89005B
LN_1450	LN_1722	LN_1985	LN_3533	LN_89006B
LN_1460	LN_1724	LN_1990	LN_354	LN_8904B
LN_1465	LN_1726	LN_301_302	LN_355	LN_8909B
LN_1466	LN_1730	LN_303	LN_3557	LN_900
LN_1470	LN_1732	LN_3041	LN_356	LN_91001
LN_1490	LN_1734	LN_308	LN_357	LN_9500
LN_1497	LN_1738	LN_310	LN_359	LN_9502
LN_1500	LN_1740	LN_312_393	LN_3619	LN_R118
LN_1505	LN_1742	LN_313	LN_362	
LN_1508	LN_1750			

Transformer Contingencies = 162 Total				
TF_AETN_GSU	TF_CARD_9X	TF_KLG2_GSU	TF_NORHAR_1X	TF_SNGTN_3X
TF_AGAWAM_1X	TF_CARP_HL_1	TF_KLST_GSU	TF_NORHAR_2X	TF_SNGTN_4X
TF_AGAWAM_2X	TF_COOL_K36X	TF_LISBON_GS	TF_NORHAR_8X	TF_SO11_SO12
TF_ALP_GSU	TF_COSCOB_GS	TF_LRD1_GSU	TF_NORWICH	TF_SO13_SO14
TF_ANSONIA	TF_CRVR_345A	TF_LRD2_GSU	TF_NRWLK_2/6	TF_SOM5_GSU
TF_AUBR_210X	TF_CRVR_345B	TF_LRD3_GSU	TF_NRWLK_8X	TF_SOM6_GSU
TF_AUBR_220X	TF_DEVON_10X	TF_LUDLOW_1X	TF_NRWLK_9X	TF_STEV_GSU
TF_BARBHL_1X	TF_DEVON_11X	TF_LUDLOW_3X	TF_NTHFLD_1X	TF_STNYB_10X
TF_BEL1_GSU	TF_DEVON_12X	TF_M1213_GSU	TF_NTHFLD_3X	TF_THAMS_GSU
TF_BEL2_GSU	TF_DEVON_13X	TF_M1415_GSU	TF_NWHV_T1	TF_TORR_10X
TF_BERRY_1X	TF_DEVON_14X	TF_MANCH_4X	TF_NWHV_T2	TF_TORR_1X
TF_BHR2_GSU	TF_DEVON_15X	TF_MANCH_5X	TF_OSG1_GSU	TF_TUNNEL_1X
TF_BHR3_GSU	TF_DEVON_17X	TF_MANCH_6X	TF_OSG2_GSU	TF_VERNON
TF_BHR4_GSU	TF_DEXT_GSU	TF_MFD12_GSU	TF_OSG3_GSU	TF_VTYA_4X
TF_BKS1_GSU	TF_EDEVON_2X	TF_MI10_GSU	TF_OSG4_GSU	TF_VTYA_GSU
TF_BKS2_GSU	TF_ES_8X_CSC	TF_MID2_GSU	TF_OST1_GSU	TF_WACHUS_T5
TF_BPTR_GSU	TF_ES_9X_CSC	TF_MID3_GSU	TF_OST2_GSU	TF_WACHUS_T6
TF_BRA4_GSU	TF_ESHORE_1X	TF_MID4_GSU	TF_PILG_GSU	TF_WACHUS_T7
TF_BRAY_3XAB	TF_ESHORE_8X	TF_MILSTN_2X	TF_PLNFD_GSU	TF_WAL12_GSU
TF_BRAY_5X	TF_ESHORE_9X	TF_MILSTN_3X	TF_PLUMTR_1X	TF_WAL345GSU
TF_BRPTE_10X	TF_EXTR_GSU	TF_MO10_GSU	TF_PLUMTR_2X	TF_WALTHM_2A
TF_BRPTE_11X	TF_FLSVL_GSU	TF_MON5_GSU	TF_QP248_GSU	TF_WAMSBY_T2
TF_BRPTE_12X	TF_FRSTB_1X	TF_MON6_GSU	TF_SACKET_PS	TF_WBRY_GSU
TF_BWTR_161X	TF_FRSTVL_2X	TF_MONT_16X	TF_SECREC_GS	TF_WFAR_174T
TF_BWTR_162X	TF_GLNBRK_4X	TF_MONTV_18X	TF_SERVRD_T1	TF_WFAR_175T
TF_CAN1_GSU	TF_GLNBRK_5X	TF_NBLOOM_5X	TF_SHEPAUG	TF_WLRC_GSU
TF_CAN2_GSU	TF_HADDAM_6X	TF_NBLOOM_7X	TF_SINGER_1X	TF_WMED_345A
TF_CANL_120X	TF_HOLB_345A	TF_NEA1_GSU	TF_SINGER_2X	TF_WMED_345B
TF_CANL_121X	TF_KENTCT_3X	TF_NEA2_GSU	TF_SNDYPD_1X	TF_WRUT_T1
TF_CANL_126X	TF_KENTCT_4X	TF_NEAS_GSU	TF_SNDYPD_2X	TF_WRUT_T2
TF_CANTON_2X	TF_KENTCT_5X	TF_NEWFANE_1	TF_SNGTN_1X	TF_WTRSD_GSU
TF_CARD_5X	TF_KILLNG_2X	TF_NORHAR_10	TF_SNGTN_2X	TF_WWALP_45A
TF_CARD_8X	TF_KLG1_GSU			

Bus Section Contingencies = 80 Total				
BS_ALLINGS_A	BS_BRDWY_BC	BS_HAWTHRN_A	BS_MONTVLL_A	BS_SHELTON_A
BS_ALLINGS_B	BS_BRDWY_T_A	BS_HAWTHRN_B	BS_MONTVLL_B	BS_SHELTON_B
BS_ANSON_T_A	BS_BRDWY_T_D	BS_INDWELL_A	BS_N_HAVEN_A	BS_TORR_69KV
BS_ANSON_T_B	BS_CONGR_A_C	BS_INDWELL_B	BS_N_HAVEN_B	BS_TRPFALS_A
BS_ASHCR_T_A	BS_CONGR_B_D	BS_JUNE_ST_A	BS_NBLOOM_B	BS_TRPFALS_B
BS_ASHCR_T_B	BS_COOLIDGE	BS_JUNE_ST_B	BS_NORWALK_A	BS_TRUMBUL_A
BS_BAIRD_T_A	BS_COSCOB_A1	BS_KENTCTY_1	BS_NORWALK_B	BS_TRUMBUL_B
BS_BAIRD_T_B	BS_COSCOB_A2	BS_MANCHST_A	BS_OLDTOWN_A	BS_VTYA_115
BS_BARNM_T_A	BS_COSCOB_A3	BS_MANCHST_B	BS_OLDTOWN_B	BS_WATERST_B
BS_BARNM_T_B	BS_DEERFLDNH	BS_MILLRV_BC	BS_PLUMTRE_A	BS_WATERST_C
BS_BEACONFLS	BS_DEVON_T_A	BS_MILLRVR_A	BS_PLUMTRE_B	BS_WDMNT_T_A
BS_BERKSHR_A	BS_DEVON_T_B	BS_MILLRVR_D	BS_QUINN_T_A	BS_WDMNT_T_B
BS_BERLIN_A	BS_ELMWEST_A	BS_MILVN_T_A	BS_QUINN_T_B	BS_WMEDWAY_S
BS_BERLIN_B	BS_ELMWEST_B	BS_MILVN_T_B	BS_ROCKY_A3	BS_WRIVER_A
BS_BRDGWTR_N	BS_GLENBRK_A	BS_MIX_T_A	BS_SACKETT_A	BS_WRIVER_B
BS_BRDGWTR_S	BS_GLENBRK_B	BS_MIX_T_B	BS_SACKETT_B	BS_WRIVER_C

Loss of Element w/o Fault (Single Breaker Opening) - Total =30				
NF_348-3	NF_BESECK_R1	NF_BERLNCT_C	NF_HADDAM_C	NF_SO11_SO12
NF_352	NF_1300-2	NF_BRANFRD_C	NF_MANCH_C1	NF_SO13_SO14
NF_387-1	NF_1751-1	NF_CANTON_C	NF_MANCH_C2	NF_1256
NF_FRSTBR_1X	NF_1783-3	NF_FRKLNDR_C	NF_NBLOOM_C	NF_689
NF_MANCH_5X	NF_1910_R	NF_FRSTB_C1	NF_SNGTN_C1	NF_693
NF_SNGTN_4X	NF_1950_R	NF_FRSTB_C2	NF_SNGTN_C2	NF_694

Loss of Element w/o Fault (Multiple Breakers Opening) - Total =48				
NF_3424_MB	NF_1300-3_MB	NF_1670-3_MB	NF_1751-3_MB	NF_1786-2_MB
NF_348-1_MB	NF_1355-1_MB	NF_1704_MB	NF_1772_MB	NF_1786-3_MB
NF_348-2_MB	NF_1355-2_MB	NF_1710-3_MB	NF_1773_MB	NF_1788_MB
NF_364_MB	NF_1355-3_MB	NF_1722-1_MB	NF_1775-1_MB	NF_1810-1_MB
NF_3754_MB	NF_1550-1_MB	NF_1722-2_MB	NF_1775-2_MB	NF_1810-3_MB
NF_1163-1_MB	NF_1550-2_MB	NF_1722-3_MB	NF_1775-3_MB	NF_1810-4_MB
NF_1163-2_MB	NF_1550-3_MB	NF_1732-1_MB	NF_1783-1_MB	NF_1950_MB
NF_1163-3_MB	NF_1572_MB	NF_1732-2_MB	NF_1783-2_MB	NF_AETN_GSU_MB
NF_1238_MB	NF_1670-1_MB	NF_1732-3_MB	NF_1786-1_MB	NF_667_MB
NF_1300-1_MB	NF_1670-2_MB	NF_1751-2_MB		

11.2 GHCC Area NERC Category C Contingencies

Breaker Failure Contingencies = 585 Total				
BF_AGAWAM_2T	BF_DEVN_T_2T	BF_KLEEN_2T	BF_NRWLK_2T	BF_SNGTN_5T
BF_AGAWAM_5T	BF_DEVN_T_3T	BF_KLEEN_3T	BF_NRWLK_3T	BF_SNGTN_6T
BF_AGAWM_22T	BF_DEVN_T_4T	BF_KLEEN_4T	BF_NRWLK_4T	BF_SNGTN_7T

BF_AGAWM_25T	BF_DEVON_10T	BF_KLEEN_6T	BF_NRWLK_5T	BF_SNGTN_9T
BF_AGAWM_26T	BF_DEVON_11T	BF_KNTC_115E	BF_NRWLK_6T	BF_SOMST_12
BF_ALLNGS_1T	BF_DEVON_12T	BF_KNTC_345B	BF_NRWLK_7T	BF_SOMST_A
BF_ALLNGS_2T	BF_DEVON_1T	BF_KNTC_345C	BF_NRWLK_8T	BF_STCKHS_1T
BF_ANSON_1T	BF_DEVON_20T	BF_KNTC_345E	BF_NRWLK_9T	BF_STEV_1560
BF_ANSON_2T	BF_DEVON_23T	BF_KNTC_345F	BF_NTHFLD_1T	BF_STEV_1876
BF_ANSON_3T	BF_DEVON_24T	BF_KNTC_4T20	BF_NTHFLD_2T	BF_STEV_1990
BF_ASHCRK_3B	BF_DEVON_25T	BF_KNTC_8510	BF_NTHFLD_3T	BF_STGTN_101
BF_AUBURN_02	BF_DEVON_26T	BF_KNTC_8520	BF_NTHFLD_4T	BF_STGTN_102
BF_AUBURN_03	BF_DEVON_27T	BF_KNTC_8589	BF_NTHFLD_5T	BF_STGTN_103
BF_AUBURN_40	BF_DEVON_28T	BF_KNTC_8910	BF_NWALFD_1T	BF_STGTN_104
BF_AUBURN_41	BF_DEVON_29T	BF_LAKERD_2T	BF_NWHART_31	BF_STGTN_105
BF_BAIRD_75A	BF_DEVON_3T	BF_LAKERD_5T	BF_NWHART_32	BF_STHEND_5T
BF_BAIRD_75B	BF_DEVON_6T	BF_LAKERD_8T	BF_NWHART_33	BF_STONY_1T2
BF_BARBH_18T	BF_DEVON_7T	BF_DEVN_T_1T	BF_NWHV_370	BF_STPSTN_1T
BF_BARBH_21T	BF_DEVON_8T	BF_LUDLOW_1T	BF_NWHV_371	BF_SWHART_1T
BF_BARBHL_3T	BF_DOOLEY_2T	BF_LUDLOW_2T	BF_NWHV_4163	BF_SWNDSR_1T
BF_BARBHL_4T	BF_EDEVN_11T	BF_LUDLOW_3T	BF_NWHV_4341	BF_THMSTN_2T
BF_BARBHL_5T	BF_EDEVN_24T	BF_LUDLOW_4T	BF_NWHV_6342	BF_TODD_1T-2
BF_BATES_1T2	BF_EHART_1T	BF_LUDLOW_5T	BF_NWHV_6442	BF_TORR_10X1
BF_BE_10X	BF_EMERDN_1T	BF_LUDLOW_6T	BF_NWNGTN_1T	BF_TORR_1T-2
BF_BE_11X	BF_ENEWBR_69	BF_LUDLOW_7T	BF_NWNGTN_2T	BF_TORR_6892
BF_BEANHL_1T	BF_ENEWBR_83	BF_LUDLOW_8T	BF_OLDTWN_1T	BF_TORR_6932
BF_BECN_1319	BF_ENFLD_1T	BF_LUDLOW_9T	BF_OXFORD_1T	BF_TRACY_1T2
BF_BECN_1570	BF_ESHOR_1K	BF_LUDLW_41T	BF_PEACE_1T2	BF_TRAPFL_1T
BF_BELL_3-20	BF_ESHOR_2K	BF_LUDLW_43T	BF_PEQNC_12T	BF_TRINGL_2T
BF_BERLIN_13	BF_ESHORE_11	BF_LUDLW_44T	BF_PEQNC_22T	BF_TRINGL_3T
BF_BERLIN_14	BF_ESHORE_12	BF_LUDLW_46T	BF_PEQNC_2T	BF_TRINGL_4T
BF_BERLIN_15	BF_ESHORE_13	BF_LUDLW_47T	BF_PEQNC_32T	BF_TRINGL_5T
BF_BERLIN_22	BF_ESHORE_21	BF_LUDLW_49T	BF_PEQNC_42T	BF_TRMBUL_1T
BF_BERLIN_23T	BF_ESHORE_22	BF_MANCH_10T	BF_PEQU_32T	BF_TRMBUL_2T
BF_BERLIN_24	BF_ESHORE_23	BF_MANCH_11T	BF_PEQU_42T	BF_TRMBUL_3T
BF_BERLIN_25	BF_ESHORE_31	BF_MANCH_13T	BF_PILGM_104	BF_TUNNEL_1T
BF_BERLIN_26	BF_ESHORE_32	BF_MANCH_14T	BF_PILGM_105	BF_TUNNEL_2T
BF_BERLIN_27	BF_ESHORE_33	BF_MANCH_15T	BF_PLUMT_1X3	BF_TUNNEL_3T
BF_BERY_345A	BF_ESHORE_41	BF_MANCH_17T	BF_PLUMT_23T	BF_TUNNEL_4T
BF_BERY_345B	BF_ESHORE_43	BF_MANCH_18T	BF_PLUMT_24T	BF_TUNNEL_5T
BF_BERY_345C	BF_ESHORE_71	BF_MANCH_19T	BF_PLUMT_25T	BF_TWKS_7-39
BF_BESECK_8T	BF_ESHORE_73	BF_MANCH_1T	BF_PLUMT_26T	BF_TWKS_8-97
BF_BLDWN_2T2	BF_FARMTN_1T	BF_MANCH_20T	BF_PLUMT_29T	BF_VERN_3TB1
BF_BLDWN_5T2	BF_FARMTN_2T	BF_MANCH_21T	BF_PLUMT_2T	BF_VERN_3TB2
BF_BLKST_101	BF_FARMTN_3T	BF_MANCH_22T	BF_PLUMT_2X3	BF_VERN_3TB3
BF_BLKST_102	BF_FLAXHL_2T	BF_MANCH_23T	BF_PLUMT_30T	BF_VERN_KTB1
BF_BLKST_103	BF_FLNDRS_1T	BF_MANCH_24T	BF_PLUMT_31T	BF_VTYK_1T
BF_BLKST_104	BF_FLSVL_694	BF_MANCH_25T	BF_PLUMT_32T	BF_VTYK_381

BF_BLMFLD_1T	BF_FRAMNG_1	BF_MANCH_2T	BF_PLUMT_4X1	BF_VTYK_40/1
BF_BLMFLD_2T	BF_FRDR_1T-2	BF_MANCH_3T	BF_PRTLND_2T	BF_VTYK_811T
BF_BLMFLD_3T	BF_FREGHT_1T	BF_MANCH_4T	BF_QNNIPC_1T	BF_VTYK_9-40
BF_BOKUM_1T	BF_FREGHT_2T	BF_MANCH_5T	BF_RESCO_9R	BF_WACH_13T
BF_BOKUM_2T	BF_FRNCON_2T	BF_MANCH_6T	BF_RKYHIL_1T	BF_WACH_141N
BF_BOKUM_3T	BF_FRSTB_14T	BF_MANCH_7T	BF_RKYHIL_2T	BF_WACH_141W
BF_BRANF_1T	BF_FRSTB_15T	BF_MANCH_8T	BF_ROCKY_1T2	BF_WACH_142N
BF_BRANF_2T	BF_FRSTB_16T	BF_MIDLTN_10	BF_ROCKY_2T2	BF_WACH_142W
BF_BRANF_4T	BF_FRSTB_1T2	BF_MIDLTN_11	BF_ROOD_1T	BF_WACH_24T
BF_BRANFRR_1	BF_FRSTB_1X2	BF_MIDLTN_3	BF_SACKET_1T	BF_WACH_2-7T
BF_BRDWAY_1T	BF_FRSTB_20T	BF_MIDLTN_7	BF_SALS_1T-2	BF_WACH_3-6T
BF_BRDWAY_2T	BF_FRSTB_21T	BF_MIDRV_1T2	BF_SASCO_1T	BF_WACH_3-7T
BF_BRGWTR_01	BF_FRSTB_22T	BF_MIDRV_2T2	BF_SCOVRK_5T	BF_WACH_4-7T
BF_BRGWTR_04	BF_FRSTB_23T	BF_MILB_0802	BF_SCOVRK_8T	BF_WACH_6T
BF_BRGWTR_07	BF_FRSTB_24T	BF_MILB_1357	BF_SCTICO_1T	BF_WACH_7T
BF_BRGWTR_13	BF_FRSTB_26T	BF_MILB_345B	BF_SERV_RD_A	BF_WALNFD_1T
BF_BRGWTR_40	BF_FRSTB_27T	BF_MILLRV_1T	BF_SHAWS_1T2	BF_WALNFD_2T
BF_BRGWTR_49	BF_FRSTB_28T	BF_MILLRV_2T	BF_SHELTN_1T	BF_WALNFD_3T
BF_BRGWTR_60	BF_FRSTB_2X2	BF_MILST_14T	BF_SHEP_1887	BF_WALNFD_4T
BF_BRGWTR_70	BF_FRSTVL_1T	BF_MILST_8T	BF_SHRMN_143	BF_WALNFD_5T
BF_BRGWTR_80	BF_FRSTVL_2T	BF_MIXAVE_1T	BF_SHUNOK_2T	BF_WALNFD_6T
BF_BRGWTR_90	BF_FTHILL_1T	BF_MIXPDS_3X	BF_SINGR_22T	BF_WATRST_1T
BF_BRISTL_1T	BF_GLBK_10K	BF_MONTV_10T	BF_SINGR_52T	BF_WATRST_2T
BF_BRKSH_12T	BF_GLBK_1753	BF_MONTV_11T	BF_SMEAD_10	BF_WBKFD_1T2
BF_BRKSH_15T	BF_GLBK_1792	BF_MONTV_12T	BF_SMEAD_2	BF_WESTSD_1T
BF_BUDNTN_4T	BF_GLBK_1867	BF_MONTV_13T	BF_SMEAD_3	BF_WFARN_170
BF_BUNKR_1T2	BF_GLBK_1977	BF_MONTV_14T	BF_SMEAD_4	BF_WFARN_176
BF_BUNKR_2T2	BF_GLBK_20K	BF_MONTV_15T	BF_SMEAD_5	BF_WFARN_710
BF_BUNKR_3T2	BF_GLBK_20T	BF_MONTV_16T	BF_SMEAD_7	BF_WFARN_711
BF_BYPT_3-3T	BF_GLBK_22T	BF_MONTV_17T	BF_SMEAD_8	BF_WFARN_714
BF_BYPT_345D	BF_GLBK_23T	BF_MONTV_18T	BF_SNAUG_1T	BF_WFARN_715
BF_CAMPVL_1T	BF_GLBK_25T	BF_MONTV_18X	BF_SNDPD_137	BF_WFARN_C
BF_CAMPVL_2T	BF_GLBK_2T2	BF_MONTV_19T	BF_SNDPD_161	BF_WFARN_F
BF_CAMPVL_3T	BF_GLBK_3T	BF_MONTV_20T	BF_SNDPD_314	BF_WHMPDN_A1
BF_CAMPVL_4T	BF_GLBK_4T	BF_MONTV_21T	BF_SNDPD_326	BF_WHMPDN_A2
BF_CANAL_112	BF_GLBK_4X12	BF_MONTV_22T	BF_SNDPD_337	BF_WILTON_1T
BF_CANAL_212	BF_GLBK_5X12	BF_MONTV_23T	BF_SNDPD_343	BF_WMDWY_101
BF_CANAL_312	BF_GLBK_7T	BF_MONTV_24T	BF_SNDPD_37E	BF_WMDWY_103
BF_CANAL_412	BF_GLBK_8T	BF_MONTV_4T	BF_SNDPD_37W	BF_WMDWY_104
BF_CANAL_512	BF_GLBK_9T	BF_MONTV_9T	BF_SNDPD_38E	BF_WMDWY_105
BF_CANAL_612	BF_GRAND_22T	BF_MYSCT_1T2	BF_SNDPD_38W	BF_WMDWY_106
BF_CANTN_1T2	BF_GRAND_32T	BF_NBLMF_13T	BF_SNDPD_412	BF_WMDWY_107
BF_CANTN_2T2	BF_GRAND_42T	BF_NBLMF_14T	BF_SNDPD_512	BF_WMDWY_108
BF_CARD_10T	BF_GRNHIL_1T	BF_NBLMF_20T	BF_SNDPD_521	BF_WMDWY_109
BF_CARD_11T	BF_GRNHIL_2T	BF_NBLMF_23T	BF_SNDPD_612	BF_WMDWY_111

BF_CARD_12T	BF_HADDAM_26	BF_NBLMF_2T	BF_SNDPD_643	BF_WMDWY_112
BF_CARD_13T	BF_HADDAM_27	BF_NBLMF_5T	BF_SNGTN_10K	BF_WNSRLK_1T
BF_CARD_14T	BF_HADDAM_29	BF_NBLMF_5X3	BF_SNGTN_11T	BF_WOODMT_1T
BF_CARD_15T	BF_HADDAM_32	BF_NBLMF_7X3	BF_SNGTN_14T	BF_WOODMT_2T
BF_CARD_16T	BF_HADDAM_33	BF_NEA_1CB2	BF_SNGTN_15T	BF_WOODRV_70
BF_CARD_1T	BF_HADDAM_35	BF_NEA_1CB3	BF_SNGTN_16T	BF_WRUT_3039
BF_CARD_345K	BF_HADDAM_37	BF_NESIMS_2T	BF_SNGTN_17T	BF_WRUT_3440
BF_CARD_3T	BF_HADDAM_5X	BF_NEWF_20T2	BF_SNGTN_18T	BF_WRUT_350
BF_CARVR_162	BF_HADDAM_6X	BF_NEWF_3320	BF_SNGTN_1T	BF_WRUT_360
BF_CARVR_262	BF_HADDMN_1T	BF_NEWF_3321	BF_SNGTN_20T	BF_WRUT_371
BF_CARVR_552	BF_HADDMN_2T	BF_NHAVEN_1T	BF_SNGTN_21T	BF_WRUT_372
BF_CARVR_652	BF_HADDMN_4T	BF_NHAVEN_2T	BF_SNGTN_22T	BF_WRUT_3740
BF_CARVR_862	BF_HALVAR_1X	BF_NORHAR_1T	BF_SNGTN_23T	BF_WRUT_3937
BF_CHIPHL_1T	BF_HAWTRN_1T	BF_NORHAR_2T	BF_SNGTN_24T	BF_WTRFRD_1T
BF_CHL_23-1T	BF_HOLBR_102	BF_NORHAR_3T	BF_SNGTN_25T	BF_WTRSD_1T2
BF_CHL_321	BF_HOLBR_107	BF_NORHAR_4T	BF_SNGTN_26T	BF_WTRSD_2T2
BF_COLONY_1T	BF_HOLBR_7	BF_NORHAR_5T	BF_SNGTN_28T	BF_WTRSD_3T2
BF_COMPO_1T	BF_HOPEWL_2T	BF_NORHAR_6T	BF_SNGTN_29T	BF_WWALP_104
BF_COOL_3TB2	BF_INDWEL_1T	BF_NORHAR_7T	BF_SNGTN_30T	BF_WWALP_105
BF_COOL_K32	BF_JUNEST_1T	BF_NORHN_1K	BF_SNGTN_31T	BF_WWALP_107
BF_COOL_K36	BF_KILLNG_22	BF_NRWLK_10T	BF_SNGTN_33T	BF_WWALP_108
BF_COSCOB_1T	BF_KILLNG_25	BF_NRWLK_11T	BF_SNGTN_3T	BF_WWALP_109
BF_COSCOB_2T	BF_KILLNG_3T	BF_NRWLK_12T	BF_SNGTN_3X3	BF_WWALP_7
BF_DARIEN_1T	BF_KLEEN_1T	BF_NRWLK_1T	BF_SNGTN_4T	BF_WWALP_8

Double Circuit Tower Contingencies = 157 Total				
DC_1000_1070	DC_1355_1610	DC_1620_1975	DC_1820_1830	DC_364_1250
DC_1000_1080	DC_1355_1690	DC_1621_1742	DC_1867_1880	DC_3642_1779
DC_1000_1090	DC_1389_1880	DC_1622_1770	DC_1867_1890	DC_368_1767
DC_1070_1080	DC_1394_1858	DC_1630_1640	DC_1867_1977	DC_3754_1466
DC_1080_100	DC_1394_515S	DC_1630_1655	DC_1880_1890	DC_376_1772
DC_1080_1280	DC_1410_100	DC_1635_1763	DC_1910_1950	DC_379_N186
DC_1080_1410	DC_1410_400	DC_1637_1720	DC_3196_1314	DC_381_N186
DC_1080_1490	DC_1416_1867	DC_1640_1685	DC_3196_1602	DC_3827_1208
DC_1080_1675	DC_1416_1880	DC_1668_1721	DC_3196_1603	DC_3827_1610
DC_1100_1200	DC_1416_1890	DC_1670_1820	DC_321_1618	DC_3827_1655
DC_1100_1300	DC_1440_1450	DC_1670_1830	DC_321_1770	DC_387_1460
DC_1130_1430	DC_1440_1750	DC_1710_1714	DC_321_1887	DC_387_1537
DC_1130_9100	DC_1445_1721	DC_1710_1730	DC_3216_1768	DC_387_1975
DC_1163_1550	DC_1448_1751	DC_1714_1720	DC_3216_1781	DC_400_500
DC_1191_1921	DC_1460_1537	DC_1714_1730	DC_325_331	DC_560N_1570
DC_1200_1300	DC_1470_1565	DC_1720_1714	DC_325_344	DC_560N_1594
DC_1207_1775	DC_1500_1605	DC_1732_1788	DC_335_1-536	DC_580/710LS
DC_1208_1640	DC_1505_1607	DC_1732_1900	DC_337_I161	DC_689_693
DC_1210_1220	DC_1537_1655	DC_1740_1750	DC_3403_1565	DC_697/710LS

DC_1222_1714	DC_1550_1910	DC_1751_1756	DC_342_120W	DC_710/714LS
DC_1235_1250	DC_1570_1580	DC_1751_1777	DC_342_194	DC_800_900
DC_1261_1598	DC_1570_1585	DC_1752_1773	DC_342_355	DC_8100_8200
DC_1272_1721	DC_1572_1620	DC_1770_1887	DC_344_A24	DC_8300_8400
DC_1280_100	DC_1575_1585	DC_1771_1820	DC_348_1772	DC_8300_8600
DC_1280_1410	DC_1575_1990	DC_1775_1786	DC_348_1975	DC_8400_8600
DC_1280_1465	DC_1580_1585	DC_1780_1790	DC_3557_1448	DC_88/89005
DC_1280_400	DC_1580_1710	DC_1788_1900	DC_356_E1	DC_88/89006
DC_1310_1635	DC_1580_1730	DC_1800_1810	DC_362_1772	DC_88003A/89
DC_1310_1763	DC_1606_1724	DC_1800_1825	DC_362_1975	DC_8804_8904
DC_1319_1570	DC_1610_1640	DC_1810_1825	DC_362_376	DC_8809_8909
DC_1319_1580	DC_1610_1685	DC_1810_1835	DC_364_1235	DC_K371_K34
DC_1319_1585	DC_1618_1887			

11.3 GHCC Area Special Protection System and Automatic Control Scheme Contingencies

SPS Contingencies = 66 Total				
SPS_1570-2	SPS_8809A	SPS_BSCON_AC	SPS_LN_1130	SPS_GR42T_RB
SPS_17101697	SPS_89003_RB	SPS_BSCON_BD	SPS_LN_1697	SPS_GR42T_TR
SPS_387+NHHB	SPS_89003_TR	SPS_BSELMARB	SPS_LN_1710	SPS_327_315
SPS_387-1	SPS_8909B	SPS_BSELMATR	SPS_LN_91001	SPS_WAT1T_RB
SPS_393+690	SPS_ALS1T_RB	SPS_BSELMBRB	SPS_MIL1T_RB	SPS_WAT1T_TR
SPS_398+690	SPS_ALS1T_TR	SPS_BSELMBTR	SPS_MIL1T_TR	LN_398+690_SPS
SPS_690	SPS_ALS2T_RB	SPS_BSWRVARB	SPS_NHHB	TF_MILSTN_3X+690_SPS
SPS_8301_RB	SPS_ALS2T_TR	SPS_BSWRVATR	ACS_SNGTN_5T	BF_CAMPVL_2T / DC_1191_1921+690_SPS
SPS_8301_TR	SPS_BF_BARDA	SPS_BSWRVBRB	SPS_TRMTB	BF_CAMPVL_4T / DC_1732_1900+690_SPS
SPS_8500_RB	SPS_BF_BARDB	SPS_BSWRVBTR	SPS_GR22T_RB	BF_MILST_14T+690_SPS
SPS_8500_TR	SPS_BF_TRM1T	SPS_CHL_231T	SPS_GR22T_TR	BF_NBLMF_23T+690_SPS
SPS_88003_RB	SPS_BF_TRM2T	SPS_D88003RB	SPS_GR32T_RB	BF_NTHFLD_1T+690_SPS
SPS_88003_TR	SPS_BS_ASHTB	SPS_D88003TR	SPS_GR32T_TR	HVDC_PHASE_2+690_SPS
SPS_88098909				

11.4 GHCC Area NERC Category D Contingencies

Generation Station Contingencies - Total = 11				
GS_BRPT_HBEN	GS_MIDDLTWN	GS_MONTVILLE	GS_NRWLKHBR	GS_WALLNGFRD
GS_COSCOB	GS_MILLSTONE	GS_NEW_HAVEN	GS_S-MEADOW	GS_WATERSIDE
GS_DEVON				

Loss of Substation contingencies - Total = 5				
SS_MANCH_345	SS_STGTN_115	SS_DEVON_115	SS_MLSTN_345	SS_MANCH_115

Loss of Right of way contingencies - Total = 5				
ROW_CHST_DLY	ROW_HBRKJ_NO	ROW_SGTN_SCO	ROW_HBRKJ_EH	ROW_STV_BNKR

Section 12
Appendix E: Steady State Testing Results

Appendix E1_Thermal_N-1_Results.xlsx

Appendix E2_Voltage_N-1_Results_PTF_Buses.xlsx

Appendix E3_Voltage_N-1_Results_non-PTF_Buses.xlsx

Appendix E4_Non-conv_N-1_Results.xlsx

Appendix E5_Gen_Adjustments_for_N-1_Cases.xlsx

Appendix E6_Thermal_N-1-1_Results.xlsx

Appendix E7_Voltage_N-1-1_Results_PTF_Buses.xlsx

Appendix E8_Voltage_N-1-1_Results_non-PTF_Buses.xlsx

Appendix E9_Non_Conv_N-1-1_Results.xlsx

Appendix E10_Gen_Adjustments_for_N-1-1_Cases.xlsx

Section 13
Appendix F: Extreme Contingency Testing Results

Appendix F - GHCC_EC_Results.xlsx

Section 14
Appendix G: Short Circuit Testing Results

Appendix G - Short Circuit Results.xlsx

Section 15
Appendix H: Critical Load Level Assessment Testing

The following sections identify the different contingency pairs evaluated and the reason for them being included in the analysis. Two tables are identified for each subarea. One consists of the thermal violations and the other has the voltage violations.

15.1 Greater Hartford Subarea

Table 15-1 has the dispatches and contingency pairs that were tested to determine the critical load level for elements in the Greater Hartford subarea with thermal violations.

Table 15-1:
Greater Hartford Subarea Thermal Violations for Critical Load Levels Assessment

Element ID	Overloading Element	Initial Element OOS	Contingency	Dispatch
1207	Manchester – E Hartford	[redacted]	[redacted]	HTFD_02
1704	S Meadow - SW Hartford	[redacted]	[redacted]	HTFD_2A
1726	N Bloomfield - Farmington	[redacted]	[redacted]	MIDD_01
1751	Bloomfield Jct – NW Hartford	[redacted]	[redacted]	HTFD_02
1752	Rocky Hill - Berlin	[redacted]	[redacted]	MIDD_01
1756	Bloomfield – NW Hartford	[redacted]	[redacted]	HTFD_02
1765	Berlin – Westside	[redacted]	[redacted]	MIDD_01
1769	Berlin – E New Britain	[redacted]	[redacted]	MIDD_01
1771	Southington - Berlin	[redacted]	[redacted]	MIDD_01
1773	S Meadow – Rocky Hill	[redacted]	[redacted]	MIDD_01
1777	N Bloomfield - Bloomfield	[redacted]	[redacted]	HTFD_02
1779	S Meadow - Bloomfield	[redacted]	[redacted]	HTFD_02
1785	Berlin - Newington	[redacted]	[redacted]	MIDD_01
1670-1	Southington – Reservoir Rd Jct	[redacted]	[redacted]	MIDD_01
1670-2	Reservoir Rd Jct - Berlin	[redacted]	[redacted]	MIDD_01
1722-1	SW Hartford – Capitol District Tap	[redacted]	[redacted]	HTFD_2A
1722-2	Capitol District Tap – NW Hartford	[redacted]	[redacted]	CCRP_04
1775-1	Riverside Tap – S Meadow	[redacted]	[redacted]	HTFD_02
1775-2	Manchester – Riverside Tap	[redacted]	[redacted]	HTFD_02
1783-1	Farmington – Newington Tap	[redacted]	[redacted]	MIDD_01
1783-2	Newington Tap - Newington	[redacted]	[redacted]	CCRP_02
1783-3	E New Britain – Riverside	[redacted]	[redacted]	MIDD_01

Element ID	Overloading Element	Initial Element OOS	Contingency	Dispatch
	Tap			
1950	Southington – Canal	[redacted]	[redacted]	CCRP_01
NWHTFD 32T	Breaker 32T Bus Segment	[redacted]	[redacted]	CCRP_04
STGTN 2X	Southington 2X Auto	[redacted]	[redacted]	CCRP_01
STGTN 3X	Southington 3X Auto	[redacted]	[redacted]	CCRP_01

Table 15-2 summarizes the dispatches and contingency pairs that were tested to determine the critical load level to eliminate the voltage violations in the Greater Hartford subarea.

