Environmental Report – Volume 1

Rhode Island Reliability Project

North Smithfield, Smithfield,
Johnston, Cranston, Warwick,
and West Warwick,
Rhode Island

Prepared for

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September 2008

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Glossary

AC:	Alternating Current. An electric current which reverses its direction of flow periodically. (In the United States this occurs 60 times a second -60 cycles or 60 Hertz). This is the type of current supplied to homes and businesses.
ACSR:	Aluminum Conductor Steel Reinforced wire
ACSS:	Aluminum Conductor Steel Supported wire
AFUDC:	Allowance for Funds Used During Construction – financing costs incurred in association with new construction
Ampere (Amp):	A unit of measure for the flow of electric current. A typical home service capability (i.e., size) is 100 amps. 200 amps or more is required for homes with electric heat.
ANSI:	American National Standards Institute
Arrester:	Provides protection for lines, transformers and equipment from transient over voltages due to lightning and switching surges by carrying the charge to ground. Arresters serve the same purpose on a line as a safety valve on a steam boiler.
Autotransformer:	A transformer with a single winding per phase in which the lower voltage is obtained by a tap on the winding (see power transformer).
BMPs:	Best Management Practices
Bundle:	Two or more wires joined together to operate as a single phase.
Cable:	A fully insulated conductor usually installed underground but in some circumstances can be installed overhead.
Circuit Breaker:	A switch that automatically disconnects power to the circuit in the event of a fault condition. Located in substations. Performs the same function as a circuit breaker in a home.
Circuit:	A system of conductors (three conductors or three bundles of conductors) through which an electric current is intended to flow and which may be supported above ground by transmission structures or placed underground.
CHP:	Combined Heat and Power
Conductor:	A metallic wire or cable which serves as a path for electric current to flow.

Conduit:	Pipes, usually PVC plastic, typically encased in concrete to house and protect underground power cables or other subsurface utilities.
dBA:	Decibel, on the A-weighted scale. A decibel is a logarithmic unit of measurement that expresses the magnitude of a sound. A-weighting is used to emphasize the range of frequencies where human hearing is most sensitive.
Demand:	The total amount of electric power required at any given time by an electric supplier's customers.
DG	Distributed Generation
Distribution Line or System:	Power lines that operate between 4 kV and 35 kV that transport electricity to the customer.
Double-Circuit:	Two circuits on one structure.
DSM:	Demand Side Management
Duct Bank:	A group of ducts or conduit usually encased in concrete in a trench.
Duct:	Pipe for underground power cables (see also Conduit).
EDR:	Environmental Design & Research, P.C.
EFSB:	Rhode Island Energy Facility Siting Board
EHS:	Extra high strength
Electric Field (EF):	A field produced as a result of voltages applied to electrical conductors and equipment; usually measured in units kilovolts per meter.
Electric Transmission:	The facilities (≥69 kV) that transmit electrical energy from generating plants to substations.
EMF:	Electric and magnetic fields
Environmental Monitor:	Inspects environmental conditions within the construction site, reviews the contractors' compliance with environmental permit conditions during the construction phase of a project, and makes recommendations for corrective actions to protect sensitive environmental resources proximate to a construction site.
Fault:	A failure or interruption in an electrical circuit (a.k.a. short circuit).
FAA	Federal Aviation Administration
FEMA:	Federal Emergency Management Agency
Gauss (G):	A unit of measure for magnetic fields. 1G equals 1,000 milligauss (mG).
Gigawatt (GW):	One gigawatt equals 1,000 megawatts.
GIS:	Gas Insulated Switchgear. This is electrical switching equipment, typically installed in a substation and insulated with SF6 gas.

Glacial till:	Type of surficial geologic deposit that consists of boulders, gravel, sand silt, and clay mixed in various proportions. These deposits are predominantly nonsorted, nonstratified sediment and are deposited directly by glaciers.
Gneiss:	Light and dark, medium- to coarse-grained metamorphic rock characterized by compositional banding of light and dark minerals, typically composed of quartz, feldspar and various amounts of dark minerals.
H-frame Structure:	A wood or steel transmission line structure constructed of two upright poles with a horizontal cross-arm and diagonal bracings.
HPFF:	High Pressure Fluid Filled. A type of underground cable.
Hz:	Hertz, a measure of the frequency of alternating current; expressed in units of cycles per second.
IEEE:	Institute of Electrical and Electronic Engineers
ISO-NE:	ISO New England, Inc. The independent system operator of New England.
kcmil:	1,000 circular mils, approximately 0.0008 square inches. A measure of conductor cross-sectional area.
kV:	Kilovolt. 1 kV equals 1,000 volts.
kV/m:	Kilovolts per meter. A measurement of electric field strength.
Load:	Amount of power delivered upon demand at any point or points in the electric system. Load is created by the power demands of customers' equipment (residential, commercial, and industrial).
LTE:	Long-Term Emergency rating
mG:	milliGauss. Equals 1/1000 Gauss (see Magnetic Field).
MODF:	Mineral Oil Dielectric Fluid
MVA:	Megavolt Ampere. Measure of electrical capacity equal to the product of the voltage, the current and the square root of 3 for three-phase systems. Electrical equipment capacities are sometimes stated in MVA.
MVAR:	Mega Volt Ampere Reactive. Reactive power, or the power associated with inductive or capacitive elements. Also called MegaVARS.
MW:	Megawatt. Megawatt equals 1 million watts. A measure of the work electricity can do.
NEEWS:	New England East-West Solution
NEPOOL:	New England Power Pool
NERC:	North American Electric Reliability Corporation
NESC:	National Electrical Safety Code
NPCC:	Northeast Power Coordinating Council

OH:	Overhead. Electrical facilities carried above-ground on supporting structures.
OPGW:	Optical ground wire
PAL:	Public Archaeological Laboratory, Inc.
Phase:	Transmission and distribution AC circuits are comprised of three conductors that have voltage and angle differences between them. Each of these conductors is referred to as a phase.
Power Transformer:	A device used to transform voltage levels to facilitate the efficient transfer of power from the generating plant to the customer. A step-up transformer increases the voltage while a step-down transformer decreases it. Power transformers have a high voltage and a low voltage winding for each phase (see also Auto Transformer).
PVC:	PolyVinyl Chloride
Reconductor:	Replacement of existing conductors with new conductors, and any necessary structure reinforcements or replacements.
Reinforcement:	Any of a number of approaches to improve the capacity of the transmission system, including rebuilding, reconductoring, uprating, conversion and conductor bundling methods.
RIDEM:	Rhode Island Department of Environmental Management
RIDOT:	Rhode Island Department of Transportation
RIGIS:	Rhode Island Geographic Information System
RINHP:	Rhode Island Natural Heritage Program
Rip Rap:	A permanent erosion-resistant ground cover of large, loose, angular stone with filter fabric or granular underlining used to protect soil from the erosive forces of concentrated runoff.
RIPDES:	Rhode Island Pollutant Discharge Elimination System
ROW:	Right of way. Corridor of land within which a utility company holds legal rights necessary to build, operate and maintain power lines.
Schist:	Light, silvery to dark, coarse to very coarse-grained, strongly to very strongly layered metamorphic rock whose layering is typically defined by parallel alignment of micas. Primarily composed of mica, quartz and feldspar; occasionally spotted with conspicuous garnets.
SF6	Sulfur hexafluoride, a gas used as electrical insulation, primarily in gas insulated switchgear (GIS).
Shield Wire:	Wire strung at the top of transmission lines intended to prevent lightning from striking transmission circuit conductors. Sometimes referred to as static wire or aerial ground wire. May contain glass fibers for communication use. See also “OPGW”.
Steel Pole Structure:	Transmission line structure consisting of tubular steel pole(s) with arms or other components to support insulators and conductors.

Step-down Transformer:	See Power Transformer.
Step-up Transformer:	See Power Transformer.
Substation:	A fenced-in yard containing switches, power transformers, line terminal structures, and other equipment enclosures and structures. Voltage change, adjustments of voltage, monitoring of circuits and other service functions take place in this installation.
Switching Station:	Same as Substation except with no power transformers. Switching of circuits and other service functions take place in this installation.
Terminal Points:	The substation or switching station at which a transmission line terminates.
Terminal Structure:	Structure typically within a substation that ends a section of transmission line.
Terminator:	An insulated fitting used to connect underground cables to overhead lines.
TMDL:	Total Maximum Daily Load, Maximum allowed pollutant load to a water body without exceeding water quality standards.
Transmission Line:	An electric power line operating at 69,000 or more volts.
USDA:	United States Department of Agriculture
USFWS:	United States Fish and Wildlife Service
USGS:	United States Geological Survey
V/m:	Volts per meter. A measure of electric field strength.
Voltage Collapse:	A condition where voltage drops to unacceptable levels and cascading interruptions of transmission system elements occur resulting in widespread blackouts.
Voltage:	A measure of the electrical pressure which transmits electricity. Usually given as the line-to-line root-mean square magnitude for three-phase systems.
Watercourse:	Rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, public or private.
Wetland:	Land, including submerged land, which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial or flood plain by the U.S. Department of Agriculture, Natural Resources Conservation Service. Wetlands include federally jurisdictional wetlands of the U.S. and navigable waters, freshwater wetlands or coastal resources regulated by a state or local regulatory authority. Jurisdictional wetlands are classified based on a combination of soil type, wetland plants, and hydrologic regime, or state-defined wetland types.

Wire:	See Conductor.
XLPE:	Cross Linked Polyethylene. A type of underground cable insulation.

1.0 Introduction

1.1 Report Preparation and Responsibilities

This Environmental Report will support applications to the Rhode Island Energy Facility Siting Board (EFSB) and other agencies in connection with the Rhode Island Reliability Project (the Project). The Project is part of the New England East-West Solution (NEEWS) Transmission Project. The Report has been prepared by The Narragansett Electric Company d/b/a National Grid (National Grid)[1] under the direction of David J. Beron P.E., P.M.P., Project Manager for the Project. Numerous employees of National Grid, including planners, engineers and legal personnel contributed to the Report. The description of the affected natural and social environments, and impact analyses were prepared by Vanasse Hangen Brustlin, Inc. (VHB) and other consultants to National Grid including the Public Archaeology Lab, Inc. (PAL for cultural resources), Environmental Design & Research, P.C. (EDR for visual resources), Exponent, Inc. (for analysis of health effects of electric and magnetic fields [EMF] and EMF calculations), Power Engineers, Inc. (PEI for engineering and design), and ATCO Noise Management (for noise analysis).

1.2 Compliance with EFSB Requirements

Compliance with the requirements of Rule 1.6 of the EFSB Rules of Practice and Procedure (the EFSB Rules) is addressed in the Application which is filed with the EFSB herewith.

1 The Narragansett Electric Company d/b/a National Grid, a subsidiary of National Grid USA, is an electricity distribution and transmission company serving approximately 465,000 customers in 38 Rhode Island communities. National Grid USA is a public utility holding company. Other subsidiaries of National Grid USA include operating companies such as New England Power Company, Massachusetts Electric Company, Nantucket Electric Company, Granite State Electric Company (in New Hampshire), and Niagara Mohawk Power Corporation (in New York), as well as National Grid USA Service Company, Inc. which provides services such as engineering, facilities construction and accounting.

2.0 Executive Summary

2.1 Introduction

This Environmental Report (ER) has been prepared in support of an application to the EFSB for construction of jurisdictional facilities and for submission with other state and local applications required for the Project. The ER has been prepared in accordance with the EFSB Rules to provide information on the potential impacts of the electric transmission system improvements proposed by National Grid. The ER details the Project, discusses the alternatives to the Project which were considered and analyzed, describes the specific natural and social features which have been assessed for the evaluation of impacts, discusses potential impacts, presents a mitigation plan for potential impacts associated with the construction of the Project, and describes permit requirements.

The purpose and need for the Project are detailed in Section 3 of this ER, and includes all studies and forecasts regarding the need for the proposed transmission system improvements. Section 4 provides a detailed description of each of the components of the Project, and also discusses construction practices, right-of-way (ROW) maintenance practices, EMF, safety and public health considerations, community outreach, estimated project costs, and anticipated project schedule. An analysis of alternatives to the Project, together with reasons for the rejection of each alternative, is presented in Section 5 of this report. A detailed description of all environmental and social characteristics within and immediately surrounding the proposed project locations is included as Sections 6 and 7, respectively. Section 8 of this report identifies the impacts of the Project on the natural and social environments both on and off site. Section 9 summarizes proposed mitigation measures which when implemented will effectively offset impacts associated with the Project. Finally, Section 10 lists the federal, state, and local government agencies which may exercise licensing authority and from which National Grid may be required to obtain approvals prior to constructing the Project.

2.2 Project Description and Proposed Action

National Grid is proposing to perform a series of electric transmission system improvements in order to continue to provide reliable electric supply to Rhode Island. The Project will significantly reinforce the existing transmission system in

Rhode Island. The Rhode Island Reliability Project will include the following components:

- Two existing 115 kV transmission lines (S-171 and T-172) in National Grid's existing ROW between West Farnum Substation in North Smithfield and the vicinity of the Kent County Substation in Warwick will be relocated and reconstructed (20.0 miles).
- A new 345 kV transmission line (359 Line) will be constructed between the West Farnum Substation and the Kent County Substation (21.4 miles) in the space on the existing ROW created by relocation of the two existing 115 kV transmission lines.
- Equipment will be installed at Kent County Substation to accommodate the new 345 kV transmission line.
- Equipment will be installed at West Farnum Substation to accommodate the new 345 kV transmission line.
- The S-171 and T-172 115 kV transmission lines between Hartford Avenue Substation in Johnston and the Johnston Tap Point will be reconductored coincident with the reconstruction of the lines.
- The G-185N 115 kV transmission line will be reconductored from Kent County Substation to Drumrock Substation (1.0 mile).
- Short segments of the H-17 kV 115 kV transmission line and the 332 345 kV transmission line will be relocated in the vicinity of West Farnum Substation to accommodate the new 345 kV line.
- A short segment of the B-23 115 kV transmission line will be relocated to accommodate equipment additions at the West Farnum Substation.
- Short segments of the L-190 and G-185S 115 kV transmission lines will be relocated to accommodate the equipment additions at the Kent County Substation.

Figure 2-1[2] provides an overview of the Project location and Figure 2-2 (sheets 1 through 40) provides more detail regarding the Project alignment.

2.3 Purpose and Need

The purpose of the proposed transmission system improvements is to enable National Grid to continue to provide reliable electric supply to the Rhode Island area. The Project will improve the reliability of electric supply to the area by increasing the loading capability of the transmission system and maintaining acceptable voltages in

▼

2 All figures are bound separately as Volume 2.

Rhode Island consistent with National Grid's planning guidelines. All National Grid transmission facilities in New England are designed in accordance with the reliability criteria contained in the latest version of the National Grid Transmission Planning Guide (May 2006) ("Transmission Planning Guide"), ISO New England, Inc. (ISO-NE)[3] and New England Power Pool (NEPOOL) standards, the Northeast Power Coordinating Council (NPCC) criteria, and the North American Electric Reliability Corporation's (NERC) Reliability Standards (collectively, the Planning Documents).

ISO-NE, National Grid, and Northeast Utilities undertook an extensive review of the transmission system in New England. The studies ("Southern New England Transmission Reliability, Report 1, Needs Analysis" (January 2008) and "New England East-West Solutions, Report 2, Options Analysis" (June 2008)) identified five problems in the southern New England transmission system:

- Rhode Island Reliability
- Interstate Transfer Capacity (RI, MA, CT)
- East-West New England Constraints
- East-West Connecticut Constraints
- Springfield Reliability.

The studies also identified four transmission projects which, taken together, address the five problems. The projects collectively are referred to as NEEWS. The four individual projects comprising NEEWS are:

- Rhode Island Reliability Project
- Interstate Reliability Project
- Greater Springfield Reliability Project
- Central Connecticut Reliability Project.

The Rhode Island Reliability Project is the subject of this filing. In reviewing the Rhode Island transmission system, the studies determined that the transmission system supplying large portions of Rhode Island was reaching the limits of its ability to serve the load. Certain system contingencies, most notably loss of the 332 345 kV line from West Farnum Substation to Kent County Substation, resulted in significant line and equipment overloads, unacceptable voltages, and/or large scale blackouts in

3 ISO New England, Inc. is a regional transmission organization serving all six New England States. ISO New England, Inc. meets the electricity demands of the region's economy and people by (1) operating the bulk electric power system, (2) developing and overseeing the region's competitive wholesale electric market, and (3) managing the planning of both the bulk electric power system and the wholesale electric market. ISO New England, Inc. is an independent, not-for-profit corporation.

the Rhode Island area. The transmission reinforcements included in the Project address the identified electric supply problems in Rhode Island.

The Rhode Island portion of the Interstate Reliability Project will be the subject of a future filing with the Rhode Island Energy Facility Siting Board. Other components of the NEEWS Project are not jurisdictional to Rhode Island, and will be sited in Massachusetts or Connecticut.

2.4 Alternatives

An analysis was undertaken to evaluate the feasibility of alternatives to the proposed transmission system improvements. National Grid evaluated multiple alternatives including the "No-Build" alternative, alternatives using the existing ROW, alternative overhead routes, underground transmission alternatives, alternative system improvements, and non-transmission alternatives. Feasibility assessments, cost considerations, reliability assessments, and impact assessments were used to evaluate the alternatives. The results of the alternatives analysis confirm that the proposed Project will address the reliability issues in the most cost-effective manner while minimizing impacts to the social and natural environments.

2.5 Summary of Environmental Effects and Mitigation

The proposed Project will be designed and constructed in a manner that minimizes and mitigates the potential for adverse environmental impacts. The Project will have minimal impact on the geologic, soil, surface water, groundwater, and wetland resources of the Project ROW. VHB performed an inventory of the Project ROW and a review of record data to identify any rare, threatened, or endangered species within the ROW.

The proposed transmission line construction and substation modifications may cause a small loss of excavated soil due to water and wind erosion. This may result in minor siltation of water bodies and wetlands. However, these impacts will be short-term and localized. To ensure that these impacts are minimized, standard Best Management Practices (BMPs) such as the installation of erosion control devices (i.e., hay bales and silt fence) and the re-establishment of vegetation will be employed to minimize wetland and water quality impacts.

Construction of the Project will result in impacts to wetland resources caused by vegetation clearing, and the placement of fill required for pole structure construction. The design of the Project has been developed to reduce wetland impacts through avoidance, minimization, and compensation. Unavoidable wetland impacts associated with the construction of pole structures have been limited to

approximately 2,465 square feet of permanent biological wetland disturbance due to filling. Four transmission structures are proposed within FEMA mapped 100-year floodplain. Approximately 6.5 acres of tree clearing will be necessary for the construction of the new 345 kV transmission line (approximately 0.75 acres of the clearing is within wetland). National Grid will prepare a mitigation plan which will provide compensatory flood storage for lost flood storage volume and compensation for impacts to wetlands. Construction plans have been designed to avoid or minimize impact to rare, threatened or endangered species.

In addition to these mitigation measures, National Grid will retain the services of an environmental monitor throughout the entire construction phase of the Project. The purpose of the environmental monitor will be to ensure compliance with all applicable federal, state, and local permit conditions, to maintain strict adherence to National Grid construction practices, and to monitor effectiveness of BMPs and make adjustments as necessary.

2.6 Summary of Social Effects and Mitigation

Based on the location of the Project, the greatest potential for social impact is the interaction of the proposed facilities and ROW maintenance on current and future land uses. Because the Project is located within an established ROW, it will not require, nor will it lead to, long-term residential or business disruption. Temporary construction impacts primarily related to construction traffic and equipment operation are expected to be minor. The construction of the Project as described herein will not adversely impact the overall social and economic condition of the Project areas.

■

2.6.1 Cultural Resources

The Project ROW has been subject to initial cultural resources assessment studies and walkover survey. Subsequent study will concentrate on areas of known and reported resources and in zones of identified archaeological sensitivity. In areas of reported cultural resources and in those areas that have been assessed as archaeologically sensitive, appropriate investigations will be undertaken prior to any excavation so that potentially significant archaeological resources can be evaluated and are not inadvertently disturbed.

■

2.6.2 Visual Resources

The visual impact analysis performed for the Project indicates that the proposed transmission line will have a similar degree of visibility to that of the existing transmission lines. This is due in large part to the use of an existing transmission line

ROW for the proposed facilities, and the fact that additional tree clearing is not required for the majority of the ROW.

Topographic viewshed analysis indicates that areas of potential visibility for the proposed 345 kV transmission line total approximately five percent more than that of the existing line within a one-mile radius study area. Factoring the screening effect of vegetation into the viewshed analysis indicates that only 29 percent of the study area should have potential views of the Project.

Line-of-sight cross section analysis indicates that existing vegetation, structures and topography will be effective in screening views of the proposed 345 kV transmission line from most areas within and adjacent to the study area (including visually sensitive sites). Visibility along selected lines of sight was typically restricted to very limited areas, generally directly adjacent to the existing transmission corridor.

Field review confirmed the results of the cross section analysis and revealed that views of the existing line are largely restricted to the close range viewer in areas such as road crossings, open fields and some newer residential subdivisions adjacent to the transmission corridor. National Grid will evaluate the feasibility of using plantings to screen views of the proposed transmission structures.

■

2.6.3 Noise

Noise associated with electric facilities generally results from power transformers located within substations. This project proposes work at two substations. At the West Farnum substation in North Smithfield no new sound generating equipment is proposed, therefore no additional noise will be generated at this substation. At the Kent County substation in Warwick a new transformer is proposed to be installed. The existing noise conditions at this substation were evaluated by direct measurements over a four day period. These measurements confirm that the existing substation complies with the City of Warwick's noise ordinance. The sound produced by the additional transformer was modeled and the results indicate that there will not be any appreciable increase in the noise levels and the substation will remain in compliance with the City's noise ordinance.

Under normal operating conditions, transmission lines do not typically generate appreciable noise levels.

■

2.6.4 Electric and Magnetic Fields

National Grid developed a plan to optimize the phasing of the new and relocated transmission lines on the ROW. The plan minimizes magnetic fields at the edge of the ROW subject to constructability and structural constraints. Using optimized

phasing, edge of ROW electric and magnetic fields in the years 2012 and 2017 were calculated at projected annual average and annual peak load levels. The post-construction field levels were compared with field levels calculated for the existing arrangement of electric lines on the ROW under predicted 2012 annual average and annual peak loads. Because of the variations in the physical arrangement of lines on the ROW, some edge of ROW field levels will increase after the Project is completed and some will decrease. The results of the EMF calculations are presented in Sections 7.8 and 8.16 of this report.

2.7 Conclusion

Completion of the Project as proposed by National Grid will address the electric reliability needs of the Rhode Island area in a cost-effective manner which minimizes environmental and social impacts. Mitigation will be provided for all impacts to state and federal regulated wetland resources. Impacts to rare, threatened, or endangered species will be avoided through appropriate avoidance or minimization techniques. Similarly, impacts to cultural resources will be avoided through investigation and coordination with the Rhode Island Historical Preservation and Heritage Commission (RIHPHC). The potential for significant impact to other environmental or social receptors in the Project vicinity is expected to be minimal.

To the extent that impacts cannot be avoided, they will be addressed through mitigation techniques as discussed in Section 9 of this report.

3.0 Purpose and Need

National Grid is obligated to provide all customers with reliable electric service at the lowest possible cost while minimizing adverse environmental effects.

Transmission planning studies are performed to determine what facilities are needed to reliably supply electric power to National Grid customers. The Rhode Island Reliability Project, the subject of this filing, is a solution to one of the five problems identified in the NEEWS Planning studies. These studies, entitled the Southern New England Transmission Reliability Report 1, Needs Analysis (ISO New England Inc., January 2008) and New England East-West Solutions Report 2, Options Analysis (ISO New England Inc., June 2008), were conducted jointly by ISO-NE, National Grid and Northeast Utilities. This work was part of one of the most geographically comprehensive planning efforts to-date in New England, addressing five interrelated problems in three states and multiple service territories (refer to Figure 3-1). The analysis was aimed at addressing the weaknesses in southern New England. NEEWS will benefit all of the New England states by addressing the issues of regional transmission system reliability and constrained generation. The Interstate Reliability Project is a solution to another of the five identified problems and a part of NEEWS. The Rhode Island portion of the Interstate Reliability Project will be the subject of a future filing with the EFSB. The other NEEWS Projects are not jurisdictional to Rhode Island.

The purpose of the Rhode Island Reliability Project is to enable National Grid to continue to provide reliable electric supply to Rhode Island. The Project will improve the reliability of electric supply to this area by increasing the loading capability of the transmission system and maintaining acceptable voltages in the Rhode Island Area for conditions with all equipment in-service and for contingency conditions.

3.1 Reliability

All National Grid transmission facilities in New England are designed in accordance with the reliability criteria contained in the latest version of the National Grid Transmission Planning Guide (Transmission Planning Guide), the ISO-NE and NEPOOL standards, the NPCC criteria, and the NERC Reliability Standards (all of these documents will be referred to as the Planning Documents.)

These criteria are followed so that transmission system facility loadings remain within system capabilities and transmission equipment is kept within a reasonable range of voltages for normal and foreseeable contingencies, including first and second contingency events (see Section 3.2.2). The equipment loading capabilities are determined using maximum allowable equipment temperatures as criteria. The allowable temperatures are established by manufacturer's design, American National Standards Institute (ANSI) and other national standards, known material properties, or, in the case of a transmission line, the design basis of the line. The range of allowable voltage is established by manufacturer's design, and ANSI and other standards. The transmission system is designed to meet these deterministic criteria to promote the reliability and efficiency of electric service on the bulk power system and also with the intent of providing an acceptable level of reliability to the customers.

As described below, transmission planning studies determined that Rhode Island transmission facilities did not meet the reliability criteria prescribed by the Planning Documents referenced above. The reliability concerns included both thermal loading violations and voltage violations.

3.2 Transmission Planning Studies

The potential low voltage problems in Rhode Island and the need to increase thermal loading capability were identified by transmission planning studies. This section discusses in general how these studies are developed and conducted.

■

3.2.1 Methodology

Transmission planning studies are undertaken to determine what facilities are needed to maintain reliable electric power to specific geographic areas throughout the transmission system. The criteria and standards defined in the Planning Documents referenced above are used to assess the reliability of the system.

To begin a transmission planning study, the geographic area whose electric supply is to be examined is determined as well as the length of time the study will cover. Studies commonly look 10 years into the future. Using electric load forecasts for the chosen time period and the chosen geographic area, along with a computer model of the existing electrical system, "load flow" analyses are performed. These load flow analyses are used to determine how the existing system reacts to future load levels under normal and contingency conditions. This is known as contingency analysis, and is described in detail in Section 3.2.2. Thermal loadings are evaluated using the criteria provided in the Planning Documents. The thermal ratings of each element in the system are determined such that maximum use can be made of the equipment without damage or undue loss of equipment life.

The load flows are analyzed to determine whether any piece of equipment is carrying more electric current than the equipment is thermally rated for based on the assumed ambient conditions. Voltage levels are checked to determine that they are within acceptable limits. System stability, fault current levels, and operability are also evaluated. Finally, the effect of future loads is also considered.

After identifying problems that could occur on the electrical system under expected electrical loads and possible contingency situations, plans are then developed to mitigate the problems. Typically these plans call for replacing existing equipment or adding facilities to the electric system. The plans are developed and evaluated based on the reliability criteria as described in the Planning Documents. Other factors used to evaluate proposed plans include equipment standards and specifications, relaying practices, operational and maintenance considerations, safety, environmental impacts, and economics. The evaluation of electrical alternatives leads to a recommended plan that is summarized in a report.

In planning studies, the analyses in the 10–year term receive the most focus, but some screening analyses are also done in the more distant future to evaluate the robustness of the proposed plans from both a technical and economic perspective. The objective is to avoid building facilities that do not fit into the long-term needs of the system.

■

3.2.2 Contingency Analysis

Contingency analysis involves two levels of study. The first level is single contingency analysis (commonly referred to as N-1 analysis). It involves testing all possible single contingencies that could impact the area of interest. A single contingency represents a “single event”, such as a single transmission line outage, a single transformer outage, a single generator outage, a single capacitor outage, a double circuit tower (DCT) (double line) outage, a busbar outage, or a stuck breaker (double element) outage. The contingency is simulated and the effects of the contingency on the power system are studied. The system loadings and voltage levels are assessed to see if they meet criteria during the contingency event.

The second level of study is second contingency analysis (commonly referred to as N-1-1 analysis). This involves taking an element, critical to the area of interest, out of service (such as a 345 kV line, a 345/115 kV transformer, or a 115 kV line). With the element out of service, the system generation can then be adjusted and/or system switching can be done to best posture the system (within 30 minutes of the first contingency) in anticipation of a second contingency. Now, with an element out of service and the generation adjusted, single contingency analysis is run again (as described above).

Fixes for all loading and voltage violations found in the first or second contingency analysis are then proposed and verified through further analysis.

Contingency analysis is carried out for various system generation dispatches and system transfers in order to ensure that the area of interest is tested under conditions that reasonably maximize the electrical stress to the area.

3.3 Rhode Island Transmission System

Rhode Island's transmission network is made up of both 115 and 345 kV lines, with the 345 kV lines providing the majority of the electricity import and voltage support to the state.

The Rhode Island 115 kV system is tied to the southeastern Connecticut system by a 115 kV line from Kent County substation to Mystic Substation in Connecticut. Rhode Island is electrically tied to Massachusetts via two 115 kV lines to Millbury Substation and five 115 kV lines that ultimately terminate at Brayton Point and Somerset Substations. Several of these 115 kV tie lines are relatively long and weak in terms of import capability, which make them considerably less effective than the 345 kV tie lines for the transfer of electricity into the state and support of Rhode Island area voltages.

The Rhode Island 345 kV system has only two lines tied to the New England 345 kV transmission system, with both lines connecting to the West Farnum 345 kV Substation in North Smithfield. Kent County Substation, a key Rhode Island load serving substation, has only one 345 kV line connecting to it (from the West Farnum 345 kV Substation).

Finally, Rhode Island has only a limited number of generating facilities connected to the 115 kV transmission system. This combination of limited 345 kV connections and limited generation on the 115 kV system makes Rhode Island vulnerable to transmission line and equipment overloads and area voltage violations under contingency conditions (particularly for N-1-1 second contingency conditions).

3.4 Need Description

The results of the Needs Analysis are based on assessments of the transmission system under projected load and generation conditions as established for the Rhode Island area at the time of the study.

■

3.4.1 Rhode Island Transmission Reliability Concerns

Transmission system reliability issues and dependence on local generation are the major concerns for the Rhode Island area. A number of overloads and voltage violations have been observed on the transmission facilities while analyzing the conditions for the system.

The reliability problems on the Rhode Island 115 kV system are caused by a number of contributing factors (both independently and in combination), including high load growth (especially in southwestern Rhode Island and the coastal communities), possible generation unit unavailability, and transmission outages (planned or unplanned). Additionally, the Rhode Island 115 kV system is constrained when one of the Rhode Island 345 kV lines is out of service. The 345 kV transmission lines critical for serving load on the Rhode Island 115 kV system are the following:

- Line 328 (Sherman Road Substation to West Farnum Substation)
- Line 315 (Brayton Point Substation to West Farnum Substation)
- Line 332 (West Farnum Substation to Kent County Substation)

An outage of any of these 345 kV transmission lines results in limits to power transfer into the Rhode Island 115 kV transmission system. For line-out conditions, the next critical contingency would involve the loss of a second 345 kV or a critical 115 kV line or the loss of a 345/115 kV autotransformer.

The most severe dispatch and contingency conditions (without the Rhode Island Reliability Project in service) are shown in Table 3-1. These conditions result in major blackouts over a wide area. There are many other dispatch and contingency conditions that result in “lesser” criteria violations that are not included in this table. This contingency testing was run for the 2012 extreme summer forecast (90/10) peak-load level. Figure 3-2 depicts the effects of a Rhode Island low voltage contingency condition.

Table 3-1 Most Severe Planning Criteria Violations in Rhode Island

Dispatch Stress	First Contingency	Second Contingency	Effect on Rhode Island System without the RI Reliability Project	Mitigation without the RI Reliability Project	Effect on Rhode Island System with the RI Reliability Project
Stressed Dispatch on a peak load day (critical 115 kV RI generator out of service)	**332** 345 kV Line (W. Farnum to Kent County)	**S-171S** 115 kV line (or any breaker failure contingency that causes the loss of the S-171S)	**Voltage Collapse** for a large part of Rhode Island (causing a black-out)	**Over 500 MW** of load must be **shed** after the first contingency but prior to the second contingency	No criteria violations
Stressed Dispatch on a peak load day (critical 115 kV RI generator out of service)	**332** 345 kV Line (W. Farnum to Kent County)	**T-172S** 115 kV line (or any breaker failure contingency that causes the loss of the T-172S)	**Voltage Collapse** for a large part of Rhode Island (causing a black-out)	**Over 500 MW** of load must be **shed** after the first contingency but prior to the second contingency	No criteria violations
Normal Dispatch on a peak load day (all critical 115 kV RI generators in service)	**332** 345 kV Line (W. Farnum to Kent County)	**S-171S** 115 kV line (or any breaker failure contingency that causes the loss of the S-171S)	**Severe Overloads**	**300 MW** of load must be **shed** after the first contingency but prior to the second contingency	No criteria violations
Normal Dispatch on a peak load day (all critical 115 kV RI generators in service)	**332** 345 kV Line (W. Farnum to Kent County)	**T-172S** 115 kV line (or any breaker failure contingency that causes the loss of the T-172S)	**Severe Overloads**	**300 MW** of load must be **shed** after the first contingency but prior to the second contingency	No criteria violations
Stressed or Normal Dispatch on a peak load day	**332** 345 kV Line (W. Farnum to Kent County)	**K-189** 115 kV line (or any breaker failure contingency that causes the loss of the K-189)	**Significant Overload**	**100 MW** of load must be **shed** after the first contingency but prior to the second contingency	No criteria violations

3.5 Conclusion

In summary, the needs analysis demonstrates that the Rhode Island transmission capabilities will be inadequate to meet NERC, NPCC, and ISO-NE reliability standards and criteria for the projected load and generation conditions in the Rhode Island area. These problems become increasingly more severe as peak load continues to grow. The problems demonstrate a need to construct new transmission facilities to significantly improve the reliability of the transmission system serving Rhode Island.

Given the lead times necessary for permitting and other pre-construction activities, as well as the time required for construction itself, these problems constitute needs that must be addressed now.

The Rhode Island Reliability Project proposes the following reinforcements to address the reliability problems described in this section:

- A new 345 kV transmission line from West Farnum Substation to Kent County Substation.
- An additional 345/115 kV transformer at Kent County Substation.
- Reconductoring of three 115 kV transmission lines and various substation terminal equipment upgrades.

These reinforcements are described in detail in the following chapters of this report.

4.0 Proposed Action and Project Descriptions

4.1 Introduction

In this section of the Environmental Report, the overall scope of the Rhode Island Reliability Project is identified, and the individual projects and facilities comprising the Project are described. This section of the report also details National Grid's construction and ROW maintenance practices, safety and public health considerations, estimated Project costs, and the anticipated schedule for the Project.

National Grid is proposing to construct a new 345 kV transmission line (359 Line) on an existing ROW between the West Farnum Substation located on Greenville Road in North Smithfield, and the Kent County Substation located on Cowesett Road in Warwick. This new 345 kV transmission line will be approximately 21.4 miles in length, passing through North Smithfield, Smithfield, Johnston, Cranston, West Warwick, and Warwick, Rhode Island.

The existing ROW presently contains one 345 kV transmission line (332 Line), two 115 kV transmission lines (S-171 and T-172 Lines) and, in places, 23 kV sub-transmission lines. In order to create adequate space within this existing ROW corridor to enable the construction of the proposed 345 kV transmission line, National Grid proposes to relocate and reconstruct the existing S-171 and T-172 115 kV transmission lines on more compact vertically configured structures. The reconfiguration of the existing 115 kV lines in this manner will create an open "slot" on the ROW in which the proposed new 345 kV transmission line can be constructed.

National Grid is also proposing to install one new 345 kV autotransformer and other equipment at the Kent County Substation to accommodate the new 345 kV transmission line. Relocations of 115 kV equipment within the Kent County Substation require the relocation of several spans of the existing G-185S and L-190 115 kV transmission lines south of the substation. Similarly, equipment additions at the West Farnum Substation in North Smithfield are proposed to integrate the new 345 kV line into the transmission network. Short segments of the 332 345 kV transmission line and two existing 115 kV transmission lines (H-17 and B-23 Lines) must be relocated in the vicinity of the West Farnum Substation to facilitate the construction.

Lastly, National Grid proposes to reconductor portions of three 115 kV transmission lines to alleviate potential overloads on these transmission lines. Reconductoring involves replacing the conductors of existing transmission lines with new larger conductors which are capable of carrying more power. The S-171 and T-172 115 kV transmission lines from the Hartford Avenue Substation to the Johnston Taps will be reconductored coincident with the reconstruction of the lines. The G-185N 115 kV transmission line from Drumrock Substation to Kent County Substation will also be reconductored.

Table 4-1 provides information on each component of the proposed Rhode Island Reliability Project.

Table 4-1 Project Description

Project Component	Length (miles)	Towns	Proposed Action
New 359 345 kV Transmission Line	21.4	North Smithfield, Smithfield, Johnston, Cranston, West Warwick, and Warwick	Construct a new 345 kV transmission line on existing ROW from the West Farnum Substation to the Kent County Substation.
S-171 and T-172 115 kV Transmission Lines	20.0	North Smithfield, Smithfield, Johnston, Cranston, West Warwick, and Warwick	Relocate, reconstruct and in segments reconductor the existing S-171 and T-172 115 kV transmission lines between West Farnum Substation and the vicinity of Kent County Substation.
332 345 kV Transmission Line	0.2	North Smithfield	Relocate the existing 332 345 kV transmission line in the vicinity of the West Farnum Substation.
H-17 115 kV Transmission Line	0.3	North Smithfield	Relocate the existing H-17 115 kV transmission line between West Farnum Substation and 0.15 miles south of Greenville Road.
B-23 115 kV Transmission Line	0.2	North Smithfield	Relocate the existing B-23 115 kV transmission line proximate to the West Farnum Substation.
G-185S/L-190 115 kV Transmission Lines	0.2	Warwick	Relocate several spans of the existing G-185S and L-190 115 kV transmission lines south of the Kent County Substation.
G-185N 115 kV Transmission Line	1.0	Warwick	Reconductor the existing G-185N 115 kV transmission line from the Kent County Substation to the Drumrock Substation.
Kent County Substation	----	Warwick	Upgrade existing equipment, add equipment, and add one 345 kV autotransformer to accommodate the proposed 345 kV transmission line.
West Farnum Substation	----	North Smithfield	Install new equipment to accommodate the proposed 345 kV transmission line.

4.2 Overall Scope of the Proposed Action

The Rhode Island Reliability Project will expand and significantly reinforce the existing transmission system in Rhode Island. The proposed transmission system improvements will provide an additional 345 kV transmission line from the West Farnum Substation in North Smithfield to the Kent County Substation in Warwick and will increase the capacity of three 115 kV lines.

The individual projects comprising the Rhode Island Reliability Project are described in more detail in the following sections. The general locations and routes of the proposed transmission system additions and reinforcements are shown on Figures 2-1 and 2-2.

4.3 Description of the Project Components

The following sections of this report provide a detailed description of the components of the proposed Rhode Island Reliability Project.

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4.3.1 Construct a New 345 kV Transmission Line from West Farnum Substation to Kent County Substation

As part of the Rhode Island Reliability Project, National Grid proposes to construct a new 345 kV transmission line from the existing West Farnum Substation, located on Greenville Road in North Smithfield, to the Kent County Substation, located on Cowesett Road in Warwick, a distance of approximately 21.4 miles. The new 345 kV transmission line will be constructed within an existing ROW held by National Grid and used for transmission purposes since the 1950s. The new 345 kV transmission line will pass through portions of North Smithfield, Smithfield, Johnston, Cranston, West Warwick, and Warwick. The route of the new 345 kV transmission line is illustrated on Figure 4-1. The existing ROW is generally 250 feet wide and presently contains the 332 345 kV transmission line, the S-171 and T-172 115 kV transmission lines, and, in places, 23 kV sub-transmission lines.

The new 345 kV transmission line will be constructed east of and adjacent to the existing 332 345 kV line on the ROW as illustrated in Figure 4-2, Sheets 1 to 5.

The new 345 kV transmission line will be constructed primarily with steel pole davit arm structures set upon reinforced concrete caisson foundations. These new structures will support conductors in a delta configuration along with two shield wires at the top of the structure. The conductors of the new 345 kV transmission line will be 2 – 954

kcmil ACSR "Rail" with an 18-inch conductor bundle spacing. One shield wire of the new 345 kV transmission line will be 3/8-inch extra high strength (EHS) steel wire, and the other shield wire will be optical ground wire (OPGW) to support high-speed relaying and communications requirements. Typical structure height will be 100 feet. A detail of a typical proposed structure for the new 345 kV transmission line is provided as Figure 4-3. Other structure types may be required to support line angle and dead-end locations. Wherever possible, the new structures will be placed adjacent to existing structures of the 332 345 kV transmission line. Preliminary design indicates that a total of 241 structures will be required to support the new 345 kV transmission line.

Tree clearing will be required in the ROW in Warwick along a portion of Hardig Road to the Kent County Substation, a distance of approximately 0.7 miles. This will result in a variable amount of clearing depending on the existing tree line. As shown on Figure 4-2, Sheet 5 of 5 the new 345 kV line requires a minimum 64-foot cleared offset from the centerline of each structure to the tree line. This 64-foot minimum offset will require tree clearing along this 0.7 mile segment that varies from no clearing up to 75 feet, and totals approximately 6.5 acres of required tree removal. Tree trimming and vegetative maintenance will be performed along the ROW as necessary to facilitate construction access and installation of erosion and sedimentation controls, as described in Section 4.4.1

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4.3.2 Relocate and Reconstruct Existing S-171 and T-172 115 kV Transmission Lines from Vicinity West Farnum Substation to Vicinity Kent County Substation

As part of the Rhode Island Reliability Project, National Grid proposes to relocate and reconstruct its existing S-171 and T-172 115 kV transmission lines from the vicinity of the West Farnum Substation in North Smithfield to the vicinity of the Kent County Substation in Warwick, a distance of approximately 20.0 miles. This reconfiguration is being done in order to create an open ROW "slot" in which to construct the proposed new 345 kV transmission line described in Section 4.3.1. Figure 4-2, Sheets 1 through 5, provide cross-section drawings showing the configuration of transmission lines and structures following the completion of the Rhode Island Reliability Project.

The S-171 and T-172 transmission lines will be reconstructed between the new 359 line and the easterly edge of the ROW, as shown in Figure 4-2, Sheets 1 to 4. To minimize the space which the S-171 and T-172 lines occupy in the ROW, the 115 kV lines will each be constructed primarily with steel pole davit arm structures set upon reinforced concrete caisson foundations. These new structures will support power conductors in a vertical configuration along with one shield wire at the top of the structures. The conductors of the reconfigured S-171 and T-172 transmission lines

will be primarily 1590 kcmil ACSR "Falcon". Between Hartford Avenue Substation and the Johnston Taps, the S-171 and T-172 115 kV transmission lines will be reconductored with 1590 kcmil ACSS "Falcon" coincident with the reconstruction (see Figure 4-5). A shield wire will be carried at the top of each of the reconfigured 115 kV lines.

Typical height of the new structures is 90 feet. A detail of a typical proposed structure for the reconfigured S-171 and T-172 115 kV transmission lines is provided as Figure 4-4. Other structure types may be required to support line angle locations, dead-end locations, or locations of loadbreak switches. Whenever possible, the new structures of the reconfigured 115 kV lines will be placed adjacent to existing structures of the 332 345 kV transmission line. This will provide the ROW with a more symmetrical and aesthetic appearance and will enable the use of existing ROW access roads to the fullest extent possible. Preliminary design indicates that a total of 224 structures will be required to support the reconfigured T-172 115 kV transmission line and 226 structures will be required to support the reconfigured S-171 115 kV transmission line.

The S-171 and T-172 transmission lines are tapped into the following substations: Farnum Pike, Wolf Hill, Putnam Pike, Hartford Avenue, Johnston, FPL Generating Plant and West Cranston. As part of the project to reconstruct S-171/T-172, the taps will be rebuilt or reconfigured as necessary (Refer to Figure 4-1.)

■

4.3.3 Relocate Existing H-17 115 kV Transmission Line in the Vicinity of West Farnum Substation

National Grid proposes to relocate its existing H-17 115 kV transmission line between the West Farnum Substation in North Smithfield to a point approximately 0.15 miles south of Greenville Road, a total distance of approximately 0.3 miles. This will create an open ROW "slot" in which to construct the proposed new 345 kV transmission line. The H-17 115 kV transmission line will be relocated approximately 30 feet to the east in this area.

The relocated 115 kV line will be constructed primarily with wooden H-frame structures supporting power conductors in a horizontal configuration along with two shield wires at the top of the structure. A detail of a typical proposed structure for the relocated H-17 115 kV transmission line is provided as Figure 4-6. Preliminary design indicates that a total of seven structures will be required to support the relocated segment of the H-17 115 kV transmission line. The H-frame structures will consist of direct embedded wood poles.

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4.3.4 Relocate B-23 Transmission Line at West Farnum Substation

In order to facilitate the equipment additions and modifications at West Farnum Substation, it will be necessary to relocate several spans of the B-23 115 kV transmission line to provide adequate clearance from the proposed substation equipment. The existing B-23 Line exits the substation to the north and runs around the perimeter of the substation, eventually heading northwest along the existing ROW toward Sherman Road Substation. The relocation will eliminate one existing structure within the substation to make room for other equipment modifications within the substation (refer to Figure 2-2, Sheet 1 of 40).

■

4.3.5 Reconductor G-185N 115 kV Transmission Line from Drumrock Substation to Kent County Substation

As part of the Rhode Island Reliability Project, National Grid proposes to reconductor its existing G-185N 115 kV transmission line from the Drumrock Substation to the Kent County Substation, a distance of approximately 1.0 mile along existing ROW in Warwick. The route of the G-185N line is shown on Figure 4-7. A typical cross-section of the ROW is shown on Figure 4-8.

The G-185N transmission line consists of several different structure types. Single shaft steel pole "Y" structures are located at both ends of the line, in the vicinity of the Drumrock Substation and the Kent County Substation. Between the substations, the G-185N line is carried on wood pole H-frame structures and single shaft steel structures. As a result of changes in National Electrical Safety Code (NESC)[4] loading criteria, the existing G-185N transmission line structures will be replaced primarily with H-Frame structures to provide the necessary strength and ground clearances required for the new, larger conductors.

All of the existing 795 kcmil ACSR conductors of the G-185N transmission line will be replaced with new 1590 kcmil ACSR conductors. The two existing shield wires of the transmission line will be replaced with one new 3/8-inch EHS steel wire and one new OPGW. Existing insulators on all structures will be replaced with new 10-disc insulator strings.

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4 The NESC is an American National Standards Institute (ANSI) standard which covers basic provisions for safeguarding of persons from hazards arising from the installation, operation, or maintenance of 1) conductors and equipment in electrical supply stations, and 2) overhead and underground electric supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment.

No tree clearing will be required along the ROW to facilitate the proposed reconductoring of the G-185N 115 kV transmission line. Tree trimming and vegetative maintenance will be performed along the ROW as necessary to facilitate construction access and installation of erosion and sedimentation controls, as described in Section 4.4.1.

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4.3.6 Modify Kent County Substation

The Kent County Substation is located on Cowesett Road in Warwick, Rhode Island. As described in Section 4.3.1, the new 345 kV transmission line is proposed to be constructed from the existing West Farnum Substation in North Smithfield to the Kent County Substation. To accommodate this new 345 kV transmission line position within the Kent County Substation, the substation must be modified with various equipment upgrades and additions, including:

- Install a new 345 kV bay to include three new 345 kV circuit breakers
- Install a third 345/115 kV 269/358/448 MVA autotransformer (the second transformer will be added in 2009 as part of a separate project)
- Install a new 115 kV bay to include two new 115 kV circuit breakers
- Relocate several spans of the existing G-185S and L-190 115 kV transmission lines south of the substation to accommodate the new and relocated equipment.

Figure 4-9 depicts the existing conditions and the proposed layout of the Kent County Substation. Figure 2-2, Sheet 38 of 40 depicts the relocated G-185S and L-190 line segments.

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4.3.7 Equipment Additions at West Farnum Substation

The West Farnum Substation is located on Greenville Road in North Smithfield, Rhode Island. To accommodate the new 345 kV transmission line position within the West Farnum Substation, the substation must be modified with various equipment upgrades and additions, including:

- Install a new 345 kV Gas Insulated Switchgear (GIS) bay to include three new 345 kV circuit breakers, associated disconnect switches and buswork
- Install a new control house for 345 kV relay and control equipment
- Install a new GIS equipment building
- Install a new line termination structure for the new 345 kV line.

Figure 4-10 depicts the existing conditions and the proposed layout of the West Farnum Substation.

4.4 Construction Practices

The proposed transmission system improvements will be constructed using conventional overhead electric power line and substation construction techniques. Hours of construction will conform to local requirements.

The transmission line work will be constructed in a progression of activities which will normally proceed as follows:

1. ROW vegetation maintenance/clearing and installation of erosion and sediment controls.
2. Access road improvements and maintenance.
3. Installation of foundations.
4. Installation of pole structures.
5. Conductor and shield wire installation.
6. Removal of old structures and/or conductor.
7. Restoration of the ROW.

Each of these transmission line construction activities is described in the following sections. Substation modification activities are described in Section 4.4.7.

National Grid will retain the services of an environmental monitor throughout the entire construction phase of the Project. The purpose of the environmental monitor will be to perform site inspections, ensure compliance with all applicable federal, state, and local permit conditions, maintain strict adherence to National Grid policies, and monitor effectiveness of and propose modifications to BMPs.

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4.4.1 ROW Vegetation Maintenance/Clearing and Installation of Erosion and Sediment Controls

To facilitate construction equipment access along the majority of the ROW and at structure sites, tree trimming or other vegetative maintenance, such as mowing, may be required in select areas. This will be done to provide access to proposed structure locations to facilitate safe equipment passage, to provide safe work sites for personnel within the ROW, and to maintain safe and reliable clearances between vegetation and transmission line conductors. More information on National Grid's ROW maintenance practices is provided in Section 4.4.7 of this report.

From the vicinity of Hardig Road south to the Kent County Substation, trees within the ROW must be removed to provide adequate clearance to electrical conductors

and access for construction and maintenance of the transmission line. Tree clearing operations will include the removal of all tall growing woody species within the required portions of the ROW. The clearing will be performed in a manner which will maximize conservation of natural resources, and minimize soil disturbance and erosion.

Prior to clearing, the boundaries of wetlands will be clearly marked to prohibit unauthorized vehicular encroachment into wetland areas. Tall growing trees will be cut close to the ground leaving the stumps and roots in place, except where grading is required for access road construction or at structure sites. The clearing will be performed so that low-growing vegetation will be preserved wherever possible. The clearing and maintenance methods will encourage the growth of low-growing shrubs, ferns, wildflowers and grasses, thus helping to stabilize the cleared areas against erosion and providing a degree of natural vegetation control. Cleared trees will be chipped and removed from the site.

Special clearing methods will be used in environmentally sensitive areas such as wetlands. Where possible, cut trees will be removed from wetland areas then chipped and removed from the Project site. In certain wetlands where soft organic substrates exist and where removing felled trees would adversely impact the wetland, cut trees will be limbed and left to decompose in place. Where the ROW crosses streams and brooks, vegetation along the stream bank will be selectively cut using standard forestry equipment. Care will be taken to minimize the disturbance of soils and potential for project related erosion.

Equipment typically used during the ROW clearing phase of construction will include motorized tree shears, log skidders, chippers, and chain saws. Pickup trucks will be used to transport work crews and handheld equipment to work sites. Box trailers will be used to remove wood chips from work sites. Grading equipment such as a bulldozer may be used to prepare a level work area on which to set equipment for the clearing operation. Low-bed trailers will be used to transport tracked equipment which cannot be operated on public roads, from a staging area to the work site.

Following the ROW clearing and vegetation maintenance activities, proper erosion control devices, such as hay bales and siltation fencing, will be installed in accordance with approved plans and permit requirements. The installation of these erosion control devices will be supervised by National Grid's environmental monitor. The devices will function to mitigate construction-related erosion and sedimentation, and will also serve as a physical boundary to delineate resource areas and to contain construction activities within approved areas.

4.4.2 Access Road Construction and Maintenance

Access roads are required along the ROW to provide the ability to construct, inspect, and maintain the existing and proposed transmission line facilities. For the proposed Project, existing access roads are suitable in a majority of the areas. In some cases, existing access roads will require maintenance or upgrading to support the proposed construction activities. It may be necessary to establish new access roads in certain locations along the ROW to facilitate new construction. In all cases, maximum feasible use will be made of existing access roads along the ROW.

Any new access roads will be located to minimize disturbance to environmentally sensitive areas and to abutters along the ROW. New access roads will be established over native soils wherever possible to minimize impact to the soil structure and to limit the amount of imported fill material. Access roads will follow the existing contours of the land as closely as possible, and, where practical, will avoid severe slope conditions. Roads will be constructed to avoid altering existing drainage patterns.

Special consideration will be given to construction of access roads within or adjacent to environmentally sensitive areas in order to minimize the potential impacts associated with construction. If it is necessary to grade soil in archaeologically sensitive areas, National Grid will conduct investigations of archaeological resources in accordance with a plan that has been approved by the RIHPHC prior to installing the access road.

Access across wetland areas and streams, where upland access is not available, will be accomplished by the temporary placement of swamp mats. Swamp mats consist of timbers which are bolted together and placed over wetland areas so as to distribute equipment loads and minimize disturbance to the wetland and soil substrates. Such temporary swamp mat access roads will be removed following completion of construction.

Any access road construction will be carried out in compliance with the conditions and approvals of the appropriate federal and state regulatory agencies. Exposed soils on access roads will be wetted and stabilized as necessary to suppress dust generation. Crushed stone aprons will be used at all access road entrances to public roadways to clean the tires of construction vehicles and minimize the migration of soils off-site.

Equipment typically used during the installation and maintenance of access roads will include dump trucks used to transport fill materials to work sites, and bulldozers, excavators, backhoes and graders which will be used to place fill materials or make cuts to achieve the proper access road profile. Cranes will be used to place swamp mats in locations where temporary access across wetland areas is

proposed. Throughout the Project, pick-up trucks will be used to transport crews and hand held equipment to work sites. Low-bed trailers will be used to transport tracked equipment which cannot be operated on public roadways to the work site.

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4.4.3 Installation of Foundations and Pole Structures

Installation of foundations and pole structures will include excavation for the foundation or pole structure, installation of the reinforced concrete foundation (required for most structures), erecting the structure, backfilling the excavation, and removal of old structures. Grading may be required at some structure locations to provide a level work surface for construction equipment and crews. Where structures are located in archaeologically sensitive areas, National Grid will conduct investigations for archaeological resources in accordance with a RIHPHC-approved plan prior to any site preparation or excavation.

If rock is encountered during excavation, rock removal can generally be accomplished by means of rock drilling. In the case of excavations for larger and deeper foundations, rock blasting could be necessary. If rock blasting is required, charges will be kept to the minimum required to break up the rock. Heavy mats will be used to contain the blast materials. Blasting activities will be performed in strict adherence to federal, state, and local regulations.

Direct embedment structures will require excavations ranging from approximately 10 to 15 feet in depth and three to six feet in diameter. Excavated material will be placed next to the excavation. Steel culvert casings will be used to support the sides of excavations. Once the structure has been properly positioned and plumbed within the hole, the excavation will be backfilled with the native soil or clean gravel, and tamped to provide structural integrity. Following the backfilling operation, any remaining excavation spoils will be spread over upland areas or removed from the site.

Dewatering may be necessary during excavations for foundations or structures near wetland areas. If there is adequate vegetation in upland areas to function as a filter medium, the water generally will be discharged to the vegetated land surface. Where vegetation is absent or where slope prohibits, the water will be pumped into a hay bale or silt fence settling basin which will be located in an upland area. The pump intake will not be allowed to rest on the bottom of the excavation throughout dewatering. The basin and all accumulated sediment will be removed following dewatering operations and the area will be seeded and mulched.

As previously discussed, most of the proposed transmission line structures will require reinforced concrete caisson foundations. Such foundations typically range from 15 to 30 feet in depth, and five to eight feet in diameter. Generally, steel casings will be used to support the sides of foundation excavations. Following the completion of foundation construction, excavated soil, clean gravel, or concrete will

be used to backfill around the foundation. The transmission structures are then erected upon the completed foundations. Any remaining excavation spoils are then spread over upland areas or removed from the site.

Equipment typically used during the installation of foundations and pole structures will include excavating equipment such as backhoes and clam shell excavators, rock drills and concrete trucks. Cranes will be used to erect structures. Hand held equipment, including shovels and vibratory tampers, will be used during the backfilling of foundations and pole structures. Dump trucks will be used to remove excavation spoils from the work site if necessary. Tracked equipment which cannot be operated on public roadways will be transported to the work site by means of a low-bed trailer.

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4.4.4 Conductor and Shield Wire Installation

Following the erection of transmission structures, insulators will be installed on the structures. Shield wires and conductors will then be installed using stringing blocks and wire stringing equipment. The wire stringing equipment is used to pull the conductors through the stringing blocks and to achieve the desired sag and tension condition. During the stringing operation, temporary guard structures or boom trucks will be placed at road and highway crossings, and at crossings of existing utility lines to ensure the public safety and the continued operation of other utility equipment. To minimize any additional disturbance to soils and vegetation, existing access roads will be used to the fullest extent possible in the placement of wire stringing equipment.

Temporary switching devices may also be installed to isolate sections of the existing S-171 and T-172 transmission lines during reconstruction.

The equipment which typically will be used during the conductor and shield wire installation operation includes puller-tensioners, conductor reel stands, and platform cranes. The booms of small cranes and bucket trucks may be used as guard structures during the stringing operation to prevent the conductors from falling across roads or other utility lines. Pickup trucks will be used to transport work crews and small materials to work sites.

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4.4.5 Removal and Disposal of Existing Line Components

The existing S-171 and T-172 transmission line structures and conductors will be removed to accommodate the relocated lines. The majority of the existing structure material will be salvaged (metal components, conductor wire, and shield wire) and

removed from the ROW. Those components not salvaged (wood poles and insulators) will be removed from the ROW to approved off-site disposal facilities.

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4.4.6 Restoration of the ROW

Restoration efforts, including final grading and installation of permanent erosion control devices, will be completed following the construction operations. All construction debris will be removed from the Project site and properly disposed of. All disturbed areas around structures and other graded locations will be seeded with an appropriate conservation seed mixture and/or mulched to stabilize the soils in accordance with applicable regulations. Temporary erosion control devices will be removed following the stabilization of disturbed areas. Pre-existing drainage patterns, ditches, roads, walls, and fences will generally be restored to their former condition. Where authorized by property owners, permanent gates and access road blocks will be installed at key locations to inhibit access onto the ROW by unauthorized persons or vehicles.

■

4.4.7 Substation Modifications

Within the fenced substation yards, concrete foundations will be constructed to support the various electrical equipment proposed. Most of the equipment foundations are shallow, with the exception of the proposed transformer foundation and the foundations of the structure which will receive the new transmission line into the substation. If dewatering is required for any of the foundation construction, the water will be pumped into temporary hay bale settlement basins. Spill prevention and countermeasure requirements will be addressed by the construction of a containment system around the proposed transformer. Any disturbed areas outside of the substation fences will be restored, stabilized and re-vegetated. Areas disturbed within the fence will be surfaced with a 6-inch thick layer of 3/4-inch crushed stone.

Conventional construction equipment, such as backhoes, dump trucks, concrete trucks, equipment delivery trucks and cranes, will be used during the substation construction.

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4.4.8 Environmental Compliance and Monitoring

Throughout the entire construction process, National Grid will retain the services of an environmental monitor. The primary responsibility of the monitor will be to enforce compliance with all federal, state, and local permit requirements and National Grid company policies. At regular intervals and during periods of prolonged precipitation, the monitor will inspect all locations to determine that the environmental controls are functioning properly and to make recommendations for

correction or maintenance, as necessary. In addition to retaining the services of an environmental monitor, National Grid will require the construction contractor to designate an individual to be responsible for the daily inspection and upkeep of environmental controls. This person will also be responsible for providing direction to the other members of the construction crew regarding matters such as wetland access and appropriate work methods. Additionally, all construction personnel will be briefed on project environmental issues and obligations prior to the start of construction. Regular construction progress meetings will reinforce the contractor's awareness of these issues.

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4.4.9 Construction Traffic

Construction-related traffic will occur over the proposed 24-month construction period. Access to the ROW for construction equipment will typically be gained from public roadways crossing the ROW in various locations along the route. Because each of the construction tasks will occur at different times and locations over the course of the construction, traffic will be intermittent at these entry roadways. Traffic will consist of various vehicle types ranging from pick-up trucks to heavy construction equipment.

National Grid's contractor will coordinate closely with the Rhode Island Department of Transportation (RIDOT) to develop acceptable traffic management plans for work within state highways. National Grid will coordinate with local authorities for work on local streets and roads. At locations where construction equipment must be staged in a public way, the contractor will follow a pre-approved work zone traffic control plan.

4.5 ROW Maintenance

As is the present case, vegetation along the ROW will continue to be managed 1) to provide clearance between vegetation and electrical conductors and supporting structures so that safe, reliable delivery of power to consumers is assured, and 2) to provide access for necessary inspection, repair, and maintenance of the facility. All vegetation maintenance is carried out in strict accordance with National Grid's "*ROW Vegetation Management Policies and Procedures,*" the requirements of the Rhode Island Department of Environmental Management (RIDEM) Division of Agriculture and federal regulations as administered by the Environmental Protection Agency.

Vegetation maintenance of the ROW will continue to be accomplished using selective application of herbicides and by hand and mechanical cutting. Herbicides will continue to be applied by licensed applicators to select target species. Herbicides are never applied in areas of standing water or within designated protective buffer areas associated with wells, surface waters, and agricultural areas.

National Grid currently utilizes a four- to five-year vegetation maintenance cycle on its transmission rights-of-way. National Grid's ROW vegetation maintenance practices encourage the growth of low-growing shrubs and other vegetation which provides a degree of natural vegetation control. Vegetation maintenance of the ROW under and adjacent to the transmission lines will be accomplished with methods identical to those currently used in maintaining vegetation along the existing ROW.

4.6 Safety and Public Health Considerations

National Grid will design, build, and maintain the facilities for the proposed Project so that the health and safety of the public are protected. This will be accomplished through adherence to all federal, state, and local regulations, and industry standards and guidelines established for protection of the public. Specifically, the proposed project will be designed, built, and maintained in accordance with the NESC. The facilities will be designed in accordance with sound engineering practices using established design codes and guides published by, among others, the Institute of Electrical and Electronic Engineers (IEEE), the American Society of Civil Engineers (ASCE), the American Concrete Institute (ACI), and the ANSI. Practices which will be used to protect the public during construction will include, but not be limited to, establishing traffic control plans for construction traffic on busy streets to maintain safe driving conditions, restricting public access to potentially hazardous work areas, and use of temporary guard structures at road and electric line crossings to prevent accidental contact with the conductor during installation.

Following construction of the facilities, all transmission structures and substation facilities will be clearly marked with warning signs to alert the public of potential hazards if climbed or entered. Trespassing on the ROW will be inhibited by the installation of gates and/or barriers at entrances from public roads.

A discussion of the current status of the health research relevant to exposure to EMF is attached as Appendix B. This report was prepared by Exponent, Inc.

4.7 Hazardous Substances

There are two substances to be used at the substations which are classified as hazardous. One is sulfur hexafluoride (SF6). SF6 is defined as hazardous by the U. S. Deptartment of Transportation (DOT). SF6 is a colorless, odorless and nonflammable gas used as an insulator in the switchgear in the substation. It is commonly used in lieu of insulating oil. When gas insulated switchgears are used indoors, as proposed at West Farnum, its hazard risk results from being an asphyxiate which displaces oxygen in the lungs when breathed. The building will be equipped with alarms to alert personnel of a release before entering the building. When gas insulated

equipment is used outdoors, any release concentration would be insignificant when exposed to the atmosphere. The proposed project will add a new outdoor gas insulated breaker to the eleven existing gas insulated breakers currently in use at the West Farnum substation.

Although SF6 is defined as hazardous by DOT, there is no risk of general public exposure because the switches are located inside the fenced substation yard. The switches are installed and maintained by trained technical staff and they are checked for integrity during inspections by National Grid personnel. The switches are made up of a number of isolated sections such that a leak would not drain all the gas but rather a small amount. Each section is gauged to an alarm which alerts National Grid personnel in the event of a leak.

The second hazardous substance to be used at both the West Farnum and Kent County substations is battery acid, which is contained in the control house batteries. The battery acid is toxic and corrosive. The battery acid has three levels of containment. Besides being in solid battery packs, it is housed inside the control building. The third level is a shallow berm surrounding the battery pack area. In the unlikely event of a leak of acid from batteries, the leak will be retained behind the berm until clean-up can begin. Hydrogen gas vapors from a leaking battery will be detected by sensors. If gases reach a 2 percent concentration, alarms are sounded in the National Grid control center and personnel will respond. The existing control house contains batteries and additional batteries will be enclosed in the proposed control house.

4.8 Project Community Outreach

National Grid has implemented a community outreach program for the benefit of transmission line abutters and others including the following activities:

- Efforts were made to reach individual abutters during the fall of 2007. As of August, 2008, 150 packages that included a fact sheet and other information were hand delivered to abutters along the route. National Grid has conducted approximately 80 face-to-face visits. These visits typically include a more detailed discussion of the Project. The community relations team plans additional one-on-one outreach during the summer and fall of 2008.
- Municipal officials along with other key stakeholders such as large commercial customers were invited to attend "Municipal Informational" sessions relating to the Project. National Grid hosted two such events with approximately 20 individuals attending. Attendees were provided a detailed overview of the project that included a virtual tour in Google Earth. These sessions were held in March, 2008.

- National Grid hosted three Open House events for the general public in June, 2008. Members of the project team were present to discuss the project in detail and answer any questions. Abutters, through the use of models developed in Google Earth, were able to see simulations of the proposed Project in relation to their home or any other location they requested. Approximately 32 abutters attended the three sessions.
- An email update was sent to abutters (who have provided e-mail contact information) and to local officials about various survey activities that were planned for the transmission line corridor during the summer of 2008.

National Grid is committed to continuing rigorous community outreach for the duration of the Project. During the construction phase of the Project, National Grid will appoint an ombudsman to serve as a contact point for abutters to the ROW.

4.9 Estimated Project Costs

National Grid prepared study grade estimates of the costs associated with the proposed Project. Study grade estimates are prepared prior to detailed engineering plans using historical cost data, data from similar projects, and other stated assumptions of the project engineer. The accuracy of study grade estimates is expected to be ± 25 percent. Estimated costs in 2008 dollars include costs of materials, labor and equipment, and Allowance for Funds Used During Construction (AFUDC). The estimated costs of the proposed Project are presented in Table 4-2.

Annual operation and maintenance activities for transmission lines include periodic ROW vegetation management, helicopter patrol, and miscellaneous route inspections. Since the ROW is occupied by existing transmission lines, any increase in operation and maintenance costs will be nominal.

Table 4-2 Estimated Project Costs

Project Components	Estimated Cost (2008 Dollars)
New 359 345 kV Transmission Line	$61,900,000
Relocate and Reconstruct S-171 and T-172 115 kV Transmission Lines	$115,600,000
Reconductor G-185N 115 kV Transmission Line	$3,800,000
Modify Kent County Substation	$22,700,000
West Farnum Substation 345 kV Equipment Additions and Upgrades	$39,400,000
H-17 115 kV Transmission Line Relocation	$750,000
B-23 115 kV Transmission Line Relocation	$250,000
G-185S/L-190 115 kV Transmission Line Relocation	$500,000
TOTAL ESTIMATED PROJECT COST	**$244,900,000**

Note: Estimate in 2008 dollars.

4.10 Project Schedule

National Grid anticipates starting construction of the facilities in the 3rd quarter of 2010, and having the facilities in service by the summer of 2012. This schedule is based on time duration estimates of project permitting and licensing, detailed engineering, materials acquisition, and construction. A high level schedule of major project tasks is shown in Figure 4-11.

5.0 Alternatives to the Proposed Action

An important goal in the planning and development of the proposed electric transmission system improvements is to ensure that the solution selected to meet the electrical system needs is the most appropriate in terms of cost and reliability, and that environmental impacts are minimized to the fullest extent possible. Analyses were undertaken to evaluate the feasibility of alternatives to the Project to ensure these objectives were met.

The alternatives analysis is presented in this section of the report. The alternatives analysis was performed in accordance with the EFSB criteria, which require an analysis of alternatives to the Project, reasons for the applicant's rejection of those alternatives, and estimates of facility costs for each alternative considered. In National Grid's alternatives analysis, a variety of alternative types were evaluated, including the "No-Build" alternative, alternative overhead routes for the new transmission line, overhead alternatives utilizing the existing ROW, underground transmission line alternatives, alternative system improvements, and non-transmission alternatives. Some of the alternatives were rejected based on feasibility assessments, or the inability of the alternative to address the identified system needs. Other alternatives which were found to be feasible and capable of addressing the identified need were further examined on the basis of estimated costs, operability, ability to meet need date, impact assessments and reliability assessments. The proposed Project was found to best balance the EFSB's criteria of cost, reliability, and minimization of impacts to the human and natural environment.

5.1 No-Build Alternative

As detailed in Section 3.0 of this report, the proposed transmission system improvements are required to satisfy the transmission planning criteria of National Grid, the ISO-NE and NEPOOL, NPCC, and NERC. Due to existing and projected electricity demand levels in the Rhode Island area and existing system limitations, these planning criteria require that the proposed transmission system improvements be completed in a timely manner to provide reliable electric supply to the area. Additionally, planning analysis has shown that contingency failures could lead to overloading of facilities throughout Rhode Island. Such an event could cause damage

to conductors and equipment, excessive sagging of conductors creating a safety risk due to reduced clearances, and low voltage conditions leading to possible voltage collapse and black-outs. The No-Build alternative would be unable to meet the identified system needs and therefore is not an acceptable alternative.

5.2 RI Reliability Electrical Alternatives

There were three electrical alternatives which were explored to meet the identified needs of the Rhode Island area. The first alternative was the proposed Project as presented in Section 4 of this filing. The other two electrical alternatives are discussed in the following sections.

■

5.2.1 New 345 kV Line from Brayton Point Substation to Kent County Substation

One electrical alternative considered was the construction of a new 345 kV transmission line from Brayton Point to Franklin Square Substation to Hartford Avenue to Kent County Substations. This option attempted to resolve some of the transmission bottlenecks by interconnecting the three substations of Brayton Point, Hartford Avenue (which would be a new 345 kV substation), and Kent County. The system modifications required for this option included:

- Construct new 345 kV line from Brayton Point to Franklin Square Substation.
- Convert the existing E105 and F106 lines from 115 kV to a single 345 kV circuit.
- Construct a new 345 kV yard at Hartford Avenue Substation.
- Construct a new 345 kV line from Hartford Avenue Substation to Kent County Substation.

Analysis showed that this electrical alternative tended to push far too much power from Brayton Point to West Farnum and Kent County, and thus heavily overloaded transmission system elements in Rhode Island. For certain contingencies under some dispatch scenarios, very low voltages were observed on the Rhode Island 115 kV system that would be difficult to mitigate. Because of poor electrical performance, this electrical alternative was not considered further.

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5.2.2 Two New 115 kV Cables from Franklin Square Substation to Sockanossett Substation

This electrical alternative considered the construction of two new 115 kV underground lines between Franklin Square Substation in Providence and Sockanossett Substation in Cranston. These underground cables would strengthen

the 115 kV transmission system that connects the Providence area to Southern Rhode Island. It was determined that this alternative does not perform well under second contingency system conditions. When the existing 345 kV line from West Farnum Substation to Kent County Substation (Line 332) is out of service, various second contingencies cause significant 345/115 kV transformer and 115 kV line overloads. The conclusion is that these two 115 kV cables do not provide a viable alternative to the second 345 kV line between West Farnum Substation and Kent County Substation.

■

5.2.3 Conclusion

After examining three electrical alternatives, it was determined that only the proposed alternative of a new 345 kV line between West Farnum and Kent County addressed the needs and reliability concerns of the Rhode Island area transmission system. Therefore, the other electrical alternatives were abandoned from further consideration.

5.3 Non-Transmission Alternatives

National Grid retained ICF Resources LLC (ICF) to prepare a study of non-transmission alternatives, on both the supply and demand side, to determine if such alternative resources have the potential to meet the required transmission reliability criteria and displace or defer the need for the Rhode Island Reliability Project.

To analyze the effect of non-transmission alternatives on the Rhode Island Reliability Project, ICF considered the addition of demand resources (including distributed generation), traditional generation supply, and combined heat and power (CHP) supply options. ICF examined the impact of a large total combined penetration of these resources on the overall reliability of the area as determined through power-flow modeling analysis at peak conditions for pre- and post-Rhode Island Reliability Project cases.

Based on the results of the analysis performed for this study that included projected new generation, DSM, and CHP resources, ICF determined that the Rhode Island Reliability Project is critical to the reliable operation of the New England transmission grid, and in particular, the Rhode Island transmission system. Further, ICF found that non-transmission alternatives to the Project were not satisfactory or sufficient in nature to displace or defer the need for the Project. This conclusion is supported by results of the power-flow analysis which indicate that, despite the addition of generation, DSM, and CHP resources, numerous transmission facility overloads and substation voltage violations could still potentially occur under system contingency conditions. The analyses further confirmed that the transmission reinforcements from the Rhode Island Reliability project would improve the

performance of the transmission system in the area of study and resolve the line and substation overloads and voltage violations.

The complete ICF report, entitled "Assessment of Non-Transmission Alternatives to the NEEWS Transmission Projects: Rhode Island Reliability Project", is attached as Appendix F.

5.4 Alternative Overhead Routes for the New 345 kV Transmission Line from the West Farnum Substation to the Kent County Substation

To verify that no preferable alternative overhead routes exist for the new 345 kV transmission line between the West Farnum Substation and the Kent County Substation, National Grid examined the general vicinity for possible alternatives to the proposed route using the existing developed ROW.

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5.4.1 Use of Undeveloped ROW held by National Grid

One alternative route considered by National Grid was to utilize the so-called Kent County to Sherman Road right-of-way which is an undeveloped ROW held by National Grid for future use. The route of this undeveloped ROW leaves Kent County Substation heading southwesterly through parts of Warwick, East Greenwich, and West Greenwich before entering Exeter and turning northwesterly around the southern tip of what was to become the Big River Reservoir. This undeveloped ROW then continues north through West Greenwich, Coventry, Foster, and Glocester before ending in Burrillville at the existing Sherman Road Substation. Existing developed ROW could then be utilized to link the proposed new 345 kV transmission line from the Sherman Road Substation to the West Farnum Substation. The length of this alternative route using what is largely undeveloped ROW is approximately 44 miles. The route of the alternative ROW is shown on Figure 5-1.

While this alternative undeveloped ROW would be suitable for a 345 kV transmission line, National Grid concluded that the resulting impacts would be far greater than those of using the existing developed ROW as proposed. To use the undeveloped ROW, it would be necessary to perform extensive tree clearing along the 44-mile route, as much of the ROW is presently forested. This alternative route would require the clearing of approximately 800 acres of forested lands. Because this alternative ROW is presently undeveloped, it would also be necessary to construct an access road network along the undeveloped corridor to facilitate the construction of the transmission line. This would result in more extensive ground disturbance and potential wetland impacts than the Project as proposed along the existing developed ROW.

Although this alternative undeveloped ROW is more than twice as long as the proposed route, the cost of constructing the new 345 kV line along the alternate route would be roughly equivalent to the Project as proposed. This is due to the fact that the use of the developed corridor as proposed necessitates the relocation and reconstruction of the existing S-171 and T-172 115 kV lines as described in Section 4.3.2. As such, the cost-savings that result in having a shorter route for the proposed 345 kV line along the existing developed corridor are offset by the need to relocate the existing lines in the corridor.

While the costs of using the alternative undeveloped ROW would be roughly equivalent to the project as proposed, National Grid concluded that it was strongly preferable to utilize the existing developed corridor so as to minimize impacts to the natural and social environments as required by the EFSB criteria. As such, the alternative of using the undeveloped ROW was rejected for the Rhode Island Reliability Project.

■

5.4.2 Use of Public Streets and Highways as an Alternative Overhead Route

National Grid examined the use of public streets and highways for the proposed 345 kV transmission line. The majority of the available road layouts would not be wide enough to accommodate an overhead 345 kV line while complying with applicable code clearances to adjoining property lines. As a result, this alternative would require the acquisition of new ROW along the edge of the existing roadways. This would add significantly to the cost and would delay the schedule of the Project. It would also cause impacts to and possible displacement of homes, businesses and other adjoining development and land uses. In addition, this alternative would render the new transmission line very visible along the heavily traveled roadways. Since there is a viable alternative that could be delivered in a more timely manner with lower impacts and costs, this option was rejected.

5.5 Overhead Alternatives Using the Existing ROW

Within the existing National Grid ROW, there were still several alternative configurations for constructing the proposed 345 kV transmission line that were considered. National Grid examined several different types of structures which could be used to support the transmission line conductors. National Grid examined these possible alternatives in detail to determine the advantages and disadvantages of each, as compared to the proposed option of installing the new 345 kV transmission line on steel pole davit arm structures. National Grid assessed the implications of utilizing alternative structure types on criteria such as project cost, reliability,

visibility of the structures, wetlands, and the level of disturbance caused by construction. The following sections describe the alternatives considered and their advantages and disadvantages.

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5.5.1 Construct New 345 kV Transmission Line Using H-frame Structures

As proposed, the new 345 kV transmission line will use steel pole davit arm structures to support the conductors in a delta configuration along with two shield wires (refer to Figure 4-3). As an alternative, National Grid evaluated using H-frame structures to support the new wires. H-frame structures consist of two pole shafts connected with a horizontal cross-arm from which the conductors are suspended. A shield wire is carried at the top of each of the pole shafts. The H-frame structure alternative was determined to have the following advantages and disadvantages relative to the proposed davit arm structure:

- H-frame structures would be 20 feet shorter than davit arm structures on average, and as such would be marginally less visible in terms of their height.
- H-frame structures and davit arm structures would be comparable in terms of their allowable span lengths, and as such, both designs would utilize approximately the same number of structures along the transmission line route.
- H-frame structures and davit arm structures are comparable in terms of their structural reliability.
- H-frame structures and davit arm structures are comparable in terms of their electrical reliability and performance.
- H-frame structures would have a wider configuration than davit arm structures, utilizing more room on the ROW. Use of H-frame structures would necessitate that the existing ROW be widened through the acquisition of additional rights along the entire 21-mile length, causing impacts to and possibly displacing existing development and land uses adjacent to the ROW. Widening the ROW would also require additional tree clearing to construct the new facilities.
- H-frame structures would increase the installed cost of the new 345 kV transmission line significantly due to the need to acquire additional land and land rights along the ROW.
- The use of H-frame structures would significantly extend the project delivery timeframe due to the need to acquire additional land and land rights, possibly through condemnation actions in some cases. As such, the project would likely not be able to be delivered in the timeframe required to support the reliability needs of the region.

After considering the relative advantages and disadvantages of utilizing H-frame structures, National Grid concluded that utilizing the proposed davit arm structures for constructing the new 345 kV transmission line offered more advantages, created fewer impacts, and was a more cost-effective and timely solution than the H-frame alternative.

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5.5.2 Construct the New 345 kV Transmission Line or the Reconstructed 115 kV Lines Using Double-Circuit Davit Arm Structures

As an alternative to constructing the new 345 kV transmission line using single-circuit davit arm structures, National Grid also evaluated utilizing a double-circuit structure to carry the transmission lines along the corridor. Pairing up either the existing 345 kV line with the proposed 345 kV line on a common set of structures, or pairing up the 115 kV lines on a common set of structures would introduce the possibility of a common mode failure. Examples of common mode failure include a single event such as a lightning strike or a single transmission line fault, which could cause both transmission lines on the structures to be interrupted. Either of these arrangements would violate planning criteria. However, one way to accomplish a double circuit alternative would be to pair a 345 kV line with one of the existing 115 kV lines.

National Grid assessed the double-circuit alternative and determined that it had the following advantages and disadvantages relative to the proposed single-circuit davit arm structure:

- Double-circuit structures and single-circuit davit arm structures would be comparable in terms of their allowable span lengths, and as such, both designs would utilize approximately the same number of structures along the transmission line route.
- Double-circuit structures and single-circuit davit arm structures would be comparable in terms of their structural reliability.
- Double-circuit failure of the paired 345-115 kV lines would be considered as a single contingency for transmission planning purposes. Upon occurrence of a second contingency, either the remaining single 115 kV line or the single 345 kV line would be out of service resulting in significant and wide-spread loss of load.
- Double-circuit structures would be approximately 25 feet taller than single-circuit davit arm structures on average, and as such would be marginally more visible.
- Double-circuit structures would involve a more complex construction process than the proposed arrangement.

After considering the relative advantages and disadvantages of utilizing the proposed double-circuit structures, National Grid concluded that utilizing single-circuit davit arm structures for constructing the new 345 kV transmission line was strongly preferable in terms of electrical reliability as compared to the double-circuit alternative.

5.6 Underground Transmission Alternative

National Grid also considered an underground transmission line as an alternative to the proposed overhead 345 kV transmission line. In its analysis, National Grid identified and evaluated two possible routing variations, and developed a preferred routing variation for the underground transmission line alternative. Cost estimates, reliability assessments, and impact assessments were developed for the underground alternative and compared with the proposed overhead alternative.

■

5.6.1 Description of Underground Alternative Routes

National Grid considered two underground routes between the required end points, West Farnum Substation and Kent County Substation. The routes were the existing overhead ROW and use of the public roadway network. The underground routes are depicted on Figure 5-2.

The public roadway route was selected to be a reasonably direct and representative connection between West Farnum Substation and Kent County Substation. The overhead ROW route was examined because it is an existing utility corridor between the two substations.

The routes are discussed in more detail in the following sections.

5.6.1.1 Existing Overhead ROW Route

National Grid examined installing an underground transmission line along the existing overhead transmission ROW between the West Farnum Substation and the Kent County Substation. The route along the overhead ROW is approximately 21.4 miles long.

There are some advantages to installing an underground transmission line along the overhead ROW corridor, as opposed to the roadway network. These would include:

- The ROW is an existing utility corridor.
- Less traffic effect on the motoring public during construction, since traffic would only be affected at roadway crossings of the ROW.

- In this case, the ROW route is somewhat shorter than a roadway route.

However, there are a number of disadvantages with the use of this overhead ROW corridor for an underground transmission line:

- There are a number of areas where the overhead ROW traverses wetlands or wetland buffer zone. With overhead construction, excavation primarily occurs at the structure locations, and it is possible in many cases to span wetlands and other sensitive areas. With underground construction, it is necessary to trench the entire route, or to use trenchless techniques such as directional drilling, which would create additional design, construction, and economic issues. Underground construction techniques, therefore, would cause an increase in short and long term impacts to wetland resources along the overhead ROW.
- There are crossings of the Stillwater Pond, the stream connecting the Simmons Upper and Lower Reservoirs, the Pawtuxet River, and numerous other stream crossings along the overhead ROW. Again, it is possible to span these areas with overhead lines, but special construction techniques would be necessary to install an underground line in these areas.
- There is significant visible rock along portions of the ROW. In some areas, there are rock cliffs or other significant grade changes. These would make constructing an underground transmission line difficult.
- To allow for ongoing construction and maintenance, it would be necessary to construct and maintain a much more substantial and permanent access road along the ROW for an underground line than for an overhead line.
- National Grid does not own the majority of the ROW in fee, but holds easements which generally do not include the right to install underground lines. Acquisition of the underground rights would significantly increase the cost and timeframe for this alternative.

On a screening level, the significant construction, operational, property right acquisition, and environmental constraints associated with the overhead transmission ROW corridor made the route undesirable for underground installation, and therefore the route was dismissed as an alternative.

5.6.1.2 Public Roadway Network

There are several advantages to installing an underground transmission line along the public roadway network, as compared to using the overhead ROW for an underground line. These would include:

- Reduced effects on the natural environment. By using the established roadway network, most construction would not directly impact wetlands or environmentally sensitive areas. Some construction could fall in areas where the

roadway is within wetland buffer zones. In these cases, suitable environmental controls would be employed to control sedimentation.

- There would likely be less rock removal with a roadway network route, since original road construction would have graded and removed a portion of the rock along the route. Roadway geometry generally is more suitable for underground transmission installation, since there would not be rock cliffs or other extreme grade changes to contend with.
- Access for ongoing maintenance is generally simpler within the roadway network.
- In general, rights for installation of underground facilities within the roadway network are obtained via a Utility Permit from a limited number of controlling agencies (Town or City DPW Departments, RIDOT, etc.)

There are some disadvantages with the use of the roadway network for an underground transmission line:

- During installation of the conduit and manhole system, there would be construction related effects on vehicular traffic. There would also be some traffic effects during cable installation and splicing, but these would be confined to manhole locations.
- In this case, the roadway route is somewhat longer than the overhead ROW route.

On an overall basis, National Grid concluded that the roadway network provided fewer environmental and property acquisition issues, and had significant operational benefits over installing an underground transmission line on the overhead ROW. For these reasons, an underground route was developed using the existing public roadway network.

The underground route was developed as a reasonably direct connection between the two endpoints, and should be considered as representative of a roadway network underground interconnection. In the event that an underground transmission solution became preferred, a more detailed routing analysis would be performed.

As illustrated on Figure 5-2, the representative underground route would originate at the West Farnum Substation in North Smithfield. The representative route would traverse:

- Portions of Route 104, Route 7, and Route 5 in North Smithfield
- Route 5 in Smithfield, Johnston, and Cranston
- Portions of Route 5, Route 2, Commonwealth Avenue, and Hardig Road in Warwick.

The representative underground route following the public roadway network crosses the Woonasquatucket Reservoir, the Woonasquatucket River, the Pawtuxet River and several smaller streams. This representative underground route is approximately 23.5 miles long.

■

5.6.2 Underground Cable Technology Assessment

At 345 kV, there are two underground cable technologies that were assessed for an underground alternative to the overhead 345 kV transmission line. These are high pressure fluid filled (HPFF) pipe type cable and solid dielectric cable. A brief description of each follows.

5.6.2.1 High Pressure Fluid Filled Pipe Type

HPFF pipe type cable consists of three single core paper-insulated fluid-impregnated cables. Metallic tapes and "skid wires" are added to the insulated cables for shielding and mechanical protection. The cables are installed in a coated steel pipe. The steel pipe is filled with a synthetic dielectric fluid, which is pressurized to approximately 200 pounds per square inch (psi). Pressurizing equipment, consisting of pumps, reservoirs, and associated controls, are required at one or both terminal ends of the cable.

The HPFF pipe type cable system offers several advantages as compared to a solid dielectric cable system:

- Long and successful experience record dating from the 1930s and at 345 kV since the 1960s, with extensive use in the United States.
- Historically, very high reliability.
- Steel pipe provides mechanical protection and compact circuit installation, accommodates three large-diameter cables, and allows for relatively long cable pulls.

Disadvantages of HPFF pipe type cable as compared to solid dielectric cable include:

- The use of dielectric fluid presents possible environmental concerns.
- Installation and maintenance of a pressurization system is needed at one or more of the terminal locations.
- Additional pressurization systems are required for route lengths exceeding 10 to 12 miles.
- A highly reliable auxiliary power supply is needed for the fluid pressurization system.

- A communication system is needed for the fluid pressurization system alarms.
- Installation and maintenance of a cathodic protection system is required since the steel pipe is susceptible to corrosion.
- Relatively long repair times and complex procedures are necessary in the event of faults on the cable system.
- Higher charging current may require more devices such as shunt reactors or other voltage compensation at the terminals.

5.6.2.2 Solid Dielectric Cable

Solid dielectric cable consists of a conductor insulated with an extruded solid material. At 345 kV, the insulation would be cross-linked polyethylene, referred to as XLPE. Additional layers are added to the insulated cables for shielding and mechanical protection.

Solid Dielectric cables are typically installed in a duct line consisting of several polyvinyl chloride (PVC) conduits encased in concrete. Manholes are required at approximately 1,500-foot intervals to allow for splicing of the cables.

In comparison with HPFF pipe type cables, solid dielectric cables exhibit the following advantages:

- No pressurization system is required.
- Absence of dielectric fluid eliminates potential environmental concerns.
- In most cases, less monitoring, control, and remote communication systems are required.
- Somewhat shorter repair time compared to HPFF pipe type systems, but still longer than typical overhead line repair times.
- The system has lower operation and maintenance requirements than pipe type cable.
- Lower charging current as compared to HPFF pipe type systems, thus relatively lower requirements for shunt reactors or other compensating devices.

Solid Dielectric cable systems have the following disadvantages in comparison to HPFF cable systems.

- Less long-term reliability history, particularly at the 345 kV level.
- Due to the shorter distance between manholes, manhole requirements are doubled when compared to an HPFF system, and quadrupled for a two XLPE cable installation.

- The conduit and manhole system, particularly at 345 kV, is larger than a pipe type installation, and may be more difficult to construct in areas with existing underground utilities.
- Cable shield bonding systems are complex and maintenance intensive.

5.6.2.3 Ampacity Requirements

The ampacity requirements for HPFF pipe type and solid dielectric cable systems were determined through loadflow analysis and are presented in Table 5-1.

Table 5-1 Ampacity Requirements of the Underground Alternative

	MVA	Amps
Normal Operating Condition @ 90˚ C Conductor Temperature	705	1180
12 Hr Emergency Condition @ 105˚ C Conductor Temperature	1150	1925

Underground ac transmission cables have an electrical characteristic referred to as "charging current", which means that it takes electrical current to "charge up " the cable before the cable can transmit useful power. At 345 kV, a 20 + mile long pipe type cable is approaching the "critical line length", where the entire cable rating is used up by the cable charging current. For a pipe type cable of this length, it was necessary to install two sets of cables to satisfy rating requirements. Normal and emergency ampacities were satisfied with two sets of 2,750 kcmil copper high pressure fluid filled pipe type cable. There would be over 1000 megavars (MVAR) of charging associated with this much pipe type cable. This is a large amount of charging, and could have significant effects on voltage control and system stability of the transmission system.

For solid dielectric cables, it was determined that one set of 3000 kcmil copper XLPE cables would satisfy ampacity requirements. Because it is much more difficult to upgrade ratings in an underground system than an overhead system, spare conduits would be included with the solid dielectric option. Future transmission system changes, such as addition of new generators or lines, could change system power flows. Spare conduits would allow for addition of a second cable or for re-cabling with a larger cable should cable loading ultimately approach cable rating.

5.6.2.4 Underground Cable Technology Assessment Conclusion

A HPFF pipe type cable system would require two cables to satisfy ampacity requirements. Ampacity requirements would be satisfied through the study period with one set of solid dielectric cable. Costs for the two-cable HPFF pipe type system would exceed the costs for the single solid dielectric system. The HPFF pipe type

system would require at least two pressurizing plants, with the associated operating and maintenance requirements. There would be approximately 400,000 gallons of dielectric fluid in the HPFF pipe type system, as opposed to essentially no fluid in the solid dielectric system. Cable charging effects would be much greater with the pipe type cable system than for a solid dielectric system.

For this application, the HPFF pipe type system was evaluated as less suitable than solid dielectric cable for the new 345 kV transmission line for cost, operational, and potential environmental concerns. For these reasons, a cable system using solid dielectric technology was developed as the preferred underground alternative for this application.

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5.6.3 Description of Underground Construction

The solid dielectric underground transmission line alternative would consist of three insulated conductors installed in a duct and manhole system. The duct line would consist of six eight-inch PVC conduits encased in concrete. Some smaller conduits would be installed for relaying and communication cables. A typical trench cross-section is shown on Figure 5-3. Cables would be installed one cable per duct, between manholes spaced at approximately 1,500 foot intervals.

A typical trench design would be 4 feet wide and 5 feet deep. The design depth would be 2.5 feet to the top of the duct line concrete encasement. In addition to the power conductors, the duct line would contain a neutral cable for shield grounding, and fiber optic cables which would be used for the communication and relaying requirements of the transmission system.

At the terminal ends, the cables would rise above ground through riser structures and would be terminated in the substation yard.

The typical construction progression for an underground installation would begin with the installation of precast concrete manholes. Excavation of the required trench would then commence. The PVC conduit would arrive in ten or twenty foot lengths and would be installed in the trench to form the duct bank. The assembled duct bank would be encased with concrete. The remaining backfill would be native soil or clean gravel. Roadways would be temporarily repaved as the construction progressed. Barriers and steel plates would be used along the trench route to provide protection and access ways for vehicles and pedestrians as necessary.

Once the manholes and duct lines were installed, the remaining construction activities would be confined to the terminals and manhole locations. These activities would consist of installing the cables in the conduits, splicing the cables at each manhole location and final testing. The ROW and streets would be restored following completion of construction.

■

5.6.4 Underground Alternative Costs

National Grid prepared study grade estimates of the underground transmission line alternative. The estimated costs associated with the underground alternative are as follows:

Table 5-2 Underground Alternative – Estimated Cost

Project Segments	345 kV Underground Alternative (2008 Dollars)
New 359 345 kV Underground Transmission Line	$336,400,000
ReconductorS-171 and T-172 115 kV Transmission Lines	$4,000,000*
Reconductor G185N 115 kV Transmission Line	$3,800,000
Modify Kent County Substation	$22,700,000
West Farnum Substation 345 kV Equipment Additions and Upgrades	$47,700,000
Relocate H17 115 kV Line	$0
Relocate B23 115 kV Transmission Line	$250,000
Relocate G185S / L190 Transmission Lines	$500,000
Total Underground Project Cost	**$415,350,000**

* For the underground alternative, this project segment includes reconductoring S171 and T172 from Hartford Ave Substation to the Johnston Tap.
Source: National Grid

■

5.6.5 Underground Operational Issues

In addition to the significantly higher costs, there are a number of system and operational issues associated with underground transmission lines. These include:

- Lengthy Outage Repair Times

  When an overhead transmission line experiences an outage, it can typically be repaired within 24 to 48 hours. In the case of a failure of an underground transmission cable, repair times can be in the range of 100 to 300 hours or more. The extended outage times for underground cables expose the remainder of the transmission system to emergency loadings for longer periods of time. There is also increased exposure to loss of another transmission segment, with possible loss of load, during the extended underground outage.

- Effect on Reclosing

  Many faults on overhead lines are temporary in nature. Often it is possible to "reclose" (re-energize) an overhead line after a temporary fault, and return the line to service with only a brief interruption. Faults on underground transmission cables are almost never temporary, and the cable must remain out of service until the problem is diagnosed and repairs can be completed.

- Cable Capacitance

  Underground cables have significantly higher capacitance than overhead lines, meaning that it takes reactive power (MVARs) to "charge up" the cable before the cable can transmit real power (MWs). This has several ramifications:

  - Part of the cable's capacity is used up by the charging current, so larger conductors are needed to transmit the equivalent amount of power.
  - Capacitance can create voltage control problems, meaning that the voltage can get too high when the transmission system is at light load. If the 345 kV transmission line extension were placed underground between the West Farnum Substation and the Kent County Substation utilizing a single XLPE cable, there would be approximately 300 MVAR of cable charging. Limited loadflow analysis indicates that the transmission system may be able to absorb this much line charging in this area. However, voltage on the transmission system would be near the outer limits of acceptable performance. Limited system stability analysis revealed that this much cable charging would create unacceptable power swings during contingencies, leading to system stability issues. Additional system reinforcements, primarily the installation of a 300 MVAR shunt reactor at West Farnum Substation, would be necessary to compensate for cable charging effects. Further reinforcements (such as breaker upgrades and protective relaying changes) might be necessary.
  - Cable capacitance causes higher switching transient voltages on the system (voltage "spikes" during switching). This can damage other system components, may trigger the need to replace surge arresters throughout the area, and complicates future system expansions.

- Cable Reactance

  The underground cable would have a significantly lower series reactance than the overhead lines that would operate in parallel with the cable. This means that there would be an unequal split of the power flow between the existing overhead line between West Farnum Substation and Kent County Substation and the underground cable, with the underground cable "hogging" the load. Under future loading conditions, the underground cable could be operating at its thermal limit, while the overhead line would be operating well below its limit. This limits operating flexibility on the transmission system and might trigger the need for additional system reinforcements.

- Ratings

  It is often difficult to match overhead line ratings with underground cables. It is also much more difficult to upgrade ratings on underground lines should that become necessary in the future.

■

5.6.6 Comparison of Underground and Overhead Alternatives

Underground and overhead transmission alternatives were compared on the basis of meeting the identified need, reliability, estimated costs and environmental considerations.

5.6.6.1 Meeting the Identified Need

Both the underground and overhead transmission alternatives would meet the identified need of providing a new 345 kV connection between the West Farnum Substation and the Kent County Substation. Both alternatives could be built with adequate capacity to meet present and future projected loads. The underground alternative presents additional operational challenges associated with cable charging issues and longer repair times.

5.6.6.2 Reliability

The reliability performance characteristics of typical overhead and underground transmission lines differ. Unplanned interruptions of underground transmission lines are relatively infrequent. However, when an interruption does occur on an underground line, it takes a relatively long time to get the line back into service. In contrast, an overhead line may have more frequent outages, but can typically be returned to service much more quickly than an underground line. Given the level of redundancy in the transmission system, loss of either the overhead line or the

underground line would not result in immediate loss of load. However, with an underground line, the remaining transmission system would be exposed to higher loading (possibly emergency loading) for longer periods of time, and the system would be exposed to the next contingency (N-1-1) for a longer period of time with the underground alternative.

5.6.6.3 Environmental Considerations

The potential environmental impacts associated with the overhead and underground alternatives were compared. A complete discussion of the potential impacts associated with the proposed overhead alternative can be found in Section 8.0 of this report.

The overhead line will be constructed in an existing overhead ROW. Construction techniques would be used that would minimize effects on the natural environment for the overhead alternative. Disturbed areas would be allowed to re-vegetate with low growing plant species, similar to existing vegetation within the cleared portions of the ROW.

In the case of the underground alternative, the majority of the construction would occur within existing roadways. Assuming an on-road route, most of the environmental effects would be to the "manmade" environment, and would primarily occur during the construction of the lines. These would include significant temporary effects on traffic during conduit and cable installation. Other construction related impacts would include temporary increases in noise from construction vehicles.

Where the roadway route would pass through buffer areas adjacent to wetlands, proper construction techniques such as use of hay bales or other sedimentation barriers would be employed to protect those areas.

There would be no visual impact with an underground line. Both the overhead and underground proposals would have little or no long term environmental effects.

5.6.6.4 Electric and Magnetic Fields

Underground cables are equipped with metallic shielding, and essentially have no external electric fields.

Underground cables do produce magnetic fields. Magnetic fields were calculated for the underground alternative. For an underground cable installed in public roads, the "edge of ROW" is not clearly defined, since the cable could be installed anywhere within the roadway alignment, and since road widths vary. Calculations were made one meter above grade directly over the cable trench.

Anticipated Annual Average Loading and Annual Peak Loading in 2012 and 2017 were used in calculations. Because of cable charging current, the current on the cable will be different at the two ends of the cable. Cable loading will be highest at the West Farnum end of the circuit, and lowest at the Kent County Substation end. As a result, magnetic fields associated with the underground cable will be highest at the West Farnum end of the cable circuit, and will decrease toward Kent County Substation.

Peak magnetic fields near the West Farnum end of the cable circuit are summarized in Table 5-3. The magnetic fields drop off rapidly as distance from the cables increases.

Table 5-3 Magnetic Fields (mG) from Underground Alternative

Segment	2012	2017
359 345 kV Cable, near West Farnum Substation, Annual Average Loading	113	114
359 345 kV Cable, near West Farnum Substation, Annual Peak Loading	116	124

Source: Exponent (2008).

For the magnetic fields associated with the proposed Project, refer to Sections 7.8 and 8.16.

5.6.6.5 Economic Comparison of Overhead and Underground Alternatives

A comparison of facility construction costs for the underground and overhead transmission alternatives was performed. Estimated capital costs (in 2008 dollars) of the proposed overhead transmission project are presented in section 4.8 and the estimated capital costs of the underground alternative are presented in section 5.6.4. Installing the new 345 kV line as an underground line adds approximately 170 million dollars of additional construction costs to the overall Project cost. An economic comparison of the overhead and underground alternatives is shown in Table 5-4.

Table 5-4 Facility Construction Cost Comparison – Proposed Project and Underground Alternative

Project Segments	Project as Proposed 345 kV Overhead Line Estimated Cost (2008 Dollars)	345 kV Underground Alternative (2008 Dollars)
New 359 345 kV Transmission Line	$61,900,000	$336,400,000
S-171 and T-172 115 kV Transmission Lines	$115,600,000*	$4,000,000*
Reconductor G185N 115 kV Transmission Line	$3,800,000	$3,800,000
Modify Kent County Substation	$22,700,000	$22,700,000
West Farnum Substation 345 kV Equipment Additions and Upgrades	$39,400,000	$47,700,000
Relocate H17 115 kV Line	$750,000	$0
Relocate B23 115 kV Transmission Line	$250,000	$250,000
Relocate G185S / L190 Transmission Lines	$500,000	$500,000
Total Project Cost	**$244,900,000**	**$415,350,000**

* This segment of the Project as proposed includes relocation and reconstruction of the S171 and T172 lines from West Farnum Substation to the vicinity of Kent County Substation, including reconductoring both circuits from Hartford Ave Substation to the Johnston Tap. For the underground alternative, this project segment includes reconductoring S171 and T172 from Hartford Ave Substation to the Johnston Tap.

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5.6.7 Underground Alternatives Conclusions

Both the overhead and underground alternatives would meet the identified needs of the Project and would be expected to have high levels of reliability. The underground alternative has operational issues, longer restoration times, and voltage control issues. Generally, the underground alternative on the public roadway network would have fewer environmental impacts than the preferred overhead alternative. There would, however, be greater temporary impacts to the public during construction. The significantly higher cost and the operational issues make the underground alternative much less preferred than the overhead alternative.

5.7 Summary of Alternatives and Conclusions

In the development of the Project and selection of the preferred alternative, National Grid developed and evaluated a variety of alternatives to the proposed action. Alternatives to the construction of the 359 345 kV overhead transmission line between West Farnum Substation and Kent County Substation included a No-Build

alternative, alternative overhead routes, alternative overhead configurations within the existing ROW, underground alternatives including various routes and cable types, and non-transmission alternatives. These were evaluated for their ability to alleviate the power supply deficiency and reliability issues identified in the ISO New England 2008 study reports.

The No-Build alternative to the 359 line project would result in overloaded transmission lines and equipment, unacceptable voltage performance, and exposure to widespread blackout conditions in Rhode Island. As such, the No-Build alternative was not considered to be acceptable.

Two alternative transmission interconnections were evaluated. One was the development of a 345 kV interconnection from Brayton Point in Somerset, MA to Kent County Substation. The second alternative would have added 115 kV connections to the Kent County Substation by installing 115 kV cables from Franklin Square Substation in Providence to Sockanossett Substation in Cranston. Both of these options offered poor electrical performance, resulting in overloaded facilities, and unacceptable system voltages. These alternatives were dismissed for these reasons

Non-transmission alternatives, including Demand Side Management, traditional generation, Distributed Generation, and Combined Heat and Power were evaluated. These technologies did not address the numerous transmission overloading and voltage performance issues on the transmission system, and were dismissed for these reasons.

In addition to the preferred alternative within the existing overhead ROW, an alternative overhead route was evaluated utilizing the National Grid owned, but presently undeveloped, ROW between the Sherman Road Substation and the Kent County Substation. Use of this 44 mile long ROW was found to be economically competitive to the proposed Project. However, environmental effects associated with clearing the undeveloped ROW were found to be much greater than for the proposed Project, and this alternative was determined to be inferior for the RI Reliability Project.

National Grid also examined an overhead 345 kV alternative route utilizing public streets and highways. In order to provide proper electrical safety clearances, ROW would have to be acquired along most public streets, potentially displacing homes, businesses, and other adjoining land uses, and adding significant cost and time to develop the alternative. The visibility of this type of installation would be much greater than for the proposed Project. This option was dismissed for these reasons.

Two alternative overhead configurations were considered within the existing ROW. These included H-frame construction for the 345 kV transmission line, and double circuit davit arm construction with one of the 115 kV lines on the same ROW. H-frame construction would have required significant ROW acquisition along the

route, and double circuit alternatives had unacceptable common mode failure issues. Both alternatives were considered inferior to the proposed Project.

Various underground alternatives were considered. These included route alternatives using the existing overhead ROW, and the public roadway network. The public roadway network was determined to be the most viable underground alternative for constructability, maintainability, property acquisition, and environmental impact. Two underground cable technologies were considered: HPFF pipe type and solid dielectric. In developing an underground alternative, solid dielectric cable was found to be preferred for this application for environmental and operational factors, and cost. However, compared to the preferred overhead plan, the underground alternative was rejected due to significantly higher construction costs, negative operational issues, and ramifications on future expansion.

Following an evaluation of the relative merits and short comings of the various transmission and non-transmission alternatives, the proposed action of constructing the 359 345 kV overhead single circuit davit arm transmission line within the existing ROW (with the associated other components of the Project) was determined to be preferable to the other alternatives.

6.0 Description of Affected Natural Environment

This section of the Report describes the existing natural environment that may be affected by the proposed project, both within and surrounding the existing transmission line ROW and substation sites. As required by the Rules and Regulations of the EFSB, a detailed description of all environmental characteristics within and immediately surrounding the proposed Project has been prepared. The following section describes the specific natural features which have been assessed for the evaluation of impacts and the preparation of a mitigation plan. Information pertaining to existing site conditions has been obtained through available published resource information, the Rhode Island Geographic Information System (RIGIS) database, various state and local agencies, and field investigations of the transmission line ROW (Project ROW).

6.1 Project Study Area

A project Study Area was established to accurately assess the existing environment within and immediately surrounding the Project ROW. This Study Area consists of a 5,000 foot wide corridor centered on the existing Project ROW (refer to Figure 6-1)[5]. The boundaries of this corridor were determined to allow for a detailed inventory of existing conditions within and adjacent to the ROW.

6.2 Climate and Weather

The weather in Rhode Island is largely influenced by the moderating effect of the Atlantic Ocean. In winter, the average temperature is 31 degrees Fahrenheit (F) and the average daily minimum temperature is 23 degrees F. In the summer, the average temperature is 71 degrees F and the average daily maximum temperature is 80 degrees F. Of the total annual precipitation of 46 inches, 18 inches or 40 percent

5 The figures cited in this chapter consist of 4 sheets covering the entire ROW from West Farnum Substation to Kent County Substation.

usually falls in April through September. Average seasonal snowfall is 31 inches (Rector, 2006).[6]

6.3 Geology

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6.3.1 Bedrock Geology

The Study Area is located within the Seaboard Lowland section of the New England physiographic province. The Study Area consists of two areas of contrasting topography and bedrock associated with the Narragansett Bay Group, West Bay: a hilly upland region underlain by igneous and metamorphic rocks, and a flat or gently rolling lowland region underlain by down folded sedimentary rocks (Hermes et al., 1994).

The northern portion of the Project ROW (West Farnum Substation to Hartford Avenue Substation) consists primarily of undivided metaclastic rock (Pennsylvania age); granite from the Edmond Igneous Suite (Late Proterozoic age); undifferentiated rock and quartzite from the Blackstone Group (Late Proterozoic age).

The southern portion of the Project ROW (Hartford Avenue to Kent County Substation) consists primarily of granite, diorite and gabbro from the Scituate Igneous Suite (Devonian age); quartzite, greenstone, amphibolite, and serpentinite from the Blackstone Group (Late Proterozoic age); granite from the Esmond Igneous Suite (Late Proterozoic age); and alkali-feldspar granite from the Scituate Igneous Suite (Devonian age).

The depth of bedrock varies throughout the extent of the Study Area. Numerous rock outcrops are present throughout the ROW, with the exception of the Cranston section, which is relatively flat.

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6.3.2 Surficial Geology

The present landscape of the Study area, as with much of the northeastern United States, was formed by the actions of the continental glacier of the Wisconsin glacial age, approximately 10,000 years ago. Many dynamic land forming processes occurred during this geologic event to produce the landforms and surficial geologic deposits within the Study area.

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6 Rector, Climate Table, Providence Station (www.nesoil.com/ri/tables/RI_Climate_Tables.txt), September 17, 2006.

The Study Area is comprised predominately of glacial till, with pockets of glaciofluvial deposits known as outwash deposits and ice contact deposits interspersed throughout. Glacial till is material carried by, and deposited directly by, glacial ice with little or no reworking by running water. Therefore, this material shows little sorting, and stones are poorly rounded. Glacial till is non-stratified glacial drift consisting of clay, silt, sand, stones and boulders transported and deposited by glacial ice. There are two forms of glacial till: lodgment till, which was deposited directly under the glacier as it moved or melted, and ablation till, which lay on top of the ice or was incorporated into the ice, and then deposited on the ground when the ice melted. Lodgement till tends to be more compact. In contrast, glaciofluvial deposits, often referred to as glacial outwash, were deposited by the abundant meltwater which flowed from the shrinking glacier. This material is typically composed of well rounded stones and contains sorted silt, sand and gravel, and to a lesser extent clay that was deposited in recognizable layers by glacial meltwater.

Glaciofluvial deposits are common in low areas of the landscape, such as broad, level plains and valleys. Landforms associated with glaciofluvial deposits include outwash terraces, outwash fans or deltas, valley trains, eskers, kames, and kame terraces. Significant areas of glacial outwash are located in almost every town and city in the State. Some of these areas are capped with windblown deposits of silt, known as loess. The boundary between areas of till and outwash deposits is often characterized by an abrupt change in slope.

Small pockets of alluvial deposits are also found with the Study Area. These deposits were formed by postglacial stream sediments. Surficial geologic characteristics of the Project corridor are depicted in Figure 6-2.

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6.3.3 Geological Hazards

Geological hazards, such as earthquakes or fault zones, could have negative impacts on transmission line or substation construction. Normal probable fault zones are evident to the east and west of the Study Area. Historically, seismic activity in the northeastern United States is the result of rebound in the earth's crust depressed by ice loading during the Pleistocene glacial event. These events are non-tectonic and do not usually result in vertical movement along faults. This rebound may cause moderate to very strong ground shaking locally and some horizontal movement, but this potential can be regarded as minimal for the design life of the Project.

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6.3.4 Sand and Gravel Mining

Sand and gravel mining occur within 600 feet of the ROW in Smithfield, north of Mountaindale Road and east of Stillwater Reservoir.

6.4 Soils

Detailed information concerning the physical properties, classification, agricultural suitability, and erodibility of soils in the vicinity of the Study Area are presented in this section. Descriptions of soil types identified within the Study area were obtained from the Soil Survey of Rhode Island (Rector, 1981), and from on-site investigations conducted by VHB. The Survey delineates map units that may consist of one or more soil series and/or miscellaneous non-soil areas that are closely and continuously associated on the landscape. In addition to the named series, map units include specific phase information that describes the texture and stoniness of the soil surface and the slope class. A total of 29 named soil series have been mapped within the Study Area. Table 6-1 lists the characteristics of the 72 soil phases (lower taxonomic units than series) found within the Study Area. Figure 6-3 depicts soil classes grouped by drainage class and erodibility hazard.

Table 6-1 Characteristics of Soil Phases within the Study Area

Soil Map Unit Symbol	Soil Phase	Drainage Class	Percent Slope
Aa	Adrian muck	vpd	0
AfA	Agawam fine sandy loam	wd	0 to 3
AfB	Agawam fine sandy loam	wd	3 to 8
BmA	Bridgehampton silt loam, till substratum	wd-mwd	0 to 3
BmB	Bridgehampton silt loam, till substratum	wd-mwd	3 to 8
BnB	Bridgehampton – Charlton complex, very stony	wd-mwd	0 to 8
BoC	Bridgehampton – Charlton complex	wd-mwd	3 to 5
BrB	Broadbrook silt loam	wd	3 to 8
CB	Canton-Urban land complex	wd	0 to15
CC	Canton-Urban land complex, very rocky	wd	0 to15
CaC	Canton-Charlton rock outcrop complex	wd	3 to 15
CaD	Canton-Charlton rock outcrop complex	wd	15 to 35
CdA	Canton & Charlton fine sandy loams	wd	0 to 3
CdB	Canton & Charlton fine sandy loam	wd	3 to 8
CdC	Canton & Charlton fine sandy loams	wd	8 to 15
CeC	Canton & Charlton fine sandy loam	wd	3 to 5
ChB	Canton & Charlton v. fine sandy loam	wd	3 to 8
ChC	Canton & Charlton v. stony fine sandy loams	wd	8 to 15
ChD	Canton & Charlton v. stony fine sandy loams	wd	15 to 25
CkC	Canton & Charlton extremely stony fine sandy loams	wd	3 to 15
Co	Carlisle muck	vpd	0
Du	Dumps	--	variable
EfA	Enfield silt loam	wd	0 to 3
EfB	Enfield silt loam	wd	3 to 8

Soil Map Unit Symbol	Soil Phase	Drainage Class	Percent Slope
GhC	Gloucester – Hinckley v. stony sandy loams	ed-swed	rolling
GhD	Gloucester – Hinckley v. stony sandy loams	ed-swed	hilly
HkA	Hinckley gravelly sandy loam	ed	0 to 3
HkC	Hinckley gravelly sandy loam	ed	rolling
HkD	Hinckley gravelly sandy loam	ed	hilly
LgC	Lippitt gravelly sandy loam, very rocky	swed	3 to 15
MmA	Merrimac sandy loam	swed	0 to 3
MmB	Merrimac sandy loam	swed	3 to 8
MU	Merrimac – Urban land complex	wd	0 to 15
NaA	Narragansett silt loam	wd	0 to 3
NaB	Narragansett silt loam	wd	3 to 8
NbB	Narragansett v. stony silt loam	wd	0 to 8
NbC	Narragansett v. stony silt loam	wd	8 to 15
NcC	Narragansett extremely stony silt loam	wd	3 to 15
Nt	Ninigret fine sandy loam	mwd	0 to 3
PaA	Paxton fine sandy loam	wd	0 to 3
PaB	Paxton fine sandy loam	wd	3 to 8
PbB	Paxton v. stony fine sandy loam	wd	0 to 8
PbC	Paxton v. stony fine sandy loam	wd	3 to 15
PD	Paxton-Urban land complex	wd	0 to 15
Pg	Pits, gravel	ed-swed	0 to 25
Pp	Podunk (Pootatuck) fine sandy loam	mwd	0 to 3
RaA	Rainbow silt loam	mwd	0 to 3
RaB	Rainbow silt loam	mwd	3 to 8
Rc	Raypol silt loam	pd	0 to 3
Re	Ridgebury fine sandy loam	pd	0 to 3
Rf	Ridgebury, Whitman, and Leicester extremely stony fine sandy loams	pd-vpd	0 to 3
Rk	Rock outcrop	--	0 to 50
Rp	Rock outcrop – Canton complex	--	0 to 35
Ru	Rumney (Rippowam) fine sandy loam	pd	0 to 3
Sb	Scarboro mucky sandy loam	vpd	0 to 3
Ss	Sudbury sandy loam	mwd	0 to 3
StA	Sutton fine sandy loam	mwd	0 to 3
StB	Sutton fine sandy loam	mwd	3 to 8
SuB	Sutton v. stony fine sandy loam	mwd	0 to 8
SvB	Sutton extremely stony fine sandy loam	mwd	0 to 8
UD	Udorthents – urban land complex	mwd-ed	variable
Ur	Urban land	--	0 to 10
W	Water	--	0
Wa	Walpole sandy loam	pd	--

Soil Map Unit Symbol	Soil Phase	Drainage Class	Percent Slope
WbA	Wapping silt loam	mwd	0 to 3
WbB	Wapping silt loam	mwd	3 to 8
WcB	Wapping v. stony silt loam	mwd	0 to 8
WgA	Windsor loamy sand	ed	0 to 3
WgB	Windsor loamy sand	ed	3 to 8
WhA	Woodbridge fine sandy loam	mwd	0 to 3
WhB	Woodbridge fine sandy loam	mwd	3 to 8
WoB	Woodbridge v. stony fine sandy loam	mwd	0 to 8

Notes:

ed – excessively drained
wd – well drained
mwd – moderately well drained
swed – somewhat excessively drained
pd – poorly drained (hydric)
vpd – very poorly drained (hydric)
8-15 percent slope – highly erodible

Source: Soil Survey of Rhode Island (Rector, 1981), Soil Data Mart (USDA NRCS website: http://soildatamart.nrcs.usda.gov/Report.aspx?Survey=RI600&UseState=RI)

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6.4.1 Soil Series

The soil series detailed in the following subsections have been identified within the Study Area. The classification follows that published in the Soil Survey of Rhode Island (Rector, 1981).

6.4.1.1 Adrian Series

The Adrian series is classified as sand or sandy-skeletal, mixed, euic, mesic, Terric Medisaprists. These very poorly drained soils formed in organic material derived from herbaceous plants and are underlain by sand and gravel. The soils are in depressions and small drainageways of glacial till uplands and outwash plains.

6.4.1.2 Agawam Series

The Agawam series is classified as coarse-loamy over sandy or sandy-skeletal, mixed, mesic Typic Dystrochrepts. These well drained soils formed in glaciofluvial deposits derived mainly from schist, gneiss, and phyllite. The soils are on terraces and outwash plains.

6.4.1.3 Bridgehampton Series

The Bridgehampton series is classified as coarse-silty, mixed, mesic Typic Dystrochrepts. These well drained to moderately well drained soils have formed in outwash and glacial till deposits derived mainly from schist, gneiss, and phyllite. These soils have thick mantles of windblown silt and fine sand. The soils are on glacial till uplands and outwash terraces.

6.4.1.4 Bridgehampton and Charlton Series

The Bridgehampton series is classified as coarse-silty, mixed, mesic Typic Dystrochrepts. These well drained to moderately well drained soils formed in outwash and glacial till deposits derived mainly from schist, gneiss, and phyllite with thick mantles of windblown silt and fine sand. The Charlton series consists of coarse-loamy, mixed mesic Typic Dystrochrepts. These well drained soils formed in friable glacial till deposits derived mainly from schist and gneiss. Because these series are similar they are grouped and mapped together as a single complex.

6.4.1.5 Broadbrook Series

The Broadbrook series is classified as coarse-loamy, mixed, mesic Typic Fragiochrepts. These well drained soils formed in a silt mantle over compact glacial till derived mainly from schist, gneiss, and phyllite. The soils are on side slopes and crests of drumlins.

6.4.1.6 Canton Series

The Canton series is classified as coarse-loamy over sandy or sandy skeletal, mixed, mesic Typic Dystrocrept. These well drained soils formed in glacial till derived mainly from schist and gneiss.

6.4.1.7 Canton and Charlton Series

The Canton series is classified as coarse-loamy over sandy or sandy skeletal, mixed, mesic Typic Dystrocrept. These well drained soils formed in glacial till derived mainly from schist and gneiss. The similar Charlton series is classified as coarse-loamy, mixed, mesic Typic Dystrochrepts. These soils were also formed in glacial till derived mainly from schist and gneiss. Charlton soils have a finer textured substratum than Canton soils. Because these series are similar they are grouped and mapped together as an association.

6.4.1.8 Carlisle Series

The Carlisle series consists of euic, mesic Typic Medisaprists. These very poorly drained, organic soils formed in deep organic deposits in depressions in outwash plains, till plains, and moraines.

6.4.1.9 Enfield Series

The Enfield series is classified as coarse-silty over sandy or sandy-skeletal, mixed, mesic Typic Dystrochrepts. These well drained soils are formed in silt mantled outwash deposits derived mainly from schist, gneiss, and phyllite. These soils are on terraces and outwash plains.

6.4.1.10 Gloucester and Hinckley Series

The Gloucester series consists of sandy-skeletal, mixed, mesic Typic Dystrochrepts. These somewhat excessively drained soils formed in glacial till derived mainly from schist, gneiss, and granite. They are on side slopes and crests of glacial till upland hills and recessional moraines. The Hinckley series is classified as sandy-skeletal, mixed, mesic Typic Udorthents. These excessively drained soils are formed in glaciofluvial deposits derived mainly from schist and gneiss. The soils are on terraces, outwash plains, and recessional moraines. These soils are grouped and mapped together as an association.

6.4.1.11 Hinckley Series

The Hinckley series is classified as sandy-skeletal, mixed, mesic Typic Udorthents. These excessively drained soils are formed in glaciofluvial deposits derived mainly from schist and gneiss. The soils are on terraces, outwash plains, and recessional moraines.

6.4.1.12 Lippitt Series

The Lippitt series consists of loamy-skeletal, mixed, mesic Typic Dystrochrepts. These moderately deep, somewhat excessively drained soils formed in glacial till derived mainly from schist, gneiss, and granite. Lippitt soils are on side slopes and crests of bedrock controlled glacial till upland hills.

6.4.1.13 Merrimac Series

The Merrimac series is classified as sandy, mixed mesic Typic Dystrochrepts. These somewhat excessively drained soils are formed in outwash deposits derived from schist, gneiss, and phyllite. The soils are on outwash plains and terraces.

6.4.1.14 Narragansett Series

The Narragansett series is classified as coarse-loamy, mixed, mesic Typic Dystrochrepts. These well drained soils are formed in glacial till derived mainly from schist, gneiss, and phyllite. The soils are on side slopes and crests of glacial till upland hills. The soil surface ranges from non-stony to extremely stony.

6.4.1.15 Ninigret Series

The Ninigret series consists of coarse-loamy over sandy or sandy-skeletal, mixed, mesic Aquic Dystrochrepts. These moderately well drained soils formed in outwash deposits derived mainly from schist, gneiss, and phyllite. The soils are in slight depressions in outwash plains and terraces.

6.4.1.16 Paxton Series

The Paxton series is classified as coarse-loamy, mixed, mesic Typic Fragiochrepts. These well drained soils are formed in compact glacial till derived mainly from gneiss and schist. They are on side slopes and crests of glacial till upland hills and drumlins. The soil surface ranges from non-stony to extremely stony.

6.4.4.17 Podunk (Pootatuck) Series

The Podunk (Pootatuck) series consists of coarse-loamy, mixed, nonacid, mesic Fluvaquentic Dystrochrepts. These moderately well drained soils formed in recent alluvium derived mainly from granite, gneiss, and schist. The soils are on flood plain landforms.

6.4.1.18 Rainbow Series

The Rainbow series is classified as coarse-loamy, mixed, mesic Typic Fragiochrepts. These moderately well drained soils are formed in silt mantled compact glacial till derived mainly from schist, gneiss, and granite. The soils are on drumlins and glacial till plains. The soil surface ranges from non-stony to very stony.

6.4.1.19 Raypol Series

The Raypol series is classified as coarse-loamy over sandy or sandy-skeletal, mixed, acid, mesic Aeric Haplaquepts. These poorly drained soils formed in windblown or water-deposited silts derived mainly from schist, gneiss, and shale. The soils are in depressions mainly on terraces and outwash plains.

6.4.1.20 Ridgebury, Whitman and Leicester Series

The Ridgebury, Whitman, and Leicester series are commonly grouped together as one soil complex due to their similar properties. However, they are distinct series with individual classifications. The Ridgebury series is classified as coarse-loamy, mixed, mesic Aeric Fragiaquepts, the Whitman series is classified as coarse-loamy, mixed, mesic Humic Fragiaquepts and the Leicester series is classified as coarse-loamy, mixed, acid, mesic Aeric Haplaquepts. Ridgebury and Leicester soils are poorly drained and Whitman soils are very poorly drained. Whitman and Ridgebury soils have a dense till layer within one meter of the soil surface. These soils are formed in loamy glacial till derived mainly from schist, gneiss and granite. These soils are in depressions, drainageways in glacial till uplands, and nearly level areas of glacial upland hills and drumlins.

6.4.1.21 Rumney (Rippowam) Series

The Rumney (Rippowam) series is classified as coarse-loamy, mixed, nonacid, mesic Aeric Fluvaquents. These poorly drained soils are formed in recent alluvium derived mainly from granite, gneiss, and schist. The soils are on flood plain landforms.

6.4.1.22 Scarboro Series

The Scarboro series is classified as sandy, mixed, mesic Histic Humaquepts. These very poorly drained soils have thin organic surfaces over sand deposits derived mainly from schist, gneiss, and shale. The soils are in depressions and drainageways in outwash plains and terraces.

6.4.1.23 Sudbury Series

The Sudbury series is classified as sandy, mixed, mesic Aquic Dystrochrepts. These moderately well drained soils are formed in glaciofluvial deposits derived mainly from schist and gneiss. These soils are on terraces and outwash plains.

6.4.1.24 Sutton Series

The Sutton series is classified as coarse-loamy, mixed, mesic Aquic Dystrochrepts. These moderately well drained soils are formed in glacial till derived mainly from schist, gneiss and granite. The soils are on side slopes and in depressions of upland hills. The soil surface ranges from non-stony to extremely stony.

6.4.1.25 Udorthents Series

Udorthents are moderately well drained to excessively drained soils that have been cut, filled, or eroded, typically by anthropogenic processes. The areas have had more than two feet of the upper part of the original soil removed or have more than two feet of fill on top of the original soil. Udorthents are extremely variable in texture. They are on glacial till plains and gravelly outwash terraces.

6.4.1.26 Walpole Series

The Walpole series is classified as sandy, mixed, mesic Aeric Haplaquepts. These poorly drained soils are formed in glaciofluvial deposits derived mainly from schist, gneiss, and granite. The soils are in depressions and drainageways.

6.4.1.27 Wapping Series

The Wapping series is classified as coarse-loamy, mixed, mesic Aquic Dystrochrepts. These moderately well drained soils are formed in silt mantled glacial till. The soils are on side slopes or in depressions of glaciated uplands.

6.4.1.28 Windsor Series

The Windsor series is classified as mixed, mesic Typic Udipsamments. These excessively drained soils are formed in glaciofluvial deposits and Pleistocene dunes derived mainly from schist, gneiss, and phyllite. The soils are on terraces, outwash plains, kames, and eskers.

6.4.1.29 Woodbridge Series

The Woodbridge series is classified as coarse-loamy, mixed, mesic Typic Fragiochrepts. These moderately well drained soils are formed in glacial till derived mainly from schist, gneiss, and phyllite. The soils are on lower slopes and crests of upland hills and drumlins.

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6.4.2 Prime Farmland Soils

Prime farmland, as defined by the United States Department of Agriculture (USDA), is the land that is best suited to producing food, feed, forage, fiber, and oilseed crops. It has the soil quality, growing season, and moisture supply needed to economically produce a sustained high yield of crops when it is treated and managed using acceptable farming methods.

Rhode Island recognizes 35 prime farmland soils. The proposed Project will cross 24 prime farmland soil units as listed in Table 6-2.

Table 6-2 USDA Prime Farmland Soils within the Study Area

Soil Map Unit Symbol	Name	Percent Slope
AfA	Agawam fine sandy loam	0 to 3
AfB	Agawam fine sandy loam	3 to 8
BmA	Bridgehampton silt loam, till substratum	0 to 3
BrB	Broadbrook silt loam	3 to 8
CdA	Canton and Charlton fine sandy loams	0 to 3
CdB	Canton and Charlton fine sandy loams	3 to 8
EfA	Enfield silt loam	0 to 3
MmA	Merrimac sandy loam	0 to 3
MmB	Merrimac sandy loam	3 to 8
NaA	Narragansett silt loam	0 to 3
NaB	Narragansett silt loam	3 to 8
Nt	Ninigret fine sandy loam	--
PaA	Paxton fine sandy loam	0 to 3
PaB	Paxton fine sandy loam	3 to 8
Pp	Podunk (Pootatuck) fine sandy loam	--
RaA	Rainbow silt loam	0 to 3
RaB	Rainbow silt loam	3 to 8
Ss	Sudbury sandy loam	0 to 3
StA	Sutton fine sandy loam	0 to 3
StB	Sutton fine sandy loam	3 to 8
WbA	Wapping silt loam	0 to 3
WbB	Wapping silt loam	3 to 8
WhA	Woodbridge fine sandy loam	0 to 3
WhB	Woodbridge fine sandy loam	3 to 8

Prime farmland soils could be utilized as cropland, pastureland, rangeland, forestland, or other land. Urbanized land and water are exempt from consideration as prime farmland. Within the Study Area, prime farmland soils exist on land occupied by commercial, institutional, recreational, agricultural and residential land use, cleared ROW, forestland, and roads.

6.4.3 Farmland of Statewide Importance

Farmland of statewide importance is land that is designated by the Rhode Island Department of Administration Division of Planning to be of statewide importance for the production of food, feed, fiber, forage, and oilseed crops. Generally, farmlands of statewide importance include those lands that do not meet the requirements to be considered prime farmland, yet they economically produce high crop yields when treated and managed with modern farming methods. Some may produce as high a yield as prime farmland if conditions are favorable.

In order to extend the additional protection of state regulation to prime farmland, the State of Rhode Island has expanded its definition of farmland of statewide importance to include all prime farmland areas. Therefore, in Rhode Island, all USDA-designated prime farmland soils are also farmland of statewide importance.

Table 6-3 lists soil units designated as farmland soils of statewide importance that are found within the Study Area.

Table 6-3 Farmland Soils of Statewide Importance within the Study Area

Soil Map Unit Symbol	Name	Percent Slope
AfA	Agawam fine sandy loam	0 to 3
AfB	Agawam fine sandy loam	3 to 8
BmA	Bridgehampton silt loam, till substratum	0 to 3
BmB	Bridgehampton silt loam, till substratum	3 to 8
BrB	Broadbrook silt loam	3 to 8
CdA	Canton and Charlton fine sandy loams	0 to 3
CdB	Canton and Charlton fine sandy loams	3 to 8
CdC	Canton and Charlton fine sandy loams	8 to 15
EfA	Enfield silt loam	0 to 3
EfB	Enfield silt loam	3 to 8
HkA	Hinckley gravelly sandy loam	0 to 3
HkC	Hinckley gravelly sandy loam	rolling
MmA	Merrimac sandy loam	0 to 3
MmB	Merrimac sandy loam	3 to 8
NaA	Narragansett silt loam	0 to 3
NaB	Narragansett silt loam	3 to 8
Nt	Ninigret fine sandy loam	--
PaA	Paxton fine sandy loam	0 to 3
PaB	Paxton fine sandy loam	3 to 8
Pp	Podunk (Pootatuck) fine sandy loam	--
RaA	Rainbow silt loam	0 to 3

Soil Map Unit Symbol	Name	Percent Slope
RaB	Rainbow silt loam	3 to 8
Rc	Raypol silt loam	--
Re	Ridgebury fine sandy loam	--
Ru	Rumney (Rippowam) fine sandy loam	--
Ss	Sudbury sandy loam	0 to 3
StA	Sutton fine sandy loam	0 to 3
StB	Sutton fine sandy loam	3 to 8
Wa	Walpole sandy loam	--
WbA	Wapping silt loam	0 to 3
WbB	Wapping silt loam	3 to 8
WgA	Windsor loamy sand	0 to 3
WgB	Windsor loamy sand	3 to 8
WhA	Woodbridge fine sandy loam	0 to 3
WhB	Woodbridge fine sandy loam	3 to 8

Source: Soil Survey of Rhode Island (Rector, 1981).

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6.4.4 Erosive Soils

The erodibility of a soil is dependent upon the slope of the land occupied by the soil and the texture of the soil. Soils are given an erodibility factor (K), which is a measure of the susceptibility of the soil to erosion by water. Soils having the highest K values are the most erodible. K values in Rhode Island range from 0.10 to 0.64 and vary throughout the depth of the soil profile with changes in soil texture. Very poorly drained soils and certain floodplain soils usually occupy areas with little or no slope. Therefore, these soils are not subject to erosion under normal conditions and are not given an erodibility factor. Soil map units described as strongly sloping or rolling may include areas with slopes greater than eight percent and soil map units with moderate erosion hazard are listed in Table 6-4.