Table 15-2:
Greater Hartford Subarea Voltage Violations for Critical Load Level Assessment

Bus Name – Voltage	Initial Element OOS	Worst-case Contingency	Dispatch
Berlin – 115 kV	[redacted]	[redacted]	MIDD_01
Bloomfield – 115 kV	[redacted]	[redacted]	HTFD_02
Capitol District – 115 kV	[redacted]	[redacted]	HTFD_02
E New Britain – 115 kV	[redacted]	[redacted]	NWCT_2A
Farmington – 115 kV	[redacted]	[redacted]	MIDD_01
Newington – 115 kV	[redacted]	[redacted]	NWCT_2A
NW Hartford – 115 kV	[redacted]	[redacted]	HTFD_02
Rocky Hill – 115 kV	[redacted]	[redacted]	MIDD_01
West Side – 115 kV	[redacted]	[redacted]	NWCT_01
SW Hartford – 115 kV	[redacted]	[redacted]	HTFD_02
Black Rock – 115 kV (Non-PTF)	[redacted]	[redacted]	MIDD_01
GE Test – 115 kV (Non-PTF)	[redacted]	[redacted]	MIDD_01

15.2 Manchester-Barbour Hill Subarea

Table 15-3 has the dispatches and contingency pairs that were tested to determine the critical load level for elements in the Manchester-Barbour Hill subarea with thermal violations.

Table 15-3:
Manchester-Barbour Hill Subarea Thermal Violations for Critical Load Level Assessment

Element ID	Overloading Element	Initial Element OOS	Worst-Case Contingency	Dispatch
1310	Manchester – South Windsor	[redacted]	[redacted]	BHIL_01
1635	South Windsor – Barbour Hill	[redacted]	[redacted]	BHIL_01
1763	Manchester – Barbour Hill	[redacted]	[redacted]	BHIL_01
MANCH 4X	Manchester 345/115 Autotransformer	[redacted]	[redacted]	MIDD_01
MANCH 6X	Manchester 345/115 Autotransformer	[redacted]	[redacted]	MIDD_01

Table 15-4 summarizes the dispatches and contingency pairs that were tested to determine the critical load level to eliminate the voltage violations in the Manchester-Barbour Hill subarea.

Table 15-4: Manchester-Barbour Hill Subarea Voltage Violations for Critical Load Level Assessment

Bus Name	Initial Element OOS	Worst-Case Contingency	Dispatch
Barbour Hill – 115 kV	[redacted]	[redacted]	BHIL_01
South Windsor – 115 kV	[redacted]	[redacted]	BHIL_01
Dexter – 115 kV (Non-PTF)	[redacted]	[redacted]	BHIL_01
Enfield – 115 kV (Non-PTF)	[redacted]	[redacted]	BHIL_01
Rockville – 115 kV (Non-PTF)	[redacted]	[redacted]	BHIL_01
Windsor Locks – 115 kV (Non-PTF)	[redacted]	[redacted]	BHIL_01

15.3 Middletown Subarea

Table 15-5 has the dispatches and contingency pairs that were tested to determine the critical load level for elements in the Middletown subarea with thermal violations.

Table 15-5:
Middletown Subarea Thermal Violations for Critical Load Level Assessment

Element ID	Overloading Element	Initial Element OOS	Worst-case Contingency	Dispatch
1050	Middletown – Dooley	[redacted]	[redacted]	HTFD_2A
1261	Haddam - Bokum (Circuit 1)	[redacted]	[redacted]	MIDD_02
1443	Portland – Middletown	[redacted]	[redacted]	MIDD_01
1588	Colony – N Wallingford	[redacted]	[redacted]	MIDD_01
1598	Haddam - Bokum (Circuit 2)	[redacted]	[redacted]	MIDD_02
1620	Middletown – Haddam	[redacted]	[redacted]	CCRP_04
1759	Hopewell – Portland	[redacted]	[redacted]	MIDD_01
1766	Dooley - Westside	[redacted]	[redacted]	HTFD_2A
1355-1	Hanover Tap – Colony	[redacted]	[redacted]	MIDD_01
1355-3	Southington – Hanover Tap	[redacted]	[redacted]	MIDD_01

Table 15-6 summarizes the dispatches and contingency pairs that were tested to determine the critical load level to eliminate the voltage violations in the Middletown subarea.

Table 15-6:
Middletown Subarea Voltage Violations for Critical Load Level Assessment

Bus Name	Initial Element OOS	Worst-case Contingency	Dispatch
Bokum – 115 kV	[redacted]	[redacted]	MIDD_01
Colony – 115 kV	[redacted]	[redacted]	MIDD_01
Dooley – 115 kV	[redacted]	[redacted]	MIDD_01
East Meriden – 115 kV	[redacted]	[redacted]	MIDD_01
Green Hill – 115 kV	[redacted]	[redacted]	MIDD_01
Haddam – 115 kV	[redacted]	[redacted]	MIDD_01
Hanover – 115 kV	[redacted]	[redacted]	MIDD_01
Hopewell – 115 kV	[redacted]	[redacted]	MIDD_01
Middletown – 115 kV	[redacted]	[redacted]	MIDD_01
N Wallingford – 115 kV	[redacted]	[redacted]	MIDD_01
Portland – 115 kV	[redacted]	[redacted]	MIDD_01
Pratt and Whitney – 115 kV	[redacted]	[redacted]	MIDD_01
Stepstone – 115 kV	[redacted]	[redacted]	MIDD_01

Bus Name	Initial Element OOS	Worst-case Contingency	Dispatch
Branford – 115 kV	[redacted]	[redacted]	MIDD_01

15.4 Northwestern Connecticut Subarea

Table 15-7 has the dispatches and contingency pairs that were tested to determine the critical load level for elements in the Northwestern Connecticut subarea with thermal violations.

Table 15-7:
Northwestern CT Subarea Thermal Violations for Critical Load Level Assessment

Element ID	Overloading Element	Initial Element OOS	Worst-case Contingency	Dispatch	Comments
1256	NE Simsbury – Canton	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
1191	Frost Bridge – Campville	[redacted]	[redacted]	CCRP_04	No SPS Action
1732	Campville – Weingarten Junction	[redacted]	[redacted]	IRP_01	Testing performed with and without 690 SPS action
1825	Bristol – Forestville	[redacted]	[redacted]	CCRP_04	No SPS Action
1835	Chippen Hill – Thomaston	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
1921	Thomaston – Campville	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
1810-1	Southington – Lake Ave Junction	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
1810-3	Lake Ave Junction – Chippen Hill	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
CMPVL 1T	Campville 1T Bus Section	[redacted]	[redacted]	CCRP_04	No SPS Action
CMPVL 3T	Campville 3T Bus Section	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action

Table 15-8 summarizes the dispatches and contingency pairs that were tested to determine the critical load level to eliminate the voltage violations in the Northwestern Connecticut subarea.

Table 15-8:
Northwestern CT Subarea Voltage Violations for Critical Load Level Assessment

Bus Name	Initial Element OOS	Worst-case Contingency	Dispatch	Comments
Bristol – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Campville – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Campville – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Canton – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action)
Chippen Hill – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action)
Falls Village – 69 kV (PTF)	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Forestville – 115	[redacted]	[redacted]	NWCT_02	No SPS Action
Franklin Drive – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
NE Simsbury – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Salisbury – 69 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Thomaston – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action)
Torrington – 115 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Torrington – 69 kV	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
Falls Village – 69 kV (non - PTF)	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action
North Canaan – 69 kV (non - PTF)	[redacted]	[redacted]	CCRP_04	Testing performed with and without 690 SPS action

Section 16
Appendix I: Critical Load Level Assessment Results

Appendix I1 -Critical Load Level for Thermal Violations.xlsx

Appendix I2 -Critical Load Level for Voltage Violations.xlsx

Section 17
Appendix J: Net Load in Connecticut Calculation

Table 17-1:
Calculation of Net Load in Connecticut for Year of Need Calculation

All Data below Excludes Transmission Losses[20]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CELT Load in CT	7,776	7,878	8,010	8,136	8,234	8,312	8,395	8,463	8,541	8,604
CT Load Fed from MA	25.8	26.1	26.6	27.0	27.3	27.6	27.9	28.1	28.3	28.5
CELT load fed from substations in CT	7,750	7,852	7,983	8,109	8,207	8,284	8,367	8,435	8,513	8,576
CT Passive DR and EE	414.2	421.2	410.3	413.6	433.4	459.8	485.2	508.7	531.1	551.6
CT Active DR	373.7	354.4	374.1	319.7	273.2	273.2	273.2	273.2	273.2	273.2
Available CT Active DR	280.3	265.8	280.6	239.7	204.9	204.9	204.9	204.9	204.9	204.9
Total DR	694.4	687.0	690.9	653.3	638.4	664.8	690.2	713.6	736.1	756.6
Net Load in CT	**7,055**	**7,165**	**7,292**	**7,456**	**7,568**	**7,620**	**7,677**	**7,721**	**7,777**	**7,819**

[20] Transmission losses are assumed to be 2.5% of the CELT load, which includes losses

Section 18
Appendix K: NERC Compliance Statement

This report is the first part of a two part process used by ISO-NE to assess and address compliance with NERC TPL standards. This Needs Assessment report provides documentation of an evaluation of the performance of the system as contemplated under the TPL standards to determine if the system meets compliance requirements. The Solutions Study report is a complimentary report that documents the study to determine which, if any, upgrades should be implemented along with the in-service dates of proposed upgrades that are needed to address the needs documented in the Needs Assessment report. The Needs Assessment report and the Solution Study report taken together provide the necessary evaluations and determinations required under the NERC TPL standards.

This study provides a detailed assessment of the Greater Hartford and Central Connecticut (GHCC) portion of New England's electric system performance for the 2013-2017 next five years and reviews system performance expected for years 2018-2022 six through ten. This study shows performance for NERC Category A conditions in Section 5.2.1.1 (Page 55), Section 5.2.2.1 (Page 68), Section 5.2.3.1 (Page 72) and Section 5.2.4.1(Page 79) and performance was inadequate. The study shows NERC Category B condition performance in Section 5.2.1.2 (Page 55), Section 5.2.2.2(Page 68), Section 5.2.3.2 (Page 72) and Section 5.2.4.2 (Page 80) and performance was inadequate. NERC Category C review can be found in Section 5.2.1.3 (Page 58), Section 5.2.2.3 (Page 68), Section 5.2.3.3 (Page 73) and Section 5.2.4.3 (Pages 84) and performance was inadequate. For NERC Category B and C review all relevant contingencies in the GHCC area were studied. A detailed description of the contingencies tested is included in Section 4.3.2(Page 40). As shown in Section 6.4 (Pages 93 to 96), the marginal violation is expected to be seen pre-2013 at a net Connecticut load level of 3,444 MW. Limited testing of NERC Category D contingencies was conducted and the results of this testing can be found in Section 5.2.7 (Page 90). These will be taken into account as part of the consideration of alternatives in the study area.

As shown in Section 3.1.6 (Page 24) the study includes a peak load of 34,105 MW in New England and 8,825 MW in Connecticut, for the year 2022. This study uses normal operating procedures as illustrated by transfers, phase shifter settings and normal capacitor settings. Transfers are as shown in Section 3.1.9(Page 27). Note that while firm transfers are not explicitly modeled or used in New England the system conditions used in this study are always sufficiently stressed to ensure transfer capability across interfaces are maintained. This study includes existing and planned Demand Resources, transmission and generation facilities as shown in Section 3.1.12(Page 33). Demand Resources effects are included in load projections. The study includes reactive resources as shown in Section 3.1.11 (Page 33). Reactive resources will provide inadequate voltage support for the next ten years. Currently there are no planned outages of sufficient duration which would impact this. The effects of existing and planned protection systems can be found in Section 3.1.13 (Page 34). There are no existing or planned control devices (Dynamic Control Systems) in the study area. ISO New England Operations coordinates and approves planned generator and transmission outages looking out one year. Long term planning studies look at 90/10 load, stressed dispatch and line out conditions that historically provide ample margin to perform maintenance.

2.D.4 *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Solutions Study* (ISO-NE, February 2015), Redacted to secure Confidential Energy Infrastructure Information (CEII)

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Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Solutions Study

Greater Hartford and Central Connecticut Working Group
(ISO New England, Northeast Utilities, and United Illuminating)

[redacted]

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February 2015

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Section 1
Executive Summary

1.1 Needs Assessment Results and Problem Statement

The objective of this analysis is to identify regulated transmission solutions that address the needs identified in the *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment*, dated May 2014[1].

A long-term (ten-year) planning horizon was used for this study based on the most recently available Capacity, Energy, Loads, and Transmission (CELT) forecast data (2013) at the time that the Needs Assessment began. This study was focused on the projected 2022 peak demand load levels for the ten-year horizon. The models reflected the following peak load conditions:

Loads:

The summer peak 90/10 load level forecast is 34,105 MW for all of New England and 8,825 MW (which represents 26% of the New England load) for the state of Connecticut.

Transmission Topology:

All relevant transmission projects with Proposed Plan Application (PPA) approval, with the exception of the NEEWS - Central Connecticut Reliability Project (CCRP), have been included in the study base case. Section 3.2.3 includes a full listing and description of all projects included.

Generation:

All generation projects with a Capacity Supply Obligation as of Forward Capacity Auction 7 (FCA #7) were included in the study base case. Section 3.2.4 of this report includes a full listing and description of generation included in the base case. Due to the submission of Non-Price Retirement (NPR) Requests for the Bridgeport Harbor 2 and the Norwalk Harbor units for FCA #8, these units have been taken out-of-service (OOS) in the base case.

Demand Resource Assumptions:

Demand Resources (active and passive) were modeled based on the Demand Resources (DR) cleared in FCA #7. In addition, any accepted NPR requests for DR and any DR terminations in Connecticut for FCA #8 were also taken into account. Finally, the energy efficiency forecast for the years corresponding to FCA #8 and beyond until 2022 were also modeled based on the 2013 energy efficiency (EE) forecast. Section 3.2.6 includes the details of the demand resources considered for this study.

All the criteria violations observed in the Greater Hartford and Central Connecticut (GHCC) area were based on steady state thermal and voltage testing. The following summarizes the needs for each subarea:

[1] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/reports/2014/ghcc_needs_assessment_report_rev2.zip

Greater Hartford Subarea

- Need to resolve N-1 and N-1-1 criteria violations observed in the Greater Hartford area
- Thermal and voltage violations observed in the following areas:
    - North Bloomfield to Manchester area
    - South Meadow – Berlin – Southington area
    - Southington area
- [redacted]

Middletown Subarea:

- Need to resolve the N-1 and N-1-1 criteria violations observed in the Middletown area
- [redacted]

Manchester – Barbour Hill Subarea

- Need to resolve the N-1-1 criteria violations observed in serving load in the Manchester-Barbour Hill area
- [redacted]

Northwestern Connecticut Subarea:

- Need to resolve N-1 and N-1-1 criteria violations observed in serving load in the Northwest Connecticut area
- [redacted]

Western Connecticut Import Interface:

- Need to resolve N-1-1 criteria violations [redacted]

Section 3 of this report contains more details of all assumptions used to complete this study.

The following types of analyses were performed as part of this study:

- **Steady-State Thermal and Voltage Analysis** – steady-state analysis was performed to determine if the proposed alternatives resolve the thermal and voltage needs identified during the GHCC Needs Assessment. A variety of one and two-unit-out generation dispatches and inter-regional stresses were evaluated for N-0 (All-facilities-in) conditions as well as following contingency events for N-1 (all-facilities-in, first contingency) and N-1-1 (facility-out, first contingency) conditions to evaluate the solution alternatives.
- **Short Circuit Analysis** – a study to ensure that the substation equipment in the study area has the ability to withstand and interrupt fault current with the preferred solution for the GHCC Study area.
- **Transfer Analysis** – analysis was performed to analyze the effect that various proposed solution alternatives may have on the transfer capabilities of the Western Connecticut Import interface.

The results of the Needs Assessment are summarized in Sections 2.2.2 and 2.3 of this report. These results indicate that there are violations of planning criteria under the assumptions and system conditions modeled, with many of the violations seen at 2013 load levels or earlier.

1.2 Recommended Solution

Alternative A for the Manchester / Barbour Hill subarea is comprised of several components as described in Table 1-1. A more detailed description of each component can be found in Section 5.3.1.

Table 1-1: Manchester / Barbour Hill Alternative A Solution Components

Component ID	Description
1	Add a new 345/115 kV autotransformer at Barbour Hill and associated terminal equipment
3	Reconductor the 115 kV line between Manchester and Barbour Hill (1763) – 7.6 miles
4	Add a 345 kV breaker in series with breaker 24T at the Manchester 345 kV switchyard

Alternative A for the Northwestern Connecticut subarea is comprised of several components as described in Table 1-2. A more detailed description of each component can be found in Section 5.3.2.

Table 1-2: Northwestern Connecticut Alternative A Solution Components

Component ID	Description
1	Add a new 10.35 mile, 115 kV line from Frost Bridge to Campville and associated terminal equipment
3	Separation of 115 kV DCT corresponding to the Frost Bridge to Campville (1191) line and the Thomaston to Campville (1921) line and add a breaker at Campville 115 kV substation
4	Upgrade terminal equipment on the 115 kV line between Chippen Hill and Lake Avenue Junction (1810-3)
5	Reconductor the 115 kV line between Southington and Lake Avenue Junction (1810-1) – 5.2 miles

The Haddam Autotransformer alternative for the Middletown subarea is comprised of several components as described in Table 1-3. A more detailed description of each component can be found in Section 5.3.3.

Table 1-3: Middletown Area 2nd Haddam Autotransformer Alternative Solution Components

Component ID	Description
1	Add a 2nd 345/115 kV autotransformer at Haddam substation and reconfigure the 3-terminal 345 kV 348 line into 2 two-terminal lines
3	Terminal equipment upgrades on the 345 kV line between Haddam and Beseck (362)
4	Separation of 115 kV double circuit towers corresponding to the Branford – Branford RR line (1537) and the Branford to North Haven (1655) line and adding a series breaker at Branford 115 kV substation
5	Terminal equipment upgrades on the Middletown to Dooley Line (1050)
6	Terminal equipment upgrades on the Middletown to Portland Line (1443)
7	Redesign the Green Hill 115 kV substation from a straight bus to a ring bus and add a 37.8 MVAR capacitor bank
8	Add a 37.8 MVAR capacitor bank at Hopewell 115 kV substation
12	Separation of 115 kV double circuit towers corresponding to the Middletown – Pratt and Whitney line (1572) and the Middletown to Haddam (1620) line

The Newington – Southwest Hartford 115 kV underground line alternative is comprised of several components as described in Table 1-4. A more detailed description of each component can be found in Section 5.3.4.

Table 1-4: Greater Hartford Area Newington – Southwest Hartford Underground Line Alternative Solution Components

Component ID	Description
1	Add a new 4 mile 115 kV underground cable from Newington to Southwest Hartford and associated terminal equipment including a 2% series reactor
3	Loop the 1779 line between South Meadow and Bloomfield into the Rood Avenue substation and reconfigure the Rood Avenue substation
4	Reconfigure the Berlin 115 kV substation including the addition of two 115 kV breakers and the relocation of a capacitor bank
5	Add a 115 kV 25.2 MVAR capacitor at Westside 115 kV substation
6	Reconductor the 115 kV line between Newington and Newington Tap (1783) – 0.01 miles
7	Separation of 115 kV DCT corresponding to the Bloomfield to South Meadow (1779) line and the Bloomfield to North Bloomfield (1777) line and add a breaker at Bloomfield 115 kV substation
8	Install a 115 kV 3% reactor on the underground cable between South Meadow and Southwest Hartford(1704)
9	Separation of 115 kV DCT corresponding to the Bloomfield to North Bloomfield (1777) line and the North Bloomfield – Rood Avenue – Northwest Hartford (1751) line and add a breaker at North Bloomfield 115 kV substation
S1	Replace the existing 3% series reactors on the 115 kV lines between Southington and Todd (1910) and between Southington and Canal (1950) with 5% series reactors
S2	Replace the normally open 19T breaker at Southington with a 3% series reactor between Southington Ring 1 and Southington Ring 2 and associated substation upgrades
S3	Add a breaker in series with breaker 5T at the Southington 345 kV switchyard
S4	Add a new control house at Southington 115 kV substation

1.3 NERC Compliance Statement

In accordance with NERC TPL Standards, this assessment provides:

- A written summary of plans to address the system performance issues described in the *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment*, dated May 2014
- A schedule for implementation, as shown in Section 8.3
- A discussion of expected required in-service dates of facilities and associated load level when required, as shown in Section 8.3
- A discussion of lead times necessary to implement plans in Section 8.3

Section 2
Needs Assessment Results Summary

2.1 Introduction

The objective of the GHCC Needs Assessment was to evaluate the system needs in the Greater Hartford and Central Connecticut (GHCC) study area and to reassess the needs which drove the Central Connecticut Reliability Project (CCRP), while considering the following:

- Future load growth
- Reliability over a range of generation patterns and transfer levels
- All NERC, NPCC and ISO New England applicable transmission planning reliability standards
- Regional and local reliability issues
- New England East-West Solution (NEEWS) project, and
- Existing and planned supply resources and demand resources

The scope of the Needs Assessment study performed for the GHCC area included evaluation of the reliability performance of the transmission system serving this area of New England for the year 2022 projected system conditions. The system was tested with all elements in-service i.e. N-0 (all-facilities-in) and under N-1 (all-facilities-in, first contingency) and N-1-1 (facility-out, first contingency) contingency conditions for a number of possible operating conditions with respect to related interface transfer levels and generating unit availability conditions.

This Needs Assessment was the first step in the study process defined in accordance with the Regional Planning Process as outlined in Attachment K to the ISO-NE Open Access Transmission Tariff (OATT).

A working group led by ISO-NE, and consisting of members from ISO-NE, Northeast Utilities (NU), and United Illuminating (UI), was formed to study the Greater Hartford and Central Connecticut transmission system. As part of the Planning Advisory Committee (PAC) process, stakeholders, which include generator owners, suppliers, load serving entities, energy efficiency entities, state regulators, and transmission owners, also provided input throughout the study process.

The results of the Needs Assessment were presented in a Needs Assessment report[2] "*Final GHCC Needs Assessment Report*," dated May 2014.

[2] http://www.iso-ne.com/system-planning/key-study-areas/greater-hartford

2.2 Needs Assessment Review

2.2.1 Areas Studied

In this study, the GHCC area has been divided into the following four subareas:

1. Greater Hartford
2. Northwest Connecticut
3. Middletown, and
4. Manchester - Barbour Hill

Table 2-1 summarizes the towns included in each of the subareas:

Table 2-1: Towns Included in Study Area

Subarea	Towns in the Subarea (*Note: Location of towns may not dictate where load is served*)
Greater Hartford	Avon, Berlin, Bloomfield, Burlington, Cromwell, East Granby, East Hartford, Farmington, Granby, Hartford, New Britain, Newington, Plainville, Rocky Hill, West Hartford, Wethersfield, Windsor
Northwest Connecticut	Barkhamsted, Bethlehem, Bristol, Canaan, Canton, Colebrook, Cornwall, Goshen, Hartland, Harwinton, Kent, Litchfield, Morris, New Hartford, Norfolk, North Canaan, Plymouth, Salisbury, Sharon, Simsbury, Thomaston, Torrington, Warren, Washington, Winchester
Middletown	Chester, Clinton, Colchester, Deep River, Durham, East Haddam, East Hampton, Essex, Guilford, Haddam, Hebron, Killingworth, Lyme, Madison, Marlborough, Meriden, Middlefield, Middletown, Old Lyme, Old Saybrook, Portland, Wallingford, Westbrook
Manchester - Barbour Hill	Bolton, East Windsor, Ellington, Enfield, Glastonbury, Manchester, Somers, South Windsor, Suffield, Tolland, Vernon, Windsor Locks

Figure 2-1 shows the geographic map of the study area and Figure 2-2 shows the one-line diagram for the study area. Each of the figures has the four study subareas delineated.

It should be noted that the Scitico substation, while geographically located within the state of CT and in the Manchester/Barbour Hill area, is fed by 115 kV lines from the Springfield area. Since the Scitico substation is not fed from the Manchester/Barbour Hill area transmission facilities, the study of the transmission system around the Scitico substation is excluded from the study area.

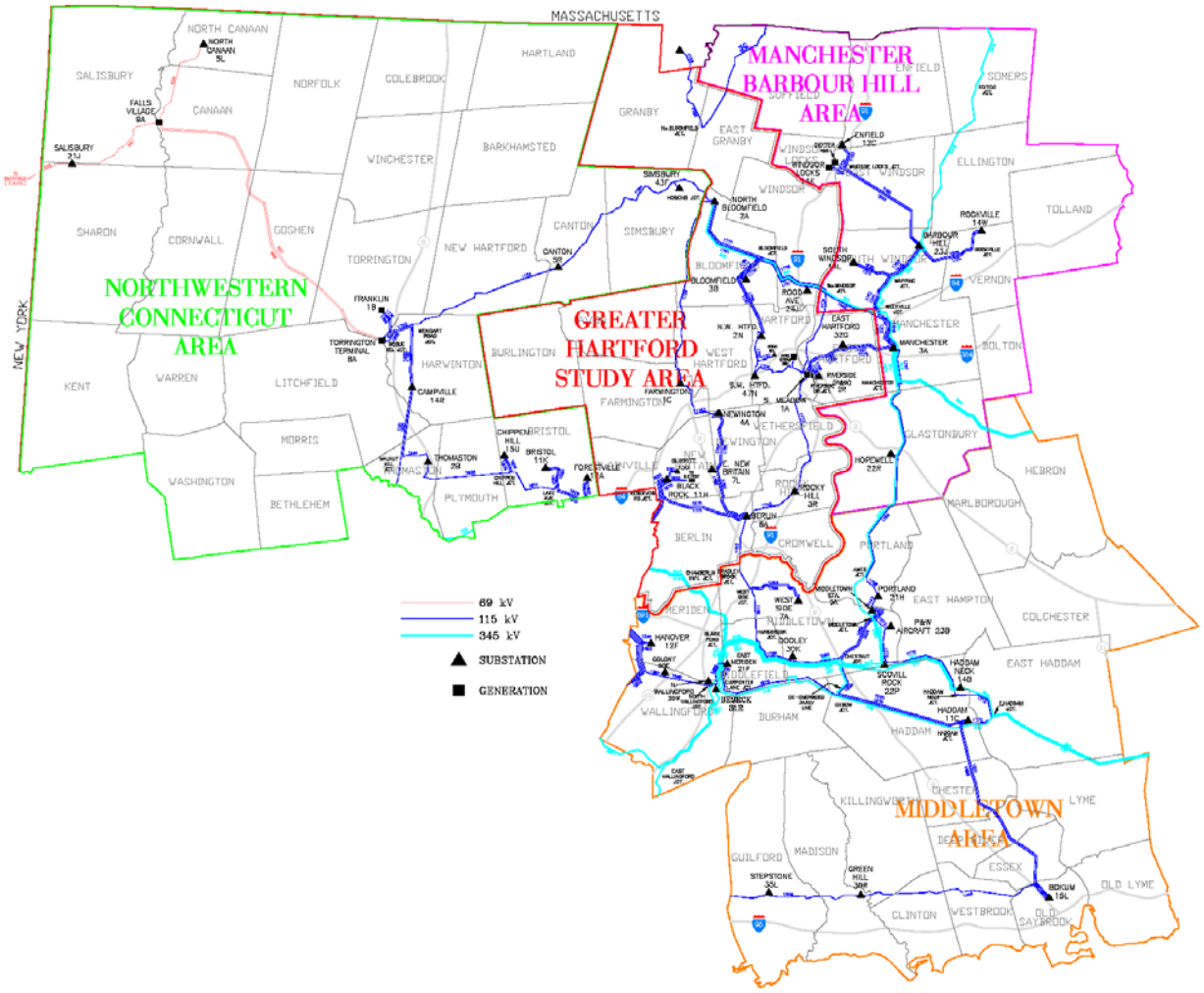


Figure 2-1: GHCC Study Area Map[3]

[3] The diagram is for illustrative purposes to show the study area. In the Manchester – Barbour Hill area, the Scitico substation is supplied from western Massachusetts but serves load in Connecticut. The Scitico station and the load fed from it has been excluded from the study



Figure 2-2: GHCC Study Area One Line Diagram

The GHCC study area is located between the Connecticut Import interface and the Southwest Connecticut (SWCT) Import interface, while only parts of the study area are within the Western Connecticut Import area. In addition to the above interfaces the export/import levels to/from New York through the AC ties, the Cross Sound Cable (CSC), and the Norwalk Northport Cable (NNC) also affect the study area. Figure 2-3 shows the interfaces impacting the study area.

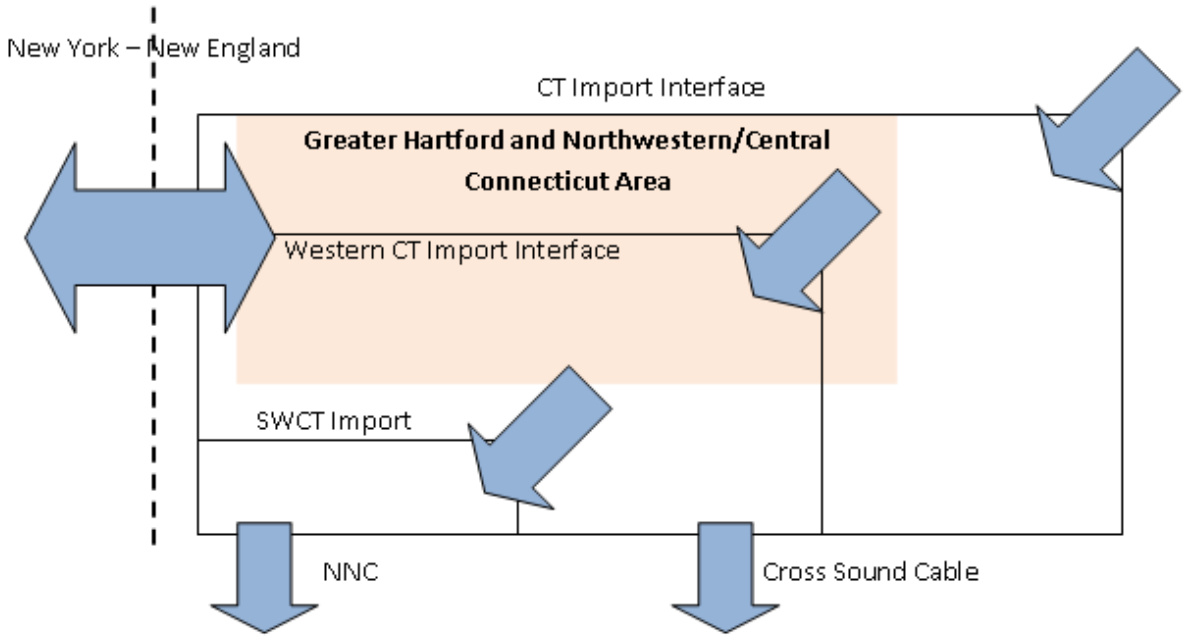


Figure 2-3: Interfaces of Interest for the GHCC Study Area

The New England East-West Solution (NEEWS) project received its Proposed Plan Application (PPA) approval in 2008 and was revised and re-approved in 2012. Since the first approval, a significant amount of new resources have been procured in Connecticut via the Forward Capacity Market (FCM). With the addition of these new resources an updated transmission-based needs analysis for the NEEWS transmission project was required. Three of the four components of NEEWS, Greater Springfield Reliability Project (GSRP), the Rhode Island Reliability Project (RIRP), and the Interstate Reliability Project (IRP) have had their needs re-affirmed. In 2010, it was determined that an updated Needs Assessment of the fourth major component of NEEWS – the Central Connecticut Reliability Project would be conducted as part of the GHCC study. CCRP, as originally designed, would add a new 345 kV line to the Western Connecticut Import interface, which lies entirely within the GHCC study area.

Some of the highest criteria violations that were seen on 115 kV lines in the Greater Hartford area in preliminary analyses were also observed in the Western Connecticut Import analysis as part of the preliminary CCRP reassessment. Accordingly, the GHCC analysis was expanded to identify needs for both local reliability issues and Western Connecticut Import requirements, with the expectation that both sets of needs could be addressed by a single integrated solution. This determination was based on the fact that recent changes in assumptions that included new generation and demand resources were expected to significantly reduce the need for increased Western Connecticut Import. This assessment considers both local load serving needs and the need for additional Western Connecticut Import capacity. However, the needs results are presented by geographic location of the element with a thermal or voltage violation and are not separated based on local load serving needs and the need for additional Western Connecticut Import capability.

2.2.2 Statement of Needs

All the criteria violations observed in the Greater Hartford and Central Connecticut (GHCC) area were based on steady state thermal and voltage testing. The following summarizes the needs for each subarea:

Greater Hartford Subarea

- Need to resolve N-1 and N-1-1 criteria violations observed in the Greater Hartford area
- Thermal and voltage violations observed in the following areas:
  - North Bloomfield to Manchester area
  - South Meadow – Berlin – Southington area
  - Southington area
- [redacted]

Middletown Subarea:

- Need to resolve the N-1 and N-1-1 criteria violations observed in the Middletown area
- [redacted]

Manchester – Barbour Hill Subarea

- Need to resolve the N-1-1 criteria violations observed in serving load in the Manchester/Barbour Hill area
- [redacted]

Northwestern Connecticut Subarea:

- Need to resolve N-1 and N-1-1 criteria violations observed in serving load in the Northwest Connecticut area
- [redacted]

Western Connecticut Interface:

- Need to resolve N-1-1 criteria violations observed [redacted]

- The needs are interrelated with the needs in the four subareas listed above.

2.3 Critical Load Level / Year of Need Analysis

The following sections summarize the critical load levels for each subarea at which all thermal and voltage violations are expected to be resolved. The critical load levels are provided in terms of Connecticut load including demand resources and energy efficiency and excluding transmission losses.

2.3.1 Summary of Results for Greater Hartford Subarea

The majority of the worst-case violations in the Greater Hartford subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 4,756 MW and the net Connecticut load at which all voltage violations would be resolved is 4,319 MW.

2.3.2 Summary of Results for Manchester-Barbour Hill Subarea

The majority of the worst-case violations in the Manchester-Barbour Hill subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 5,616 MW and the net Connecticut load at which all the PTF voltage violations would be resolved is 5,069 MW.

2.3.3 Summary of Results for Middletown Subarea

The majority of the worst-case violations in the Middletown subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 3,444 MW and the net Connecticut load at which all voltage violations would be resolved is 3,694 MW.

2.3.4 Summary of Results for Northwestern CT Subarea

The majority of the worst-case violations in the Northwestern Connecticut subarea are expected to be seen at expected summer peak load levels before 2013. The net Connecticut load minus DR at which all thermal violations will be resolved is 4,225 MW and the net Connecticut load at which all voltage violations would be resolved is 5,694 MW.

Section 3
Solutions Study Assumptions

3.1 Analysis Description

Since the needs identified in the GHCC Needs Assessment were based on steady state analysis, the development of the solutions was also based on steady state analysis. The objective of the analysis is to resolve the thermal and voltage criteria violations observed in the GHCC study area. The study area was divided into four subareas and the solutions were developed for these subareas. The needs for Western Connecticut Import were seen across multiple subareas but a solution for these needs would be focused in the Hartford and Middletown subareas. Hence, the solution for these needs was combined with the Greater Hartford and Middletown subareas. More details on solution alternative development are provided in Section 5.