Table 6-4 Soil Mapping Units with Potential Steep Slopes within the Study Area

Soil Map Unit Symbol	Soil Phase	Percent Slope	Surface K Values
CaC	Canton-Charlton rock outcrop complex	3 to 15	0.20
CaD	Canton-Charlton rock outcrop complex	15 to 35	0.20
CdC	Canton & Charlton fine sandy loams	8 to 15	0.20/0.24
ChC	Canton & Charlton v. stony fine sandy loams	8 to 15	0.20/0.24
ChD	Canton & Charlton v. stony fine sandy loams	15 to 25	0.20
GhC	Gloucester – Hinckley v. stony sandy loams	rolling	0.17
GhD	Gloucester – Hinckley v. stony sandy loams	hilly	0.17
HkC	Hinckley gravelly sandy loam	rolling	0.17
HkD	Hinckley gravelly sandy loam	hilly	0.17
NbC	Narragansett v. stony silt loam	8 to 15	0.24
PbC	Paxton v. stony fine sandy loam	3 to 15	0.20

Source: Soil Survey of Rhode Island (Rector, 1981) and United States Department of Agriculture, Natural Resources Conservation Service, Highly Erodible Soil Map Units of Rhode Island, Revised January 1993.

6.5 Surface Water

The majority of the proposed Project lies within the Pawtuxet drainage basin and the Woonasquatucket drainage basin of Rhode Island. The southernmost tip of the Study Area lies within the Narragansett Bay drainage basin.

A drainage basin is the area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel (Dunne and Leopold, 1978), and is synonymous with watershed. Within the Pawtuxet drainage basin, Woonasquatucket drainage basin and the Narragansett drainage basin are numerous subordinate watersheds associated with river systems. The Narragansett Bay Basin is directly linked to the adjacent Mount Hope Bay Basin, and includes the system of waterways in Rhode Island and Massachusetts that discharge into the Narragansett and Mount Hope Bays. The Bays in turn discharge into Rhode Island Sound, and ultimately the Atlantic Ocean.

The waters of the State of Rhode Island (meaning all surface water and groundwater of the State) are assigned a Use Class which is defined by the most sensitive, and therefore governing, uses which it is intended to protect. Waters are classified according to specific physical, chemical, and biological criteria which establish parameters of minimum water quality necessary to support the water Use Classification. The water quality classification of the major surface waters within the Study Area are identified in the descriptions of the water courses that follow. Classification and use of all water courses within the Study Area are presented in Table 6-5.

The Study Area is drained by waterways which generally flow to the east and southeast into Narragansett Bay. Figure 6-4 depicts surface waters within the Study Area.

Pursuant to the requirements of Section 305(b) of the Federal Clean Water Act, waterbodies which are determined to be not supporting their designated uses in whole or in part are considered impaired, and placed on the Clean Water Act, Section 303(d) List of Impaired Waters where they are prioritized and scheduled for restoration. The causes of impairment are those pollutants or other stressors that contribute to the actual or threatened impairment of designated uses in a waterbody. Causes include chemical contaminants, physical parameters, and biological parameters. Sources of impairment are not determined until a total maximum daily load (TMDL) assessment is conducted on a waterbody. Nine impaired waters are associated with the Study Area: Assapumpset Brook, Hardig Brook and tributaries, Maskerchugg River, Pawtuxet River Main Stem, Pawtuxet River North Branch, Pawtuxet River South Branch, Pocasset River, Simmons Reservoir, and Woonasquatucket River.

Table 6-5 Surface Water Resources within the Study Area

Water Body Name	Town	Classification and Partial Use	Present Water Quality
Furnace Hill Brook	Cranston	B	Compliant
Tributary to Meshanticut Brook	Cranston	B	Compliant
Almy Reservoir	Johnston	B	Compliant
Assapumpset Brook	Johnston	B	Impaired
Dry Brook	Johnston	B	Compliant
Duck Ponds	Johnston	A	Compliant
Hughesdale Pond	Johnston	B	Compliant
Pocasset Pond	Johnston	B	Compliant
Pocasset River	Johnston	B	Impaired
Simmons Reservoir	Johnston	B	Impaired
Cherry Brook	North Smithfield	B	Compliant
Todds Pond	North Smithfield	A	Compliant
Woonasquatucket River	North Smithfield/Smithfield	B	Impaired
Capron Pond	Smithfield	B	Compliant
Hawkins Brook	Smithfield	B	Compliant
Mountaindale Reservoir	Smithfield	B	Compliant
Reaper Brook	Smithfield	B	Compliant
Stillwater Pond	Smithfield	B	Compliant
Stillwater Reservoir	Smithfield	B	Compliant
Tributary to Maskerchugg River	Warwick	B	Impaired
Natick Pond	West Warwick	A	Compliant
Pawtuxet River Main Stem	West Warwick	B1	Impaired

Water Body Name	Town	Classification and Partial Use	Present Water Quality
Pawtuxet River North Branch	West Warwick	B	Impaired
Pawtuxet River South Branch	West Warwick	B1	Impaired
Hardig Brook	West Warwick/Warwick	B	Impaired

Classification	Use
A	Primary and secondary contact recreational activities and for fish and wildlife habitat. Suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have excellent aesthetic value.
B	Fish and wildlife habitat and primary and secondary contact recreational activities. Suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.
B1	Primary and secondary contact recreational activities and fish and wildlife habitat. Suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges. However all Class B criteria must be met.

Source: R.I. Department of Environmental Management. Water Quality Regulations (July 2006).
R.I. Department of Environmental Management. State of Rhode Island and Providence Plantations 2004 Section 305(b) State of the State's Waters Report

Table 6-6 Impaired Surface Water Resources within the Study Area

Water Body	Impairment	Group
Assapumpset Brook	Pathogens	1
Hardig Brook & Tributaries	Lead (Pb); Biodiversity Impacts	2
	Pathogens	5
Maskerchugg River	Lead (Pb); Copper (Cu); Cadmium (Cd)	2
	Pathogens	5
Pawtuxet River Main Stem	Mercury (Hg); Cadmium (Cd); Pathogens	2
	Low DO; Biodiversity Impacts; Nutrients	5
Pawtuxet River North Branch	Lead (Pb); Mercury (Hg)	2
Pawtuxet River South Branch	Lead (Pb)	2
Pocasset River	Lead (Pb); Pathogens	2
Simmons Reservoir	Phosphorus; Siltation; Excess Algal Growth/CHL-A; Turbidity	2
Woonasquatucket River	Zinc (Zn)	1

Group	Explanation
1	Waters are not meeting Rhode Island Water Quality Standards and TMDL development is currently underway.
2	Waters are not meeting Rhode Island Water Quality Standards and TMDL development is planned for the future.
5	A TMDL, or a control action functionally equivalent to a TMDL, has been developed for these waterbodies. Implementation is underway which will result in attainment of the standards. However, the standard will not be met within the next two years. For control actions functionally equivalent to a TMDL, a determination must be made that the identified impairment is caused by the source(s) to be controlled.

Source: R.I. Department of Environmental Management. State of Rhode Island 2006 303(d) List of Impaired Waters, Final November 2006.

■

6.5.1 Assapumpset Brook

Assapumpset Brook originates northwest of the Project ROW, crossing it at Cat Rocks in Johnston, and flows southeast into the Woonasquatucket River.

■

6.5.2 Dry Brook

Dry Brook is situated in the central portion of the Study Area. Dry Brook discharges from the Almy (Jillson) Reservoir, flowing into the Hughesdale Pond. A tributary of Dry Brook begins just west of the Project ROW. Wetlands associated with this tributary are located in the ROW. In the vicinity of the Project ROW, Dry Brook is a state-designated Class B watercourse, while the water quality is downgraded to a Class B1 designation at a location approximately 0.3 miles south of the Almy Reservoir, as the result of a permitted wastewater discharge input.

■

6.5.3 Furnace Hill Brook

Furnace Hill Brook is crossed by the Project ROW south of Pippin Orchard Road. A small, unnamed man-made pond is located in the ROW north of Furnace Hill Brook, and is an impoundment of an unnamed stream which enters Furnace Hill Brook from the north within the Project ROW. Downstream of the ROW, Furnace Hill Brook flows into Meshanticut Brook, which is a tributary of the Pawtuxet River. Furnace Hill Brook is a state-designated Class B water.

■

6.5.4 Hardig Brook

Hardig Brook is crossed by the ROW south of Centerville Road (Route 117) and west of the I-95 southbound ramps. Hardig Brook enters a culvert on the west side of the I-95 ramps and discharges on the east side into a rip-rapped channel. Downstream of the ROW, Hardig Brook flows into Gorton Pond. An unnamed tributary to Hardig Brook crosses the ROW and is located north of Centerville Road and discharges on the south side into Hardig Brook. Hardig Brook and its tributaries are located within the Narragansett Bay Basin (Hardig Brook discharges directly to Greenwich Bay) and are state-designated Class B waters.

■

6.5.5 Pawtuxet River and Tributaries

The Pawtuxet River is crossed by the ROW east of its confluence of the North and South Branches at Riverpoint. Several tributaries of the Pawtuxet River, located south

of New London Avenue, are also crossed by the ROW. Additional tributaries flow to the Pawtuxet River via Meshanticut Brook. The first tributary is located south of the West Warwick and Cranston municipal boundary, and flows in a northeasterly direction to Meshanticut Brook. The second tributary flows southerly from Laten Knight Road approximately 1.3 miles along the ROW before diverging from the ROW in an easterly direction to Meshanticut Brook. The Pawtuxet River and its tributaries, from Riverpoint to the Pawtuxet Cove Dam, are state-designated Class B1 Waters.

■

6.5.6 Pocasset River

The Pocasset River headwaters begin north of Route 6 in central Johnston and flow in a southeasterly direction through Pocasset Pond and Print Works Pond to its confluence with the Pawtuxet River at the municipal boundary between Cranston and Warwick. Dry Brook is a tributary of the Pocasset River.

■

6.5.7 Simmons Reservoir

The Simmons Reservoir system has two impoundments, the Simmons Upper and Lower Reservoirs. The ROW crosses between these two water bodies. The wetlands located within the ROW between these water bodies is characterized as emergent marsh. The Simmons Reservoirs and their tributaries have been designated as Class B waters.

■

6.5.8 Woonasquatucket River

The Woonasquatucket River headwaters begin north of Primrose Pond in North Smithfield and flows south into the Woonasquatucket Reservoir. The River then outlets east and flows through a series of impoundments at Stillwater Pond, Capron Pond, and Georgiaville Pond. The Woonasquatucket River then flows southeast through Smithfield, North Providence and Providence before its confluence with the Providence River. The ROW crosses Stillwater Pond.

■

6.5.9 Floodplain

The 100-year floodplain represents the extent of flooding that would result during a storm event having a one percent chance of occurring per year. Based on available Federal Emergency Management Agency (FEMA) mapping for the towns within the Study Area, the Project ROW crosses several areas of designated 100-year (Zone A, Zone AE or shaded Zone X (North Smithfield)) frequency floodplain. These areas

include the floodplain of Hardig Brook in Warwick, the Pawtuxet River in West Warwick, the Pocasset River in Johnston, Stillwater Pond in Smithfield, an unnamed swamp in Smithfield, and Cedar Swamp in North Smithfield. Within the Study Area, 100-year floodplain is also associated with Furnace Hill Brook, Cherry Brook, Pocasset Pond, Reaper Brook, the Woonasquatucket River, and Stillwater Reservoir. It is recognized that, by definition provided in the RIDEM Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act (RIDEM 2007) (the "Rules") all streams, intermittent streams and rivers have 100-year floodplain though they may not be mapped by FEMA.

6.6 Groundwater

Groundwater resources within the Study Area are depicted on Figure 6-4. The presence and availability of groundwater resources is a direct function of the geologic deposits in the Study Area. The majority of the Study Area is classified as GA. These groundwater resources are presumed suitable for public drinking water use without prior treatment, however these resources have a lower potential yield and quality than that of the highest state classification, GAA. The entire Project is located within areas classified as GA by the RIDEM. The GA class is subject to the same groundwater quality standards and preventative action limits for organic and inorganic chemicals, microbiological substances, and radionuclides as the GAA classification.

Approximately one percent of the Study Area is located within areas classified as GB. Class GB groundwater are areas where groundwater may not be suitable for drinking water supply without prior treatment based on the potential for degraded quality resulting from overlying land usage. Class GB areas are served by a public water supply.

Class GC groundwater is known to be unsuitable for drinking water use due to waste disposal practices such as landfills. Class GC groundwater resources do not occur within the Study Area.

The RIDEM Office of Water Resources has identified and mapped several areas of non-community wellhead protection areas within the Study Area, including two that overlap the ROW: one in the vicinity of the Stillwater Road/Route 116 intersection in Smithfield, and one south of Wakefield Street in West Warwick.

■

6.6.1 Sole Source Aquifers

The major groundwater resource identified within the Study Area is the Hunt-Annaquatucket/Pettaquamscutt (HAP) aquifer, in the vicinity of the Kent County Substation in Warwick. The United States Environmental Protection Agency

has designated the HAP as a Sole Source Aquifer. The HAP Aquifer Area is the primary source of groundwater for public use in most of North Kingstown and East Greenwich, and portions of Coventry, Exeter, Warwick, West Greenwich, and West Warwick. The purpose of sole source aquifer designation is to manage land use practices within the aquifer recharge area to protect groundwater quality. The sole source aquifer is depicted on Figure 6-4.

6.7 Vegetation

The Study Area contains a variety of vegetative cover types typical of southern New England. These types include oak/pine forest, old field, and managed lawn. This section of the report focuses on upland communities. Wetland communities are discussed in Section 6.8 of the report.

■

6.7.1 Oak/Pine Forest Community

Forested cover types within the Study Area are typically dominated by oaks with or without a white pine (*Pinus strobus*) component. Although these woodlands may appear similar throughout the Study Area, differences in the structure and composition of species in these forests may occur between sites. Soil moisture holding capacity and slope aspect are important factors in determining the plant associations present at a particular site. Plant associations growing on hilltops and south facing slopes are likely to face moisture deficits during the summer. Sandy soils associated with glacial outwash deposits have lower moisture holding capacity in comparison with soils formed over deposits of glacial till. Forests established in these drier sites are often characterized by smaller and more widely spaced trees in comparison with more mesic sites.

Common associates of the hilltop oak/pine forests in the vicinity of the Project ROW include black (*Quercus velutina*), scarlet (*Q. coccinea*), and white (*Q. alba*) oaks as well as aspen (*Populus sp.*) and gray birch (*Betula populifolia*). The shrub/sapling understory includes such species as black cherry (*Prunus serotina*), lowbush blueberry (*Vaccinium angustifolium*) and greenbrier (*Smilax rotundifolia*). Sheep laurel (*Kalmia angustifolia*) and sweet fern (*Comptonia peregrina*) occasionally occur in openings between oak stands with canopy openings and on rocky slopes. Herbaceous species include bracken fern (*Pteridium aquilinum*), tree clubmoss (*Lycopodium obscurum*) and hayscented fern (*Dennstaedtia punctilobula*). These hilltop communities occur where excessively drained soils predominate, and on hilltops throughout the Study Area.

There is an increase in the diversity within plant communities on midslopes compared with dry hilltops. The increase in soil moisture produces this greater diversity in trees, shrubs and herbs. Midslope tree species in addition to oaks include black birch (*Betula lenta*), white ash (*Fraxinus americana*), American beech (*Fagus grandifolia*) and several

species of hickory (*Carya* sp.). Shrubs include witch hazel (*Hamamelis virginiana*), sassafras (*Sassafras albidum*) and ironwood (*Carpinus caroliniana*). Greenbrier and poison ivy (*Toxicodendron radicans*) are also common in this community. Common groundcover species include tree clubmoss and wintergreen (*Gaultheria procumbens*). Midslope oak/pine communities occur on mesic mid-slope and lower slope positions and adjacent to forested wetlands on the uncleared portion of the ROW.

■

6.7.2 Old Field Community

Upland vegetation within the cleared portions of the ROW is typically representative of an old field successional community. Old field communities are established through the process of natural succession from cleared land to mature forest. Within the cleared ROW, periodic vegetation management has favored the establishment and persistence of grasses and herbs. Over time, pioneer woody plant species including gray birch, sumac (*Rhus sp.*) and eastern red cedar (*Juniperus virginiana*) have become established.

Within the cleared portions of the ROW, vegetation varies considerably. On dry hilltops, little bluestem (*Schizachyrium scoparium*), bluets (*Houstonia caerulea*), sweet fern *(Comptonia peregrina)* and eastern red cedar are common. On the mid-slope, greenbrier and blackberry (*Rubus* sp.) form dense, impenetrable thickets. Numerous herbs including goldenrod (*Solidago* sp.), sheep sorrel (*Rumex acetosella),* wild indigo (*Baptisia tinctoria*), and mullein (*Verbascum thapsus*) are also common.

■

6.7.3 Upland Scrub-Shrub Community

The project ROW has been managed to remove trees as they interfere with safe operation of transmission lines. Shrubs dominate portions of the ROW where succession of old field has occurred and where ROW management has resulted in tree sapling removal. Sweet fern (*Comptonia peregrina*), bayberry (*Myrica pensylvanica*), and northern arrowwood (*Viburnum recognitum*) are shrub species that are commonly found within the ROW.

Forest vegetation abuts the area of managed ROW in many places along the corridor. This forested edge contains species of trees and the ROW contains saplings that require more sunlight, such as black cherry (*Prunus serotina*), grey birch (*Betula populifolia*) and eastern red cedar. Mature forest containing northern red oak, and red maple (*Acer rubrum*) are also present along the corridor, and saplings of these species are occasionally found in the ROW.

■

6.7.4 Managed Lawn/Grass

Portions of the cleared ROW contain managed residential lawn or commercial golf course. Typically these areas consist of a continuous grass cover which may include Kentucky bluegrass (*Poa pratensis*), red fescue (*Festuca rubra*), clover (*Trifolium* sp.), and plantains (*Plantago* sp.). Ornamental shrubs may also occur within these areas.

■

6.7.5 Agricultural Areas

Based on the existing land use mapping obtained from the RIGIS and field survey, the ROW crosses land of agricultural use in Johnston, Cranston, and West Warwick.

6.8 Wetlands

Wetlands have been identified as resources potentially providing ecological functions and societal values. Wetlands are characterized by three criteria including the (i) presence of undrained hydric soils, (ii) a prevalence (>50 percent) of hydrophytic vegetation, and (iii) wetland hydrology, soils that are saturated near the surface or flooded by shallow water during at least a portion of the growing season.

■

6.8.1 Study Area Wetlands

State-regulated freshwater wetlands and/or streams have been identified and delineated within the ROW. Figure 2-2 depicts wetlands field delineated within the ROW and Figure 6-5 depicts wetland resources within the Project Study Area based upon RIGIS mapping. Field methodology for the delineation of State-regulated resource areas was based upon vegetative composition, presence of hydric soils, and evidence of wetland hydrology. Based on the provisions of the Rhode Island Fresh Water Wetlands Act and the Rules, State-regulated fresh water wetlands include swamps, marshes, bogs, forested or shrub wetlands, emergent plant communities and other areas dominated by wetland vegetation and showing wetland hydrology. Swamps are defined as wetlands dominated by woody species and are three acres in size, or greater. Marshes are wetlands dominated by emergent species and are one acre or greater in size. Bogs are wetlands dominated by “bog” species and generally support sphagnum moss. Bogs have no minimum size criteria. Emergent wetlands communities are areas similar to marshes in vegetation composition; however, they are less than one acre in size. Forested and shrub wetlands are similar to swamps, but do not meet the three-acre size criteria.

The upland area within 50 feet of the edge of a swamp, marsh, or bog is regulated as the 50-foot Perimeter Wetland under the Rules. Emergent wetland communities, forested wetlands, and shrub wetlands do not merit a 50-foot Perimeter Wetland.

In addition to these vegetated wetland communities, Rhode Island also regulates activities in and around streams and open water bodies, which include Rivers, Ponds, and Areas Subject to Storm Flowage (ASSF). A River is any perennial stream indicated as a blue line on a U.S. Geological Survey (USGS) 7.5-minute series topographic map. If the River is less than 10 feet wide, the area within 100 feet of each bank is regulated as 100-foot Riverbank Wetland. If the River is greater than 10 feet wide, the area within 200 feet of each bank is regulated as 200-foot Riverbank Wetland.

A Pond is an area of open standing or slow moving water present for six or more months during the year and at least one-quarter acre in size. Ponds have a 50-foot Perimeter Wetland associated with the boundary. An ASSF is defined as any body of flowing water as identified by a scoured channel or change in vegetative composition or density that conveys storm runoff into or out of a wetland.

Vegetation community types and their dominant plant species located within the existing Project ROW are described below.

6.8.1.1 Pond

The boundary of a Pond is determined by the extent of water which is delineated and surveyed. Ponds located within the Study Area are Duck Ponds, Hughesdale Pond, Pocasset Pond, Todd's Pond, Capron Pond, Stillwater Pond, and Natick Pond.

Two ponds occur within the cleared ROW itself: Stillwater Pond, and a man-made unnamed pond located just south of Scituate Avenue in Cranston. The pond is located in the ROW north of Furnace Hill Brook, and flows into an unnamed stream which joins Furnace Hill Brook east of the ROW crossing.

Several reservoirs, which are in essence very large, permanently flooded ponds, are found within the Study Area, including Almy Reservoir, Simmons Upper and Lower Reservoirs, Mountaindale Reservoir, and Stillwater Reservoir.

6.8.1.2 Wetland Complex

Wetland Complexes in the Study Area contain a combination of open water, emergent vegetation, forested and shrub cover types. Throughout the Project ROW these Wetland Complexes are dominated by open water typical of a pond with fringing sapling/shrubs comprised of red maple, sweet pepperbush (*Clethra alnifolia*), winterberry (*Ilex verticillata*), meadowsweet (*Spiraea alba*), highbush blueberry

(*Vaccinium corymbosum*), swamp azalea (*Rhododendron viscosum*), and common greenbrier. Five Wetland Complexes are present within the Project ROW.

6.8.1.3 Swamp

Swamps are defined as areas at least three acres in size, dominated by woody vegetation, where groundwater is at or near the ground surface for a significant part of the growing season. A 50-foot Perimeter Wetland is applied to both Wooded and Shrub Swamps. Shrub Swamps are areas dominated by broad-leaved deciduous shrubs and often have an emergent herbaceous layer. Dominant species in Shrub Swamps include sweet pepperbush, highbush blueberry, winterberry, and swamp azalea. Other species occurring in these swamps include arrowwood (*Viburnum dentatum*) and silky dogwood (*Cornus amomum*). Drier portions of Shrub Swamps are often densely overgrown with wild grape (*Vitus labrusca*) and greenbrier. Common species in the herbaceous layer include cinnamon fern (*Osmunda cinnamomea*), sensitive fern (*Onoclea sensibilis*), poison ivy (*Toxicodendron radicans*), and dewberry (*Rubus hispidus*). Shrub Swamp generally occurs in areas where the wetland crosses the managed portion of the ROW, and tree cover is managed.

Wooded Swamps mainly occur on the edges of the managed ROW where the Shrub Swamps are present, but where tree cover is allowed to dominate. Vegetation in a forested swamp includes red maple, willow (*Salix* sp.), black gum (*Nyssa sylvatica*), alder (*Alnus* sp.), silky dogwood, sweet pepperbush, winterberry, swamp azalea, cinnamon fern, common reed (*Phragmites* sp.), and peat moss (*Sphagnum* spp.).

Forty-eight Swamps are present within the Project ROW.

6.8.1.4 Marsh

Marshes are wetlands at least one acre in size where water is generally above the surface of the substrate and where the vegetation is dominated by emergent herbaceous species. Marshes are the dominant cover type in several large wetlands within the ROW. Marsh vegetation is typically dominated by broad-leaved cattail (*Typha latifolia*) and tussock sedge (*Carex stricta*), with lesser amounts of common reed, sensitive fern, marsh fern (*Thelypteris palustris*), soft rush (*Juncus effusus*), purple loosestrife (*Lythrum salicaria*), and button bush (*Cephalanthus occidentalis)*. Eight Marsh or Marsh/Shrub Swamp Wetland Complexes are present within the Project ROW.

6.8.1.5 River

Rivers located within the Study Area are the Pocasset River, Woonasquatucket River, and Pawtuxet River (Main Stem, North Branch and South Branch).

6.8.1.6 Stream/Intermittent Stream

A stream is any flowing body of water or watercourse other than a river which flows during sufficient periods of the year to develop and maintain defined channels. Such watercourses carry groundwater discharge and/or surface runoff. Such watercourses may not have flowing water during extended dry periods but may contain isolated pools or standing water. Smaller unnamed streams may also be internal to a particular wetland. Streams within the Study Area are Furnace Hill Brook, Assapumpset Brook, Dry Brook, Cherry Brook, Hawkins Brook, Reaper Brook, and Hardig Brook. Other unnamed tributaries associated with these waterways occur within the ROW as well, including tributaries to Meshanticut Brook and the Maskerchugg River.

6.8.1.7 Emergent Plant Community

Emergent plant communities within the Project ROW wetlands are characterized by cattail, bullrush (*Scirpus pungens*), woolgrass (*Scirpus cyperinus*), Joe-Pye weed (*Eupatoriadelphus maculatus*), sensitive fern (*Onoclea sensibilis*), soft rush, and reed canary grass (*Phalaris arundinacea*). Nine emergent plant communities were identified within the ROW.

6.8.1.8 Shrub/Forested Wetland

Shrub wetlands in the Project ROW are dominated by highbush blueberry, sweet pepper bush, arrowwood, maleberry, meadowsweet, greenbrier, and poison ivy, with herbaceous species that include skunk cabbage, cinnamon fern, and jewelweed (*Impatiens capensis*). Some wetlands on the ROW are composed entirely of shrub wetland. Fifty-eight shrub wetlands are present within the ROW.

Forested wetlands occur at the edge of the maintained ROW where most shrub wetlands are present. Vegetation includes red maple, yellow birch (*Betula alleghaniensis*) and ash with an understory generally consisting of vegetation mentioned previously in the shrub wetland. Three forested wetlands are located within the ROW.

6.8.1.9 Floodplain

A floodplain is the land area adjacent to a river or stream or other body of flowing water that is, on the average, likely to be covered with flood waters resulting from a 100-year frequency storm event. Based on available FEMA mapping, 100-year floodplain is crossed by the ROW at Hardig Brook in Warwick, the Pawtuxet River in West Warwick, the Pocasset River in Johnston, Stillwater Pond in Smithfield, an unnamed swamp in Smithfield, and Cedar Swamp in North Smithfield. It is recognized that by definitions provided in the Rules, all Rivers, streams and

intermittent streams have 100-year floodplain though they may not be mapped by FEMA.

6.8.1.10 Area Subject to Storm Flowage

ASSFs are channel areas and water courses which carry storm, surface, groundwater discharge or drainage waters out of, into, and/or connect freshwater wetlands or coastal wetlands. ASSFs are recognized by evidence of scouring and/or a marked change in vegetative density and/or composition. Two ASSFs were identified within the ROW.

6.8.1.11 Special Aquatic Site

A Special Aquatic Site is a contained basin that lacks a permanent above ground outlet. It fills with water with the rising water table of fall and winter or with the meltwater and runoff of winter and spring snow and rain. Special Aquatic Sites contain water for a few months in the spring and early summer. Two special aquatic sites and one marsh/special aquatic site complex were identified within the ROW.

6.9 Wildlife

As previously described, the proposed transmission Project passes through a variety of aquatic and terrestrial habitats. The wildlife assemblages present within the Study Area vary according to habitat characteristics. An overall list of wildlife species expected to occur within the Project ROW was compiled. This list is based upon the major habitats encountered within the ROW. It should be noted that individual species may not occur in one particular area as opposed to another, but may be found in the general area of the transmission line. A list of amphibian, reptiles, birds, and mammals expected to occur within a given habitat are provided in Table 6-7. This information is based on geographical distribution and habitat preferences as described in New England Wildlife: Habitat, Natural History and Distribution (DeGraaf and Yamasaki, 2001).

Table 6-7 Expected and Observed Wildlife Species within the Study Area

	Terrestrial Habitats						Aquatic Habitats								Other		
	Oak/ Pine Forest	Shrub/ Old Field	Cultivated Field	Grass Field	Managed Lawn	Orchard	Sedge Meadow	Shallow Marsh	Shrub Swamp	Pond	Lake	Stream	River	Riparian	Stable Bank	Ledge/ Cliff	Structure
AMPHIBIANS AND REPTILES																	
Marbled Salamander[B]	X								X					X			
Spotted Salamander[B]	X						X	O	O	X				X			
Red Spotted Newt[B]	X						X	X	X	X	X	X		X			
Northern Dusky Salamander[B]	X									X		X		X			
Northern Redback Salamander[B]	X							X									
Four-toed Salamander[B]	X						X	X	X			X					
Northern Two-Lined Salamander[B]	X											X		X			
American Toad[B]	O	O	X	O		X	X	O	X	X	X			X	O		
Fowler's Toad[B]	X	X	X	X		X	X	X	X	X	X			X	X		
Northern Spring Peeper[B]	X						X	O	O	X				X			
Gray Treefrog[B]	O						X	X	X	X	X			X			
American Bullfrog[B]								X	X	O	X	X	X	X			
Green Frog[B]							O	O	O	O	X	X	O	O			
Wood Frog[B]	X					X	X	O	O					X			
Pickerel Frog[B]	X			X			O	O		X	X	X		X			
Common Snapping Turtle[B]	X	X	X	X		X		X	X	X	X	X	X	X	X		
Spotted Turtle[B]	X	X	X	X		X	X	O	O	X		X		X			
Wood Turtle[B]	X	X	X	X		X	X	X	X	X	X	X	X	X	X		
Eastern Box Turtle[B]	X	O		X		X	X	X	X			X		X	X		
Common Musk Turtle[B]		X		X		X	X	X	X	X	X	X	X	X			
Northern Water Snake[B]							X	X	X	X	X	X	X	X	X		X
Northern Red-bellied Snake[B]	X	X							X								X
Common Garter Snake[B]	O	O		X		X	O	O	O	X		X		X			X
Eastern Ribbon Snake[B]	X						X	O	O	X		X		X			X
Eastern Hognose Snake[B]	X	X	X	X		X		X						X			
Northern Ringneck Snake[B]	X																
Eastern Worm Snake[B]	X	X	X														

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	Terrestrial Habitats						Aquatic Habitats								Other		
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Northern Black Racer[B]	X	X		X		X		X	O					X		X	X
Eastern Smooth Green Snake[B]	X	X		X			X	X	X								
Black Rat Snake[B]	X	X		X		X										X	X
Eastern Milk Snake[B]	X	X		X		X										X	X
BIRDS																	
Double-crested Cormorant[B]										O	X		X	X			
Least Bittern[B (Rare)]								X	X								
Great Blue Heron[B]	X						X	X	X	X	X	X	X	X			
Green Heron[B]	X						X	X	X	O	X	X	X	X			
Turkey Vulture[B]	X	O	X	O													
Canada Goose[B]			X	X	O		X	X		X		X	O	X			
Mute Swan[B]			X	X			X	X	X	X	X	X	X				
Wood Duck[B]	X							X	X	O	X	X	X	X			
American Black Duck[B]							X	X	X	X	X	X	X	X			
Mallard[B]			X	X			X	X	X	O	X	X	X	X			
Bufflehead[M]											X	X	X				
Hooded Merganser[B (Rare)]	X									X	X	X	X				
Common Merganser[M]	X									X	X	X	X	X			
Sharp-shinned Hawk[M]	X					X							X				
Cooper's Hawk[B (Rare)]	O	O		X		X											
Northern Goshawk[B (Rare)]	X	X		X		X											
Red-shouldered Hawk[B]	X								X					X			
Broad-winged Hawk[B]	X			X		X											
Red-tailed Hawk[B]	O	O	X	O					X								
Rough-legged Hawk[M]		X	X	X			X	X	X								
American Kestrel[B]	X	X	X	X		X	X	X									
Ring-necked Pheasant[B]		X	X	X		X											
Ruffed Grouse[B]	X	X				X											
Wild Turkey[B]	X	X	X	X		X											

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Northern Bobwhite[B (Rare)]	X	X	X	X		X											
Virginia Rail[B]								X									
Sora[B (Rare)]							X	X	X	X							
Killdeer[B]			X				X							X			O
Spotted Sandpiper[B]				X						O	X	X	X	X			
Wilson's (Common) Snipe[M]		X					X	X	X					X			
American Woodcock[B]	X	X	X				X		O					X			
Herring Gull[B]											X		X				
Rock Dove[B]			X														X
Mourning Dove[B]	X	O	O	O		X											O
Black-billed Cuckoo[B]	O	X				X			x								
Yellow-billed Cuckoo[B]	X	X				X											
Barn Owl[B (Rare)]			X	X		X											
Eastern Screech-Owl[B]	X	X		X		X	X	X						X			
Great Horned Owl[B]	X	X	X	X		X	X	X	x					X			
Barred Owl[B]	X	X		X		X								X			
Northern Saw-whet Owl[B (Rare)]	X					X								X			
Common Nighthawk[B (Rare)]	X	X	X	X		X	X							X		X	X
Whip-poor-will[B]	X	X		X		X											
Chimney Swift[B]		X	X	X		X	X										X
Ruby-throated Hummingbird[B]	O	O				X										O	
Belted Kingfisher[B]										X	X	X	X	X	X		
Red-bellied Woodpecker[B]	X					X								X			
Yellow-bellied Sapsucker[B]	X					X								X			
Downy Woodpecker[B]	O	O				X								X			
Hairy Woodpecker[B]	X													X			
Northern Flicker[B]	O	O	X	O		X											X
Eastern Wood-Pewee[B]	O	O				X			O					X			
Acadian Flycatcher[B (Rare)]	X													X			

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	Oak/ Pine Forest	Shrub/ Old Field	Cultivated Field	Grass Field	Managed Lawn	Orchard	Sedge Meadow	Shallow Marsh	Shrub Swamp	Pond	Lake	Stream	River	Riparian	Stable Bank	Ledge/ Cliff	Structure
Willow Flycatcher[B]	X	X															
Least Flycatcher[B]	X					X								X			
Eastern Phoebe[B]	O	O		O		X			O								X
Great Crested Flycatcher[B]	O	O				X											
Eastern Kingbird[B]	O	O		X		X	X	X	O				O	O			
Northern Shrike[M]	X	X		X		X	X	X									
White-eyed Vireo[B]	X	X							X					X			
Yellow-throated Vireo[B]	X													X			
Warbling Vireo[B]	O	O				X								X			
Red-eyed Vireo[B]	O					X								X			
Blue Jay[B]	O	O		O		X								O			
American Crow[B]	O	O	X	X		X											
Fish Crow[B (Rare)]								X		X	X	X	X	X			
Horned Lark [B (Rare)]			X	X													
Purple Martin[B]		X	X	X		X	X	X		X	X	X	X	X			X
Tree Swallow[B]	O	O	X	O		X	X	O	O	X	X	X	X	X			
Northern Rough-winged Swallow[B]	X	X	X	X		X	X	X		X		X	O	O	X		
Bank Swallow[B]	X	X	X	X		X	X	X		X		X	X	X	X		
Barn Swallow[B]	X			X		X	X	X		X		X	X	X			X
Black-capped Chickadee[B]	O	O				X			O					X			
Tufted Titmouse[B]	O	O				X			O					X			
Red-breasted Nuthatch[B (Rare)]	X					X											
White-breasted Nuthatch[B]	O	O				X								X			
Brown Creeper[B]	X					X								X			
Carolina Wren[B]	O	O							O					X			
House Wren[B]	O	O		O		X			O					X			X
Winter Wren[B (Rare)]	X								X					X			
Golden-crowned Kinglet[B (Rare)]	X																
Ruby-crowned Kinglet[M]	X																
Blue-gray Gnatcatcher[B]	O	O				X			O								

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	Oak/ Pine Forest	Shrub/ Old Field	Cultivated Field	Grass Field	Managed Lawn	Orchard	Sedge Meadow	Shallow Marsh	Shrub Swamp	Pond	Lake	Stream	River	Riparian	Stable Bank	Ledge/ Cliff	Structure
Eastern Bluebird[B]	O	O		X		X			O								X
Veery[B]	X													X			
Hermit Thrush[B]	X	X							X								
Wood Thrush[B]	X													X			
American Robin[B]	O	O	X	X		X			O					X			
Gray Catbird[B]	O	O		O		X			O					X			
Northern Mockingbird[B]	O	O				X			O								
Brown Thrasher[B]	O	O												X			
European Starling[B]	O	O	X	O		X								X			X
Cedar Waxwing[B]	X	O				X			O					X			
Blue-winged Warbler[B]	X	O		X					O								
Golden-winged Warbler[B (Hist.)]	X	X															
Nashville Warbler[B (Rare)]	X								X								
Yellow Warbler[B]	X	O				X			O					X			
Chestnut-sided Warbler[B]		X							X								
Black-throated Green Warbler[B]	X																
Pine Warbler[B]	X																
Prairie Warbler[B]	O	O															
Black–and-white Warbler[B]	X					X								X			
American Redstart[B]	X					X			O					X			
Worm-eating Warbler[B]	X																
Ovenbird[B]	X																
Northern Waterthrush[B]	X								X								
Louisiana Waterthrush[B]	X											X		X			
Common Yellowthroat[B]	O	O					O	O	O	X				X			
Hooded Warbler[B]	X	X							X								
Canada Warbler[B]	X								X					X			
Scarlet Tanager[B]	O																
Eastern Towhee[B]	O	O															
American Tree Sparrow[M]	X	X		X		X	X	X	X					X			

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Chipping Sparrow[B]	X		X	X		X											
Field Sparrow[B]		O	X	O		X											
Savannah Sparrow[B]			X	X			X	X									
Grasshopper Sparrow[B (Rare)]			X	X													
Fox Sparrow[M]	X	X															
Song Sparrow[B]	O	O	X	O		X	O	X	O					X			
Swamp Sparrow[B]							X	X	X	X				X			
White-throated Sparrow[B (Rare)]	X	O		X		X								X			
Dark-eyed Junco [B (Rare)]	X			X		X											
Lapland Longspur[M]			X	X													
Snow Bunting[M]			X	X			X	X									
Northern Cardinal[B]	O	O				X			X					X			
Rose-breasted Grosbeak[B]	O	O				X			O					O			
Indigo Bunting[B]	X	X		X		X								X			
Bobolink[B]				X			X	X									
Red-winged Blackbird[B]			X	X			X	O	O	O				X			
Eastern Meadowlark[B]			X	X		X				X							
Rusty Blackbird[M]														X			
Common Grackle[B]	X		X	X		X	X	X	X		X			X			
Brown-headed Cowbird[B]	O	O	X	X		X		X						X			
Orchard Oriole[B (Rare)]	X					X								X			
Baltimore Oriole[B]	O	O				X			O					X			
Pine Grosbeak[M]	X		X			X											
Purple Finch[B]	X	X				X											
House Finch[B]	X					X											O
Common Redpoll[M]	X	X	X	X		X		X	X								
Pine Siskin[M]	X	X		X					X					X			
American Goldfinch[B]	O	O	X	O		X	O	O	O					X			
Evening Grosbeak[B (Rare)]	X					X								X			
House Sparrow[P]			X	X													X

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MAMMALS																	
Virginia Opossum[B]	X	X	X	X		X	X	X	X					X	X	X	
Masked Shrew[B]	X	X		X		X	X	X	X					X			
Water Shrew[B]	X						X	X	X	X	X	X	X	X			
Northern Short-tailed Shrew[B]	X	X		X		X	X	X	X					X			
Star-nosed Mole[B]							X	X	X	X	X	X	X	X			
Little Brown Myotis[B]	X	X	X	X		X	X	X	X	X	X	X	X	X			X
Northern Myotis[M]	X	X	X	X		X	X	X	X	X	X	X	X	X			X
Silver-haired Bat[M]	X	X	X	X		X	X	X	X	X	X	X	X	X			
Eastern Pipistrelle[B]	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X
Big Brown Bat[B]	X	X	X	X		X	X	X	X	X	X	X	X	X			X
Red Bat[B]	X	X	X	X		X	X	X	X	X	X	X	X	X			
Hoary Bat[M]	X	X	X	X		X	X	X	X	X	X	X	X	X			
Eastern Cottontail[B]	X	O		X		X	X	X	X					X			
New England Cottontail[B]	X	X		X		X	X	X	X					X			
Snowshoe Hare[B]	X	X						X									
Eastern Chipmunk[B]	O	O		X													
Woodchuck[B]	X	X	X	X		X									X		
Gray Squirrel[B]	X													X			
Red Squirrel[B]	X																
Southern Flying Squirrel[B]	X					X											
Beaver[B]	X							X	X	X	X	X	X	X			
White-footed Mouse[B]	X	X		X		X	X		X					X			X
Southern Red-backed Vole[B]	X	X	X	X					X					X			
Meadow Vole[B]	X	X		X		X	X	X	X					X			
Woodland Vole[B]	X	X		X		X											
Muskrat[B]							X	X	X	X	X	X	X	X			
Southern Bog Lemming[B (Rare)]	X	X		X		X	X	X						X			
Norway Rat[B]		X	X	X		X											X

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House Mouse[B]		X	X	X		X											X
Meadow Jumping Mouse[B]	X	X		X		X	X	X	X					X			
Coyote[B]	X	X		X		X	X	X	X					X	X	X	
Red Fox[B]	X	X	X	X		X	X	X	X					X	X	X	
Gray Fox[B]	X	X					X	X	X					X	X	X	
Raccoon[B]	X	X	X	X		X	X	X	X					O		X	
Ermine[B (Rare)]	X	X	X	X				X	X					X	X	X	X
Fisher[B]	X	O															
Long-tailed Weasel[B]	X	X	X	X		X	X	X	X					X	X		X
Mink[B]	X						X	X	X	X	X	X	X	X	X		
Striped Skunk[B]	X	X	X	X		X	X	X	O					X	X		X
River Otter[B]	X							X	X	X	X	X	X	X	X		
White-tailed Deer[B]	O	O	X	X		X	X	X	X					X			

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6.9.1 Fisheries

The RIDEM Division of Fish and Wildlife conducted fish surveys in Rhode Island's streams and ponds between 1993 and 2002. Table 6-8 summarizes the fish that were found in major waterways and waterbodies associated with the Project Study Area. Data were not available for Jillson (Almy) Reservoir, Duck Ponds, Hughesdale Pond, Pocasset Pond, Cherry Brook, Todd's Pond, Capron Pond, Hawkins Brook, Mountaindale Reservoir, Reaper Brook, Stillwater Pond, Stillwater Reservoir, or Natick Pond. Electro-fishing was the primary sampling method used, though trap nets, seine hauls, gill nets, and diving were used where the waterways were not accessible with the electro-fishing boat.

RIDEM currently stocks the Woonasquatucket River, the main, northern, and southern branches of the Pawtuxet River, and Meshanticut Brook with rainbow trout.

Table 6-8 Fish Survey Results

	WATERWAYS/WATERBODIES							
	Pawtuxet River	Pocasset River	Furnace Hill Brook	Assapumpset Brook	Dry Brook	Upper Simmons Reservoir	Woonasquatucket River	Hardig Brook
FISH								
American Eel	X	X		X			X	X
Blacknose dace				X				
Bluegill	X	X		X	X	X	X	
Brown Bullhead	X					X		
Brown Trout			X					
Chain Pickerel					X		X	
Common Carp	X					X		
Creek Chubsucker							X	
Fallfish							X	
Golden Shiner		X				X	X	X
Largemouth Bass					X	X	X	X
Longnose Dace		X	X					
Pumpkinseed			X			X	X	X
Rainbow Trout							X	
Redfin Pickerel		X					X	X
Tessellated Darter							X	X
White Perch	X							
White Sucker	X		X			X	X	X
Yellow Bullhead							X	
Yellow Perch						X		

Legend:
X = Reported as present in Fish Surveys
Source: Rhode Island Department of Environmental Management, Division of Fish and Wildlife "A Preliminary Summary of Fish Surveys That Were Conducted in Rhode Island's Streams and Ponds Between 1993 and 2002, "Alan D. Libby, May 2004.

■

6.9.2 Rare and Endangered Species

The Rhode Island Natural Heritage Program (RINHP) database hosted on the RIDEM Environmental Resource Mapping website[7] as the "Regulatory Overlays:

▼

7 http://www.dem.ri.gov/maps/index.htm

Natural Heritage Areas" identifies four rare species habitat polygons within the project corridor. VHB previously received information on these polygons from Richard W. Enser, former coordinator of the RINHP, as detailed in correspondence dated April 11, 2003 (refer to Appendix A) and in a follow up meeting with him.

On July 25, 2007 the U.S. Fish and Wildlife Service (USFWS) was sent a letter to confirm the presence of any federally listed or proposed, threatened and endangered species known to exist in the Project ROW. The USFWS responded with a letter received by VHB August 30, 2007 that confirmed that no such species or habitat critical to such species is present within the ROW. Thus no Endangered Species Act Coordination is required.

During the summer and early fall of 2007 VHB scientists conducted multiple field surveys in order to verify the presence of rare species per Mr. Enser's 2003 letter and the RIDEM Natural Heritage Areas overlay.

Mr. Enser described a polygon near the West Farnum Substation as a population of slender gerardia (*Agalinis tenuifolia*), which is listed by RIDEM as a Species of Concern in Rhode Island[8]. Species under this listing are not considered to be State Endangered or State Threatened, but are listed due to various factors or rarity and/or vulnerability. The global ranking for *Agalinis tenfuifolia* is G5, which is "demonstrably secure throughout its range, but possibly rare in parts." The population near the West Farnum Substation was observed by VHB staff during a rare species survey conducted on September 26, 2007.

VHB staff surveyed the area of the ROW between Iron Mine Hill Road and Rocky Hill Road in North Smithfield on the same date, and identified a large and previously undocumented population of Smith's Bulrush (*Schoenoplectus smithii)*, a State Threatened species[9]. Previously this species was only known to exist in Washington County. The global ranking for this species is G5, suggesting it is relatively stable.

The same stretch of ROW was the site of two ribbon snake observations in May 2007, and a fisher on August 28, 2007. Ribbon snake is listed by RIDEM as a Species of Concern within Rhode Island[10]. Fisher was previously listed as a Species of Concern but was recently removed[11] due to sufficiently stable populations (J. Osenkowski, RIDEM, personal comm.).

The attached NHP letter indicates that the polygon south of Mountaindale Road in Smithfield is a population of piled sedge *(Carex cumulata)*. VHB staff searched for this

▼

8 Rare Native Plants of Rhode Island September 2007
9 Rare Native Plants of Rhode Island September 2007
10 Rare Native Animals of Rhode Island September 2006
11 Rare Native Animals of Rhode Island September 2006

species in this location during a rare species survey conducted on October 26, 2007 but found no plants.

The large polygon south of Greenville Avenue/Route 5 in Johnston is a population of slender gerardia and an observation of eastern ribbon snake. A search for the gerardia in this location by VHB staff on September 26, 2007 did not yield any results, as the plant community has succeeded and is no longer suitable for this species.

The polygon just south of Route 117 in Warwick denotes an observation of the frosted elfin butterfly (*Callophrys irus*). Wild indigo (*Baptisia tinctoria*) is a food plant for this species. Populations of the butterfly species were not observed during field work, but a field with substantial amounts of the host plant was observed during rare species surveys conducted on October 26, 2007 and May 30, 2008.

6.10 Air Quality

The National Ambient Air Quality Standards (NAAQS) were established by the Federal Clean Air Act Amendments (CAAA), and are designed to protect both public health and welfare. Air quality analyses for projects that may impact motor vehicular traffic are required to evaluate their impact on ozone (O_3) and carbon monoxide (CO).

Rhode Island developed a State Implementation Plan (SIP) in 1982 to comply with the 1977 CAAA requirements for O_3 and CO. While three pollutants, CO, Nitrogen Oxide (NOx), and Volatile Organic Compounds (VOCs), play a role in O_3 formation, the Environmental Protection Agency (EPA) determined in 1980 that SIPs must require the reduction of VOCs as the most effective strategy to achieve the O_3 standard. The 1990 CAAA requires states to update their SIPs to evaluate the impact of reducing all three pollutants.

The State of Rhode Island is required by the CAAA to attain the NAAQS "as expeditiously as practicable." In March 2003, the RIDEM submitted the "Rhode Island Attainment Plan for the One-Hour National Ambient Air Quality Standard" to the EPA as a revision to the SIP. The plan demonstrated that Rhode Island would attain the one-hour ozone standard by 2007. In the Attainment Plan, Rhode Island agreed to submit to EPA by December 31, 2004 a mid-course review demonstrating that Rhode Island remained on track to attain the one-hour standard by 2007. In December 2004 the RIDEM submitted the "Mid-Course Review of the Rhode Island Attainment Plan for the One-Hour Ozone National Ambient Air Quality Standard" to the EPA which demonstrated that Rhode Island was still on track to attain the one-hour standard by 2007.

The EPA revoked the one-hour standard as of June 15, 2005 and subsequent planning and emissions reduction efforts were required to focus on achieving the more stringent 8-hour standard.

In April 2008 the RIDEM submitted the "Revision of the Rhode Island State Implementation Plan to Address Interstate Transport of Pollutants Affecting Attainment and Maintenance of the 8-Hour Ozone and Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standards" to the EPA as a revision to the State's SIP. The plan demonstrated that emissions from Rhode Island sources do not contribute significantly to downwind ozone attainment and will not prevent downwind areas from attaining the NAAQS by their required attainment dates.

7.0 Description of Affected Social Environment

The EFSB Rules require a detailed description of all environmental characteristics of the proposed site including the physical and social environment on and off site. The proposed Project is located within an existing ROW, some of which is easement and some of which is owned in fee by National Grid in the Towns of North Smithfield, Smithfield, Johnston, and West Warwick and the Cities of Cranston and Warwick, Rhode Island (the Host Communities).

As per sections 45-22.2-2 et seq. of the Rhode Island Comprehensive Planning and Land Use Act Rhode Island General Laws, all cities and towns are required to adopt and periodically update Local Comprehensive Land Use Plans. In compliance with these requirements, the cities and towns are in the process of updating their local Plans. Due in part to the timing of the update, local municipalities have relied on available 1990 Census data to prepare various sections of the Plans. At this time, 2000 Census data is available and has been incorporated into this report for use as current information to more accurately assess current conditions in each Host Community.

7.1 Population Trends

The population within the Host Communities increased steadily between 1980 and 2000 as shown in Table 7-1. The Host Communities can be characterized as being a mix of urban and suburban areas with a 2000 population that accounted for 24.2 percent of the total State population.

Table 7-1 Population Trends, 1980 - 2000

Area	1980	1990	2000	Change 1980- 1990 Absolute	Change 1980- 1990 Percent	Change 1990- 2000 Absolute	Change 1990- 2000 Percent
State of Rhode Island	947,154	1,003,464	1,048,319	56,310	6.0%	44,855	4.5%
Host Communities*	237,906	246,957	254,084	9,051	3.8%	7,127	2.9%
Percent of State Population	25.1%	24.6%	24.2%				
North Smithfield	9,972	10,497	10,618	525	5.3%	121	1.2%
Smithfield	16,886	19,163	20,613	2,277	13.5%	1,450	7.6%
Johnston	24,907	26,542	28,195	1,635	6.6%	1,653	6.2%
Cranston	71,992	76,060	79,269	4,068	5.7%	3,209	4.2%
West Warwick	27,026	29,268	29,581	2,242	8.3%	313	1.1%
Warwick	87,123	85,427	85,808	(1,696)	(1.9%)	381	0.4%

Notes:
* Towns of North Smithfield, Smithfield, Johnston, and West Warwick and Cities of Cranston and Warwick.
( ) Negative
Source: U.S. Department of Commerce, Rhode Island Census, 2000

According to the Rhode Island Statewide Planning projections, the population of the Host Communities will slightly decrease by 3.1 percent (7,903 people) between 2000 and 2020 but is projected to increase by 9.2 percent (22,651 people) between 2020 and 2030 (see Table 7-2). From 2020 to 2030 the rate of growth for the Host Communities is expected to be more than three times that of the State of Rhode Island.

Table 7-2 Population Projections, 2000- 2030

Area	2000	2020[1]	2030[2]	Change in Population 2000 – 2020 Absolute	Change in Population 2000 – 2020 Percent	Change in Population 2020 – 2030 Absolute	Change in Population 2020 – 2030 Percent
State of Rhode Island	1,048,319	1,111,464	1,140,543	63,145	6.0%	29,079	2.6%
Host Communities*	254,084	246,181	268,832	(7,903)	(3.1%)	22,651	9.2%
Percent of State Population	24.2%	22.1%	23.6%				
North Smithfield	10,618	11,021	11,207	403	3.8%	186	1.7%
Smithfield	20,613	22,939	24,011	2,326	11.3%	1,072	4.7%
Johnston	28,195	30,247	31,192	2,052	7.3%	945	3.1%
Cranston	79,269	83,811	85,903	4,542	5.7%	2,092	2.5%
West Warwick	29,581	30,928	31,755	1,347	4.6%	827	2.7%
Warwick	85,808	85,235	84,764	(573)	(0.7%)	(471)	(0.6%)

Notes:
1 2020 Population Projections based on the 2000 Census information
2 2030 Population Projections based on the Rhode Island Statewide Planning
* Towns of North Smithfield, Smithfield, Johnston, and West Warwick and Cities of Cranston and Warwick.
( ) Negative
Source: U.S. Bureau of the Census, 2000
Rhode Island Statewide Planning Program, 2004.

7.2 Employment Overview and Labor Force

Recent population growth, urbanization, and a substantial commuter-based population have produced greater demands for and a wider selection of trades and services. According to the Rhode Island Economic Development Corporation (RIEDC), Rhode Island as a whole has enormous growth potential in the health and life science industry due to the emerging biotechnology companies. The financial services sector is extremely important to Rhode Island employing over 32,000 individuals. Many manufacturers that invest in technologies and workforce training to compete in the global market have corporate or divisional headquarters in Rhode Island.

Labor force and employment trends are shown in Table 7-3.

Table 7-3 Labor Force and Employment Estimates, 1990-2000

	North Smithfield	Smithfield	Johnston	Cranston	West Warwick	Warwick	State
2000							
Labor Force	5,858	11,244	14,954	40,271	16,246	45,926	530,590
Employment	5,663	10,788	14,266	38,589	15,512	44,058	500,731
Unemployment	195	456	688	1,682	734	1,868	29,859
Unemployment Rate	3.3%	4.1%	4.6%	4.2%	4.5%	4.1%	5.6%
1990							
Labor Force	5,562	10,497	14,691	39,175	16,275	46,294	522,603
Employment	5,253	9,944	13,727	36,848	15,235	43,769	487,913
Unemployment	309	553	964	2,327	1,040	2,525	34,690
Unemployment Rate	5.6%	5.3%	6.6%	5.9%	6.4%	5.5%	6.6%
Increase in Total Employment 1990-2000	410	844	539	1,741	277	289	12,818

Source: U.S. Department of Commerce, Bureau of the Census, 1990, 2000.
Rhode Island Department of Labor and Training

Historically, the leading employment sectors in the Host Communities have been manufacturing and retail trade. Recently, however, there has been a general shift from manufacturing employment to the professional, scientific, management, administrative and waste management sector.

Currently, the professional, scientific, management, administrative and waste management sector is the largest source of employment in the Host Communities (see Table 7-4). Retail trade ranked second in the Host Communities. These two categories are predicted to continue to make up the largest employers in the future.

Table 7-4 Employment by Industry, 2000

	North Smithfield	Smithfield	Johnston	Cranston	West Warwick	Warwick	Host Communities	
	2000	2000	2000	2000	2000	2000	Total	% of Total
Agricultural, Forestry, Fishing and Hunting, and Mining	70	55	241	227	35	368	996	0.9%
Construction	232	785	865	1,509	296	1,840	5,527	5.2%
Manufacturing	687	1,549	2,038	5,811	1,954	6,381	18,420	17.5%
Wholesale Trade	393	801	538	2,502	512	1,954	6,700	6.4%
Retail Trade	1,147	2,458	2,187	6,475	2,024	13,338	27,629	26.2%
Transportation and Warehousing, and Utilities[1]	236	144	570	1,823	435	2,603	5,811	5.5%
Finance, Insurance, Real Estate, and Rental and Leasing[2]	52	1,322	1,194	1,196	374	4,524	8,662	8.2%
Professional, Scientific, Management, Administrative, and Waste Management	1,053	2,753	2,144	8,798	1,447	15,382	31,577	30.0%
Total	3,870	9,867	9,777	28,341	7,077	46,390	105,322	100%

Notes: Industry data for 1990 and 2000 are not comparable due to changes in the classification system by industry. 2000 Census data not available for the following industries: Information; Educational, Health and Social Services; Arts, Entertainment, Recreation, Accommodation and Food Service; Other Services (Except Public Administration); and Public Administration.

1 Public Utilities Employment included

2 Real Estate Employment included

Source: Rhode Island Statewide Planning.
U.S. Department of Commerce, Bureau of the Census, 2000.

7.3 Land Use

This section describes existing and future land use within the Study Area. The scope of this discussion will address those features which might be affected by the Project.

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7.3.1 Study Area Land Use

As depicted in Figure 7-1, several dominant land use patterns are evident within the Study Area. These generalized land use patterns include residential, commercial/industrial, institutional, recreational, agricultural and waste disposal uses. Growth in the Study Area over the past two decades has been strongly influenced by its geographic location in northern and central Rhode Island.

The major land use located within the affected municipalities is single-family residential development in varying densities. In recent years, residential subdivisions have been the predominant land use which breaks up large parcels of open agricultural land. Large lot subdivisions are a recent trend that will likely continue as the Study Area changes from primarily rural to suburban.

Commercial/industrial development is primarily focused in the vicinity of the Route 7 (Douglas Pike) and Route 116 (George Washington Highway) intersection in Smithfield; Route 5 (Cedar Swamp Road) and Route 44 (Putnam Pike) in Smithfield; along Route 6A (Hartford Avenue) in Johnston; south of Route 14 (Plainfield Pike) in Cranston; along Providence Street in Warwick/West Warwick; and Route 2 (Bald Hill Road) in Warwick. Most of the commercial growth is characterized by a mixture of uses including car dealerships, convenience stores, restaurants, and shopping malls.

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7.3.2 Land Use Along the Transmission Line Corridor

The northern terminus of the Study Area is located at the West Farnum Substation, west of Cedar Swamp and northeast of Todd's Pond. The route then crosses Route 104 (Farnum Pike) and continues south through woodlands and scattered wetland areas into the Town of Smithfield.

From the North Smithfield – Smithfield town line, the ROW continues south through forested and wetland areas, crossing scattered commercial and agriculture uses before crossing Route 7 (Douglas Pike). The ROW continues southwest through forested and wetland areas before crossing scattered commercial and residential uses east and west along Route 116 (George Washington Highway) and Stillwater Road. The ROW crosses Stillwater Pond, and runs south approximately 1.9 miles through forested and scattered residential land uses, across Route 5/104 (Farnum Pike) to the Wolf Hill Substation, north of Mountaindale Road in Smithfield. After crossing Mountaindale Road in Smithfield, the ROW continues south, passing forested areas, residential and commercial areas, crossing Route 44 (Putnam Pike), to the west of the Putnam Pike Substation, located approximately 500 feet north of the Smithfield-Johnston town line.

After crossing over the Smithfield-Johnston town line, the ROW continues south through forested and shrub areas for approximately 4,000 feet, crossing a residential area at Greenville Avenue, continuing south an additional 1.6 miles through forested and wetland areas until adjacent to the I-295 and Route 6A (Hartford Avenue) Interchange, the existing location of the Hartford Avenue Substation. Approximately 1,500 feet south of the Hartford Avenue Substation lies the I-295 and Route 6 Interchange. The ROW continues southwest across Dry Brook and residential areas along Central Avenue, across agricultural and commercial areas adjacent and south of Route 12 (Scituate Avenue), southwest between Simmons Upper Reservoir and Simmons Lower Reservoir, to Route 14 (Plainfield Pike) on the Johnston – Cranston town line.

From the Johnston-Cranston town line, the next 1.6 miles of the ROW continue southwest through agricultural, residential, wetlands, and forested areas with sparse commercial uses. The ROW crosses Furnace Hill Brook, east of the West Cranston Substation and continues southeast for an additional 2.6 miles parallel to an

unnamed stream that flows through agricultural, wetland and forested areas and eventually into an unnamed pond at the Cranston Country Club, approximately 1,500 feet north of the Cranston – West Warwick town line.

The next 1.3 miles of the ROW is located in West Warwick and travels past an unnamed pond, forested and agricultural areas, crossing the Pawtuxet River, commercial areas and then Providence Street, before heading southeast into Warwick.

The ROW continues southeast through residential and forested areas, crossing commercial and institutional areas along Route 2 (Bald Hill Road) and residential areas across Route 117 (Centerville Road) and paralleling I-95 south to the Kent County Substation.

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7.3.3 Open Space and Recreation

Several areas of open space, including recreational areas, are present within the Project Study Area. Powder Mill Ledges is an Audubon Society Refuge located south of Putnum Pike in Smithfield. Snake Den State Park, located north of Hartford Avenue in Johnston, provides year round opportunities for hiking and nature study, and includes Dame Farm, a family-run working farm. Other areas of open space include lands associated with farmlands, wetlands, streams and rivers within the Project Study Area.

Established recreational areas within the Study Area include the Riverpoint Park (formerly the West Warwick Town Landfill), located at the junction of the north and south branches of the Pawtuxet River in West Warwick. This facility includes soccer and baseball fields, a riverwalk, bike trails, skateboard park, concessions and picnic areas. Land surrounding the Jillson (Almy) and Simmons Reservoirs in Johnson provide open space and recreational areas. Woonasquatucket Reservoir and the segment of the Woonasquatucket River south to Capron Road provide opportunities for fishing, access to walking trails, and scenic views. The project Study Area crosses the Washington-Secondary Bike Trail developed by the Department of Transportation where it crosses the Pawtuxet River in West Warwick.

Other recreational areas include the Cranston Country Club off Phenix Avenue in Cranston; the West Warwick County Club and the Midville Country Club in West Warwick; and the Valley Country Club in Warwick. Numerous educational facilities located within the Study Area provide passive recreational areas.

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7.3.4 Future Land Use

In order to assess future land use, an analysis of current zoning was undertaken. Typically, towns and cities manage future growth through zoning regulations which

provide a degree of control over a community. The majority of the Study Area is zoned agricultural, forested, or residential in varying densities, with industrial and commercial pockets in Johnston, Warwick, and West Warwick. Specifically, the route crosses low or medium low density residential areas within the Study Area in the Towns of North Smithfield, Smithfield, Johnston, West Warwick, and the Cities of Cranston and Warwick. The ROW does not cross any areas currently zoned as high density residential.

Currently forested land within the existing Study Area in North Smithfield, Smithfield, Cranston, and West Warwick can be used for future residential development in accordance with the town zoning ordinances. Current agricultural and/or pasture land within the Study Area consists of a cranberry/fish farm adjacent to the ROW at Rocky Hill Road and Cranberry Lane in North Smithfield; an open field located on the west side of the ROW immediately north of Route 7 /Douglas Pike in Smithfield; an orchard just north of Route 14/Plainfield Pike between Taylor Road and Everbloom Drive in Johnston; several large fields in the ROW south of Scituate Avenue in Johnston, several large fields south of Pippin Orchard Road and south of Hope Road in Johnston; and an open field in the ROW just south of Route 14/Plainfield Pike in Cranston, adjacent to the Wakefield Hills Elementary School.

Portions of the Study Area are located within Snake Den State Park in Johnston, and land zoned as open space or conservation area is located in the Towns of Smithfield, Cranston, West Warwick, and the City of Warwick.

The Comprehensive Community Plan for the Town of Johnston adopted December 1991 and the City of Cranston Comprehensive Plan, adopted by City Council on February 24, 1992 (amended as of July 13, 2006) do not address utility transmission line construction.

The Town of North Smithfield's Comprehensive Community Plan Five-Year Update, approved September 2005, states that proposals for power line extensions or major improvements to high voltage lines should consider burying lines underground. The Plan noted that most of the power lines are somewhat removed from any concentrations of housing in North Smithfield.

The Town of Smithfield Comprehensive Community Plan Five-Year Update, approved April 4, 2006, cites two land use objectives pertaining to power/transmission lines: The goal of Objective LU 4.1 is to "Develop and enforce adequate location and siting criteria within the Town's land use regulations for power lines, pipe lines and landfills." The goal of Objective LU 4.2 is to "Minimize the adverse impacts of power transmission facilities on the environment by careful planning and by capitalizing on potential compatible uses to the greatest extent possible." There are no specific action measures identified to achieve these objectives.

According to the City of Warwick Comprehensive Plans as approved December 20, 2002 regarding park facility improvements, Planning District 7 in the vicinity of Duchess Street noted concern over the presence of transmission lines. They would ultimately like a new park site. The proposed project will not be located in the vicinity of Duchess Street.

The Town of West Warwick Comprehensive Plan, approved March 1992 (adjusted March 2005), notes that municipalities surrounding West Warwick currently have open land that will be developed in future years, which may require the installation of new service lines that pass through West Warwick. The plan suggests reducing the impacts to communities through the placement of new utility lines in a common corridor.

7.4 Visual Resources

The visual quality of a place is determined by the perceived aesthetic value of the available views as influenced by the topography, vegetation, and land use. The National Grid ROW extends approximately 21 miles through multiple towns in Rhode Island. The visual study area for this Project was defined as the area within a one-mile radius of the center line of the existing transmission corridor. The topography in the study area varies from level plains to gently rolling hills and valleys. Land use is a mix of undeveloped forestland, occasional agricultural fields, as well as suburban and urbanized areas characterized by high density residential development interspersed with commercial corridors and "big box" retail development. A relatively small area of industrial development exists in the central portion of the study area. Forest vegetation is primarily an oak-hickory community intermixed with white pine/red pine forest. Mature forest vegetation typically occurs in large intact blocks that provide a strong sense of enclosure and screening along streets and around residential and commercial areas. There are several lakes, ponds, rivers, and small streams within the study area, but they are typically obscured from direct view by dense forest vegetation.

The study area does include a number of resources/sites that could be considered visually sensitive from a statewide, regional or local perspective. Visually sensitive resources within the study area include state historic sites, numerous public recreational sites and several areas designated as scenic by RIDEM. Designated scenic areas within the study area include Brayton Road, Evans Road/Tarklin Road, and Stillwater Reservoir in Smithfield; Burlingame Road/Laten Knight Road in Cranston; Grange Road in North Smithfield; Natick Hill in Warwick; and Pippin Orchard Road/Seven Mile Road in Cranston and Johnston.

Areas of intensive land use in the study area are also considered visually sensitive due to the number of potential viewers. These areas include residential neighborhoods, commercial districts and transportation corridors. Specific viewer

groups within the study area include commuters and through-travelers, local residents, business employees, and recreational users.

7.5 Noise

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7.5.1 Introduction[12]

Environmental sound levels are quantified by a variety of parameters and metrics. This section introduces general concepts and terminology related to acoustics and environmental noise.

Sound energy is physically characterized by amplitude and frequency. Sound amplitude is measured in decibels (dB) as the logarithmic ratio of a sound pressure to a reference sound pressure which corresponds to the typical threshold of human hearing. Generally, the average listener considers a 1 dB change in a constant broadband noise “imperceptible” and a 3 dB change "just barely perceptible". Similarly, a 5 dB change is generally considered "clearly noticeable" and a 10 dB change is generally considered a doubling (or halving) of the apparent loudness. Frequency is measured in hertz (Hz), which is the number of cycles per second. The typical human ear can hear frequencies ranging from approximately 20 Hz to 20,000 Hz. Typically, the human ear is most sensitive to sounds in the middle frequencies (1,000 to 8,000 Hz) and is less sensitive to sounds in the low and high frequencies. As such, the A-weighting scale was developed to simulate the frequency response of the human ear to sounds at typical environmental levels. The A-weighting scale emphasizes sounds in the middle frequencies and de-emphasizes sounds in the low and high frequencies. Any sound level to which the A-weighting scale has been applied is expressed in A-weighted decibels, dBA. For reference, the A-weighted sound pressure levels associated with some common noise sources are shown in Table 7-5.

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12 This introduction including Table 7-5 is taken from an Environmental Noise Assessment prepared for the Southern Rhode Island Transmission Project by Black & Veatch Corporation.

Table 7-5 Typical Sound Pressure Levels Associated with Common Noise Sources

Sound Pressure Level (dBA)	Subjective Evaluation	Environment	
		Outdoor	Indoor
140	Deafening	Jet aircraft at 75 ft	
130	Threshold of pain	Jet aircraft takeoff at 300 ft	
120	Threshold of feeling	Elevated train	Rock band concert
110	Extremely Loud	Jet flyover at 1000 ft	Inside propeller plane
100	Very Loud	Motorcycle at 25 ft, auto horn at 10 ft, crowd noise at football game	
90	Very Loud	Propeller plane flyover at 1000 ft, noisy urban street	Full symphony or band, food blender, noisy factory
80	Moderately Loud	Diesel truck (40 mph) at 50 ft	Inside auto at high speed, garbage disposal, dishwasher
70	Loud	B-757 cabin during flight	Close conversation, vacuum cleaner, electric typewriter
60	Moderate	Air-conditioner condenser at 15 ft, near highway traffic	General office
50	Quiet		Private office
40	Quiet	Farm field with light breeze, birdcalls, soft stereo music in residence	Bedroom, average residence (without television and stereo)
30	Very quiet	Quiet residential neighborhood	
20	Very Quiet	Rustling leaves	Quiet theater, whisper
10	Just audible		Human breathing
0	Threshold of hearing		

Source: Adapted from Architectural Acoustics, M. David Egan, 1988 and Architectural Graphic Standards, Ramsey and Sleeper, 1994.

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7.5.2 Kent County Substation

In order to characterize the acoustical environment around the existing substation, an ambient sound level survey was conducted between June 3 and June 6, 2008. The primary sources of noise were found to be vehicular traffic on both Cowesett Road and Interstate 95, existing substation equipment and natural sounds. The City of Warwick has a noise ordinance that limits permissible noise levels that may be perceived as a nuisance to nearby residents or other receptors. Regulated noise levels include harsh, prolonged or unnatural to 60 dBA sound levels between the hours of 8 AM to 10 PM, 50 dBA sound levels between the hours of 10 PM and 8 AM or any noise that exceeds 10 dBA above ambient sound levels at the property line. A comparison of the existing conditions performed by ATCO Noise Management entitled Environmental Noise Assessment, Kent County Substation, Warwick, Rhode

Island (ATCO Noise Management July 21, 2008) indicates that the substation is in compliance with the City of Warwick maximum permissible noise limits.

7.6 Cultural Resources

PAL conducted a Phase I (a/b) reconnaissance archaeological survey consisting of archival research and a project site walkover investigation to assess the potential for pre-contact, contact, and post-contact period cultural resources to be present within the existing ROW. As a result of the survey, the ROW has been stratified into zones of high, moderate, and low archaeological sensitivity, relative to the probability that potentially significant cultural resources can be expected to be (or have been) located within those zones. Further consideration of cultural resources was recommended for area-specific construction and construction-related impacts within the identified zones of high and moderate archeological sensitivity.

Zones of high and moderate archaeological sensitivity were identified in sections of the ROW that have not been substantially disturbed and are situated in attractive environmental settings (elevated terrain, well-drained soils, within 500 meters of a source of water) and/or are within or proximate to identified cultural resources. Poorly drained areas (wetlands) and sections of the existing ROW substantially disturbed through activities such as sand and gravel mining were identified as zones of low sensitivity.

7.7 Transportation

The transportation needs of the Study Area are served by a network of federal, state and local roads and highways. The primary transportation arteries in the Study Area running north/south are Interstate 295, whose on/off ramps cross the ROW at the interchange at Routes 6 and 6A in Johnston, and Interstate 95, which crosses near the southern terminus of the corridor at the Drum Rock and Kent County Substations. State highway systems within the Study Area that serve the urban and suburban areas include Route 2, Route 5, Route 6, Route 6A, Route 7, Route 12, Route 14, Route 33, Route 44, Route 104, Route 115, Route 116, Route 117, and Route 146. The ROW crosses thirty-nine roadways. Multiple local roads and state roads within the Study Area are crossed by the ROW. Construction access to the ROW may be from any of the roadways described above. National Grid will coordinate with applicable entities for permission to utilize these public ways for construction access.

7.8 Electric and Magnetic Fields

EMF is a term used to describe electric and magnetic fields that are created by voltage (electric field) and electric current (magnetic field). National Grid, like all North American electric utilities, supplies electricity at 60 Hertz (Hz). Therefore, the

electric utility system and the equipment connected to it, produce 60-Hz (power-frequency) EMF. These fields can be measured using instruments and can be calculated using a computer model.

Power frequency EMFs are present wherever electricity is used. Sources of these fields include utility transmission lines, distribution lines, substations, building wiring in homes, offices, and schools, and the appliances and machinery used in these locations.

Electric fields are present whenever voltage exists on a wire, and are not dependent on the magnitude of the current flow. The magnitude of the electric field is primarily a function of the configuration and operating voltage of the line and decreases with the distance from the source (i.e., the transmission line.) Electric fields are shielded (i.e., the strength is reduced) by conducting surfaces, including trees, fences, walls, buildings, and most types of structures. The strength of an electric field is measured in volts per meter (V/m) or kilovolts per meter (kV/m).

Magnetic fields are present whenever current flows in a conductor and are not dependent on the voltage present on the conductor. The magnetic field strength resulting from a transmission line is a function of both the current flow on the conductor and the configuration of the transmission line. The strength of these fields also decreases with distance from the source. However, unlike electric fields, most common materials have little shielding effect on magnetic fields.

Magnetic fields are measured in units called Gauss. However, for the low levels normally encountered during daily activities, the field strength is expressed in a much smaller unit, the milliGauss (mG), which is one thousandth of a Gauss.

Electric and magnetic fields from the existing transmission lines were calculated at the edges of the ROW for each of eight segments of the ROW using projected annual average and annual peak load levels for the year 2012. Table 7-6 shows calculated electric field levels at the edge of the ROW for the eight transmission line segments. Tables 7-7 and 7-8 show the magnetic field (RMS Resultant) levels produced by the existing transmission lines on the ROW under average and peak loads, respectively. The magnetic field at peak loading level is not a good predictor of potential exposure because peak loading on the proposed and existing lines would be expected to occur at most during a few hours on a few days of the year.

Table 7-6 Calculated Electric Field Levels (kV/m) at Edges of ROW under Existing Conditions (2012 pre-construction) +

ROW Segment	ROW Configuration**	East edge of ROW	West Edge of ROW
Cross section 1 - 0.16 Mi South of Rt 104 to Rt 44 (W. Farnum to Farnum Pike)	Figure 4-2, Sheet 1 of 5	0.65	1.79
Cross section 2 - 0.16 Mi South of Rt 104 to Rt 44 (Wolf Hill to Putnam Pike)	Figure 4-2, Sheet 1 of 5	0.65	1.79
Cross section 3 - Rt 5 to Hartford Ave Substation	Figure 4-2, Sheet 2 of 5	0.28	1.79
Cross section 4 - .60 Mi North of Phenix Avenue to .13 Mi North of Providence Street	Figure 4-2, Sheet 1 of 5	0.56	1.81
Cross section 5 - .13 Mi North of Providence Street to Providence Street	Figure 4-2, Sheet 3 of 5	0.05	3.84
Cross section 6 - New London Avenue to Bald Hill Road	Figure 4-2, Sheet 2 of 5	0.34	1.81
Cross section 7 - Bald Hill Road to 0.10 Mi North of Rt 117	Figure 4-2, Sheet 4 of 5	0.07	1.81
Cross section 8 - .16 Mi South of Rt 117 to .11 Mi North of Cowesett Rd	Figure 4-2, Sheet 5 of 5	1.31	0.15

+ Electric field levels do not vary with load.
** Figure showing physical arrangement of lines on ROW.
Source: Exponent (2008).

Table 7-7 Calculated Magnetic Field Levels (mG) at Edges of ROW (Annual Average Load) under Existing Conditions (2012 pre-construction)

ROW Segment	ROW Configuration*	East edge of ROW	West edge of ROW
Cross section 1 - 0.16 Mi South of Rt 104 to Rt 44 (W. Farnum to Farnum Pike)	Figure 4-2, Sheet 1 of 5	10.5	26.7
Cross section 2 - 0.16 Mi South of Rt 104 to Rt 44 (Wolf Hill to Putnam Pike)	Figure 4-2, Sheet 1 of 5	6.2	25.7
Cross section 3 - Rt 5 to Hartford Ave Substation	Figure 4-2, Sheet 2 of 5	10.8	25.4
Cross section 4 - .60 Mi North of Phenix Avenue to .13 Mi North of Providence Street	Figure 4-2, Sheet 1 of 5	21.9	26.9
Cross section 5 - .13 Mi North of Providence Street to Providence Street	Figure 4-2, Sheet 3 of 5	6.6	47.9
Cross section 6 - New London Avenue to Bald Hill Road	Figure 4-2, Sheet 2 of 5	10.8	27.1
Cross section 7 - Bald Hill Road to 0.10 Mi North of Rt 117	Figure 4-2, Sheet 4 of 5	2.5	27.1
Cross section 8 - .16 Mi South of Rt 117 to .11 Mi North of Cowesett Rd	Figure 4-2, Sheet 5 of 5	21.3	4.7

* Figure showing physical arrangement of lines on ROW.
Source: Exponent (2008).

Table 7-8 Calculated Magnetic Field Levels (mG) at Edges of ROW (Annual Peak Load) under Existing Conditions (2012 pre-construction)

ROW Segment	ROW Configuration*	East edge of ROW	West edge of ROW
Cross section 1 - 0.16 Mi South of Rt 104 to Rt 44 (W. Farnum to Farnum Pike)	Figure 4-2, Sheet 1 of 5	7.1	34.0
Cross section 2 - 0.16 Mi South of Rt 104 to Rt 44 (Wolf Hill to Putnam Pike)	Figure 4-2, Sheet 1 of 5	12.3	32.4
Cross section 3 - Rt 5 to Hartford Ave Sub	Figure 4-2, Sheet 2 of 5	14.8	31.8
Cross section 4 - .60 Mi North of Phenix Avenue to .13 Mi North of Providence Street	Figure 4-2, Sheet 1 of 5	45.6	36.9
Cross section 5 - .13 Mi North of Providence Street to Providence Street	Figure 4-2, Sheet 3 of 5	12.2	65.0
Cross section 6 - New London Avenue to Bald Hill Road	Figure 4-2, Sheet 2 of 5	30.0	37.1
Cross section 7 - Bald Hill Road to 0.10 Mi North of Rt 117	Figure 4-2, Sheet 4 of 5	4.1	37.1
Cross section 8 - .16 Mi South of Rt 117 to .11 Mi North of Cowesett Rd	Figure 4-2, Sheet 5 of 5	28.7	6.3

∗ Figure showing physical arrangement of lines on ROW.
Source: Exponent (2008).

A discussion of the current status of the health research relevant to exposure to electric and magnetic fields is included in Appendix B. This report was prepared by Exponent, Inc.

8.0 Impact Analysis

This chapter presents an analysis of the potential impacts of the Project on existing environmental and social conditions within the Study Area. As with any construction project, potential adverse impacts can be associated with the construction, operation or maintenance of an electric transmission line or substation. These impacts have been minimized by the careful location of structures, facilities and access roads, and by the adoption of numerous mitigation practices.

This project will be constructed in a manner that minimizes the potential for adverse environmental impacts. A monitoring program will be conducted by National Grid to ensure that the Project is constructed in compliance with all relevant licenses and permits and all applicable federal, state, and local laws and regulations. Design and construction mitigation measures will ensure that construction related environmental impacts are minimized.

8.1 Geology

The Project will have negligible impact on the bedrock and surficial geologic resources of the Project ROW. The Project ROW consists of ablation till with pockets of lodgment till and organic deposits associated with wetland areas. Glacial outwash deposits make up the majority of the soils in the vicinity of the Assapumpset Brook, Simmons Reservoirs, and Pawtuxet River valleys. Organic deposits and sections of urban land are scattered throughout the Project ROW.

Bedrock is expected to be encountered throughout a large majority of the Project ROW during excavation for structure foundations. If bedrock is encountered at or below the surface and it is sufficiently stable and unfractured, the pole structures may be anchored directly to the bedrock which will serve as the footing for the structures. If the bedrock is inadequate as a pole footing, it will be drilled or blasted to the required depth and a concrete footing will be prepared, or the pole set and backfilled with clean granular material.

If required, blasting activities will be performed with strict adherence to relevant local, state and federal regulations. Proper safeguards will be taken to protect personnel and property in the area. Charges will be kept to the minimum required to

break up the rock. Mats of heavy steel mesh or other material will be used to prevent the scattering of rock and debris.

The Project includes limited grading activities. Minor grading may be necessary to improve existing access roads and/or prepare a work site for structure construction.

8.2 Soils

Construction activities which expose unprotected soils have the potential to increase natural erosion and sedimentation rates. Soil compaction and decreased infiltration rates may result from equipment operations. To minimize these impacts, standard construction techniques and BMPs such as the installation of hay bales and siltation fencing, the re-establishment of vegetation and dust control measures, will be employed to minimize any short- or long-term effects due to construction activity. These devices will be inspected by National Grid's Environmental Monitor frequently during construction and repaired or replaced if necessary. National Grid will develop and implement a Storm Water Pollution Prevention Plan (SWPPP) which will detail BMPs and inspection protocols.

Excess soil from excavation at pole structures in uplands will be spread around the poles and stabilized to prevent migration to wetland areas. Excess material excavated from pole structure locations in wetlands will be disposed of at upland sites. Topsoil will then be spread over the excess excavated subsoil material to promote rapid revegetation.

Highly erodible soils are encountered within the Project ROW. However, on all slopes greater than eight percent which are above sensitive areas, disturbed soils will be stabilized with hay or chipped brush mulch to prevent the migration of sediments.

The Project ROW crosses several areas of prime farmland soils. The majority of these areas are currently occupied by active agricultural fields between the Simmons Reservoirs in Johnston and Hope Road in Cranston. A hayfield south of Wakefield Street in West Warwick is also located in prime farmland soils. Both residential and transportation land uses also occupy a portion of these areas throughout the Project ROW. The Project will displace prime farmland soils only at new pole locations.

8.3 Surface Water

Any impact of the Project upon surface watercourses will be minor and temporary. Construction activities temporarily increase risks for erosion and sedimentation that may temporarily degrade existing water quality; however, appropriate BMPs will be implemented and maintained to effectively control sediment. In addition,

construction equipment will not cross rivers and streams along the construction corridor without the use of temporary mat bridges or other crossing structures. Emphasis has been placed on utilizing existing gravel roadways within the ROW and seeking access points that avoid crossing wetlands and surface waters.

The major surface water features within the Project ROW include Cherry Brook, Woonasquatucket River, Stillwater Pond, Hawkins Brook, Assapumpset Brook, Pocasset River, Dry Brook, Simmons Brook (between Simmons Upper and Lower Reservoirs), Furnace Hill Brook, Meshanticut Brook, Pawtuxet River, Hardig Brook and the unnamed perennial watercourses. Swamp mats will be used to access structure locations within or adjacent to surface water features as conditions warrant. Access to most structure locations adjacent to these watercourses will be provided without impacting the channels either by using alternate upland access on the ROW or by spanning the areas using temporary wooden mats during construction. Sedimentation and erosion within these watercourses will be minimized through the implementation of BMPs prior to construction activities.

Potential impacts to surface waters if sediment transport is not controlled include increased sedimentation (locally and downstream) and subsequent alterations of benthic substrates, decreases in primary production and dissolved oxygen concentrations, releases of toxic substances and/or nutrients from sediments, and destruction of benthic invertebrates. Erosion and sedimentation controls will effectively minimize the potential for this situation to occur. The implementation and maintenance of stringent erosion and sedimentation control BMPs will limit the levels of project related sedimentation and will minimize adverse impacts to surface waters.

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8.3.1 Water Quality

The primary potential impact to water quality from any major construction project is the increase in turbidity of surface waters in the vicinity of construction resulting from soil erosion and sedimentation from the disturbed site. A second potential impact is the spillage of petroleum or other chemical products near waterways. Disturbance to previously undisturbed areas on the ROW will be minimized through the use of existing roadways. Overhead transmission line construction requires only a minimal disturbance of soil for pole foundation excavation. Further, equipment will not be refueled or maintained near wetland or surface water resources. Therefore, it is anticipated that any adverse impacts to water resources resulting from construction of the proposed transmission line will be negligible.

The removal of vegetation prior to construction may result in increased erosion potential so that slightly higher than normal sediment yields may be delivered to area streams and wetlands during a heavy rainfall. However, these short-term impacts should be minor as a result of the relatively small area to be disturbed, the use of selective clearing within 25 feet of streams, the implementation of erosion control measures and the short duration of construction activities. In addition, a detailed Erosion Control Plan will be designed and implemented which will confine sediment within the immediate construction area and minimize impacts to downstream areas.

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8.3.2 Hydrology

Some minor, temporary impacts to surface drainage can be expected during construction and maintenance of the transmission lines. These impacts will be associated with access road improvements and installation of the pole structures. Following construction, the topography within the work corridor will generally be restored to its pre-construction contours with the exception of structure pads and permanent access roads.

The hydrology of surface waters will not be significantly affected during or after construction since temporary wooden mat bridges will be constructed across some stream channels to allow for the passage of construction equipment without disturbing the stream or its channel substrate. These bridges will be removed following construction. A slightly higher rate of storm water runoff may result from the clearing of vegetation which would otherwise function to absorb some of the precipitation and slow the rate of runoff. These impacts will be short-term because vegetative cover will quickly reestablish in the construction corridor following construction.

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8.3.3 Floodplain

Based on available FEMA mapping, 100-year floodplain is crossed by the ROW at Hardig Brook in Warwick, the Pawtuxet River in West Warwick, the Pocasset River in Johnston, Stillwater Pond in Smithfield, an unnamed swamp in Smithfield, and Cedar Swamp in North Smithfield. The 100-year floodplain represents the extent of flooding that would result during a storm event having a one percent chance of occurring per year. It is recognized that by definitions provided in the Rules, all Rivers, streams and intermittent streams have 100-year floodplain though they may not be mapped by FEMA.

Permanent impacts to floodplain will occur at Structure 43 on the reconfigured T-172 Transmission Line, Structure 120 on both the reconfigured S-171 and T-172 Transmission Lines, and at Structure 104 on the proposed 359 Transmission Line, and totals approximately 201 square feet of permanent disturbance. In accordance with

state and local regulations, National Grid will provide incremental floodplain compensation as close as practicable to each impact.

8.4 Groundwater

Any impact of the Project upon groundwater resources will be minor.

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8.4.1 Transmission Lines

Potential impacts to groundwater resources within the Project ROW as a result of construction activity will be negligible. Equipment used for the construction of the transmission line will be properly maintained and operated to reduce the chances of spill occurrences of petroleum products. Refueling of equipment will be conducted in upland areas. Within primary groundwater recharge areas, special safeguards will be implemented to assure the protection of groundwater resources. Refueling equipment will be required to carry spill containment and prevention devices (i.e., absorbent pads, clean up rags, five gallon containers, absorbent material, etc.) at all times. In addition, maintenance equipment and replacement parts for construction equipment will be on hand to repair failures and stop a spill in the event of equipment malfunction. Following construction, the normal operation and maintenance of the transmission line facility will pose no threat to groundwater resources.

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8.4.2 Substation

One 345/115 kV auto transformer is proposed to be installed at the Kent County Substation. The transformer is filled with approximately 19,420 gallons of mineral oil dielectric fluid (MODF) for insulation and cooling. Although MODF is not listed as a hazardous material, it is hydrocarbon based and therefore warrants special attention.

In accordance with EPA spill prevention control and countermeasures (SPCC) requirements (Title 40 CFR Part 112), containment must be provided to prevent spills from reaching navigable waters. The proposed transformer will be supported on concrete foundations with a secondary containment system. Secondary containment systems will be designed in conformance with guidelines developed by National Grid which are in use throughout National Grid's service territory.

The EPA regulations require that substation transformers containing oil based fluids must have secondary containment for the entire contents of the unit plus sufficient freeboard to allow for precipitation. At the Kent County Substation the transformer will be surrounded by a containment system sized to contain at least 125 percent of its MODF volume. Other electrical equipment such as the regulators and breakers contain

much smaller amounts of MODF. Any potential leak from these will be trapped in the crushed stone surface.

Due to their critical role, National Grid performs regular inspections and maintenance of its substations. In addition if a leak was to occur, the substation equipment is alarmed to notify National Grid's 24 hour a day trouble center to dispatch a crew to address the problem.

The modifications at Kent County Substation and West Farnum Substation will not involve storage of hazardous materials but do require installation of batteries to provide power in the event of an emergency. The acid contained in the batteries is toxic and corrosive, and is classified as a hazardous material. Leaks from substation batteries are an infrequent event. In the unlikely event of a leak, the liquid will be contained behind the berm until cleanup is performed. Hydrogen gas vapors from a leaking battery will be detected by sensors. If a hydrogen gas condition is detected an alarm is transmitted to National Grid's Control Center and fans are automatically activated to purge gas from the substation control building. These engineering controls, coupled with National Grid's regular inspection and maintenance program, make it unlikely that the battery acid would pose a hazard to the public or the environment.

Due to their unique construction, substations typically do not generate large increases in storm water runoff. Substations yards are constructed with well drained gravel to create a near level pad and surfaced with a layer of crushed stone. After storm events, the crushed stone surface and underlying gravel will cause rainfall to infiltrate and prevent standing water. Impervious surfaces are limited to the concrete equipment foundations, access driveway and control house roof. Runoff from these areas will sheet into the crushed stone and infiltrate into the soil.

8.5 Vegetation

Impacts to vegetation will occur along segments of the 332 transmission line around West Farnum Substation in North Smithfield and along the transmission line ROW from Hardig Road to Kent County Substation in Warwick. The clearing of vegetation will consist of cutting trees and saplings within 64 feet of the proposed centerline of the transmission line alignment. This will result in a variable amount of clearing that is required depending on the existing tree line. Approximately 6.5 acres of existing vegetation will be cleared for the Project.

Woody species with a mature height over 10 feet will be removed. Low growing vegetation will be preserved wherever possible. Following construction, disturbed areas in the vicinity of the pole structures will be seeded and mulched.

A well-managed ROW is required to maintain the reliability of the transmission system. Following construction, vegetation management is necessary to prevent trees and other tall woody species from growing into or falling into the lines. Dense

woody vegetation also restricts visual and physical access which is necessary for inspection, repair and maintenance of the transmission lines.

National Grid manages vegetation on its ROWs through integrated procedures combining removal of danger trees, hand cutting, targeted herbicide use, mowing, selective trimming and side trimming. Three methods of targeted herbicide treatments are utilized: basal application, cut stump treatment, and foliar application.

The appropriate method of vegetation management is chosen by a National Grid forester or arborist in accordance with National Grid's vegetation management policy. The typical maintenance cycle for this ROW is five years, although occasionally site specific conditions may require a shorter cycle. Any permits necessary for vegetation management operation are obtained prior to the initiation of management procedures.

8.6 Wetlands

Construction of the Project will result in temporary and permanent impacts to wetland resources. The following sections describe the impacts associated with construction of the Project including vegetation clearing, excavation for pole structures and access road construction.

8.6.1 Clearing and Vegetation Management

Approximately 0.75 acres of vegetation clearing will occur within biological wetland and state-regulated buffer areas to facilitate construction and maintenance of the proposed transmission line. Appropriate erosion and sediment control measures will minimize impacts to wetlands from adjacent disturbed areas.

8.6.2 Access Roads

Following the delineation of wetland boundaries within the 21.4 mile Project ROW, a site inspection was conducted to determine access to pole structures which would minimize impacts to wetland areas. Access road locations have been chosen to avoid wetlands completely, to cross wetlands at previously impacted locations or to traverse the edges of wetlands. Temporary crossings using timber mats will be used where possible.

No permanent access roads will be constructed within wetland areas for this Project.

8.6.3 Structures

Under the current design of the proposed transmission facilities, engineering and safety requirements necessitate the placement of 174 pole structures within state regulated wetland areas, of which 49 pole structures are also within federally regulated wetland areas and four pole structures within State-regulated 100-year floodplain. The only fill needed for structures is the concrete associated with the foundations and any crushed stone backfill required around the foundation caisson. This would amount to approximately 1.9 cubic yards per foot of concrete reveal and crushed stone per structure. To mitigate this impact, National Grid will provide incremental floodplain compensation.

8.7 Wildlife

During construction, displacement of wildlife may occur due to disturbance associated with ROW clearing and the operation of construction equipment. Wildlife currently utilizing the forested edge of the cleared ROW may be impacted by the construction of the Project. Larger, more mobile species, such as eastern white tailed deer or red fox, will leave the construction area. Individuals of some bird species will also be temporarily displaced. Depending on the time of year of these operations, this displacement could impact breeding and nesting activities.

Smaller and less mobile animals such as small mammals, reptiles, and amphibians may be killed during vegetation clearing and the transmission line construction. The species impacted during the construction of the transmission line are expected to be limited in number. Effects will be localized to the immediate area of construction around structure locations and along existing access roads. However, this is anticipated to be a temporary impact as it is anticipated that existing wildlife utilization patterns will resume and population sizes recover during the operational phase of the project.

The removal of trees from forested areas within the ROW may affect wildlife species populations by favoring species that prefer shrub or other early successional cover types over those that inhabit closed canopy forested communities. However, at present forest is dominant cover type in New England while shrublands and other early successional habitats have declined through the 20th Century to the present and now only comprise an estimated 12 percent of the land area (Trani et al. 2001, Schlossberg and King 2007). The decline of shrublands and other early successional cover types has been related to the significant decline of bird species dependent on this habitat for breeding and cover (Witham and Hunter 1992). Transmission line corridors are one of the few sources of persistent shrubland cover in the northeastern U.S. and provide important habitat for a variety of bird and wildlife species (Confer et al. 2008).

A study conducted by Nickerson and Thibodeau (1984) of three ROWs in Massachusetts indicated an increase in wildlife utilization, especially avian species, following clearing of the ROWs. The study attributed this increase in wildlife usage to the conversion of forested areas into both wetland and upland shrub and emergent plant communities, and provided edge effect feeding, nesting and cover habitat for various species. The ROWs also serve as open corridors connecting non-contiguous natural areas.

Impacts to sensitive habitats of rare, threatened or endangered species will be avoided through careful project planning which has involved a detailed ROW inventory, an evaluation of avoidance and mitigation of potential impacts, and close coordination with the RIDEM. Impacts to rare, threatened or endangered species will be considered as part of the RIDEM Freshwater Wetlands permit process.

8.8 Social and Economic Impacts

Based on the proposed location of the Project, the greatest potential for social impact is the interaction of construction and maintenance on current and future land uses abutting the ROW.

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8.8.1 Social Impacts

The Project will enable National Grid to continue to provide reliable electric services to homes, business and industry throughout Rhode Island. The proposed Project does not require nor will it lead to residential or business disruption. Temporary construction impacts, primarily related to construction traffic and equipment operation are expected to be minor; however, the Project will not adversely impact the overall social and economic condition of the Project ROW. As described in Section 4.0, the proposed transmission line will be located entirely within an existing ROW presently occupied by other electric lines. Therefore, the Project will not require the acquisition of property or disrupt orderly planned development, thus avoiding adverse impacts.

In order to minimize social impacts, National Grid has engaged in extensive outreach to abutters of the ROW and to municipal officials as described in Section 4.7. National Grid will also appoint an Ombudsman to serve as a contact for abutters during the construction phase of the Project.

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8.8.2 Population

Project construction and maintenance will have no impact on the population but will improve existing electrical service reliability to the population throughout Rhode Island. It also will provide the capability to serve residential, commercial and industrial developments planned for the future.

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8.8.3 Employment

The construction of the transmission line may have minor beneficial effects on the area economy by creating new jobs for the construction period. Project expenditures may also have a small spin-off impact as funds are recirculated and spent within the local economy.

By meeting the current and projected demands for increased power in the area, the construction of the Project will support the state's effort to stimulate additional growth and economic activity in the region.

8.9 Land Use and Recreation

The following discussion addresses the compatibility of the proposed transmission line with various land uses along the proposed route.

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8.9.1 Land Use

Land use impacts can be separated into short-term and long-term impacts. Short-term land use impacts may occur during the construction phase of the proposed project. Impacts associated with the construction phase of the Project will be temporary, and most present land uses within the existing ROW could resume following construction. National Grid will provide notification of the intended construction plan and schedule to affected abutters so that the effect of any temporary disruptions may be minimized.

The Project is proposed entirely within an existing ROW, which is already occupied by electric facilities. The reconstruction and construction of the transmission lines within the existing ROW will be consistent with the established land use and therefore will not present long-term land use impacts. Proposed modifications to the Kent County Substation are consistent with the present uses of the site. Generally, existing land uses within the existing Project ROW will be allowed to continue following construction.

8.9.1.1 Residential

A number of residential areas are located in proximity to the ROW and substation sites. In many locations, existing vegetation will continue to provide visual screening of the facilities from residences. Because the proposed transmission lines and substation will occupy areas dedicated to use for electrical facilities, the Project will not displace any existing residential uses, nor will it adversely affect any future development proposals.

8.9.1.2 Agriculture

The proposed Project crosses a number of areas which are presently in agricultural use. Impacts to agricultural uses will occur as a result of the proposed Project but will be limited to the footprints of the transmission line structures, and access roads.

8.9.1.3 Educational Institutions

Wakefield Hills Elementary School, Drum Rock Elementary School, and Toll Gate High School are the only public institutional facilities located along the proposed route. Wakefield Hills Elementary School is located at 505 Wakefield Street in West Warwick. The existing transmission lines are visible from Wakefield Hills Elementary School. Drum Rock Elementary School and Toll Gate High School are located at 575 Centerville Road in Warwick. The existing transmission lines are visible from Drum Rock Elementary School and from the Toll Gate High School access road. The proposed work in these locations will have no significant impact on existing land uses in the vicinity of these schools.

8.9.1.4 Commercial and Industrial

The proposed route will cross several business areas. These businesses include industrial, commercial, retail, office, recreational and agricultural uses. Normal operations will not be adversely affected by the Project. No displacement of business will result from the Project.

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8.9.2 Recreation

No existing recreational uses will be displaced by the Project.

Impacts to existing parks and recreational areas from the proposed electric transmission line will be minimal and short-term. Since the Project is located within an existing electric transmission line ROW, potential long-term impacts will be avoided.

8.9.3 Consistency with Local Planning

As documented in the Purpose and Need section of this report, there is a clear need for improving the electrical reliability to the area. The Towns of North Smithfield, Smithfield, Johnston, West Warwick and the Cities of Cranston and Warwick have Comprehensive Plans which describe the local viewpoint regarding future development and growth in each community. Each municipality's Comprehensive Plan was evaluated with regard to expressed town-wide goals. The proposed project was then evaluated for consistency with the local planning initiatives in each community.

Because the proposed Project will use existing ROW, it will not alter existing land use patterns and will not adversely impact future planned development. The Project will provide an adequate supply of electricity for the growth and development envisioned by the Comprehensive Plans of the communities in northern Rhode Island.

8.10 Visual Resources

National Grid engaged EDR to analyze the potential visibility and visual impact of the Project. The Visual Impact Analysis (VIA) procedures used by EDR are based on methodologies developed by the U.S. Department of the Interior, Bureau of Land Management (1980 and 1986). They are also consistent with guidance provided by the U.S. Department of Agriculture, National Forest Service (1974), the U.S. Department of Transportation, Federal Highway Administration (1981), and the New York State Department of Environmental Conservation (not dated and 2000). Within the visual study area, EDR defined landscape similarity zones (LSZ's) based on the USGS National Land Cover Data set and field review. LSZ's are areas of similar landscape/aesthetic character based on patterns of landform, vegetation, water resources, land use, and user activity. This effort resulted in the definition of six final LSZs, including the following: 1) Medium/High Density Residential, 2) Commercial, 3) Low Density Residential/Developed Open Space, 4) Forested, 5) Transportation, and 6) Water/Waterfront.

The VIA utilized several evaluation techniques, including viewshed analysis, line of sight cross sections, field evaluation, computer-assisted visual simulations, and the evaluation of the Project's visual impact by a panel of landscape architects. This comprehensive analysis evaluated the effect of the proposed Project on the aesthetic character /resources of the study area.

Viewshed analysis mapping determined the potential visibility of the existing and proposed transmission structures based on the screening effect of topography only. This is a "worst-case" analysis, in that the screening effect of vegetation and built structures is not considered. Topographic viewshed mapping revealed there is very

little change in potential structure visibility that would result from construction of the proposed Project. The screening effect of forest vegetation was taken into consideration by running a vegetation viewshed analysis. This analysis assigned a 40 foot height to all mapped forest vegetation and determined that the proposed 345 kV structures would potentially be visible from 29% of the one mile radius study area. The vegetation viewshed is limited primarily to the existing cleared ROW, open road corridors, and areas of higher density development.

Cross-section analysis more accurately accounts for the screening effect of vegetation and structures in the study area. Four cross-sections were prepared to illustrate potential project visibility. The cross-section locations were chosen to include visually sensitive areas (i.e., trails, water bodies, historic and recreational sites) within and adjacent to the study area. As a whole, the cross-sections demonstrate that the extensive forest vegetation and undulating topography within the area will effectively screen views of the proposed project from most locations.

Field verification was conducted after the viewshed mapping and cross-section studies to more accurately evaluate potential visibility of the proposed transmission facilities from ground-level vantage points. This fieldwork confirmed that the visibility of the existing transmission line is limited in the northern portion of the study area due to the hill and valley topography and the dense forest vegetation surrounding most public roads and areas of development. Longer distance views are generally confined to the central and southern portions of the study area. Throughout the study area visibility of the existing transmission line is largely limited to locations where the transmission line crosses existing roads or is in proximity to cleared yards in recently developed residential areas.

EDR next prepared computer-generated visual simulations for eleven selected viewpoints which were presented to a panel of registered landscape architects for evaluation. This evaluation methodology involves rating the visual quality of representative viewpoints with and without the Project in place. The eleven viewpoints were selected to represent the LSZs and viewer groups within the study area that would have views of the Project. The conclusion based on the rating results was that to a large extent the Project's visual impact from all viewpoints was mitigated by the presence of the existing transmission line and cleared ROW. Siting the Project within an existing transmission corridor minimizes the need for additional ROW clearing, and significantly reduces the Project's contrast with existing land use and impact on baseline scenic quality.

In selected locations where new ROW clearing or lack of existing foreground vegetation increases the visibility of the proposed line, National Grid will evaluate the feasibility of evergreen screen plantings. Plantings located between the close range viewer and the proposed structures can over time effectively screen the proposed structures. They would also enhance screening provided by existing deciduous trees.

8.11 Noise

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8.11.1 Kent County Substation

The main source of noise within a substation are the power transformers. The existing Kent County Substation has five transformers. As part of the RI Reliability Project, an additional 345 kV autotransformer is proposed. The noise emission associated with the proposed transformer was modeled in accordance with ISO 9613 using noise prediction software Cadna/A. The results indicate that the addition of the transformer does not significantly impact the noise levels at the property lines, and the substation remains in compliance with the City's noise ordinance.

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8.11.2 West Farnum Substation

No additional sound generating equipment is proposed at West Farnum Substation. Therefore, no change to the noise levels will result from the proposed Project.

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8.11.3 Transmission Line

The proposed transmission lines will not generate an audible sound level under normal operating conditions. As a result, the existing ambient noise levels will not be altered by the proposed Project.

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8.11.4 Construction Noise

Temporary noise impacts will occur during construction of the Project. Proper mufflers will be required to control noise levels generated by construction equipment. Hours of construction will comply with applicable local requirements.

8.12 Transportation

The construction related traffic increase will be small relative to total traffic volume on public roads in the area. In addition, it will be intermittent, temporary, and will cease once construction of the project is completed. The addition of this traffic for the limited periods of time is not expected to result in any additional congestion or change in operating conditions along any of the roadways along the ROW.

National Grid's contractor will coordinate closely with RIDOT to develop acceptable traffic management plans for work within state highway rights-of-way. At all locations where access to the ROW intersects a public way, the contractor will follow a pre-approved work zone traffic control plan and where appropriate, police details. Although the volume of traffic entering and exiting the ROW at these locations is expected to be small, vehicles entering and exiting the site will do so safely and with minimal disruption to traffic along the public way. Following construction, traffic activity will be minimal and will occur only when the ROW or transmission lines have to be maintained. As a result, the construction and operation of the transmission line will have minimal impact on the traffic of the surrounding area roadways.

Similarly, the Kent County and West Farnum Substations are unmanned stations, and no long-term impacts to existing traffic patterns or volumes are anticipated following completion of the construction.

8.13 Cultural Resources

The Phase I (a/b) archaeological survey conducted by PAL resulted in the identification of zones of high, moderate, and low archaeological sensitivity, relative to the probability that potentially significant cultural resources can be expected within these zones. In accordance with the PAL's recommendations for sensitive locations, National Grid will conduct further Phase I(c) intensive archaeological survey at specific construction sites within zones of high and moderate sensitivity. As recommended by PAL, the investigations will be conducted prior to construction at proposed structures, access road cut locations, and ancillary work or equipment storage areas involving soil disturbance in archaeologically sensitive zones. The investigations will consist of excavating five test pits at structure locations; one central test pit will be located at the pole site and four test pits will be arrayed in the cardinal directions five meters from the central test pit. A set of five test pits will also be excavated at each access road cut and at each designated work and/or equipment storage area. Depending on the configuration of each area, test pits will be placed either along a linear transect or within an array configuration. Each pit will be dug in ten centimeter levels with all soils sifted through a ¼-inch screen. Any recovered cultural materials will be collected by test pit and level. Soil profiles of each test pit will be recorded, describing the color and texture of the associated stratum of any recovered artifacts.

If archaeological materials or potential historic properties are discovered, National Grid will conduct additional investigations at the Phase II archaeological site examination level to determine the spatial extent of the resource. Once this is established, National Grid will, if possible, relocate or redesign the structure, access road, or work/storage area to avoid the resource. In the unlikely event that the resource cannot be avoided, National Grid will work closely with the RIHPHC to develop a strategy of mitigation. Any identified properties will be documented and

all recovered cultural materials will be processed and cataloged in accordance with RIHPHC procedures, and accepted professional standards.

8.14 Air Quality

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8.14.1 Construction Impacts

Exposed soils will be wetted and stabilized as necessary to suppress dust generation, and crushed stone aprons will be used at all access road entrances to public roadways, consequently fugitive dust emissions will be low. In addition, minimal quantities of earth will be moved or disturbed during construction. Therefore, any impacts from fugitive dust particles will be of short duration and localized.

Due to the transitory nature of the construction, air quality in the Project ROW will not be significantly affected by construction along the ROW. Emissions produced by the operation of construction machinery (nitrogen oxides, sulfur oxides, carbon monoxide, and particulate matter) are short-term and not generally considered significant.

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8.14.2 Project Impacts

In part, air quality is a function of area wide emissions of O_3 precursors (CO, NOx, and VOCs) from the change in daily traffic volumes along lengths of area roadways. The Project itself will not generate air emissions. The Project will not change traffic and emissions parameters, nor affect the travel characteristics of the vehicles traveling in North Smithfield, Smithfield, Cranston, Johnston, West Warwick, and Warwick, Rhode Island. Therefore, the mobile source emissions will not be changed due to the proposed project.

8.15 Safety and Public Health

National Grid substations are locked and enclosed with chain link fence topped with barbed wire to prevent unauthorized entry. Transformers and other equipment which use MODF are provided with secondary containment systems to prevent the release of the MODF in the event of a leak. MODF levels are continuously monitored and alarmed by protective systems.

SF6 gas will be used in the new 345 kV GIS installed at the West Farnum Substation. Under routine operation, the GIS is sealed and there will be no release of SF6 to the environment.

Although SF6 is defined as hazardous by DOT, there is no risk of general public exposure. The GIS is located inside a chain-link fence enclosed yard. The GIS is made up of a number of isolated sections, so that a leak would not drain all the gas, but rather a small amount. The individual gas sections are equipped with pressure gauges and alarms to detect leaks. The GIS will be installed and maintained by trained technical staff. It will be checked for integrity during routine inspections by company personnel.

Following construction of the facilities, all transmission line structures and substation facilities will be clearly marked with warning signs to alert the public to potential hazards if climbed or entered. Trespassing on the ROW will be inhibited by the installation of gates and/or barriers at entrances from public roads.

Because the proposed facilities will be designed, built and maintained in accordance with the standards and codes as described in Section 4.7, the public health and safety will be protected.

A discussion of the current status of the health research related to exposure to EMFs is attached in Appendix B. This report was prepared by Exponent Health Sciences.

8.16 Electric and Magnetic Fields

The electric and magnetic fields produced by the existing transmission lines at the edges of the ROW in 2012 are compared here to the expected field levels after completion of the Project in 2012 and five years later (2017).

■

8.16.1 Electric Fields

Electric field levels, which are a function of voltage and line configuration, were calculated and are shown in Table 8-1 for the eight segments of the ROW both prior to and after construction. The electric field level at the edge of the ROW increases in some segments and decreases in others after the Project is completed.

The Project will change the electric fields at the edges of the ROW very little from the existing field levels. Small increases in some segments and small decreases in other segments are projected after the Project is completed. The changes are not uniform because of variations in the configuration and spacing of the lines in the eight segments (see Fig. 4-2, sheets 1 to 5). On all but one cross section, the increase in the electric field at the ROW edge is $\leq$ 0.14 kV/m. The greatest increase at the ROW edge in any cross section is 0.48 kV/m (the western edge of cross section 8). The electric fields will not change substantially following construction of this Project between 2012 and 2017 because the voltage applied to the lines will not change.

Table 8-1 Calculated Electric Field Levels (kV/m) at Edges of ROW+

ROW Segment	ROW Configuration**	Timeframe	East Edge of ROW	West Edge of ROW
Cross section 1 - 0.16 Mi South of Rt 104 to Rt 44 (W. Farnum to Farnum Pike)	Figure 4-2, Sheet 1 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	0.65 0.24 0.24	1.79 1.93 1.93
Cross section 2 - 0.16 Mi South of Rt 104 to Rt 44 (Wolf Hill to Putnam Pike)	Figure 4-2, Sheet 1 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	0.65 0.24 0.24	1.79 1.93 1.93
Cross section 3 - Rt 5 to Hartford Ave Sub	Figure 4-2, Sheet 2 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	0.28 0.07 0.07	1.79 1.93 1.93
Cross section 4 - .60 Mi North of Phenix Avenue to .13 Mi North of Providence Street	Figure 4-2, Sheet 1 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	0.56 0.36 0.36	1.81 1.92 1.92
Cross section 5 - .13 Mi North of Providence Street to Providence Street	Figure 4-2, Sheet 3 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	0.05 0.12 0.12	3.84 3.80 3.80
Cross section 6 - New London Avenue to Bald Hill Road	Figure 4-2, Sheet 2 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	0.34 0.27 0.27	1.81 1.92 1.92
Cross section 7 - Bald Hill Road to 0.10 Mi North of Rt 117	Figure 4-2, Sheet 4 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	0.07 0.11 0.11	1.81 1.93 1.93
Cross section 8 - .16 Mi South of Rt 117 to .11 Mi North of Cowesett Rd	Figure 4-2, Sheet 5 of 5	pre-construction (2012) post-construction (2012) post-construction (2017)	1.31 1.36 1.36	0.15 0.63 0.63

+ Electric field levels do not vary with load.
** Figure showing physical arrangement of lines on ROW.
Source: Exponent (2008).

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8.16.2 Magnetic Fields

For projects involving construction of new or reconfigured transmission lines, it is National Grid's standard practice to evaluate low cost/no cost options for reducing edge of ROW magnetic field levels through optimization of phase configurations (Ref. Transmission Line Engineering Document GL.06.01.101).

Consistent with this practice, Exponent calculated the effect of 216 possible phase combinations for the 359, S171 and T172 lines on magnetic field levels between West Farnum and Kent County Substations. The phase combinations resulting in the lowest edge of ROW magnetic field levels were then reviewed with consideration given to constructability, cost and structural requirements to implement the optimal phase combinations.

The phasing on the proposed 359 line had a dominant influence on edge of ROW magnetic field levels. However, for the 359 line, there was less flexibility in the choice of phasing options due to constructability issues resulting from the need to construct a large, complicated structure in a highly visible location to align the phases in the optimum arrangement near the Kent County Substation. Two phasing options for the 359 line which were constructible and resulted in lower edge of ROW magnetic field levels, were evaluated in combination with optimized S171 and T172 phase arrangements. The evaluation identified one phase configuration for the S171 and T172 lines between West Farnum and Hartford Avenue substations and a second phase configuration between Hartford Avenue and Kent County substations in combination with a single phase configuration for the 359 line between West Farnum and Kent County substations as capable of reducing magnetic field levels without seriously compromising other design and environmental factors.

The recommended phasing plan represents a constructible, low cost solution with minimal incremental visual impact. In general, the recommended plan will result in lower edge of ROW magnetic fields after completion of the Project.

The magnetic field (RMS Resultant) levels were calculated for the eight segments of the ROW for annual average and peak loads, before (pre-construction 2012) and immediately after construction (2012) and five years after construction (2017). The results are summarized in Tables 8-2 and 8-3.

Table 8-2 Calculated Magnetic Field Levels (mG) at Edges of ROW (Annual Average Load)

ROW Segment	ROW Configuration*	Timeframe	East Edge of ROW	West Edge of ROW
Cross section 1 - 0.16 Mi South of Rt 104 to Rt 44 (W. Farnum to Farnum Pike)	Figure 4-2, Sheet 1 of 5	pre-construction (2012)	10.5	26.7
		post-construction (2012)	8.5	21.0
		post-construction (2017)	9.3	22.0
Cross section 2 - 0.16 Mi South of Rt 104 to Rt 44 (Wolf Hill to Putnam Pike)	Figure 4-2, Sheet 1 of 5	pre-construction (2012)	6.2	25.7
		post-construction (2012)	8.6	20.5
		post-construction (2017)	9.5	21.6
Cross section 3 - Rt 5 to Hartford Ave Sub	Figure 4-2, Sheet 2 of 5	pre-construction (2012)	10.8	25.4
		post-construction (2012)	19.7	20.5
		post-construction (2017)	20.2	21.5
Cross section 4 - .60 Mi North of Phenix Avenue to .13 Mi North of Providence Street	Figure 4-2, Sheet 1 of 5	pre-construction (2012)	21.9	26.9
		post-construction (2012)	20.8	20.9
		post-construction (2017)	21.8	21.9
Cross section 5 - .13 Mi North of Providence Street to Providence Street	Figure 4-2, Sheet 3 of 5	pre-construction (2012)	6.6	47.9
		post-construction (2012)	25.8	33.2
		post-construction (2017)	27.8	34.7
Cross section 6 - New London Avenue to Bald Hill Road	Figure 4-2, Sheet 2 of 5	pre-construction (2012)	10.8	27.1
		post-construction (2012)	37.0	21.1
		post-construction (2017)	39.4	22.1
Cross section 7 - Bald Hill Road to 0.10 Mi North of Rt 117	Figure 4-2, Sheet 4 of 5	pre-construction (2012)	2.5	27.1
		post-construction (2012)	10.9	20.7
		post-construction (2017)	11.6	21.7
Cross section 8 - .16 Mi South of Rt 117 to .11 Mi North of Cowesett Rd	Figure 4-2, Sheet 5 of 5	pre-construction (2012)	21.3	4.7
		post-construction (2012)	17.0	10.1
		post-construction (2017)	17.8	10.6

∗ Figure showing physical arrangement of lines on ROW.
Source: Exponent (2008).

Table 8-3 Calculated Magnetic Field Levels (mG) at Edges of ROW (Annual Peak Load)

ROW Segment	ROW Configuration*	Timeframe	East edge of ROW	West edge of ROW
Cross section 1 - 0.16 Mi South of Rt 104 to Rt 44 (W. Farnum to Farnum Pike)	Figure 4-2, Sheet 1 of 5	pre-construction (2012)	7.1	34.0
		post-construction (2012)	19.7	24.8
		post-construction (2017)	14.7	28.6
Cross section 2 - 0.16 Mi South of Rt 104 to Rt 44 (Wolf Hill to Putnam Pike)	Figure 4-2, Sheet 1 of 5	pre-construction (2012)	12.3	32.4
		post-construction (2012)	29.4	24.2
		post-construction (2017)	24.1	27.9
Cross section 3 - Rt 5 to Hartford Ave Sub	Figure 4-2, Sheet 2 of 5	pre-construction (2012)	14.8	31.8
		post-construction (2012)	36.4	24.0
		post-construction (2017)	33.5	27.6
Cross section 4 - .60 Mi North of Phenix Avenue to .13 Mi North of Providence Street	Figure 4-2, Sheet 1 of 5	pre-construction (2012)	45.6	36.9
		post-construction (2012)	37.8	25.4
		post-construction (2017)	38.8	28.9
Cross section 5 - .13 Mi North of Providence Street to Providence Street	Figure 4-2, Sheet 3 of 5	pre-construction (2012)	12.2	65.0
		post-construction (2012)	24.8	39.4
		post-construction (2017)	26.2	44.9
Cross section 6 - New London Avenue to Bald Hill Road	Figure 4-2, Sheet 2 of 5	pre-construction (2012)	30.0	37.1
		post-construction (2012)	35.7	25.5
		post-construction (2017)	36.1	29.0
Cross section 7 - Bald Hill Road to 0.10 Mi North of Rt 117	Figure 4-2, Sheet 4 of 5	pre-construction (2012)	4.1	37.1
		post-construction (2012)	11.7	25.1
		post-construction (2017)	12.5	28.5
Cross section 8 - .16 Mi South of Rt 117 to .11 Mi North of Cowesett Rd	Figure 4-2, Sheet 5 of 5	pre-construction (2012)	28.7	6.3
		post-construction (2012)	20.8	12.4
		post-construction (2017)	23.6	14.1

∗ Figure showing physical arrangement of lines on ROW.
Source: Exponent (2008).

As described above, National Grid has optimized the phasing of the new and reconstructed lines to maximize the mutual cancellation of the magnetic fields from the phase conductors on the ROW. As with electric fields, the magnetic fields decrease at the edge of the ROW in some of the eight segments and increase in other segments. The proposed project will reduce the magnetic field on the west edge of the ROW by 4 to 15 mG for cross sections 1-7 and increase the magnetic field at this side of cross section 8 by less than 6 mG. On the east side of the ROW the magnetic field will decrease between 1 and 4 mG in sections 1, 4, and 8 and increase (between 2 and 29 mG) in cross sections 2, 3, 5, 6 and 7.

The electric and magnetic field levels produced by the existing and proposed facilities are well below guidelines for public exposure recommended by the International Committee on Electromagnetic Safety and the International Committee on Nonionizing Radiation Protection. No national scientific or public health agency has determined that exposure to field levels below these guideline levels pose any health hazard. A discussion of the current state of the health research relevant to

exposure to electric and magnetic fields is included in Appendix B. This report was prepared by Exponent, Inc.

The projected electric and magnetic fields at the edges of the ROW after completion of the Project were calculated and compared to pre-construction values.

9.0 Mitigation Measures

Mitigation measures will effectively minimize Project impacts on the natural and social environment. Mitigation measures have been designed for the Project to minimize impacts associated with each phase of construction. Many of these measures are standard proven procedures that National Grid incorporates in all transmission line and substation construction projects. Others are site specific measures designed to meet the needs of this particular Project. These measures are described in the following sections.

9.1 Design Phase

In order to reduce the impacts associated with the construction and operation of the transmission line facility, National Grid has incorporated design measures to minimize the impacts of the Project. These measures include alignment, design, pole structure locations and use of existing access roads where possible, which have resulted in the avoidance and minimization of residential and wetland impacts, and soil disturbance. Residential impacts are minimized by locating the proposed electric transmission line in the existing ROW. The design and construction of the proposed electric transmission line incorporates measures which minimize impacts to wetlands and other natural features within the ROW. Of the 712 proposed transmission line structures, 538 have been located outside of wetland areas. Further, a wetland mitigation plan, which includes the implementation of BMPs (i.e., hay bales, silt fence, vegetation management, etc.) during and following construction, to minimize impacts associated with the proposed project, will be filed with the wetlands application for the Project.

The following sections detail the various measures that were implemented in the design phase of the Project to reduce impacts to the natural and social environment.

■

9.1.1 Mitigation of Natural Resource Impacts

9.1.1.1 Transmission Line

The design of the transmission lines has been developed to reduce wetland impacts through avoidance, minimization, and compensation. Consequently, unavoidable wetland impacts associated with the construction of pole structures for the Project have been limited to approximately 2,465 square feet of permanent biological wetland disturbance due to filling. Mitigation for these alterations of wetland must be provided in order to comply with federal wetland regulations.

The RIDEM requires compensation for any loss of 100-year flood storage. In accordance with these requirements, National Grid will provide floodplain compensation for fills related to structure placement. Erosion controls will be installed along the perimeter of the excavation areas to avoid sedimentation of the adjacent wetlands. Following excavation, the disturbed areas will be seeded and mulched.

Potential short-term and long-term impacts to wildlife will be mitigated. Wildlife impacts in the short term will be mitigated by limiting ground disturbances to pole structure and access road locations, and restoring and/or stabilizing areas immediately following construction. Vehicle and equipment traffic will be limited to established access roads as much as practical. Long-term mitigation efforts will include minimizing permanent wetland disturbance and maintaining wetland functions following construction.

Overall, the proposed mitigation plan has been designed to minimize impacts to environmental resources resulting from the proposed project.

9.1.1.2 Access Roads

As a further mitigating measure, proposed access routes have been situated to cross streams and wetlands at the narrowest practical point to minimize disturbance. Each of the proposed access ways through wetlands was thoroughly scrutinized for consistency with the Rhode Island Freshwater Wetland Rules and will not be a random, unnecessary, or undesirable alteration of a freshwater wetland. Each location was selected to traverse the wetland fringe or a previously disturbed area within the wetland. No permanent roads will be built in wetland areas for this Project.

9.1.2 Mitigation of Social Resource Impacts

In addition to avoiding and minimizing impacts to the natural environment within the Project ROW, several design practices have been incorporated to minimize or avoid impacts to the surrounding social environment. To minimize impacts to adjacent residences and undisturbed areas, National Grid will locate the Project within an existing ROW parallel to existing electric lines. National Grid also proposes to locate new pole structures adjacent to existing structures, where feasible, to minimize the potential for visual impact. Vegetation clearing will be limited so that a visual buffer between residences and the Project is maintained where possible.

National Grid has engaged and will continue to engage in community outreach to advise ROW abutters and others of Project plans.

9.2 Construction Phase

National Grid will implement several measures during construction which will minimize impacts to the environment. These include the use of existing access roads and structure pads where possible, installation of erosion and sedimentation controls, supervision and inspection of construction activities within resource areas by an environmental monitor and minimization of disturbed areas. The following section details various mitigation measures which will be implemented to minimize construction related impacts.

9.2.1 Mitigation of Natural Resource Impacts

Given the engineering constraints for the proposed transmission line, in the design of the facility it was necessary to site 49 structures within biological wetland, 123 structures within state-regulated wetland buffers, and four structures within state-regulated floodplain (two of the four structures within floodplain are also within buffer). Table 9-1 summarizes wetland impacts by project component.

Table 9-1 Summary of Wetland Impacts by Project Component

Project Component	Total No. Structures	Structures in Biological Wetland	Structures in Wetland Buffer	Structures in Floodplain
Proposed 359 Line	241	13	46	1
S-171 Line	226	16	39	1
T-172 Line	224	19	35	2
Relocated H-17 Line	7	1	2	0
Relocated B-23 Line	-1	0	0	0
G-185N	11	0	1	0
G-185S/L-190	4	0	0	0
Total	**712**	**49**	**123**	**4***

* Two of the four structures within floodplain are also located within buffer.

With construction of the existing transmission lines in the 1950s, access roads were established within portions of the ROW. During construction of the Project, vehicles will utilize these existing access roads where practical to minimize disturbance within the ROW.

Access to the structures through wetland areas will be provided by utilizing swamp mats from the existing maintained portion of the ROW, where possible. Construction access will be limited to the existing and proposed structure locations, and will be lined with erosion and sedimentation control BMPs. Following erection of the structure, each area will be restored.

Clearing and vegetation management operations will be confined to the ROW. Excavated soils will be stockpiled and spread in approved upland locations well outside all biological wetland areas in such a manner that general drainage patterns will not be affected. Clearing adjacent to wetland areas is of particular concern due to the potential for erosion, and therefore, specific mitigation measures will be implemented to minimize this potential. These measures will include the installation of hay bale diversion berms across the slope to intercept storm water runoff which will be directed through hay bales or silt fence to remove suspended sediment. These structures will be maintained until vegetative cover is re-established. In addition, silt fence or hay bales will be installed across disturbed slopes adjacent to wetland areas in accordance with an erosion and sediment control plan.

Stream crossings will be located perpendicular to the channel to the extent possible to reduce the crossing length and reduce the potential for disturbance to the water body. Design and implementation of all stream crossing structures (i.e., temporary mat bridges) will comply with standards and specifications as outlined in the "Rhode Island Soil Erosion and Sediment Control Handbook." Pole structures have been located to minimize the number of temporary and permanent stream crossings required. Temporary access is used where the substrate is sufficiently firm or level to support equipment without creating a disturbance to the soil substrate.

9.2.1.1 Erosion and Sedimentation Control

Erosion and sediment control devices will be installed along the perimeter of identified wetland resource areas prior to the onset of soil disturbance activities to ensure that spoil piles and other disturbed soil areas are confined and do not result in downslope sedimentation of sensitive areas. Woody species with a mature height greater than 10 feet will be cleared within specified portions of the ROW. Low growing tree species, shrubs and grasses will only be mowed along access roads and at pole locations. To avoid disturbing the root mat, tree stumps will be left in place except at structure locations and within access roads. Erosion control will be inspected on a regular basis during construction and maintained or replaced as necessary.

Dewatering may be necessary during excavations for pole structures adjacent to wetland areas. If there is adequate vegetation in upland areas to function as a filter medium, the water generally will be discharged to the vegetated land surface. Where vegetation is absent or where slope prohibits, water will be pumped into a hay bale or silt fence settling basin which will be located in approved areas outside wetland resource areas. The pump intake hose will not be allowed to set on the bottom of the excavation throughout dewatering. The basin and all accumulated sediment will be removed following dewatering operations and the area will be seeded and mulched.

9.2.1.2 Supervision and Monitoring

Throughout the entire construction process, National Grid will retain the services of an environmental monitor. The primary responsibility of the monitor will be to oversee construction activities including the installation and maintenance of erosion and sedimentation controls, on a routine basis to ensure compliance with all federal and state permit requirements, National Grid company policies and other commitments. The environmental monitor will be a trained environmental scientist responsible for supervising construction activities relative to environmental issues. The environmental monitor will be experienced in the erosion control techniques described in this report and will have an understanding of wetland resources to be protected.

During periods of prolonged precipitation, the monitor will inspect all locations to confirm that the environmental controls are functioning properly. In addition to retaining the services of an environmental monitor, National Grid will require the contractor to designate an individual to be responsible for the daily inspection and upkeep of environmental controls. This person will also be responsible for providing direction to the other members of the construction crew regarding matters of wetland access and appropriate work methods. Additionally, all construction personnel will be briefed on project environmental compliance issues and obligations prior to the start of construction. Regular construction progress meetings will provide the opportunity to reinforce the contractor's awareness of these issues.

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9.2.2 Mitigation of Social Resource Impacts

National Grid will minimize social resource impacts during construction by incorporating several standard mitigation measures. By use of an established transmission line ROW rather than creating a new ROW, the potential for disruption due to construction activities will be limited to an area already dedicated to transmission line uses. Construction generated noise will be limited by the use of mufflers on all construction equipment. Dust will be controlled by wetting and stabilizing access road surfaces, as necessary, and by maintaining crushed stone aprons at the intersections of access roads with paved roads. By notifying abutters of planned construction activities before and during construction of the line, National Grid will minimize the potential for disturbance from the construction.

Some short term impacts are unavoidable, even though they have been minimized. By carrying out the construction of the line in a timely fashion, National Grid will keep these impacts to a minimum. The construction of the new lines in the existing ROW may cause some temporary disturbance to the abutting property owners.

National Grid will prepare a traffic management plan which will minimize impacts associated with increased construction traffic on local roadways.

If archaeological materials or properties are discovered during construction, National Grid will respond as described in Section 8.13 of this report.

National Grid will provide periodic updates by email to abutters during construction. National Grid's ombudsman will be a point of contact for abutters.

9.3 Post-Construction Phase

Following the completion of construction, National Grid uses standard mitigation measures on all transmission line construction projects to minimize the impacts of projects on the natural and social environment. These measures include revegetation and stabilization of disturbed soils, ROW vegetation management practices and vegetation screening maintenance at road crossings and in sensitive areas. Other measures are used on a site specific basis. National Grid will implement the following standard and site specific mitigation measures for the proposed project.

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9.3.1 Mitigation of Natural Resource Impacts

Restoration efforts, including final grading and installation of permanent erosion control devices, and seeding of disturbed areas, will be completed following construction. Construction debris will be removed from the Project site and disposed

of at an appropriate landfill. Pre-existing drainage patterns, ditches, roads, fences, and stone walls will be restored to their former condition, where appropriate. Permanent slope breakers and erosion control devices will be installed in areas where the disturbed soil has the potential to impact wetland resource areas.

Vegetation maintenance of the ROW will be accomplished with methods identical to those currently used in maintaining vegetation along the existing lines on the ROW. National Grid's ROW vegetation maintenance practices encourage the growth of low-growing shrubs and other vegetation which provides a degree of natural vegetation control. In addition to reducing the need to remove tall growing tree species from the ROW, the vegetation maintained on the ROW inhibits erosion.

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9.3.2 Mitigation of Social Resource Impacts

Where possible, National Grid will limit access to the ROW by installing permanent gates and barriers where access roads enter the ROW from public ways.

10.0 Permit Requirements

10.1 Permit and Other Regulations

National Grid must obtain permits under the following state, local and federal statutes and regulations prior to the construction of the Project.

■

10.1.1 State Permits

10.1.1.1 EFSB License

The Project will require a license to construct a major energy facility from the EFSB pursuant to Rhode Island General Laws ("R.I.G.L.") Sec. 42-98-1 et seq.

10.1.1.2 RIDEM Freshwater Wetlands Permit

The Project will require a freshwater wetlands permit from RIDEM pursuant to R.I.G.L. Sec. 2-1-18 et seq. for alteration of freshwater wetlands in connection with the construction of certain structures and access roads.

10.1.1.3 RIPDES Storm Water Discharge Associated with Construction Activities

The Project will require a permit from RIDEM for approval of storm water discharge associated with construction activities pursuant to Rule 31 of the Rhode Island Pollutant Discharge Elimination System ("RIPDES") Regulations. It is expected that the Project will qualify for authorization under the General Permit and will be automatically authorized as part of the freshwater wetlands permit.

10.1.1.4 Water Quality Certification

The Project will need a water quality certification from RIDEM under Section 401 of the Clean Water Act. It is expected that the water quality certification will be issued as part of the freshwater wetlands permit.

10.1.1.5 RIDOT Permits

The Project will require freeway and highway utility permits from the RIDOT for the installation of wires across freeways and state highways, and access off of freeways or state highways during construction pursuant to R.I.G.L. Chapters 10 and 8 of Title 24.

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10.1.2 Local Permits

10.1.2.1 Zoning

The Project will require the following zoning relief:

Cranston

According to the Cranston Building Official, only a dimensional variance from height restrictions in all zoning districts is required for the Project in Cranston. Cranston Zoning Ordinance, § 17.20.120.

Johnston

A special use permit is required for the Project located in districts zoned R-40, R-20, B2, B3, I-L in Johnston. Johnston Zoning Ordinance, art. III, Table III D-1, § 5. A use variance may be required for those portions of the Project located in the B-3 district. Johnston Zoning Amends. Ordinance No. 999. A dimensional variance from height restrictions is required in all zoning districts. See Johnston Zoning Ordinance, § F, Table III F-1; Johnston Zoning Amendments, Ordinance No. 999.

North Smithfield

In North Smithfield a special use permit will be required for the Project. North Smithfield Zoning Ordinance, §§ 5.4, 5.6.3.4, 9.2. Also, a special use permit and a development permit will be required for any portion of the Project located in the Flood Hazard Overlay District. North Smithfield Zoning Ordinance, §§ 6.18.4, 6.18.5(1) and 9.2. A dimensional variance from the height restrictions will be required in all of the zoning districts. North Smithfield Zoning Ordinance, §§ 5.5 and 9.3. The Project will require development plan review, unless an exemption is granted by the Building Inspector and Town Planner. North Smithfield Zoning Ordinance, §17.0.