The following criteria violations in the GHCC area were not resolved by the Solutions Study:

For each subarea, multiple alternatives were pursued and each alternative would resolve all criteria violations. To compare the steady state performance of the alternatives the number of residual high loadings and the amount of re-dispatch required between first and second contingencies was compared. In addition for the Greater Hartford and Middletown area the impact on western Connecticut transfer capability was also conducted since the solution for Western Connecticut Import based needs was developed in conjunction with local needs in these subareas.

Additionally, for the preferred alternative based on cost and steady state performance a short circuit analysis was conducted to ensure that no breakers were over-dutied as a result of the preferred solution.

To complete the analysis, the following software applications were used:

- Steady State Analysis - PSS/E version 32.2.1 and PowerGEM TARA version 7.65e
- Short Circuit Analysis - Aspen version 12.4
- Transfer Analysis – PowerGEM TARA version 7.65e

3.2 Steady State Model Assumptions

3.2.1 Study Assumptions

The regional steady-state model was developed to be representative of the 10-year projection of the 90/10 summer peak system demand levels to assess reliability performance under stressed system conditions. The assumptions included consideration of area generation unit unavailability conditions as well as variations in surrounding area regional interface transfer levels. These study assumptions are consistent with ISO-NE Planning Procedure No. 3 (PP 3), "Reliability Standards for the New England Area Bulk Power Supply System".

3.2.2 Source of Power Flow Models

The power flow study cases used in this study were obtained from the ISO-NE Model on Demand system with selected upgrades to reflect the system conditions in 2022. A detailed description of the system upgrades included is provided in later sections of this report.

3.2.3 Transmission Topology Changes

Transmission projects with Proposed Plan Application (PPA) approval in accordance with Section I.3.9 of the Tariff, as of the April 2011 RSP Project Listing, have been included in the study base case. New projects in Connecticut that were relevant to the study area were added to the base cases as of the October 2013 project listing. Projects outside of Connecticut that were added to the project listing were deemed to not have a significant impact on the study area and were excluded. The only exception to this was the inclusion of updates to the NEEWS projects that occurred in May 2012. A listing of the major projects is included below.

Maine

- Maine Power Reliability Program (MPRP) (RSP ID: 905-909, 1025-1030, 1158)
- Down East Reliability Improvement (RSP ID: 143)

New Hampshire

- Second Deerfield 345/115 kV Autotransformer Project (RSP ID: 277, 1137-1141)

Vermont

- Northwest Vermont Reliability Projects (RSP ID: 139)
- Vermont Southern Loop Project (RSP ID: 323, 1032-1035)

Massachusetts

- Auburn Area Transmission System Upgrades (RSP ID: 59, 887, 921, 919)
- Merrimack Valley / North Shore Reliability Project (RSP ID: 775-776, 782-783, 840)
- Long Term Lower SEMA Upgrades (RSP ID: 592, 1068, 1118)
- Central/Western Massachusetts Upgrades (RSP ID: 924- 929, 931-932, 934-935, 937- 950, 952- 955)
- NEEWS – Greater Springfield Reliability Project (RSP ID: 196, 259, 687-688, 818-820, 823, 826, 828-829, 1010, 1070-1075, 1078-1080, 1100-1105)
- NEEWS – Interstate Reliability Project (RSP ID: 1094,1202)

Rhode Island

- Greater Rhode Island Transmission Reinforcements (RSP ID: 484, 786, 788, 790-793, 913-918, 1098)
- NEEWS – Rhode Island Reliability Project (RSP ID: 795, 798-800, 1096-1097, 1099, 1106, 1109)
- NEEWS – Interstate Reliability Project (RSP ID: 190, 794, 1095, 1233-1234)

Connecticut

- NEEWS – Greater Springfield Reliability Project (RSP ID: 816, 1054, 1092)
- NEEWS – Interstate Reliability Project (RSP ID: 191, 802, 810, 1085, 1090-1091, 1235)
- Northeast Simsbury Substation 115 kV Circuit Breaker Project (RSP ID: 1230)
- Advanced NEEWS Projects – (RSP ID:1370,1235,1245)
- SWCT Minimum Load Project – Haddam Neck 150 MVAR Shunt Reactor (RSP ID:1400)

For the GSRP, RIRP and IRP components of NEEWS the model reflects the revised PPA that received ISO-NE approval in May 2012. An upgrade that would impact the GHCC study area is the reconductoring of the 1784 line between North Bloomfield and Northeast Simsbury and the replacement of the 2% reactor on this line at North Bloomfield with a reactor of equal impedance but higher thermal rating.

Several upgrades in the SWCT area have received PPA approval since these base cases were created, but since the Southwest Connecticut working group was reassessing the needs and solutions for that area those upgrades were not included. The only upgrade from the SWCT area that is approved and not under reassessment that was included was the Haddam Neck shunt reactor.

The Central Connecticut Reliability Project (CCRP) component of the NEEWS projects was also excluded since as a part of the GHCC Needs Assessment the needs for these upgrades were reassessed.

In addition to the new transmission projects in Connecticut that were added during the Needs Assessment, any changes to element ratings or impedances as a part of the base case update process were captured on an ongoing basis. These upgrades may have varied some of the line ratings or impedances to reflect the most accurate future system condition. A significant change in this area was the replacement of the Torrington 115/69 kV autotransformer in December 2013.

Eight transmission substation buses in the GHCC study area are arranged as ring buses. Under contingency conditions, a large amount of power could flow through the bus and the traditional model of buses in the base cases would not capture these flows. The updated analysis completed in this Needs Assessment report accurately captured the modeling of these ring buses and reports violations on any of the bus elements that were seen under contingency conditions.

In addition to the topology changes listed above any changes or corrections to the ratings and impedances of the facilities since the Needs Assessment was finalized has been included in the Solutions Study base cases.

Finally, as upgrades were added as a part of the Solutions Study the associated topology changes and contingency changes were made to the models.

3.2.4 Generation Assumptions (Additions & Retirements)

Generation projects with a FCM Capacity Supply Obligation as of Forward Capacity Auction 7 (FCA #7) were included in the study base case. A listing of the recent major new projects cleared in FCA #1 through FCA #7 is included below.

Maine

- QP 244 – Wind Project (FCA #4)

New Hampshire

- QP 251 – Biomass Project (FCA #4)
- QP 307 – Biomass Project (FCA #4)

Massachusetts

- QP 089 – Cape Wind Turbine Generators (FCA #7)
- QP 196 – Northfield Mountain Up-rate 88 MW (FCA #4, #6 and #7)
- QP 387-2 – Combined Cycle Unit (FCA #7)

Rhode Island

- QP 332 – RISEP Increase (FCA #5)

Connecticut

- QP 155.6 – Fuel Cell Project in Fairfield, CT (FCA #4)
- QP 289 – Fuel Cell Project in New Haven County, CT (FCA #4)

In March 2012, the Ansonia generation unit (QP-193) withdrew its PPA. As a result the Ansonia generation has been removed from the case. The generator had previously cleared in FCA #2.

On September 18, 2012, a Non-Price Retirement Request was submitted for AES Thames; following a reliability review by ISO-NE, the Non-Price Retirement Request was accepted on November 13, 2012. For this study, the AES Thames unit was assumed OOS as a base case condition.

On September 16, 2013 a full Non-Price Retirement (NPR) Request for Bridgeport Harbor 2 was submitted for FCA #8. Following a reliability review by ISO-NE, the NPR request was accepted on October 16, 2013. As a result, for this study, the Bridgeport Harbor 2 unit was assumed OOS as a base case condition.

On September 30, 2013 a Non-Price Retirement request for Norwalk Station (Norwalk 1, 2 and 10) was submitted for the FCA #8 commitment period. The NPR request was accepted on December 20, 2013. As a result, the Norwalk Station was assumed out–of-service as a base condition.

No new generation cleared in Connecticut in FCA#8 and hence no new generators were added to the base case based on FCA #8.

Real Time Emergency Generation (RTEG) represents distributed generation facilities which have air permit restrictions that limit their operations to OP 4, Action 6 – an emergency action which also implements voltage reductions of five percent (5%) of normal operating voltage that require more than 10 minutes to implement. The impact of RTEG was not included in this analysis because in general, long-term analyses should not be performed such that the system must be in an emergency state as required for the implementation of OP 4, Action 6.

3.2.5 Explanation of Future Changes Not Included

The following projects were not added:

- Transmission projects that have not been fully developed and have not received PPA approval as of the April 2011 RSP Project Listing. These projects were not modeled in the study base case due to the uncertainty concerning their final development or lack of an impact on the GHCC study area.
- Transmission Projects that have been added to the project listing since the April 2011 project listing update, but do not have a significant impact on the study area

Additionally, the NEEWS – Central Connecticut Reliability Project component has PPA approval but was not included in the base case because the scope of this study includes the re-assessment of the transmission reliability needs for this component.

The following projects in SWCT were not included for the base cases used for the thermal and voltage testing:

- Stamford Reliability Cable Project (115 kV cable between Glenbrook and South End substations)
- SONO Substation Addition (CMEEC)
- Fitch Substation Addition (CMEEC)
- 115 kV Circuit Breaker (40 kA) Addison at Newtown Substation

The first three projects are located in the Norwalk Stamford area and were added to resolve local load serving issues. The exclusion of these projects would not affect the thermal and voltage results because:

- The net load in Norwalk Stamford does not change and hence the power flowing through the GHCC Study area does not change
- The change in impedance based on the new Glenbrook to South End cable would not affect the flows through the GHCC study area
- Any contingency changes would not affect the results since the contingencies in Norwalk Stamford are not modeled in the GHCC study since they would not have a significant impact on flows in the GHCC study area

The Newtown breaker addition is also not modeled since contingencies around Newtown are not modeled in the GHCC study and hence any changes based on the breaker addition would not have shown any change in the GHCC study results.

However, once the GHCC preferred solution was selected this solution was tested with the SWCT preferred solutions to ensure that the combined solution still resolved all the needs. This test was performed by both study groups (GHCC and SWCT) and no modifications were required to the preferred solutions developed by each study independently.

3.2.6 Forecasted Load

A ten-year planning horizon was initially used for this study based on the 2012 CELT report when the Needs Assessment for the study area. During the course of the Needs Assessment and in the Solutions Study, the forecasted load was updated in the base case to reflect the 2013 CELT report,

which was released in May 2013, but the study year remained as 2022. This study focused on the projected 2022 peak demand load levels for the ten-year horizon.

The 2022 summer peak 90/10 demand forecast for New England is 34,105 MW.

The CELT load forecast includes both system demand and losses (transmission and distribution) from the power system. The power flow modeling programs have the transmission system explicitly modeled and hence the losses on the transmission system are calculated by the software. Therefore, the actual system load modeled in the case was reduced to account for transmission system losses which are explicitly calculated in the system model. Load distributions in the case are based on the most recent 2013 MMWG case library data.

Demand Resources (DR) are treated as capacity resources in the Forward Capacity Auctions (FCA). DR is split into two major categories, Passive and Active DR. Passive DR is largely comprised of energy efficiency and is expected to lower the system demand during designated peak hours in the summer and winter. Active DR is commonly known as Demand Side Management (DSM) and can be dispatched on a zonal basis if a forecasted or real-time capacity shortage occurs on the system. Starting in 2012, forecasting passive DR has become part of the annual load forecasting process. This forecast takes into account additional electrical efficiency (EE) savings beyond FCM results across the ten-year planning horizon. This forecast is primarily based on forecasted financial investment in state-sponsored EE programs and its correlation with historical data on reduction in peak demand per dollar spent. This EE forecast was published in the annual CELT Report beginning in spring 2012. Active DR is modeled in the base case at the levels of the most recent Forward Capacity Auction (FCA #7), multiplied by a Performance Factor of 75% based on historical performance of similar resources. Passive DR is modeled at 2022 levels based on the passive DR cleared through FCA #7 (2010-2016) and the aforementioned EE forecast for the years until 2022 (2017-2022). In addition, Active and Passive DR levels in Connecticut[4] were scaled down to account for the submission of several Non-Price Retirement Requests for FCA #8 and DR terminations post-FCA #7.
Starting in 2010, DR values are now published in the CELT Report. Because DR is modeled at the low-side of the distribution bus in the power-flow model, all DR values were increased by 5.5% to account for the reduction in losses on the local distribution network. Passive DR is modeled by load zone and Active DR is modeled by dispatch zone. The amounts modeled in the cases are listed in Table 3-1 and Table 3-2 and detailed reports can be seen in Appendix A: Load Forecast.

[4] Since this study is only looking at developing solutions for local issues in and around the Greater Hartford area, it was determined that NPR requests submitted for DR outside of Connecticut had a negligible effect on the results of the analyses and were not taken into account in this study.

Table 3-1: 2022 Passive DR Values - DR through FCA #7 and EE Forecast

Load Zone	Passive DR (FCA-1-7) DRV[5] (MW)	Passive DR Terminations DRV (MW)	Passive DR NPR DRV (MW)	EE Forecast (2017-2022) DRV (MW)	Total Passive DR DRV (MW)
Maine	150	Not Included	Not Included	56	206
New Hampshire	77	Not Included	Not Included	53	130
Vermont	120	Not Included	Not Included	89	209
Northeast Massachusetts & Boston	331	Not Included	Not Included	276	607
Southeast Massachusetts	185	Not Included	Not Included	147	332
West Central Massachusetts	235	Not Included	Not Included	165	400
Rhode Island	137	Not Included	Not Included	114	251
Connecticut	385	-25	-8	139	523
New England Total	**1,620**	**-25**	**-8**	**1,039**	**2,658**

Table 3-2: FCA #7 - Active DR Values through FCA #7

Dispatch Zone	Active DR DRV[6] (MW)	Active DR NPR DRV (MW)	Total Active DR DRV (MW)
Bangor Hydro	56	Not Included	56
Maine	207	Not Included	207
Portland, ME	32	Not Included	32
New Hampshire	49	Not Included	49
New Hampshire Seacoast	12	Not Included	12
Northwest Vermont	38	Not Included	38
Vermont	25	Not Included	25
Boston, MA	81	Not Included	81
North Shore Massachusetts	36	Not Included	36
Central Massachusetts	51	Not Included	51
Springfield, MA	33	Not Included	33
Western Massachusetts	78	Not Included	78
Lower Southeast Massachusetts	20	Not Included	20
Southeast Massachusetts	121	Not Included	121
Rhode Island	74	Not Included	74
Eastern Connecticut	49	-12	37
Northern Connecticut	100	-16	84

[5] DRV = Demand Reduction Value = the actual amount of load reduced measured at the customer meter; these totals are forecasted values for the commitment period beginning June 1, 2022. These values exclude transmission and distribution losses.

[6] Includes DR terminations in CT

Dispatch Zone	Active DR DRV[6] (MW)	Active DR NPR DRV (MW)	Total Active DR DRV (MW)
Norwalk-Stamford, Connecticut	37	-3	34
Western Connecticut	117	-13	104
New England Total	**1,216**	**-44**	**1,171**

3.2.7 Load Levels Studied

Consistent with ISO-NE planning practices, transmission planning studies utilize the ISO-NE extreme weather 90/10 forecast assumptions for modeling summer peak load profiles in New England. A summary breakdown of the load modeled in the 2022 cases, taking into account transmission and distribution losses, is shown in Table 3-3. A more detailed report of the loads modeled and how the numbers were derived from the CELT values can be seen in Appendix A: Load Forecast in Table 9-2.

Table 3-3: Net New England Load Levels Studied

	Summer Peak (MW)
New England CELT Load	34,105
Transmission Losses (2.5%)	-853
Non-CELT Load (Maine)	364
Passive DR[7]	-1,709
Forecasted EE[7]	-1,096
Active DR[7] [8]	-927
Net NE Total Load	**29,884**
Total Station Service Load[9]	950
Net NE Total Load (w/ SS)	30,834

After taking into account the aforementioned transmission losses, the subtraction of demand response loads, and the addition of non-CELT loads, the net load level modeled in the base cases for this study was approximately 29,900 MW.

Prior to completion of this study, the 2014 CELT report was issued in May 2014. The forecasted 2022 summer 90/10 peak demand forecast for New England of 33,865 MW. The state of Connecticut forecast for 2022 remained unchanged from the 2013 to 2014 forecast of 8,825 MW. The New England system had a reduction of 240 MW (0.7%) from the 2013 forecast. With an annual growth rate in New England of over 300 MW per year, this represents less than 1 year of load growth and does not defer the year of need out of the 10-year planning horizon. Therefore this change in forecast did not require a re-run of the power flow analysis.

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[7] This value has been adjusted up by 5.5% to account for distribution losses.

[8] This value has been adjusted down by 25% based on performance assumptions for Active DR.

[9] This is an approximate value; this number does not count against the total net reported load in this study due to the variability of total station service load in service based on generation dispatch.

3.2.8 Load Power Factor Assumptions

Load power factors consistent with the local transmission owner's planning practices were applied uniformly at each substation. Demand resource power factors were set to match the power factor of the load at that bus in the model. A list of overall power factors by company territory can be found in the detailed load report in Appendix A: Load Forecast in Table 9-2.

3.2.9 Transfer Levels

In accordance with the reliability criteria of the NERC, NPCC and the ISO, the regional transmission power grid must be designed for reliable operation during stressed system conditions. The following external transfers were utilized for the study:

- N-1 Analysis
  - New York to New England (AC ties) – 0 MW / 1,200 MW Import
  - Cross Sound Cable – 346 MW Export to Long Island[10]
  - Norwalk-Northport Cable – 200 MW Export to Long Island[11]
  - Highgate HVDC – 200 MW Import into New England
  - Phase II HVDC – 2,000 MW Import[12] into New England
  - New Brunswick to New England – 1,000 MW Import
- N-1-1 Analysis
  - New York to New England (AC Ties) – 0 MW Export
  - Cross Sound Cable – 0 MW Export
  - Norwalk-Northport Cable – 0 MW Export
  - Highgate HVDC – 200 MW Import into New England
  - Phase II HVDC – 2,000 MW Import into New England
  - New Brunswick to New England – 1,000 MW Import

For this Solutions Study, the generation dispatch dictated the internal transfer levels.

3.2.10 Generation Dispatch Scenarios

All generators in the base case are modeled with a maximum capacity corresponding to their Qualified Capacity as of FCA #7.

Table 3-4 shows the Qualified Capacities of the generating units in the study area.

Table 3-4: Qualified Generating Capacities of Study Area Units

Area	Generating Unit	Qualified Capacity (MW)	Fast-Start [13] Unit
Two Largest Critical Units in Connecticut	Millstone 2	877	No
	Millstone 3	1225	No
Middletown Subarea	Middletown 2	117	No
	Middletown 3	236	No
	Middletown 10	17	Yes
	Branford Jet	19	Yes
Eastern CT	Kleen Energy	620	No
Greater Hartford Subarea	CDECCA	55	No
	South Meadow 5	23	No
	South Meadow 6	25	No
	South Meadow 11	36	Yes
	South Meadow 12	38	Yes
	South Meadow 13	38	Yes
	South Meadow 14	37	Yes
Northwest Connecticut Area	Bristol Refuse/ Forestville	13	No
	Falls Village	3	No
	Franklin Drive 10	15	Yes
	Torrington Terminal Jet	19	Yes
Manchester-Barbour Hill Subarea	Dexter	37	No
	Rainbow	8	No
Other Units in Western CT & outside SWCT	Middletown 4	400	No
	Middletown 12	47	Yes
	Middletown 13	47	Yes
	Middletown 14	47	Yes
	Middletown 15	47	Yes
	New Haven Harbor 1	448	No
	New Haven Harbor 2	43	Yes
	New Haven Harbor 3	43	Yes
	New Haven Harbor 4	43	Yes
Two Largest Units in Southwest CT	Bridgeport Harbor 3 (BH3)	383	No
	Bridgeport Energy (BE)	448	No

Twenty two dispatches were created for the four study areas and for the Western Connecticut Import and Connecticut Import Needs Assessment. The dispatches were created by taking out one or two critical units in each subarea.

[13] "Fast-start" generators are those units that can go from being off-line to their full Seasonal Claimed Capability in 10 minutes. These units do not need to participate in the 10-minute reserve market to be considered a fast-start unit in planning studies.

At all locations in the study area where a single fast-start unit was available, that unit was assumed OOS for each dispatch. For subareas where there were two single fast-start units, one of the two fast-start units was assumed online and available, if non-fast-start units were taken out of service in that subarea. For example, if the Middletown 3 unit is assumed OOS as a non-fast-start unit then one of the two single fast-starts in the Middletown subarea, Branford Jet or Middletown 10, is assumed to be in-service.

The Connecticut fast-start units were dispatched such that approximately 80% of the fast-start capability in Connecticut was online. The most up-to-date voltage schedules for area units provided by Northeast Utilities were utilized in this study. The fast-start dispatch assumptions detailed above were turned on in the base case and no adjustments were made to these fast start units post first contingency.

The historical performance of one of the hydroelectric units in the study area, Rainbow Hydro, was examined and it was determined that an availability of 10% of its nameplate capacity at summer peak was a reasonable assumption. This assumption was extended to all the Connecticut hydro units. This was acceptable since there are very few hydro units in Connecticut and just two of them are in the study area: Rainbow Hydro and Falls Village.

Table 3-5 provides the outputs assumed for the hydro units in Connecticut for units above 5 MW.

Table 3-5: Dispatch of Hydro Units in Connecticut

Unit Name	Dispatched Amount (MW)	Name Plate (50 degree rating; MW)	Location
Rainbow Hydro	0.8	8.2	Manchester/ Barbour Hill
Stevenson Hydro	2.9	28.9	SWCT
Falls Village	1.0	9.8	NWCT
Rocky River	2.9	29.4	SWCT
Shepaug	4.3	42.9	SWCT
Bulls Bridge	0.8	8.4	SWCT
Derby Dam	0.7	7.1	SWCT

The dispatches for each subarea are defined in the following section:

- **Middletown Subarea**: [redacted]
  Since these units are located on the same bus, only the largest of the two (Middletown 3) was taken OOS to create a one-unit-out dispatch. The Middletown study area has two single fast-start units, Middletown 10 and Branford Jet. For each case, one-unit-out case and two-unit-out case, two dispatches were created based on fast-start dispatch. Cases with the Middletown 10 off and Branford Jet on are called MIDD_01 (two units OOS) and MIDD_1A (one unit out). Alternately, cases with the Middletown 10 on and Branford Jet off are called MIDD_02 (two units OOS) and MIDD_2A (one unit out). This leads to a total of four dispatches for this subarea.

- **Manchester-Barbour Hill Subarea**: [redacted] ince the Rainbow Hydro unit is a small unit, only one single unit out dispatch was created with Dexter out-of-service. This leads to a total of two dispatches for this subarea.
- **Northwest Connecticut Subarea**: [redacted] ince the Falls Village Hydro unit is a small unit, only one single unit out dispatch was created with the Forestville unit out of service. The Northwest Connecticut study area has two single fast-start units, Franklin Drive 10 and Torrington Terminal Jet. For each case, one-unit-out case and two-unit-out case, two dispatches were created based on fast-start dispatch. Cases with the Franklin Drive 10 on and Torrington Terminal Jet off are called NWCT_01 (two units OOS) and NWCT_1A (one unit out). Alternately, cases with the Franklin Drive 10 off and Torrington Terminal Jet on are called NWCT_02 (two units OOS) and NWCT_2A (one unit out). This leads to a total of four dispatches for this subarea.
- **Hartford Subarea**: [redacted] There were two different two-units-out dispatches for this study area. The first has the two South Meadow units OOS and the other has one South Meadow unit (#6) and the Capitol District unit OOS. Two one-unit-out dispatches were also created, taking out the larger South Meadow unit (#6) and the Capitol District unit separately. This leads to a total of four dispatches for this subarea.
- **Western Connecticut Import Analysis**: Four dispatches were established to test the need for additional Western Connecticut Import capability.
    - **Dispatch 1** – High SWCT Import – Bridgeport Harbor 3 OOS and Bridgeport Energy OOS
    - **Dispatch 2** – Moderate Western CT Import – New Haven Harbor and Kleen Energy OOS (Kleen is an eastern CT unit very close to the western CT import interface)
    - **Dispatch 3** – High Western CT Import – Bridgeport Harbor 3 and New Haven Harbor OOS (two largest 115 kV generators in western Connecticut)
    - **Dispatch 4** – High Western CT Import – Bridgeport Energy and New Haven Harbor OOS (two largest generators in western Connecticut)

    Additionally, two one-unit out dispatches were created.

    - **Dispatch 3A** – High SWCT Import –Bridgeport Energy OOS
    - **Dispatch 4A** – High western CT Import – New Haven Harbor OOS

    This leads to a total of six dispatches for the Western CT Import analysis.

- **Connecticut Import Analysis**: As a part of the NEEWS Interstate analysis several line overloads were seen in the GHCC Study area. The overloads seen in the Interstate analysis were not resolved and were examined as a part of this analysis. [redacted] Since these units are located on the same bus, only the largest of the two (Millstone 3) was taken OOS to create a one-unit-out dispatch. This leads to a total of two dispatches for this analysis.

The twenty-two dispatches just described are summarized in Table 3-6 and Table 3-7 on the following pages.

Table 3-6: Two-Unit–Out Generation Dispatches

Major Area Units	Dispatch Name / Number											
	Middletown #1	Middletown #2	Barbour Hill #1	NWCT #1	NWCT #2	HTFD #1	HTFD #2	CCRP #1	CCRP #2	CCRP # 3	CCRP #4	IRP #1[14]
Middletown 2	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 3	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 10[15]	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Branford Jet[15]	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Dexter	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON
Rainbow	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON
Falls Village	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	ON
Forestville	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	ON
Franklin Drive 10[15]	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Torrington Term. Jet[15]	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
South Meadow 5	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON
South Meadow 6	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON	ON
CDECCA	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON	ON
Bridgeport Energy	ON	ON	ON	ON	ON	ON	ON	OFF	ON	ON	OFF	ON
Bridgeport Harbor 3	ON	ON	ON	ON	ON	ON	ON	OFF	ON	OFF	ON	ON
Kleen Energy	ON	ON	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON
New Haven Harbor 1	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	ON
Millstone 2	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
Millstone 3	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF

[14] [redacted]

[15] Fast-Start unit

Table 3-7: One-Unit-Out Generation Dispatches

Major Area Units	Dispatch Name/Number									
	Middletown #1A	Middletown #1B	Barbour Hill #1A	NWCT #1A	NWCT #2A	HTFD #1A	HTFD #2A	CCRP #3A	CCRP # 4A	IRP #1A[16]
Middletown 2	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 3	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON
Middletown 10[17]	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Branford Jet[17]	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Dexter	ON	ON	OFF	ON	ON	ON	ON	ON	ON	ON
Rainbow	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Falls Village	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Forestville	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON
Franklin Drive 10[17]	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
Torrington Term. Jet[17]	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF
South Meadow 5	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
South Meadow 6	ON	ON	ON	ON	ON	OFF	ON	ON	ON	ON
CDECCA	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON
Bridgeport Energy	ON	ON	ON	ON	ON	ON	ON	OFF	ON	ON
Bridgeport Harbor 3	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Kleen Energy	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
New Haven Harbor 1	ON	ON	ON	ON	ON	ON	ON	ON	OFF	ON
Millstone 2	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Millstone 3	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF

3.2.11 Reactive Resource and Dispatch Assumptions

All area shunt reactive resources were assumed available and dispatched when required. Reactive output of generating units was modeled to reflect defined limits. A summary of the reactive output of units and shunt devices connected to the transmission system that played a significant role in the study area can be found in the power flow case summaries included in Appendix B: Case Summaries and Load Flow Plots.

[16] [redacted]

[17] Fast-Start unit

3.2.12 Market Solutions Consideration

In accordance with Attachment K of the OATT, all resources that have cleared in the markets were assumed in the model for future planning reliability studies. This included numerous new generation and demand resources from FCA #1 through 7 as listed in Section 3.2.4 and Section 3.2.6.

It should be noted that during the course of the Solutions Study, FCA #8 was completed in February 2014. The results of the auction were deemed to not have a significant impact in the current study and the cases were not re-run to reflect those changes.

3.2.13 Demand Resource Assumptions

As stated in Section 3.2.6, Passive DR, as forecasted for the year 2022, and Active DR that cleared as of FCA #7 in 2013 were modeled for this study, minus approximately 52 MW of demand resources in Connecticut that have accepted NPR Requests for FCA #8. Passive DR was assumed to perform to 100% of their forecasted amount. The Passive DR included the forecasted EE which was assumed to perform to 100% of the forecast. Active DR was assumed to perform to 75% of their cleared amount. Real Time Emergency Generation (RTEG) was not modeled, consistent with all needs and solutions planning analyses.

Table 3-8: New England Demand Resource Performance Assumptions

Region	Passive DR	Energy Efficiency	Active DR	RTEGs
New England	100%	100%	75%	0%

3.2.14 Description of Existing and Planned Protection and Control System Devices Included in the Study



Figure 3-1: Southington Substation

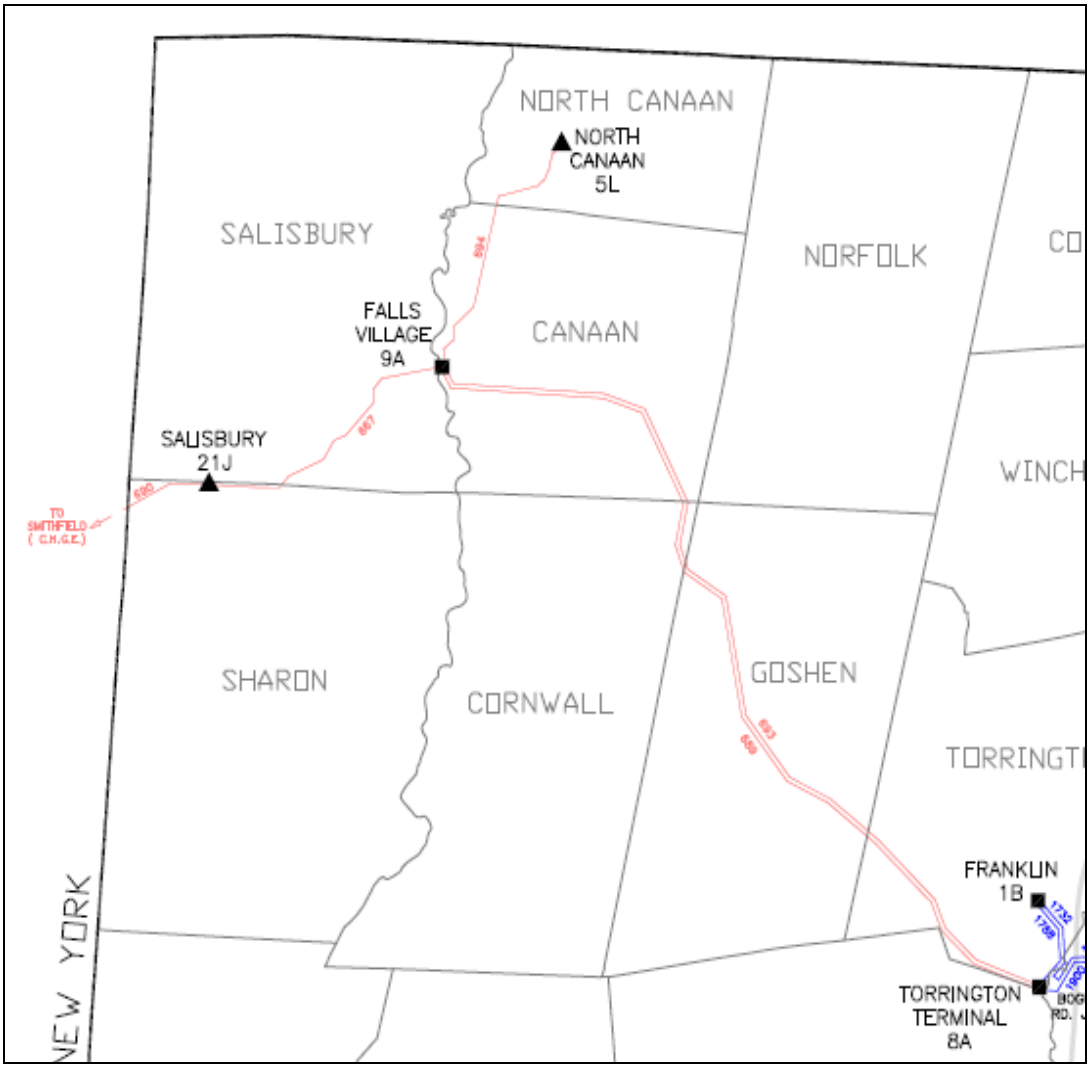


Figure 3-2: The 69 kV System in Northwestern Connecticut

3.3 Stability Modeling Assumptions

Not applicable to this study.

3.4 Short Circuit Model Assumptions

3.4.1 Study Assumptions

The short circuit study evaluated the projected 2022 available fault current levels around the GHCC area after the addition of the GHCC preferred solution. It also included the effects of area reliability project upgrades as well as selected proposed generation interconnection projects as outlined in Section 3.4.3 and Section 3.4.4 of this study document.

3.4.2 Short Circuit Model

The ASPEN Circuit Breaker Rating Module software was used to calculate all circuit breaker duties. The case for the short circuit study included all PPA-approved transmission projects, as discussed in

Section 3.2.3 of this scope document, were added to that model. The Central Connecticut Reliability Project (CCRP) was excluded from the base case, similar to the steady-state base cases. In addition to the projects described in Section 3.2.3, the following projects in SWCT were added to the base cases:

- Stamford Reliability Cable Project (115 kV cable between Glenbrook and South End substations)
- 115 kV Circuit Breaker (40 kA) Addison at Newtown Substation
- SONO Substation Addition (CMEEC)
- Fitch Substation Addition (CMEEC)

3.4.3 Contributing Generation Assumptions (Additions & Retirements)

The model included proposed generation interconnection projects that have PPA approval as well as those generator projects that have FCA Capacity Supply Obligations (CSOs).

The following relevant generation projects were modeled for this study:

- QP 095 – Kleen Energy (FCA #2)
- QP 125 – Cos Cob 13&14 (FCA #1)
- QP 140 – A.L. Pierce (FCA #1)
- QP 150 – Plainfield Renewable Energy Project (FCA #3)
- QP 155.6 – Fuel Cell Project in Fairfield, CT (FCA #4)
- QP 161 – Devon 15-18 (FCA #2)
- QP 161 – Middletown 12-15 (FCA #2)
- QP 199 – Waterbury Generation (FCA #1)
- QP 206 – Kimberly Clark Energy (FCA #2)
- QP 248 – New Haven Harbor 2-4 (FCA #3)
- QP 289 – Fuel Cell Project in New Haven County, CT (FCA #4)
- QP 384 – Combined Cycle Project in New Haven County, CT

Due to accepted Non-Price Retirement requests for Norwalk Harbor 1, 2, and 10 as well as Bridgeport Harbor 2, these units were removed from the short circuit base case. The only significant change in generation projects from the short circuit assessment done in the Needs Assessment is the addition of QP 384 to the base cases.

3.4.4 Generation and Transmission System Configurations

NPCC Regional Reliability Reference Directory #1, “Design and Operation of the Bulk Power System” and PP-3 require short circuit testing to be conducted with all transmission and generation facilities in-service for all potential operating conditions.

3.4.5 Boundaries

This study included testing of all 69 kV, 115 kV and 345 kV substations and breakers in the GHCC study area.

3.4.6 Short Circuit Study Scenarios

The following three (3) scenarios were studied as part of the short circuit analysis to study the effect of closing the 19T circuit breaker at Southington and provide breaker duties of the CL&P-owned circuit breakers in Connecticut (69 kV and above) in Connecticut. This was based on the preferred solution for the Southington area issues being the replacement of the normally open breaker 19T at Southington with a normally closed 3% series reactor.

- **Scenario #1**: Pre-project topology with the 19T circuit breaker **opened** at the Southington Substation
- **Scenario #2**: Pre-project topology with the 19T circuit breaker **closed** at the Southington Substation
- **Scenario #3**: Southington 19T circuit breaker replaced with a normally in-service 3% series reactor between the two ring buses at Southington.

3.4.7 Other Relevant Modeling Assumptions

Not applicable to this study.

3.5 Other System Studies

3.5.1 Thermal Transmission Transfer Capability Analysis

According to Section 4 of the ISO PP-3, "The New England bulk power supply system shall be designed with adequate inter-Area and intra-Area transmission transfer capability to minimize system reserve requirements, facilitate transfers, provide emergency backup of supply resources, permit economic interchange of power, and to assure the system will remain reliable under contingency conditions."

Transmission transfer capability analysis determines the ability of a region to serve load utilizing resources within the area, as well as imports from neighboring areas. As load grows and if no future resources are placed in service in the region or no additional transmission capability is built to import more power, load cannot be served reliably. The key inputs to this analysis are the load, area resources, and the import limits into an area from surrounding areas.

To determine a transfer limit, the Siemens PTI program Managing and Utilizing System Transmission (MUST) was used to increase transfers in the network model until a transmission element becomes overloaded in the base case or after a contingency event. To increase transfer levels in a case, the output of a set of generators in the sending region of the transfer (the "source") is increased and, at the same time, the output of a set of generators in the receiving region of the transfer (the "sink") is decreased. Testing was performed under all-lines-in and line-out conditions. The transfer level at which an element becomes overloaded is determined to be the transfer limit. The generators in the source and sink were adjusted up or down based on their maximum machine capability.

3.5.1.1 Western Connecticut Import Thermal Transfer Analysis

The Western Connecticut Import analysis was conducted to determine post-project import interface limits (N-1-1) for four combinations of solution alternative packages for the Greater Hartford and Middletown study subareas, in order to determine whether any of them provided a significantly greater transfer capability than the others. To determine the limits, the transfer was established so that the source would be east of the Western Connecticut Import interface and the sink would within the bounds of the Western Connecticut Import interface. This interface is described in Table 3-9.

Table 3-9: Western Connecticut Import Interface Summary

The detailed dispatch for this case can be found in Appendix B: Case Summaries and Load Flow Plots. This case was tested for every combination of possible solution alternatives for the Greater Hartford and Middletown subareas as described in Section 5.3, with three different initial element-out scenarios: the 364, 3533, and 348 lines. All of these lines lie along the Western Connecticut Import interface.

The same sink was used for all three line-out scenarios tested. The sink is comprised of the units described in Table 3-10. As Western Connecticut Import transfer levels increase, these units are ramped down in the ratio of their maximum outputs.

Table 3-10: Western Connecticut Sink Composition

Generation Units	Ramp-Down Capability (MW)
Devon 10, 11, 12, 13, 14, 15, 16, 17 and 18	267
Milford 1 and 2	783

The same source was used for all transfer scenarios tested. The source is comprised of the units described in Table 3-11. As Western Connecticut Import transfer levels increase, these units are ramped up in the ratio of their maximum outputs.

Table 3-11: Rest of New England Source Composition

Generation Units	Ramp-Up Capability (MW)
MIS	267
Footprint Power (QP 387-2)	714

3.5.1.2 Connecticut Import Thermal Transfer Analysis

Hence, as a part of the Barbour Hill area solutions development it was important to ensure that Connecticut Import limits were not adversely impacted. For each of the two alternatives developed in the Manchester/Barbour Hill area, N-1-1 Connecticut Import analysis was performed to ensure that Connecticut Import capability is not adversely impacted.

A 2016 summer peak load level case was used for this analysis. All components of NEEWS, with the exception of CCRP, were included.

The Connecticut Import definition is provided in Table 3-12.

Table 3-12: Connecticut Import Interface Summary

The generation sink and source tested during this analysis are summarized in Table 3-13 and Table 3-14, respectively.

Table 3-13: Connecticut Sink Composition

Generation Units	Ramp-Down Capability (MW)
Millstone 3	1276
Montville 5 and 6	505
Kleen GT1	187
Middletown 4	415
Bridgeport Energy	485
Wallingford 1-5	220
AL Pierce	78
New Haven Harbor 2-4	183
Devon 11-18	334
Waterside	74
Waterbury	104
Norwalk Harbor 1 and 2	352

Table 3-14: SEMA/Boston Source Composition

Generation Units	Ramp-Up Capability (MW)
NEA Bellingham	288
West Medway J1-J3	173
Kendall CT	174
Mystic 7	615
Canal 1 and 2	1196
Brayton Point 4	458
ANP Bellingham	560
ANP Blackstone	557
Dighton Power	171

3.6 Changes in Study Assumptions

Not applicable to this study.

Section 4
Analysis Methodology

4.1 Planning Standards and Criteria

The applicable NERC, NPCC and ISO-NE standards and criteria will be tested as part of this evaluation. Descriptions of each of the NERC, NPCC and ISO-NE standard tests that were used to assess system performance are discussed later in this section.

4.2 Performance Criteria

4.2.1 Steady State Criteria

The Solutions Study was performed in accordance with NERC TPL-001, TPL-002, TPL-003 and TPL-004 Transmission Planning System Standards, NPCC "Regional Reliability Reference Directory #1, Design and Operation of the Bulk Power System", dated 04/20/12, and the ISO Planning Procedure No. 3, "Reliability Standards for the New England Area Bulk Power Supply System", dated 03/01/13. The contingency analysis steady-state voltage and loading criteria, solution parameters and contingency specifications that were used in this analysis are consistent with these documents.

4.2.2 Steady State Thermal and Voltage Limits

Loadings on all transmission facilities rated at 69 kV and above in the study area were monitored. The thermal violation screening criteria defined in Table 4-1 were applied.

Table 4-1: Steady-State Thermal Criteria

System Condition	Maximum Allowable Facility Loading
Normal (all-lines-in) (Pre-Contingency)	Normal Rating
Post-Contingency	Long Time Emergency (LTE) Rating

Voltages were monitored at all buses with voltages 69 kV and above in the study area. System bus voltages outside of limits identified in Table 4-2 were identified for all normal (pre-contingency) and post-contingency conditions.

Table 4-2: Steady-State Voltage Criteria

Transmission Owner	Voltage Level	Bus Voltage Limits (Per-Unit)	
		Normal Conditions (Pre-Contingency)	Emergency Conditions (Post-Contingency)
Northeast Utilities	69 kV & above	0.95 to 1.05	0.95 to 1.05
Millstone / Seabrook[18]	345 kV	1.00 to 1.05	1.00 to 1.05
Pilgrim	345 kV	0.995 to 1.05	0.99 to 1.05
Vermont Yankee	115 kV 345 kV	1.00 to 1.05 0.985 to 1.05	1.00 to 1.05 0.985 to 1.05

4.2.3 Steady State Solution Parameters

The steady-state analysis was performed with pre-contingency solution parameters that allow for adjustment of load tap-changing transformers (LTCs), static VAR devices (SVDs, including automatically-switched capacitors), and phase angle regulators (PARs). For post-contingency, only the load tap-changing transformers (LTCs) were allowed to be adjusted. Table 4-3 displays these solution parameters.

Table 4-3: Study Solution Parameters

Case	Area Interchange Control	Tap Adjustments	Adjust Phase Shift	Switched Shunt Adjustments
Base	Tie Lines and Loads Enabled	Stepping	Enabled	Enabled
Contingency	Disabled	Stepping	Disabled	Disabled

4.2.4 Stability Performance Criteria

Not applicable to this study.

4.2.5 Short Circuit Performance Criteria

This study was performed in accordance with appropriate IEEE C37 standards and specific design parameters of the circuit breakers. This includes specific considerations for total-current rated and symmetrical-current rated breakers as appropriate.

The circuit breakers were evaluated for short circuit adequacy based on the following criteria:

- *Acceptable-duty*: Circuit breaker fault interrupting duty less than 90% of the available fault current. No action required.
- *Marginal-duty*: Circuit Breaker Fault Interrupting Duty greater than or equal to 90% and less than 100%.

[18] This is in compliance with NUC-001-2, *"Nuclear Plant Interface Coordination Reliability Standard,"* adopted August 5, 2009.

- *Over-duty Condition*: Circuit Breaker Fault Interrupting Duty greater than 100%. This is considered an unacceptable operating condition requiring a solution to be developed to eliminate the over-duty condition.

4.3 System Testing

4.3.1 System Conditions Tested

Testing of system conditions included the evaluation of system performance under a number of resource outage scenarios, variation of related transfer levels, and an extensive number of transmission equipment contingency events

4.3.2 Steady State Contingencies Tested

Each base case was subjected to single element contingencies such as the loss of a transmission circuit or an autotransformer. In addition, single contingencies which may cause the loss of multiple transmission circuit facilities, such as those on a common set of tower line structures were simulated. The steady-state contingency events in this study also included circuit breaker failures and substation bus fault conditions that could result in removing multiple transmission elements from service. A comprehensive set of contingency events, listed in Appendix D: Contingency Listings, were tested to monitor thermal and voltage performance of the GHCC study area transmission network. A listing of all contingency types that were tested is included in Table 4-4.

Additional analyses evaluated N-1-1 conditions with an initial outage of a key transmission element or generator followed by another contingency event. The N-1-1 analyses examined the summer peak load case with stressed conditions. For these N-1-1 cases, reliability standards, including ISO-NE Planning Procedure 3, allow specific manual system adjustments, such as fast-start generation re-dispatch, phase-angle regulator adjustment or HVDC adjustments between the first and second single contingency event. A summary listing of first element-out scenarios is provided in Table 4-5. A total of 113 element-out scenarios were tested. A detailed listing of all the element out scenarios tested is provided in Appendix C: Element-Out Scenarios for N-1-1 Analysis.

It should be noted that a distinction was made in this Solutions Study based on the nature of a no-fault contingency as follows:

- Type 1: No-fault contingencies involving the opening of a terminal of a line independent of the design of the terminating facility
- Type 2: A subset of the above contingencies that involves the opening of a single breaker

For N-1 testing, all Type 1 contingencies above were simulated. However, for N-1-1 testing only the Type 2 contingencies were simulated as 2nd contingencies.

Table 4-4: Summary of NERC, NPCC and/or ISO-NE Contingencies Included in Study

Contingency Type	NERC Type	NPCC D-1 Section	ISO PP 3 Section	Tested in This Study
All Facilities in-service	A	5.4.2.b	3.2.b	Yes
Generator (Single Unit)	B1	5.4.1.a	3.1.a	Yes
Transmission Circuit	B2	5.4.1.a	3.1.a	Yes
Transformers	B3	5.4.1.a	3.1.a	Yes
Element w/o Fault	B5	5.4.1.d	3.1.d	Yes
Bus Section	C1	5.4.1.a	3.1.a	Yes
Breaker Failure	C2	5.4.1.e	3.1.e	Yes
Double Circuit Tower	C5	5.4.1.b	3.1.b	Yes
Extreme Contingencies	D	5.6	6	Yes (Limited)

Table 4-5: Summary of N-1-1 First Element-Out Scenarios

Contingency Type	Number of Element Out Scenarios
Overhead 345 kV lines	24
Autotransformers	15
Generators	6
Underground 115 kV cables	3
Overhead 115 kV lines	67
Overhead 69 kV Lines	3
Total Number of Scenarios	**118**

4.3.3 Use of Re-Dispatch

As outlined in PP-3, allowable actions after the first contingency event and prior to the second contingency event include re-dispatch of generation. During the analysis, available generation in the study area and its vicinity were allowed to reduce their output if online. Remote generation in Eastern New England was used to replace the lost generation within the area of study to simulate the re-dispatch of 10 minute reserves within New England to keep load balance. A maximum limit of 1,200 MW of re-dispatch was considered acceptable. Anything higher than 1,200 MW could not be considered acceptable due to the amount of reserves typically available on the system.

To simulate these actions in power flow analysis, the Security Constrained Re-Dispatch (SCRD[19]) tool in the TARA software package was used.

Additionally, since the shunt devices were assumed to be locked for post contingency conditions as indicated in Table 4-3, pre-contingency adjustment of capacitors were allowed to prevent post-contingency voltage concerns. The adjustment was primarily performed to the Southington 115 kV and Frost Bridge 115 kV capacitors.

[19] TARA's SCRD tool does not consider economics in the objective function to solve violation constraints. It solely uses the most effective generation that will resolve a particular constraint on the system

4.3.4 Stability Contingencies/Faults Tested

Not applicable to this study.

4.3.5 Short Circuit Faults Tested

The ASPEN circuit breaker rating module software was used to calculate all circuit breaker duties. The pre-fault operating voltage for all GHCC study area buses was set to be 1.04 per unit (p.u.). Figure 4-1 shows the ASPEN options that were used in this study.

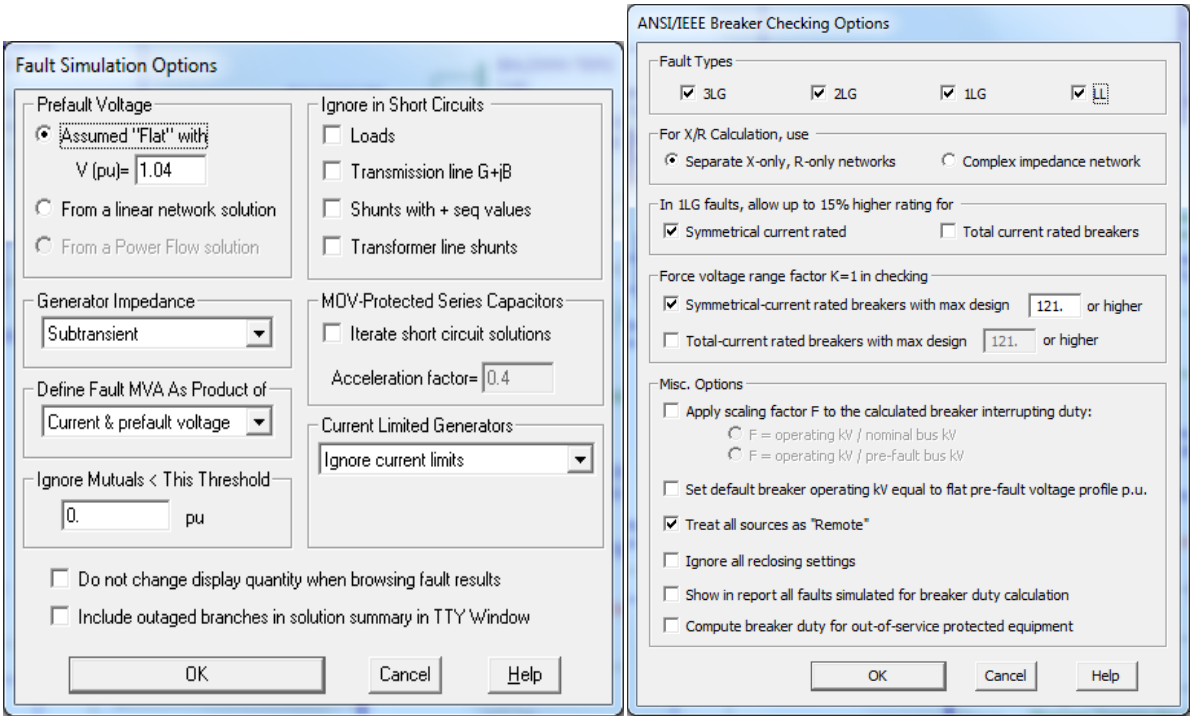


Figure 4-1: Circuit Breaker Testing Parameters

Section 5
Development of Alternative Solutions

The GHCC 2022 Needs Assessment identified numerous system weaknesses in the four study subareas and a need for additional transfer capacity across the Western Connecticut Import interface. The subarea weaknesses were evident mostly under generation deficiency conditions in each area. However, a number of issues were also seen when all of the generation in a given subarea is available, which would indicate that those issues are independent of generation dispatch.

The alternative solutions were developed to find ways to strengthen connections to the load pockets by adding new sources into the pocket, improving the remaining elements after N-1-1 contingency events to adequately handle the additional loading, or eliminating the contingency condition causing the violations. These additions and other improvements were designed with the objective of also increasing Western Connecticut Import capability by adding an element to the Western Connecticut Import interface or increasing the capability of one or more existing elements of the interface. A description of all the alternative solutions is in Section 5.3. All of the alternative solutions were first evaluated to ensure that the solution components resolve all the identified criteria violations identified in the Needs Assessment. These evaluations are described in Section 6. The next step was to compare the alternative solution components in terms of cost, constructability, environmental concerns, and several other criteria. These comparisons are described in Section 7.

5.1 Preliminary Screen of Alternative Solutions

During the conceptual phase of the Solutions Study, several solutions were proposed to address the identified needs. The addition of new 345 and/or 115 kV lines or new 345/115 kV autotransformers were discussed as possible solutions to serve the subareas. In addition, the CCRP portion of NEEWS was also included as a potential alternative. However, it was determined that with the implementation of the preferred GHCC solution, as described in later sections of this report, the need for CCRP was eliminated.

5.2 Coordination of Alternative Solutions with Other Entities

The working group for this study consisted of representatives from NU, UI, and ISO New England. This working group helped to ensure that the study of solution alternatives for the GHCC area took into account planned transmission system changes outside of the study area and the impact of the proposed GHCC solution alternatives on the surrounding transmission system. In particular, the working group has collaborated with the Southwestern Connecticut working group to ensure that the solutions developed for each area are coordinated.

5.3 Description of Alternative Solutions

The Greater Hartford and Central Connecticut study area covers the majority of the state of Connecticut west of the New England East-West transmission interface that was not studied as part of the ongoing Southwestern Connecticut study. It was determined that the solutions for different subareas within the greater GHCC area could be analyzed independently of one another, since the needs for the area were largely driven by load serving issues following the loss of critical 115 kV

sources into each subarea. Figure 5-1 shows the GHCC geographic area with each study subarea defined.

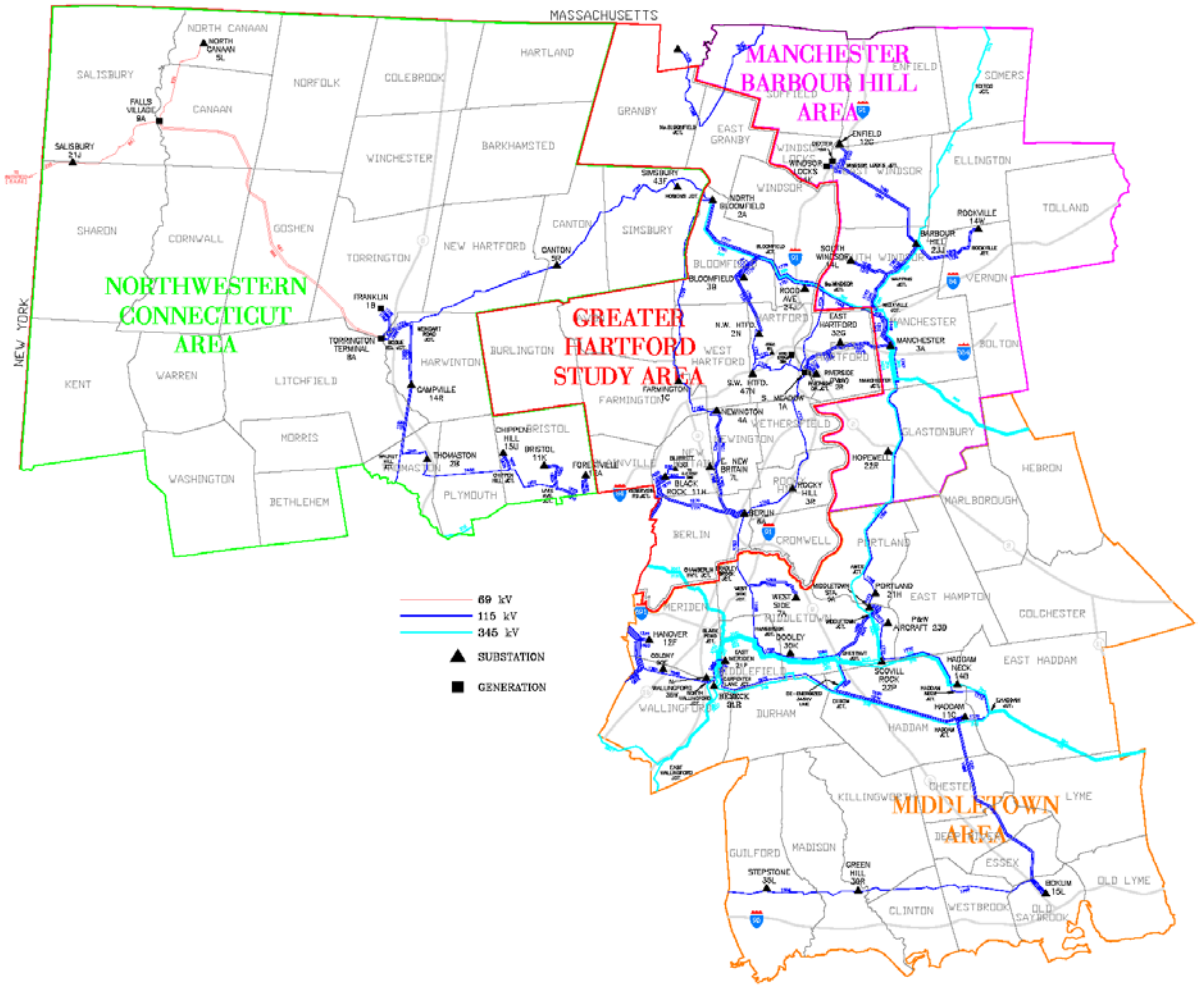


Figure 5-1: GHCC Study Area Map

After a preferred solution alternative was chosen for each subarea, an overall preferred solution for the entire study was tested to ensure that all violations observed during the Needs Assessment were resolved and that the combined solution did not cause any adverse interactions.

5.3.1 Manchester / Barbour Hill Subarea

The Manchester-Barbour Hill subarea consists of about 452 MW of load including demand resources in 2022. The area has one generator (Dexter) that has a qualified capacity of 37 MW and is considered a regular generator and one hydro station (Rainbow Hydro) that has a total qualified capacity of about 8 MW. The hydro station is dispatched to 10% of its nameplate capacity at 0.8 MW.

5.3.1.1 Manchester / Barbour Hill Subarea Needs Assessment Results

Looking at the load and generation it can be observed that the Manchester-Barbour Hill subarea is a net importer of energy and relies on the surrounding areas to serve local load. [redacted]

[redacted] There are also 115 kV ties into the Manchester-Barbour Hill area from the Greater Hartford and Middletown subareas.

All criteria violations in this subarea were observed under N-1-1 conditions. The violations may be broadly divided into two categories:

- Barbour Hill Load Pocket
- Manchester Autotransformers

The Barbour Hill load pocket consists of five 115 kV substations and the details for this load pocket are shown in Figure 5-2. The total load within this load pocket is about 326 MW including demand resources. The area is fed by the following three transmission elements:

- The 345/115 kV autotransformer at Barbour Hill (Barbour Hill Auto)
- A 115 kV line from Manchester to Barbour Hill (Line 1763)
- A 115 kV line from Manchester to South Windsor (Line 1310)

[redacted]

The criteria violations are only seen under N-1-1 conditions. [redacted]

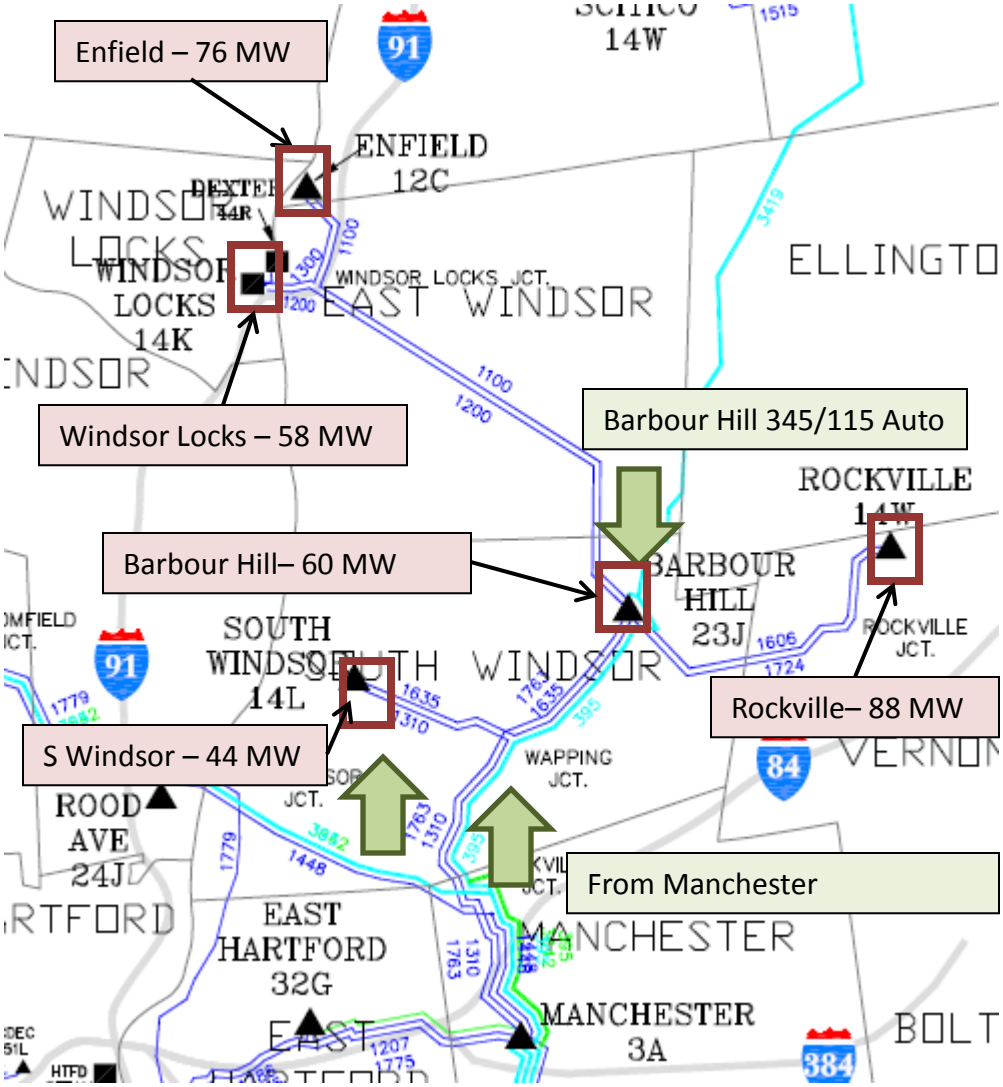


Figure 5-2: Manchester / Barbour Hill Subarea Existing Geographic One-Line

[redacted]

5.3.1.2 Manchester / Barbour Hill Subarea Alternative Solutions

Two local solution alternatives were developed to solve the violations in the Manchester / Barbour Hill subarea. Both alternatives provide a new 115 kV source into the Barbour Hill load pocket, and additional components were added to the new source to resolve the remaining criteria violations. The two different solution alternatives are summarized in Table 5-1 below.

Table 5-1: Manchester / Barbour Hill Subarea Solution Alternatives

Component ID	Description	Included in Alternative A	Included in Alternative B
1	Add a new 345/115 kV autotransformer at Barbour Hill and associated terminal equipment	**Y**	
2	Add a new 7.6 mile, 115 kV line from Manchester to Barbour Hill and associated terminal equipment		**Y**
3	Reconductor the 115 kV line between Manchester and Barbour Hill (1763) – 7.6 miles	**Y**	
4	Add a 345 kV breaker in series with breaker 24T at the Manchester 345 kV switchyard	**Y**	**Y**
5	Add two 345 kV breakers in series with breaker 18T and 19T at the Manchester 345 kV switchyard		**Y**
6	Add a 115 kV breaker in series with breaker 13T at the Manchester 115 kV switchyard		**Y**



Figure 5-3: Manchester / Barbour Hill Subarea Alternative A Upgrades



Figure 5-4: Manchester / Barbour Hill Subarea Alternative B Upgrades

It should be noted that some of the upgrades proposed as part of these two alternative solutions are for the purposes of relieving constraints on the Connecticut Import transmission interface following the implementation of either solution. Initial development of the alternative solutions for this subarea only included Component #1 of Alternative A and Components #2, 5 and 6 for Alternative B. [redacted] As a result, upgrades were added to both alternatives (Components #3 and 4 of Alternative A and Component #4 of Alternative B) in order to prevent any adverse impact on CT Import capability under post-project conditions. A summary of the observed CT Import transfer levels with and without the Manchester-Barbour Hill alternative solutions in place is included in Table 5-2. More details on this can be found in Appendix G: Transfer Analysis Testing Results.

Table 5-2: Summary of CT Import Transfer Levels Following Implementation of Manchester – Barbour Hill Alternative Solutions

Manchester – Barbour Hill Subarea Solution Alternative	CT Import Upgrades Included?	CT Import Level (MVA)		Delta (MW)	Limiting Constraint	Contingency
		Pre-Project	Post-Project			
Alternative A	No	1,793	1,202	**-591**	[redacted]	[redacted]
Alternative A	No	1,793	1,756	**-37**		
Alternative A	Yes	1,793	2,444	**+651**		
Alternative B	No	1,793	1,770	**-23**		
Alternative B	Yes	1,793	2,501	**+708**		

5.3.2 Northwestern Connecticut Subarea

The Northwestern Connecticut (NWCT) subarea consists of about 511 MW of load including demand resources in 2022. The area has one generator at Forestville at 17 MW which is classified as a regular generator and a hydro station (Falls Village) that has a total qualified capacity of about 3 MW. The hydro station is dispatched to 10% of its nameplate capacity (9 MW) at 0.9 MW, based on historical performance data for hydroelectric generation in the area during summer peak load conditions. The subarea also has two fast start generators at Franklin Drive and Torrington Terminal that total to 31 MW.

5.3.2.1 Northwestern Connecticut Subarea Needs Assessment Results

Looking at the load and generation it can be observed that the Northwestern Connecticut subarea is a net importer of energy and relies on the surrounding areas to serve local load. The major transmission elements that feed this subarea are:

- Two 115 kV lines from Southington (Line 1810 and 1800):
  - 1800: Southington – Forestville
  - 1810: Southington – Chippen Hill – Bristol
- A 115 kV line from N Bloomfield (Line 1256):
  - 1256: North Bloomfield – Northeast Simsbury
- A 115 kV line from Frost Bridge (Line 1191):
  - 1191: Frost Bridge – Chippen Hill
- A 69 kV line from New York (Line 690):
  - 690: Smithfield substation in NY to Salisbury substation in CT

[redacted]

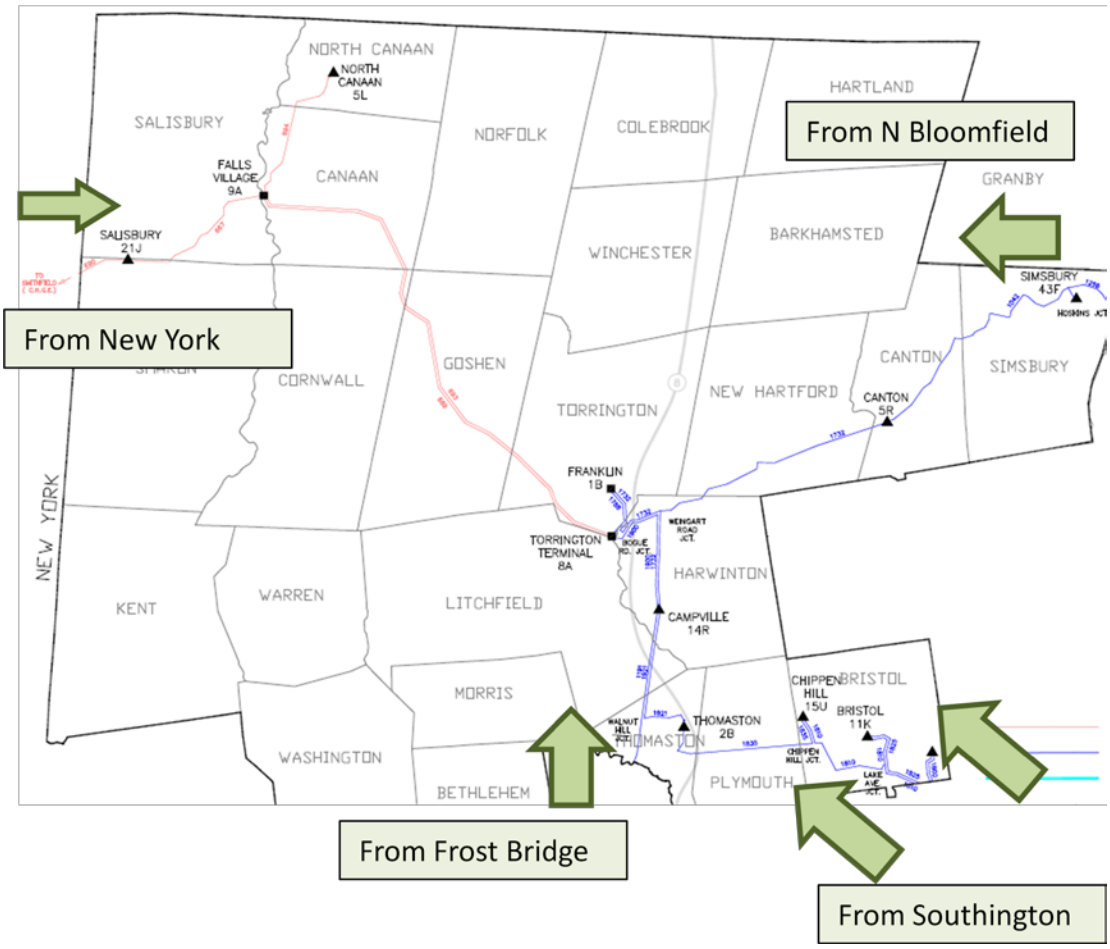


Figure 5-5: Northwestern Connecticut Subarea Existing Geographic One-Line

The worst-case criteria violations were observed [redacted]

The criteria violations observed under N-1-1 conditions are almost identical with one or two units OOS.

In addition to the N-1-1 issues, some N-1 and N-0 criteria violations were also observed in the Northwestern Connecticut subarea. [redacted]

5.3.2.2 Northwestern Connecticut Subarea Alternative Solutions

Two local solution alternatives were developed to solve the violations in the Northwestern Connecticut subarea. A third alternative solution, which consisted of a new 115 kV line from North Bloomfield to Campville as well as additional minor upgrades, was analyzed as well. However, this

alternative proved to be very cost-prohibitive and was eliminated in favor of a plan that features the construction of a new 115 kV line between North Bloomfield and Canton and other minor upgrades. Both Alternative A and Alternative B provide a new 115 kV source into the subarea, as well as resolve all additional violations not addressed by the new 115 kV source. The two different solution alternatives are summarized in Table 5-3 below.