Smithfield

A special use permit will be required for the Project in Smithfield. Smithfield Zoning Ordinance, §§ 3.10, 3.13 & 4.2 Table of Uses. A dimensional variance will be required for any portion of the Project located within 100 feet of a Fresh Water Wetland and for Project structures located within 100 feet of a residential zone. Smithfield Zoning

Ordinance, § 5.3.4. A dimensional variance from height restrictions is also necessary in all districts. Smithfield Zoning Ordinance, §§ 5.3.5 & 5.4.

Warwick

In Warwick the substation improvements at Kent County substation will require a special use permit. Warwick Zoning Ordinance, §§401.7 and 300. A dimensional variance from the height restrictions will be required, as well as a dimensional variance from any portion of the substation improvements located within 50 feet from the inland edge of a coastal feature or any freshwater wetland. Warwick Zoning Ordinance, §§302, 503 and 504.

According to the Warwick Building Official, no zoning relief or review is required for the new transmission line or the existing transmission line improvements, relocations and reconfigurations.

West Warwick

In West Warwick a special use permit will be required for the portions of the Project that are located in residential districts zoned R-10 and R-7.5. W. Warwick Zoning Ordinance, art. I, § 5.3. A dimensional variance from height restrictions is necessary for those portions of the project located in districts zoned B and CI.

10.1.2.2 Erosion and Sediment Control

Each of the six municipalities within the project corridor require the submission and approval of an erosion and sediment control plan as detailed below. The municipalities of Smithfield, Johnston, Cranston, West Warwick, and Warwick each have similar exemptions from the erosion and sediment control requirements. However, the Project will not qualify for these exemptions.

North Smithfield

A Determination of Applicability must be filed with the Building Inspector to determine if an erosion and sediment control plan must be filed. North Smithfield Code Sections 18.2-3. The Building Inspector would approve, approve with conditions or disapprove such erosion and sediment control plan.

Smithfield

An erosion and sediment control permit must be obtained from the building official for any development project that may cause a disturbance to the natural terrain, topsoil or vegetative ground cover upon any property within the Town of Smithfield. Smithfield Code Section 299-5.

Johnston

An erosion and sediment control permit must be obtained for any development project that may cause a disturbance to the natural terrain, topsoil or vegetative ground cover upon any property within the Town of Johnston. Johnston Code Chapter 22B.

Cranston

An erosion and sediment control permit must be obtained from the building official for any development project that may cause a disturbance to the natural terrain, topsoil or vegetative ground cover upon any property within the City of Cranston. Cranston Code Section 15.28.020.

West Warwick

A Determination of applicability must be filed with the building official to determine if soil erosion and sediment control plan must be filed. West Warwick Code Section 15-5.4.

Warwick

An erosion and sediment control permit must be obtained from the building official for any development project that requires a building permit. Warwick Code Section 68-3(a)(1).

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10.1.3 Federal Permits

Army Corps of Engineers

The project will require an ACOE Section 404 Permit for the filling of wetlands in connection with the construction of the structures in wetlands, clearing in wetlands, and the construction of certain temporary access roads.

Historic Preservation

The project will require consultation with the State Historic Preservation Office and the applicable Tribal Historic Preservation Office(s) in compliance with Section 106 of the National Historic Preservation Act.

Federal Aviation Administration

The Project site is located within three miles of Runway 5-23 at T.F. Green Airport, which has a precision instrument approach, and Runway 5 at North Central Airport,

which has a non-precision instrument approach. As such, the Project is located within protected airspace and operational control areas used for air navigation. Protected surfaces extend over the project site placing the project within the jurisdiction of the Federal Aviation Administration (FAA) and triggering the need for an FAA Obstruction Evaluation and Airport Airspace Analysis. National Grid will provide a Notice of Construction to the FAA along with information to enable the FAA to review the Project. If any issues are identified by the FAA during its review, National Grid will take the necessary steps to address those concerns.

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Appendix A

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Field Office
70 Commercial Street, Suite 300
Concord, New Hampshire 03301-5087

August 28, 2007

Reference:	Project	Location
	Electric transmission system improvements	No. Smithfield, Smithfield, Cranston, Johnston, West Warwick, Warwick, RI

RECEIVED
AUG 3 0 2007
VANASSE HANGEN BRUSTLIN, INC.
PROVIDENCE, RI

Adam Rosenblatt
Vanasse Hangen Brustlin, Inc.
530 Broadway
Providence, RI 02909-1820

Dear Mr. Rosenblatt:

This responds to your recent correspondence requesting information on the presence of federally-listed and/or proposed endangered or threatened species in relation to the proposed activity(ies) referenced above.

Based on information currently available to us, no federally-listed or proposed, threatened or endangered species or critical habitat under the jurisdiction of the U.S. Fish and Wildlife Service are known to occur in the project area(s). Preparation of a Biological Assessment or further consultation with us under Section 7 of the Endangered Species Act is not required.

This concludes our review of listed species and critical habitat in the project location(s) and environs referenced above. No further Endangered Species Act coordination of this type is necessary for a period of one year from the date of this letter, unless additional information on listed or proposed species becomes available.

In order to curtail the need to contact this office in the future for updated lists of federally-listed or proposed threatened or endangered species and critical habitats, please visit the Endangered Species Consultation page on the New England Field Office's website:

www.fws.gov/northeast/newenglandfieldoffice/EndangeredSpec-Consultation.htm

In addition, there is a link to procedures that may allow you to conclude if habitat for a listed species is present in the project area. If no habitat exists, then no federally-listed species are present in the project area and there is no need to contact us for further consultation. If the above conclusion cannot be reached, further consultation with this office is advised. Information describing the nature and location of the proposed activity that should be provided to us for further informal consultation can be found at the above-referenced site.

Thank you for your coordination. Please contact us at 603-223-2541 if we can be of further assistance.

Sincerely yours,

Anthony P. Tur
Endangered Species Specialist
New England Field Office

RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
235 Promenade Street, Providence, RI 02908-5767 TDD 401-222-4462

RECEIVED
APR 15 2003
VANASSE HANGEN BRUSTLIN, INC.
PROVIDENCE, RI

Susan Moberg
Vanasse Hangen Brustlin, Inc.
530 Broadway
Providence, RI 02909-1820

April 11, 2003

RE: Narragansett Electric Company, Line 332 Improvements
Warwick to North Smithfield, RI

Dear Ms. Moberg:

Thank you for contacting the Rhode Island Natural Heritage Program for information regarding the presence rare and endangered species and exemplary natural communities along the ROW corridor as identified in your letter and maps received at this office on April 7, 2003. I can offer the following comments regarding the identified Natural Heritage locations.

1. East portion of Apple Valley Parkway, Smithfield:
This is a location of the sedge *Carex cumulata*, a species currently listed under the Concern category, but also one I suspect is more common than indicated due to difficulties in identification among the Carices. This particular population was verified in 1994.

2. Between Route 5 and Belfield Drive, Johnston:
There are two species records for this area. On the dry, steep open slope is a population of Slender Gerardia (*Agalinis tenuifolia*), also a species listed in the Concern category with approximately 9 records statewide. This location has been verified annually from when it was first located in 1987. The second record is for the Eastern Ribbon Snake (*Thamnophis sauritus*), based on a collection record from 1984. This species is generally found in open, wet meadow type habitats and was found in the wetland at the base of the slope. It is also a species of Concern.

3. Between Hardig Brook and Route 95, Warwick:
The record from this location is for the Frosted Elfin butterfly (*Incisala irus*) located here in 1984 and again in 1990. This record would be of most interest as this is a relatively rare species in southern New England that we list as State Threatened. The best way to locate this species is to key in on the food plants which are either Wild Lupine, or in the case of this location, Wild Indigo (*Baptisia*). Because of my own interest in the status of this species in Rhode Island, I will plan on revisiting this site during the flight period for this species in May to determine the current condition.

30% post-consumer fiber

As our inventory is ongoing more information may become available concerning additional occurrences of rare species in the identified corridor. If I can provide any additional information regarding this review, please contact me at 401-222-2776, extension 4308

Sincerely,

Richard W. Enser

Richard W. Enser, Coordinator
RI Natural Heritage Program

Transportation
Land Development
Environmental
Services

Vanasse Hangen Brustlin, Inc.

530 Broadway
Providence, Rhode Island 02909
401 272-8100
FAX 401 273-9694

Memorandum

To: Susan Moberg

Date: June 12, 2008

Project No.: 72005

From: Linda Vanderveer
Jeff Peterson

Re: Rare, Threatened, and Endangered Species on the RIRP Corridor

---

This memo summarizes the findings of reports of rare and endangered species in National Grid's Rhode Island Reliability Project (RIRP) corridor, stretching from the West Farnum substation in North Smithfield to the Kent County substation in Warwick, Rhode Island.

Key Findings:

- There are no federally listed plant or animal species within the RIRP corridor.
- Three State-listed plant species and one State-listed animal species occur within the RIRP corridor.
    - Slender gerardia, a Species of State Concern in Rhode Island, is more common within the RIRP corridor than is documented by the Rhode Island Natural Heritage Program.
    - A previously undocumented plant Species of State Concern, Smith's bulrush, occurs within the RIRP corridor.
    - Pale corydalis, a previously documented plant Species of State Concern, occurs within the RIRP corridor.
    - Ribbon snake, a previously documented animal Species of State Concern, occurs within the RIRP but is difficult to track.
- Wild indigo, the host plant for the frosted elfin butterfly, a State Threatened species, occurs within a distribution line corridor that runs perpendicular to the RIRP ROW. Frosted elfin butterfly presence has not been confirmed, but no work for the RIRP is planned for this area.

Correspondence sent to the U.S. Fish and Wildlife Service on July 25, 2007 requested guidance on the presence of any federally listed threatened or endangered species or candidate species in the Study Area that are protected under the Endangered Species Act (ESA). The Service responded with a letter received by VHB August 30, 2007 that stated there were no known records of federally threatened or endangered species or habitat critical to listed species within the ROW. Thus no coordination under the ESA will be required.

The RIDEM Freshwater Wetlands permitting regulations require that National Grid coordinate with the Rhode Island Natural Heritage Program (RINHP) and obtain their concurrence that the Project as proposed will be carried out in a manner that is protective of any State-listed Rare, Threatened, or Endangered (RTE) species that are identified within the ROW.

The RINHP database hosted on the RIDEM Environmental Resource Mapping website[1] ("Regulatory Overlays: Natural Heritage Areas" layer) identifies four rare species habitat polygons either within or in the vicinity of the RIRP ROW (refer to attached Rare Species figure). VHB previously received background information on these polygons from Richard W. Enser, former coordinator of the RINHP, as detailed in correspondence dated April 11, 2003 and in a follow up meeting with him.

Mr. Enser described the polygon identified nearest the West Farnum substation as a population of slender gerardia (*Agalinis tenuifolia*), which is listed as a Species of Concern in Rhode Island[2]. Species under this listing are not considered to be State Endangered or State Threatened, but are listed due to various factors of rarity and/or vulnerability. The global ranking for *Agalinis tenuifolia* is G5, which is "demonstrably secure throughout its range, but possibly rare in parts."

The slender gerardia population near the West Farnum substation was observed by VHB staff during a survey conducted on September 26, 2007. Numerous stations of this species were observed in the vicinity of the substation, which were documented by VHB. This documentation was not filed with RIDEM. It was estimated that several hundred to thousands of individual plants are present along the edges of a maintained gravel access path parallel to the RIRP transmission line. The ongoing maintenance of shrubland and early successional habitat along the ROW is critical to the continued presence and health of this population, which generally prefers open habitat that can range from damp to dry[3].

A second polygon of slender gerardia is mapped in the vicinity of the RIRP corridor between Route 5/Greenville Avenue and Belfield Drive in Johnston. Mr. Enser had indicated that an eastern ribbon snake (*Thamnophis sauritus sauritus*), a species of State Concern[4], had also been observed in this area. This area was inspected on September 26, 2007, but did not produce any records confirming the presence of either species. This is in part because the plant community has succeeded and is no longer suitable for the slender gerardia. However, the lack of observation of eastern ribbon snake during this field inspection is likely due to the mobility of snakes, not the absence of the species altogether in this area, and is typical of the hit or miss nature of wildlife observations.

During the course of the summer of 2007, VHB staff conducting wetland delineations and breeding and fall migrant bird surveys noted populations of slender gerardia in suitable habitat along gravel paths along much of the RIRP ROW, making the species appear more common than suggested by the RINHP listing. The regular, mechanical clearing of habitat to maintain an early successional state along the powerline is likely the reason this species is thriving in the corridor.

Mr. Enser indicated that a population of piled sedge (*Carex cumulata)* was verified in 1994 along the east portion of Apple Valley Parkway in Smithfield, Rhode Island. VHB staff searched for this species in this location during a rare species survey conducted on October 26, 2007, but found no plants. *Carex cumulata* is a species of State Concern[5] with a global ranking of G4, which is "apparently secure throughout its range, but possibly rare in parts."

VHB staff surveyed the area of the ROW between Iron Mine Hill Road and Rocky Hill Road in North Smithfield on September 26, 2007 and identified several large and previously undocumented populations of Smith's bulrush (*Schoenoplectus smithii*), a State Threatened plant species[6]. The populations were vigorous and thickest within wet ruts and depressions within the ROW kept open by ATV operations. The continuing disturbance of mucky sediments by ATVs maintains an open,

1 http://www.dem.ri.gov/maps/index.htm
2 RINHP Rare Native Plants of Rhode Island September 2007
3 Newcomb's Wildflower Guide 1977
4 RINHP Rare Native Animals of Rhode Island March 2006
5 RINHP Rare Native Plants of Rhode Island September 2007
6 RINHP Rare Native Plants of Rhode Island September 2007

organic-rich substrate similar to a seasonally exposed lakeshore, which is this species' typical habitat. Other species characteristic of lakeshore habitats such as rice cut grass (*Leersyia oryzoides*) were also observed in these vehicle wallows. Previously the only known population of this species in Rhode Island was located in Washington County. The global ranking for this species is G5, suggesting it is relatively stable. Paperwork documenting the presence of Smith's bulrush has not yet been filed with RIDEM.

This same stretch of ROW was the site of two ribbon snake observations in May 2007, and a fisher on August 28, 2007. Fisher was recently removed from the RIDEM list of Rare Animals of Rhode Island[7].

Finally, Mr. Enser listed the occurrence of the frosted elfin butterfly (*Incisalia irus*) along the RIRP ROW north of the Kent County substation (Rare Species Habitat 4 on the attached figure). Frosted elfin butterfly is a State Threatened species in Rhode Island[8]. Wild indigo (*Baptisa tinctoria*) is a food source for this species. Populations of the butterfly species were not observed during field work due to the butterfly's narrow flight window, but a survey conducted on October 26, 2007 located substantial amounts of the host plant within a cleared distribution line (Line 237) that runs perpendicular to the RIRP corridor. Wild indigo favors dry open places[9], and is well suited to powerline corridors as a result. It is believed that this population of wild indigo would be substantial enough to support populations of the frosted elfin butterfly. However, smooth buckthorn (*Rhamnus frangula*), an aggressive invasive species, is invading some of the stands of wild indigo, and over time, may displace it.

On May 5, 2008 VHB scientists surveyed the area described above and found the wild indigo population to still be considerable enough to support a population of frosted elfin butterfly. Pollinator species such as bumble bee were also abundant, adding to the health of the host plant population. Although a thorough search of the area was conducted, no elfin butterfly species were observed during this survey. On May 30, 2008 VHB staff conducted a search of the same area looking for frosted elfin larvae, but none were found. As this corridor will not be impacted by the RIRP project, no additional searches are planned for this area.

In January 2008 VHB received updated information about RTE species in the RIRP corridor from Mr. Erik Endrulat, data manager of the RINHP. This information confirmed the listing of the four species noted by Mr. Enser and described above. It also identified two additional State-listed species that were reported within the ROW within the past five years. Pale corydalis (*Capnoides [Corydalis] sempervirens),* a plant species of State Concern[10], was observed in two separate locations within the ROW in 2006: south of Mountaindale Road in Smithfield, and south of Route 5/Greenville Avenue in Johnston. In 2005 the species was also observed just north of where Mountaindale Road crosses the ROW. The global ranking of pale corydalis is G4/G5, split between "apparently secure throughout its range, but possibly rare in parts" and "demonstrably secure throughout its range, but possibly rare in parts." Ringed boghaunter (*Williamsonia lintneri*), a State Endangered dragonfly[11], was last observed within the ROW in 2004 near the Route 6/I-295 interchange in Johnston. Information about the presence and location of these species was not available at the time that VHB staff conducted rare species surveys in 2007. Consequently, additional seasonally appropriate field surveys were conducted by VHB staff in 2008 to determine the presence of these species in the ROW.

On May 1, 2008 pale corydalis was located by VHB scientists along the ROW south of Route 5 near Poppy Hill Road in Johnston. A search of the area produced approximately eight genets on dry rocky outcrops with northern aspects on the east side of the ROW. The plants were located just

7 RINHP Rare Native Animals of Rhode Island March 2006
8 RINHP Rare Native Animals of Rhode Island March 2006
9 Newcomb's Wildflower Guide 1977
10 RINHP Rare Native Plants of Rhode Island September 2007
11 RINHP Rare Native Animals of Rhode Island March 2006

south of structure 91, and approximately 40 feet west/northwest of structure T172-123. An additional single genet was found approximately 20 feet south of structure 124. Additional plants may exist and have yet to be located.

On May 5, 2008 VHB staff located pale corydalis in three areas on the ROW north of Mountaindale Road in Smithfield. One population of approximately 17 plants was located just north of structure S171-92. A second population of approximately seven genets was located adjacent to two small cedars near the summit of a hill directly south of structure S171-92. A third population was located south of structure 64 on the west side of the ROW. On the same day, a population of approximately 25 pale corydalis plants was located by VHB staff near Ledgemont Drive in Smithfield. The plants were located on a dry rocky outcrop almost due west of wetland 52, and just north of structure 69.

As a species of State Concern, pale corydalis populations are somewhat tenuous in Rhode Island. Construction activities in areas of the ROW known to support this species could have significant impacts on the statewide population. Any work conducted in the vicinity of the above locations should be coordinated in advance with VHB scientists.

Data provided by Mr. Endrulat also indicated that three State-listed species may have occurred within the ROW historically but may now be extirpated: featherfoil (*Hottonia inflata)*, four-leaved milkweed (*Asclepias quadrifolia)*, and purple needlegrass (*Aristida purpurascens)*. Featherfoil, a species of State Concern[12], was last observed within the ROW in 1978 in Snake Den State Park, and follow up searches conducted in 1995 and 1998 yielded no results. On May 1, 2008 VHB staff searched for featherfoil within the pools of wetland 69, just north of Belfield Drive, but found no evidence of the plant. This species has a global ranking of G4, "apparently secure throughout its range, but possibly rare in parts."

Four-leaved milkweed, a State Threatened species[13], was last observed in 1978 in an area along the Pocasset River in Johnston, but directions indicating its location are imprecise, and occurrence within the ROW is not definitive. The global ranking for this species is G5. Finally, purple needlegrass, a State Threatened species[14] with a global ranking of G5, was last observed on the north side of the main branch of the Pawtuxet River in 1931. Directions indicating its location are imprecise, and historic occurrence within the ROW has never been confirmed.

While it is unlikely that populations of the above three species remain within the ROW, additional seasonally appropriate field surveys may be necessary to confirm absence.

12 RINHP Rare Native Plants of Rhode Island September 2007
13 RINHP Rare Native Plants of Rhode Island September 2007
14 RINHP Rare Native Plants of Rhode Island September 2007

Appendix B

Exponent Health Sciences

Electric and Magnetic Field Research Update: Rhode Island Reliability Project

Electric and Magnetic Field Research Update: Rhode Island Reliability Project

Prepared for:

National Grid
25 Research Drive
Westborough, MA 01582-0099

Prepared by:

Exponent
Health Sciences Practice
420 Lexington Avenue, Suite 1740
New York, NY 10170

August 6, 2008

© Exponent, Inc.

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Acronyms and Abbreviations

AC	Alternating current
ALL	Acute lymphocytic leukemia
ELF	Extremely low frequency
EMF	Electric and Magnetic Fields
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
HCN	Health Council of the Netherlands
HPA	Health Protection Agency of Great Britain
Hz	Hertz
IARC	International Agency for Research on Cancer
ICES	International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-ionizing Radiation
IEEE	Institute of Electrical and Electronics Engineers
kV/m	Kilovolts per meter
mG	Milligauss
NAS	National Academy of Sciences
NCI	National Cancer Institute
NIEHS	National Institute of Environmental Health Sciences
NRPB	National Radiological Protection Board of Great Britain
OR	Odds ratio
ROW	Right-of-way
TWA	Time-weighted average
UK	United Kingdom
UKCCS	United Kingdom Childhood Cancer Study
US	United States
USEPA	US Environmental Protection Agency
V/m	Volts per meter
WHO	World Health Organization

Executive Summary

Over the last 30 years, research has been conducted in the United States (US) and abroad to examine whether exposures to electric and magnetic fields (EMF) have health or environmental effects. People living in technologically advanced societies are surrounded by EMF, as these invisible fields are associated with anything that generates, transmits or uses electricity, such as all appliances, wiring, and motors, in addition to the power lines that deliver electricity. Electric and magnetic fields are also produced by natural sources, such as the human body as a result of the normal electrical communication of different systems like the heart and muscles. EMF research began with the basic goal of understanding how these internal fields operate within the body, and subsequent research examined whether EMF from man-made sources could cause any short-term or long-term health effects. A brief introduction to the nature and sources of EMF is provided in Section 1.

Research on EMF and long-term human health effects was prompted by an epidemiology study conducted in 1979 of children in Denver, Colorado, which studied the relationship of their cancers with the potential for EMF exposure from nearby distribution and transmission lines. The associations reported in some analyses in this study prompted further research with regard to childhood leukemia and EMF. Childhood leukemia has remained the focus of EMF and health research, although epidemiologic and laboratory investigations have studied many other diseases, including other cancers in children and adults, neurodegenerative diseases, reproductive effects, cardiovascular diseases, and suicide and depression. The current consensus of scientists who have reviewed this large body of literature for scientific and regulatory organizations including the World Health Organization (WHO), the International Agency for Research on Cancer (IARC), the National Institute of Environmental Health Sciences (NIEHS), the Health Council of the Netherlands (HCN), and the Health Protection Agency (HPA) of Great Britain is that no cause-and-effect relationship between EMF and health has been established at the levels generally found in residential and occupational environments.

The purpose of this report is to describe the basic methods that scientists use to evaluate scientific research (Section 2) and the conclusions of the scientific panels that have utilized these standard methods to review the body of EMF research (Section 3). This report also summarizes the recommendations of scientific organizations in terms of standards and guidelines (Section 4).

1 Introduction

Electricity in our homes and workplaces is transmitted over considerable distances from generation sources to transmission systems and substations and finally to distribution systems to reach our homes, workplaces and commercial establishments. Electricity is transmitted as alternating current (AC) over power lines. The power provided by electric utilities in North America oscillates 60 times per second, i.e., at a frequency of 60 Hertz (Hz). These extremely low frequency (ELF) fields[1] differ significantly from fields at the higher frequencies characteristic of radio and television signals, microwaves from ovens, cellular phones, and radar (which can have frequencies up to billions of Hz), and therefore are evaluated separately.

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); a kV/m is equal to 1,000 V/m. Most objects including fences, shrubbery, and buildings easily block electric fields. Therefore, certain appliances within homes and the workplace are the major sources of electric fields indoors, while power lines are the major sources of electric fields outdoors (Figure 1, lower panel).

Magnetic fields are produced by the flow of electric currents; however, unlike electric fields, most materials do not readily block magnetic fields. The strength of magnetic fields is commonly expressed as magnetic flux density in units called gauss (G), or in milligauss (mG), where 1 G is equal to 1,000 mG.[2] The strength of the magnetic field at any point depends on characteristics of the source, including the arrangement of the electrical conductors, the amount of current flow through the source, and its distance from the point of measurement. The intensity of both electric and magnetic fields diminishes with increasing distance from the source; higher magnetic field levels are measured close to the conductors of distribution lines, sub-transmission lines, and transmission lines (Figure 1, upper panel) and decrease with increasing distance from the conductors.

The strongest sources of AC magnetic fields that we encounter indoors are electrical appliances. Fields near appliances vary over a wide range, from a fraction of a mG to 1,000 mG or more. For example, Gauger (1985) reported the maximum AC magnetic field at 3 centimeters from a sampling of appliances as 3,000 mG (can opener), 2,000 mG (hair dryer), 5 mG (oven), and 0.7 mG (refrigerator).

---

[1] Some sources cited in this report refer to fields in this frequency range as ELF-EMF. In this report, the term EMF is sometimes used to refer to this frequency range.

[2] Scientists more commonly refer to magnetic flux density at these levels in units of microtesla (µT). Magnetic flux density in milligauss units can be converted to µT by dividing by 10, i.e., 1 mG = 0.1 µT.

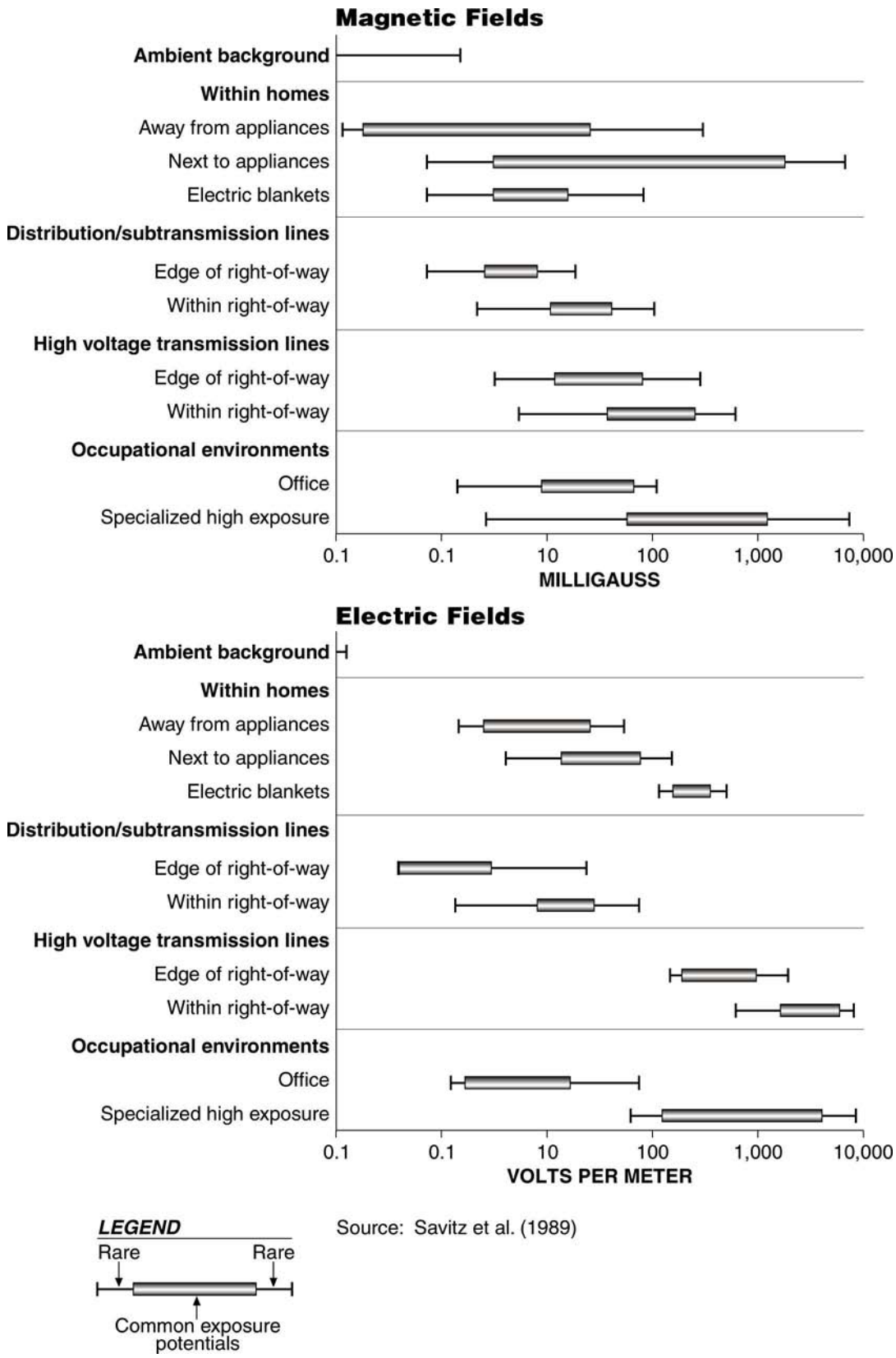

Figure 1. Electric and Magnetic Field Strengths in the Environment.

2 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 observe and interpret their observations and experience. Therefore, scientists use systematic methods to 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. When applied to risk assessment, these general methods include an assessment of the kind of effect that can be caused by an exposure (qualitative assessment), as well as an assessment of the levels of exposure that can produce these effects (quantitative assessment). Various scientific agencies and organizations have used these scientific methods to draw conclusions about many exposures in our environment.

The proper scientific methodology for assessing potential risk to human health from environmental exposures is often described as a *weight-of-evidence* approach and is used by scientists, scientific organizations, and regulatory agencies worldwide. These 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 regulates public exposures (WHO, 1994; USEPA, 1993; USEPA, 1996). Some of the scientific panels that have considered EMF have described the weight-of-evidence approach in the introductory sections of their reviews or in separate publications (ICNIRP, 2002; IARC, 2006; SCENIHR, 2007; SSI, 2007; WHO, 2007a). The weight-of-evidence approach is based on a comprehensive assessment of *all* the relevant scientific research, which includes epidemiologic and experimental studies of humans, experimental studies in animals (*in vivo*) and experimental studies in isolated cells and tissues (*in vitro*).

2.1 Epidemiology and experimental studies are complementary

To assess the potential health effects from any exposure, data from several types of studies, including epidemiologic observations of people and experimental studies on animals, humans, and tissues in laboratory settings, must be evaluated critically.

Epidemiology is the study of the relationship between diseases and exposures in human populations. Epidemiology studies are observational, in that they examine and analyze groups of people going about their normal, daily lives. Such studies are designed to quantify and evaluate statistical associations between exposures to environmental factors (e.g., vegetable intake or cigarette smoking) and health outcomes (e.g., coronary artery disease). Epidemiology studies are evaluated in the context of established guidelines, referred to as *Hill's criteria*, to determine whether observed statistical associations in epidemiologic studies are consistent with

the findings from other areas of research, i.e., experimental *in vivo* and *in vitro* studies, as described in Section 2.4 below. There have been circumstances where the epidemiologic evidence is sufficient (e.g., the relationship between cigarette smoking and lung cancer, as well as the relationship between benzene exposure and leukemia) to establish a causal relationship because the strength, exposure-response, and consistency of the observed statistical association provide strong support for causality. But, under the more common circumstance, where the associations are weak, there are concerns about bias and confounding, the results are not clearly consistent or an exposure-response gradient is not present across the various studies, epidemiology cannot be used as the sole basis for assessing causation and, hence, experimental evidence in animals and other biological systems also must be considered.

In contrast to epidemiology studies, experimental studies are conducted under controlled laboratory conditions. Experimental studies are undertaken in humans, animals (*in vivo*), and cells and tissues (*in vitro*). Experimental studies are designed to test specific hypotheses under controlled conditions and are generally required to establish cause-and-effect relationships, as discussed above. Conversely, the results of experimental studies by themselves may not always be directly extrapolated to human populations. It is, therefore, both important and desirable that biological responses to agents that could present a potential health threat be explored by epidemiologic methods in human populations, as well as by experimental studies in the research laboratory. The scientific method requires continued testing by multiple, independent investigators in both experimental and epidemiologic studies to establish the reliability of study findings through replication. Without replication, factors aside from the factors of interest (i.e., chance, effects of bias and confounding variables) may account for many of the findings reported in the scientific research literature (Ioannidis, 2005; Moonesinghe et al., 2007).

Toxicology is an important part of laboratory research designed to evaluate the potential beneficial or harmful effects of an agent (e.g., a chemical or a magnetic field). The goal of toxicology studies is to identify the nature of effects that result from exposure and the dose of the agent in the target tissue that elicits that effect. A critical distinction, therefore, must be made between harmless biological responses or effects, and those that are truly adverse or deleterious. Many agents produce biological responses in organisms —like the response of the eye to light or the influence of food and water on growth and cellular metabolism— at quite low concentrations or intensities. Hence, the mere demonstration of a biological response or effect does not indicate that exposure to an agent is hazardous *per se*. Rather, it is imperative to ascertain whether biological responses are deleterious or merely normal, and to establish what, if any, exposure concentrations may be toxic and under what conditions.

2.2 Evaluating epidemiologic studies

The main quantitative result of an epidemiologic study is the statistical association between exposures (e.g., alcohol intake) and health outcomes (e.g., breast cancer). An association uses various statistical measures, including relative risk (RR) and odds ratio (OR), to describe the relationship between how exposure and disease vary together. When these measures have values equal to 1.0, there is no association; when these values are greater than 1.0 there is a positive association and an increased risk of disease associated with the exposure is suggested.

Conversely, when the values are less than 1.0, there is a negative association and a decreased risk of disease associated with the exposure is suggested. For example, an epidemiologic study may find that women with breast cancer are more likely to report a history of frequent alcohol intake, compared to women who do not have breast cancer (i.e., a positive association >1.0, although not necessarily causal). Or, an epidemiologic study may find that women with breast cancer are less likely to report a history of frequent alcohol intake, compared to women who do not have breast cancer (i.e., a negative association <1.0, although not necessarily protective). To evaluate the role that chance may play in the observed findings, each statistical association is reported with a range of likely values, called the 95% confidence interval (CI). The CI tells you the range of values that would be observed should the experiment be conducted repeatedly; positive and negative associations are described as statistically significant if the CI does not include the value 1.0, meaning the researcher can exclude the possibility of no association. For example, in the study of breast cancer and alcohol intake described above, an observed association of 2.0 with a 95% CI of 1.5–2.5 would be reported as statistically significant.

To evaluate the validity of an association reported in an epidemiologic study, it is first necessary to evaluate whether the observed association is likely to be "real" or whether it is possible that a spurious association was produced due to chance, bias, or confounding. Bias refers to any systematic error in the design, implementation or analysis of a study that results in a mistaken estimate of an exposure's effect on the risk of disease. For example, if a proxy or surrogate is used to estimate exposure in place of a true exposure measurement, there is the potential to introduce random or systematic error into the study's findings. A confounder is something that is related to both the disease (or condition) under study and the exposure of interest, such that it is difficult to determine whether the confounder or the exposure of interest is truly associated with the disease.[3] If care is not taken to minimize bias and confounding during the design and analysis phases of the study, these factors can distort the study's results and interpretation. Recent studies of magnetic fields and leukemia have been designed to improve exposure assessment and minimize bias and confounding. Still, the effects of bias and confounding have not been eliminated fully from studies of childhood leukemia and EMF, given the many difficulties associated with estimating magnetic field exposure and the lack of knowledge about the causes of childhood leukemia (Greenland et al., 2000; IARC, 2002; Linet et al., 2003; WHO, 2007a).

2.3 Evaluating experimental studies

Experimental or laboratory studies of humans, animals, and cells and tissues complement epidemiology studies because, while people are the species of interest, there are large variations in uncontrolled factors such as genetics, diet, and other health-related exposures in epidemiologic studies. In laboratories, variables (e.g., the intensity and duration of exposure) can be controlled to provide precise information regarding biological effects on cells or animals under defined conditions. These variables can be much better controlled or eliminated in experimental studies of animals, compared to observational studies of humans. *In vitro* studies

[3] For example, an association between coffee drinking in mothers and low birth weight babies has been reported in the past. Some women, however, who drink coffee also smoke cigarettes. It was found that when the smoking habits of the mothers are taken into account, coffee drinking was not associated with low birth weight babies (Kelsey et al., 1996). In this example, smoking is a confounder.

are designed to evaluate the way that the exposure acts on cells and tissues outside of the body, i.e., the mechanism of action.

Studies in which laboratory animals receive high exposures in a controlled environment provide an important basis for evaluating the safety of environmental, occupational, and drug exposures. These approaches are widely used by health agencies to assess risks to humans from medicines, chemicals and physical agents (USEPA, 2002; USEPA, 2005; IARC, 2002; Health Canada, 1994; WHO, 1994). From a public health perspective, long-term (or chronic) studies in which animals undergo exposure over most of their lifetime, or during their entire pregnancy, are of high importance in assessing potential risks of cancer and other adverse effects in a risk assessment. In these long-term studies, researchers examine a large number of anatomical sites to assess changes and adverse effects in body organs, cells, and tissues. Standard protocols for long-term animal studies usually specify at least 50 animals of each sex per dose level, in each of 3 different dose groups. One of these dose groups is a high level termed the "maximum tolerated dose," which is close to, but below, the level that increases mortality or produces significant morbidity. Additional dose levels are used below this maximum level. An unexposed group, or control group, is maintained under the same conditions during the same time period for comparison. This study design permits a separate evaluation of the incidence rate for each tumor type in the exposed group compared to the unexposed control group. Statistical methods are used in the analysis of results to assess the role of chance in any differences in the rates between exposed and unexposed, or among the dose groups. If effects are observed in a study, other studies are considered because similarity of results in different studies, laboratories, and species strengthens the evidence. Key factors in evaluating individual experimental studies include the details of the protocol; the plan for selecting animals and conducting and analyzing the study; the adequacy of the dose levels selected; the way in which the study was actually conducted, including adherence to good laboratory practices in animal housing and monitoring; and the evaluation of the effects on toxicity, tumors, or malformations, considering both biological and statistical issues (USEPA, 2005).

Data from long-term animal studies are instrumental in the risk assessment or weight-of-evidence process to determine whether an environmental exposure is likely to produce cancer or damage organs and tissues. The EPA, for example, recently stated, "…the absence of tumors in well-conducted, long-term animal studies in at least two species provides reasonable assurance that an agent may not be a carcinogenic concern for humans" (page 2-22, USEPA, 2005).

In vitro studies are used to investigate the mechanisms for effects that are observed in living organisms. The relative value of *in vitro* tests to human health risk assessment, however, is less than that of *in vivo* and epidemiologic studies because responses of cells and tissues outside the human body may not reflect the response of those same cells if existing in a living system (IARC, 1992). It is difficult to extrapolate from simple cellular systems to complex, higher organisms to predict risks to health because the mechanism underlying effects observed *in vitro* may not correspond to mechanisms underlying complex processes like carcinogenesis (i.e., the progression of normal cells to cancerous cells). In addition, the results of *in vitro* studies cannot be interpreted in terms of potential human health risks unless they are performed in a well-studied and validated test system. For these reasons, the IARC and other agencies treat data from *in vitro* studies as supplementary to data obtained from epidemiology and whole animal studies.

2.4 Evaluating causation

In order to support a cause-and-effect relationship, the cumulative data must present a logically coherent and consistent picture. Various considerations have been used to evaluate the plausibility of a cause-and-effect relationship between a particular exposure and disease. These considerations, commonly referred to as *Hill's criteria* after the British physician, Bradford Hill, who outlined them (Hill, 1965), typically form the foundation of causal inference (Rothman and Greenland, 1998). Since the publication of Hill's criteria in 1965, numerous revisions and updates have been published (e.g., Susser, 1991; CDC, 2004), although the basic tenets remain. As described in Table 1, Hill's criteria are often used as an analytic framework in the weight-of-evidence review process (e.g., ICNIRP, 2002; USEPA, 2005). Each consideration is not met with a simple 'yes' or 'no,' nor are the considerations meant to be an inflexible set of rules; rather, they serve as guidance for weighing the evidence to reach a decision about cause and effect. The more firmly these considerations are met by the data, the more convincing the evidence in support of causation.

These criteria are considered only in the presence of an observed association in the epidemiologic literature. Once this has been established, the consistency, exposure-response features, and strength of this association is evaluated, in concert with the information gained from experimental studies on coherence, plausibility and analogy. As described above, the epidemiologic data is frequently not strong enough (i.e., associations are weak, inconsistent and do not follow a consistent pattern with dose) to draw conclusions regarding cause-and-effect solely based on epidemiologic data.

Table 1. Considerations for evaluating causation

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 the disease.
Temporality	The exposure occurs prior to the onset of the 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 or exposure-response relationship, i.e., the observation that the stronger or greater the exposure is, the stronger or greater the effect.
Experiment	This occurs when observations result from situations in which natural conditions imitate experimental conditions. This criterion has also been stated as a change in disease outcome in response to a non-experimental change in exposure patterns in population.

(Source: CDC, 2004)

3 Weight-of-Evidence Evaluation of EMF Research

Over the last 30 years, research has been conducted in the US and abroad to examine whether exposures to EMF may have health or environmental effects. The scientific research has focused largely on magnetic fields, since objects such as trees and walls easily shield electric fields. Numerous organizations responsible for health decisions, including national and international organizations, have convened groups of scientists to review the body of EMF research. These expert groups, including the WHO, NIEHS, IARC, HPA, Health Council of the Netherlands (HCN), and the Swedish Radiation Protection Authority (SSI) have included dozens of scientists with diverse skills that reflect the different research approaches required to answer questions about health.

In summary, there is a general consensus in the scientific community, as expressed in these multidisciplinary weight-of-evidence reviews, that the cumulative body of research does not suggest a causal relationship between EMF and any long-term adverse health effect. The only adverse health effects that have been conclusively linked with EMF are short-term, shock-like effects due to exposures to very high levels of electric and magnetic fields (see Section 4 below for a discussion of relevant guidelines). No standards or guidelines have been recommended for exposures to EMF below these high levels, which is consistent with the lack of strong evidence for a health effect and the small degree of remaining uncertainty, although low and no-cost precautionary measures have been recommended.

Since the WHO published the most recent comprehensive weight-of-evidence review of the research on EMF and health, the following discussion focuses on the conclusions of this report, in concert with the preceding 2002 report from the IARC evaluating the carcinogenicity of EMF. The WHO report only included studies published from 2002 through approximately December 2005 because the literature prior to 2002 had already been thoroughly evaluated by IARC. The discussion below notes studies published from December 2005 through June 2008, to evaluate whether the findings of these recent studies alter the conclusions published by the WHO in their 2007 report. Since most of the uncertainty arises from epidemiologic studies in this area, this update systematically addresses epidemiology studies, but relies largely on WHO conclusions with regard to *in vivo* and *in vitro* studies.

3.1 Background and overall conclusions of the WHO report

The WHO is a scientific organization within the United Nations system whose mandate includes providing leadership on global health matters, shaping the health research agenda, and setting norms and standards. The WHO established the International EMF Project in 1996, in response to public concerns about exposures 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 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.

The WHO published a Monograph in June 2007 as part of their Environmental Health Criteria (EHC) Programme summarizing the health research in the ELF range and making recommendations for future research. The Monograph used standard scientific procedures, as outlined in its Preamble, 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,[4] where possible, and (with regard to cancer) mainly focused on evaluating studies published after the IARC review in 2002.

The WHO Task Group and IARC used specific terms to describe the strength of the evidence in support of causality, which will be retained in this report's discussions. *Limited evidence* describes a body of research where the findings are inconsistent or there are outstanding questions about study design or other methodological issues that preclude making strong conclusions. *Inadequate evidence* describes a body of research where it is unclear whether the data is supportive or unsupportive of causation because there is a lack of data or there are major quantitative or qualitative issues. These evidence classifications are combined from multiple lines of evidence (epidemiologic, *in vivo* and *in vitro*) to assign overall carcinogenicity classifications (from highest risk to lowest risk): carcinogenic to humans, probably carcinogenic to humans, possibly carcinogenic to humans, unclassifiable, and probably not carcinogenic to humans.

The overall conclusion of the 446-page WHO report was that the scientific evidence was inadequate to conclude that there is a statistical association between EMF and any cancer, with the exception of childhood leukemia, where a statistical association has been observed with higher levels of estimated time-weighted average (TWA) magnetic field exposure, i.e., > 3-4 mG. The current scientific consensus, however, is that the cumulative body of research does not suggest that the statistical association observed in these epidemiologic studies is causal in nature. This conclusion is based on several observations, including the numerous sources of bias in the epidemiologic studies of childhood leukemia and magnetic fields (namely, selection bias,[5] information bias, and uncontrolled confounding) and the lack of a consistent increase in adverse health effects in long-term studies of animals exposed to high levels of magnetic fields or a plausible explanation for how magnetic fields could result in carcinogenic, developmental, or other adverse effects at the cellular level. The WHO noted areas of uncertainty regarding magnetic fields in its assessment and recommended specific areas for further inquiry. Further research on responses to external electric fields were not proposed as "there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public" (WHO, 2007b). Since the publication of their 2007 report, which included research

[4] 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. Although the two terms are similar, a health risk assessment differs from a weight-of-evidence review in that it also incorporates an exposure and exposure-response assessment.

[5] Selection bias occurs when there are differences in the type of person who participates in the study compared to the type of person who does not participate in the study.

published through approximately 2005, numerous studies have been published, some of which have addressed these WHO research recommendations, as described below.

Specifically, the WHO concluded the following:

> 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 (p. 355, WHO 2007a).

3.2 WHO conclusions regarding specific health conditions

3.2.1 Cancer overall

The overwhelming majority of health research related to EMF has focused on the possibility of a relationship with cancer, including leukemia, lymphoma, breast cancer, and brain cancer. The vast majority of epidemiologic studies on this topic are case-control studies, i.e., they enrolled persons with a specific cancer type (cases), selected a group of individuals similar to the cancer cases (controls), estimated past magnetic or electric field exposures, or both, and compared the exposures of the cases and controls to test for statistical differences in past exposures. Some of these studies looked for statistical associations of these diseases with magnetic fields produced by nearby power lines or appliances (estimated through calculations or distance), while other studies actually measured magnetic field levels in homes or estimated personal magnetic field exposures from all sources. In some studies of adult cancers, occupational magnetic field exposures were estimated, as well.

In vivo studies in this field exposed animals to high levels of magnetic fields (up to 50,000 mG) over the course of their entire lifetime to observe whether exposed animals had higher rates of cancer than unexposed animals. Some of these studies exposed animals to magnetic fields in tandem with a known carcinogen to test whether magnetic field exposure promoted carcinogenesis. Researchers believe it is highly unlikely that electric or magnetic fields can directly damage DNA, because there is relatively low energy associated with EMF. Therefore, *in vitro* studies in this field have focused largely on investigating whether ELF-EMF could promote damage from other known carcinogens or cause cancer through a pathway other than DNA damage (e.g., hormonal or immune effects).

The IARC is the division of the WHO with responsibility to coordinate and conduct research on the causes of human cancer and the mechanisms of carcinogenesis and to develop scientific strategies for cancer control. The IARC convened a scientific panel in 2001 to conduct an extensive review and arrive at a conclusion about the carcinogenicity of ELF-EMF (IARC, 2002). As discussed above, the IARC has a standard method for classifying exposures based on scientific research in support of carcinogenicity. As a result of two pooled analyses reporting an association between high, average magnetic field exposure and childhood leukemia, the epidemiologic data was classified as providing "limited evidence of carcinogenicity" in relation to childhood leukemia. The epidemiologic evidence was classified as inadequate with regard to all other cancer types. The IARC panel also reported that there was "inadequate evidence of carcinogenicity" in studies of experimental animals. Overall, magnetic fields were evaluated as "possibly carcinogenic to humans." The IARC usage of "possible" denotes an exposure in which epidemiologic evidence points to a statistical association, but other explanations cannot be ruled out as the cause of that statistical association (e.g., bias and confounding) and the experimental data does not support a carcinogenic risk.

The WHO report reviewed research related to cancer since the publication of the IARC report and with respect to cancer concluded, "[n]ew human, animal, and in vitro studies published since the 2002 IARC Monograph, do not change the overall classification of ELF as a possible human carcinogen" (p. 347, WHO 2007a).

3.2.2 Childhood cancers

The issue that has received the most attention is childhood leukemia. Research in this area was prompted by a case-control study of children in the US that reported a statistical association between childhood leukemia and assumed exposure to higher magnetic field levels estimated from characteristics of nearby distribution and transmission lines (Wertheimer and Leeper, 1979). Subsequently, some case-control studies reported that children with leukemia were more likely to live closer to power lines or have higher estimates of magnetic field exposure (compared to children without leukemia), while other epidemiologic studies did not report this statistical association.

In 2000, researchers combined the data from a selection of these previously published case-control studies of magnetic fields and childhood leukemia that met specified criteria (Ahlbom et al., 2000; Greenland et al., 2000). The researchers pooled the data on the individuals from each of the studies, creating a study with a much larger number of subjects and, as a result, greater statistical power to detect an effect (should one exist) than any single study. In both pooled analyses, a weak, statistically significant association was reported between childhood leukemia and estimates of average magnetic field exposures greater than 3-4 mG. No association was evident at lower levels of exposure. The authors were appropriately cautious in the interpretation of their analyses, and noted the uncertainty related to pooling estimates of exposure obtained by different methods from studies of diverse design, as did other researchers (e.g., Elwood, 2006). Of note, however, is that the investigators who performed the largest case-control studies of childhood leukemia considered in the pooled analyses and who actually measured personal magnetic field exposure (as opposed to estimating exposure through

calculations or distance), did not report a consistent statistical association or an exposure-response relationship with exposure to higher magnetic field levels (Linet et al., 1997; McBride et al., 1999; UKCCS, 1999).

The results of the pooled analyses were not considered to provide strong epidemiologic support for a causal relationship because of the limitations associated with this epidemiologic data (e.g., a weak association, crude exposure assessments, and the unknown effects of confounding and selection bias). Furthermore, *in vivo* studies have not found that magnetic fields induce or promote cancer in animals exposed under highly controlled conditions for their entire lifespan, nor have *in vitro* studies found a cellular mechanism by which magnetic fields could induce carcinogenesis. As discussed above, these findings resulted in the classification of magnetic fields as a possible carcinogen (IARC, 2002).

The WHO evaluated two more recently published studies related to childhood leukemia and magnetic fields (Draper et al, 2005; Kabuto et al., 2006). In addition, since December 2005, a number of studies have been published addressing new hypotheses related to the association between childhood cancer and magnetic fields (Feizi and Arabi, 2007; Foliart et al., 2006, 2007; Mejia-Arangure et al., 2007; Schüz et al., 2007; Svendson et al., 2007; Mezei et al. 2008b).[6]

Draper et al. conducted a case-control study of childhood cancer, which included 9,700 children with leukemia (i.e., cases) and an equal number of children that did not have leukemia (i.e., controls). The study compared the distance of home address at birth to 275-kV, 400-kV, and some 132-kV transmission lines among cases and controls and reported a weak association between childhood leukemia and home address at birth within 200 meters of high-voltage transmission lines, with a still weaker association out to 600 meters. No associations with central nervous system tumors, brain tumors or other types of childhood cancer and distance were reported. The recent literature includes an additional case-control study of childhood leukemia and distance from power lines in Iran (Feizi and Arabi, 2007). The authors reported that living within 500 meters of a transmission line or having estimated exposures greater than 4.5 mG (using a simple formula to calculate magnetic-field exposures from power lines) were associated with acute leukemia (acute lymphocytic leukemia [ALL] and acute myeloid leukemia [AML] combined). The validity of this study is limited significantly by its small size, possible selection bias, lack of assessment of possible confounding variables (such as socioeconomic status and mobility), and reliance upon distance as a proxy for exposure. The results related to distance from this study are similar to, but much more limited than, the much larger study by Draper et al. (2005). The WHO concluded the following, with respect to the Draper et al. findings:

> [the] observation of the excess risk so far from the power lines, both noted by the authors and others, is surprising. Furthermore, distance is known to be a very poor predictor of magnetic field exposure, and therefore, results of this material based on calculated magnetic fields, when completed, should be much more informative. (p. 270, WHO 2007a)

[6] Lowenthal et al. (2007) also included cases of leukemia among children, although most cases were among adults so this study is included in the adult leukemia section (Section 3.2.4).

Kabuto et al. (2006) conducted a smaller case-control study in Japan that measured the average, weekly magnetic field level in the bedrooms of 312 children with leukemia and 603 children without leukemia. The investigators reported that children with leukemia were more likely to have average magnetic field levels > 4 mG compared to children without leukemia.

The WHO did not assign a high weight or significance to these studies in their overall evaluation, stating that the low participation rate in Kabuto et al. (2006) and the use of distance as a proxy for magnetic field exposure in Draper et al. (2005) were important limitations. Less weight should be placed on these studies relative to studies that used good exposure assessment techniques and had high participation rates (e.g., Linet et al., 1997, McBride et al., 1999; UKCCS, 1999). The WHO described the results of these two recent studies as consistent with the classification of limited epidemiologic evidence in support of carcinogenicity and, together with the largely negative *in vivo* and *in vitro* research, consistent with the classification of magnetic fields as a possible carcinogen.

The WHO concluded that several factors might be fully, or partially, responsible for the consistent association observed between high, average magnetic fields and childhood leukemia, including misclassification of magnetic field exposure due to poor exposure assessment methods, confounding from unknown risk factors, and selection bias. The WHO concluded that reconciling the epidemiologic data on childhood leukemia and the negative (i.e., no hazard or risk observed) experimental findings through innovative research is currently the highest priority in the field of EMF research. Given that few children are expected to have average magnetic field exposures greater than 3-4 mG, however, the WHO stated that the public health impact of magnetic fields on childhood leukemia would be low if the association was determined to be causal. It is also important to recognize that these studies address just one of the many exposures being studied with respect to the etiology of childhood leukemia, including pesticides, benzene, paternal alcohol consumption, ionizing radiation and infections (McNally and Parker, 2006).

Studies published after the WHO review continue to observe statistically significant associations between estimates of magnetic field exposure and childhood leukemia, including reports of an association between childhood leukemia and magnetic field levels greater than approximately 4 mG in children genetically susceptible to leukemia (Mejia-Arangure et al., 2007) and in children with poor outcomes following leukemia diagnosis (Foliart et al., 2006, 2007; Svendson et al., 2007). There was no consistent exposure-response relationship in these studies, however, and small numbers in the upper exposure categories, among other limitations noted below, limited inferences.

The study by Mejia-Arangure et al. (2007) in Mexico suggested a link between higher magnetic field exposure and the development of childhood leukemia in Down syndrome patients, a population genetically susceptible to childhood leukemia. Children with this genetic disorder have a more than 20-fold greater risk of developing leukemia (Podvin et al., 2006). Given the study's limitations (a small sample size, the use of spot measurements taken after the onset of disease as an estimate of exposure prior to diagnosis, and limited control for confounders), further confirmatory research is needed before any conclusions can be drawn. Separate studies in the United States and Germany reported an association between overall survival after a diagnosis of leukemia and average magnetic field levels greater than 4 mG (Foliart et al., 2006;

Svendson et al., 2007, respectively), although no associations were observed between clinical indices of poorer survival and magnetic field exposure in the US population (Foliart et al., 2007). The interpretation of these results is limited by low participation rates, small numbers in the highest exposure categories, and the lack of relevant and prospective information on magnetic field exposures (measurements were made in the house where the child lived the longest *before* diagnosis). Given these limitations, neither the American or German study investigators concluded that there was a causal relationship between magnetic-field exposure and the risk of death following leukemia diagnosis.

It has been hypothesized that nighttime residential magnetic-field exposure may be a more biologically relevant exposure in children. Schüz et al. (2007) evaluated this hypothesis in a pooled analysis of previously published studies, in which magnetic field exposure was based on measurements obtained between 10:00 PM and 6:00 AM. The authors observed similar associations between leukemia and nighttime exposures as in the original analyses of associations with 24- and 48-hour exposures (Ahlbom et al., 2000), leading them to conclude that the results "do not support the hypothesis that leukemia risk in children is more strongly associated with residential ELF-EMF exposure measurements taken at night" and that the similarity of risk estimates between daytime and nighttime measurements "indicates that the nighttime component cannot, on its own, account for the pattern observed."

The WHO report recommended the following with respect to childhood brain tumors:

> Childhood brain cancer studies have shown inconsistent results. 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 (p. 18, WHO 2007a).

In response to this recommendation, Mezei et al. (2008a) published a meta-analysis of studies on childhood brain tumors and residential magnetic field exposure. Thirteen epidemiologic studies were identified that used various proxies of magnetic field exposure (distance, wire codes, calculated magnetic fields, and measured magnetic fields). For all of the exposure proxies considered, the combined effect estimate was close to 1.0 and not statistically significant, indicating no association between magnetic field exposure and childhood brain tumors.

A sub-group of five studies, however, with information on childhood brain tumors and calculated or measured magnetic fields greater than 3-4 mG reported a combined OR that was elevated but not statistically significant (OR=1.68, 95% CI=0.83-3.43). The authors suggested two explanations for this elevated OR. First, they stated that an increased risk of childhood brain tumors could not be excluded at high exposure levels (i.e., >3-4 mG). They also stated that the similarity of this result to the findings of the pooled analyses of childhood leukemia studies for exposures greater than 3-4 mG suggests that control selection bias is operating in both analyses. Control selection bias means that the procedure by which the controls were selected resulted in important differences between the control group used in the study and the population from which the controls came, such that one sees an error in the estimate of risk.

Selection bias can introduce systematic error into the study and limit the interpretation of the study results. Overall, the authors concluded that the analysis did not find a significant increase in childhood brain cancer risk using various proxies of residential exposure to magnetic fields.

An additional study by Mezei et al. (2008b) assessed the likelihood of control selection bias in a previously published study of childhood leukemia in Canada (McBride et al., 1999). This study evaluated whether there were differences between the controls that participated in the 1999 study and the controls that did not participate in the 1999 study. The goal of the study was to assess whether the non-participating controls had a higher prevalence of some factor that made them more likely to have a higher magnetic field exposure than the participating controls and, thus, resulted in an under-representation of exposure prevalence in the control group and an overestimation of the risk estimate.

The authors reported a slightly higher prevalence of the very high current configuration wire code among non-participating controls, resulting in an attenuation of the association between childhood leukemia and magnetic fields when the ideal control group was used. The study also found that non-participating controls had a lower socioeconomic status, which has been associated with higher magnetic field exposures in previous studies. Thus, the study suggested that control selection bias was operating to some extent, although the authors noted the inherent problems associated with estimating magnetic field exposure using wire codes as a proxy and, therefore, concluded, "the role of selection bias cannot entirely be dismissed on the basis of these results alone."

In response to WHO recommendations to "focus on new aspects of exposure, potential interaction with other factors or on high exposure groups" (p. 17), recent research has been innovative in the area of childhood leukemia and magnetic field exposure. These recent studies, like some early studies, have observed associations between estimates of high average magnetic field exposure and childhood leukemia, although recent data suggests that control selection bias may play some role in this observed association. None of these recent studies are sufficiently strong methodologically, nor do the findings display causal patterns (exposure-response, consistency and strength) to alter previous conclusions that the epidemiologic evidence on magnetic fields and childhood leukemia is limited. Chance, confounding, and several sources of bias cannot be ruled out.

3.2.3 Breast cancer

Research on breast cancer has examined the possible effects of EMF from three sources: workplace exposures, residential exposure from power lines, and electric blankets. Some of the early epidemiologic studies reported a weak association between breast cancer and higher magnetic field exposures, while others did not; however, the conclusions that could be drawn from this initial body of research were limited because of study quality issues (e.g., poor exposure assessment, inadequate control for confounding variables, and small sample sizes within subgroups with reported associations). Review panels evaluating this initial body of research concluded that the evidence in support of an association was weak, but should be evaluated further with higher quality studies (NRPB, 2001a; IARC, 2002; ICNIRP, 2003).

A large number of studies on breast cancer and magnetic field exposure have been conducted since the publication of the IARC review in 2002. These studies were reviewed systematically by the WHO and included seven studies that estimated residential magnetic field exposure, four studies that evaluated associations with electric blanket usage, and nine studies that estimated occupational magnetic field exposure. No consistent association was observed between magnetic field exposure and breast cancer in these studies. The WHO concluded that this recent body of research was higher in quality compared with previous studies, and, for that reason, provides strong support to previous reviews 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" (p. 9, WHO 2007a). The WHO recommended no further research with respect to breast cancer and magnetic field exposure.

Since the publication of the WHO report, two case-control studies have estimated the association between EMF exposure and breast cancer, both of which focused on occupational exposures (McElroy et al., 2007; Ray et al., 2007).[7] Neither of these two recently published studies provides strong evidence contradicting previous WHO conclusions regarding EMF exposure and breast cancer. This conclusion is consistent with a recently published review of the literature by Feychting and Forssén (2006) in Sweden, which concluded the following:

> … considering the results of the latest well designed studies performed specifically to test the hypothesis that ELF magnetic field exposure increase breast cancer risk, one must conclude that the weight of the evidence available today suggest that power frequency magnetic field exposure most likely is not a risk factor for breast cancer development. (p. 557)

3.2.4 Adult leukemia, lymphoma and brain cancer

A large number of studies of varying quality and with a wide range of techniques have been conducted in both occupational and residential settings to explore the possible relationship between EMF exposure and adult brain cancer and leukemia. The scientific committees assembled by the IARC, National Radiation Protection Board of Great Britain (NRPB)[8] and the International Committee on Non-Ionizing Radiation Protection (ICNIRP) concluded that the evidence is weak and does not support a role for electric or magnetic fields in the etiology of brain cancer or leukemia among adults (NRPB, 2001a; IARC, 2002; ICNIRP, 2003).

The WHO reviewed the body of research published since the time of these reviews, including three cohort studies estimating residential exposure, four cohort studies estimating occupational

[7] An additional case-control study was published post-2005 that examined residential magnetic field exposure and breast cancer (Davis and Mirick, 2007). It was not evaluated fully in this report because it was a re-analysis of a study published by the same investigators in 2001 (Davis et al., 2001a), with the addition of a few variables.

[8] The NRPB merged with the Health Protection Agency (HPA) of Great Britain in 2005.

exposure, and eight case-control studies reporting on occupation and brain cancer or leukemia risk. The WHO concluded,

> 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 diseases remains inadequate (p. 307, WHO 2007a).

The WHO panel recommended updating the existing cohorts of occupationally exposed individuals in Europe and then pooling the epidemiologic data on brain cancer and adult leukemia to confirm the absence of an association. Recent studies updated a cohort of 28,000 Danish utility workers (Johansen et al., 2007) and 20,000 Swiss railway workers (Röösli et al., 2007), and a meta-analysis was conducted by Kheifets et al. (2008) of recent studies of occupational EMF exposure and adult brain cancer and leukemia.

In Johansen et al. (2007), the utility workers were followed for the incidence of cancer and classified into magnetic field exposure categories (high, medium and background) based on their first reported job title. The authors reported that male employees in high exposure jobs were no more likely to be diagnosed with leukemia than persons in medium or background exposure jobs.

Röösli et al. (2007) estimated cumulative magnetic field exposure by linking each cohort member's occupational history with exposures based on measurements and modeling. The previous publication on this cohort provided some evidence to support an association between leukemia mortality and increased magnetic field exposure (Minder and Pfluger, 2001). The current study, however, which evaluated an additional 9 years of follow-up and included 29 additional deaths due to leukemia, did not report an association between overall leukemia mortality and increasing magnetic field exposure. Leukemia and lymphoma mortality was also compared between stationmasters (who spent most of their time in the station and on the platforms) and train attendants (who were exposed to magnetic fields from the 16.7-Hz AC engines). The authors noted a stronger association among alpine train drivers, lowland train drivers, shunting yard engineers, and train attendants when compared with stationmasters, but the associations were not statistically significant. No associations between EMF and brain tumor incidence were observed in the Danish study of utility workers, and no associations between EMF and brain tumor mortality were observed in the Swiss study of railway workers (Johansen et al., 2007; Röösli et al., 2007).

Thus, neither cohort study found a statistically significant association between occupational EMF exposure and leukemia or brain cancer risk. The Röösli et al. (2007) study was limited by the use of death certificate data[9] and small numbers, while the Johansen et al. (2007) study was based on a relatively large number of incident cancer cases. Neither cohort controlled for possible confounding factors. Both cohorts, however, had a long period of follow-up and

[9] Death certificates may not always contain the diagnosis of interest because they may only report immediate, and not underlying, causes of death. Furthermore, survival is increasing for many cancers. Thus, if a person survives their cancer, the cancer diagnosis will not be listed on their death certificate. Both of these limitations can result in an under-ascertainment of cases, which could bias risk estimates toward 1.0.

consisted of persons who were presumably occupationally exposed to high levels of magnetic fields.

Two Australian case-control studies were published related to magnetic field exposure and adult leukemia (Lowenthal et al., 2007; Karpidis et al., 2007a), and two case-control studies were published related to magnetic field exposure and specific brain cancer types, acoustic neuroma and glioma (Forssén et al., 2006; Karipidis et al., 2007b, respectively):

- Lowenthal et al. (2007) grouped cases in five cancer diagnostic categories (including ALL) as lymphoproliferative disorders (LPD) and three diagnostic categories (including some types of leukemia) as myeloproliferative disorders (MPD). These groups included both adults and children of all ages. The authors estimated exposure by obtaining a lifetime residential history and assessing distance of residences from 88-kV, 110-kV, or 220-kV power lines. An individual's exposure was based on the closest distance ever having lived from a power line, grouped in categories of 0-50 meters, 51-300 meters, and > 300 meters. Lowenthal et al. (2007) reported elevated, but not statistically significant ORs for those who lived within 50 meters of any of these power lines, and an indication of decreasing ORs with increasing distance. The number of observed cases was small, however, and chance could not be ruled out as a factor in any of these results. The authors also reported an increased OR when only considering exposures that occurred up to the age of 15; the authors presented the concept of a possible effect of childhood exposure on long-term disease risk as a "novel finding" deserving further study.

  This study of LPD and MPD by Lowenthal et al. (2007) has many limitations that may introduce bias, reduce validity, and detract from its findings. For example, data was obtained from cases by interview, but information was obtained from controls by postal questionnaires, thus breaking a cardinal rule in epidemiology that information from cases and controls should be obtained in the same manner; it is possible that the quality of information obtained from the case group was better than that obtained for the control group, resulting in a better reporting of exposure prevalence in the case group and an inflated risk estimate.

  As the discussions above illustrate, epidemiologic studies typically evaluate each different type of cancer individually because there are differences among cancers in etiology, as suggested by different patterns of age at diagnosis, cell type, rate of growth and response to different treatments. Therefore, cancer etiology is studied separately for each type of cancer. The combination of different diseases and age groups, the highly imprecise exposure surrogate, the different methods for evaluating cases and controls, and the role of chance diminish the implications of the study's findings.

- In another Australian case-control study, occupational history was evaluated for associations with non-Hodgkin lymphoma (NHL) (Karpidis et al., 2007a). The authors estimated cumulative exposure to magnetic fields based on reported occupations. When considering other factors, including age, sex, place of residence, ethnic origin, and exposure to solvents (other than benzene) and to wood dust and particles, the authors observed a significant trend of more cases than controls classified with higher

cumulative exposure to magnetic fields. A statistically significant association with NHL was reported in the highest category of exposure (OR=1.59). Overall, the Australian study was well conducted, with its most significant limitation being the possibility of uncontrolled confounding because very little is known about the causes of NHL.

This is one of the first population-based studies examining an association between NHL and magnetic field exposure using calculated exposure estimates. An earlier Swedish case-control study estimated occupational magnetic field exposure using a job-exposure matrix and reported an elevated, but not statistically significant, association between higher occupational magnetic field exposure and NHL (OR=1.50, Dryver et al., 2004). Further research on NHL and magnetic fields is required before any firm conclusions can be provided.

- Forssén et al. (2006) is the first case-control study to report on the possible association between magnetic field exposure and acoustic neuroma, a benign (non-cancerous) and rare brain tumor for which causes are unknown. The large study consisted of all diagnoses of acoustic neuroma in Sweden over a 12-year period (N=793) and controls randomly selected from the entire Swedish population (N=101,762). TWA and peak occupational magnetic field exposure were estimated using a job-exposure matrix[10] based on actual measurements and occupations listed on the country's census forms. The authors did not find any evidence that magnetic field exposure increases the risk of acoustic neuroma, regardless of the exposure level or the time period considered. This study was advanced because selection, recall, and participation bias were not an issue since no participation was required of the cases or controls; however, incomplete occupational data was an important limitation.

- Glioma risk was evaluated in a case-control study of men and women in Melbourne, Australia (Karipidis et al, 2007b). Occupational history was obtained for each subject by an in-person interview, and magnetic field exposure was classified in three ways: self-reported exposure, exposure estimated by an industrial hygienist, and a job-exposure matrix. No statistically significant associations with glioma were observed for men or for women based on any of three exposure classifications. This study had a number of significant limitations (low participation rates and a high percentage of proxy interviews among cases) that limit its validity.

Kheifets et al. (2008) collected relevant publications of occupational EMF exposure and adult leukemia and brain cancer, including some of the publications discussed above (Johansen et al., 2007; Karipidis et al, 2007b), and calculated summary risk estimates using various schemes to weight and categorize the study data. The analysis followed standard methods for meta-analysis of observational epidemiologic data, including a clearly defined search strategy, a thorough examination of heterogeneity through sensitivity analysis and meta-regression, a systematic evaluation of study quality, and an assessment of publication bias (Stroup et al., 2000). The authors reported a small and statistically significant increase of leukemia and brain cancer in relation to the highest estimate of magnetic field exposure in the individual studies. Several

[10] A job-exposure matrix classifies job titles by exposure estimates. Job-exposure matrices are used to estimate cumulative occupational exposure (e.g., magnetic field exposure) based on an individual's job history.

findings, however, suggested that magnetic field exposure is not responsible for the observed associations with leukemia and brain cancer, including that there is no consistent pattern among leukemia subtypes when the past and new meta-analyses were compared. In addition, for brain cancer, the present meta-analysis reports a weaker estimated association than the previous meta-analysis, whereas a stronger association would be expected should a true risk exist since the quality of studies has increased over time. Thus, the authors concluded, "the lack of a clear pattern of EMF exposure and outcome risk does not support a hypothesis that these exposures are responsible for the observed excess risk" (p. 677).

In conclusion, the recently published updates of large cohorts occupationally exposed to magnetic fields are in line with the previous summary conclusions from IARC, ICNIRP, and WHO with regard to adult leukemia and brain cancer. The cumulative body of evidence does not support a consistent epidemiologic association between magnetic fields and adult leukemia, brain cancer or lymphoma.

3.2.5 *In vivo* experimental research on carcinogenesis

It is standard procedure to conduct studies of laboratory animals to determine whether exposure to a specific agent leads to the development of cancer (USEPA, 2005). This approach is used because all known human carcinogens cause cancer in laboratory animals. Of the 70,000 chemicals in common use, few have been subjected to tests considered as the 'gold standard' for assessing potential carcinogenic effects. Fortunately, such tests have been conducted for EMF. Of particular importance are studies in which rodents have been exposed to high levels of magnetic fields over the course of their lifetime and tissue evaluations have been performed to assess the incidence of cancer in many organs.

In these studies, magnetic field exposure sometimes 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-carcinogenic effect), or in combination with a known carcinogen and a known promoter (to test for a co-promotional effect). The WHO described four large-scale, long-term studies of rodents exposed to magnetic fields as high as 50,000 mG over the course of their lifetime that did not report increases in any type of cancer (Mandeville et al., 1997; Yasui et al., 1997; McCormick et al., 1999; Boorman et al., 2000a,b). No directly relevant animal model for childhood ALL currently exists; however, some animals develop a type of lymphoma similar to childhood ALL. Studies exposing transgenic mice predisposed to this lymphoma to power-frequency magnetic fields have not reported an increased incidence of lymphoma associated with exposure (Harris et al., 1998; McCormick et al., 1998). Other strains of mice with a genetic susceptibility to leukemia do not develop the disease more frequently or more rapidly when exposed to weak or strong magnetic fields (Sommer and Lerchel, 2004; Sommer and Lerchl, 2006).

Other studies have investigated whether exposure to magnetic fields can promote cancer or act as a co-carcinogen used known cancer-causing agents, such as ionizing radiation, UV radiation or chemicals like 7,12-dimethylbenz[a]anthracene (DMBA). No effects were observed for studies on chemically-induced pre-neoplastic liver lesions, leukemia/lymphoma, skin tumors, or

brain tumors; however, the incidence of chemically-induced mammary tumors was increased with magnetic field exposure in a series of German experiments, suggesting that magnetic field exposure increased the proliferation of mammary tumor cells (Löscher et al., 1993, 1994, 1997; Mevissen et al., 1993a,b, 1996a,b, 1998; Baum et al., 1995; Löscher and Mevissen, 1995). These results were not replicated in a subsequent series of experiments in a US laboratory (Anderson et al., 1999; Boorman et al.1999a,b; NTP, 1999), possibly due to differences in experimental protocol and the species strain (Fedrowitz et al., 2004). A recent study by Fedrowitz and Löscher (2008) exposed 108 DMBA-treated Fischer 344 rats to either high levels of magnetic fields (1,000 mG) or no exposure for 26 weeks and reported that the incidence of adenocarcinomas was significantly elevated in the group exposed to magnetic fields. The series of experiments from the German laboratory suggest that magnetic fields promote mammary tumorigenesis, however, questions remain regarding the relevance of species differences.

In summary, the WHO concluded with respect to *in vivo* research, "[t]here is no evidence that ELF magnetic field exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate" (p. 10, WHO, 2007a). Recommendations for future research include the development of a rodent model for childhood ALL and the continued investigation of whether magnetic fields could act as a co-carcinogen.

Negishi et al. (2008) exposed new-born DMBA-treated mice to 0, 70, 700, or 3,500 mG magnetic field levels for 22 hours per day for 30 weeks and observed them daily for the development of malignant lymphoma/lymphatic leukemia; the experiment was conducted two times. The authors reported that the percentage of mice with malignant lymphoma/lymphatic leukemia was not higher in magnetic field exposed groups compared to the sham-exposed group. The authors concluded, "these data provide no evidence to support the hypothesis that power frequency MFs [magnetic fields] is a significant risk factor for hematopoietic neoplasia" (p. 29).

3.2.6 *In vitro* experimental research on carcinogenesis

In vitro studies are widely used to investigate the mechanisms for effects that are observed in humans and animals. As discussed in Section 2.3, the relative value of *in vitro* tests to human health risk assessment, however, is much less than that of *in vivo* and epidemiologic studies. Responses of cells and tissues outside the body may not always reflect the response of those same cells if maintained in a living system, so the relevance of *in vitro* studies cannot be assumed (IARC, 1992).

The IARC and other scientific review panels that systematically evaluated *in vitro* studies concluded that there is no clear evidence indicating how ELF magnetic fields could adversely affect biological processes in cells (IARC, 2002; ICNIRP, 2003; NRPB, 2004). The WHO panel reviewed the *in vitro* research published since the time of these reviews and reached the same conclusion. The WHO noted that previous studies have not indicated a genotoxic effect of ELF magnetic fields on mammalian cells, however, a recent series of experiments reported DNA damage in human fibroblasts exposed intermittently to 50-Hz magnetic fields (Ivancsits et al., 2002, 2003a,b). These findings have not been replicated by other laboratories (Scarfi et al.,

2005), and the WHO recommended continued research in this area. Research in the field of *in vitro* genotoxicity of magnetic fields combined with known DNA-damaging agents was also recommended by the WHO, following suggestive findings from several laboratories. As noted by the SSI, the levels at which these effects were observed are much higher than the levels to which we are exposed in our everyday environments and are, therefore, not directly relevant to questions about low-level, chronic exposures (SSI, 2007).

In vitro studies investigating other possible mechanisms, including gene activation, cell proliferation, apoptosis, calcium signaling, intercellular communication, heat shock protein expression and malignant transformation, have produced "inconsistent and inconclusive" results (p. 347, WHO, 2007a).

3.2.7 Reproductive effects

Epidemiologic studies have been conducted to observe whether maternal or paternal EMF exposures are associated with adverse reproductive effects, including effects on fertility, reproduction, miscarriage, and prenatal and postnatal growth and development. A body of *in vivo* literature is also available on this topic. Early studies on the potential effects of EMF exposures on reproductive outcomes were limited because the majority of the studies used surrogate measures of exposure (including visual display terminal use, electric blanket use or wire code data) or assessed exposure retrospectively.

Two recent studies related to miscarriage improved exposure assessment by directly measuring magnetic field exposure. These two studies reported a positive association between miscarriage and exposure to high maximum, or instantaneous, peak magnetic fields (Lee et al., 2000, 2002; Li et al., 2002); however, no consistent associations were reported with high, average magnetic field levels, the typical method for assessing magnetic field exposure. The WHO noted a few of the issues that have been raised by other investigators and scientific review panels concerning the validity of these associations (HCN, 2004; NRPB, 2004; Feychting et al., 2005; Mezei et al., 2006; Savitz et al., 2006).

First, the studies had a low response rate, which means that the case and control groups may not be comparable because those who participated in the study may differ from those who declined (i.e., selection bias). Second, in the study by Lee et al. magnetic field measurements were taken 30 weeks after a woman's last menstrual period. Some of these women had already miscarried at 30 weeks when magnetic field exposure was measured. This introduces the possibility for bias because pregnancy may alter physical activity levels and physical activity may be associated with magnetic field exposure in pregnant women, as recently confirmed in a study by Savitz et al. (2006). It is possible that the women who miscarried prior to 30 weeks in the study by Lee et al. (2002) subsequently increased their physical activity levels (i.e., returned to work or their normal routine), which resulted in greater opportunities to encounter higher peak magnetic field levels. Furthermore, there is no biological basis to indicate that EMF increases the risk of reproductive effects. The WHO report concluded that *in vivo* studies exposing animals to high levels of EMF reported no significant, adverse 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 outcomes. The evidence from epidemiologic studies on miscarriage is inadequate, and further research on this possible association was recommended, although low priority was given to this recommendation.

No studies were identified that evaluated EMF exposure and adverse reproductive outcomes since the WHO review. A study related to developmental outcomes and EMF exposure, however, was recently published (Fadel et al., 2006). Fadel et al. (2006) is a cross-sectional study of 390 children living in Abu-Sultan, with residences within 50 meters of high-voltage power lines, and 390 children living in El-Shiekh Zayed, with residences not located near power lines. The authors reported that children living in the region near power lines had a statistically significant lower weight at birth and a reduced head and chest circumference and height at all ages.

There are three main limitations of this study. First, it is a cross-sectional study, meaning that dynamic characteristics such as height and weight were measured at a single point in time. To assess causation, the relationship between exposure, and in this case, measures of developmental outcome would need to be considered over time as are accounted for in more powerful study designs. Second, although the authors noted that socioeconomic status was similar between the two regions, they did not collect or provide data to support this assertion, nor did they account for some key factors that might influence growth, such as nutrition, in their analyses. The final limitation is that the authors observed statistically significant associations, but did not discuss the biological importance of their findings.

The WHO concluded that, "Overall the evidence for developmental effects and for reproductive effects is inadequate" (p. 254, WHO 2007a). The study by Fadel et al. (2006) does not provide evidence that would alter that conclusion.

3.2.8 Neurodegenerative diseases

Research into the possible effect of magnetic fields on the development of neurodegenerative diseases began in 1995, and the majority of research since then has focused on Alzheimer's disease and a specific type of motor neuron disease called amyotrophic lateral sclerosis (ALS), which is also known as Lou Gehrig's disease. The inconsistency of the Alzheimer's studies prompted the NRPB to conclude that there is "only weak evidence to suggest that it [extremely low frequency magnetic fields] could cause Alzheimer's disease" (p. 20, NRPB, 2001b). Early studies on ALS, which had no obvious biases and were well conducted, reported an association between ALS mortality and estimated occupational magnetic field exposure. The review panels, however, were hesitant to conclude that the associations provided strong support for a causal relationship. Rather, the scientific panels felt that an alternative explanation (i.e., electric shocks received at work) may be the source of the observed association. The NRPB concluded: "In summary, the epidemiological evidence suggests that employment in electrical occupations may increase the risk of ALS, possibly, however, as a result of the increased risk of receiving an electric shock rather than from the increased exposure to electromagnetic fields" (p. 20, NRPB, 2001b).

The majority of recent studies reported statistically significant associations between occupational magnetic field exposure and mortality from Alzheimer's disease and 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). There is currently no biological data to support an association between magnetic fields and 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.

Garcia et al. (2008) conducted a systematic review and meta-analysis of studies of occupational EMF exposure and Alzheimer's disease published through April 2006. The authors identified 14 epidemiologic studies with information on the risk of Alzheimer's disease related to occupational exposure to EMF; the WHO considered the majority of these studies in their 2007 review. A statistically significant association between Alzheimer's disease and occupational EMF exposure was observed for both case-control and cohort studies (OR =2.03, 95% CI=1.38-3.00 and RR =1.62, 95% CI=1.16-2.27, respectively), although the results from the individual studies were so different that the authors cautioned against the validity of these combined results. While some subgroup analyses had statistically significant increased risks and were not significantly heterogeneous between studies, the findings were contradictory between study design types (e.g., elevated pooled risk estimates were reported for *men* in cohort studies and elevated pooled risk estimates were reported for *women* in case-control studies). The authors found no exposure-response patterns and publication bias was apparent. The authors concluded that their work suggests an association between Alzheimer's disease and occupational magnetic field exposure, but noted the numerous limitations associated with these studies, including the difficulty of assessing EMF exposure during the appropriate time period, case ascertainment issues due to diagnostic difficulties, and differences in control selection. They recommended further research that uses more advanced methods.

Three original studies on neurodegenerative diseases and magnetic field exposures have been published since the WHO report; none of these studies were included in the meta-analysis discussed above. Davanipour et al. (2007) extended the early hypothesis-generating study by Sobel et al. by collecting cases from eight California Alzheimer's Disease Diagnostic and Treatment Centers (Sobel et al. examined the 9th Center in 1996). Occupational information (i.e., self-reported primary occupation) was collected from patients with verified diagnoses of Alzheimer's disease and compared to occupational information collected from persons diagnosed with other dementia-related problems at the Centers. The results of this study were consistent with the previous studies by Sobel et al.; cases were approximately twice as likely to be classified as having medium/high magnetic field exposures, compared with controls. When the authors analyzed the data for males and females separately, the association was statistically significant among females, but not among males. The strengths of this study included its large size, self-reported occupational information, and that disease status was based on expert diagnosis. The latter is only a relative advantage as firm diagnosis of this disease is only possible at autopsy. The main limitation of this study was that the exposure assessment only considered a person's primary occupation, classified as low, medium or high magnetic field exposure. The WHO noted limitations of the 1996 publication that are relevant to this publication as well, including the use of controls with dementia (which some studies report have an increased risk of Alzheimer's disease) and the classification of seamstresses, dressmakers

and tailors as “high exposure” occupations, which drives the increase in risk (as documented by the high risk observed only among females).

Death from several neurodegenerative conditions was also evaluated in the cohort of more than 20,000 Swiss railway workers described above (Röösli et al., 2007b). Magnetic field exposure was characterized by specific job titles as recorded in employment records; stationmasters were considered to be in the lowest exposure category and were, therefore, used as the reference group. Train drivers were considered to have the highest exposure, and shunting yard engineers and train attendants were considered to have exposure intermediate to stationmasters and train drivers. Cumulative magnetic field exposure was also estimated for each occupation using on-site measurements and modeling of past exposures. The authors reported an excess of senile dementia disease among train drivers, compared to station masters, however, the difference was not statistically significant; the association was larger when restricted to Alzheimer’s disease, but was still not statistically significant (hazard ratio=3.15, 95% CI=0.90-11.04). No elevation in mortality was reported for multiple sclerosis, Parkinson’s disease, or ALS among train drivers, shunting yard engineers, or train attendants, compared with stationmasters, nor were more deaths from these causes observed for higher estimated magnetic field exposures. Similar to another recent Swedish study (Feychting et al., 2003), the authors reported that more recent exposure is more strongly associated with this disease than earlier exposure.

This study has several unique advantages relative to the existing body of data, as described by the study authors:

> Swiss railway employees are an appealing study population for several reasons. They are generally employed long-term, with limited job changes. The exposure circumstances at a given workplace are well characterized but vary greatly across different occupations, with train drivers being exposed to very high ELF/MF levels, whereas exposure in other employees is comparable to the general population. Detailed company registers reduce the potential for selection bias and allow assessments of ELF-MF exposure that are based on individual job histories. Exposures to chemicals or electric shocks, which often occur in other occupational settings (for example in electric utility workers or welders) are rare (p. 198).

Sorahan and Kheifets (2007) followed a cohort of approximately 84,000 electrical and generation workers in the United Kingdom for deaths attributed to neurodegenerative disease on death certificates. Cumulative magnetic field exposure was calculated for each worker, using job and facility information. The authors reported that the cohort did not have a significantly greater number of deaths due to Alzheimer’s disease or motor neuron disease, compared to the general United Kingdom population. They also reported that persons with higher estimated magnetic field exposures did not have a consistent excess of death due to Alzheimer’s disease or motor neuron disease, compared to persons with lower estimated magnetic field exposure. A statistically significant excess of deaths due to Parkinson’s disease was observed in the cohort, although there was no association between calculated magnetic field exposure and Parkinson’s disease. The authors concluded “our results provide no convincing evidence for an association

between occupational exposure to magnetic fields and neurodegenerative disease" (p. 14). This result is consistent with two other Alzheimer's mortality follow-up studies of electric utility workers in the US (Savitz et al., 1998) and Denmark (Johansen and Olsen, 1998). The findings may be limited by the use of death certificate data, but are strengthened by the detailed exposure assessment.

Studies of neurodegenerative disease and magnetic field exposure have had significant methodological limitations that make them difficult to interpret. The onset of Alzheimer's disease occurs late in life and is difficult to define precisely because it is preceded by a period of dementia that is difficult to distinguish from other etiologies, such as cerebrovascular disease. Since magnetic field exposure occurs throughout a person's life, it is also a challenge to design studies that ascertain lifetime exposure accurately and at the etiologically relevant time period (Brown et al., 2005). An advantage of the more recent cohort studies is that they estimated cumulative magnetic field exposure based on a person's known job tasks in the electric or railway industries (Röösli et al., 2007b; Sorahan and Kheifets 2007). A complication, however, is that these studies used death certificates to ascertain cases. Use of death certificates or other mortality data is likely to result in a large number of missed cases, and therefore introduce possible bias, because a large percentage of elderly Alzheimer's patients die from other causes and Alzheimer's disease may not be mentioned on the death certificate (Brown et al., 2005). Furthermore, none of these studies estimated residential exposure and most did not control for the possible confounding effect of other risk factors for Alzheimer's disease (increasing age, family history, Down syndrome, and a genetic predisposition).

The WHO stated that there is inadequate data in support of an association between magnetic field exposure and Alzheimer's disease or ALS; the recent studies do not alter this conclusion. The meta-analysis by Garcia et al. (2008) confirmed that the associations reported in these studies are highly inconsistent and the studies have many limitations. Overall, the three recent, original studies contribute some valuable information to the growing body of literature regarding magnetic field exposure and neurodegenerative diseases, particularly the well-conducted cohort study by Röösli et al. (2007b). Further studies are still required, however, to address the numerous limitations of the existing body of literature. Moreover, there are no consistent biological data that would support the plausibility of such an association. The WHO panel highly recommended that further studies be conducted with regard to neurodegenerative diseases, particularly studies where the association between magnetic fields and ALS is estimated while controlling for the possible confounding effect of electric shocks.

3.2.9 Neuroendocrine

The mechanism hypothesized by some investigators to explain a relationship between cancer (particularly breast cancer) and magnetic field exposure involves a decrease in the production of a hormone called melatonin induced by magnetic fields, which (according to the theory) could result in cancer because of melatonin's putative anti-carcinogenic effects and its regulatory control of reproductive hormones such as estrogen. This idea was proposed in the late 1980s and is now referred to as the "melatonin hypothesis."

The WHO report concluded the following with respect to the melatonin hypothesis and other neuroendocrine pathways:

> The results of volunteer studies as well as residential and occupational studies suggest that the neuroendocrine system is not adversely affected by exposure to power-frequency electric and/or magnetic fields. This applies particularly to the circulating levels of specific hormones of the neuroendocrine system, including melatonin, released by the pineal gland, and a number of hormones involved in the control of body metabolism and physiology, released by the pituitary gland. Subtle differences were sometimes observed in the timing of melatonin release or associated with certain characteristics of exposure, but these results were not consistent. It is very difficult to eliminate possible confounding by a variety of environmental and lifestyle factors that might also affect hormone levels.
> Most laboratory studies of the effects of ELF exposure on night-time melatonin levels in volunteers found no effect when care was taken to control possible confounding (p. 185).

The Health Protection Agency of Great Britain also published an extensive weight-of-evidence review that evaluated the available experimental and epidemiologic evidence related to the melatonin hypothesis (HPA, 2006). The review concluded that there is no consistent evidence in experimental or epidemiologic studies to suggest that magnetic fields can alter melatonin levels. *In vitro* and *in vivo* studies have suggested that melatonin can limit growth of cancer cells, however, epidemiologic data linking reduced melatonin levels to subsequent breast cancer risk is limited. Consistent with our evaluation and the reports from other review panels, the HPA review also concluded that the epidemiologic evidence does not support an association between magnetic fields and breast cancer. Taking all of this evidence together, the review concluded the following:

> In aggregate, the evidence to date does not support the hypothesis that exposure to power frequency EMFs affects melatonin levels or risk of breast cancer (p. 161).

The HPA review included a series of studies related to the role of melatonin in the etiology of breast cancer conducted by a group of investigators in Seattle (Davis and Mirick, 2007). The initial case-control study by these investigators reported no association between residential magnetic field exposure and breast cancer (Davis et al., 2001a), but an extension of this study reported that urinary levels of a melatonin metabolite (6-sulfatoxymelatonin) were reduced in persons with higher magnetic field measurements in the bedroom, although the results were only statistically significant when considered among persons taking medications known to reduce melatonin levels (Davis et al., 2001b).

To explore this result further, a re-analysis of the 2001 case-control study evaluated whether the association between breast cancer and residential magnetic field exposure was more pronounced among persons reporting medication use; no significant association was reported when medication users were considered alone (Davis and Mirick, 2007). A cross-over experiment, however, by the same group of investigators reported statistically lower urinary levels of 6-

sulfatoxymelatonin in women exposed to controlled magnetic field levels over the course of five consecutive nights (Davis et al., 2006). In a recent study by a separate group of investigators, 59 workers in a variety of occupations were monitored for magnetic field exposure during three complete work shifts and 6-sulfatoxymelatonin levels were then measured in their urine. The levels of 6-sulfatoxymelatonin were not significantly different in persons occupationally exposed to higher TWA levels of magnetic fields (> 2 mG), compared to persons occupationally exposed to less than 2 mG. Thus, recent studies do not provide strong or consistent evidence to support the conclusion that magnetic fields cause cancer through a melatonin-driven pathway (Davis et al., 2006; Gobba et al., 2006; Davis and Mirick, 2007).

3.2.10 Neurobehavioral

The WHO report concluded the following with respect to neurobehavioral outcomes:

> The evidence for other neurobehavioural effects in volunteer studies, such as the effects on brain electrical activity, cognition, sleep, hypersensitivity and mood, is less clear. Generally, such studies have been carried out at exposure levels below those required to induce the effects described above, and have produced evidence only of subtle and transitory effects at best. The conditions necessary to elicit such responses are not well-defined at present.
>
> There is some evidence suggesting the existence of field-dependent effects on reaction time and on reduced accuracy in the performance of some cognitive tasks, which is supported by the results of studies on the gross electrical activity of the brain. Studies investigating whether magnetic fields affect sleep quality have reported inconsistent results. It is possible that these inconsistencies may be attributable in part to differences in the design of the studies.
>
> Some people claim to be hypersensitive to EMFs in general. However, the evidence from double-blind provocation studies suggests that the reported symptoms are unrelated to EMF exposure.
>
> There is only inconsistent and inconclusive evidence that exposure to ELF electric and magnetic fields causes depressive symptoms or suicide. Thus, the evidence is considered inadequate. (WHO, 2007a, pp. 5-6)

Only one new epidemiology study of neurobehavioral measures has been published after the WHO report (2007). Yamazaki et al. (2006) collected data from women living in the vicinity of overhead power lines with voltages between 22-kV and 500-kV in metropolitan areas of Japan. Like the majority of previously published epidemiology studies evaluating neurobehavioral measures in relation to power lines, this study has a cross-sectional design, meaning that all data relate to a particular moment or cross-section in time. Since neurobehavioral measures are not particularly stable over time, this study design is weaker than the cohort or case-control designs for this outcome.

The investigators distributed questionnaires to 1,000 mothers from a control group of a previously published study on childhood leukemia (Kabuto et al., 2005) to collect data on age, self-reported disease status, annual household income, occupational status, educational level, and responses to a quality of life survey that was used to assess mental health status (MHS) and screen for depression. Only 25% of the mothers responded, and the investigators interviewed the respondents and confirmed the distance from the home to power lines by reference to maps. The authors reported that the odds of having a low MHS score was not significantly related to distance from the lines (0-100 m; 101-300 m; >300 m), nor was there a trend toward lower scores among those living closest to the lines. A second analysis based upon other exposure categories (0-430 m and 431-1,000 m) also did not report a statistically significant association between MHS scores and distance from the line.

The study had several limitations, including the lack of information on the length of time that the participant had lived at their current residence. The relationship between MHS scores and distance could have been biased if the residential mobility of participants was associated with MHS scores and varied by distance from the lines. The very low participation rate is also problematic. As the authors noted, the participants' perceptions about power lines were not known and could have been a potential source of selection bias.

This one study of mental health scores for depression in women living within 1,000 m of low voltage and high voltage power lines adds little information to the available literature. As noted by WHO "the literature on depressive symptoms and EMF exposure is difficult to interpret because the findings are not consistent." (WHO 2007a, p. 143).

4 Standards and Guidelines

Following a thorough review of the research, scientific agencies develop exposure standards to protect against known health effects. The major purpose of a weight-of-evidence review is to identify the lowest exposure level below which no health hazards have been found (i.e., a threshold). Exposure limits are then set well below the threshold level to account for any individual variability or sensitivities that may exist.

Several scientific organizations have published guidelines for exposure to EMF based on acute health effects that can occur at very high field levels. The ICNIRP reviewed the epidemiologic and experimental evidence through 1997 and concluded that there was insufficient evidence to warrant the development of standards or guidelines on the basis of hypothesized long-term adverse health effects such as cancer; rather, the guidelines put forth in their 1998 document set limits to protect against acute health effects (i.e., the stimulation of nerves and muscles) that occur at much higher field levels. The ICNIRP recommends a residential screening value of 833 mG and an occupational exposure screening value of 4,200 mG (ICNIRP, 1998). If exposures exceed these screening values, then additional dosimetry evaluations are needed to determine whether basic restrictions on induced current densities are exceeded.

The International Committee on Electromagnetic Safety (ICES) also recommends limiting magnetic field exposures at high levels because of the risk of acute effects, although their guidelines are higher than ICNIRP's guidelines; the ICES recommends a residential exposure limit of 9,040 mG and an occupational exposure limit of 27,100 mG (ICES, 2002). Both guidelines incorporate large safety factors.

The ICNIRP and ICES guidelines provide guidance to national agencies and only become legally binding if a country adopts them into legislation. The WHO strongly recommends that countries adopt the ICNIRP guidelines, or use a scientifically sound framework for formulating any new guidelines (WHO, 2006).

There are no national or state standards in the US limiting exposures to ELF fields based on health effects. Two states, Florida and New York, have enacted standards to limit magnetic fields at the edge of the right-of-way (ROW) from transmission lines (150 mG and 200 mG, respectively) (NYPSC, 1978; FDER, 1989; NYPSC, 1990; FDEP, 1996). The basis for limiting magnetic fields from transmission lines in Florida and New York was to maintain the "status quo" so that fields from new transmission lines would be no higher than those produced by existing transmission lines.

Table 2. Screening guidelines for EMF exposure

Exposure (60 Hz)	Electric field	Magnetic field
ICNIRP		
Occupational	8.3 kV/m	4.2 G (4,200 mG)
General Public	4.2 kV/m	0.833 G (833 mG)
ICES		
Occupational	20 kV/m	27.1 G (27,100 mG)
General Public	5 kV/m^	9.040 G (9,040 mG)

Sources: ICNIRP, 1998; ICES, 2002

^Within power line right-of-ways, the guideline is 10 kV/m under normal load conditions.

5 Summary of EMF and Human Health Research

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

The evidence in support of a causal relationship is weak because it is founded largely, if not entirely, on *some* epidemiology studies that reported statistical associations between magnetic field exposure (or some proxy of exposure) and a disease. Scientists have placed less weight on these associations because they are weak, often inconsistent across studies, and possibly due to errors in the way the study was designed or conducted. Overall, the animal studies have not reported an increase in cancer among animals exposed to high levels of electric or magnetic fields, and no mechanism has been discovered in laboratory studies that would explain how electric or magnetic fields could initiate disease.

Most notably, a weak but statistically significant association has been reported consistently between childhood leukemia and estimates of long-term exposure to high, average magnetic field levels. However, the reported associations are weak, most studies have poor exposure assessments, there is no evidence of a consistent exposure-response relationship, and there is lingering concern regarding selection bias. Furthermore, the strongest individual epidemiologic studies of childhood leukemia and magnetic fields, which were conducted in the US, Canada, and the UK, do not indicate an association. Given the lack of convincing evidence from epidemiology and the lack of consistent findings from animal and laboratory studies, the overall body of research does not indicate that this association, or any other, is causal in nature.

The only studies that can be said to confirm a relationship between electric or magnetic fields and an adverse biological or health effect are those in which very high levels of exposure to these fields produce currents and fields in the body, a shock-like effect. The levels at which these short-term effects occur are very high and several organizations have recommended exposure guidelines to protect against their occurrence.

These conclusions are echoed in the WHO report released in June 2007:

> Acute biological effects have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection. Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted (p. 355, WHO 2007a).

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

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Appendix C

Visibility and Visual Impact Assessment (EDR, P.C., August 2008) (Bound Separately)

Appendix D

Southern New England Transmission Reliability Report 1
Needs Analysis

(c) ISO New England Inc.

January 2008

Southern New England Regional Working Group

ISO New England

National Grid

Northeast Utilities

The results of this study were first presented to ISO New England stakeholders in July 2006, with a draft report posted on the ISO's Web site the following month. Since then, the report has been modified to reflect clarifying comments that have been received. The working group has not intended to change any of the original results, assumptions, or conclusions.

Executive Summary

National Grid, Northeast Utilities, and ISO New England (ISO) formed a working group to conduct the studies necessary to develop a 10-year plan for transmission system improvements for the southern New England (SNE) region. The 10-year plan specifically addresses western and central Massachusetts (particularly the Springfield area), Rhode Island, and eastern and central Connecticut.

The objective of this plan is to ensure that the SNE region, as described in Section 1, complies with criteria and reliability standards established by the North American Electric Reliability Corporation (NERC), the Northeast Power Coordinating Council (NPCC), and the ISO.[1] These criteria and standards (summarized in Section 2) define regional transmission requirements and transmission-transfer capabilities with respect to stability, steady state, and fault-current simulations. They are in place to ensure, for the long term, that the regional transmission system serving New England is robust and flexible, reliably delivers power to customers under a wide range of projected future system conditions, and accounts for uncertainties and unforeseen events.

The first working group task was to assess the ability of the New England transmission system to satisfy these national and regional reliability standards, assuming an "as is" electric transmission system under future conditions. It also identified potential reliability violations (statements of need) for the southern New England transmission system and any likelihood of portions of this region not meeting the criteria and standards by 2009.[2] Section 3 presents the results of the coordinated needs-related studies.

The working group then developed solution options (groups of system upgrades) to address the deficiencies (needs) identified in this report and improve the transmission system in conjunction with the ISO's 10-year regional system planning process. A separate report, *New England East–West Solutions, Report 2—Options Analysis*, reviews the results of the working group's analysis of the solution options. It also explains how the solutions were developed to meet the identified needs, describes the main features of the solutions, and compares the solutions in terms of system performance characteristics.

The studies conducted were part of one of the most geographically comprehensive planning efforts to date in New England, addressing five interrelated problems in three states and multiple service territories. When the identified weaknesses in southern New England are improved, the regional

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[1]The ISO system must comply with NERC and NPCC criteria and standards and ISO planning and operating procedures. As certified by the Federal Energy Regulatory Commission in 2006, NERC is the "electric reliability organization" (ERO) whose mission is to improve the reliability and security of the bulk power system in North America. Information on NERC requirements is available online at http://www.nerc.com (Princeton, NJ: NERC, 2007). NPCC is the cross-border regional entity and criteria services corporation for northeastern North America. NPCC's mission is to promote and enhance the reliable and efficient operation of the international, interconnected bulk power system in the geographic area that includes New York State, the six New England states, and the Ontario, Québec, and the Maritime provinces. Additional information on NPCC is available online http://www.npcc-cbre.org/default.aspx (New York: NPCC Inc., 2007). Information about ISO New England Planning Procedure No. 3 (PP 3), *Reliability Standards for the New England Area Bulk Power Supply System*, is available online at http://www.iso-ne.com/rules_proceds/isone_plan/PP3_R3.doc (Holyoke, MA: ISO New England, 2006).

[2] Summaries of the ISO's projections for the southern New England transmission system have appeared in the *2005, 2006*, and *2007 Regional System Plans* (RSPs) as well as previous years' Regional Transmission Expansion Plans. These reports are available online at http://www.iso-ne.com/trans/rsp/index.html.

transmission system will be more reliable and generation will be less constrained, which should benefit all the New England states.

Method and Criteria

Following the Northeast Blackout of 1965, what is now known as NERC was formed to prevent future occurrences by establishing broad-based standards. NPCC, of which ISO New England (representing the New England Power Pool [NEPOOL]) is a member, was subsequently formed to develop regionally specific criteria based on NERC standards. ISO power system planning procedures are designed to meet these reliability standards, per ISO Planning Procedure No. 3 (PP 3), *Reliability Standards for the New England Bulk Power Supply System*, the specific standards that provide consistent system planning criteria throughout New England.

PP 3 defines the standards used to plan the interconnected generators and transmission circuits that comprise the region's electrical network. A number of "tests" must be "passed" before a system can be determined to meet these standards. These tests take into account historical data and system occurrences and examine the following:

- **Area Transmission Requirements:** Is the area transmission system capable of delivering the necessary generation to the system load under anticipated facility outage events? (PP 3, Section 3)
- **Transmission Transfer Capability:** Is the interconnected transmission system designed with adequate capability to transfer power within the ISO New England Control Area and between ISO New England and neighboring control areas? (PP 3, Section 4)

Similar standards exist throughout North America.

When analyzing future system reliability needs, planners must consider possible system configurations (load and generation scenarios) and possible system contingencies (e.g., the sudden and unplanned outage of a generating unit or a transmission line). Given the geographic scope of the SNE region, a tremendous number of variables and interrelationships are involved in studying the possible system configurations and contingencies. Moreover, individual solutions in one area must be evaluated to ensure that they do not produce unintended consequences in another area. Specifically, the potential effects that system conditions in one area have on another part of the system must be understood. For instance, as illustrated in Figure 1, an outage on a 345 kV line supplying the Manchester area in north-central Connecticut could overload facilities in the western Massachusetts–Springfield area and the northeastern Connecticut–Rhode Island area when redistributing the power flow in trying to reach the load.

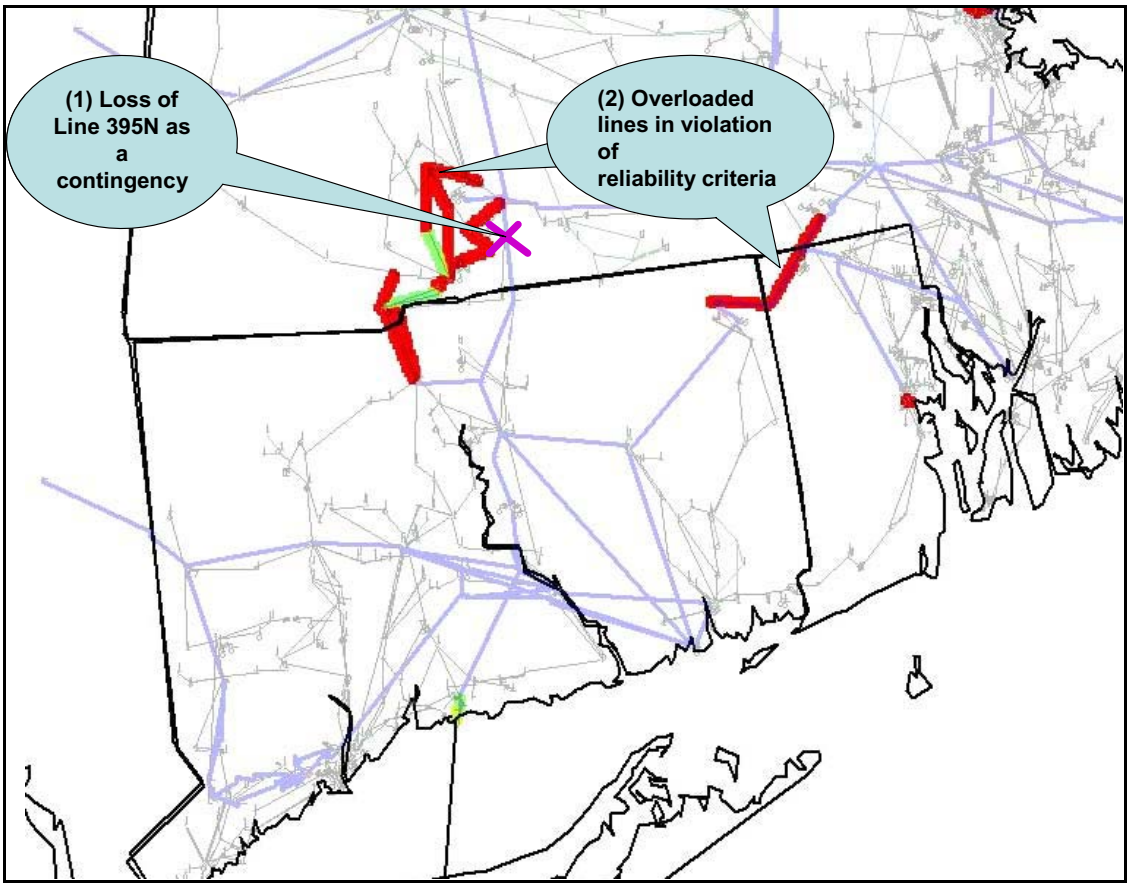

Figure 1: Illustration of interrelationships in the southern New England region.

Statements of Need

Analyses performed for the 10-year period (from 2007 to 2016) showed that on the basis of ISO planning procedures, the SNE transmission system over the 10-year study period has five major reliability concerns and a number of system deficiencies in transmission security, specifically area transmission requirements and transfer capabilities. These deficiencies form the justification for the needed transmission system improvements.

Reliability Concerns

The reliability concerns are as follows and are depicted in Figure 2.

- **East–West New England Constraints:** Regional east–west power flows could be limited during summer peak periods across the SNE region as a result of thermal and voltage violations on area transmission facilities under contingency conditions.
- **Springfield Reliability:** The Springfield, Massachusetts, area could be exposed to significant thermal overloads and voltage problems under numerous contingencies at or near summer peak-load periods. The severity of these problems would increase as the transmission system attempts to move power into Connecticut from the rest of New England.

- **Interstate Transfer Capacity:** Transmission transfer capability into Connecticut and into Rhode Island during summer peak periods could be inadequate under existing generator availabilities for criteria contingency conditions.
- **East–West Connecticut Constraints:** East-to-west power flows in Connecticut could stress the existing system under "line-out," or N-1-1, contingency conditions (i.e., conditions under which a transmission element is unavailable and a single power system element is lost) during system peaks.
- **Rhode Island Reliability**: The system depends heavily on limited transmission lines or autotransformers to serve its peak-load needs, which could result in thermal overloads and voltage problems during contingency conditions.

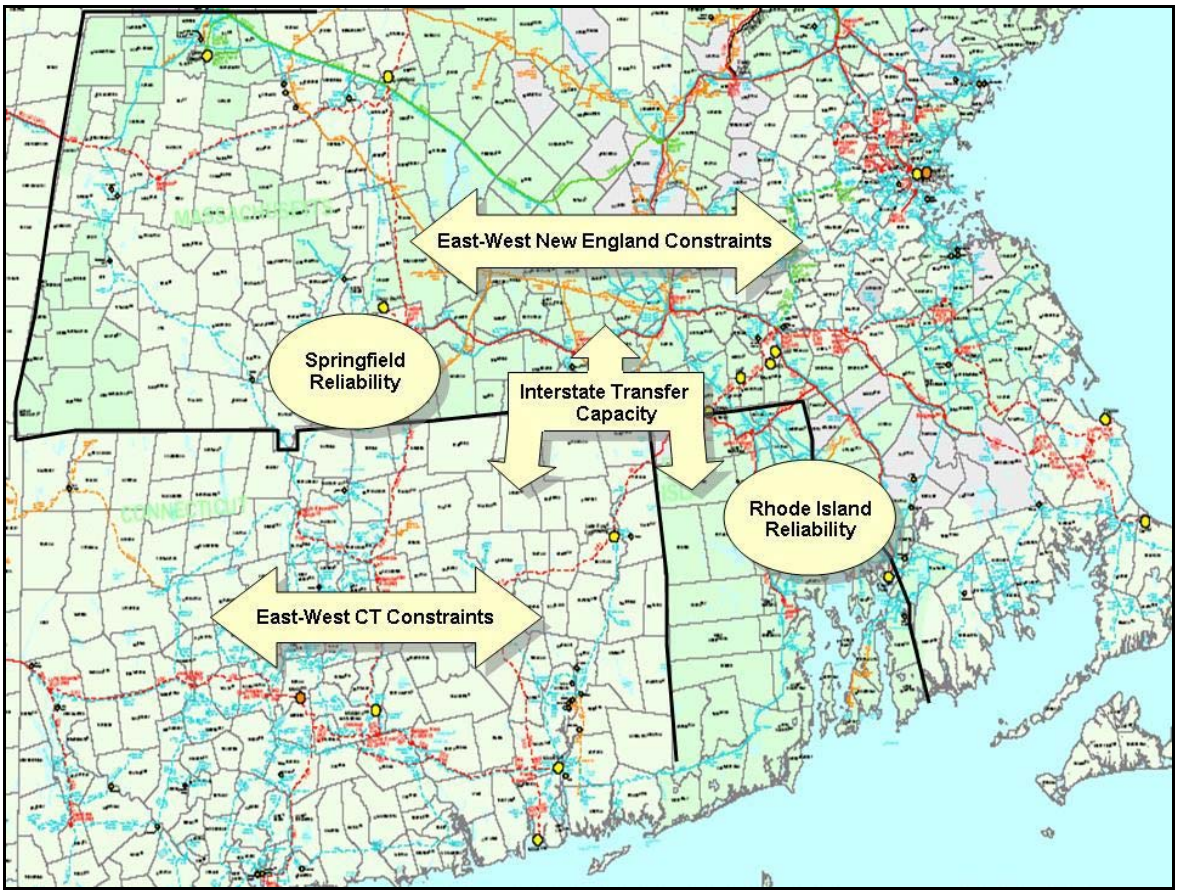

Figure 2: Reliability concerns in the southern New England region.

Transmission Security Concerns

The analysis identified the following transmission security concerns related to meeting transfer capability and area transmission requirements:

Transfer Capability Concerns

- Power-transfer capabilities in the Connecticut area will not meet the area's import requirements as early as 2009. If improvements are not made by 2016, the import deficiency (outlined using a "load margin" approach in RSP06) for this area under conditions of

generator unavailability and the loss of a single power system element (N-1 conditions) is expected to be greater than 1,500 MW assuming no new capacity is added.

- Based on planning assumptions concerning future generation additions and retirements within the Connecticut area, an import level of 3,600 MW for N-1 conditions and 2,400 MW for N-1-1 conditions will be needed by 2016.
- Connecticut currently has internal elements that can limit transfers from neighboring New England states under certain system conditions. These constraints limit the Connecticut east–west power transfers across the central part of Connecticut. The movement of power from east to west in conjunction with higher import levels to serve Connecticut overloads transmission facilities located within Connecticut that eventually tie into the new Middletown–Norwalk facilities.
- Under line-out (N-1-1) conditions and certain dispatch scenarios, the 345 kV transmission system in the southeastern Massachusetts and Rhode Island areas currently cannot support the requirements of southeast Massachusetts–Rhode Island, New England east–west, and the Connecticut power transfers following a contingency. These interfaces all have simultaneous and interrelated power-transfer limits.
- Rhode Island and Springfield have insufficient import capability to meet their load margins through 2016.
- The flow of power through the Springfield 115 kV system into Connecticut increases when the major 345 kV tie line between western Massachusetts and Connecticut (the Ludlow–Manchester–North Bloomfield 345 kV line) is open because of either an unplanned or a planned outage. As a result, numerous overloads occur in the 2009 simulations. These overloads are exacerbated when Connecticut transfers increase.

Concerns about Area Transmission Requirements

- In the Springfield area, local double-circuit tower (DCT) outages, stuck-breaker outages, and single-element outages currently can result in severe thermal overloads and low-voltage conditions.
- The severity, number, and location of the Springfield overloads and low-voltage conditions highly depend on the area's generation dispatch. Additional load growth and unit outages in the Springfield area would significantly aggravate these problems. As a result, network constraints in the Springfield area limit the system's present ability to serve local load under contingency conditions.
- Thermal and voltage violations can occur on the existing Rhode Island transmission system, dependent on unit availability and transmission outages (planned or unplanned). Relatively high load growth in the southwestern area and the coastal communities in recent years has increased the possible occurrence of criteria violations.
- The capabilities of the underlying Rhode Island 115 kV system currently are insufficient to handle the power requirements within the state following the loss of 345 kV transmission facilities, both lines and autotransformers, under certain system conditions. For line-out conditions, the next critical contingency involving the loss of a 345/115 kV autotransformer or a second 345 kV line would result in numerous thermal and voltage violations.

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Section 1
Introduction and Background Information

The analysis presented in this report is the culmination of several joint studies by ISO New England (ISO) transmission owners (TOs). The New England transmission system serving the southern New England (SNE) area was studied to evaluate projected future load and generation requirements to assess the performance of the transmission system and its ability to meet existing reliability standards. This report identifies the likely deficiencies in the performance of the electric transmission system in the future.

1.1 Southern New England

The map shown in Figure 1-1 depicts the load density for the geographic area of southern New England, namely Massachusetts, Rhode Island, and Connecticut. As shown in this figure, a substantial number of significant load pockets exist—Boston and its suburbs, central Massachusetts, Springfield, Rhode Island, Hartford/central Connecticut, and Southwest Connecticut. The load pockets of Springfield, Rhode Island, Hartford/central Connecticut, and Connecticut as a whole are primary areas of concern in this study with respect to the ability of the existing transmission and generation systems to reliably serve projected load requirements in these areas.

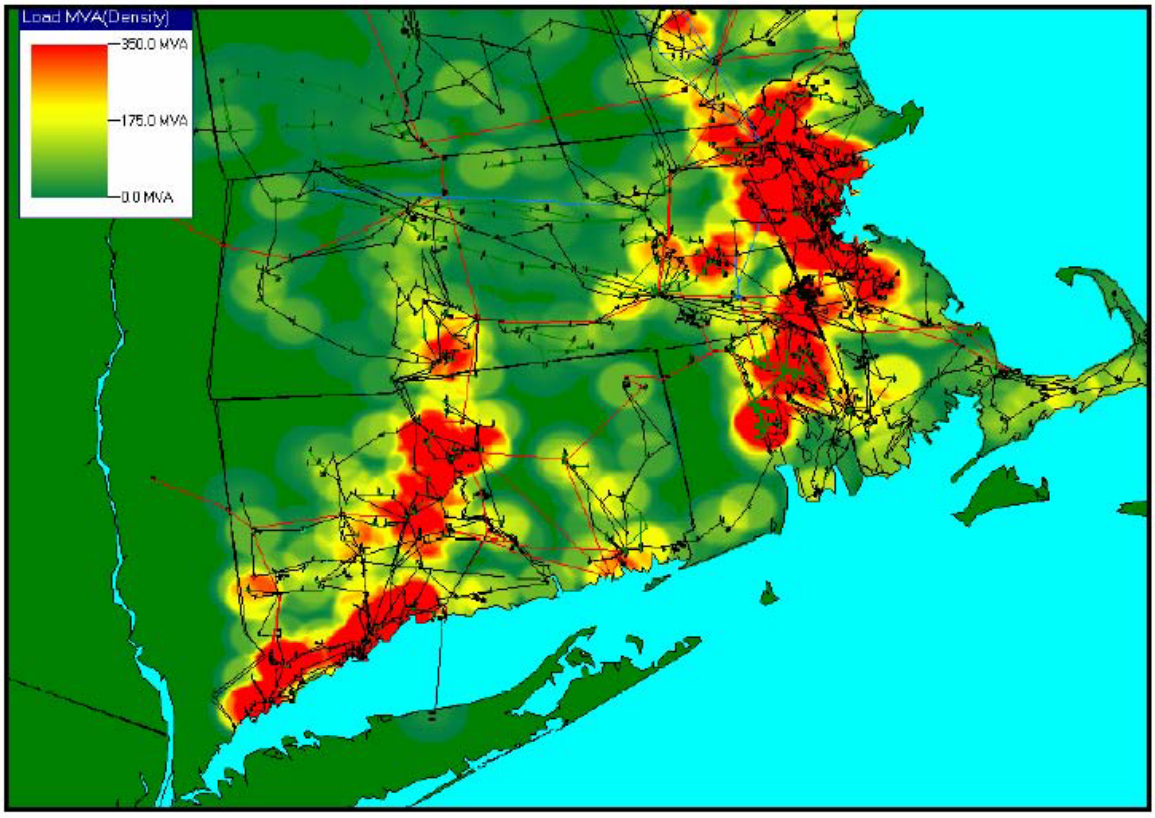

Figure 1-1: Southern New England load concentrations.

Southern New England accounts for approximately 80% of the New England load. The 345 kV bulk transmission network is the key infrastructure that integrates the region's supply resources with load centers. The major southern New England generation resources, as well as the supply provided via ties from northern New England, Hydro-Québec, and New York, primarily rely on the 345 kV transmission system for delivery of power to the area's load centers. This network provides significant bulk power supply to Massachusetts, Rhode Island, and Connecticut and is integral to the supply of the Vermont load in northwestern New England. The SNE area has experienced significant load growth, numerous resource changes, and changes in inter-area transfers.

The east–west transmission interface facilities divide New England roughly in half. Vermont, southwestern New Hampshire, western Massachusetts, and Connecticut are located to the west of this interface; while Maine, eastern New Hampshire, eastern Massachusetts, and Rhode Island are to the east. The primary east–west transmission links are three 345 kV and two 230 kV transmission lines. A few underlying 115 kV facilities are also part of the interface; however, most run long distances, have relatively low thermal capacity, and do not add significantly to the transfer capability. In the early 1990s, this interface was important to monitor in day-to-day operations because of constraints in moving power from the significant generation in the west to Boston and its suburbs in the east. Following the influx of new generation in the east in the late 1990s, this interface now becomes constrained in the opposite direction, from east to west.

Supplying southern New England with electricity involves a number of complex and interrelated performance concerns. Connecticut's potential supply deficiencies, the addition of the Stoughton 345 kV station to serve the Boston area, and the demands of Rhode Island and western New England combine to significantly strain the existing 345 kV network. These challenges are compounded further by transmission constraints in the Springfield and Rhode Island areas under contingency conditions. The following transmission transfer capabilities are all interrelated:

- Southeastern Massachusetts (SEMA) export
- Greater Rhode Island export (mostly generation located in Massachusetts bordering on Rhode Island)
- Boston import
- Rhode Island import
- New England East–West interface
- Connecticut import
- Connecticut East–West interface
- Southwest Connecticut (SWCT) import

Transfers through these paths can contribute to heavy loadings on the same key transmission facilities.

These relationships exist for both thermal and stability limits. Studies have identified the relationship of stability limits among SEMA interface transfers, SEMA/RI exports, New England East–West transfers, New York–New England transfers, and the status of certain generators. Unacceptable torsional impacts on generators as a result of line reclosing also have become an issue in the SNE area. These behaviors illustrate the interdependent nature of the SNE 345 kV network. Recent analyses have quantified an additional interdependence between the ability to import power into Connecticut and the ability to supply load in the Springfield area. Springfield's reliability issues must

be studied within the context of the overall southern New England analysis to not limit the benefits that improvements bring to the area and the ability to better integrate the supplies to the various load pockets in the region.

The existing transmission system does not allow for delivering surplus capacity to all load centers in southern New England. Regional east-west transfer limits and Connecticut power-transfer limitations do not allow this surplus capacity to be delivered to the load centers within Connecticut. The Springfield and Rhode Island areas have additional transmission reliability concerns, both thermal limitations and voltage violations, which lead to a set of interrelated concerns with respect to the reliability of transmission service across southern New England (see Figure 1-2).

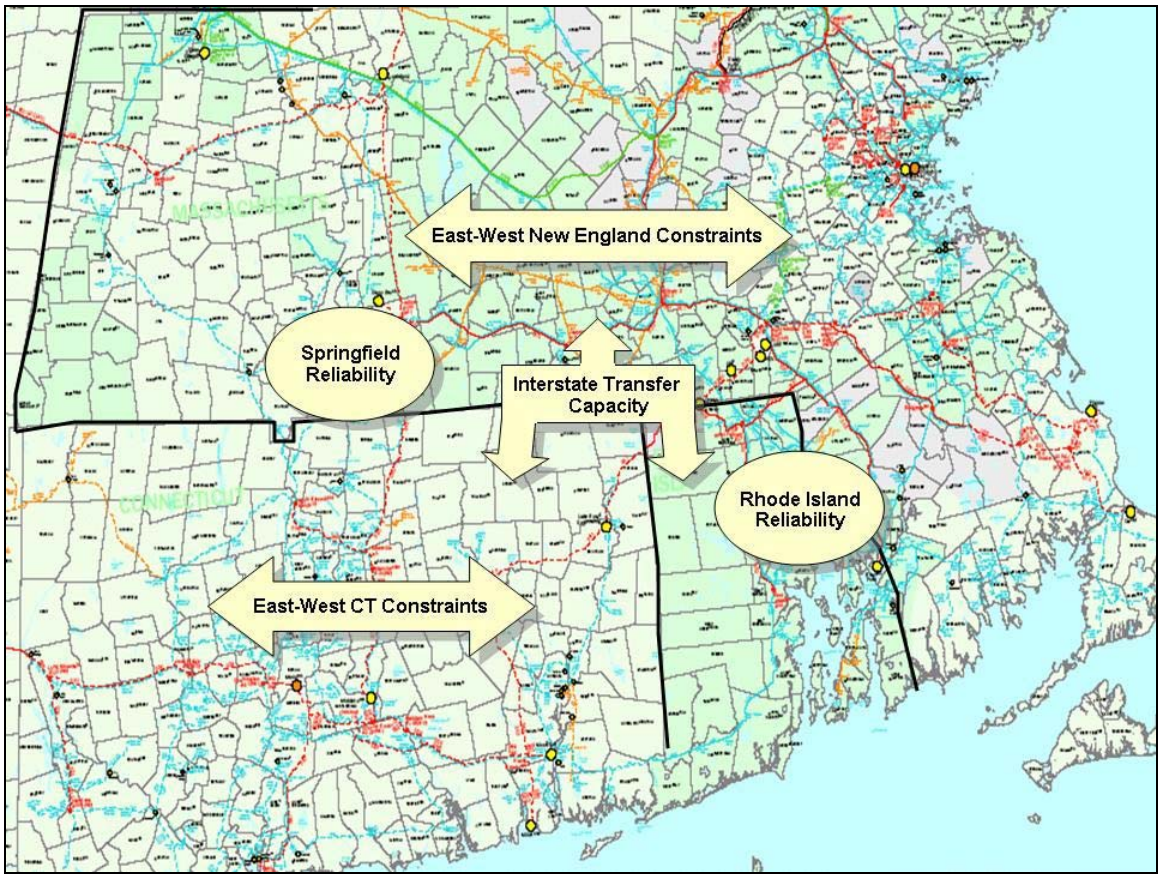

Figure 1-2: Southern New England subareas and constraints.

1.2 Connecticut

Approximately 70% of the Connecticut load is concentrated in the western part of the state, and 30% of the Connecticut load is located in the eastern part of the state. Approximately 6,779 MW of internal generation supplies Connecticut. Fifty-five percent of this internal generation is located in the eastern part of the state. Connecticut has two of the larger generators in New England, Millstone Point 2 and Millstone Point 3, which combine for approximately 2,000 MW. Around 55% (3,800 MW) of the internal generation is over 30 years old, 30% (2,100 MW) is over 40 years old, and 81 MW is over 60 years old.

Connecticut is integrated into the regional network primarily through three 345 kV lines, one 138 kV phase-angle regulator-controlled line, four 115 kV lines and one 69 kV line. Connecticut is tied to Massachusetts through the Manchester–North Bloomfield–Ludlow (395) 345 kV tie and three 115 kV ties (Southwick–North Bloomfield–1768, South Agawam–North Bloomfield–1821, and South Agawam–North Bloomfield–1836). Connecticut is tied to Rhode Island through a 345 kV line between Lake Road and Sherman (347) and a 115 kV line between Mystic and Wood River (1870). Connecticut is tied to the neighboring New York area through the Long Mountain–Pleasant Valley (398) 345 kV tie and through the Norwalk–Northport (1385) 138 kV tie. A high-voltage direct-current (HVDC) interconnection with Long Island Power Authority in New York is rated at 330 MW.

Transmission import capability into Connecticut is influenced by several simultaneous transfers. Conditions that can affect the ability to import power into Connecticut include New York–New England imports and exports, New England east–west transfers, SEMA/RI exports, east–west transfers within Connecticut, and Springfield/western Massachusetts generation dispatches.

1.3 Greater Rhode Island

The Greater Rhode Island (GRI) area includes the transmission system in the state of Rhode Island and surrounding 345 kV transmission in Massachusetts and Connecticut. The Rhode Island transmission system consists of two 345 kV connections to Massachusetts, one 345 kV connection to Connecticut, and an underlying 115 kV network. The two Rhode Island–Massachusetts 345 kV connections are (1) line 315 from Brayton Point in Somerset, Massachusetts, to West Farnum in North Smithfield, Rhode Island, and (2) line 3361 from ANP–Blackstone in Massachusetts to Sherman Road in Rhode Island. Line 347 is the 345 kV connection that runs from Sherman Road to Lake Road, Connecticut. The Ocean State Power Plant is connected to Sherman Road via a 345 kV radial line (line 333).

Three 345/115 kV substations supply the underlying 115 kV system in Rhode Island—Brayton Point, West Farnum, and Kent County. The system is tied to the southeastern Connecticut system by a 115 kV interconnection from Kent County to Mystic. It is tied to Massachusetts via two 115 kV lines to Millbury substation and several 115 kV lines that ultimately terminate at Brayton Point and Somerset substations.

1.4 Western Massachusetts/Springfield

Western Massachusetts encompasses the four western counties of Massachusetts. Western Massachusetts Electric Company (WMECO)'s existing transmission circuits in Massachusetts consist of 104.5 circuit miles of 345 kV, 346.0 circuit miles of 115 kV (which includes 9.4 miles of underground cables and an abundance of double-circuit towers), and 5.5 circuit miles of 69 kV lines. The WMECO transmission system is interconnected to other electric utilities, including Connecticut Light and Power Company (CL&P), National Grid, Holyoke Gas and Electric, Holyoke Water Power Company (HWP), Public Service of New Hampshire (PSNH), and the Massachusetts Municipal Wholesale Electric Company (MMWEC).

The WMECO service territory is divided into two areas, Pittsfield/Greenfield and Springfield. The Springfield area is of concern for this analysis. The Springfield area includes the City of Springfield and extends west to Blandford, south to the Connecticut border, north to Amherst, and east to Ludlow. WMECO is the primary service provider for this area. Other providers that serve load in this area are Holyoke Gas and Electric, Holyoke Water Power Company, Chicopee Electric Light, Westfield Gas and Electric, South Hadley, and National Grid.

1.5 New England Regional Load Forecast Projections

The ISO develops a forecast of the regional peak load for New England on an annual basis. The New England regional forecast is derived by modeling load for each of the New England states on the basis of NEPOOL load data from various New England subareas. The results for each state are combined to produce the New England regional forecast. The analysis conducted to develop a New England forecast was based on the ISO's April 2005 published peak-load forecast. The most recent updated version of the ISO's peak-load forecast, published in March 2007, indicates that New England is expected to experience a slighter higher peak load than the April 2005 forecast used in the analysis in this report. This change is relatively small and would not change the results of the analysis performed for any of the areas studied. Consequently, the need and timing for system upgrades would not be affected as a result of the slight change in system load forecast. While forecasts and load levels vary from year to year, they tend to be insignificant when studying a relatively large area for a number of years into the future.

Table 1-1 summarizes the ISO's *2005 Regional System Plan* (RSP05) subarea peak and energy forecast.

Table 1-1
Energy and Peak-Load Forecast Summary for the ISO New England Control Area and States

Area	Net Energy for Load (GWh)			Summer Peak Loads (MW)					Winter Peak Loads (MW)				
				50/50		90/10			50/50		90/10		
	2005	2014	CAGR\ (a)	2005	2014	2005	2014	CAGR (a)	2005/06	2014/15	2005/06	2014/15	CAGR (a)
NE Control Area	**134,085**	**152,505**	**1.4**	**26,355**	**30,180**	**27,985**	**32,050**	**1.5**	**22,830**	**26,005**	**23,740**	**27,030**	**1.5**
BHE	2,135	2,215	0.4	360	380	380	400	0.6	355	370	365	380	0.5
ME	6,500	7,520	1.6	1,045	1,225	1,090	1,280	1.8	1,065	1,235	1,090	1,260	1.7
SME	3,630	4,135	1.5	595	685	620	715	1.6	575	655	590	670	1.5
NH	9,665	11,540	2.0	1,860	2,250	2,010	2,440	2.1	1,675	1,990	1,745	2,070	1.9
VT	7,190	7,940	1.1	1,220	1,360	1,295	1,440	1.2	1,175	1,315	1,210	1,350	1.3
BOSTON	26,770	29,720	1.2	5,360	5,940	5,685	6,295	1.1	4,515	5,070	4,700	5,275	1.3
CMA/NEMA	8,520	9,635	1.4	1,705	1,965	1,815	2,085	1.6	1,470	1,645	1,540	1,720	1.3
WMA	10,775	11,735	1.0	2,015	2,200	2,140	2,335	1.0	1,865	2,035	1,940	2,115	1.0
SEMA	13,420	15,405	1.5	2,750	3,210	2,915	3,405	1.7	2,270	2,585	2,370	2,695	1.5
RI	11,285	12,985	1.6	2,390	2,755	2,540	2,925	1.6	1,905	2,200	1,975	2,280	1.6
CT	17,065	19,980	1.8	3,515	4,165	3,740	4,430	1.9	2,990	3,490	3,120	3,645	1.7
SWCT	11,275	12,950	1.6	2,290	2,645	2,440	2,815	1.6	1,980	2,260	2,065	2,360	1.5
NOR	5,880	6,760	1.6	1,250	1,415	1,330	1,505	1.4	1,000	1,170	1,045	1,220	1.8

(a) CAGR refers to the compound annual growth rate.

Section 2
Methodology for Analyzing System Reliability

One of the main activities of the ISO's transmission planning process is to analyze system reliability according to a number of planning standards and criteria, as described in this section. The results of these analyses show potential criteria violations that form the basis of this Needs Analysis.

2.1 Transmission Planning Process

Transmission planning for the New England electric power system is a dynamic, ongoing activity that is summarized annually in a regional system plan (RSP). This systemwide summary is the result of numerous assessments that evaluate the capacity and reliability of the transmission facilities that make up the New England bulk power transmission system and identify system needs, which may be addressed by market responses, including both transmission and nontransmission alternatives. In addition, the reliability needs within geographic subareas of the system are investigated to ensure that the load requirement of each subarea is reliably served. Absent appropriate market solutions proposing either transmission or nontransmission alternatives, the ISO is authorized to engage in the development of transmission solutions.

The future performance of the system under projected operating conditions over a 10-year period is periodically reviewed. To perform these evaluations, analytical modeling software simulates the systemwide performance of the transmission system. These models are designed to simulate load-flow patterns and loading characteristics across the system.