Table 5-3: Northwestern Connecticut Subarea Solution Alternatives

Component ID	Description	Included in Alternative A	Included in Alternative B
1	Add a new 10.35 mile, 115 kV line from Frost Bridge to Campville and associated terminal equipment	**Y**	
2	Add a new 12.80 mile, 115 kV line from North Bloomfield to Canton and associated terminal equipment		**Y**
3	Separation of 115 kV DCT corresponding to the Frost Bridge to Campville (1191) line and the Thomaston to Campville (1921) line and add a breaker at Campville 115 kV substation	**Y**	
4	Upgrade terminal equipment on the 115 kV line between Chippen Hill and Lake Avenue Junction (1810-3)	**Y**	**Y**
5	Reconductor the 115 kV line between Southington and Lake Avenue Junction (1810-1) – 5.2 miles		
6	Add a 25.2 MVAR capacitor at Campville substation		**Y**

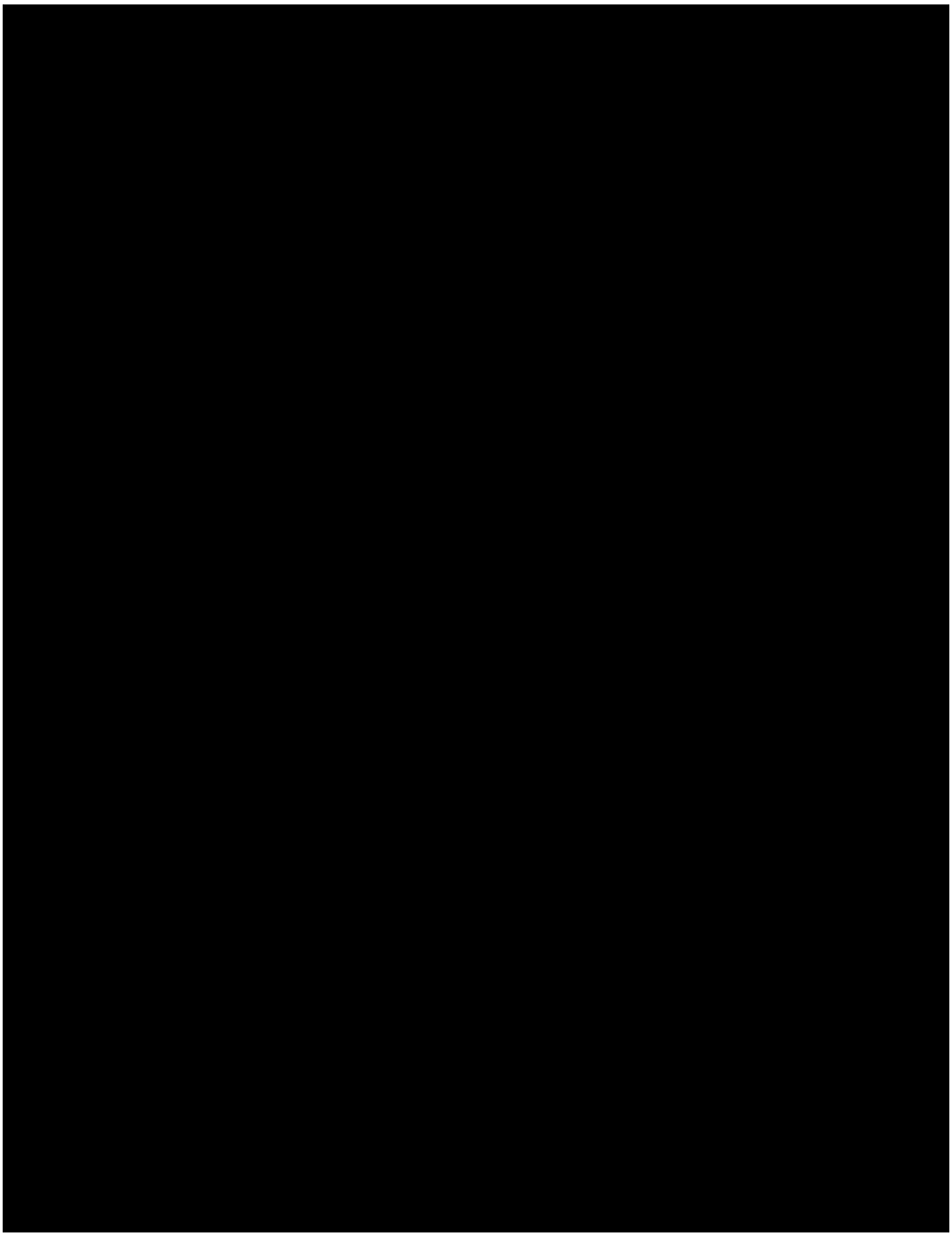


Figure 5-6: Northwestern Connecticut Alternative A Upgrades



Figure 5-7: Northwestern Connecticut Alternative B Upgrades

5.3.3 Middletown Subarea

The Middletown subarea consists of about 656 MW of load including demand resources in 2022. The area has two generators totaling to about 353 MW (Middletown 2 and 3) that may be classified as regular generators and two generators (Middletown 10 and Branford 10) totaling to about 33 MW that are classified as fast-start units.

5.3.3.1 Middletown Subarea Needs Assessment Results

The GHCC Needs Assessment observed that the Middletown subarea does depend on the surrounding areas to serve the local load, but has a substantial amount of local generation which reduces the need for import capability when all units are available.

The major transmission elements that feed this subarea are:

- A 345/115 kV autotransformer at Haddam (Haddam 6X)
- A 115 kV line from Southington to Colony (Line 1355)
- A 115 kV line from Manchester to Hopewell (Line 1767)
- A 115 kV line from Branford to Stepstone (Line 1738)
- A 115 kV line from Berlin to Westside (Line 1765)

[redacted]

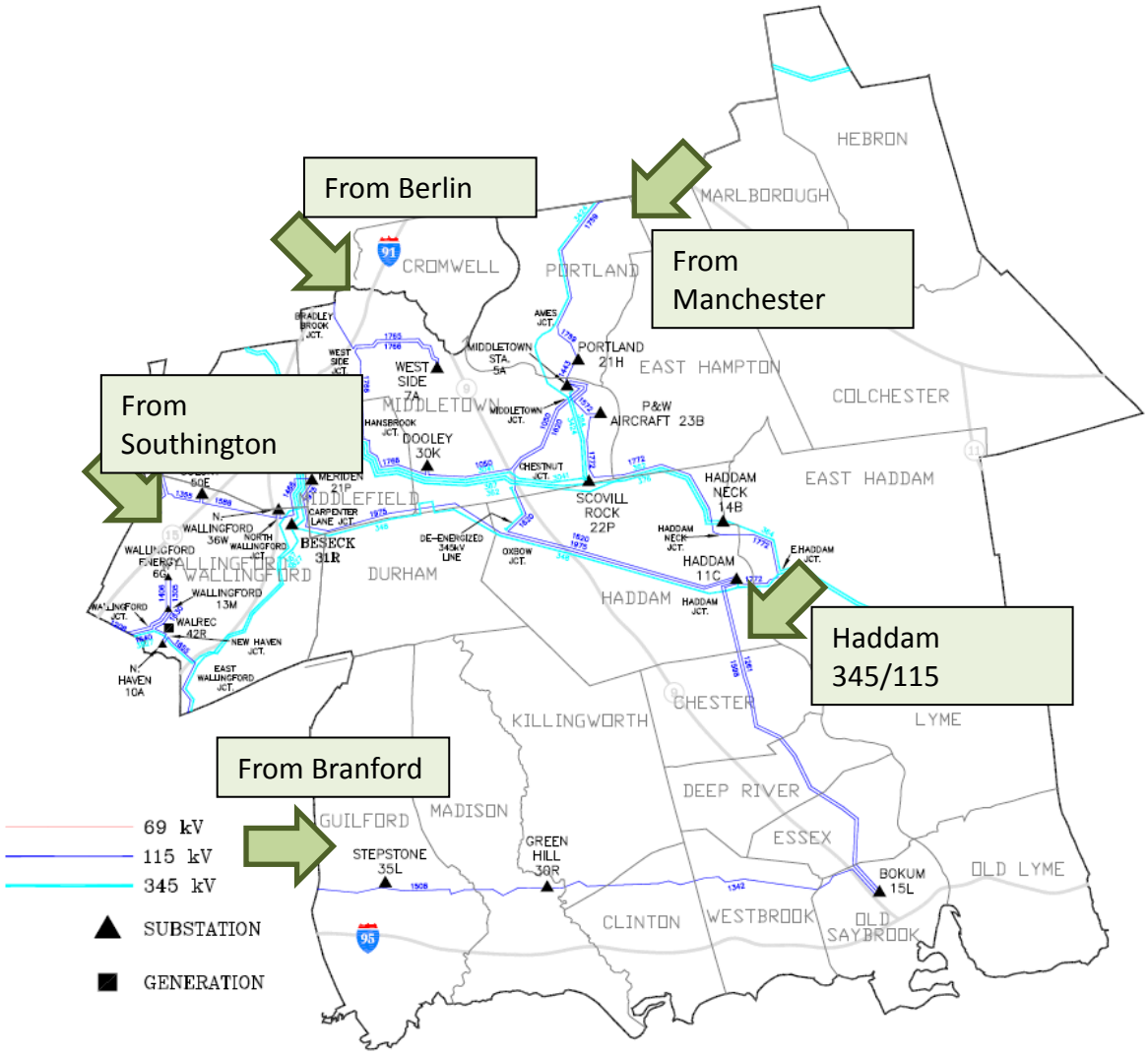


Figure 5-8: Middletown Subarea Existing Geographic One-Line

A smaller load pocket between Haddam and Branford on the 115 kV network experiences some violations for all the dispatches. This load pocket consists of four substations totaling 180 MW of load including demand resources. [redacted] The dispatch of other regular units has an insignificant impact on these violations.

This load pocket is fed by:

- Two 115 kV lines from Haddam to Bokum (Line 1261 and 1598)
- One 115 kV line from Branford - Stepstone (Line 1738)

Thermal and voltage violations were observed under N-1 and N-1-1 conditions when load was fed radially out of Haddam under contingency conditions.

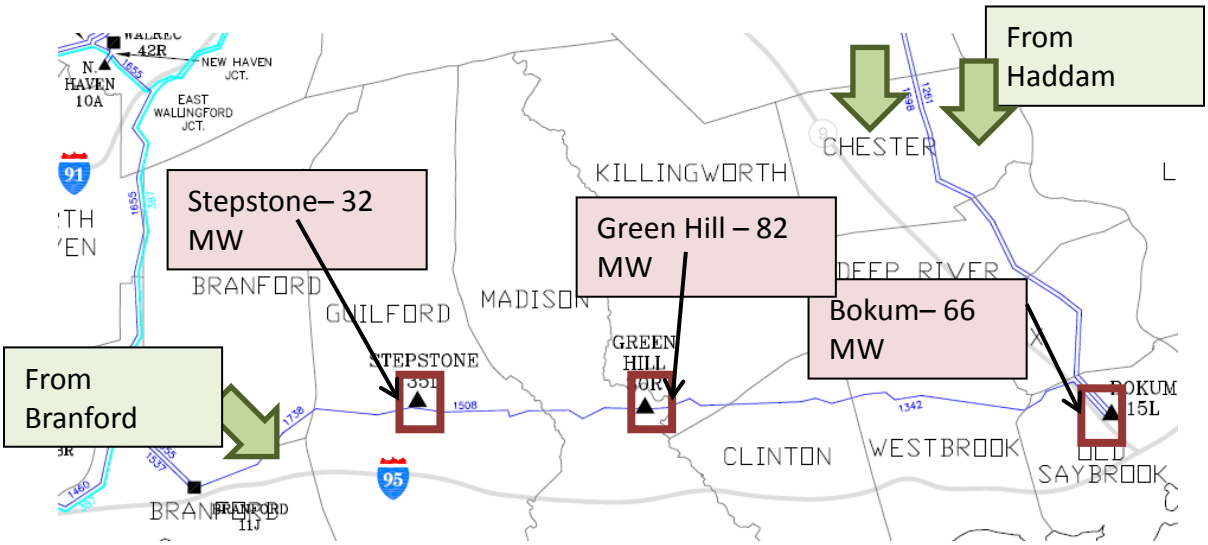


Figure 5-9: Branford - Haddam Load Pocket

[redacted]

[redacted]

5.3.3.2 Middletown Subarea Alternative Solutions

Two local solution alternatives were developed to solve the observed violations in the Middletown subarea. Both alternatives, described and summarized in Table 5-4 below, provide a new step-down connection from the 345 kV transmission network into the subarea. Additional minor upgrades were added to each plan to address all remaining violations that the new autotransformers did not.

Table 5-4: Middletown Subarea Solution Alternatives

Component ID	Description	Included in Haddam Auto Alternative	Included in Scovill Rock Alternative
1	Add a 2nd 345/115 kV autotransformer at Haddam substation and reconfigure the 3-terminal 345 kV 348 line into 2 two-terminal lines	**Y**	
2	Add a new 345/115 kV autotransformer at Scovill Rock substation and add a 3.3 mile 115 kV line from Scovill Rock to Middletown substation including associated terminal equipment		**Y**
3	Terminal equipment upgrades on the 345 kV line between Haddam and Beseck (362)	**Y**	**Y**
4	Separation of 115 kV double circuit towers corresponding to the Branford – Branford RR line (1537) and the Branford to North Haven (1655) line and adding a series breaker at Branford 115 kV substation	**Y**	**Y**
5	Terminal Equipment upgrades on the Middletown to Dooley Line (1050)	**Y**	**Y**
6	Terminal Equipment upgrades on the Middletown to Portland Line (1443)	**Y**	**Y**
7	Redesign the Green Hill 115 kV substation from a straight bus to a ring bus and add a 37.8 MVAR capacitor bank	**Y**	**Y**
8	Add a 37.8 MVAR capacitor bank at Hopewell 115 kV substation	**Y**	
9	Eliminate sag limit on the 115 kV line between Colony and Lucchini Junction (1355-1)		**Y**
10	Reconductor the 115 kV line between North Wallingford and Colony (1588) – 2.6 miles		**Y**
11	Upgrade the 115 kV line between Southington and Lucchini Junction (1355-3) - 4.6 miles		**Y**
12	Separation of 115 kV double circuit towers corresponding to the Middletown – Pratt and Whitney line (1572) and the Middletown to Haddam (1620) line	**Y**	
13	Add a 37.8 MVAR capacitor bank at Haddam 115 kV substation		**Y**

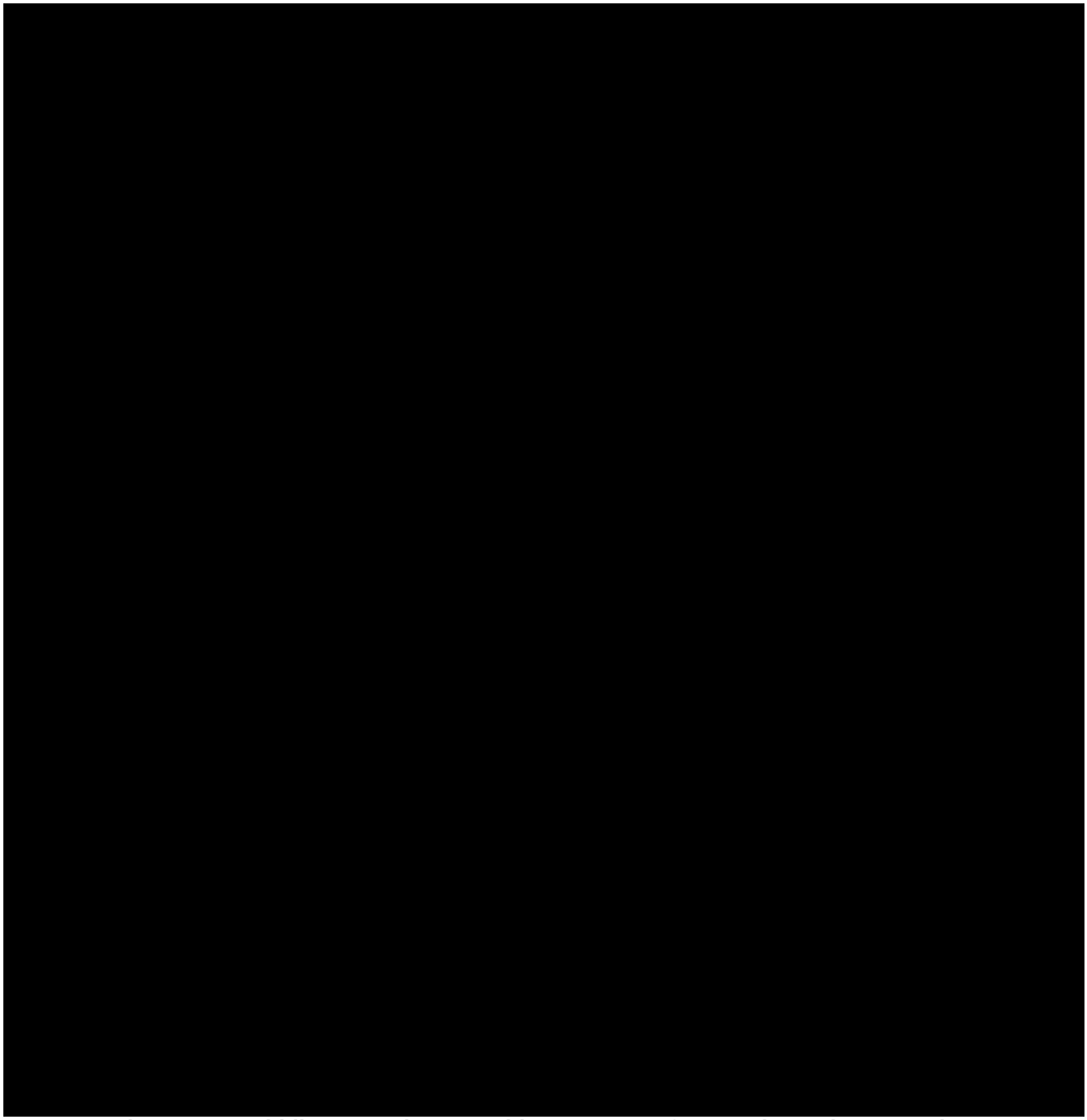


Figure 5-10: Middletown Subarea Haddam Autotransformer Alternative Upgrades



Figure 5-11: Middletown Subarea Scovill Rock Autotransformer Alternative Upgrades

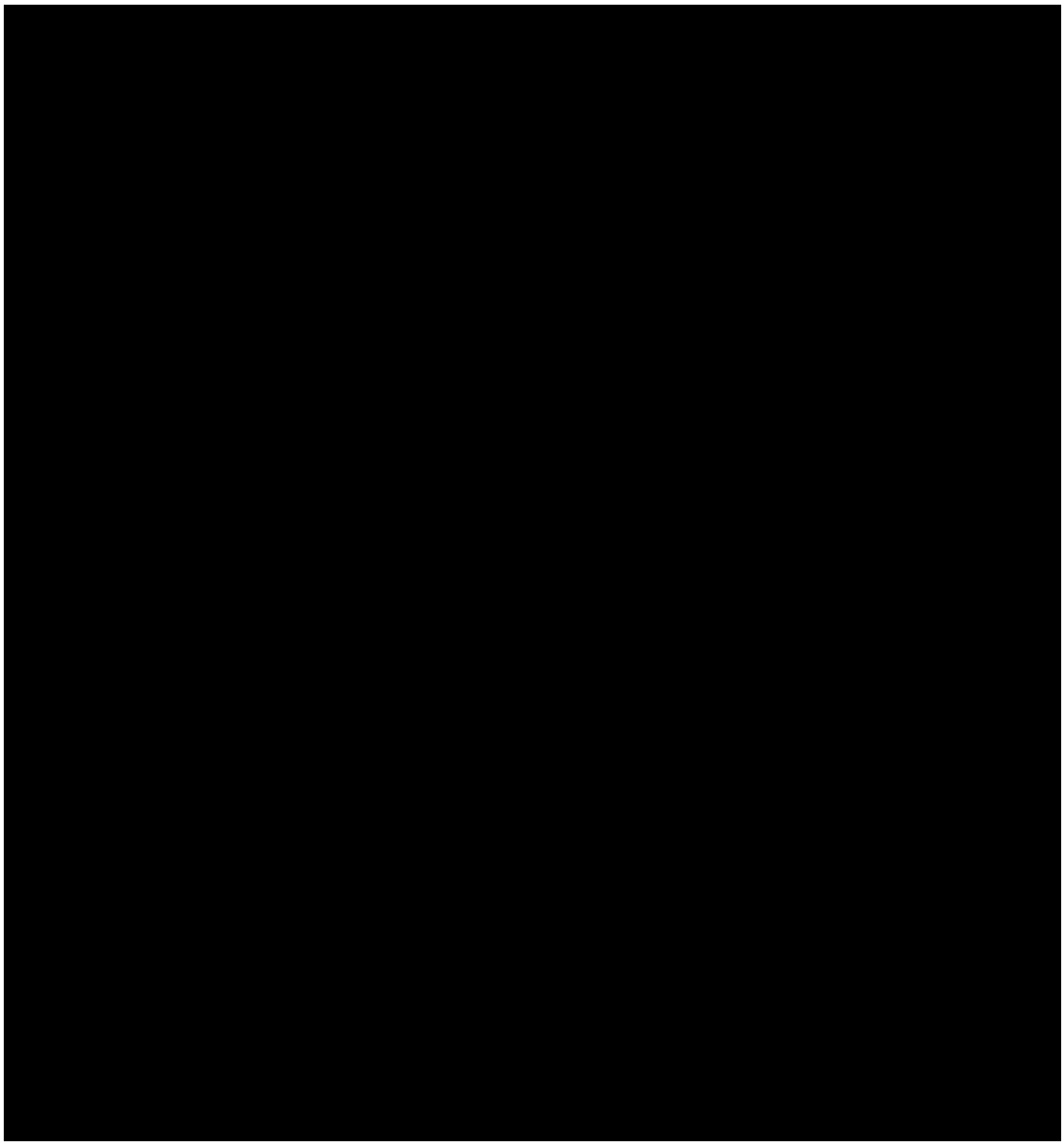


Figure 5-12: Middletown Subarea Scovill Rock Autotransformer Alternative Upgrades (Cont'd.)

5.3.4 Greater Hartford Subarea

The Greater Hartford subarea net load for 2022 after demand resources are subtracted is about 1,227 MW of load. The area has three generators totaling to about 103 MW that may be classified as regular units and four generators totaling to about 149 MW that are classified as fast-start units.

5.3.4.1 Greater Hartford Subarea Needs Assessment Results

As stated in the GHCC Needs Assessment report, it can be observed that the Greater Hartford area is a net importer of energy and relies on the surrounding areas to serve local load. The major 115 kV lines that feed this subarea are:

- Three 115 kV lines from North Bloomfield (Lines 1726, 1751, and 1777)
  - 1726: North Bloomfield – Farmington
  - 1751: North Bloomfield – Northwest Hartford – Rood Avenue
  - 1777: North Bloomfield – Bloomfield
- Three 115 kV lines from Manchester (Lines 1207, 1448 and 1775)
  - 1207: Manchester – East Hartford
  - 1448: Manchester – Rood Avenue
  - 1775: Manchester – Riverside Drive – South Meadow
- Two 115 kV lines from Southington (Lines 1670 and 1771)
  - 1670: Southington – Black Rock – Berlin
  - 1771: Southington – Berlin
- One 115 kV line from Middletown (Line 1765)
  - 1765: Westside – Berlin

[redacted] There were no N-0 violations.

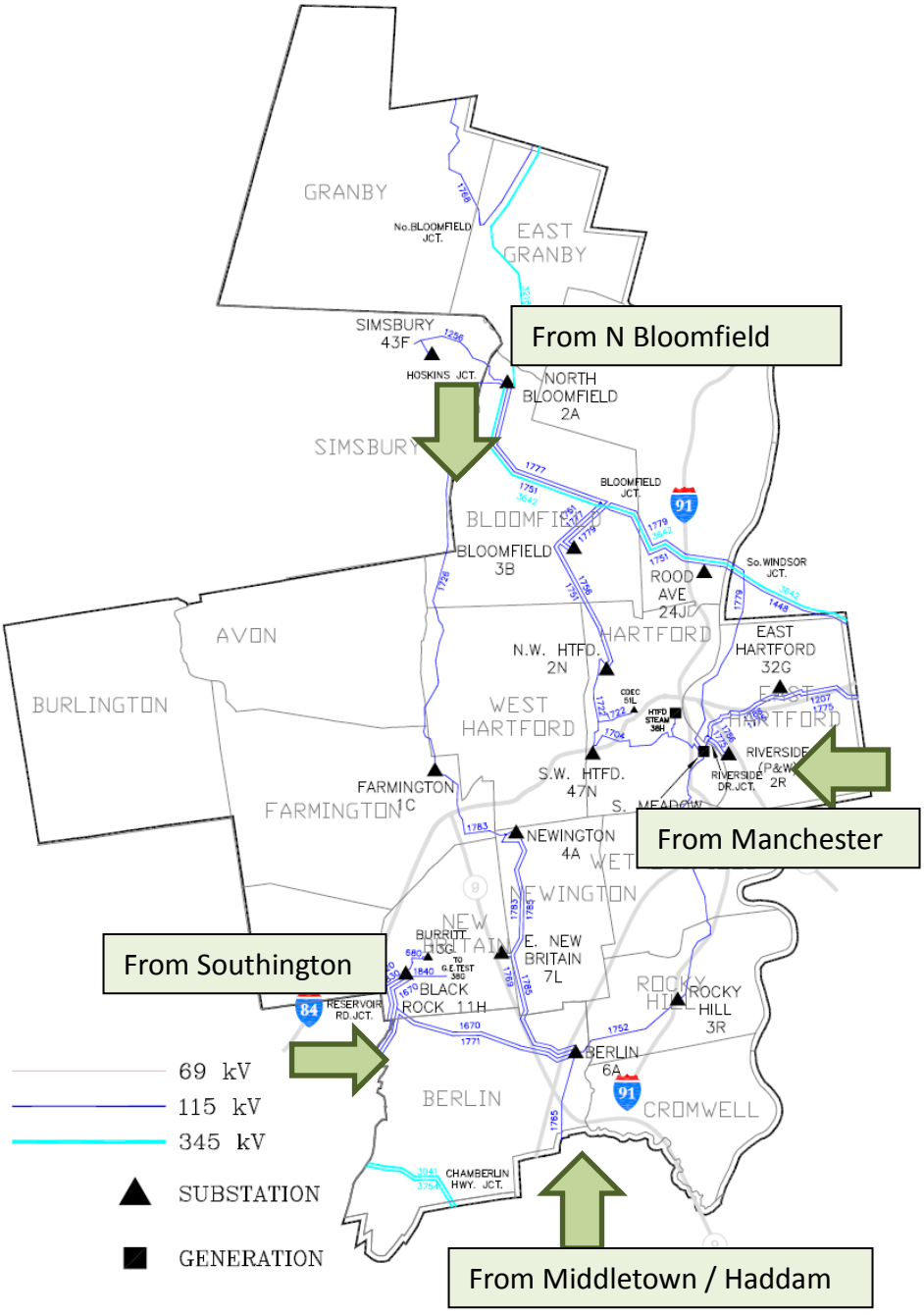


Figure 5-13: Greater Hartford Subarea Existing Geographic One-Line

The needs in the Greater Hartford subarea were further divided into three areas: Southington, North Bloomfield – Manchester; and South Meadow – Berlin. A single solution that would be common to all solutions for the entire subarea was developed for Southington. Two major alternatives for addressing weaknesses in the other two areas, which together make up the rest of the Greater Hartford subarea, were developed.

5.3.4.2 Southington Area Common Solution

The Southington substation has five 115 kV facilities that are a part of the SWCT import interface. There are 4 autotransformers at Southington that feed into these SWCT import lines. The violations seen in this area are all thermal violations. [redacted]

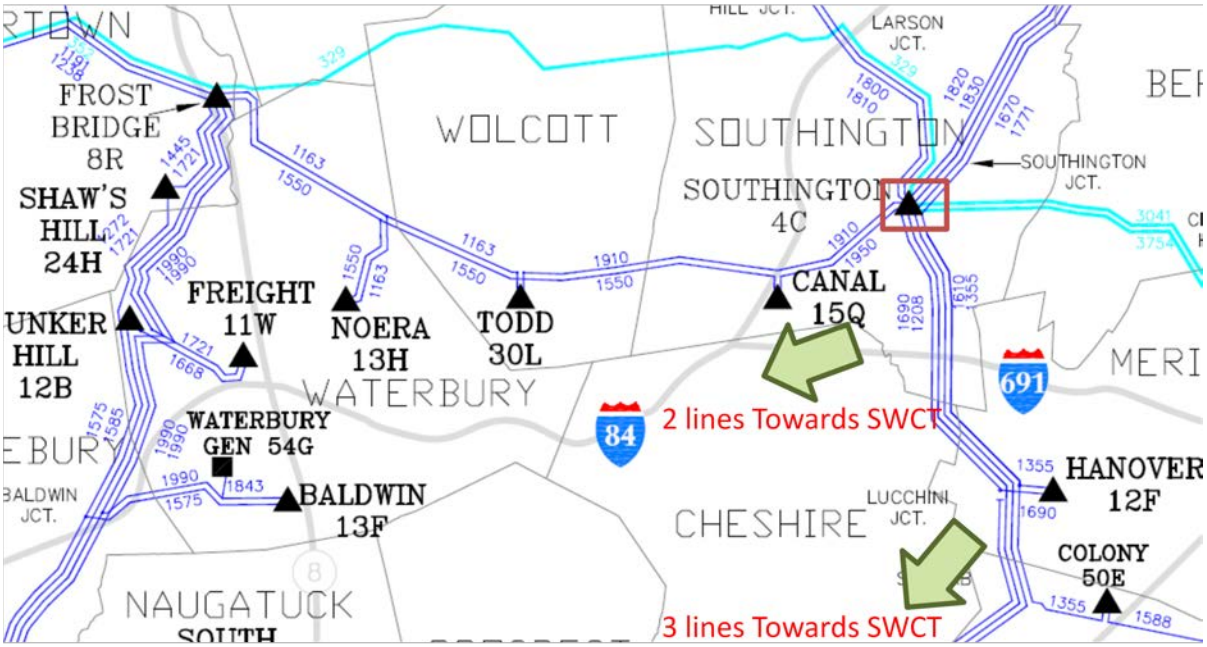


Figure 5-14: Southington Substation and SWCT Import Interface

The Southington common solutions involve improvements to both the 345 kV and 115 kV portions of the Southington substation.

Table 5-5: Southington Area Common Solution Upgrades

Component ID	Description
S1	Replace the existing 3% series reactors on the 115 kV lines between Southington and Todd (1910) and between Southington and Canal (1950) with 5% series reactors
S2	Replace the normally open 19T breaker at Southington with a 3% series reactor between Southington Ring 1 and Southington Ring 2 and associated substation upgrades
S3	Add a breaker in series with breaker 5T at the Southington 345 kV switchyard
S4	Add a new control house at Southington 115 kV substation



Figure 5-15: Southington Area Common Solution Upgrades

5.3.4.3 Rest of Greater Hartford Subarea

As noted, the rest of the Greater Hartford Subarea consists of two separate load pockets, the South Meadow and Berlin area and the North Bloomfield – Manchester area. Solutions that would address the needs in both load pockets were developed.

5.3.4.3.1 South Meadow and Berlin Area Needs

This area has a 2022 load of about 569 MW after DR loads are subtracted. The load is distributed across seven substations. This load pocket is served by five 115 kV lines:

- Two 115 kV lines from Southington to Berlin (Lines 1670 and 1771)
- A 115 kV line from North Bloomfield to Farmington (Line 1726)
- A 115 kV line from South Meadow to Rocky Hill (Line 1773)

- A 115 kV line from Westside towards Berlin (Line 1765)

There is no generation located within this load pocket;

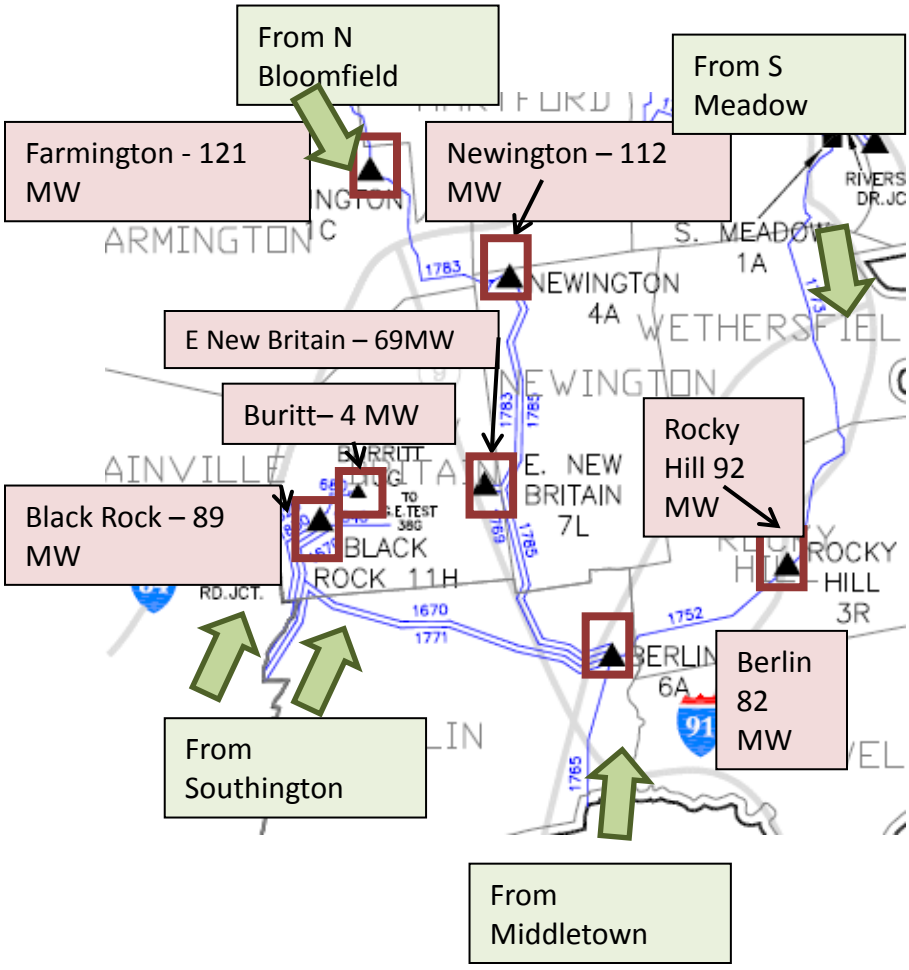


Figure 5-16: South Meadow, Berlin and Southington Load Area

Within this load area is the Farmington, Newington and East New Britain load pocket. This load pocket has a net load of 302 MW for 2022 after DR loads are subtracted. The load is distributed across three 115 kV substations. This load pocket served by three 115 kV lines:

- A 115 kV line from North Bloomfield to Farmington (Line 1726)
- A 115 kV line from Berlin to Newington (Line 1785)
- A 115 kV line from Berlin to East New Britain (Line 1769)

[redacted]

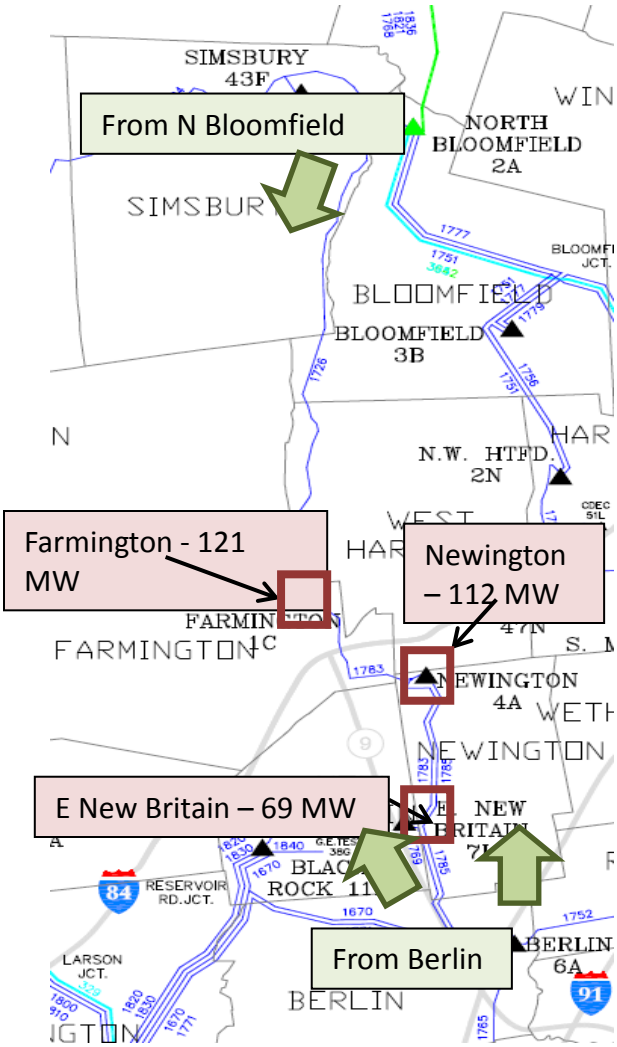


Figure 5-17: Farmington, Newington and East New Britain Load Pocket

5.3.4.3.2 North Bloomfield – Manchester Area Needs

This area is bound by feeds from North Bloomfield and Manchester and is served by five 115 kV lines:

- A three-terminal 115 kV line from North Bloomfield to Northwest Hartford to Rood Avenue (Line 1751)
- A 115 kV line from North Bloomfield to Bloomfield (Line 1777)
- A three terminal 115 kV line from Manchester – Riverside – South Meadow (Line 1775)
- A 115 kV line from Manchester – East Hartford (Line 1207)
- A 115 kV line from Manchester – Rood Avenue (Line 1448)

CDECCA generation and South Meadow generation are located at the center of this area [redacted]

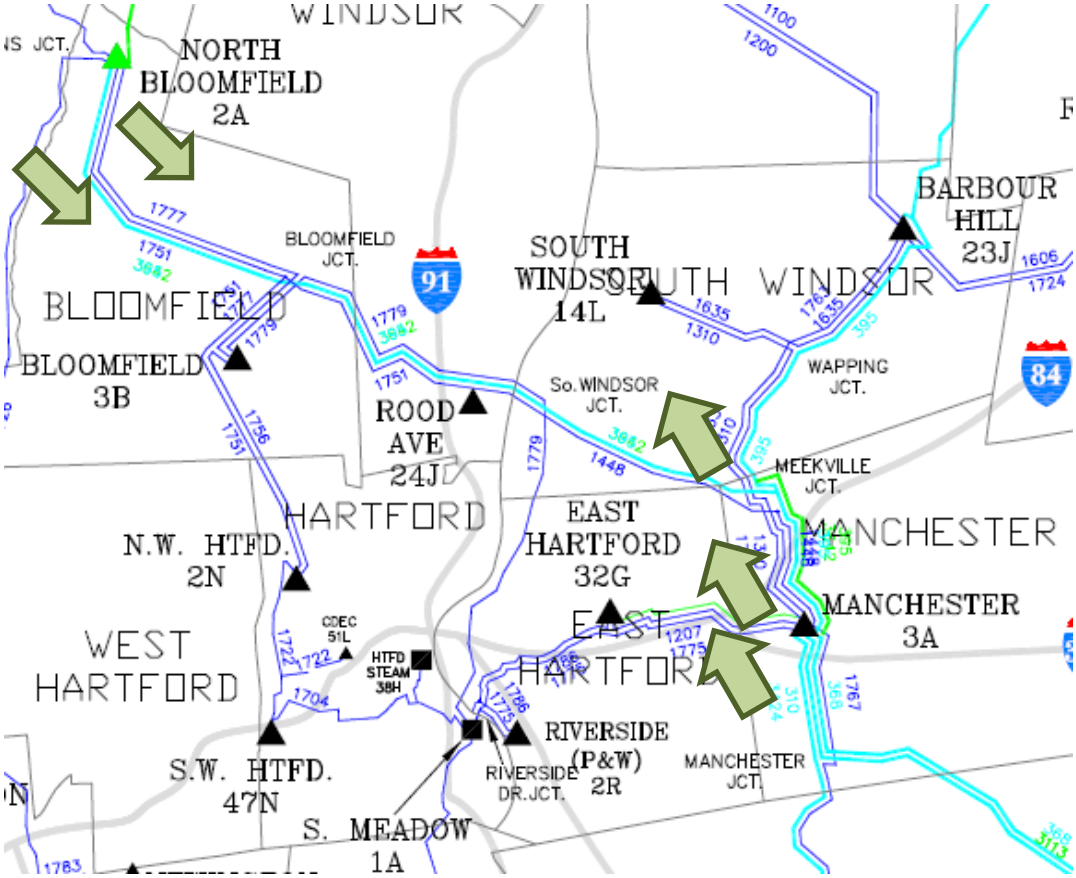


Figure 5-18: North Bloomfield - Manchester Area

5.3.4.3.3 Rest of Greater Hartford Solutions

The violations in the two load pockets (excluding the Southington area) that make up the rest of the Greater Hartford subarea could be addressed by the solution alternatives described in Table 5-6. The two major alternative components provide a new 115 kV transmission source into the subarea via a new underground cable or overhead line, as well as address the remaining violations that exist with the addition of either of the two alternatives. The two sets of solutions are denoted by their major components ("Underground Line" or "Overhead Line"):

Table 5-6: Rest of Greater Hartford Subarea Solution Alternatives

Component ID	Description	Included in Underground Line Alternative	Included in Overhead Line Alternative
1	Add a new 4 mile 115 kV underground cable from Newington to Southwest Hartford and associated terminal equipment including a 2% series reactor	**Y**	
2	Add a new 11.67 mile 115 kV line from North Bloomfield to Farmington and associated terminal equipment		**Y**
3	Loop the 1779 line between South Meadow and Bloomfield into the Rood Avenue substation and reconfigure the Rood Avenue substation	**Y**	**Y**
4	Reconfigure the Berlin 115 kV substation including the addition of two 115 kV breakers and the relocation of a capacitor bank	**Y**	**Y**
5	Add a 115 kV 25.2 MVAR capacitor at Westside 115 kV substation	**Y**	**Y**
6	Reconductor the 115 kV line between Newington and Newington Tap (1783) – 0.01 miles	**Y**	**Y**
7	Separation of 115 kV DCT corresponding to the Bloomfield to South Meadow (1779) line and the Bloomfield to North Bloomfield (1777) line and add a breaker at Bloomfield 115 kV substation	**Y**	**Y**
8	Install a 115 kV 3% reactor on the underground cable between South Meadow and Southwest Hartford(1704)	**Y**	**Y**
9	Separation of 115 kV DCT corresponding to the Bloomfield to North Bloomfield (1777) line and the North Bloomfield – Rood Avenue – Northwest Hartford (1751) line and add a breaker at North Bloomfield 115 kV substation	**Y**	**Y**
10	Terminal upgrades on the 115 kV line between South Meadow and Rocky Hill		**Y**
11	Upgrade the 115 kV line between Farmington and Newington Tap (1783) – 3.61 miles		**Y**

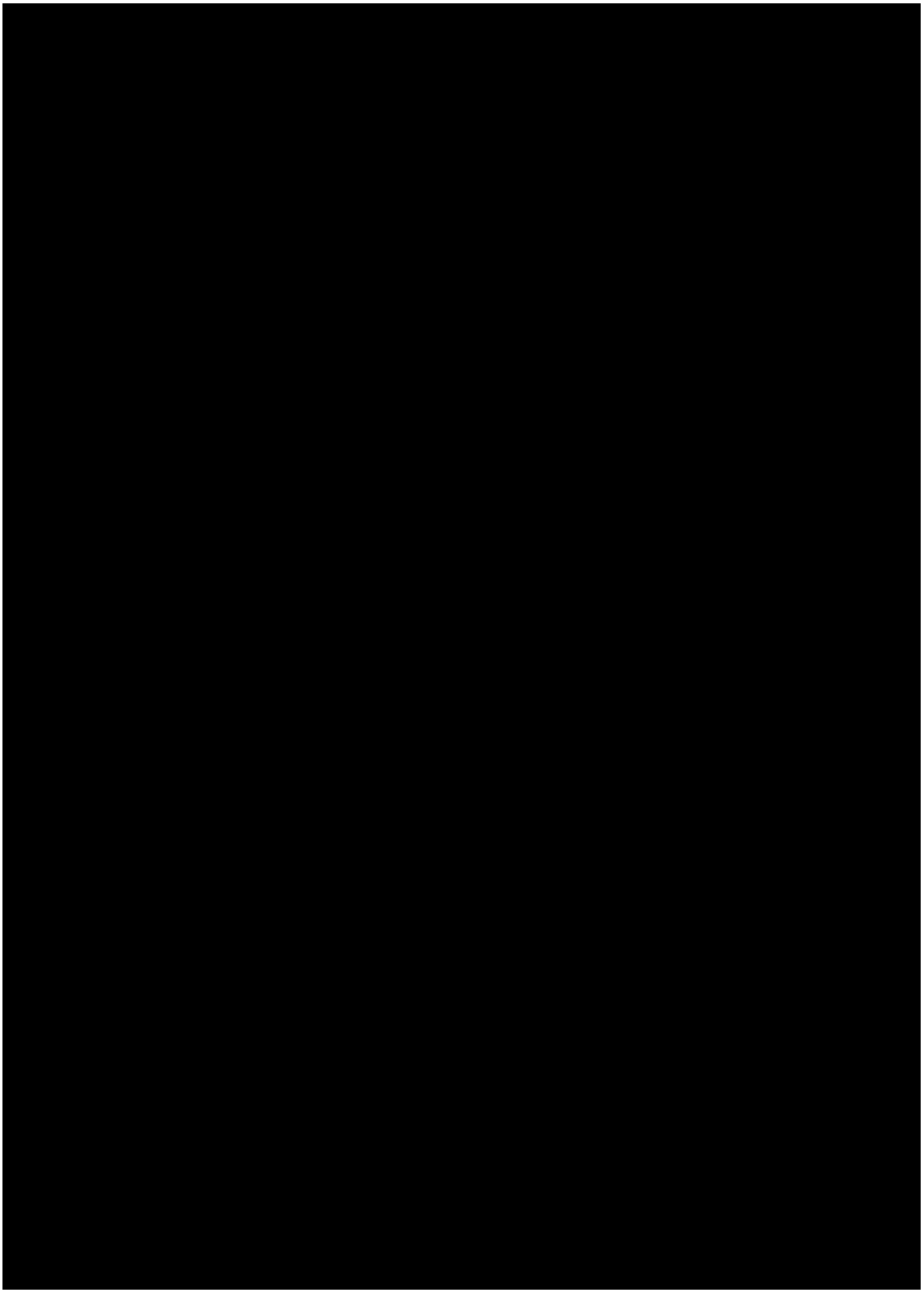


Figure 5-19: Rest of Greater Hartford Underground Line Alternative Upgrades



Figure 5-20: Rest of Greater Hartford Underground Line Alternative Upgrades (Cont'd.)

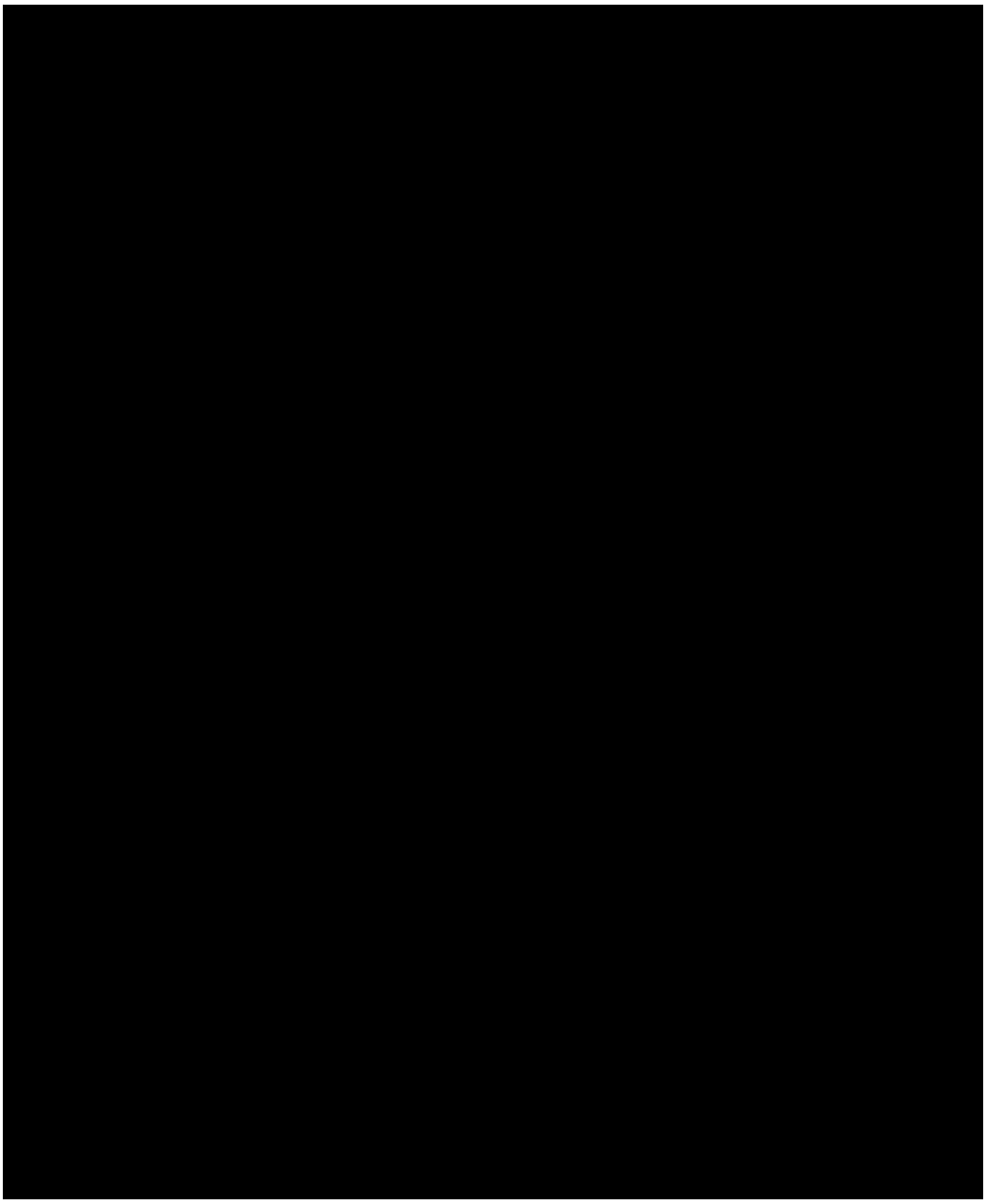


Figure 5-21: Rest of Greater Hartford Overhead Line Alternative Upgrades

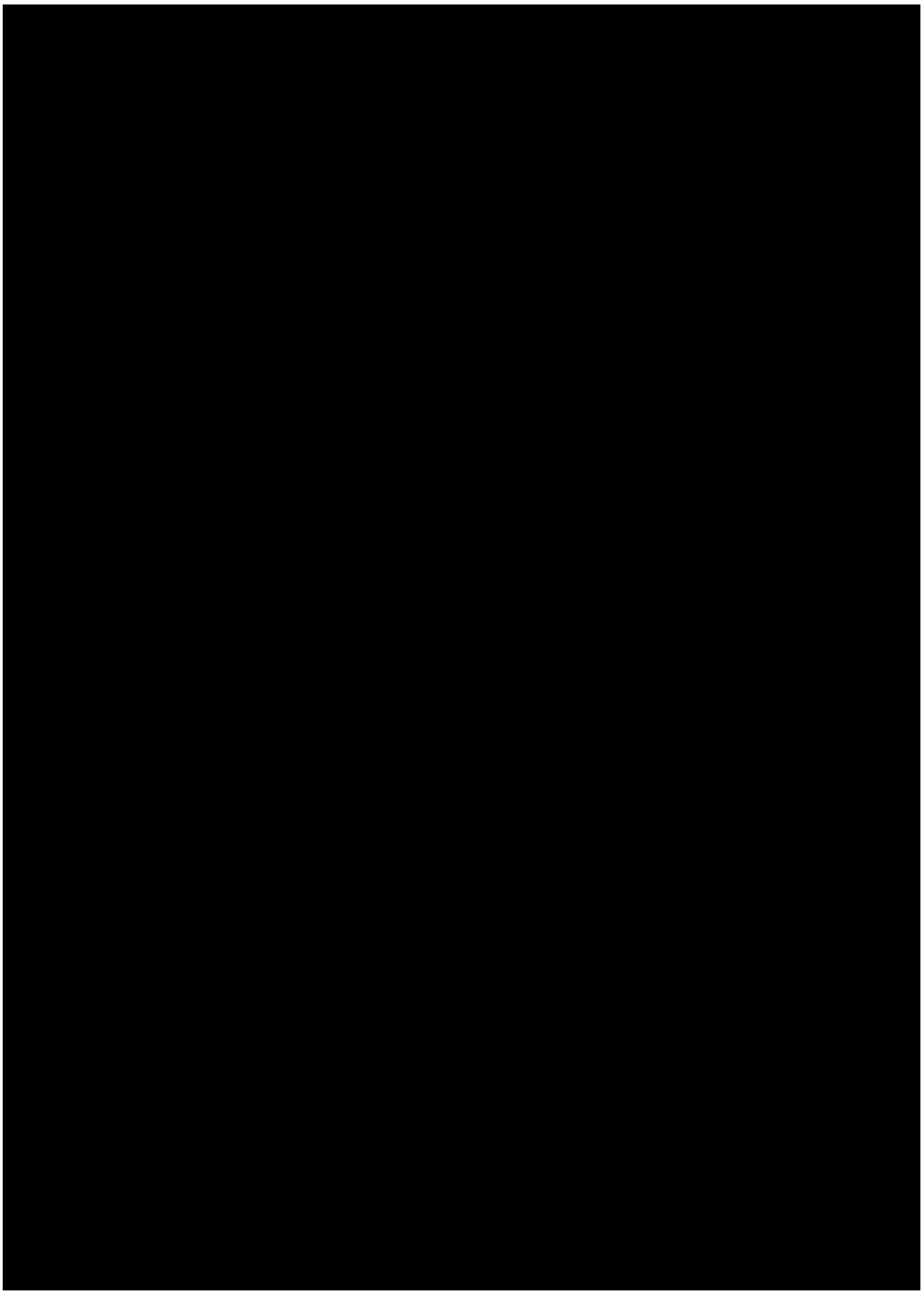


Figure 5-22: Rest of Greater Hartford Overhead Line Alternative Upgrades (Cont'd.)

5.3.5 Western Connecticut Import Interface

The Western Connecticut Import interface is made up of the transmission elements listed in Table 3-9. The alternative solutions to the local area load serving problems in the Greater Hartford subarea were designed to include elements that would also relieve congestion on the Western Connecticut Import interface. Both the Overhead Line and Underground Line alternatives for the Greater Hartford

subarea would add a new 115 kV element to the interface. Additionally, terminal equipment upgrades to the 362 line at either Haddam Neck or Beseck would increase the capacity of an existing element of the interface. These improvements are the major contributors to an increase in transfer capacity that eliminates all of the pre-project violations that were associated with high Western Connecticut Import levels or driven by the contingency loss of lines across the Western Connecticut Import interface.

Section 6
Alternative Solution Performance Testing and Results

All results presented in this section were derived based on the criteria and assumptions identified in Section 3. Since it was determined that the needs for each study subarea were relatively independent of those in the other subareas, each alternative solution was first tested independently of the others to ensure that it resolved all known thermal and voltage criteria violations in its respective subarea. Once the preferred solution alternative for each subarea was selected, the four preferred solution alternatives were studied all at once to ensure that their concurrent implementation did not create any unforeseen criteria violations. The preferred GHCC solution was tested alongside the preferred transmission solution set for the Southwestern Connecticut area; the results of this testing are discussed in the following sections.

6.1 Steady State Performance Results

The alternative solutions described in this report all resolved the thermal and voltage criteria violations in their respective study subareas and eliminated criteria violations associated with constraints on the Western Connecticut Import interface. A description of the results of the alternatives is described in the following sections. Detailed steady state analysis results can be found in Appendix E: Steady State Testing Results.

6.1.1 N-0 Thermal and Voltage Performance Summary

N-0 study indicated no violations found.

6.1.2 N-1 Thermal and Voltage Performance Summary

The N-1 study of the GHCC preferred solutions found two remaining thermal violations in the northwestern Connecticut subarea, as summarized in Table 6-1.

Table 6-1: GHCC and SWCT Preferred Solutions N-1 Thermal Violations Summary

Study Subarea	Circuit ID	kV	Stations	Worst Dispatch	Worst Contingency	Worst Loading (%LTE)
NWCT	1825	115	Bristol - Forestville	[redacted]	[redacted]	114.15%
NWCT	690	69	Salisbury – Smithfield (NY)	[redacted]	[redacted]	230.94%

The N-1 study of the GHCC preferred solutions found eight remaining voltage violations in the study area, as summarized in Table 6-2.

Table 6-2: GHCC and SWCT Preferred Solutions N-1 Voltage Violations Summary

Study Subarea	Substation	kV	Worst Dispatch	Worst Contingency	Worst Voltage (p.u.)
Middletown	Hanover	115	[redacted]	[redacted]	0.7697
Manchester / Barbour Hill	Scitico	115	[redacted]	[redacted]	0.9413
NWCT	Canton	115	[redacted]	[redacted]	0.9031
NWCT	Forestville	115	[redacted]	[redacted]	0.9193
NWCT	Torrington Terminal	115	[redacted]	[redacted]	0.5796
NWCT	Falls Village	69	[redacted]	[redacted]	0.5784
NWCT	North Canaan	69	[redacted]	[redacted]	0.5648
NWCT	Salisbury	69	[redacted]	[redacted]	0.8009

6.1.3 N-1-1 Thermal and Voltage Performance Summary

The N-1-1 study of the GHCC preferred solutions found one remaining thermal violation in the study area, as summarized in Table 6-3.

Table 6-3: GHCC and SWCT Preferred Solutions N-1 Thermal Violations Summary

Study Subarea	Circuit ID	kV	Stations	Worst Dispatch	Line Out	Worst Contingency	Worst Loading (%LTE)
NWCT	1825	115	Bristol - Forestville	[redacted]	[redacted]	[redacted]	114.18%

[redacted]

The N-1-1 study of the GHCC preferred solutions found two remaining voltage violations in the study area, as summarized in Table 6-4

.

Table 6-4: GHCC and SWCT Preferred Solutions N-1-1 Voltage Violations Summary

Study Subarea	Substation	kV	Worst Dispatch	Line Out	Worst Contingency	Worst Voltage (p.u.)
NWCT	Canton	115		[redacted]	[redacted]	0.9041
NWCT	Forestville	115		[redacted]	[redacted]	0.9189

[redacted]

Table 6-5: GHCC and SWCT Preferred Solutions N-1-1 Non-Converged Scenarios

Study Subarea	Line Out	Contingency	Dispatch
NWCT	[redacted]	[redacted]	ALL
NWCT	[redacted]	[redacted]	ALL
NWCT	[redacted]	[redacted]	ALL
NWCT	[redacted]	[redacted]	ALL

6.1.4 Results of Extreme Contingency Testing

Extreme contingency testing did not show any concerns with inter-area impacts as a result of any the tested contingencies.

6.2 Stability Performance Results

Not applicable to this study.

6.3 Short Circuit Performance Results

After the preferred solution alternatives were selected, Northeast Utilities studied short circuit duties in the GHCC study area. Particular attention was paid to the effect that the possible replacement of the normally open 19T bus-tie breaker at Southington with a 3% series reactor would have on short circuit duties following the implementation of the preferred solution. Detailed results of the short circuit studies performed are provided in Appendix F: Short Circuit Testing Results.

6.3.1 Short Circuit Performance Results

Summarized results of all three short circuit scenarios analyzed (as described in Section 3.4.6) are provided in Table 6-6.

Table 6-6: Short Circuit Duties at Southington 115 kV Substation

Study Scenario	Highest Duty at Southington 115 kV
1 [redacted]	73.4%
2 [redacted]	100.6%
3 [redacted]	81.2%

[redacted]

The results of the short circuit study show that the proposed replacement of the normally open bus tie at Southington with a 3% series reactor resolves all observed pre-project breaker over-duties [redacted]

No other breakers in the study area had a duty over 90%, either pre- or post-project.

As a part of the GHCC and SWCT PPA study the impact of both projects on short circuit duty will be evaluated. Since the independent projects did not cause a significant change in breaker duties the combined project is not expected to cause any breaker over-duties. However, this will be verified by the PPA study.

6.4 Other Assessment Performance Results

6.4.1 Western Connecticut Import Thermal Transfer Comparative Analysis Results

All of the solution alternatives for the Greater Hartford and Middletown subareas resolved the criteria violations associated with insufficient transfer capacity across the Western Connecticut Import interface. To determine whether any of the alternatives provided significantly higher thermal transfer capabilities, a limited set of transfer analyses was completed as described in Section 3.5.1. Detailed results of the transfer analysis studies performed are provided in Appendix G: Transfer Analysis Testing Results.

Transfer analysis results of the four different solution alternative combinations are shown in Table 6-7.

Table 6-7: WCT Import N-1-1 Thermal Transfer Comparative Analysis Results

Middletown Solution Alternative	Greater Hartford Solution Alternative	Limiting Element	kV	Initial Line-Out	Contingency	WCT Import Limit (MW)
Haddam Auto	Underground Line	[redacted]	[redacted]	[redacted]	[redacted]	**2,997**
Scovill Rock Auto	Underground Line	[redacted]	[redacted]	[redacted]	[redacted]	**3,025**
Haddam Auto	Overhead Line	[redacted]	[redacted]	[redacted]	[redacted]	**3,035**
Scovill Rock Auto	Overhead Line	[redacted]	[redacted]	[redacted]	[redacted]	**3,045**

It should be noted that in determining the transfer levels above, certain constraints that could be resolved by adjustments between 1st and 2nd contingencies were excluded in the transfer analysis. It was assumed that back-down of local generation could be performed between the two contingencies. However, the Scovill Rock autotransformer alternative required a larger amount of re-dispatch between contingencies compared to the Haddam autotransformer alternative.

Section 7
Comparison of Alternative Solutions

7.1 Factors Used to Compare Alternative Solutions

When the estimated cost (+50%/-25%) accuracy was similar, the key factors used to compare the solution alternatives included:

- Better operational performance (solution alternative requires less or no re-dispatch or capacitor switching)
- Better system performance – Thermal
- Better system performance – Voltage
- Expected in-service date (ISD)
- Expected ease of permitting (e.g. environmental, siting, etc…)
- Ease of constructability (during the construction phase)
- Fewer construction outages (number and length of outages)

The siting issues took into consideration easements along existing rights-of-way as well as available space in the existing substation. Total cost estimates were used to consider differences between all solution alternatives. All of the solution alternatives provide a stronger transmission system in the study area.

7.2 Cost Estimates for Selected Alternative Solutions

All cost estimates were developed consistent with ISO-NE cost estimation procedures as defined in Attachment D of ISO Planning Procedure No. 4. All cost estimates in this report were developed with +50/-25% accuracy.

For the Manchester / Barbour Hill area, two alternatives were evaluated, designated Alternative A and Alternative B. The cost estimates for the common components of each solution are shown in Table 7-1.

Table 7-1: Manchester / Barbour Hill Common Components Cost Estimates

ID	Solution Component	Cost ($M)
4	Add a 345 kV breaker in series with breaker 24T at the Manchester 345 kV switchyard	2.1
Subtotal of Common Solution Components		**2.1**

The following solution components shown in Table 7-2 were not common between solution alternatives and represent the differences between the two plans.

Table 7-2: Manchester / Barbour Hill Alternative Solution Components Cost Estimates

ID	Solution Component	Cost ($M)	Included in Alternative A	Included in Alternative B
1	Add a new 345/115 kV autotransformer at Barbour Hill and associated terminal equipment	31.2	Y	
2	Add a new 7.6 mile, 115 kV line from Manchester to Barbour Hill	42.1		Y
3	Reconductor the 115 kV line between Manchester and Barbour Hill (1763) – 7.6 miles	13.5	Y	
5	Add two 345 kV breakers in series with breaker 18T and 19T at the Manchester 345 kV switchyard	4.1		Y
6	Add a 115 kV breaker in series with breaker 13T at the Manchester 115 kV switchyard	1.1		Y
Solution Alternative Totals			**44.7**	**47.3**

The next set of cost estimates shown in Table 7-3 and Table 7-4 are for the two solution alternatives in the Northwestern Connecticut subarea.

Table 7-3: Northwestern Connecticut Common Components Cost Estimates

ID	Solution Component	Cost ($M)
4	Upgrade terminal equipment on the 115 kV line between Chippen Hill and Lake Avenue Junction (1810-3)	12.1
5	Reconductor the 115 kV line between Southington and Lake Avenue Junction (1810-1) – 5.2 miles	
Subtotal of Common Solution Components		**12.1**

Table 7-4: Northwestern Connecticut Alternative Solution Components Cost Estimates

ID	Solution Component	Cost ($M)	Included in Alternative A	Included in Alternative B
1	Add a new 10.35 mile, 115 kV line from Frost Bridge to Campville and associated terminal equipment	45.5	**Y**	
2	Add a new 12.80 mile, 115 kV line from North Bloomfield to Canton and associated terminal equipment	66.9		**Y**
3	Separation of 115 kV DCT corresponding to the Frost Bridge to Campville (1191) line and the Thomaston to Campville (1921) line and add a breaker at Campville 115 kV substation	5.5	**Y**	
6	Add a 25.2 MVAR capacitor at Campville substation	7.0		**Y**
Solution Alternative Totals			**51.0**	**73.9**

The next set of cost estimates shown in Table 7-5 and Table 7-6 are for the two solution alternatives in the Middletown subarea.

Table 7-5: Middletown Common Components Cost Estimates

ID	Solution Component	Cost ($M)
3	Terminal equipment upgrades on the 345 kV line between Haddam and Beseck (362)	0.5
4	Separation of 115 kV double circuit towers corresponding to the Branford – Branford RR line (1537) and the Branford to North Haven (1655) line and adding a series breaker at Branford 115 kV substation	2.0
5	Terminal Equipment upgrades on the Middletown to Dooley Line (1050)	0.1
6	Terminal Equipment upgrades on the Middletown to Portland Line (1443)	0.1
7	Redesign the Green Hill 115 kV substation from a straight bus to a ring bus and add a 37.8 MVAR capacitor bank	7.6
Subtotal of Common Solution Components		**10.3**

Table 7-6: Middletown Alternative Solution Components Cost Estimates

ID	Solution Component	Cost ($M)	Included in Haddam Auto Alternative	Included in Scovill Rock Auto Alternative
1	Add a 2nd 345/115 kV autotransformer at Haddam substation and reconfigure the 3-terminal 345 kV 348 line into 2 two-terminal lines	46.7	**Y**	
2	Add a new 345/115 kV autotransformer at Scovill Rock substation and add a 3.3 mile 115 kV line from Scovill Rock to Middletown substation including associated terminal equipment	59.6		**Y**
8	Add a 37.8 MVAR capacitor bank at Hopewell 115 kV substation	4.3	**Y**	
9	Eliminate sag limit on the 115 kV line between Colony and Lucchini Junction (1355-1)	1.1		**Y**
10	Reconductor the 115 kV line between North Wallingford and Colony (1588) – 2.6 miles	6.3		**Y**
11	Upgrade the 115 kV line between Southington and Lucchini Junction (1355-3) - 4.6 miles	8.9		**Y**
12	Separation of 115 kV double circuit towers corresponding to the Middletown – Pratt and Whitney line (1572) and the Middletown to Haddam (1620) line	1.9	**Y**	
13	Add a 37.8 MVAR capacitor bank at Haddam 115 kV substation	4.0		**Y**
Solution Alternative Totals			**52.9**	**79.9**

The final set of cost estimates shown in Table 7-7, Table 7-8, and Table 7-9 are for the solution alternatives in the Greater Hartford subarea.

Table 7-7: Southington Area Common Components Cost Estimates

ID	Solution Component	Cost ($M)
S1	Replace the existing 3% series reactors on the 115 kV lines between Southington and Todd (1910) and between Southington and Canal (1950) with 5% series reactors	5.2
S2	Replace the normally open 19T breaker at Southington with a 3% series reactor between Southington Ring 1 and Southington Ring 2 and associated substation upgrades	8.7
S3	Add a breaker in series with breaker 5T at the Southington 345 kV switchyard[22]	1.8
S4	Add a new control house at Southington 115 kV substation	22.6
Subtotal of Common Solution Components		**38.3**

Table 7-8: Rest of Greater Hartford Area Common Components Cost Estimates

ID	Solution Component	Cost ($M)
3	Loop the 1779 line between South Meadow and Bloomfield into the Rood Avenue substation and reconfigure the Rood Avenue substation	10.7
4	Reconfigure the Berlin 115 kV substation including the addition of two 115 kV breakers and the relocation of a capacitor bank	4.2
5	Add a 115 kV 25.2 MVAR capacitor at Westside 115 kV substation	2.9
6	Reconductor the 115 kV line between Newington and Newington Tap (1783) – 0.01 mile	1.0
7	Separation of 115 kV DCT corresponding to the Bloomfield to South Meadow (1779) line and the Bloomfield to North Bloomfield (1777) line and add a breaker at Bloomfield 115 kV substation	7.1
8	Install a 115 kV 3% reactor on the underground cable between South Meadow and Southwest Hartford(1704)	3.6
9	Separation of 115 kV DCT corresponding to the Bloomfield to North Bloomfield (1777) line and the North Bloomfield – Rood Avenue – Northwest Hartford (1751) line and add a breaker at North Bloomfield 115 kV substation	20.1
Subtotal of Common Solution Components		**49.6**

[22] With the doubling of the 5T breaker and the addition of a 3% series reactor between the two 115 kV Southington ring buses, the automatic control scheme associated with the 5T breaker at Southington will no longer be required.

Table 7-9: Rest of Greater Hartford Alternative Solution Components Cost Estimates

ID	Solution Component	Cost ($M)	Included in Underground Line Alternative	Included in Overhead Line Alternative
1	Add a new 4 mile 115 kV underground cable from Newington to Southwest Hartford and associated terminal equipment including a 2% series reactor	91.0	**Y**	
2	Add a new 11.67 mile 115 kV line from North Bloomfield to Farmington and associated terminal equipment	77.0		**Y**
10	Terminal upgrades on the 115 kV line between South Meadow and Rocky Hill	0.6		**Y**
11	Upgrade the 115 kV line between Farmington and Newington Tap (1783) – 3.61 miles	9.5		**Y**
Solution Alternative Totals			**91.0**	**87.1**

7.3 Comparison of Alternative Solutions

Table 7-10 below shows the total cost estimates for each alternative in each GHCC study subarea.

Table 7-10: Summary of GHCC Solution Alternatives Total Cost Estimates

Subarea	Solution Alternative	Common Components Cost Estimate +50/-25% ($M)	Unique Components Cost Estimate +50/-25% ($M)	Total Cost Estimate +50/-25% ($M)
Manchester / Barbour Hill	Alternative A	2.1	44.7	**46.8**
	Alternative B	2.1	47.3	**49.4**
Northwestern Connecticut	Alternative A	12.1	51.0	**63.1**
	Alternative B	12.1	73.9	**86.0**
Middletown	2nd Haddam Auto	10.3	52.9	**63.2**
	Scovill Rock Auto	10.3	79.9	**90.2**
Greater Hartford (including Southington)	Underground Line (Newington – SW Hartford)	87.9	91.0	**178.9**
	Overhead Line (N Bloomfield – Farmington)	87.9	87.1	**175.0**

When evaluating between the two alternatives for each subarea, they contain several common components. To differentiate between the two, only the projects that are not common in each alternative will be evaluated against the remaining key factors. All alternatives are expected to be constructible.

7.4 Comparison Matrix of Alternative Solutions

The primary factor in selecting the preferred solution was cost. Other factors included permitting, constructability, operational performance, and expected in-service date. Table 7-11 shows a comparison matrix for the two alternative solutions for the Manchester / Barbour Hill subarea.

Table 7-11: Comparison Matrix of Manchester / Barbour Hill Alternative Solutions

Key Factors	Alternative A (Barbour Hill Auto)	Alternative B (Manchester – Barbour Hill 115 kV Line)
Expected Ease of Permitting (e.g. environmental, siting, etc.)	✓	✗
Ease of Constructability (during construction phase)	✗	✓
Better System Performance – Thermal	✓	✓
Better System Performance – Voltage	✓	✗
Ease of Expandability	✓	✓
Expected In-Service Date	2017	2017
Estimated Cost for Unique Solution Components ($M with +50/-25% accuracy)	44.7 ✓	47.3 ✗

✗ - Is applied to the Alternative which does not achieve the objective as well as the other Alternative

✓ - Is applied to the Alternative which better achieves the objective

Alternative A was chosen as the preferred solution for this subarea for several reasons. Both solution alternatives resolved all thermal and voltage criteria violations in the 10-year planning horizon. However, Alternative A was chosen based on its slightly lower cost and better post-project voltage performance over Alternative B.