The simulation software makes it possible to run a series of "what if" scenarios to analyze the impact of a contingency event on the transmission system and to test various operational adjustments that could be implemented to address any inadequacies discovered as a result of the contingency analysis. These adjustments typically include system reconfigurations, phase-angle regulator adjustments, fast-response unit dispatch, and load transfers between substations or transmission circuits. If the model shows that the transmission system would experience violations even with those adjustments in place, a reliability issue must be addressed through a more significant effort (i.e., the addition or upgrade of transmission facilities). Models were developed to test various alternatives for mitigating the reliability concern.

Because a relatively long lead-time is involved in identifying, planning, and implementing transmission line additions and upgrades, the 10-year planning-process horizon is designed to provide sufficient time to identify and plan for needed large-scale system changes, additions, or upgrades. However, the 10-year horizon also involves a significant amount of uncertainty as to the impact of future events, load-growth trends, and local area load growth on the system.

2.2 Planning Standards and Criteria

The ISO is responsible for dispatching generation and conducting the day-to-day operation of the integrated transmission system. It operates the various transmission systems owned by electric utilities in New England as a single transmission system. The performance of the New England transmission system must adhere to reliability standards and criteria established by NERC, NPCC, and the ISO, which ensure the electric power systems serving New England are appropriately designed to provide an adequate and reliable electric power delivery system.

These standards are under the purview of NERC, which has national authority to ensure the reliability of transmission systems across the United States.[3] NERC oversees a number of regional councils, one of which is the NPCC. The NPCC covers New York, New England, and Canada. Under this framework, NERC has established a general set of rules and criteria applicable to all geographic areas. NPCC has established a set of rules and criteria particular to the Northeast, although they also encompass the more general NERC standards. In turn, ISO New England has developed standards and criteria specific to New England that coordinate with the NPCC rules. Similar standards exist throughout the nation and other portions of North America.

Whether developed by NERC, NPCC, or the ISO, the standards and criteria applicable to the New England transmission system are applied in a deterministic fashion to assess the ability for 115 kV and 345 kV transmission systems to perform under contingency situations. Specifically, these standards and criteria dictate a set of operating circumstances or contingencies under which the New England transmission system must perform without experiencing thermal overloads, voltages below limits, or loss of synchronism. For NPCC, these performance measurements are set forth in *Basic Criteria for the Design and Operation of Interconnected Power Systems* (revised May 2004) (NPCC standards). For the ISO, these measurements are set forth in PP 3, which are used to plan the interconnected electrical network (generators and transmission circuits).

Both NPCC and ISO standards establish that the electric transmission system must pass specific tests to comply with the established criteria. These tests take into account historical data and occurrences and include an examination of the following:

- **Area Transmission Requirements:** Is the area transmission system capable of delivering the necessary generation to the system load under anticipated facility outage events? (PP 3, Section 3)
- **Transmission Transfer Capability:** Is the interconnected transmission system designed with adequate capability to transfer power within the ISO New England Control Area and between ISO New England and neighboring control areas? (PP 3, Section 4)

ISO Planning Procedure 3 states that:

> "The bulk power system should be 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, should not result from any reasonably foreseeable contingencies. . . . Analyses of simulations of these contingencies should include assessment of the potential for widespread cascading outages due to overloads, instability or voltage collapse."[4]

The standards specifically define "reasonably foreseeable contingencies" that must be tested and the conditions under which these contingencies must be evaluated.[5] These circumstances generally

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[3] *The Energy Policy Act of 2005* authorized the creation of a self-regulatory electric reliability organization (ERO) that spans North America, with Federal Energy Regulatory Commission (FERC) oversight in the United States. On July 20, 2006, FERC issued an order certifying NERC as the ERO for the United States.

[4] ISO New England Planning Procedure No. 3, *Reliability Standards for the New England Area Bulk Power Supply System*, February 1, 2005, Pg. 2.

[5] Ibid., Pg. 4

consider the loss of transmission system elements and the availability (or unavailability) of generating resources.

The New England transmission system is operated with sufficient capacity to serve area loads under normal operating conditions, as well as facility outage conditions. These outages, referred to as "contingencies," are planned or unplanned events wherein a transmission element, substation transformer, or autotransformer is out of service. The reliability criteria specify that system voltages and transmission line and equipment loadings should be within applicable normal and emergency limits under a set of predefined conditions.[6]

To determine whether the system complies with the applicable criteria, analytical models are built to represent the existing system configuration and capabilities. These models then undergo contingency testing (i.e., the loss of one or more elements). Specifically, the criteria require a simulation of system performance in the event of an N-1 (single) contingency, which is the base system minus one element. For example, an N-1 contingency would occur when a transmission line is forced out of service because of a lightning strike or a fallen tree, for example. To perform this analysis, an exhaustive list of the transmission elements on the system is compiled. The elements include transmission lines, transformers, and breakers. A series of simulations are run to test the system with each of these individual elements taken out of service (contingencies). The simulations are used to monitor the power flows on all other elements in the event of each contingency and to technically evaluate the system's capacity to meet normal and emergency operating requirements.

Events that include the outage of two transmission elements (N-1-1 contingency analyses) also are performed to evaluate the transmission system capabilities in each area. These analyses assess the performance of the system assuming the base-case condition minus two major resources, such as a loss of one transmission system element followed by the loss of a second transmission system element (assuming available resources are adjusted between outages). To the extent that the analysis determines an area's resources to be inadequate under contingency conditions, it also identifies the increase in transmission capacity or level of area resources needed in these conditions to avoid being short of supply. Area resources can be added either by adding new supply-side resources or new transmission capacity. The addition of transmission capacity improvements to address the traditional reliability concerns associated with N-1 contingencies also may provide added capacity in support of N-1-1 area supply issues.

[6] Ibid.

Section 3
Assessment of Projected Southern New England System Performance

The study included the entire State of Connecticut and the State of Rhode Island as well as the Springfield area system. Previous analysis revealed the interrelationships that exist between these areas. For example, the power-transfer capability for the State of Connecticut is directly affected by the requirements and constraints of the Rhode Island and Springfield area supply systems. As indicated in Section 3.1 and Section 3.2, each area has its own set of resource requirements and transfer limits, and as shown in the results section (Section 3.3), their own set of reliability concerns. The analyses discussed in this section are based on tests of the projected system performance for the three study areas assuming the system would have no major transmission system upgrades beyond those currently planned (see list below) or extensive generation additions beyond those already installed.

The load levels tested include the 2009 and the 2016 peak-load conditions for summer based on the ISO's most recently available system load forecast (90/10) at the time of the study. Planned transmission upgrades expected to occur prior to 2009 were included in the base case. (At the initiation of the study, all the southwest Connecticut system upgrades were scheduled to be in place before summer 2009.) Subsequent discussion details the load, generation, and transmission system transfer capabilities assessed for the base-case conditions.

Additionally, all the projects listed below were included in the base-case models used to assess system performance and were considered as being in service before the implementation of the upgrades proposed in this analysis.

- Southwest Connecticut Phase I and II Projects
- Boston 345 kV Transmission Reliability Project
- Northeast Reliability Interconnection Project
- Northwest Vermont Reliability Projects
- Central Massachusetts Reliability Projects
- Southwest Rhode Island Reliability Projects
- Barbour Hill Reliability Project
- Killingly Reliability Project

3.1 Area Transmission and Projected Transfer-Capability Requirements

Table 3-1 and Table 3-2 summarize the load, generation, resource assumptions, transfer requirements, and transfer capabilities for the study areas. The interfaces used for Rhode Island and Springfield were defined for the purpose of conducting the reliability assessments and are not interfaces used for operational purposes. Similarly, the loads defined for these areas were based on the loads encompassed by the study interfaces and do not necessarily match any currently defined subareas of the system.

The resource assumptions consider likely generation additions, generation retirements based on a 60-year age limit, and equivalent forced outage rates (EFOR) based on typical EFOR statistical performance for each of the areas of concern. The new generation additions for Connecticut were based on the assumption that 500 MW of additional generation is fully operational by 2016. The Connecticut power-transfer capabilities are based on an assumption that the Springfield transmission system constraints are not limiting as they apply to Connecticut import capabilities.

The data in Table 3-1 and Table 3-2 suggest that certain areas in the southern New England system are of concern at present and that all areas analyzed will experience substantial reliability concerns by 2016. Specifically, these tables assess the resource requirements and adequacy for each of the areas under study and include the following items:

- *Area loads*—The projected area peak loads are identified on the basis of the ISO's 2005 90/10 forecast. These forecast loads are the loads that are encompassed by the interfaces being studied and do not necessarily align with state or ISO zone boundaries.
- *Existing capacity*—The existing generation capacity values are based on the summer claimed capability values in the *2005 Capacity, Energy, Load and Transmission (CELT) report*.[7]
- *Retirements*—The retirement values were determined based on an assumption that generation units greater than 60 years old would no longer be available.
- *EFOR*—The EFOR values are based on calculated values for the equivalent forced outage rate for units in the specified areas.
- *Unavailable generation*—The unavailable generation values are derived from the values of the largest unit in the area. Under emergency import conditions, the largest unit is assumed to be available and import capability is based on loss of two transmission elements.
- *New generation*—As stated above, new generation for Connecticut was assumed to be 500 MW based on the likelihood that either one large unit, such as the Kleen Project, or a number of smaller ones would be in service by 2016.
- *Total resource*—Total resource values are based on the net sum of existing capacity plus new generation less retirements, EFOR, and unavailable generation.
- *Transfer required*—Comparing the total area resource value with projected peak loads provides the transfer levels that would be needed to serve area peak loads.
- *Existing transfer capability*—Existing transfer capabilities are based on today's values as derived through the studies.
- *Load margin/(deficiency)*—The load margin is the amount of additional load that can be supplied reliably. Conversely, the load deficiency is the amount of load that cannot be supplied reliably.

[7] *2005– 2014 Forecast of Capacity, Energy, Loads, and Transmission*. Available on line at http://www.iso-ne.com/trans/celt/report/2005/2005_celt_report.pdf (Holyoke, MA: ISO New England, April 2005).

Table 3-1
Summary of 2009 Area Requirements

	CT Normal	CT Emergency	RI Normal	RI Emergency	Springfld Normal	Springfld Emergency
2009 area load 90/10 [(a)]	8,065	8,065	1,883	1,883	1,015	1,015
Existing capacity	6,797	6,797	1,016	1016	874	874
Retirements >60 yrs old	-81	-81	0	0	-31	-31
EFOR	-501	-501	-23	-43	-60	-70
Unavailable generation	-1,200	0	-515	0	-231	0
New generation	0	0	0	0	0	0
Total resource	5,015	6,215	478	993	552	773
Transfer required	3,050	1,850	1,405	910	463	242
Existing transfer capability	2,500	1,220	1420	900	446[(b)]	326[(b)]
Load margin/(deficiency)	(550)	(630)	15	(10)	(17)	84

(a) This analysis is based on the ISO's April 2005 published peak-load forecast.

(b) The import values exclude constraints associated with 115 kV double-circuit tower contingencies that are not normally used in daily operation of the system. Thus, transfer capability into the Springfield load pocket would be greatly reduced if these design contingencies were included.

Table 3-2
Summary of 2016 Area Requirements

	CT Normal	CT Emergency	RI Normal	RI Emergency	Springfld Normal	Springfld Emergency
2016 area load 90/10 [(a)]	8,970	8,970	2,085	2,085	1,135	1,135
Existing capacity	6,797	6,797	1,016	1,016	874	874
Retirements >60 yrs old	-204	-204	0/0	0/0	-31	-31
EFOR	-501	-501	-30	-50	-60	-70
Unavailable generation	-1,200	0	-515	0	-231	0
New generation	500	500	0	0	0	0
Total resource	5,392	6,592	471	966	552	773
Transfer required	3,578	2,378	1,614	1,119	583	362
Existing transfer capability	2,500	1,220	1370	865	205[(b)]	274[(b)]
Load margin/(deficiency)	(1078)	(1158)	(244)	(254)	(378)	(88)

(a) This analysis is based on the ISO's April 2005 published peak-load forecast.

(b) The import values exclude constraints associated with 115 kV double-circuit tower contingencies that are not normally used in daily operation of the system. Thus, transfer capability into the Springfield load pocket would be greatly reduced if these design contingencies were included.

3.2 Interface Transfer Limits

The transmission system interfaces that define each of the study areas for this analysis are summarized below. The interfaces described may not be identical to interfaces that system operators currently use for the day-to-day management of system resources under varying system conditions. The Connecticut import interface is commonly used in daily system operations; however, the Rhode Island and Springfield interfaces were developed for this study and were based on the limiting transmission elements of their boundaries.

3.2.1 Connecticut Power-Transfer Limits

For these studies, the set of transmission system elements shown in Table 3-3 define the Connecticut import area.

Table 3-3
Connecticut Import Interface Definition

Line #	Transmission Element				% of Interface Flow
	From Bus Name	kV	To Bus Name	kV	
395	Ludlow	345	Meekville Junction	345	30.0
330	Lake Rd.	345	Card	345	29.08
	Killingly	345	Killingly	115	5.5
398	Pleasant Valley	345	CT/NY border	345	23.7
1870	Wood River	115	CT/RI border	115	4.1
1768	Southwick	115	North Bloomfield	115	2.4
1830	South Agawam	115	North Bloomfield	115	2.6
1821	South Agawam	115	North Bloomfield	115	2.6

The Connecticut import interface as defined in Table 3-3 is capable of reliably supporting import levels of 2,500 MW. As shown, the 395 and 330 lines carry approximately 60% of the Connecticut import flows under typical dispatch conditions. The projected Connecticut resource requirements indicate that the existing transmission infrastructure will not be sufficient to support future import requirements.

3.2.2 Rhode Island Power-Transfer Limits

For these studies, the set of transmission system elements shown in Table 3-4 define the Rhode Island import area.

Table 3-4
Rhode Island Import Interface Definition

Line #	From Bus	From kV	To Bus	To kV	Ckt ID	% of Interface Flow
175X	West Farnum	345	West Farnum	115	1	13.5
174X	West Farnum	345	West Farnum	115	2	19.5
3X	Kent County	345	Kent County	115	1	32.8
W4	Somerset	115	Swansea	115	1	4.4
T7	Somerset	115	Pawtucket	115	1	3.5
X3	Somerset	115	Phillipsdale	115	1	3.9
1870	CT/RI border	115	Wood River	115	1	-2.8[(a)]
Q143	Millbury	115	Whitins Pond	115	1	-3.2
R144	Millbury	115	Woonsocket	115	1	-6.1
E183	Brayton Point	115	Warren 83	115	1	13.3
F184	Brayton Point	115	Warren 84	115	1	21.0

(a) The negative numbers indicate that flows on these elements are generally in the export direction.

The import capability of these facilities is approximately 1,420 MW in 2009, which is reduced to 1,370 MW in 2016 as a result of load growth. About 65% of the flows into the area are delivered through three 345 kV to 115 kV autotransformers, and another 30 to 35% is delivered via the Brayton Point 115 kV station.

3.2.3 Springfield Power-Transfer Limits

For these studies, the set of transmission system elements shown in Table 3-5 define the Springfield import area.

Table 3-5
Springfield Import Interface Definition

	Transmission Element				% of Interface Flow [(a)]
Line #	From Bus	kV	To Bus	kV	
1421	Pleasant	115	Blandford	115	5.1
1768	North Bloomfield	115	Southwick	115	5.7
1481	Ludlow	115	East Springfield	115	15.8
1552	Ludlow	115	Orchard	115	13.2
1845	Ludlow	115	Shawinigan	115	36.0
1515	Ludlow	115	Scitico	115	6.2
1821	North Bloomfield	115	South Agawam	115	9.0
1836	North Bloomfield	115	South Agawam	115	9.0

(a) The percent flow values vary as a function of Connecticut import levels.

The import capability of the Springfield facilities is approximately 450 MW in 2009 and, as a result of load growth, is reduced to 200 MW in 2016. About 65% of the flows into the area are delivered through three 115 kV lines emanating from the Ludlow substation.

3.3 Results of Transmission Reliability Analysis

This section describes the results of the 2009 analysis concerning the reliability performance of the transmission systems in Connecticut, Springfield, and Rhode Island. These results are based on assessments of the transmission system under projected load and generation conditions as established for these areas at the time of the study. *Not all of the reliability violations found are being included in the descriptions, tables, and diagrams that follow. Results noted in subsequent sections are obtained using only sample, representative system conditions. A wide variety of other probable system conditions also were analyzed, the results for which are not described herein.*

Also, "all-lines-in" refers to an N-1 (first-contingency) analysis, and "lines-out" refers to an N-1-1 (second-contingency) analysis. Both analyses are dictated by criteria.

3.3.1 Connecticut Power-Transfer Concerns

The 2009 resource requirements for the Connecticut area demonstrate the need for improvements to the area's import capability, generating resources, or a combination of both. Some improvement in import capability can be obtained by mitigating the limitations associated with the Springfield area. However these improvements are still insufficient to meet the projected supply resource requirements for the 2009 Connecticut peak-load conditions. Limitations of the Connecticut import capabilities are a result of insufficient available 345 kV transmission capacity. This can be seen through simulation of 345 kV contingencies associated with the Connecticut interface. Loss of major 345 kV transmission lines on the interface results in overloads of the underlying 115 kV transmission. This problem is most prevalent in the Springfield area and, as shown in Table 3-6 and Table 3-7, a number of Springfield area 115 kV transmission facilities would overload from the loss of a major 345 kV line under the simulated import conditions.

Table 3-6
Connecticut Transmission Line Overloads, 2009 Peak Load, All-Lines-In (N-1)

Worst Scenario		Overloaded Elements						
Generator Out of Service	Contingency	Line/ Auto	From Bus	From kV	To Bus	To kV	Rating	Max Loading (%) Over Rating
Largest generator unavailable Average EFOR One unit retired	This data has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.		ANP Blackstone	345	Sherman Road	345	1400	110.9
			Sherman Road	345	CT/RI	345	1618	109.6
			Carpenter Hill	345	Millbury	345	1405	102.2
			Ludlow	345	Barbour Hill autotrans.	345	1604	121.9
			Barbour Hill autotrans.	345	Meekville Junction	345	1604	103.1
			Bloomfield Junction	115	Northwest Hartford	115	228	114.7

Table 3-7
Connecticut Transmission Line Overloads, 2009 Peak Load, Line-Out (N-1-1)

Worst Scenario			Overloaded Element						
Generator Out of Service	Line/Auto Out of Service	Contingency	Line/ Auto	From Bus	From kV	To Bus	To kV	Rating	Max Loading (%) Over Rating
Average EFOR One unit retired	This data has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.		Ludlow autotrans.	Ludlow	345	Ludlow	115	705	124.0
			371	Montville	345	Millstone	345	1793	112.7
			364	Montville	345	Haddam Neck	345	1912	114.7
			348	Millstone	345	Haddam autotrans.	345	1912	112.5
			353	Manchester	345	Portland Junction	345	1446	108.9
			1207	Manchester	115	East Hartford	115	382	101.1
			1777	North Bloomfield	115	Bloomfield	115	228	106.0
			1751	Bloomfield Junction	115	Northwest Hartford	115	228	131.0

Consequently, significant improvement in Connecticut's power-transfer capability is essential for maintaining an adequate and reliable level of supply resource for the Connecticut area beginning in 2009 and beyond. The risk of system disruptions increases as the in-service date for such improvements is postponed beyond 2009.

Table 3-6 shows that elements of the Connecticut area transmission system overload for the 2009 system at a power-transfer level of 3,050 MW, which is the transfer level required per Table 3-1 to ensure system security. Transmission line overloads specific to the Springfield area are not included in Tables 3-6 and 3-7 but are addressed in Section 3.3.3. The line overload summary tables in this section show only the most severe overload contingency conditions and do not list all of the outage conditions that may overload the element shown. In many cases, numerous outage events may overload the elements shown. Additionally, more significant N-1-1 overloads are not shown here because of the special protection system (SPS) that backs down the Millstone plant output for certain contingency conditions

Figure 3-1 and Figure 3-2 are one-line 345 kV diagrams that display these overloads.

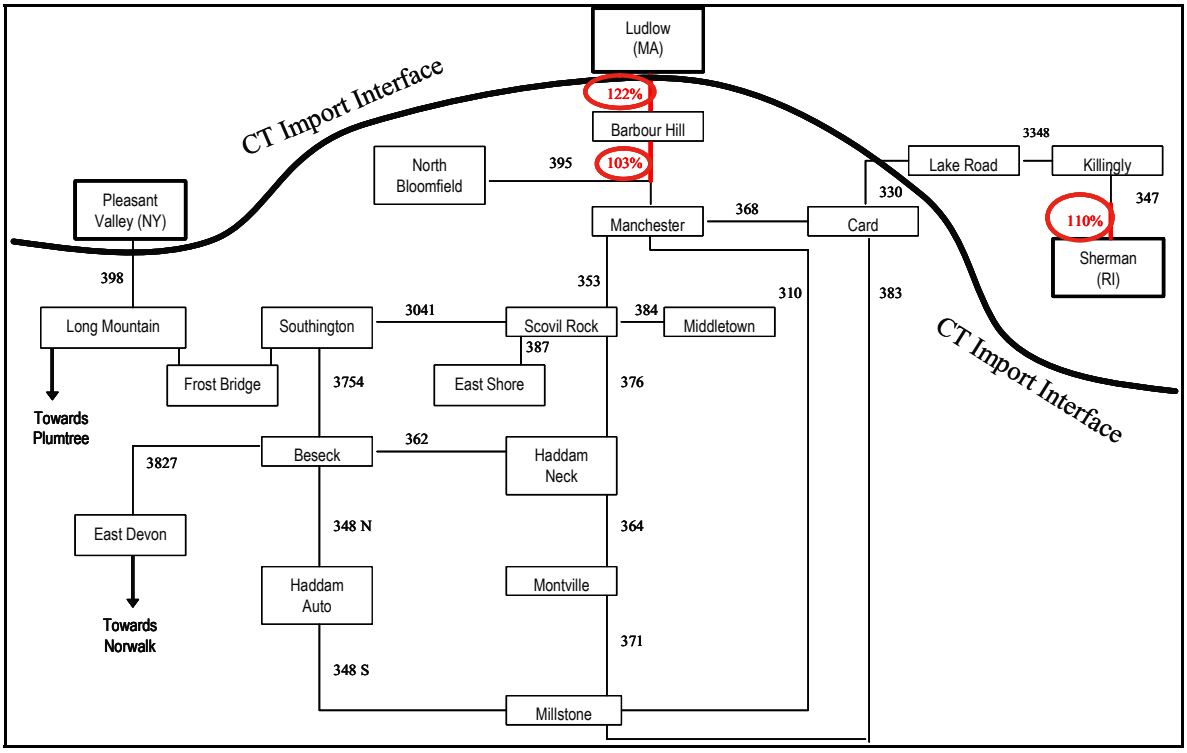

Figure 3-1: 2009 Connecticut transmission line overloads, N-1.

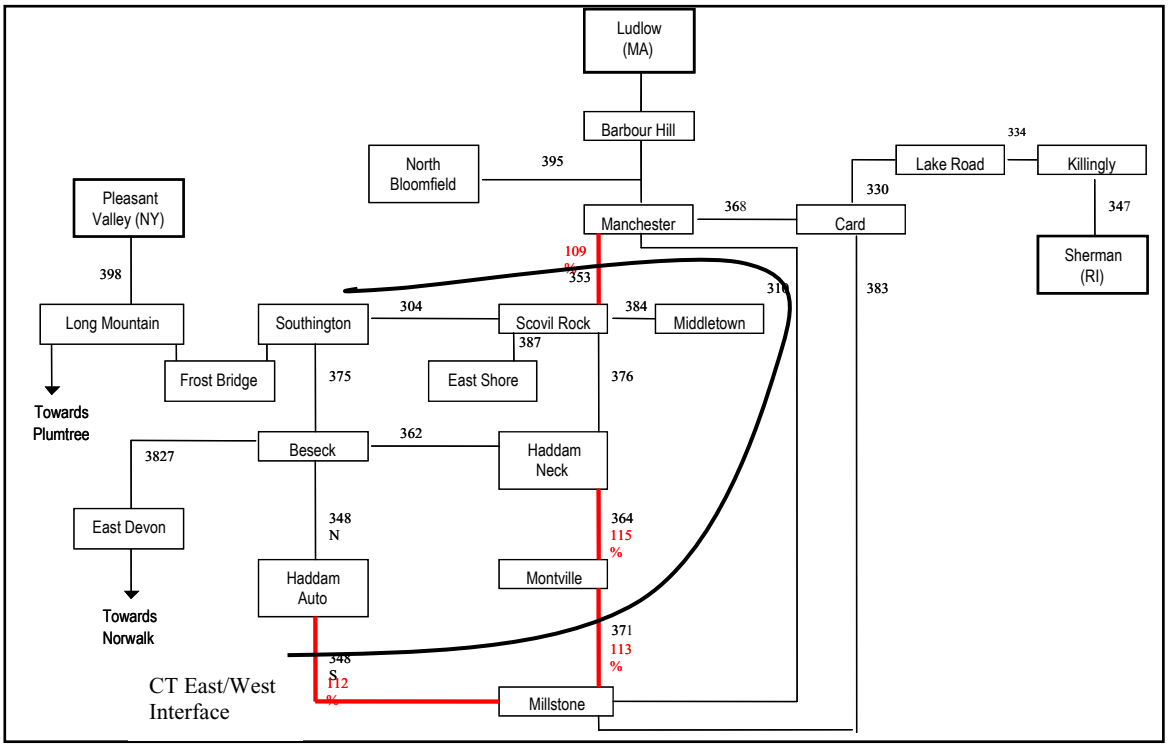

Figure 3-2: 2009 Connecticut transmission line overloads, N-1-1.

3.3.2 Rhode Island Area Transmission Reliability Concerns

Transmission system reliability and dependence on local generation are the major concerns for the Greater Rhode Island area. A number of steady-state thermal and voltage violations have been observed on the transmission facilities while analyzing the conditions for the 2009 system.

The reliability problems on the Rhode Island 115 kV system are caused by a number of contributing factors (both independently and in combination), including high load growth (especially in southwestern Rhode Island and the coastal communities), generation unit availability, and transmission outages (planned or unplanned). Additionally, the Rhode Island 115 kV system is constrained when one of the Greater Rhode Island 345 kV lines is out of service. The 345 kV transmission lines critical for serving load in the Rhode Island 115 kV system are as follows:

- Line 328 (Sherman Rd–West Farnum)
- Line 332 (West Farnum–Kent County)
- Line 315 (West Farnum–Brayton Point)
- Line 303 (ANP Bellingham–Brayton Point)

Outage of any of these transmission lines result in limits to power transfer into Rhode Island. For line-out conditions, the next critical contingency would involve a loss of a 345/115 kV autotransformer or the loss of a second 345 kV tie.

The contingency testing for transmission system outages for the Rhode Island system, as summarized in Table 3-8 and Table 3-9, were run for the 2009 system and represented the extreme summer

forecast (90/10) peak-load levels. They were run with the Connecticut import operating at its required level (per Table 3-1), 3,050 MW (normal) and 1,850 MW (emergency), given projected load and generation conditions in Connecticut. For the N-1 analysis, the largest unit in the area was considered unavailable, as was the equivalent forced outage of other area generation. For the N-1-1 analysis, only the equivalent forced outage generation was considered unavailable. Table 3-8 and Table 3-9 show the most severe overload contingency conditions only and do not list all the outage conditions that may overload the element shown. In many cases, numerous outage events may overload the elements shown.

Table 3-8
Rhode Island Line Overloads, 2009 Peak Load,
All-Lines-In (N-1), One Generator Out of Service

	Overloaded Elements						
Worst Contingency	**Line/Auto**	**From Bus**	**From KV**	**To Bus**	**To kV**	**Rating (MVA)**	**Loading (%)**
This data has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.	Kent Co. 3 transformer	Kent Co.	345	Kent Co.	115	478	101.4
	E-105	Franklin Square	115	Hartford Ave.	115	240	145.7
	F-106	Franklin Square	115	Hartford Ave.	115	240	145.7
	T3	Somerset	115	Pawtucket	115	128	121.1
	G-185 N	Drumrock	115	Kent T1	115	286	116.3
	C-181 S	Brayton Point	115	Chartley Pond	115	268	115.2
	J-188	Drumrock	115	Kilvert T8	115	218	112.0
	Kent Co. 3 transformer	Kent Co.	345	Kent Co.	115	550	109.4
	E-183 E	Brayton Point	115	Warren 83	115	410	104.9
	I-187	Drumrock	115	Amtrak 187	115	218	102.0
	S-171 S	Johnston 171	115	Hartford Ave.	115	426	101.6

Table 3-9
Rhode Island Line Overloads, 2009 Peak Load,
Line-Out (N-1-1), No Generation Out of Service

		Overloaded Elements						
Line Out of Service	**Worst Contingency**	**Line/Auto**	**From Bus**	**From KV**	**To Bus**	**To kV**	**Rating (MVA)**	**Loading (%)**
This data has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.		S-171 S	Rise 171	115	West Cranston 71	115	449	229.3
		T-172 S	West Cranston 72	115	Rise 172	115	449	227.6
		S-171 S	Drumrock	115	West Cranston 71	115	449	216.4
		T-172-S	Drumrock	115	West Cranston 72	115	449	214.7
		F-106	Franklin Square	115	Hartford Ave.	115	240	182.5
		E-105	Franklin Square	115	Hartford Ave.	115	240	178.4
		S-171 S	Johnston 171	115	Hartford Ave.	115	426	151.1
		G-185 N	Drumrock	115	Kent T1	115	286	146.7
		P-142 S	Wyman Gordan TP42	115	Millbury	115	141	133.8
		T-172 S	Johnston 172	115	Rise 172	115	449	126.0
		S-171 S	Johnston 171	115	Rise 171	115	449	125.6
		Rise Tap	Rise 171	115	Rise	115	550	124.4
		Rise Tap	Rise 172	115	Rise	115	550	124.2
		T7	Somerset	115	Pawtucket	115	128	121.1
		1870-S	Wood River	115	CT/RI 1870	115	218	114.6
		J-188	Drumrock	115	Kilvert T8	115	218	111.3
		D-182 S	Brayton Point	115	Mansfield 82	115	283	107.5
		Brayton Point 3B Transformer	Brayton Point	345	Brayton Point	115	361	106.1
		K-189	Drumrock	115	Kent T7	115	359	104.4
		Kent Co. 3 Transformer	Kent Co.	345	Kent Co.	115	550	103.1
		F-184	Brayton Point	115	Warren 84	115	370	100.9
		W4	Somerset	115	Swansea	115	165	100.9
		Brayton Point T3	Brayton Point	115	Brayton Point T3 MID	99	561	100.8
		I-187	Drumrock	115	Amtrak 187	115	218	100.5

Each of these criteria violations are made worse by the unavailability of local area generation and transmission outages (line-out conditions). Figure 3-3 to Figure 3-5 depict a sampling of the Rhode Island reliability violations.

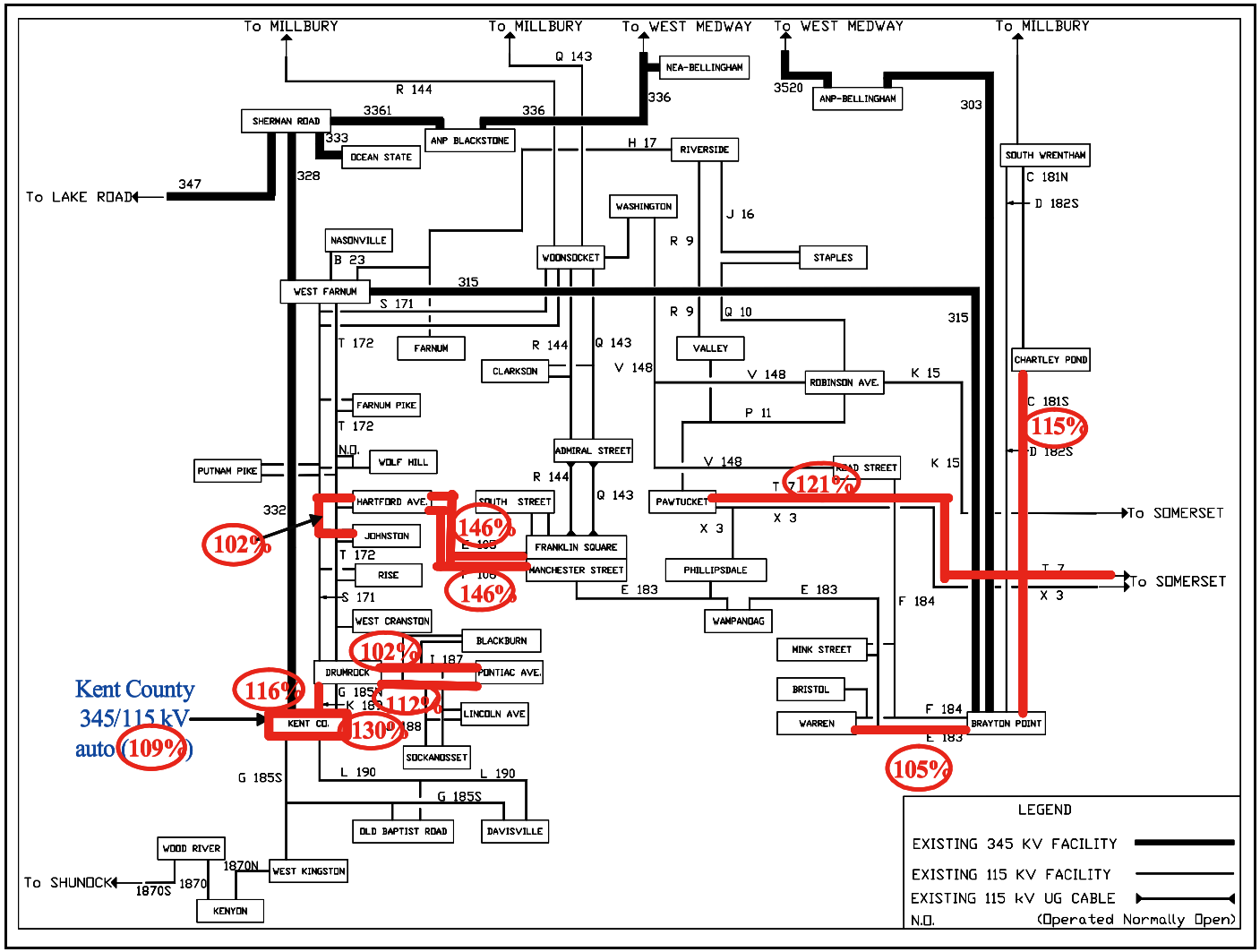

Figure 3-3: 2009 Rhode Island reliability problems, N-1 thermal overloads.

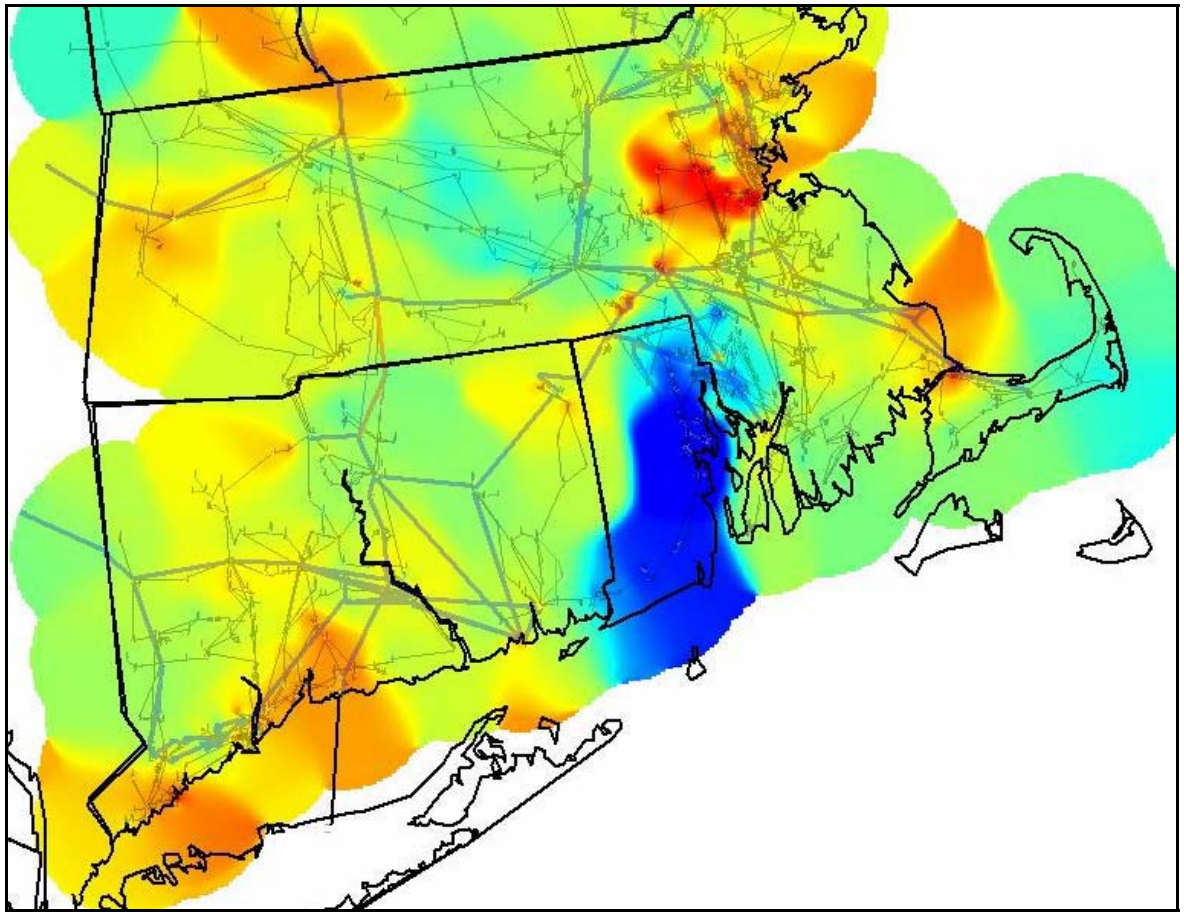

Figure 3-4: 2009 Rhode Island low voltages for an area “design” contingency.

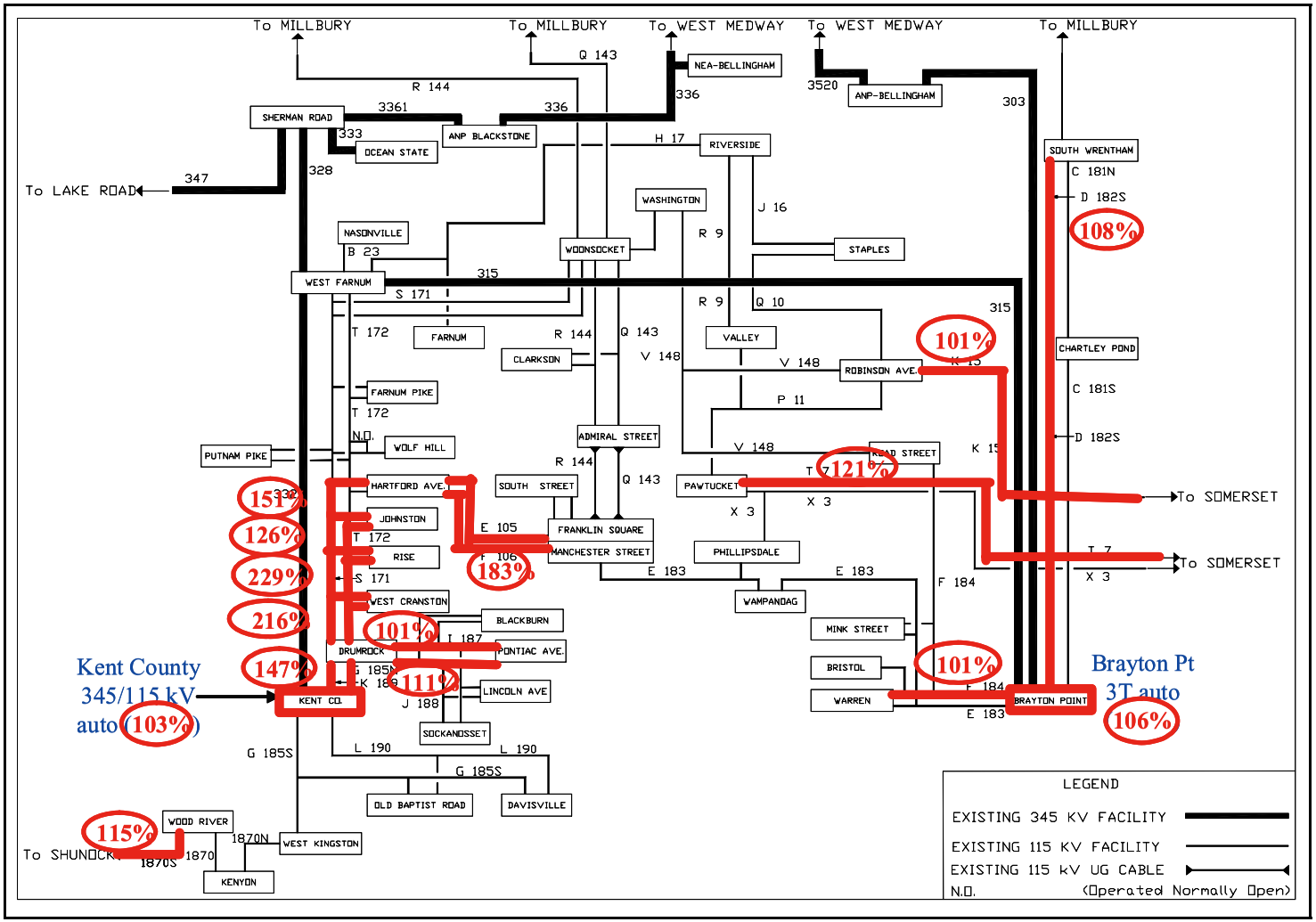

Figure 3-5: 2009 Rhode Island reliability problems, N-1-1 thermal overloads.

3.3.3 Springfield Area Transmission Reliability Concerns

The Springfield area faces a number of reliability concerns. Many local single outages, double-circuit tower outages and stuck breaker outages result in severe line overloads and low voltages in the Springfield area.

Additionally, the Springfield 115 kV transmission system is one of the paths for transporting power into Connecticut. The flow of power through the Springfield 115 kV system increases when the major 345 kV tie line between western Massachusetts and Connecticut (the Ludlow–Manchester–North Bloomfield 345 kV line) is open as a result of a forced or planned outage. For all years simulated, this leads to the appearance of numerous overloads on the Springfield 115 kV system, and increased Connecticut imports aggravate the thermal loadings in Springfield.

Overall, the severity, number, and location of the Springfield overloads or low-voltage conditions highly depend on the area's generation dispatch. These dependencies are illustrated in Figure 3-6 through Figure 3-9. The number of violations in the tables below indicates the number of transmission circuits that overload. Each transmission circuit may overload for multiple contingencies.

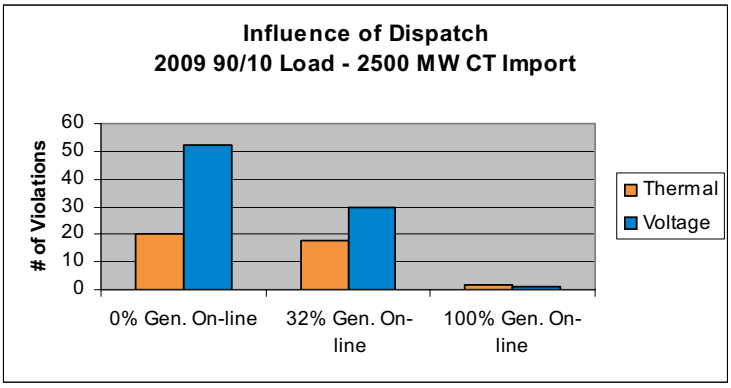

Figure 3-6: Influence of dispatch on Springfield violations—number of violations.

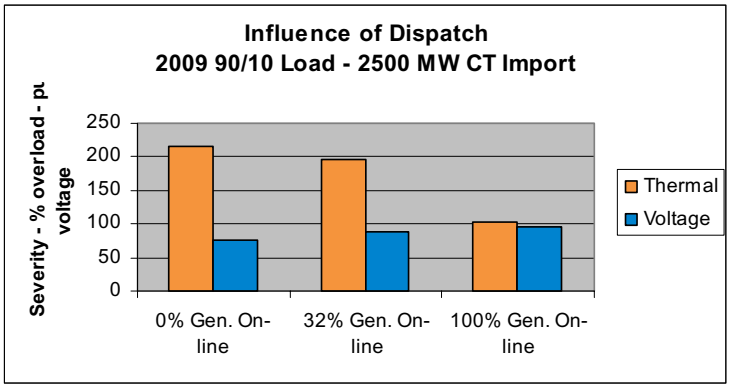

Figure 3-7: Influence of dispatch on Springfield violations—severity of violations.

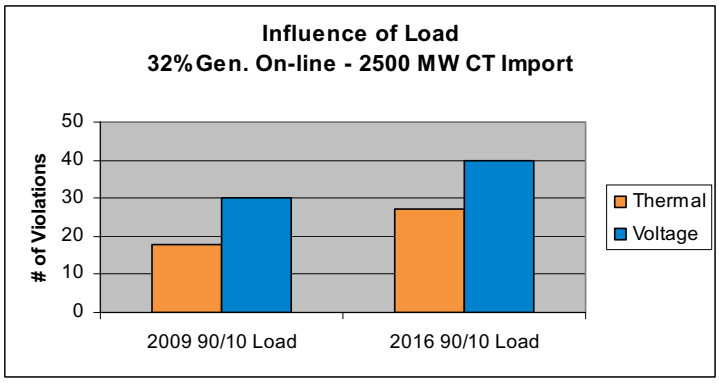

Figure 3-8: Influence of load on Springfield violations—number of violations.

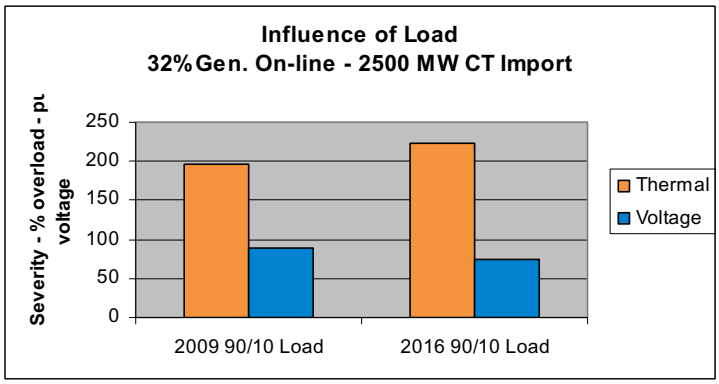

Figure 3-9: Influence of load on Springfield violations—severity of violations.

The above analysis indicates that network constraints in the Springfield area limit the ability to serve load under contingency conditions and also limit the Connecticut import capability through Springfield under certain area dispatch conditions.

The specific overload and voltage violation conditions are summarized in Table 3-10 through Table 3-12. The line overload summary tables in this section only show the most severe overload contingency conditions and do not list all of the outage conditions that may overload the element shown. In many cases, numerous outage events may overload the elements shown.

Table 3-10
Springfield Line Overloads, 2009 Peak Load, All-Lines-In (N-1)

Worst Scenario		Overload Elements						
Generator Out of Service	Contingency	Line/Auto	From Bus	From kV	To Bus	To kV	Rating	Max Loading (%) Over Rating
This data has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.		1254	East Springfield Junction 1254	115	Chicopee	115	265	111.6
		1254	East Springfield Junction 1254	115	Freemont South	115	282	101.9
		1254	East Springfield Junction 1254	115	Shawinigan	115	382	152.3
		1512	Southwick	115	Granville Junction	115	191	101.8
		1768	Southwick	115	North Bloomfield	115	165	100.3
		1433	West Springfield	115	Breckwood	115	140	249.9
		1314	Agawam	115	Chicopee	115	228	105.7
		1322	Breckwood	115	East Springfield	115	141	295.3
		1481	East Springfield	115	Ludlow	115	289	117.4
		1552	Orchard	115	Ludlow	115	305	101.0
		1845	Ludlow	115	Shawinigan	115	311	107.7
		1723	Piper Rd.	115	East Springfield Junction 1723	115	164	113.3

Table 3-11
Springfield Voltage Violations, 2009 Peak Load, All-Lines-In (N-1)

Worst Scenario		Bus Terminals		
Generator Out of Service	**Contingency**	**Bus**	**Bus kV**	**Low Voltage (per unit)**
This data has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.		Five Corners 13	115	0.8477
		Five Corners 34	115	0.8463
		Agawam	115	0.9215
		Amherst	115	0.8368
		Breckwood	115	0.9357
		Chicopee	115	0.9033
		Clinton	115	0.924
		Franconia	115	0.9214
		Freemont North	115	0.8485
		Freemont South	115	0.8514
		Gunn	115	0.8588
		Midway	115	0.8534
		Mt. Tom	115	0.8537
		Orchard	115	0.9488
		Piper Rd.	115	0.9131
		Pochassic	115	0.8859
		South Agawam	115	0.948
		South Agawam	115	0.948
		Scitico	115	0.8988
		Silver 81	115	0.9252
		Silver 82	115	0.9252
		South Agawam	115	0.9269
		Southampton	115	0.8666
		West Springfield	115	0.9245

Table 3-12
Springfield Line Overloads, 2009 Peak Load, Line-Out (N-1-1)

Worst Scenario			Overloaded Elements						
Generator Out of Service	Line/Auto Out of Service	Contingency	Line/ Auto	From Bus	From kV	To Bus	To kV	Rating	Max Loading (%) Over Rating
This data has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.			1512	Blandford	115	Granville Junction	115	147	118.3
			1421	Blandford	115	Pleasant	115	167	112.7
			1322	Breckwood	115	East Springfield	115	141	252.3
			1481	East Springfield	115	Ludlow	115	289	131.6
			1426	East Springfield	115	Orchard	115	311	102.8
			1007	Elm	115	Agawam	115	239	100.9
			1254	East Springfield Junction 1254	115	Freemont South	115	282	108.8
			1254	East Springfield Junction 1254	115	Shawinigan	115	382	137.2
			1525	Holyoke	115	Frreemont South	115	192	107.9
			Auto 1X	Ludlow	345	Ludlow	115	705	110.4
			1552	Orchard	115	Ludlow	115	305	119.9
			1723	Piper Rd.	115	East Springfield Junction 1723	115	164	104.1
			1781	South Agawam	115	Silver 81	115	228	108.6
			1782	South Agawam	115	Silver 82	115	228	108.2
			1512	Southwck	115	Granville Junction	115	191	138.0
			1412	West Springfield	115	Agawam	115	143	144.0
			1311	West Springfield	116	Agawam	116	143	144.0
			1433	West Springfield	115	Breckwood	115	140	210.4
			1371	Woodland	115	Pleasant	115	228	109.3

Figure 3-10 to Figure 3-12 of Springfield area transmission display the overloads and low voltages shown above.

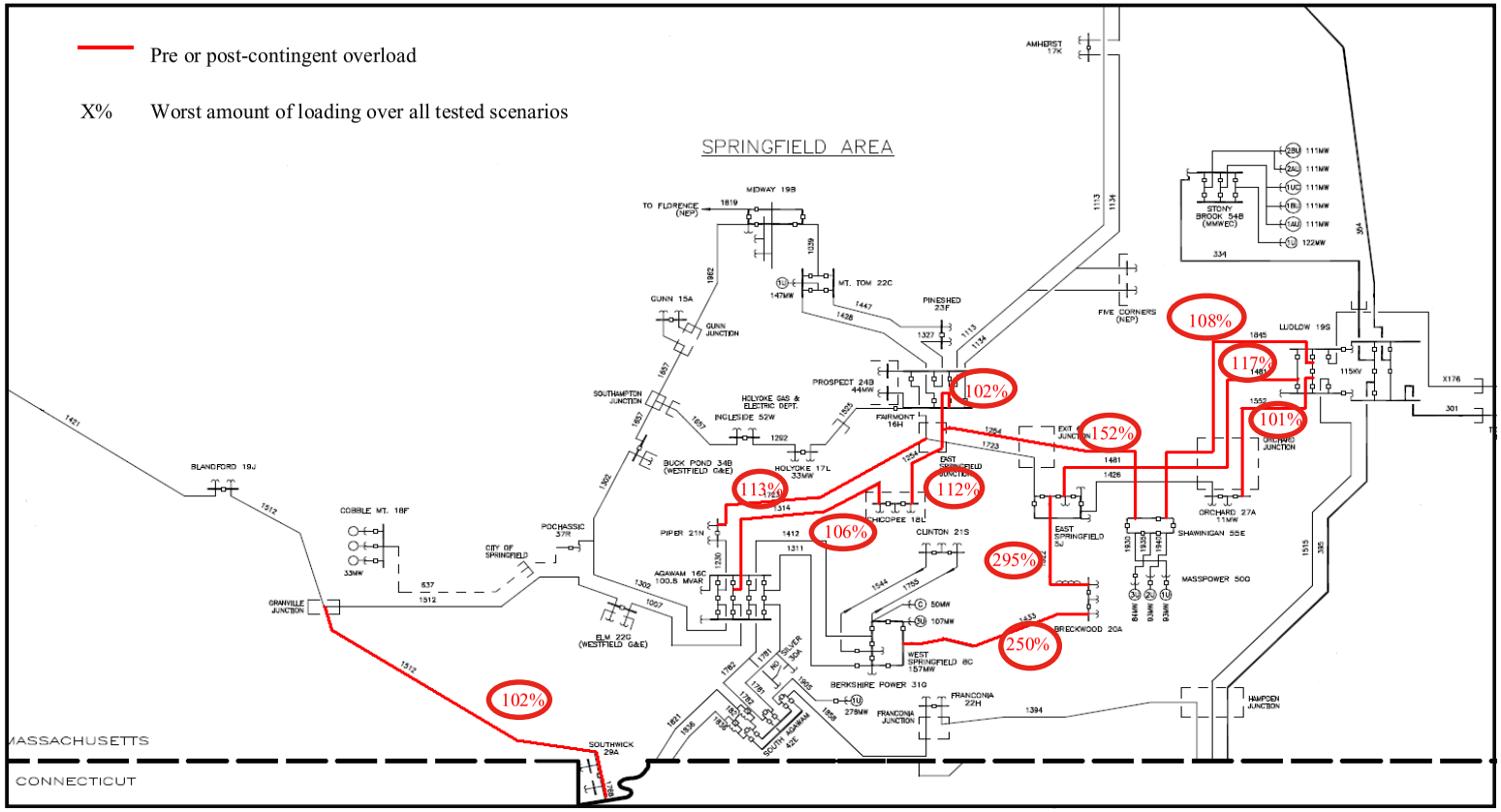

Figure 3-10: 2009 Springfield overloads, N-1.

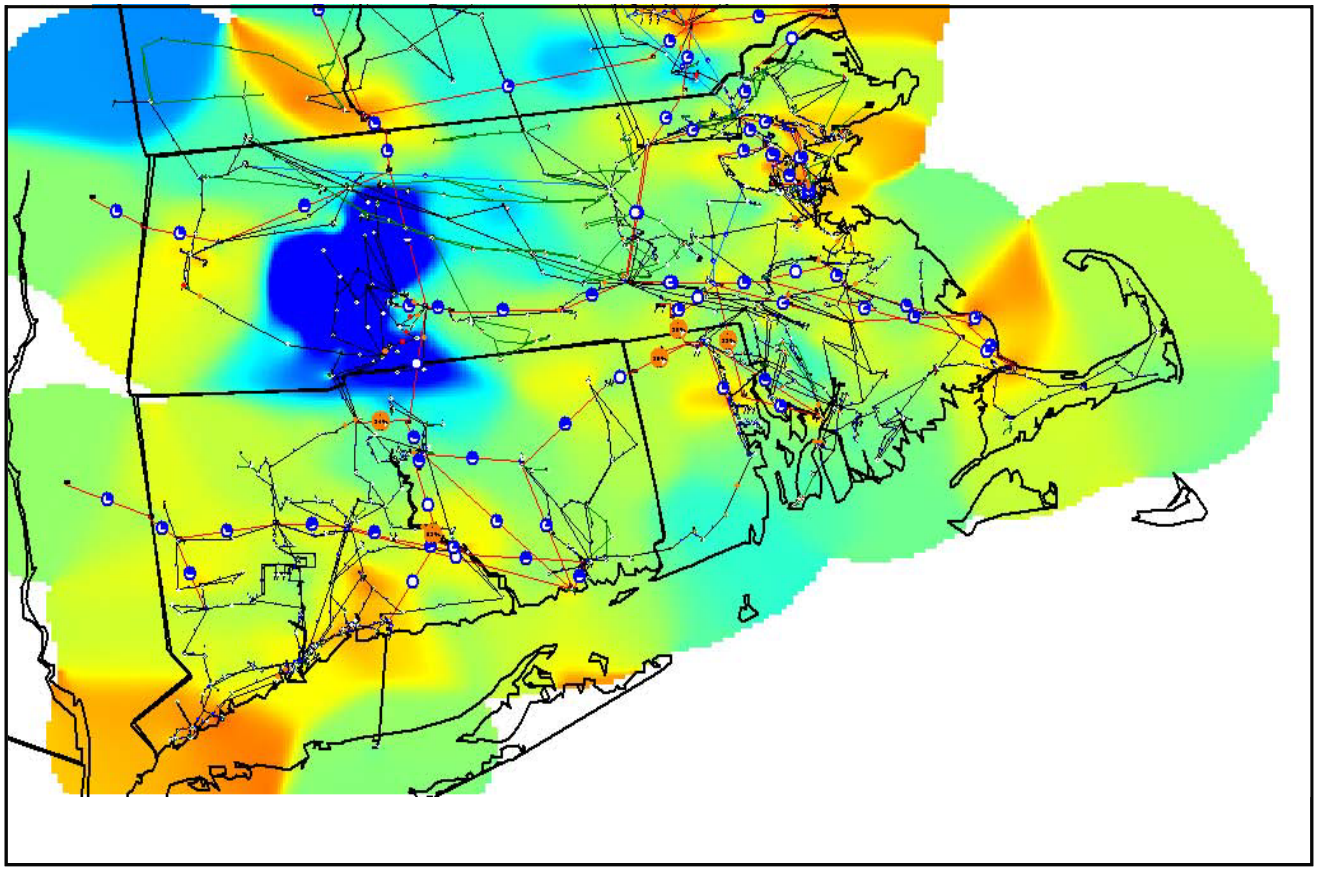

Figure 3-11: 2009 Springfield N-1 low voltages for an area “design” contingency.

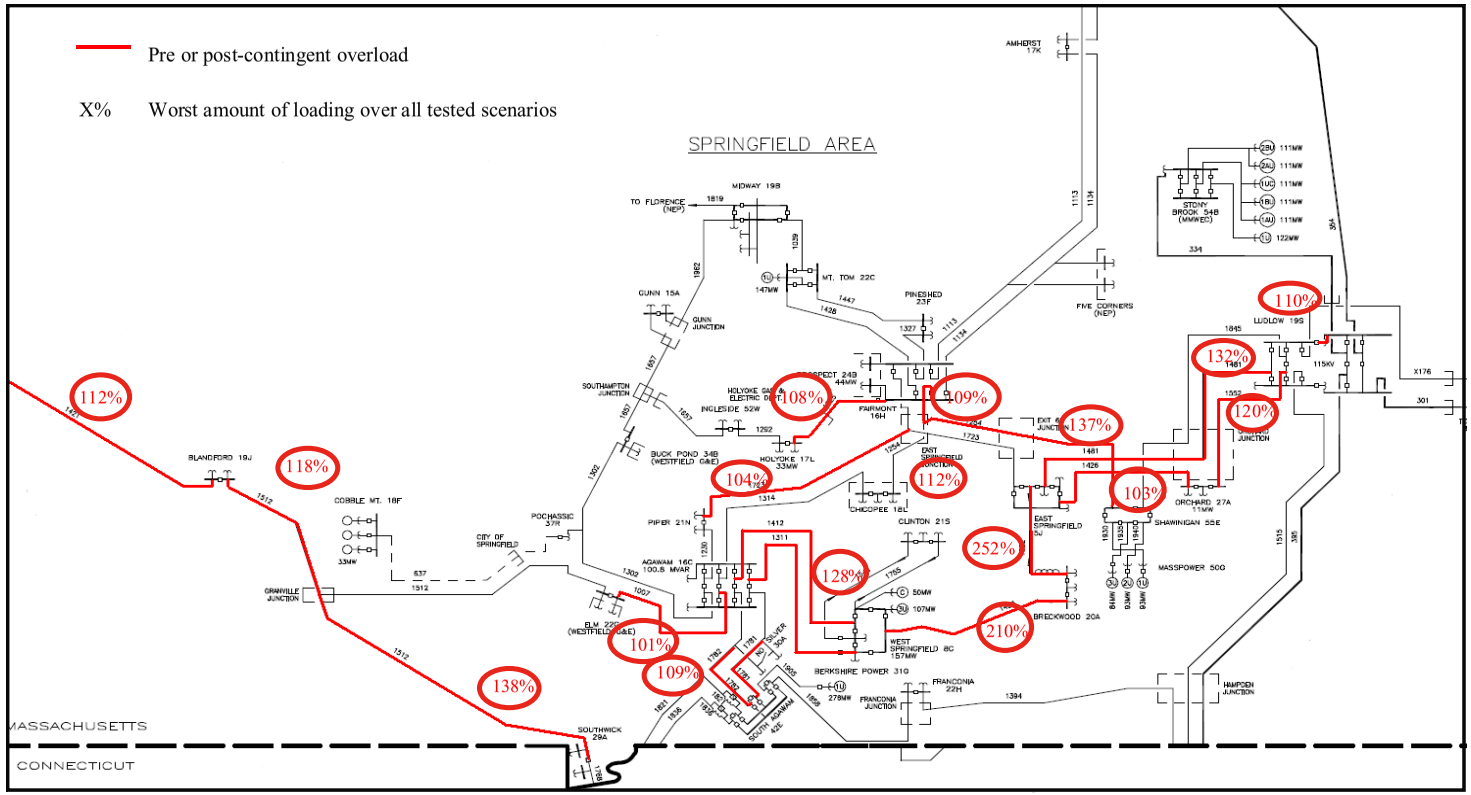

Figure 3-12: 2009 Springfield overloads, N-1-1.

3.4 Needs Analysis Conclusions

In summary, this analysis demonstrates that in 2009 area transmission capabilities will be inadequate to meet NERC, NPCC, and ISO New England reliability standards and criteria for the projected load and generation conditions in the Connecticut, Springfield, and Rhode Island areas. These problems, some of which may already exist, become increasingly more severe as peak load continues to grow. The problems enumerated in this report demonstrate a need to construct new transmission facilities to significantly improve the reliability of the transmission grid serving Connecticut, Rhode Island, and western Massachusetts. Given the lead times necessary for permitting and other preconstruction activities, as well as the time required for construction itself, these problems constitute needs that should be addressed now.

Appendix E

New England East–West Solutions

(Formerly Southern New England Transmission Reliability)

Report 2
Options Analysis

(Redacted)

(c) ISO New England Inc.

June 2008

Southern New England Regional Working Group

ISO New England

National Grid

Northeast Utilities

Executive Summary

National Grid, Northeast Utilities, and ISO New England (ISO) formed a working group to conduct the studies necessary to develop a 10-year plan for transmission system improvements for the southern New England (SNE) region. The 10-year plan specifically addresses western and central Massachusetts (particularly the Springfield area), Rhode Island, and eastern and central Connecticut.

The objective of this 10-year plan is to ensure that the SNE region continues to comply with criteria and reliability standards established by the North American Electric Reliability Corporation (NERC), the Northeast Power Coordinating Council (NPCC), and the ISO.[1] These criteria and standards define regional transmission requirements and transmission-transfer capabilities with respect to stability, steady state, and fault-current conditions. They are in place to ensure, for the long term, that the regional transmission system serving New England is robust and flexible, reliably delivers power to customers under a wide range of projected future system conditions, and is able to address reasonably foreseeable contingencies.

The working group developed the transmission system improvements described in this analysis in conjunction with the ISO's 10-year regional system planning process, which showed the likelihood of portions of the SNE region not meeting the criteria and standards by 2009.[2] A full explanation and review of the criteria, the results of the analysis, and the statement of need for the SNE transmission system are contained in the January, 2008, report, *Southern New England Transmission Reliability (SNETR) Report 1—Need Analysis* (Needs Analysis).[3]

This report, *Report 2—Options Analysis*, describes the results of the working group's analysis of the options that address the needs identified in the Needs Analysis. The Options Analysis explains how the options were developed to meet the identified needs, describes the main features of the solutions, and compares the solutions in terms of system performance characteristics. As shown in this report, a number of the potential solutions would ensure reliable system performance for the SNE region for the time periods under study.

---

[1]The ISO system must comply with NERC and NPCC criteria and standards and ISO planning and operating procedures. As certified by the Federal Energy Regulatory Commission in 2006, NERC is the "electric reliability organization" (ERO) whose mission is to improve the reliability and security of the bulk power system in North America. Information on NERC requirements is available online at http://www.nerc.com (Princeton, NJ: NERC, 2007). NPCC is the cross-border regional entity and criteria services corporation for northeastern North America. NPCC's mission is to promote and enhance the reliable and efficient operation of the international, interconnected bulk power system in the geographic area that includes New York State, the six New England states, and the Ontario, Québec, and the Maritime provinces of Canada. Additional information on NPCC is available online at http://www.npcc-cbre.org/default.aspx (New York: NPCC Inc., 2007). Information about ISO New England Planning Procedure No. 3 (PP 3), *Reliability Standards for the New England Area Bulk Power Supply System*, is available online at http://www.iso-ne.com/rules_proceds/isone_plan/PP3_R3.doc (Holyoke, MA: ISO New England, 2006).

[2] Summaries of the ISO's projections for the southern New England transmission system have appeared in the 2005, 2006, and 2007 Regional System Plans (RSPs) as well as previous years' Regional Transmission Expansion Plans. These reports are available online at http://www.iso-ne.com/trans/rsp/index.html.

[3] The *Southern New England Transmission Reliability (SNETR) Report 1—Needs Analysis* can be obtained by contacting ISO Customer Service at 413-540-4220 or custserv@iso-ne.com.

Development and Assessment of Plan Components and Options

The first step for this study was to establish the design objectives for the future southern New England transmission system based on the reliability deficiencies identified in the Needs Analysis. Using these design objectives, the working group developed and evaluated a combination of complementary options for upgrading the system to meet the identified performance objectives during the long-term planning horizon.