Table 7-12 shows a comparison matrix for the two alternative solutions for the Northwestern Connecticut subarea.

Table 7-12: Comparison Matrix of Northwestern Connecticut Alternative Solutions

Key Factors	Alternative A (Frost Bridge – Campville 115 kV Line)	Alternative B (North Bloomfield - Canton 115 kV Line)
Expected Ease of Permitting (e.g. environmental, siting, etc.)	✓	✓
Ease of Constructability (during construction phase)	✓	✓
Better System Performance – Thermal	✓	✓
Better System Performance – Voltage	✓	✗
Ease of Expandability	✓	✓
Expected In-Service Date	2017	2017
Estimated Cost for Unique Solution Components ($M with +50/-25% accuracy)	51.0 ✓	73.9 ✗

✗ - Is applied to the Alternative which does not achieve the objective as well as the other Alternative

✓ - Is applied to the Alternative which better achieves the objective

Alternative A was chosen as the preferred solution for this subarea for several reasons. Both solution alternatives resolved all thermal and voltage criteria violations in the 10-year planning horizon. However, Alternative A was chosen based on its substantially lower cost and better voltage performance. Alternative B required additional reactive support to be installed at the Campville in order to boost voltages in the area under certain conditions.

Table 7-13 shows a comparison matrix for the two alternative solutions for the Middletown subarea.

Table 7-13: Comparison Matrix of Middletown Alternative Solutions

Key Factors	2nd Haddam Autotransformer Alternative	Scovill Rock Autotransformer Alternative
Expected Ease of Permitting (e.g. environmental, siting, etc.)	✓	✗
Ease of Constructability (during construction phase)	✓	✗
Better System Performance – Thermal	✓	✓
Better System Performance – Voltage	✓	✓
Better System Performance – Re-Dispatch Requirements	✗	✓
Better System Performance – Western Connecticut Import Transfer Capability	✗	✓
Ease of Expandability	✓	✓
Expected In-Service Date	2017	2017
Estimated Cost for Unique Solution Components ($M with +50/-25% accuracy)	52.9 ✓	79.9 ✗

✗ - Is applied to the Alternative which does not achieve the objective as well as the other Alternative

✓ - Is applied to the Alternative which better achieves the objective

The Haddam Auto alternative was chosen as the preferred solution for this subarea. Both solution alternatives resolved all thermal and voltage criteria violations in the 10-year planning horizon. However, the Haddam Auto plan was chosen based on its substantially lower cost, In addition, the substation reconfiguration and expansion to accommodate an additional autotransformer at Haddam would not be as extensive as that required to place a new autotransformer at Scovill Rock.

Table 7-14 shows a comparison matrix for the two alternative solutions for the Greater Hartford subarea.

Table 7-14: Comparison Matrix of Greater Hartford Alternative Solutions

Key Factors	Newington – SW Hartford 115 kV Underground Line Alternative	North Bloomfield – Farmington 115 kV Overhead Line Alternative
Expected Ease of Permitting (e.g. environmental, siting, etc.)	✓	✘
Ease of Constructability (during construction phase)	✓	✘
Better System Performance – Thermal	✓	✓
Better System Performance – Voltage	✓	✓
Better System Performance – Re-Dispatch Requirements	✓	✘
Ease of Expandability	✓	✓
Expected In-Service Date	2017	2017
Estimated Cost for Unique Solution Components ($M with +50/-25% accuracy)	91.0 ✘	87.1 ✓

✘ - Is applied to the Alternative which does not achieve the objective as well as the other Alternative

✓ - Is applied to the Alternative which better achieves the objective

The Underground Line alternative was chosen as the preferred solution for this. While both solution alternatives resolved all thermal and voltage criteria violations in the 10-year planning horizon, the Newington-SW Hartford 115 kV alternative shows better performance for redispatch requirements for a little less than a $4 million estimated difference, making it the most cost effective overall solution.

7.5 Recommended Solution Alternative

Based on the key factors used to compare the solution alternatives, Alternative A for the Manchester / Barbour Hill subarea, Alternative A for the Northwestern Connecticut subarea, the second Haddam autotransformer alternative for the Middletown subarea, and the Newington – Southwest Hartford 115 kV underground line alternative for the Greater Hartford subarea are the preferred set of solution alternatives for the entire Greater Hartford and Central Connecticut study area. All of the solution alternatives resolve all thermal and voltage violations identified in the Needs Assessment.

Section 8
Conclusion

For each of the four study subareas, two alternatives were evaluated in the comparison of alternatives. The comparison of alternatives was based on the costs, system performance and other key factors like ease of permitting, constructability and expandability. The preferred solution to resolve the criteria violations found in the 10-year planning horizon is a combination of the Manchester/Barbour Hill Alternative A, Northwestern Connecticut Alternative A, the second Haddam autotransformer alternative for Middletown, and the Newington – Southwest Hartford 115 kV underground line for Greater Hartford.

8.1 Recommended Solution Description

8.1.1 Manchester / Barbour Hill Subarea

Alternative A for the Manchester / Barbour Hill subarea is comprised of several components as described in Table 8-1. A more detailed description of each component can be found in Section 5.3.1.

Table 8-1: Manchester / Barbour Hill Alternative A Solution Components

Component ID	Description
1	Add a new 345/115 kV autotransformer at Barbour Hill and associated terminal equipment
3	Reconductor the 115 kV line between Manchester and Barbour Hill (1763) – 7.6 miles
4	Add a 345 kV breaker in series with breaker 24T at the Manchester 345 kV switchyard

8.1.2 Northwestern Connecticut Subarea

Alternative A for the Northwestern Connecticut subarea is comprised of several components as described in Table 8-2. A more detailed description of each component can be found in Section 5.3.2.

Table 8-2: Northwestern Connecticut Alternative A Solution Components

Component ID	Description
1	Add a new 10.35 mile, 115 kV line from Frost Bridge to Campville and associated terminal equipment
3	Separation of 115 kV DCT corresponding to the Frost Bridge to Campville (1191) line and the Thomaston to Campville (1921) line and add a breaker at Campville 115 kV substation
4	Upgrade terminal equipment on the 115 kV line between Chippen Hill and Lake Avenue Junction (1810-3)
5	Reconductor the 115 kV line between Southington and Lake Avenue Junction (1810-1) – 5.2 miles

8.1.3 Middletown Subarea

The Haddam Auto alternative for the Middletown subarea is comprised of several components as described in Table 8-3. A more detailed description of each component can be found in Section 5.3.3.

Table 8-3: Middletown Area 2nd Haddam Autotransformer Alternative Solution Components

Component ID	Description
1	Add a 2nd 345/115 kV autotransformer at Haddam substation and reconfigure the 3-terminal 345 kV 348 line into 2 two-terminal lines
3	Terminal equipment upgrades on the 345 kV line between Haddam and Beseck (362)
4	Separation of 115 kV double circuit towers corresponding to the Branford – Branford RR line (1537) and the Branford to North Haven (1655) line and adding a series breaker at Branford 115 kV substation
5	Terminal Equipment upgrades on the Middletown to Dooley Line (1050)
6	Terminal Equipment upgrades on the Middletown to Portland Line (1443)
7	Redesign the Green Hill 115 kV substation from a straight bus to a ring bus and add a 37.8 MVAR capacitor bank
8	Add a 37.8 MVAR capacitor bank at Hopewell 115 kV substation
12	Separation of 115 kV double circuit towers corresponding to the Middletown – Pratt and Whitney line (1572) and the Middletown to Haddam (1620) line

8.1.4 Greater Hartford Subarea

The Newington – Southwest Hartford 115 kV underground line alternative is comprised of several components as described in Table 8-4. A more detailed description of each component can be found in Section 5.3.4.

Table 8-4: Greater Hartford Area Newington – Southwest Hartford Underground Line Alternative Solution Components

Component ID	Description
1	Add a new 4 mile 115 kV underground cable from Newington to Southwest Hartford and associated terminal equipment including a 2% series reactor
3	Loop the 1779 line between South Meadow and Bloomfield into the Rood Avenue substation and reconfigure the Rood Avenue substation
4	Reconfigure the Berlin 115 kV substation including the addition of two 115 kV breakers and the relocation of a capacitor bank
5	Add a 115 kV 25.2 MVAR capacitor at Westside 115 kV substation
6	Reconductor the 115 kV line between Newington and Newington Tap (1783) – 0.01 miles
7	Separation of 115 kV DCT corresponding to the Bloomfield to South Meadow (1779) line and the Bloomfield to North Bloomfield (1777) line and add a breaker at Bloomfield 115 kV substation
8	Install a 115 kV 3% reactor on the underground cable between South Meadow and Southwest Hartford(1704)
9	Separation of 115 kV DCT corresponding to the Bloomfield to North Bloomfield (1777) line and the North Bloomfield – Rood Avenue – Northwest Hartford (1751) line and add a breaker at North Bloomfield 115 kV substation
S1	Replace the existing 3% series reactors on the 115 kV lines between Southington and Todd (1910) and between Southington and Canal (1950) with 5% series reactors
S2	Replace the normally open 19T breaker at Southington with a 3% series reactor between Southington Ring 1 and Southington Ring 2 and associated substation upgrades
S3	Add a breaker in series with breaker 5T at the Southington 345 kV switchyard
S4	Add a new control house at Southington 115 kV substation

Table 8-5 summarizes all of the cost estimates for the preferred set of solutions for the GHCC study area.

Table 8-5: Preferred Solution Total Cost Estimates

Subarea	Preferred Solution Set	Cost Estimate +50/-25% ($M)
Manchester / Barbour Hill	Alternative A	46.8
Northwestern Connecticut	Alternative A	63.1
Middletown	Haddam Auto	63.2
Greater Hartford	Underground Line	178.9
Total Cost Estimate for All Preferred Solutions		**352.0**

8.2 Solution Component Year of Need

The Needs Assessment states the majority of violations occur in today's system or earlier. Currently operations postures the system by generation re-dispatch and other system adjustments to prevent violations. The projected in-service date of all solution components is by the end of 2017.

8.3 Schedule for Implementation, Lead Times and Documentation of Continuing Need

In accordance with NERC TPL Standards, this assessment provides:

- A written summary of plans to address the system performance issues described in the *Greater Hartford and Central Connecticut (GHCC) Area Transmission 2022 Needs Assessment*, dated May 2014
- A schedule for implementation as described below
- A discussion of expected required in-service dates of facilities and associated load level when required as described below
- A discussion of lead times necessary to implement plans, described below

The planned completion date of the preferred combined solution as described in Section 8.1 above is 2017. With this schedule the preferred combined solution will be in service after potential violations of the NERC Standard Requirements occur. Currently, System Operations postures the system by generation re-dispatch and other system adjustments to prevent these violations. The longest lead time items required to complete the project are large power transformers with a projected lead time of one year. This study has reviewed the continuing need and has identified a recommended solution.

Section 9
Appendix A: Load Forecast

Table 9-1:
2013 CELT Seasonal Peak Load Forecast Distributions

		Peak Load Forecast at Milder Than Expected Weather				Reference Forecast at Expected Weather	Peak Load Forecast at More Extreme Than Expected Weather				
Summer (MW)	2013	26470	26715	27045	27420	27840	28285	28735	29385	30135	30790
	2014	26900	27150	27485	27865	28290	28740	29200	29860	30620	31280
	2015	27410	27665	28005	28390	28825	29285	29750	30425	31185	31860
	2016	27910	28165	28515	28910	29350	29815	30295	30980	31740	32420
	2017	28325	28590	28940	29340	29790	30265	30750	31445	32210	32900
	2018	28675	28940	29295	29700	30155	30635	31125	31830	32615	33315
	2019	29025	29295	29655	30065	30525	31010	31505	32220	33010	33720
	2020	29345	29615	29980	30395	30860	31350	31855	32575	33380	34095
	2021	29670	29950	30315	30735	31205	31700	32210	32935	33755	34480
	2022	29970	30250	30625	31045	31520	32020	32535	33270	34105	34840
WTHI (1)		78.49	78.73	79.00	79.39	79.88	80.30	80.72	81.14	81.96	82.33
Dry-Bulb Temperature (2)		88.50	88.90	89.20	89.90	90.20	91.20	92.20	92.90	94.20	95.40
Probability of Forecast Being Exceeded		90%	80%	70%	60%	50%	40%	30%	20%	10%	5%
Winter (MW)	2013/14	22025	22140	22235	22295	22445	22595	22765	22865	23080	23505
	2014/15	22205	22320	22420	22480	22630	22780	22955	23055	23255	23685
	2015/16	22385	22500	22595	22660	22810	22960	23135	23235	23440	23870
	2016/17	22540	22660	22755	22815	22970	23125	23295	23400	23620	24050
	2017/18	22680	22795	22895	22955	23110	23265	23440	23540	23780	24205
	2018/19	22800	22920	23020	23080	23235	23390	23565	23670	23920	24345
	2019/20	22915	23035	23130	23195	23350	23505	23685	23785	24045	24470
	2020/21	23030	23150	23250	23315	23470	23625	23805	23910	24160	24590
	2021/22	23145	23265	23365	23425	23585	23745	23920	24025	24280	24705
	2022/23	23255	23380	23480	23540	23700	23860	24040	24145	24395	24820
Dry-Bulb Temperature (3)		10.72	9.66	8.84	8.30	7.03	5.77	4.40	3.58	1.61	(1.15)

FOOTNOTES:

(1) WTHI - a three-day weighted temperature-humidity index for eight New England weather stations. It is the weather variable used in producing the summer peak load forecast. For more information on the weather variables see http://www.iso-ne.com/trans/celt/fsct_detail/.

(2) Dry-bulb temperature (in degrees Fahrenheit) shown in the summer season is for informational purposes only.

(3) Dry-bulb temperature (in degrees Fahrenheit) shown in the winter season is a weighted value from eight New England weather stations.

Table 9-2: 2022 Detailed Load Distributions by State and Company

ISO New England Basecase DB - Load File Report by Company

Study Date : 08/15/2022 **Study Name :** GHCC Revised

File Created : 2014-01-22 **CELT Forecast :** 2013 **Forecast Year :** 2022

Season : Summer Peak **Weather :** 90/10 **Load Distribution :** N+10_SUM

ISO-NE CELT : 34105 MW **% of Peak :** 100.000% **Tx Losses :** 2.50%

State CELT L&L		2.50% Tx Losses		Non-CELT Load		Station Service		Area 104 NE Load		Area 101 Load
34105 MW	-	852.6 MW	+	364.4 MW	+	0.0 MW	-	42.8 MW	=	33574.3 MW

1: State CELT L&L: This represents the sum of the 6 State CELT forecasts. This number can sometimes be 5-10 MW different than the ISO-NE CELT forecast number due to round-off error.
2: Non-CELT Load: This is the sum of all load modeled in the case that is not included in the CELT forecast. An example is the "behind the meter" paper mill load in Maine.
3: Station Service: This is the amount of generator station service modeled. If station service is off-line, the Area 101 report totals will be different since off-line load is not counted in totals.
4: Area 104 NE Load: This load is load modeled in northern VT that is electrically served from Hydro Quebec. To make Area Interchange load independent, this load is assigned Area 104.

Maine **State Load = 2450 MW - 2.50% Tx Losses = 2388.75 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CMP	85.42%	2040.39	655.06	0.952	332.06
BHE	14.59%	348.42	133.15	0.934	17.81

New Hampshire **State Load = 3150 MW - 2.50% Tx Losses = 3071.25 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
PSNH	78.73%	2418.00	344.54	0.990	
UNITIL	12.13%	372.58	53.09	0.990	
GSE	9.14%	280.68	6.42	1.000	1.85

Vermont **State Load = 1220 MW - 2.50% Tx Losses = 1189.5 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
VELCO	100.00%	1189.57	200.18	0.986	95.79

Massachusetts **State Load = 16055 MW - 2.50% Tx Losses = 15653.625 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
BECO	28.31%	4431.86	1146.57	0.968	37.79
COMEL	11.63%	1820.19	368.90	0.980	
MA-NGRID	39.34%	6157.37	355.79	0.998	38.49
WMECO	6.34%	992.13	141.36	0.990	
MUNI:BOST-NGR	3.40%	532.23	93.80	0.985	
MUNI:BOST-NST	1.21%	189.87	29.00	0.989	
MUNI:CNEMA-NGR	2.10%	328.38	33.68	0.995	
MUNI:RI-NGR	0.88%	137.44	16.67	0.993	
MUNI:SEMA-NGR	1.86%	290.39	30.91	0.994	
MUNI:SEMA-NST	1.74%	272.37	50.29	0.983	
MUNI:WMA-NGR	1.01%	157.79	15.67	0.995	
MUNI:WMA-NU	2.20%	343.77	48.98	0.990	

Rhode Island **State Load = 2405 MW - 2.50% Tx Losses = 2344.875 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
RI-NGRID	100.00%	2344.90	229.64	0.995	45.44

Connecticut **State Load = 8825 MW - 2.50% Tx Losses = 8604.375 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CLP	76.26%	6561.83	935.10	0.990	82.50
CMEEC	4.71%	405.62	57.80	0.990	
UI	19.02%	1636.87	163.66	0.995	10.00

Table 9-3: Detailed Demand Response Distributions by Zone

ISO New England Basecase DB - Demand Resources File Report

Study Date : 08/15/2022 **Study Name :** GHCC Revised
File Created : 2014-01-22 **CCP :** 2016/2017 **Load Season :** 2022 - Summer Peak
Load Distrb : N+10_SUM **Distrb Losses :** 5.50% **DR Season :** SUM

	Demand Reduction Value (DRV)	X	Load Dependent Capability Assumption (LDCA)	X	Performance Assumption (PA)	+	Distribution Losses Gross-Up	-	Area 104 DR	=	Area 101 DR
Passive :	1670.15 MW		100.00%		100.00%		91.86 MW		4.77 MW		1757.05 MW
Forecast EE :	1038.85 MW		100.00%		100.00%		57.14 MW		3.37 MW		1092.68 MW
Active :	1171.84 MW		100.00%		75.00%		48.34 MW		1.72 MW		925.35 MW

Demand Reduction Value (DRV): Amount of DR measured at the customer meter without any gross-up values for transmission or distribution losses.
Load Dependent Capability Assumption (LDCA): De-rate factor applied based on % of CELT load. (i.e. Light load is 45% of 50/50 load, so the LDCA would be 45%.)
Performance Assumption (PA): De-rate factor applied based on expected performance of DR after a dispatch signal from Operations.
Area 104 DR: This load is modeled in northern VT and is electrically served from Hydro Quebec. To make Area Interchange load independent, this load is assigned Area 104.

Passive Demand Resources - (On-Peak and Seasonal Peak)

DR Modeled = (DRV_SUM * 100.00% LDCA * 100.00% PA) + 5.50% Distrb Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_P_ME	20	Load Zone - Maine	158.72	-167.44	-60.62
DR_P_NH	21	Load Zone - New Hampshire	79.75	-84.16	-11.66
DR_P_VT	22	Load Zone - Vermont	125.44	-132.24	-22.07
DR_P_NEMABOS	23	Load Zone - Northeast Massachusetts & Boston	341.18	-359.90	-79.19
DR_P_SEMA	24	Load Zone - Southeast Massachusetts	193.94	-204.59	-20.15
DR_P_WCMA	25	Load Zone - West Central Massachusetts	244.71	-258.17	-21.99
DR_P_RI	26	Load Zone - Rhode Island	141.90	-149.65	-14.66
DR_P_CT	27	Load Zone - Connecticut	384.51	-405.67	-54.52

Forecasted Energy Efficiency

DR Modeled = (DRV_EE * 100.00% LDCA * 100.00% PA) + 5.50% Distrb Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_P_ME	20	Load Zone - Maine	56.48	-59.57	-21.50
DR_P_NH	21	Load Zone - New Hampshire	52.78	-55.67	-7.69
DR_P_VT	22	Load Zone - Vermont	88.88	-93.88	-15.70
DR_P_NEMABOS	23	Load Zone - Northeast Massachusetts & Boston	276.34	-291.52	-64.14
DR_P_SEMA	24	Load Zone - Southeast Massachusetts	146.98	-155.05	-15.30
DR_P_WCMA	25	Load Zone - West Central Massachusetts	164.62	-173.68	-14.80
DR_P_RI	26	Load Zone - Rhode Island	113.89	-120.16	-11.81
DR_P_CT	27	Load Zone - Connecticut	138.88	-146.52	-19.68

Active Demand Resources - (Real-Time Demand Resource (RTDR), Excludes RTEG)

DR Modeled = (DRV_SUM * 100.00% LDCA * 75.00% PA) + 5.50% Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_A_ME_BHE	30	Dispatch Zone - ME - Bangor Hydro	56.40	-44.63	-23.28
DR_A_ME_MAIN	31	Dispatch Zone - ME - Maine	206.61	-163.53	-55.36
DR_A_ME_PORT	32	Dispatch Zone - ME - Portland Maine	31.49	-24.89	-8.12
DR_A_NH_NEWH	33	Dispatch Zone - NH - New Hampshire	48.62	-38.46	-5.28
DR_A_NH_SEAC	34	Dispatch Zone - NH - Seacoast	12.10	-9.58	-1.36
DR_A_VT_NWVT	35	Dispatch Zone - VT - Northwest Vermont	38.46	-30.40	-4.93
DR_A_VT_VERM	36	Dispatch Zone - VT - Vermont	24.83	-19.64	-3.51
DR_A_MA_BOST	37	Dispatch Zone - MA - Boston	81.06	-64.09	-16.39
DR_A_MA_NSHR	38	Dispatch Zone - MA - North Shore	35.48	-28.06	-3.39
DR_A_MA_CMA	39	Dispatch Zone - MA - Central Massachusetts	51.46	-40.67	-2.04
DR_A_MA_SPFD	40	Dispatch Zone - MA - Springfield	32.76	-25.91	-3.69
DR_A_MA_WMA	41	Dispatch Zone - MA - Western Massachusetts	78.27	-61.92	-5.86
DR_A_MA_LSM	42	Dispatch Zone - MA - Lower Southeast Massachusetts	20.01	-15.85	-2.60
DR_A_MA_SEMA	43	Dispatch Zone - MA - Southeast Massachusetts	121.48	-96.13	-6.76
DR_A_RI_RHOD	44	Dispatch Zone - RI - Rhode Island	73.75	-58.38	-5.69
DR_A_CT_EAST	45	Dispatch Zone - CT - Eastern Connecticut	36.55	-28.90	-4.12
DR_A_CT_NRTH	46	Dispatch Zone - CT - Northern Connecticut	84.10	-66.53	-9.48
DR_A_CT_NRST	47	Dispatch Zone - CT - Norwalk-Stamford	34.23	-27.08	-3.70
DR_A_CT_WEST	48	Dispatch Zone - CT - Western Connecticut	104.18	-82.42	-10.71

Section 10
Appendix B: Case Summaries and Load Flow Plots

Quick links to case summaries for each of the dispatches described in Table 3-6 and Table 3-7 are provided below. Each file contains all of the case summaries for the portion of the study area noted in the title. Proposed solution alternatives were added to these to create the post-project cases for analysis.

Appendix B1: Barbour Hill Subarea Dispatches

Appendix B2: CCRP Dispatches

Appendix B3: Greater Hartford Subarea Dispatches

Appendix B4: IRP Dispatches

Appendix B5: Middletown Subarea Dispatches

Appendix B6: Northwestern Connecticut Subarea Dispatches

Section 11
Appendix C: Element-Out Scenarios for N-1-1 Analysis

Table 11-1: N-1-1 First Element-Out Scenarios

Line/ Autotransformer	Station A	Station B	Station C
Underground cables			
1704	South Meadow 115 kV	Southwest Hartford 115 kV	
1722	Southwest Hartford 115 kV	CDEC 115 kV	Northwest Hartford 115 kV
115 kV Line (Future)	Newington 115 kV	Southwest Hartford 115 kV	
Overhead 345 kV lines			
310	Manchester 345 kV	Millstone 345 kV	
329	Frost Bridge 345 kV	Southington 345 kV	
330	Card 345 kV	Lake Road 345 kV	
347	Killingly 345 kV	Sherman Road 345 kV	
348E (Future)	Millstone 345 kV	Haddam 345 kV	
348W (Future)	Haddam 345 kV	Beseck 345 kV	
352	Frost Bridge 345 kV	Long Mountain 345 kV	
352 (w/ Element Restored)[23]	Frost Bridge 345 kV	Long Mountain 345 kV	
362	Beseck 345 kV	Haddam Neck 345 kV	
364	Montville 345 kV	Haddam Neck 345 kV	
368	Manchester 345 kV	Card 345 kV	
371	Millstone 345 kV	Montville 345 kV	
376	Scovill Rock 345 kV	Haddam Neck 345 kV	
383	Millstone 345 kV	Card 345 kV	
3041	Southington 345 kV	Scovill Rock 345 kV	
3196	Agawam 345 kV	Ludlow 345 kV	
3216	North Bloomfield 345 kV	Agawam 345 kV	
3271	Lake Road 345 kV	Card 345 kV	
3348	Killingly 345 kV	Lake Road 345 kV	
3419	Barbour Hill 345 kV	Ludlow 345 kV	
3424	Manchester 345 kV	Kleen Energy 345 kV	
3557	Barbour Hill 345 kV	Manchester 345 kV	
3642	North Bloomfield 345 kV	Manchester 345 kV	
3827	Beseck 345 kV	East Devon 345 kV	

[23] In some cases, the initial element-out scenario also disconnects another element connected to the same breaker position. In some cases the restoration of this additional element in the 30 minutes prior to the next contingency can have an impact on the results. For these conditions, two different initial line-out scenarios were analyzed, one in which the additional element remains offline and one in which the element is restored before the second contingency.

Line/ Autotransformer	Station A	Station B	Station C
Overhead 115 kV lines			
1042	North Bloomfield 115 kV	Northeast Simsbury 115 kV	
1042 (w/ Element Restored)	North Bloomfield 115 kV	Northeast Simsbury 115 kV	
1050	Middletown 115 kV	Dooley 115 kV	
1100	Enfield 115 kV	Barbour Hill 115 kV	
1191	Frost Bridge 115 kV	Campville 115 kV	
1200	Windsor Locks 115 kV	Barbour Hill 115 kV	
1207	Manchester 115 kV	East Hartford 115 kV	
1208	Southington 115 kV	Wallingford 115 kV	
1256	Canton 115 kV	Northeast Simsbury 115 kV	
1261	Haddam 115 kV	Bokum 115 kV	
1300	Windsor Locks 115 kV	Enfield 115 kV	
1310	Manchester 115 kV	East Windsor 115 kV	
1342	Bokum 115 kV	Green Hill 115 kV	
1355	Southington 115 kV	Hanover 115 kV	Colony 115 kV
1443	Portland 115 kV	Middletown 115 kV	
1448	Manchester 115 kV	Rood Avenue 115 kV	
1448 (w/ Element Restored)	Manchester 115 kV	Rood Avenue 115 kV	
1460	East Shore 115 kV	Branford RR 115 kV	
1466	North Wallingford 115 kV	East Meriden 115 kV	
1508	Stepstone 115 kV	Green Hill 115 kV	
1508(w/ Element Restored)	Stepstone 115 kV	Green Hill 115 kV	
1537	Branford 115 kV	Branford RR 115 kV	
1572_1772	Middletown 115 kV	P&W Aircraft 115 kV	Haddam 115 kV
1588	North Wallingford 115 kV	Colony 115 kV	
1598	Haddam 115 kV	Bokum 115 kV	
1606	Barbour Hill 115 kV	Rockville 115 kV	
1610			
1620	Haddam 115 kV	Middletown 115 kV	
1635	Barbour Hill 345 kV	South Windsor 115 kV	
1655	North Haven 115 kV	Branford 115 kV	
1670	Berlin 115 kV	Southington 115 kV	Black Rock 115 kV
1690	Southington 115 kV	Hanover 115 kV	
1724	Barbour Hill 115 kV	Rockville 115 kV	
1726	Farmington 115 kV	North Bloomfield 115 kV	
1732	Franklin Drive 115 kV	Campville 115 kV	Canton 115 kV
1738	Stepstone 115 kV	Branford 115 kV	
1751	North Bloomfield 115 kV	Rood Avenue 115 kV	Northwest

Line/ Autotransformer	Station A	Station B	Station C
			Hartford 115 kV
1752	Berlin 115 kV	Rocky Hill 115 kV	
1756	Bloomfield 115 kV	Northwest Hartford 115 kV	
1759	Hopewell 115 kV	Portland 115 kV	
1763	Manchester 115 kV	Barbour Hill 115 kV	
1765	Berlin 115 kV	West Side 115 kV	
1766	Dooley 115 kV	West Side 115 kV	
1767	Manchester 115 kV	Hopewell 115 kV	
1769	Berlin 115 kV	East New Britain 115 kV	
1771	Berlin 115 kV	Southington 115 kV	
1773	Rocky Hill 115 kV	South Meadow 115 kV	
1775	South Meadow 115 kV	Riverside Drive 115 kV	Manchester 115 kV
1777	Bloomfield 115 kV	North Bloomfield 115 kV	
1783	East New Britain 115 kV	Newington 115 kV	Farmington 115 kV
1785	Berlin 115 kV	Newington 115 kV	
1786	South Meadow 115 kV	East Hartford 115 kV	Riverside Drive 115 kV
1788	Torrington Terminal 115 kV	Franklin Drive 115 kV	
1788 (w/ Element Restored)	Torrington Terminal 115 kV	Franklin Drive 115 kV	
1800	Southington 115 kV	Forestville 115 kV	
1810	Southington 115 kV	Bristol 115 kV	Chippen Hill 115 kV
1820	Southington 115 kV	Black Rock 115 kV	
1825	Bristol 115 kV	Forestville 115 kV	
1830	Southington 115 kV	Black Rock 115 kV	
1835	Thomaston 115 kV	Chippen Hill 115 kV	
1900	Torrington Terminal 115 kV	Campville 115 kV	
1900 (w/ Element Restored)	Torrington Terminal 115 kV	Campville 115 kV	
1921	Campville 115 kV	Thomaston 115 kV	
1975	Haddam 115 kV	East Meriden 115 kV	
1779-1 (Future)	Rood Avenue 115 kV	Bloomfield 115 kV	
1779-2 (Future)	South Meadow 115 kV	Rood Avenue 115 kV	
115 kV Line (Future)	Frost Bridge 115 kV	Campville 115 kV	
Overhead 69 kV Lines			
667_689	Salisbury 69 kV	Falls Village 69 kV	Torrington Terminal 69 kV
690	Salisbury 69 kV	Smithfield 69 kV	
693_694	Torrington Terminal 69 kV	Falls Village 69 kV	North Canaan 69 kV
Autotransformers			

Line/ Autotransformer	Station A	Station B	Station C
Barbour Hill 1X	Barbour Hill 345 kV	Barbour Hill 115 kV	
Barbour Hill 2X (Future)	Barbour Hill 345 kV	Barbour Hill 115 kV	
Frost Bridge 1X	Frost Bridge 345 kV	Frost Bridge 115 kV	
Frost Bridge 1X(w/ Element Restored)	Frost Bridge 345 kV	Frost Bridge 115 kV	
Haddam 5X (Future)	Haddam 345 kV	Haddam 115 kV	
Haddam 6X	Haddam 345 kV	Haddam 115 kV	
North Bloomfield 5X	North Bloomfield 345 kV	North Bloomfield 115 kV	
North Bloomfield 7X	North Bloomfield 345 kV	North Bloomfield 115 kV	
Manchester 4X	Manchester 345 kV	Manchester 115 kV	
Manchester 5X	Manchester 345 kV	Manchester 115 kV	
Manchester 6X	Manchester 345 kV	Manchester 115 kV	
Southington 1X	Southington 345 kV	Southington115 kV	
Southington 2X	Southington 345 kV	Southington115 kV	
Southington 3X	Southington 345 kV	Southington115 kV	
Southington 4X	Southington 345 kV	Southington115 kV	
Generators			
Bridgeport Energy	Bridgeport Energy 115 kV		
Bridgeport Harbor 3	Pequonnock 115 kV		
Middletown 4	Middletown 345kV		
New Haven Harbor	New Haven 115 kV		
South Meadow 6	South Meadow 115 kV		
Capitol District	CDECCA 115 kV		

Section 12
Appendix D: Contingency Listings

12.1 GHCC Area NERC Category B Contingencies

Generator Contingencies = 91 Total				
GN_11_10BE	GN_DEXT_2	GN_LRD1	GN_MON6	GN_SOM6
GN_12_10BE	GN_DV10	GN_LRD2	GN_NHHB	GN_STEV
GN_AETN_CC	GN_DV11	GN_LRD3	GN_NORWICH	GN_THAM
GN_ALP	GN_DV12	GN_MFD1	GN_NRW1	GN_TORR
GN_ANSONIA	GN_DV13	GN_MFD2	GN_NRW2	GN_TUNN
GN_BHR2	GN_DV14	GN_MI12	GN_NRW3	GN_UCONN_CC
GN_BHR3	GN_DV15	GN_MI13	GN_PLAINFLD	GN_WAL1
GN_BHR4	GN_DV16	GN_MI14	GN_QP248_2	GN_WAL2
GN_BPTR	GN_DV17	GN_MI15	GN_QP248_3	GN_WAL3
GN_BRAN	GN_DV18	GN_MIDLTWN10	GN_QP248_4	GN_WAL4
GN_BRF	GN_EXTR	GN_MIDLTWN2	GN_ROCK	GN_WAL5
GN_BULL	GN_FALS	GN_MIDLTWN3	GN_SECR	GN_WBRY
GN_CC10	GN_FOXWOOD_1	GN_MIDLTWN4	GN_SHEP	GN_WLRC
GN_CC11	GN_FOXWOOD_2	GN_MIL2	GN_SO11	GN_WTSD_1
GN_CC12	GN_FRDR	GN_MIL3	GN_SO12	GN_WTSD_2
GN_CC13	GN_KIMB_CC	GN_MO10	GN_SO13	GN_WTSD_3
GN_CC14	GN_KLEEN_CC	GN_MO11	GN_SO14	GN_YALE_DG_1
GN_DERB	GN_LISB	GN_MON5	GN_SOM5	GN_YALE_DG_2
GN_DEXT_1				

Line Contingencies = 275 Total				
LN_100	LN_1515S	LN_1751	LN_314	LN_364
LN_1000	LN_1522	LN_1752	LN_315	LN_3642
LN_1042	LN_1537	LN_1753	LN_316	LN_366
LN_1050	LN_1545	LN_1756	LN_3161	LN_368
LN_1070	LN_1550_1950	LN_1759	LN_3165	LN_370
LN_1080	LN_1555	LN_1760_1876	LN_3196	LN_371
LN_1090	LN_1560N	LN_1763	LN_321	LN_3754
LN_1100	LN_1560S	LN_1765	LN_3216	LN_376
LN_1120	LN_1565	LN_1766	LN_322	LN_381
LN_1130	LN_1570	LN_1767	LN_323	LN_3827
LN_1163	LN_1572_1772	LN_1769	LN_325	LN_383
LN_1165	LN_1575	LN_1770	LN_326	LN_384
LN_1191	LN_1580	LN_1771	LN_327	LN_387
LN_1200	LN_1585	LN_1773	LN_3271	LN_389
LN_1207	LN_1588	LN_1775	LN_328	LN_3921
LN_1208	LN_1594	LN_1776	LN_3280	LN_398
LN_1210	LN_1598	LN_1777	LN_329	LN_399
LN_1220	LN_1605	LN_1780	LN_330	LN_400

LN_1222	LN_1606	LN_1783	LN_331	LN_500
LN_1235	LN_1607	LN_1785	LN_332	LN_601
LN_1238_1813	LN_1610	LN_1786	LN_3320	LN_602
LN_1250	LN_1617	LN_1788	LN_3321	LN_603
LN_1256	LN_1618	LN_1790	LN_333	LN_667_689
LN_1261	LN_1620	LN_1792	LN_334	LN_690
LN_1270	LN_1621	LN_1800	LN_3340	LN_693_694
LN_1272	LN_1622	LN_1810	LN_3348	LN_800
LN_1280	LN_1630	LN_1820	LN_335	LN_8100
LN_1300	LN_1635	LN_1825	LN_336	LN_8200
LN_1310	LN_1637	LN_1830	LN_3361	LN_8300
LN_1319	LN_1640	LN_1835	LN_3381	LN_8301
LN_1337	LN_1650	LN_1840	LN_340	LN_8400
LN_1342	LN_1655	LN_1843	LN_3403	LN_84004
LN_1350	LN_1668	LN_1867	LN_341	LN_8500
LN_1355	LN_1670	LN_1870S	LN_3419	LN_8600
LN_1363	LN_1675	LN_1880	LN_342	LN_8700
LN_1365	LN_1682	LN_1887	LN_3424	LN_8702
LN_1389	LN_1685	LN_1890	LN_343	LN_88003A
LN_1394	LN_1690	LN_1900	LN_344	LN_88003A_UG
LN_1410	LN_1697	LN_1910	LN_347	LN_88005A
LN_1416	LN_1704	LN_1921	LN_350	LN_88006A
LN_1430	LN_1710	LN_1943	LN_3512	LN_8804A
LN_1440	LN_1710_LS	LN_1955	LN_352	LN_8809A
LN_1443	LN_1714	LN_1975	LN_3520	LN_89003B
LN_1445	LN_1720	LN_1977	LN_3521	LN_89003B_UG
LN_1448	LN_1721	LN_1985	LN_3533	LN_89005B
LN_1450	LN_1722	LN_1990	LN_354	LN_89006B
LN_1460	LN_1724	LN_301_302	LN_355	LN_8904B
LN_1465	LN_1726	LN_303	LN_3557	LN_8909B
LN_1466	LN_1730	LN_3041	LN_356	LN_900
LN_1470	LN_1732	LN_308	LN_357	LN_91001
LN_1490	LN_1734	LN_310	LN_359	LN_9500
LN_1497	LN_1738	LN_312_393	LN_3619	LN_9502
LN_1500	LN_1740	LN_313	LN_362	LN_R118
LN_1505	LN_1742	LN_FB_CMPVL	LN_ROOD_BLMF	LN_NEWN_SWHFD
LN_1508	LN_1750	LN_348E	LN_348W	LN_SMEAD_ROOD

Transformer Contingencies = 164 Total				
TF_AETN_GSU	TF_CARD_9X	TF_KLG2_GSU	TF_NORHAR_1X	TF_SNGTN_3X
TF_AGAWAM_1X	TF_CARP_HL_1	TF_KLST_GSU	TF_NORHAR_2X	TF_SNGTN_4X
TF_AGAWAM_2X	TF_COOL_K36X	TF_LISBON_GS	TF_NORHAR_8X	TF_SO11_SO12
TF_ALP_GSU	TF_COSCOB_GS	TF_LRD1_GSU	TF_NORWICH	TF_SO13_SO14
TF_ANSONIA	TF_CRVR_345A	TF_LRD2_GSU	TF_NRWLK_2/6	TF_SOM5_GSU
TF_AUBR_210X	TF_CRVR_345B	TF_LRD3_GSU	TF_NRWLK_8X	TF_SOM6_GSU
TF_AUBR_220X	TF_DEVON_10X	TF_LUDLOW_1X	TF_NRWLK_9X	TF_STEV_GSU
TF_BARBHL_1X	TF_DEVON_11X	TF_LUDLOW_3X	TF_NTHFLD_1X	TF_STNYB_10X
TF_BEL1_GSU	TF_DEVON_12X	TF_M1213_GSU	TF_NTHFLD_3X	TF_THAMS_GSU
TF_BEL2_GSU	TF_DEVON_13X	TF_M1415_GSU	TF_NWHV_T1	TF_TORR_10X
TF_BERRY_1X	TF_DEVON_14X	TF_MANCH_4X	TF_NWHV_T2	TF_TORR_1X
TF_BHR2_GSU	TF_DEVON_15X	TF_MANCH_5X	TF_OSG1_GSU	TF_TUNNEL_1X
TF_BHR3_GSU	TF_DEVON_17X	TF_MANCH_6X	TF_OSG2_GSU	TF_VERNON
TF_BHR4_GSU	TF_DEXT_GSU	TF_MFD12_GSU	TF_OSG3_GSU	TF_VTYA_4X
TF_BKS1_GSU	TF_EDEVON_2X	TF_MI10_GSU	TF_OSG4_GSU	TF_VTYA_GSU
TF_BKS2_GSU	TF_ES_8X_CSC	TF_MID2_GSU	TF_OST1_GSU	TF_WACHUS_T5
TF_BPTR_GSU	TF_ES_9X_CSC	TF_MID3_GSU	TF_OST2_GSU	TF_WACHUS_T6
TF_BRA4_GSU	TF_ESHORE_1X	TF_MID4_GSU	TF_PILG_GSU	TF_WACHUS_T7
TF_BRAY_3XAB	TF_ESHORE_8X	TF_MILSTN_2X	TF_PLNFD_GSU	TF_WAL12_GSU
TF_BRAY_5X	TF_ESHORE_9X	TF_MILSTN_3X	TF_PLUMTR_1X	TF_WAL345GSU
TF_BRPTE_10X	TF_EXTR_GSU	TF_MO10_GSU	TF_PLUMTR_2X	TF_WALTHM_2A
TF_BRPTE_11X	TF_FLSVL_GSU	TF_MON5_GSU	TF_QP248_GSU	TF_WAMSBY_T2
TF_BRPTE_12X	TF_FRSTB_1X	TF_MON6_GSU	TF_SACKET_PS	TF_WBRY_GSU
TF_BWTR_161X	TF_FRSTVL_2X	TF_MONT_16X	TF_SECREC_GS	TF_WFAR_174T
TF_BWTR_162X	TF_GLNBRK_4X	TF_MONTV_18X	TF_SERVRD_T1	TF_WFAR_175T
TF_CAN1_GSU	TF_GLNBRK_5X	TF_NBLOOM_5X	TF_SHEPAUG	TF_WLRC_GSU
TF_CAN2_GSU	TF_HADDAM_6X	TF_NBLOOM_7X	TF_SINGER_1X	TF_WMED_345A
TF_CANL_120X	TF_HOLB_345A	TF_NEA1_GSU	TF_SINGER_2X	TF_WMED_345B
TF_CANL_121X	TF_KENTCT_3X	TF_NEA2_GSU	TF_SNDYPD_1X	TF_WRUT_T1
TF_CANL_126X	TF_KENTCT_4X	TF_NEAS_GSU	TF_SNDYPD_2X	TF_WRUT_T2
TF_CANTON_2X	TF_KENTCT_5X	TF_NEWFANE_1	TF_SNGTN_1X	TF_WTRSD_GSU
TF_CARD_5X	TF_KILLNG_2X	TF_NORHAR_10	TF_SNGTN_2X	TF_WWALP_45A
TF_CARD_8X	TF_KLG1_GSU	TF_HADDAM_5X	TF_BARBHL_2X	

Bus Section Contingencies = 80 Total				
BS_ALLINGS_A	BS_BRDWY_BC	BS_HAWTHRN_A	BS_MONTVLL_A	BS_SHELTON_A
BS_ALLINGS_B	BS_BRDWY_T_A	BS_HAWTHRN_B	BS_MONTVLL_B	BS_SHELTON_B
BS_ANSON_T_A	BS_BRDWY_T_D	BS_INDWELL_A	BS_N_HAVEN_A	BS_TORR_69KV
BS_ANSON_T_B	BS_CONGR_A_C	BS_INDWELL_B	BS_N_HAVEN_B	BS_TRPFALS_A
BS_ASHCR_T_A	BS_CONGR_B_D	BS_JUNE_ST_A	BS_NBLOOM_B	BS_TRPFALS_B
BS_ASHCR_T_B	BS_COOLIDGE	BS_JUNE_ST_B	BS_NORWALK_A	BS_TRUMBUL_A
BS_BAIRD_T_A	BS_COSCOB_A1	BS_KENTCTY_1	BS_NORWALK_B	BS_TRUMBUL_B
BS_BAIRD_T_B	BS_COSCOB_A2	BS_MANCHST_A	BS_OLDTOWN_A	BS_VTYA_115
BS_BARNM_T_A	BS_COSCOB_A3	BS_MANCHST_B	BS_OLDTOWN_B	BS_WATERST_B
BS_BARNM_T_B	BS_DEERFLDNH	BS_MILLRV_BC	BS_PLUMTRE_A	BS_WATERST_C
BS_BEACONFLS	BS_DEVON_T_A	BS_MILLRVR_A	BS_PLUMTRE_B	BS_WDMNT_T_A
BS_BERKSHR_A	BS_DEVON_T_B	BS_MILLRVR_D	BS_QUINN_T_A	BS_WDMNT_T_B
BS_BERLIN_A	BS_ELMWEST_A	BS_MILVN_T_A	BS_QUINN_T_B	BS_WMEDWAY_S
BS_BERLIN_B	BS_ELMWEST_B	BS_MILVN_T_B	BS_ROCKY_A3	BS_WRIVER_A
BS_BRDGWTR_N	BS_GLENBRK_A	BS_MIX_T_A	BS_SACKETT_A	BS_WRIVER_B
BS_BRDGWTR_S	BS_GLENBRK_B	BS_MIX_T_B	BS_SACKETT_B	BS_WRIVER_C

Loss of Element w/o Fault (Single Breaker Opening) - Total =32				
NF_352	NF_BESECK_R1	NF_BERLNCT_C	NF_HADDAM_C	NF_SO11_SO12
NF_387-1	NF_1300-2	NF_BRANFRD_C	NF_MANCH_C1	NF_SO13_SO14
NF_FRSTBR_1X	NF_1751-1	NF_CANTON_C	NF_MANCH_C2	NF_1256
NF_MANCH_5X	NF_1783-3	NF_FRKLNDR_C	NF_NBLOOM_C	NF_689
NF_SNGTN_4X	NF_1910_R	NF_FRSTB_C1	NF_SNGTN_C1	NF_693
NF_GRNHL_C1	NF_1950_R	NF_FRSTB_C2	NF_SNGTN_C2	NF_694
NF_HPWL_C1	NF_WSTSD_C1			

Loss of Element w/o Fault (Multiple Breakers Opening) - Total =48				
NF_3424_MB	NF_1300-3_MB	NF_1670-3_MB	NF_1751-3_MB	NF_1786-2_MB
NF_348-1_MB	NF_1355-1_MB	NF_1704_MB	NF_1772_MB	NF_1786-3_MB
NF_348-2_MB	NF_1355-2_MB	NF_1710-3_MB	NF_1773_MB	NF_1788_MB
NF_364_MB	NF_1355-3_MB	NF_1722-1_MB	NF_1775-1_MB	NF_1810-1_MB
NF_3754_MB	NF_1550-1_MB	NF_1722-2_MB	NF_1775-2_MB	NF_1810-3_MB
NF_1163-1_MB	NF_1550-2_MB	NF_1722-3_MB	NF_1775-3_MB	NF_1810-4_MB
NF_1163-2_MB	NF_1550-3_MB	NF_1732-1_MB	NF_1783-1_MB	NF_1950_MB
NF_1163-3_MB	NF_1572_MB	NF_1732-2_MB	NF_1783-2_MB	NF_AETN_GSU_MB
NF_1238_MB	NF_1670-1_MB	NF_1732-3_MB	NF_1786-1_MB	NF_667_MB
NF_1300-1_MB	NF_1670-2_MB	NF_1751-2_MB		

12.2 GHCC Area NERC Category C Contingencies

Breaker Failure Contingencies = 586 Total				
BF_AGAWAM_2T	BF_DEVN_T_2T	BF_KLEEN_2T	BF_NRWLK_2T	BF_SNGTN_6T
BF_AGAWAM_5T	BF_DEVN_T_3T	BF_KLEEN_3T	BF_NRWLK_3T	BF_SNGTN_7T
BF_AGAWM_22T	BF_DEVN_T_4T	BF_KLEEN_4T	BF_NRWLK_4T	BF_SNGTN_9T

BF_AGAWM_25T	BF_DEVON_10T	BF_KLEEN_6T	BF_NRWLK_5T	BF_SOMST_12
BF_AGAWM_26T	BF_DEVON_11T	BF_KNTC_115E	BF_NRWLK_6T	BF_SOMST_A
BF_ALLNGS_1T	BF_DEVON_12T	BF_KNTC_345B	BF_NRWLK_7T	BF_STCKHS_1T
BF_ALLNGS_2T	BF_DEVON_1T	BF_KNTC_345C	BF_NRWLK_8T	BF_STEV_1560
BF_ANSON_1T	BF_DEVON_20T	BF_KNTC_345E	BF_NRWLK_9T	BF_STEV_1876
BF_ANSON_2T	BF_DEVON_23T	BF_KNTC_345F	BF_NTHFLD_1T	BF_STEV_1990
BF_ANSON_3T	BF_DEVON_24T	BF_KNTC_4T20	BF_NTHFLD_2T	BF_STGTN_101
BF_ASHCRK_3B	BF_DEVON_25T	BF_KNTC_8510	BF_NTHFLD_3T	BF_STGTN_102
BF_AUBURN_02	BF_DEVON_26T	BF_KNTC_8520	BF_NTHFLD_4T	BF_STGTN_103
BF_AUBURN_03	BF_DEVON_27T	BF_KNTC_8589	BF_NTHFLD_5T	BF_STGTN_104
BF_AUBURN_40	BF_DEVON_28T	BF_KNTC_8910	BF_NWALFD_1T	BF_STGTN_105
BF_AUBURN_41	BF_DEVON_29T	BF_LAKERD_2T	BF_NWHART_31	BF_STHEND_5T
BF_BAIRD_75A	BF_DEVON_3T	BF_LAKERD_5T	BF_NWHART_32	BF_STONY_1T2
BF_BAIRD_75B	BF_DEVON_6T	BF_LAKERD_8T	BF_NWHART_33	BF_STPSTN_1T
BF_BARBH_18T	BF_DEVON_7T	BF_DEVN_T_1T	BF_NWHV_370	BF_SWHART_1T
BF_BARBH_21T	BF_DEVON_8T	BF_LUDLOW_1T	BF_NWHV_371	BF_SWNDSR_1T
BF_BARBHL_2T	BF_DOOLEY_2T	BF_LUDLOW_2T	BF_NWHV_4163	BF_THMSTN_2T
BF_BARBHL_5T	BF_EDEVN_11T	BF_LUDLOW_3T	BF_NWHV_4341	BF_TODD_1T-2
BF_BATES_1T2	BF_EDEVN_24T	BF_LUDLOW_4T	BF_NWHV_6342	BF_TORR_10X1
BF_BE_10X	BF_EHART_1T	BF_LUDLOW_5T	BF_NWHV_6442	BF_TORR_1T-2
BF_BE_11X	BF_EMERDN_1T	BF_LUDLOW_6T	BF_NWNGTN_1T	BF_TORR_6892
BF_BEANHL_1T	BF_ENEWBR_69	BF_LUDLOW_7T	BF_NWNGTN_2T	BF_TORR_6932
BF_BECN_1319	BF_ENEWBR_83	BF_LUDLOW_8T	BF_OLDTWN_1T	BF_TRACY_1T2
BF_BECN_1570	BF_ENFLD_1T	BF_LUDLOW_9T	BF_OXFORD_1T	BF_TRAPFL_1T
BF_BELL_3-20	BF_ESHOR_1K	BF_LUDLW_41T	BF_PEACE_1T2	BF_TRINGL_2T
BF_BERLIN_13	BF_ESHOR_2K	BF_LUDLW_43T	BF_PEQNC_12T	BF_TRINGL_3T
BF_BERLIN_14	BF_ESHORE_11	BF_LUDLW_44T	BF_PEQNC_22T	BF_TRINGL_4T
BF_BERLIN_15	BF_ESHORE_12	BF_LUDLW_46T	BF_PEQNC_2T	BF_TRINGL_5T
BF_BERLIN_22	BF_ESHORE_13	BF_LUDLW_47T	BF_PEQNC_32T	BF_TRMBUL_1T
BF_BERLIN_23T	BF_ESHORE_21	BF_LUDLW_49T	BF_PEQNC_42T	BF_TRMBUL_2T
BF_BERLIN_24	BF_ESHORE_22	BF_MANCH_10T	BF_PEQU_32T	BF_TRMBUL_3T
BF_BERLIN_25	BF_ESHORE_23	BF_MANCH_11T	BF_PEQU_42T	BF_TUNNEL_1T
BF_BERLIN_27	BF_ESHORE_31	BF_MANCH_13T	BF_PILGM_104	BF_TUNNEL_2T
BF_BERY_345A	BF_ESHORE_32	BF_MANCH_14T	BF_PILGM_105	BF_TUNNEL_3T
BF_BERY_345B	BF_ESHORE_33	BF_MANCH_15T	BF_PLUMT_1X3	BF_TUNNEL_4T
BF_BERY_345C	BF_ESHORE_41	BF_MANCH_17T	BF_PLUMT_23T	BF_TUNNEL_5T
BF_BESECK_8T	BF_ESHORE_43	BF_MANCH_18T	BF_PLUMT_24T	BF_TWKS_7-39
BF_BLDWN_2T2	BF_ESHORE_71	BF_MANCH_19T	BF_PLUMT_25T	BF_TWKS_8-97
BF_BLDWN_5T2	BF_ESHORE_73	BF_MANCH_1T	BF_PLUMT_26T	BF_VERN_3TB1
BF_BLKST_101	BF_FARMTN_1T	BF_MANCH_20T	BF_PLUMT_29T	BF_VERN_3TB2
BF_BLKST_102	BF_FARMTN_2T	BF_MANCH_21T	BF_PLUMT_2T	BF_VERN_3TB3
BF_BLKST_103	BF_FARMTN_3T	BF_MANCH_22T	BF_PLUMT_2X3	BF_VERN_KTB1
BF_BLKST_104	BF_FLAXHL_2T	BF_MANCH_23T	BF_PLUMT_30T	BF_VTYK_1T
BF_BLMFLD_1T	BF_FLNDRS_1T	BF_MANCH_25T	BF_PLUMT_31T	BF_VTYK_381
BF_BLMFLD_2T	BF_FLSVL_694	BF_MANCH_2T	BF_PLUMT_32T	BF_VTYK_40/1

BF_BLMFLD_3T	BF_FRAMNG_1	BF_MANCH_3T	BF_PLUMT_4X1	BF_VTYK_811T
BF_BOKUM_1T	BF_FRDR_1T-2	BF_MANCH_4T	BF_PRTLND_2T	BF_VTYK_9-40
BF_BOKUM_2T	BF_FREGHT_1T	BF_MANCH_5T	BF_QNNIPC_1T	BF_WACH_13T
BF_BOKUM_3T	BF_FREGHT_2T	BF_MANCH_6T	BF_RESCO_9R	BF_WACH_141N
BF_BRANF_1T	BF_FRNCON_2T	BF_MANCH_7T	BF_RKYHIL_1T	BF_WACH_141W
BF_BRANF_4T	BF_FRSTB_14T	BF_MANCH_8T	BF_RKYHIL_2T	BF_WACH_142N
BF_BRANFRR_1	BF_FRSTB_15T	BF_MIDLTN_10	BF_ROCKY_1T2	BF_WACH_142W
BF_BRDWAY_1T	BF_FRSTB_16T	BF_MIDLTN_11	BF_ROCKY_2T2	BF_WACH_24T
BF_BRDWAY_2T	BF_FRSTB_1T2	BF_MIDLTN_3	BF_SACKET_1T	BF_WACH_2-7T
BF_BRGWTR_01	BF_FRSTB_1X2	BF_MIDLTN_7	BF_SALS_1T-2	BF_WACH_3-6T
BF_BRGWTR_04	BF_FRSTB_20T	BF_MIDRV_1T2	BF_SASCO_1T	BF_WACH_3-7T
BF_BRGWTR_07	BF_FRSTB_21T	BF_MIDRV_2T2	BF_SCOVRK_5T	BF_WACH_4-7T
BF_BRGWTR_13	BF_FRSTB_22T	BF_MILB_0802	BF_SCOVRK_8T	BF_WACH_6T
BF_BRGWTR_40	BF_FRSTB_23T	BF_MILB_1357	BF_SCTICO_1T	BF_WACH_7T
BF_BRGWTR_49	BF_FRSTB_24T	BF_MILB_345B	BF_SERV_RD_A	BF_WALNFD_1T
BF_BRGWTR_60	BF_FRSTB_26T	BF_MILLRV_1T	BF_SHAWS_1T2	BF_WALNFD_2T
BF_BRGWTR_70	BF_FRSTB_27T	BF_MILLRV_2T	BF_SHELTN_1T	BF_WALNFD_3T
BF_BRGWTR_80	BF_FRSTB_28T	BF_MILST_14T	BF_SHEP_1887	BF_WALNFD_4T
BF_BRGWTR_90	BF_FRSTB_2X2	BF_MILST_8T	BF_SHRMN_143	BF_WALNFD_5T
BF_BRISTL_1T	BF_FRSTVL_1T	BF_MIXAVE_1T	BF_SHUNOK_2T	BF_WALNFD_6T
BF_BRKSH_12T	BF_FRSTVL_2T	BF_MIXPDS_3X	BF_SINGR_22T	BF_WATRST_1T
BF_BRKSH_15T	BF_FTHILL_1T	BF_MONTV_10T	BF_SINGR_52T	BF_WATRST_2T
BF_BUDNTN_4T	BF_GLBK_10K	BF_MONTV_11T	BF_SMEAD_10	BF_WBKFD_1T2
BF_BUNKR_1T2	BF_GLBK_1753	BF_MONTV_12T	BF_SMEAD_2	BF_WESTSD_1T
BF_BUNKR_2T2	BF_GLBK_1792	BF_MONTV_13T	BF_SMEAD_3	BF_WFARN_170
BF_BUNKR_3T2	BF_GLBK_1867	BF_MONTV_14T	BF_SMEAD_4	BF_WFARN_176
BF_BYPT_3-3T	BF_GLBK_1977	BF_MONTV_15T	BF_SMEAD_5	BF_WFARN_710
BF_BYPT_345D	BF_GLBK_20K	BF_MONTV_16T	BF_SMEAD_7	BF_WFARN_711
BF_CAMPVL_1T	BF_GLBK_20T	BF_MONTV_17T	BF_SMEAD_8	BF_WFARN_714
BF_CAMPVL_2T	BF_GLBK_22T	BF_MONTV_18T	BF_SNAUG_1T	BF_WFARN_715
BF_CAMPVL_3T	BF_GLBK_23T	BF_MONTV_18X	BF_SNDPD_137	BF_WFARN_C
BF_CAMPVL_4T	BF_GLBK_25T	BF_MONTV_19T	BF_SNDPD_161	BF_WFARN_F
BF_CANAL_112	BF_GLBK_2T2	BF_MONTV_20T	BF_SNDPD_314	BF_WHMPDN_A1
BF_CANAL_212	BF_GLBK_3T	BF_MONTV_21T	BF_SNDPD_326	BF_WHMPDN_A2
BF_CANAL_312	BF_GLBK_4T	BF_MONTV_22T	BF_SNDPD_337	BF_WILTON_1T
BF_CANAL_412	BF_GLBK_4X12	BF_MONTV_23T	BF_SNDPD_343	BF_WMDWY_101
BF_CANAL_512	BF_GLBK_5X12	BF_MONTV_24T	BF_SNDPD_37E	BF_WMDWY_103
BF_CANAL_612	BF_GLBK_7T	BF_MONTV_4T	BF_SNDPD_37W	BF_WMDWY_104
BF_CANTN_1T2	BF_GLBK_8T	BF_MONTV_9T	BF_SNDPD_38E	BF_WMDWY_105
BF_CANTN_2T2	BF_GLBK_9T	BF_MYSCT_1T2	BF_SNDPD_38W	BF_WMDWY_106
BF_CARD_10T	BF_GRAND_22T	BF_NBLMF_14T	BF_SNDPD_412	BF_WMDWY_107
BF_CARD_11T	BF_GRAND_32T	BF_NBLMF_20T	BF_SNDPD_512	BF_WMDWY_108
BF_CARD_12T	BF_GRAND_42T	BF_NBLMF_23T	BF_SNDPD_521	BF_WMDWY_109
BF_CARD_13T	BF_GRNHIL_1T	BF_NBLMF_2T	BF_SNDPD_612	BF_WMDWY_111
BF_CARD_14T	BF_GRNHIL_2T	BF_NBLMF_5T	BF_SNDPD_643	BF_WMDWY_112

BF_CARD_15T	BF_HADDAM_26	BF_NBLMF_5X3	BF_SNGTN_10K	BF_WNSRLK_1T
BF_CARD_16T	BF_HADDAM_27	BF_NBLMF_7X3	BF_SNGTN_11T	BF_WOODMT_1T
BF_CARD_1T	BF_HADDAM_29	BF_NEA_1CB2	BF_SNGTN_14T	BF_WOODMT_2T
BF_CARD_345K	BF_HADDAM_32	BF_NEA_1CB3	BF_SNGTN_15T	BF_WOODRV_70
BF_CARD_3T	BF_HADDAM_33	BF_NESIMS_2T	BF_SNGTN_16T	BF_WRUT_3039
BF_CARVR_162	BF_HADDAM_35	BF_NEWF_20T2	BF_SNGTN_17T	BF_WRUT_3440
BF_CARVR_262	BF_HADDAM_37	BF_NEWF_3320	BF_SNGTN_18T	BF_WRUT_350
BF_CARVR_552	BF_HADDAM_5X	BF_NEWF_3321	BF_SNGTN_1T	BF_WRUT_360
BF_CARVR_652	BF_HADDMN_1T	BF_NHAVEN_1T	BF_SNGTN_20T	BF_WRUT_371
BF_CARVR_862	BF_HADDMN_2T	BF_NHAVEN_2T	BF_SNGTN_22T	BF_WRUT_372
BF_CHIPHL_1T	BF_HADDMN_4T	BF_NORHAR_1T	BF_SNGTN_23T	BF_WRUT_3740
BF_CHL_23-1T	BF_HALVAR_1X	BF_NORHAR_2T	BF_SNGTN_24T	BF_WRUT_3937
BF_CHL_321	BF_HAWTRN_1T	BF_NORHAR_3T	BF_SNGTN_25T	BF_WTRFRD_1T
BF_COLONY_1T	BF_HOLBR_102	BF_NORHAR_4T	BF_SNGTN_26T	BF_WTRSD_1T2
BF_COMPO_1T	BF_HOLBR_107	BF_NORHAR_5T	BF_SNGTN_28T	BF_WTRSD_2T2
BF_COOL_3TB2	BF_HOLBR_7	BF_NORHAR_6T	BF_SNGTN_29T	BF_WTRSD_3T2
BF_COOL_K32	BF_HOPEWL_2T	BF_NORHAR_7T	BF_SNGTN_30T	BF_WWALP_104
BF_COOL_K36	BF_INDWEL_1T	BF_NORHN_1K	BF_SNGTN_31T	BF_WWALP_105
BF_COSCOB_1T	BF_JUNEST_1T	BF_NRWLK_10T	BF_SNGTN_33T	BF_WWALP_107
BF_COSCOB_2T	BF_KILLNG_22	BF_NRWLK_11T	BF_SNGTN_3T	BF_WWALP_108
BF_DARIEN_1T	BF_KILLNG_25	BF_NRWLK_12T	BF_SNGTN_3X3	BF_WWALP_109
BF_HADDAM_34	BF_KILLNG_3T	BF_NRWLK_1T	BF_SNGTN_4T	BF_WWALP_7
BF_ROOD_BT	BF_KLEEN_1T	BF_HADDAM_28	BF_HADDAM_BT	BF_WWALP_8
BF_ROOD_CT	BF_HADDAM_31	BF_ROOD_DT	BF_SWHART_AT	BF_HADDAM_ET
BF_SWHART_BT				

Double Circuit Tower Contingencies = 160 Total				
DC_1000_1070	DC_1355_1610	DC_1620_1975	DC_1820_1830	DC_364_1250
DC_1000_1080	DC_1355_1690	DC_1621_1742	DC_1867_1880	DC_3642_1779
DC_1000_1090	DC_1389_1880	DC_1622_1770	DC_1867_1890	DC_368_1767
DC_1070_1080	DC_1394_1858	DC_1630_1640	DC_1867_1977	DC_3754_1466
DC_1080_100	DC_1394_515S	DC_1630_1655	DC_1880_1890	DC_376_1772
DC_1080_1280	DC_1410_100	DC_1635_1763	DC_1910_1950	DC_379_N186
DC_1080_1410	DC_1410_400	DC_1637_1720	DC_3196_1314	DC_381_N186
DC_1080_1490	DC_1416_1867	DC_1640_1685	DC_3196_1602	DC_3827_1208
DC_1080_1675	DC_1416_1880	DC_1668_1721	DC_3196_1603	DC_3827_1610
DC_1100_1200	DC_1416_1890	DC_1670_1820	DC_321_1618	DC_3827_1655
DC_1100_1300	DC_1440_1450	DC_1670_1830	DC_321_1770	DC_387_1460
DC_1130_1430	DC_1440_1750	DC_1710_1714	DC_321_1887	DC_387_1537
DC_1130_9100	DC_1445_1721	DC_1710_1730	DC_3216_1768	DC_387_1975
DC_1163_1550	DC_1460_1537	DC_1714_1720	DC_3216_1781	DC_400_500
DC_1191_1921	DC_1470_1565	DC_1714_1730	DC_325_331	DC_560N_1570
DC_1200_1300	DC_1500_1605	DC_1720_1714	DC_325_344	DC_560N_1594
DC_1207_1775	DC_1505_1607	DC_1732_1788	DC_335_1-536	DC_580/710LS
DC_1208_1640	DC_1550_1910	DC_1732_1900	DC_337_I161	DC_689_693

DC_1210_1220	DC_1570_1580	DC_1740_1750	DC_3403_1565	DC_697/710LS
DC_1222_1714	DC_1570_1585	DC_1751_1756	DC_342_120W	DC_710/714LS
DC_1235_1250	DC_1575_1585	DC_1752_1773	DC_342_194	DC_800_900
DC_1261_1598	DC_1575_1990	DC_1770_1887	DC_342_355	DC_8100_8200
DC_1272_1721	DC_1580_1585	DC_1771_1820	DC_344_A24	DC_8300_8400
DC_1280_100	DC_1580_1710	DC_1775_1786	DC_348_1772	DC_8300_8600
DC_1280_1410	DC_1580_1730	DC_1780_1790	DC_348_1975	DC_8400_8600
DC_1280_1465	DC_1606_1724	DC_1788_1900	DC_3557_1448	DC_88/89005
DC_1280_400	DC_1610_1640	DC_1800_1810	DC_356_E1	DC_88/89006
DC_1310_1635	DC_1610_1685	DC_1800_1825	DC_362_1772	DC_88003A/89
DC_1310_1763	DC_1618_1887	DC_1810_1825	DC_362_1975	DC_8804_8904
DC_1319_1570	DC_1319_1585	DC_1810_1835	DC_362_376	DC_8809_8909
DC_1319_1580	DC_3642_ROOD_SMEAD	DC_3642_ROOD_BLMF	DC_364_1235	DC_K371_K34

12.3 GHCC Area Special Protection System and Automatic Control Scheme Contingencies

SPS Contingencies = 65 Total				
SPS_1570-2	SPS_8809A	SPS_BSCON_AC	SPS_LN_1130	SPS_GR42T_RB
SPS_17101697	SPS_89003_RB	SPS_BSCON_BD	SPS_LN_1697	SPS_GR42T_TR
SPS_387+NHHB	SPS_89003_TR	SPS_BSELMARB	SPS_LN_1710	SPS_327_315
SPS_387-1	SPS_8909B	SPS_BSELMATR	SPS_LN_91001	SPS_WAT1T_RB
SPS_393+690	SPS_ALS1T_RB	SPS_BSELMBRB	SPS_MIL1T_RB	SPS_WAT1T_TR
SPS_398+690	SPS_ALS1T_TR	SPS_BSELMBTR	SPS_MIL1T_TR	LN_398+690_SPS
SPS_690	SPS_ALS2T_RB	SPS_BSWRVARB	SPS_NHHB	TF_MILSTN_3X+690_SPS
SPS_8301_RB	SPS_ALS2T_TR	SPS_BSWRVATR	SPS_TRMTB	BF_CAMPVL_2T / DC_1191_1921+690_SPS
SPS_8301_TR	SPS_BF_BARDA	SPS_BSWRVBRB	SPS_GR22T_RB	BF_CAMPVL_4T / DC_1732_1900+690_SPS
SPS_8500_RB	SPS_BF_BARDB	SPS_BSWRVBTR	SPS_GR22T_TR	BF_MILST_14T+690_SPS
SPS_8500_TR	SPS_BF_TRM1T	SPS_CHL_231T	SPS_GR32T_RB	BF_NBLMF_23T+690_SPS
SPS_88003_RB	SPS_BF_TRM2T	SPS_D88003RB	SPS_GR32T_TR	BF_NTHFLD_1T+690_SPS
SPS_88003_TR	SPS_BS_ASHTB	SPS_D88003TR	SPS_88098909	HVDC_PHASE_2+690_SPS

12.4 GHCC Area NERC Category D Contingencies

Generation Station Contingencies - Total = 11				
GS_BRPT_HBEN	GS_MIDDLTWN	GS_MONTVILLE	GS_NRWLKHBR	GS_WALLNGFRD
GS_COSCOB	GS_MILLSTONE	GS_NEW_HAVEN	GS_S-MEADOW	GS_WATERSIDE
GS_DEVON				

Loss of Substation contingencies - Total = 5				
SS_MANCH_345	SS_STGTN_115	SS_DEVON_115	SS_MLSTN_345	SS_MANCH_115

Loss of Right of way contingencies - Total = 5				
ROW_CHST_DLY	ROW_HBRKJ_NO	ROW_SGTN_SCO	ROW_HBRKJ_EH	ROW_STV_BNKR

Section 13
Appendix E: Steady State Testing Results

Quick links to Excel files containing PivotTables of the steady state testing results summarized in Section 6.1 are provided below. Each file contains all of the analysis results for the portion of the study area noted in the title.

Appendix E1: Manchester / Barbour Hill Final Alternatives N-1-1 Thermal Results

Appendix E2: Manchester / Barbour Hill Final Alternatives N-1-1 Voltage Results

Appendix E3: Manchester / Barbour Hill Final Alternatives N-1-1 Non-Converged Scenarios

Appendix E4: NWCT Final Alternatives N-1-1 Thermal Results

Appendix E5: NWCT Final Alternatives N-1-1 Voltage Results

Appendix E6: NWCT Final Alternatives N-1-1 Non-Converged Scenarios

Appendix E7: Greater Hartford / Middletown Final Alternatives N-1 Thermal Results

Appendix E8: Greater Hartford / Middletown Final Alternatives N-1 Voltage Results

Appendix E9: GHCC and SWCT Preferred Solutions N-1 Thermal Results

Appendix E10: GHCC and SWCT Preferred Solutions N-1 Voltage Results

Section 14
Appendix F: Short Circuit Testing Results

A quick links to an Excel file containing detailed results of the short circuit testing performed, as summarized in Section 6.3, is provided below.

Appendix F: Short Circuit Testing Results

Section 15
Appendix G: Transfer Analysis Testing Results

A quick link to an Excel file containing detailed results of the transfer analysis performed, as summarized in Section 6.4.1, is provided below.

Appendix G: Western Connecticut Import Transfer Analysis Results