In formulating each option, the working group considered more than just the performance of the option under specific conditions. It also considered the relationship that each option could have with other components of the comprehensive solution for the SNE region, with other elements of the transmission system, and with the regional transmission system as a whole. Consideration of these relationships ensured that the development of a "solution" was comprehensive and did not have an adverse impact on other parts of the bulk transmission system. These relationships led the working group to develop an approach to solving the SNE region's needs with these four components:

- **Interstate Component**—This component provides an additional link between Massachusetts, Rhode Island and Connecticut or, in one case, just between Rhode Island and Connecticut, and improves regional transfer capabilities. Initial brainstorming sessions among working group members resulted in 17 options for the Interstate component, of which five viable options remain.
- **Rhode Island Component**—This component increases Rhode Island's access to New England's 345 kV bulk transmission system and eliminates both thermal overloads and voltage violations. Three options (two Interstate options plus one independent option) were developed to better connect Rhode Island to the rest of the system, three options were developed to extend these new facilities farther into the major load center in southwest Rhode Island, and two options were developed to bring an additional source into the 115 kV load center from the east.
- **Connecticut East–West Component**—This component provides an additional link between western and eastern Connecticut and improves system transfer capabilities between these areas. Initially, four options were developed for this component. One option was eliminated as a result of poor performance, which left three options for further study.
- **Springfield Component**—This component eliminates both thermal and voltage violations in the Springfield area while increasing the area's access to the 345 kV bulk transmission system. The number of 345 kV options for the Springfield component was limited; however, 35 options were initially developed because a number of possible 115 kV solutions would work well with any of the 345 kV options, which created a multiplicative effect. Three 345 kV options remain, each having four 115 kV variations, for a total of 12 potential solutions.

Developing the options for each of these four components has been an iterative process for the working group. Options that appeared to be capable of mitigating reliability concerns were formulated and then analyzed for compliance with design criteria and objectives. Additional modifications were formulated as necessary and then the option was reevaluated. This step was repeated until either the option was clearly workable or was determined to be not viable or not practical because it would require too many modifications.

Component Options that Exhibited Superior Performance

In each of the four components, most of the options that were found to meet or exceed the system criteria and objectives involve adding new 345 kV transmission lines, although all the upgrades associated with the four components also include 115 kV facilities and autotransformers.

Interstate Component Options

The Interstate component serves to strengthen the ties between the southern New England states and increase the ability to move power between eastern New England and western New England. For the five Interstate options that exhibited superior performance in meeting system criteria and objectives, the new 345 kV lines that would act as the 'backbone' for the options are listed below.

- **Interstate Option A**—a new 345 kV line from the Millbury, MA, substation to the West Farnum, RI, substation and then to the Lake Road, CT, substation and terminate at the Card, CT, substation
- **Interstate Option B**—a new 345 kV line from the West Farnum substation to the Kent County, RI, substation and then to the Montville, CT, substation. (The line from the West Farnum substation to the Kent County substation is part of the Rhode Island component.)
- **Interstate Option C**—a new 345 kV line from the Millbury substation to the Carpenter Hill, MA, substation and terminate at the Manchester, CT, substation
- **Interstate Option D**—a new 345 kV line from the Millbury substation to the Carpenter Hill substation to the Ludlow, MA, substation to the Agawam, MA, substation to the North Bloomfield, CT, substation. (The line from the Ludlow substation to the Agawam substation to the North Bloomfield substation is part of the Springfield component.)
- **Interstate Option E**—a new 1,200 MW high-voltage direct-current (HVDC) tie between the Millbury substation and the Southington, CT, substation

Rhode Island Component Options

The Rhode Island component upgrades would serve three basic functions: (1) bring an additional source (in the form of a new transmission line) into Rhode Island, (2) extend a second source (transmission line) to the southwest area of Rhode Island, and (3) add a new source (345/115 kV autotransformer) from the east into the 115 kV load center.

Bringing an additional source into Rhode Island is handled as part of Interstate Options A and B or by installing a second Sherman Road, RI–West Farnum 345 kV line as part of Interstate Options C, D, and E.

The addition of a second West Farnum–Kent County 345 kV line proved to be the most cost-effective option for extending a second source to the southwest area. Adding 115 kV lines and upgrades proved unable to support the loss of the existing West Farnum–Kent County 345 kV line.

Similarly, adding a new 345/115 kV substation into the 115 kV system from the east side proved to be the most effective option for eliminating the 115 kV voltage concerns that had been identified and forecast. This new substation would be looped into the existing 345 kV line (the 303 line) that extends from Brayton Point to ANP–Bellingham. The 115 kV lines that currently tie the South Wrentham substation to the Brayton Point substation (the 181 and 182 lines) also would be looped into this new substation under this option.

Connecticut East–West Component Options

The Connecticut East–West component increases the ability to move power between eastern and western Connecticut. It can be thought of as an extension to the Interstate component by helping to move power from eastern to western New England, and vice versa, depending on the dispatch of existing generation and on the location of future generators. The three options for the Connecticut East–West component that exhibited superior performance are as follows:

- **Option A**—a new 345 kV line from Manchester to Southington
- **Option B**—a new 345 kV line from Manchester to Scovill Rock and from Berlin to Hans Brook Junction
- **Option C**—a new 345 kV line from North Bloomfield to Frost Bridge

Springfield Component Options

The Springfield component reduces Springfield's dependence on internal generation by increasing the area's access to the 345 kV bulk transmission system and eliminates the thermal and voltage criteria violations of the area. The three options for the Springfield component that exhibited superior performance in meeting these objectives are as follows:

- **Option A**—a new 345 kV line from Ludlow to Agawam to North Bloomfield
- **Option B**—a new 345 kV line from Ludlow to North Bloomfield
- **Option C**—a new 345 kV line from Ludlow to Manchester

Relationships among Components and Options

The relationships among the four components and options are as follows:

- **Interstate Component—**The preferred Interstate option can be selected without respect to other component selections; however, this selection will dictate some of the Rhode Island component selections. Interstate Option E, which adds a HVDC line from the Millbury substation to the Southington substation, obviates the need for a separate 345 kV line to mitigate Connecticut East–West constraints.
- **Rhode Island Component—**As stated, some of the system improvements that make up the Rhode Island options depend on which Interstate option is selected (as shown in Appendix A, Table A-2). Therefore, the Interstate option selected will directly affect which Rhode Island option is selected. Some of the improvements of the Rhode Island component options are independent of the selections for any of the other components of the plan.
- **Connecticut East–West Component—**The improvements for the Connecticut East–West component options are independent of the selections for any of the other component options. However, as stated, the selection of Interstate Option E would obviate the need for a Connecticut East–West 345 kV option, since it would satisfy the reliability need for both the Interstate and the Connecticut East–West components.
- **Springfield Component—**The improvements for the Springfield component are independent of the preferred Interstate option unless Option D is selected. In this case, additional Springfield area upgrade(s) would be required. This component is independent of the Rhode Island and Connecticut East–West Component options.

Next Steps

The next part of the process is for the participating transmission owners to analyze the environmental impacts, cost, constructability, and routing for each option of each component. Once this information is gathered and analyzed, preferred options for each of the four plan components can be identified.

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Section 1
Introduction

National Grid, Northeast Utilities, and ISO New England (ISO) formed a working group to conduct the studies necessary to develop a 10-year plan for transmission system improvements for the southern New England (SNE) region. The plan specifically addresses western and central Massachusetts (particularly the Springfield area), Rhode Island, and eastern and central Connecticut (see Figure 1-1).

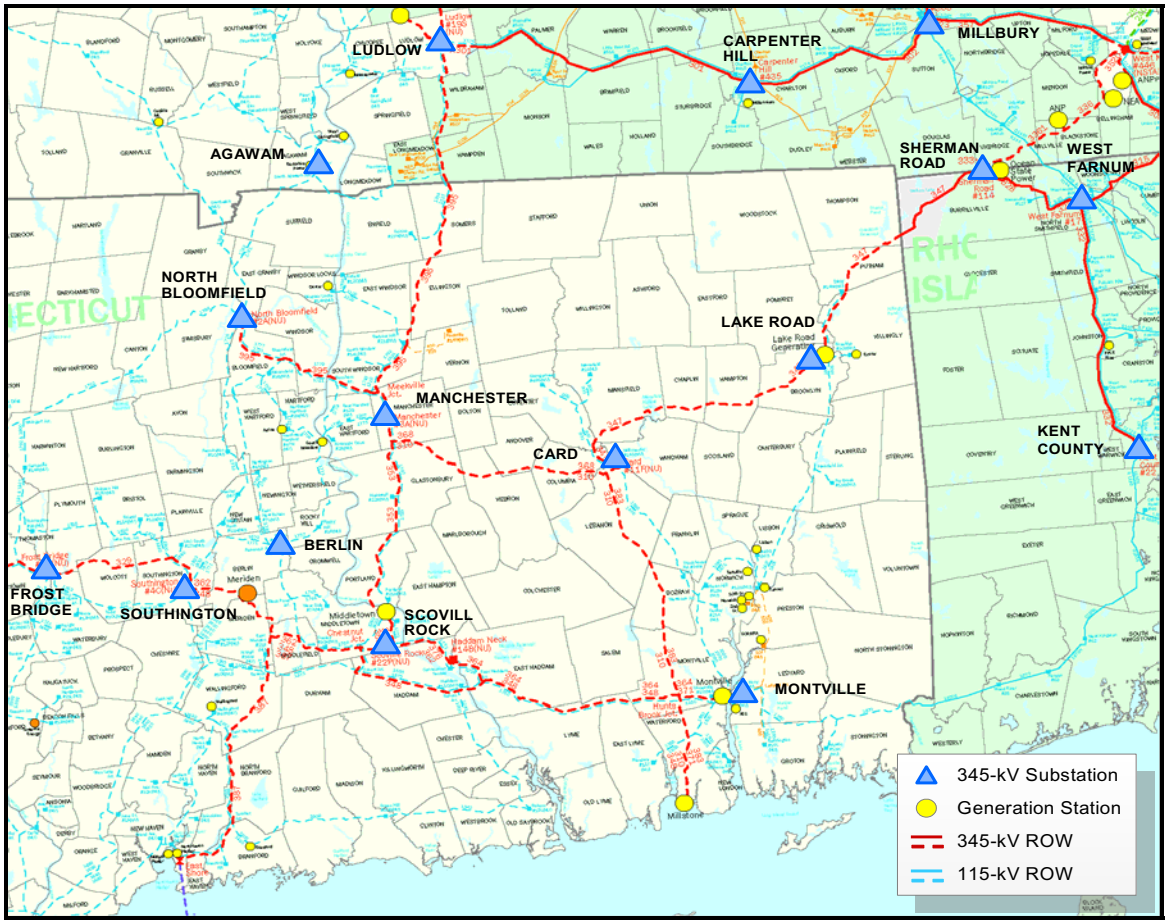

Figure 1-1: Key substations in southern New England.

The objective of the 10-year integrated SNE transmission enhancement plan is to ensure that the region complies with a number of design, operation, and reliability criteria and standards, as follows, to improve the long-term reliability and performance of the southern New England transmission system:

- North American Electric Reliability Corporation's (NERC) Reliability Standards for the Bulk Power Systems of North America[4]
- Northeast Power Coordinating Council's (NPCC) Basic Criteria for the Design and Operation of Interconnected Power Systems[5]
- The ISO's Planning Procedure No. 3 (PP 3), Reliability Standards for the New England Area Bulk Power Supply System[6]

These criteria and standards are in place to ensure that the regional transmission system serving New England can reliably deliver power to customers under a wide range of system conditions, such as anticipated facility outage events and system contingencies (i.e., the sudden and unplanned outage of a generating unit or transmission facility). The standards and criteria also ensure the adequate transfer of power among the New England Control Area and the surrounding control areas and account for possible future system configurations (i.e., load and generation scenarios). To comply with PP 3, the system meets the minimum acceptable level of reliable service if it passes the test conditions under simulation, as specified in this procedure.

A full explanation and review of the criteria, the statement of need for the SNE regional transmission system, and the results of an analysis of the needs are contained in *Southern New England Transmission Reliability (SNETR) Report 1—Needs Analysis* (Needs Analysis).[7] This report, *Report 2—Options Analysis*, summarizes the needs identified in the first report and describes each of the solutions and how they were developed for addressing the identified needs. This report also discusses the results of the analysis for developing options for solutions and compares them in terms of system performance characteristics.

A number of the transmission upgrades that were developed were found to meet the stated requirements for ensuring reliable and adequate system performance for the areas and time periods under study.

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[4] As certified by the Federal Energy Regulatory Commission in 2006, NERC is the "electric reliability organization" (ERO) whose mission is to improve the reliability and security of the bulk power system in North America. Information on NERC requirements is available online at http://www.nerc.com (Princeton, NJ: NERC, 2007).

[5] NPCC is the cross-border regional entity and criteria services corporation for northeastern North America. NPCC's mission is to promote and enhance the reliable and efficient operation of the international, interconnected bulk power system in the geographic area that includes New York State, the six New England states, and the Ontario, Québec, and the Maritime provinces of Canada. Additional information on NPCC is available online at http://www.npcc-cbre.org/default.aspx (New York: NPCC Inc., 2007).

[6] ISO New England Planning Procedure No. 3, *Reliability Standards for the New England Area Bulk Power Supply System*, is available online at http://www.iso-ne.com/rules_proceds/isone_plan/PP3_R3.doc (Holyoke, MA: ISO New England, 2006).

[7] The *Southern New England Transmission Reliability (SNETR) Report 1—Needs Analysis* (August 7, 2006) can be obtained by contacting ISO Customer Service at 413-540-4220 or custserv@iso-ne.com.

Section 2
Overview of Transmission System Problems and Needs

Through its analyses of the 10-year planning period, the working group identified a number of deficiencies in transmission system security that could lead to violations of the planning criteria and standards the system must meet. These deficiencies—many of which are a result of the significant degree of load growth in the SNE region—form the justification for the needed transmission system improvements. Although discussed in detail in the Needs Analysis, the specific reliability needs are summarized as follows for quick reference:

- The amount of power that can be delivered between eastern New England and western New England must be increased. The east–west power flows across southern New England could be limited because of potential thermal and voltage violations of area transmission facilities under contingency conditions.
- The amount of power that can be moved between Connecticut, Massachusetts, and Rhode Island must be increased to eliminate transmission security criteria violations.
- The reliability of the transmission supply to the Springfield, Massachusetts, area must be improved by eliminating thermal overloads and voltage problems under numerous contingencies. The severity of these problems increases as the system attempts to move power into Connecticut from the rest of New England. In the Springfield area, local double-circuit tower outages (DCT), stuck-breaker outages, and single-element outages all can result in severe thermal overloads and low-voltage conditions. **This sentence has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.**
- The ability to move power into and out of Connecticut must be enhanced. In the past, the limited ability to export power from Connecticut to the rest of New England was the more serious problem; however, this has reversed in recent years. The ability to import power presently is limited and could eventually result in the inability to serve load under many probable system conditions. Power-transfer capabilities in the Connecticut area are forecast to be insufficient for meeting the area's requirements as early as 2009.[8] If improvements are not made by 2016, the deficiency for this area under "generator unavailability conditions" (i.e., when the largest unit plus a historical average amount of other generation is out-of-service) and when a single power system element is lost (N-1 conditions) is expected to be greater than 1,500 MW, assuming a transfer limit of 2,500 MW and no new capacity additions. On the basis of planning assumptions of future generation additions of 500 MW and retirements of 204 MW within the Connecticut area, by 2016 a deficiency of approximately 1,100 MW will occur for N-1 conditions, and 1,200 MW for N-1-1 conditions (i.e., conditions under which a transmission element is unavailable and a single power system element is lost).
- The amount of power that can be delivered from eastern Connecticut to western Connecticut must be increased by eliminating transmission security criteria violations. These violations, which can cause thermal constraints, limit the Connecticut east–west power transfers across the central part of Connecticut. The movement of power from east to west, in conjunction

[8] RSP06, Table 9-3

with higher import levels to serve Connecticut, overloads transmission facilities within Connecticut.

- The reliability of the transmission supply to the Rhode Island area must be improved by eliminating thermal overloads and voltage problems. Rhode Island now is overly dependent on a limited number of transmission lines or autotransformers to serve its needs, which could result in thermal overloads and voltage problems during contingency conditions. Causal factors for these conditions include high load growth (especially in southern Rhode Island and the coastal communities), unit availability, and planned and unplanned transmission outages. The Rhode Island 115 kV system is constrained when a 345 kV line is out of service. Outage of any one of a number of 345 kV transmission lines limits the amount of power that can be transferred into Rhode Island. For line-out conditions, the next critical contingency involving the loss of a 345/115 kV autotransformer or a second 345 kV line results in numerous thermal and voltage violations.

Section 3
Development and Assessment of Options

Developing and assessing the options for addressing the identified reliability needs has been a highly complex effort. The first part of the process was to establish the objectives for the future performance of the SNE transmission system based upon the reliability deficiencies shown in the Regional System Plans (RSPs) and as discussed in the Needs Analysis report. Using these performance objectives, the working group developed and evaluated a combination of complementary options for transmission system upgrades for the long-term planning horizon. This section describes the design objectives for the options as well as the ability of each set of options to meet these objectives.

3.1 Developing the Four-Component Approach

In formulating each option, the working group considered not only the performance of the option but also the relationship that each option could have with other components of the comprehensive solution, with other elements of the transmission system, and with the regional transmission system as a whole. Consideration of these relationships ensured that the development of one "solution" was comprehensive and did not have an adverse impact on other parts of the system. These relationships led the working group to develop an approach to solving the SNE region's needs with these four components:

- **Interstate Component**—This component either provides an additional link between Massachusetts, Rhode Island, and Connecticut or, in one case, just between Rhode Island and Connecticut, and improves regional transfer capabilities. Initial brainstorming sessions identified 17 options for the Interstate component, of which five viable options remain.
- **Rhode Island Component**—This component increases Rhode Island's access to New England's 345 kV bulk transmission system and eliminates both thermal overloads and voltage violations. Three options (two Interstate options plus one independent option) were developed to better connect Rhode Island to the rest of the system, three options were developed to extend these new facilities farther into the major load center in southwest Rhode Island, and two options were developed to bring an additional source into the 115 kV load center from the east.
- **Connecticut East–West Component**—This component provides an additional link between western and eastern Connecticut and improves system transfer capabilities. Four options were initially developed for this component; one was eliminated as a result of poor performance, which left three options for further study.
- **Springfield Component**—This component eliminates both thermal and voltage violations in the Springfield area while increasing the area's access to the 345 kV bulk transmission system. The number of 345 kV options for the Springfield component was limited; however, 35 options were initially developed because a number of possible 115 kV solutions would work well with any of the 345 kV options. Three 345 kV options remain, each having four 115 kV variations, for a total of 12 potential solutions.

As shown in Figure 3-1, a number of factors were considered in formulating and evaluating the options within each component of the plan. These factors ranged from considering the impacts of an option on the New York–New England transfer capabilities to assessing the impact of adding a specific generating unit.

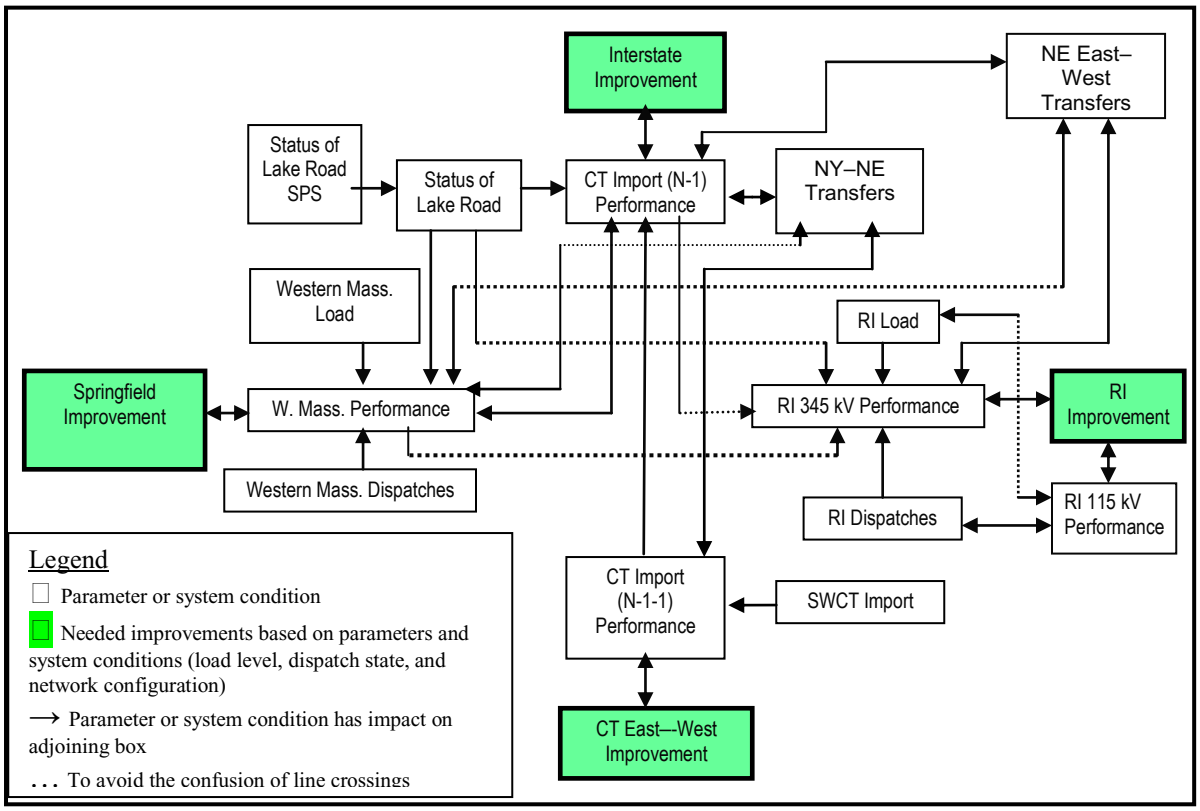

Figure 3-1: Diagram of relationships among southern New England components.

The lines interconnecting the boxes in Figure 3-1 show how the components can have an impact on one another. For example, the performance of the Rhode Island 345 kV system depends, to some extent, on all the following:

- RI Load (Rhode Island load levels)
- NE East-West Transfers (transfer level from eastern to western New England)
- CT Import (N-1) Performance (transfer level into Connecticut)
- RI Dispatches (generation dispatch in Rhode Island)
- Status of Lake Road (generation dispatch on the borders)
- W. Mass. Performance (performance of western Massachusetts system [i.e., Ludlow to Manchester loading])

To ensure the resiliency of the solutions, the design of the system upgrades accounted for the premature loss of generation concurrent with the ability of the system to maintain an acceptable level of performance under line-out-of-service conditions. This is an important planning consideration because implementing a transmission system upgrade to ensure system reliability in response to an unforeseen event can require from three to five years. To create solutions that are sufficient to meet minimum reliability requirements for both the foreseeable and the unforeseen circumstances, the following assumptions have been included as planning considerations:

- Connecticut generation—the unavailability of the following generation, alone or in combination, plus no new major generation additions:
  - Millstone #3 (1,260 MW)
  - Other major area generation (Equivalent demand forced-outage rates are calculated at over 500 MW.[9])
- Rhode Island generation—the unavailability of any of the following units or stations, alone or in combination, plus no new major generation additions:
  - Rhode Island State Energy combined-cycle unit (448 MW)
  - Manchester Street station (357 MW)
  - Brayton Point 115 kV generation (479 MW)
  - Milford Power and Tiverton generation (433 MW)
- Springfield generation—the unavailability of any of the following plants, alone or in combination:
  - Berkshire Power (280 MW)
  - Mount Tom (147 MW)
  - West Springfield station (194 MW)

All these assumptions enable the design of a system that would be responsive to potential events or conditions that limit the resources available to a supply area. The development and selection of options that contemplate such conditions allow for a more robust and flexible system and, ultimately, system upgrades with greater longevity.

Developing these options has been an iterative process. Options that seemed capable of mitigating reliability concerns were formulated and analyzed for compliance with the design criteria and objectives. Additional modifications were formulated as necessary and the options reevaluated. This step was repeated until either a workable option was identified or it became clear that the option was not viable because it would require too many system modifications.

3.2 Assessing the Options

All the system upgrades associated with the four plan components were designed to resolve the reliability concerns for the southern New England transmission system over the projected planning horizon, as identified in the Needs Analysis. The options for the four plan components were evaluated for their potential to improve the reliability and performance of the transmission system, including the following factors:

- Improving the capability to transfer power into and within the load centers in southern New England
- Improving east-to-west and west-to-east transfer capability across New England and within Connecticut
- Eliminating projected line overloads under contingency conditions

[9] An e*quivalent demand forced-outage rate* is the portion of time a unit is in demand but is unavailable because of a forced outage.

- Improving system voltages under contingency conditions
- Decreasing system losses
- Improving system expandability and flexibility

The options also were compared on the basis of the thermal transfer limits across key New England interfaces that would be affected by these improvements. These included the New England–New York interface, the New England East–West interface, the Connecticut Import interface, and the Connecticut East–West interface. Thermal transfer limits are a function of a number of variables, as follows:

- Load levels
- Load distribution
- Generation availability assumptions
- Generation source and sink combinations[10]
- Transmission facility outage assumptions
- Transmission facility equipment ratings
- Phase-angle regulator settings
- Solution techniques

Varying any of these factors produces a range of values for any interface transfer limit. System conditions could exist that restrict transfers below the limits stated. Conversely, system conditions also could allow for even higher transfers. For comparing the transfer-capability improvements resulting from the various options of each component, all thermal transfer limit variables were held constant in this analysis.

The study evaluated the number of times an element is highly loaded (above 90%) under various contingency and dispatch conditions for each of the options within the Interstate component. Similarly, the study compared contingency voltage levels. These performance measures convey the relative strength of each option. The likelihood of each option reducing system losses, which provides both economic and efficiency improvements, also was evaluated.

Limiting the increase in short-circuit duty for areas of the transmission system that may experience future short-circuit constraints is important for developing future generation. Areas that presently contain existing equipment that is close to the short-circuit limit are less likely to attract new generation because of the potential cost for system upgrades that would be required for the generation to interconnect. Therefore, comparing options on the basis of their impact on the short-circuit duty of an area's existing equipment is useful. This analysis did not consider the number of locations where increases may occur but rather only the highest increase at any single location observed on the system.

[10] A *source* point is a point on the transmission system where electric energy is injected, such as an increase in generation. A *sink* point is a point on the transmission system where electric energy is withdrawn, such as a decrease in generation or an increase in load.

The working group also evaluated each option's potential for enhancing system expandability and flexibility. This is a key consideration given that transmission assets typically have lifetimes that exceed 40 years.

Section 4
Interstate Component Options

System studies have extensively examined the existing key transmission paths that interconnect Connecticut, Massachusetts, and Rhode Island. These studies have determined that reinforcing or otherwise modifying existing facilities alone will not bring the system into compliance with applicable reliability criteria and planning standards for the future. The most practical options to meet reliability criteria and simultaneously improve interstate transfer capability and load-serving ability were determined to be adding new 345 kV lines coupled with other reinforcements, as described elsewhere in this report.

Accordingly, all five options for the Interstate component include the addition of new 345 kV lines, together with additional modifications and reinforcements. In general, each of the proposed Interstate options, coupled with the solutions of the three other components, will improve the ability of the SNE bulk transmission system to move power between eastern New England and western New England and enhance transmission security in Connecticut. They also will mitigate area transmission supply concerns for the Springfield and the Rhode Island supply areas and relieve transmission constraints for the transfer of power between eastern Connecticut and western Connecticut.

Each option has been designed such that its general performance meets the design criteria established for the reliability of the SNE system. However, some salient characteristics related to such areas of concern as transfer capabilities, line loadings, voltage levels, and expandability are unique to each solution.

This section summarizes the five options of the Interstate component and each option's potential to improve system performance and reliability. The factors used in evaluating each option are discussed and their individual characteristics compared in terms of their impact on other system characteristics. Detailed listings of the upgrades associated with each option are included in Appendix A.

4.1 Process to Develop and Eliminate Interstate Options

During an initial study session, 17 Interstate options were developed for discussion. The options identified as impractical, infeasible, or likely poor performers were eliminated over time, and new options were added to the mix. One of three original HVDC options was modified and reconsidered. Fourteen options were retained for further testing, which eventually were reduced to the five remaining options. The review process is depicted in Table 4-1, which also summarizes the 14 options and the reasoning used to either eliminate or retain them.

Table 4-1
The Process to Develop and Eliminate the Interstate Options

Original 345 kV Interstate Options	Disposition	Final Top 5 Options
1 Card–Lake Road	This option was eliminated because it proved to be only a partial solution without adequate increases in interstate transfer capability.	
2 Card–Lake Road–Sherman Road		
3 Card–Lake Road–Sherman Road–Millbury	This option was eliminated because of performance issues compared with option 4.	
4 Card–Lake Road–West Farnum–Millbury		4. Card–Lake Road–West Farnum–Millbury (designated Option A)
5 Card–Lake Road–Sherman Road–West Farnum–Millbury	This option was eliminated because of performance issues compared with option 4.	
6 Millbury–Sherman Road–West Farnum–Kent County–Montville		6. Millbury–Sherman Road–West Farnum–Kent County–Montville (designated Option B)
7 Card–Lake Road–Carpenter Hill	This option was eliminated because it proved to be only a partial solution without adequate increases in interstate transfer capability.	
8 Montville–Brayton Point	This option was eliminated because of performance issues. (Constructability issues also were raised.)	
9 Manchester–Carpenter Hill	This option was eliminated because it proved to be only a partial solution without adequate increases in interstate transfer capability.	
10 Manchester–Carpenter Hill–Millbury		10. Manchester–Carpenter Hill–Millbury (designated Option C)
12 North Bloomfield–Agawam–Ludlow–Carpenter Hill–Millbury	Options 12 and 12a were combined into one option: option 12.	12 Ludlow–Carpenter Hill–Millbury, plus separation of existing 395 line (designated Option D)
12a North Bloomfield–Agawam–Ludlow–Carpenter Hill–Millbury, plus separation of existing 395 line (Ludlow–Manchester–North Bloomfield)		
13 Montville–Kent County–Manchester–Brayton Point	This option was eliminated because of performance issues. (Constructability issues also were raised.)	
14 Ludlow–Agawam–North Bloomfield	This option became part of the Springfield Component analysis.	
	DC–Millbury–Southington (added)	DC–Millbury–Southington (designated Option E)

The five final Interstate options are as follows:

- **Interstate Option A**—a new 345 kV line from the Millbury, MA, substation to the West Farnum, RI, substation and then to the Lake Road, CT, substation, terminating at the Card, CT, substation
- **Interstate Option B**—a new 345 kV line from the West Farnum substation to the Kent County, RI, substation and then to the Montville, CT, substation. (The line from the West Farnum substation to the Kent County substation is part of the Rhode Island component.)
- **Interstate Option C**—a new 345 kV line from the Millbury substation to the Carpenter Hill, MA, substation, terminating at the Manchester, CT, substation
- **Interstate Option D**—a new 345 kV line from the Millbury substation to the Carpenter Hill substation to the Ludlow, MA, substation to the Agawam, MA, substation to the North Bloomfield, CT, substation. (The line from the Ludlow substation to the Agawam substation to the North Bloomfield substation is part of the Springfield component.)
- **Interstate Option E**—a new 1,200 MW high-voltage direct-current (HVDC) tie between the Millbury substation and the Southington, CT, substation

4.2 Description and Performance of the 345 kV Interstate Options

This section describes each of the interstate options in further detail. One-line diagrams of the 345 kV transmission upgrades for each option are included. These figures do not show associated 115 kV system improvements; however, Appendix A contains a detailed description of all the upgrades included in each option. For simplicity, these figures also do not show some intermediate 345 kV substations, such as Barbour Hill and Killingly.

Each section also contains a table summarizing how the option performed with respect to the assessment process as described in Section 3.2.

4.2.1 Interstate Option A—Millbury to West Farnum to Lake Road to Card 345 kV Major Upgrades

This option adds a new 345 kV line that connects Millbury to West Farnum and then continues on to connect West Farnum to Card, with an intermediate connection at Lake Road. The reconductoring of the portion of the Sherman Road to Lake Road 345 kV line that physically is in Rhode Island also is part of this option.

Figure 4-1 depicts the major upgrades that comprise Interstate Option A. Table 4-2 summarizes the assessment results for this option.

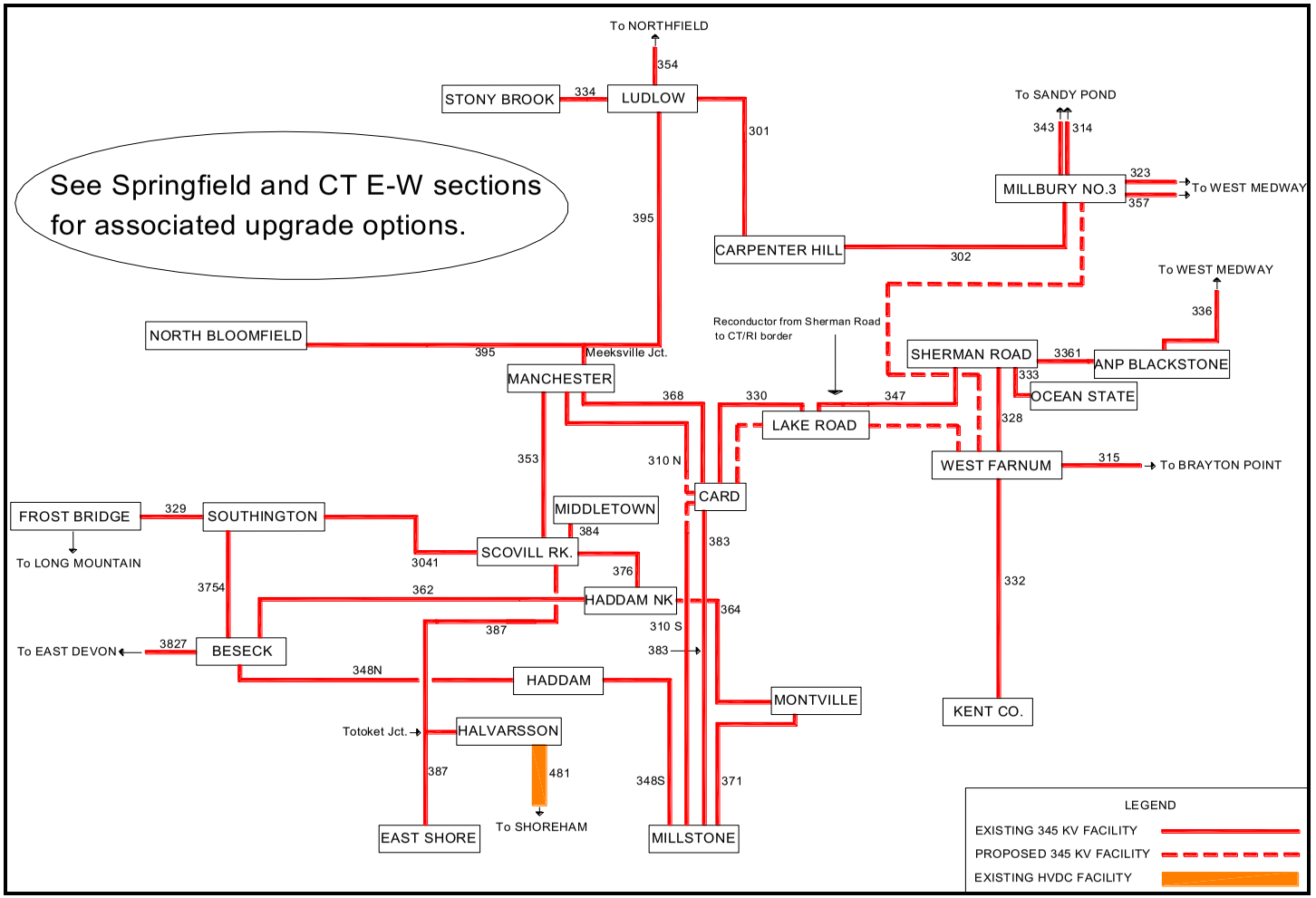

Figure 4-1: Interstate Option A—Millbury to West Farnum to Lake Road to Card 345 kV major upgrades.

Table 4-2
System Performance Factors of Interstate Option A

System Performance Factors	Results	Comments[a]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details.
Improving New England east–west transfer capability	Increases capability by 1,376 MW (to 4,174 MW total)	Ranked third
Improving Connecticut's import capability	N-1 import capability increases by 1,766 MW (to 4,443 total); N-1-1 import capability increases by 1,591 MW (to 2,783 MW)	N-1 limit tied for third among the options; N-1-1 ranked second
Eliminating high line loadings under contingencies (2016)	46 high line loadings total; 3 high all-lines-in loading; 43 high line-out loadings	Ranked first—lowest number of high loadings
Improving system voltages during contingencies (2016)	6 borderline voltage cases following N-1 contingencies	Ranked first—-lowest number of borderline voltage issues
Decreasing system losses	56 MW reduction in system losses compared with pre-project system	Ranked fourth
Decreasing short-circuit duty	8.9% increase on worst location	Ranked fourth
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.2 Interstate Option B—West Farnum to Kent County to Montville 345 kV Major Upgrades

Interstate Option B extends the existing 345 kV line from the West Farnum station to the Kent County station into Connecticut to Montville station, providing a common supply path for both Rhode Island and Connecticut. This option also includes the reconductoring of the 345 kV line from Millbury through Carpenter Hill to Ludlow and the 345 kV line from ANP Blackstone (MA) to Sherman Road.

Figure 4-2 depicts the major upgrades that comprise Interstate Option B. Table 4-3 summarizes the assessment results for this option.

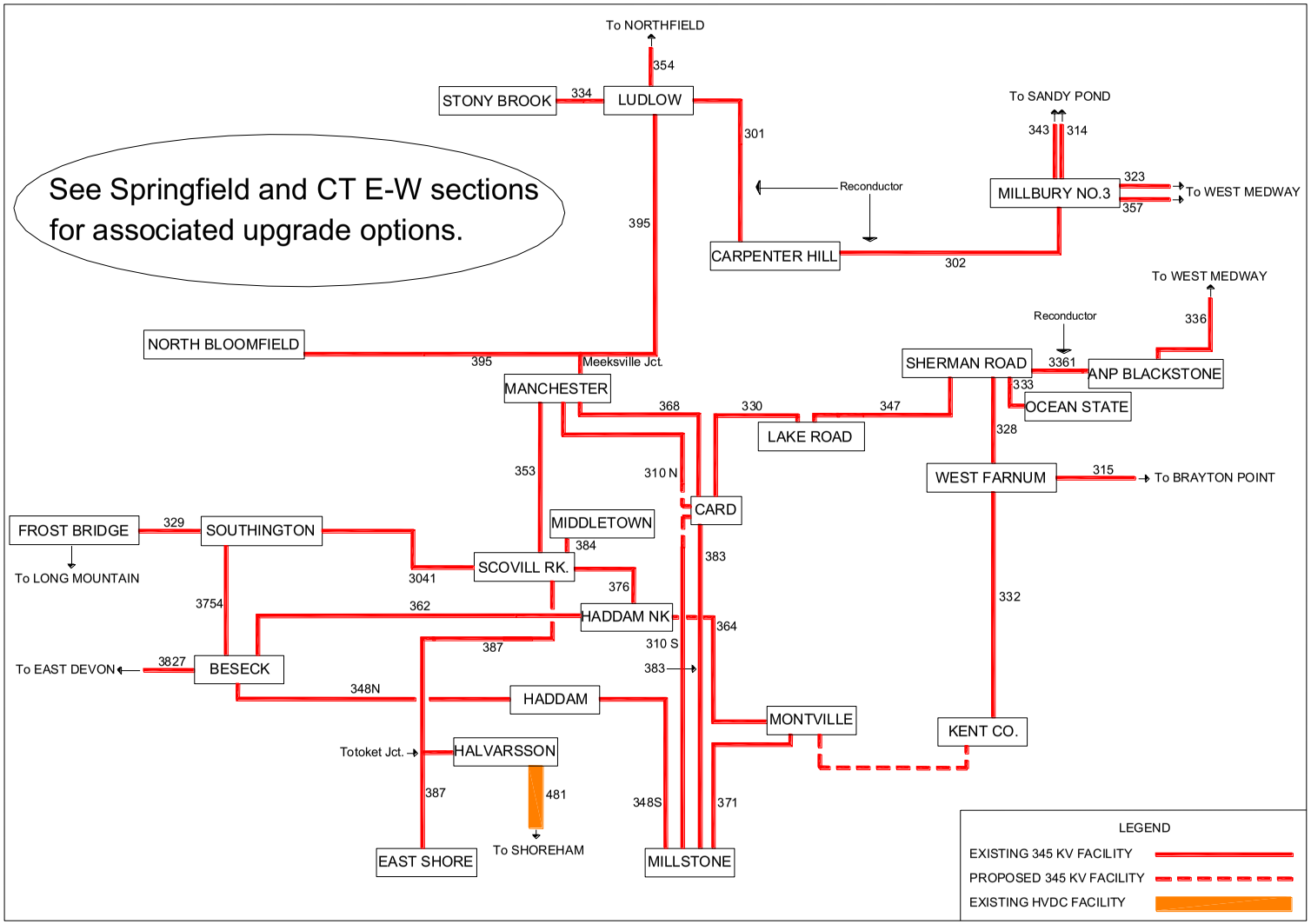

Figure 4-2: Interstate Option B—West Farnum to Kent County to Montville 345 kV major upgrades.

Table 4-3
System Performance Factors of Interstate Option B

System Performance Factors	Results	Comments[a]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,198 MW (to 3,996 MW total)	Ranked fifth
Improving Connecticut's import capability	N-1 import capability increases by 1,298 MW (to 3,975 total); N-1-1 import capability increases by 1,347 MW (to 2,539 MW)	N-1 limit ranked fifth among the options; N-1-1 ranked fourth
Eliminating high line loadings under contingencies (2016)	118 high line loadings total; 21 high all-lines-in loading; 97 high line-out loadings	Ranked fifth—highest number of high loadings
Improving system voltages during contingencies (2016)	29 borderline voltage cases following N-1 contingencies	Ranked fifth—highest number of borderline voltage issues
Decreasing system losses	55 MW reduction in system losses compared with pre-project system	Ranked fifth
Decreasing short-circuit duty	5.3% increase on worst location	Ranked second
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.3 Interstate Option C—Millbury to Carpenter Hill to Manchester 345 kV Major Upgrades

Interstate Option C provides a new 345 kV line from Millbury through Carpenter Hill to Manchester. In addition, a new 345 kV line from Sherman Road to West Farnum is required.

Figure 4-3 depicts the major upgrades that comprise Interstate Option C. Table 4-4 summarizes the assessment results for this option.

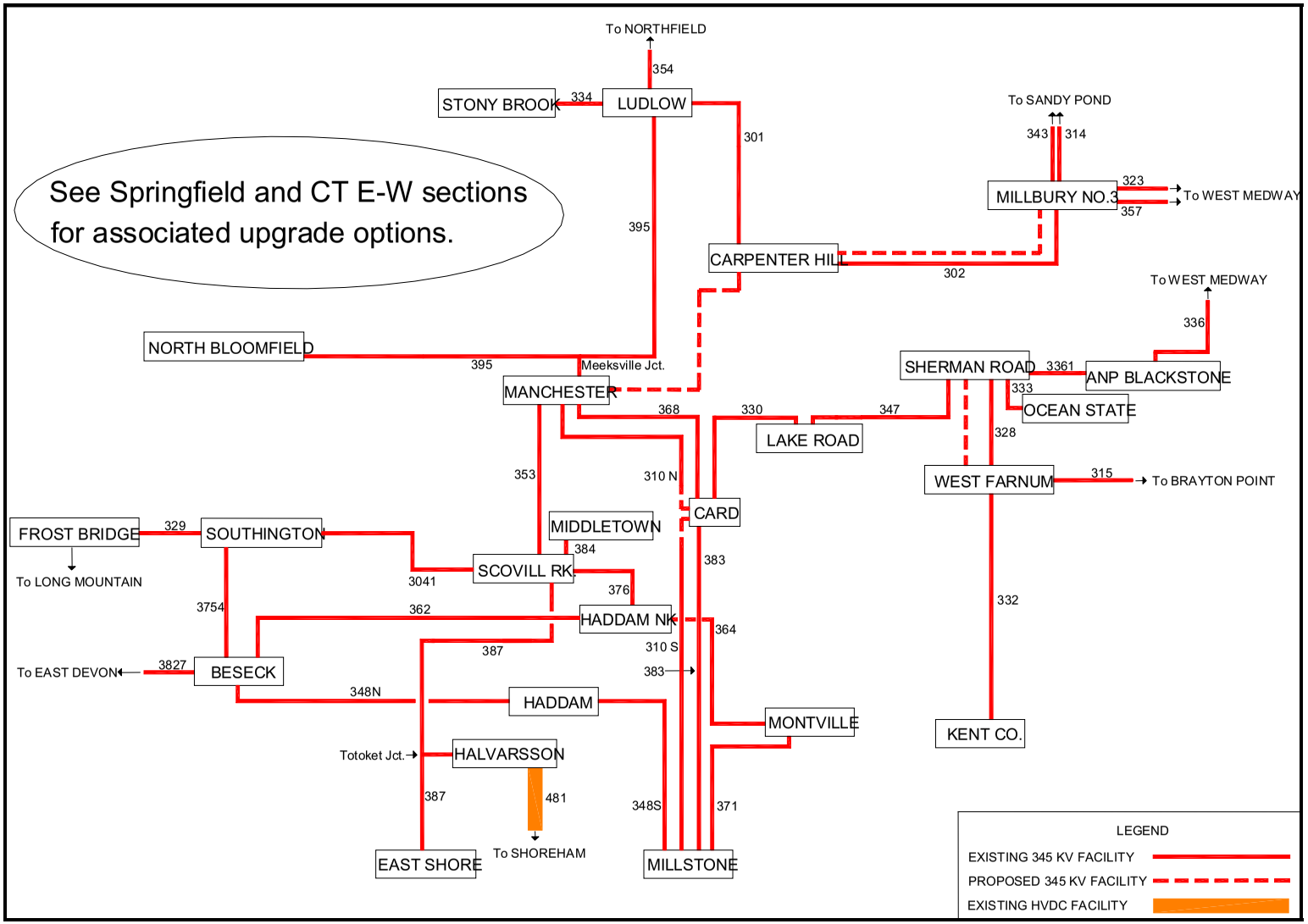

Figure 4-3: Interstate Option C—Millbury to Carpenter Hill to Manchester major 345 kV upgrades.

Table 4-4
System Performance Factors of Interstate Option C

System Performance Factors	Results	Comments[a]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,293 MW (to 4,091 MW total)	Ranked fourth
Improving Connecticut's import capability	N-1 import capability increases by 1,766 MW (to 4,443 total); N-1-1 import capability increases by 1,535 MW (to 2,727 MW)	N-1 limit tied for third among the options; N-1-1 ranked third
Eliminating high line loadings under contingencies (2016)	73 high line loadings total; 6 high all-lines-in loading; 67 high line-out loadings	Ranked second
Improving system voltages during contingencies (2016)	8 borderline voltage cases following N-1 contingencies	Ranked second
Decreasing system losses	69 MW reduction in system losses compared with pre-project system	Ranked first
Decreasing short-circuit duty	9.3% increase on worst location	Ranked fifth
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.4 Interstate Option D—Millbury to Carpenter Hill to Ludlow 345 kV Major Upgrades

Interstate Option D builds a new 345 kV line from Millbury to Carpenter Hill to Ludlow and takes advantage of the proposed Springfield area improvements to complete the interstate connection. It also requires uprating of the 345 kV lines from Ludlow to Manchester and from Sherman Road to the state border. A new line from Sherman Road to West Farnum also is required.

Figure 4-4 depicts the major upgrades that comprise Interstate Option D. Table 4-5 summarizes the assessment results for this option.

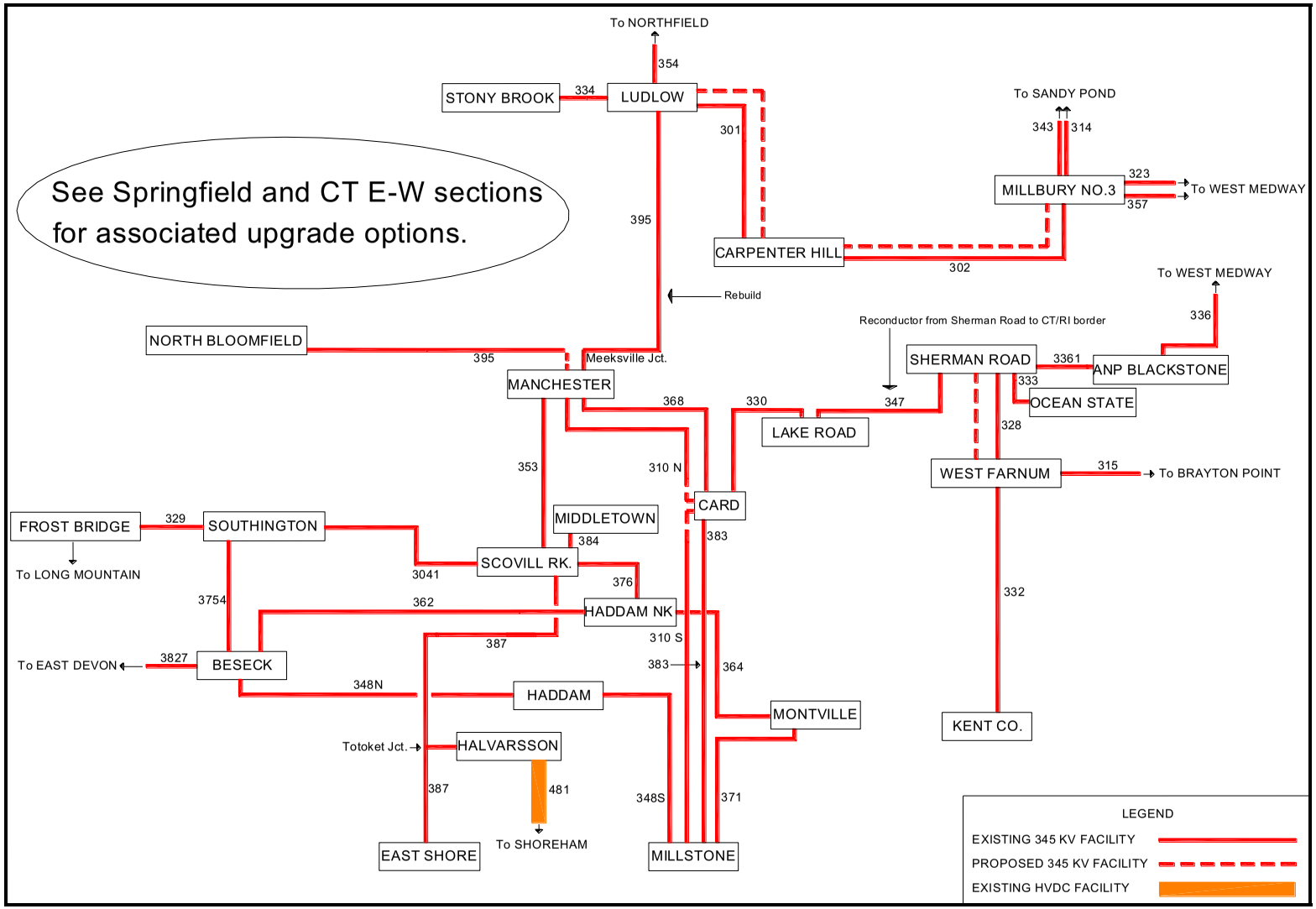

Figure 4-4: Interstate Option D—Millbury to Carpenter Hill to Ludlow major 345 kV upgrades.

Table 4-5
System Performance Factors of Interstate Option D

System Performance Factors	Results	Comments[(a)]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,853 MW (to 4,651 MW total)	Ranked first
Improving Connecticut's import capability	N-1 import capability increases by 1,903 MW (to 4,580 total); N-1-1 import capability increases by 1,262 MW (to 2,454 MW)	N-1 limit tied for second among the options; N-1-1 ranked fifth
Eliminating high line loadings under contingencies (2016)	76 high line loadings total; 5 high all-lines-in loading; 71 high line-out loadings	Ranked third
Improving system voltages during contingencies (2016)	9 borderline voltage cases following N-1 contingencies	Ranked third
Decreasing system losses	57 MW reduction in system losses compared with pre-project system	Ranked third
Decreasing short-circuit duty	7.5% increase on worst location	Ranked second
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.5 Interstate Option E—Millbury to Southington High Voltage DC Major Upgrades

Interstate Option E involves the installation of HVDC facilities and provides an independent, controllable supply path through the addition of a bipole HVDC line from Millbury to Southington. A new 345 kV line from Sherman Road to West Farnum also is required in connection with Interstate Option E.

Figure 4-5 depicts the major upgrades that comprise Interstate Option E. Table 4-6 summarizes the assessment results for this option.

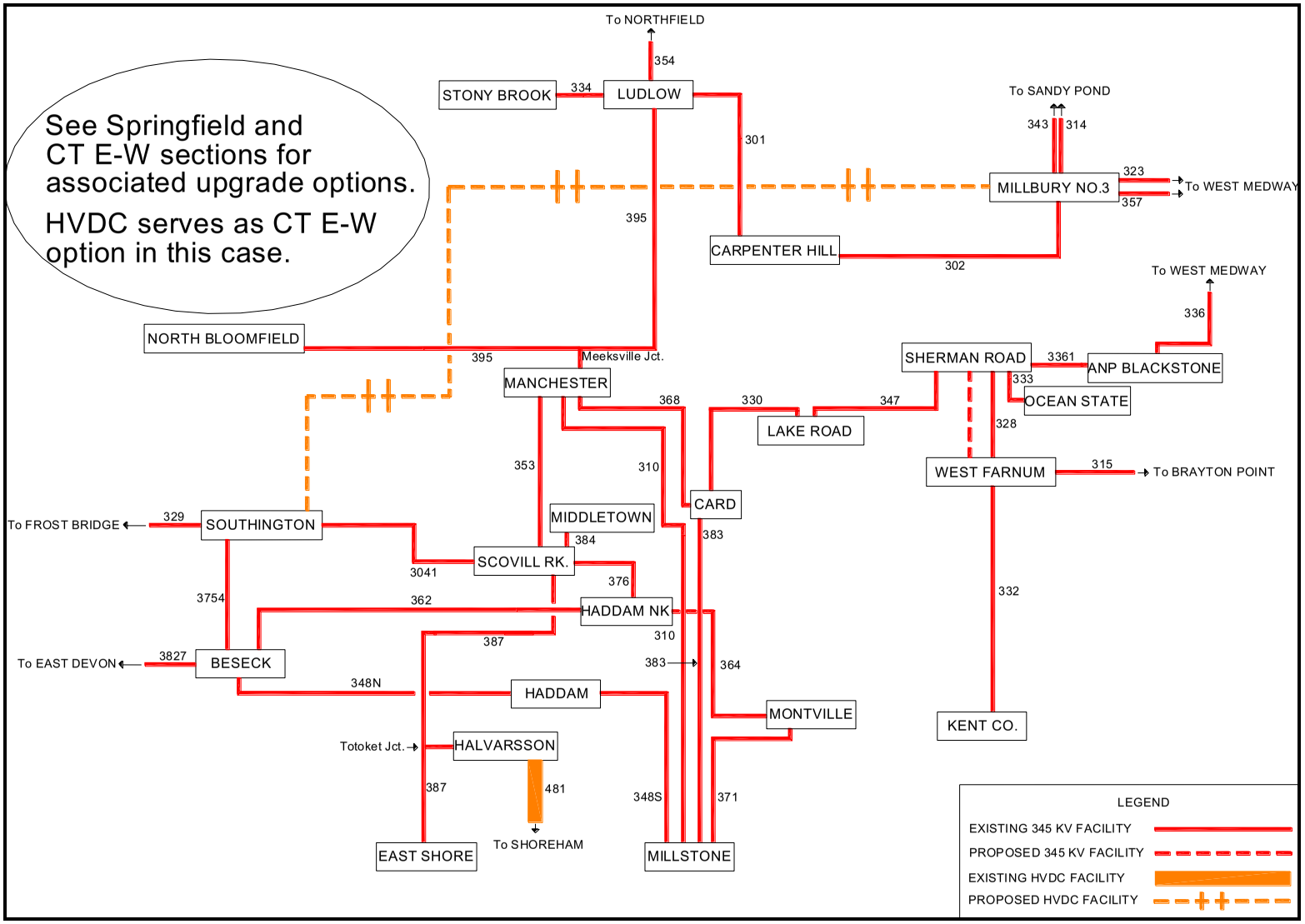

Figure 4-5: Interstate Option E—Millbury to Southington HVDC line.

Table 4-6
System Performance Factors of Interstate Option E

System Performance Factors	Results	Comments[(a)]
Effect on transfer capability between New York and New England	This option was originally more limiting on NY to NE. However, the 2010 western MA improvements eliminate that limiting condition.	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,580 MW (to 4,378 MW total)	Ranked second
Improving Connecticut's import capability	N-1 import capability increases by 1,974 MW (to 4,651 total); N-1-1 import capability increases by 1,621 MW (to 2,813 MW)	N-1 limit ranked first among the options; N-1-1 ranked first
Eliminating high line loadings under contingencies (2016)	100 high line loadings total; 18 high all-lines-in loading; 82 high line-out loadings	Ranked fourth
Improving system voltages during contingencies (2016)	23 borderline voltage cases following N-1 contingencies	Ranked fourth
Decreasing system losses	68/33 MW (conventional DC/DC light) reduction in system losses compared with pre-project system	Ranked second/fifth
Decreasing short-circuit duty	7.5% increase on worst location	Ranked first
Improving system expandability	No	DC system not easily expandable; an additional converter station would be needed for adding a generator or substation

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.3 Comparison of Interstate Options

Each of the five options of the Interstate component fully addresses all the reliability concerns for the SNE bulk transmission system over the projected planning horizon, although each has its own set of characteristics with respect to system performance improvements. This section compares the improvements that each option could contribute to system performance for the reliability-based characteristics important for the southern New England system and includes comparison tables for several of the electrical performance factors.

Target values shown in these tables are based on either the project design objectives or the minimum requirements needed to satisfy the reliability requirements for the system.

Table 4-7 is a master comparison table that includes all the factors. Each factor is discussed in detail.

Table 4-7
Comparison of Interstate Options

Interstate Options and Needs	Pre-Project System	Option A	Option B	Option C	Option D	Option E
New England east–west transfer capability (MW)	2,798	4,174	3,996	4,091	4,651	4,378
CT import: N-1 (MW)	2,677	4,443	3,975	4,443	4,580	4,651
CT import: N-1-1 (MW)	1,192	2,783	2,539	2,727	2,454	2,813
Number of 'high' 'all-lines-in' loadings in 2016	NA	3	21	6	5	18
Number of 'high' 'line-out' loadings in 2016	NA	43	97	67	71	82
Total high loadings	NA	46	118	73	76	100
Number of borderline voltage cases	NA	6	29	8	9	23
Decrease in New England system losses (MW)	NA	56	55	69	57	68 (conv)/ 33 (light)
Short-circuit impact (percent increase)	NA	8.9	5.3	9.3	7.5	3.8

4.3.1 New England East–West Transfer Capability

The improvement in New England east–west transfer capability ranged from a low of about 1,200 MW for Interstate Option B to a high of about 1,900 MW for Option D. Table 4-8 shows the incremental improvement for each of the options for N-1 conditions.

Table 4-8
New England East–West 2012 N-1 Transfer Capability Improvement

Interstate Option	New England East–West Transfer Capability (MW)	Incremental Increase in New England East–West Transfer Capability (MW)
Base	2,798	
A	4,174	1,376
B	3,996	1,198
C	4,091	1,293
D	4,651	1,853
E	4,378	1,580

4.3.2 Connecticut Import Improvement

The results for improving the import capability into the Connecticut area show that each option more than satisfies the year 2012 planning horizon requirements for area supply, although each option differs in the amount of improvement it could provide to the system.

Table 4-9 and Table 4-10 show the target improvement level, the import level, and the incremental improvement for each of the options for both N-1 and N-1-1 conditions, respectively.

Table 4-9
Connecticut 2012 N-1 Import Comparison

Interstate Option	CT Import: N-1 (MW)	Incremental Improvement in CT Import: N-1 (MW)
Base	2,677	
Target[(a)]	3,574	923
A	4,443	1,766
B	3,975	1,298
C	4,443	1,766
D	4,580	1,903
E	4,651	1,974

(a) The target of 3,574 MW is the result of adding the year 2012 N-1 shortage of 1,074 MW (from Table 9-3 in RSP06) to the existing N-1 limit of 2,500 MW.

Table 4-10
Connecticut 2012 N-1-1 Import Comparison

Interstate Option	CT Import: N-1-1 (MW)	Incremental Improvement in CT Import: N-1-1 (MW)
Base	1,192	
Target[(a)]	2,374	1,308
A	2,783	1,591
B	2,539	1,347
C	2,727	1,535
D	2,454	1,262
E	2,813	1,621

(a) The target of 2,374 MW is the result of adding the year 2012 N-1-1 shortage of 1,154 MW (from table 9-3 in RSP06) to the existing N-1-1 limit of 1,220 MW.

The target is a 923 MW increase for N-1 and a 1,308 MW increase for N-1-1 Connecticut-import capability.

Interstate Option A provides an improvement of almost 1,800 MW over the existing N-1 Connecticut-import capability. The N-1-1 improvement under this option for the Connecticut-import capability is about 1,600 MW, one of the highest.

Interstate Option B provides the least improvement in Connecticut-import capability, increasing N-1 imports by about 1,300 MW, which is almost 700 MW less than the option with the greatest improvement. The N-1-1 import capability improvement for this option also is about 1,300 MW, one of the lowest.

Interstate Option C provides an improvement in N-1 and N-1-1 import capability similar to Option A.

Interstate Option D provides an improvement of N-1 import capability at about 1,900 MW, one of the highest. However, the N-1-1 import capability improvement for Option D of less than 1,300 MW is the lowest of all options.

Interstate Option E (HVDC) provides the greatest level of N-1 import improvement of all options studied at about 2,000 MW. The N-1-1 import capability improvement for this option is about 1,600 MW, also the highest among all options.

4.3.3 Line Loading during Contingencies

All five Interstate options eliminate transmission element overloads that occur for N-1 or N-1-1 contingency conditions. A comparison of the number of line loadings above 90%-of-rating following such events suggests the amount of additional transmission capacity margin each option could provide. Alternatives with fewer high loadings indicate more robust plans.

These results are displayed in Table 4-11. In total, Interstate Options A, C, and D performed somewhat better than the other two options.

Table 4-11
Comparison of Line Loadings in 2016

Interstate Option	Number of High "All-Lines-In" Loadings	Number of High "Line-Out" Loadings	Total Number of Line Loadings
A	3	43	46
B	21	97	118
C	6	67	73
D	5	71	76
E	18	82	100

4.3.4 System Voltages during Contingencies

Similar to the number of contingency high line loadings, the lower the number of borderline contingency voltage cases that occur in an option might also suggest that it is a more robust option. In general, Interstate Options A, C, and D performed somewhat better than the other options. The voltage results appear in Table 4-12 and reflect the number of cases of low or high equipment voltages during contingency events for each of the Interstate options.

Table 4-12
Comparison of Voltages during Disturbances in 2016

Interstate Option	Number of Borderline Voltage Cases
A	6
B	29
C	8
D	9
E	23

4.3.5 System Losses

The Interstate options varied in their ability to reduce system losses from about 55 MW to as high as 69 MW, as shown in Table 4-13.

Table 4-13
Comparison of System Loss Reductions

Interstate Option	Decrease in New England System Losses (MW)
A	56
B	55
C (assuming the Route I-84 path)	69
D	57
E	68 (conventional DC) 33 (DC light)

4.3.6 Stability Screening Analysis

A stability screening analysis was performed to determine if any options exhibited undesirable transient behavior following a fault condition. Generally, all the options improved system performance; however, some findings are worth noting.

If the West Medway South bus were out of service, only Option A would be able to mitigate system instability for a three-phase fault on West Medway bus B (stuck breaker 104). Similarly, only Option A would prevent a Lake Road trip if the 330 line (Lake Road–Card 345 kV) were out of service and the 347 line (Sherman Road–Killingly 345 kV) had a fault. This also would hold true if the fault were on the 330 line and the 347 line were out of service. Also under Option A, Lake Road would not trip if the 347 line were out of service and the 383 line (Millstone-Card 345 kV) at Card had a three-phase fault that resulted in a 3T stuck-breaker condition (the 383 line, the 330 line, and the autotransformer).

Option B is the only option that does not mitigate a Lake Road and Ocean States Power trip for the condition where the 330 line is out of service and Sherman Road has a subsequent stuck breaker (stuck breaker 142, which takes the 3361 line from Sherman Road to ANP Blackstone and the 328 line from Sherman Road to West Farnum out of service). This indicates the need to add a second Card–Lake Road 345 kV line or a second West Farnum–Sherman Road 345 kV line or to eliminate the possible stuck-breaker condition.

4.3.7 Short-Circuit Duty Impacts

Based on a high-level approximation of the percent increase in short-circuit duty at constrained locations, Interstate Option E showed the lowest increase in fault duty compared with the other options, and Option C showed the greatest increase. The differences in these results, which are displayed in Table 4-14, do not appear to be significant and may not be a material factor for selecting a preferred alternative. However, the testing did serve as an effective screening tool for determining whether any options were fatally flawed. Once the preferred selection is made and the associated short-circuit studies are completed, more clearly determining any significant impacts will be possible.

Table 4-14
Comparison of Short-Circuit Impacts

Interstate Option	Short Circuit Impact (percent increase)
A	8.9
B	5.3
C	9.3
D	7.5
E	3.8

4.3.8 System Expandability and Flexibility

In terms of future system expandability and system flexibility, all four AC options offer much more expandability than the DC option. DC systems historically have been used for relatively long, point-to-point type delivery and have not been integrated into the center of AC systems.

The only action required to increase the capacity of an AC line might be a simple reconductoring; increasing the capacity of a DC system would require, at a minimum, either major converter additions or converter change-outs at each end of the line. Adding a new generator midpoint to a DC line would most likely require a new converter station, possibly with two new converters. Similarly, the need to connect to a lower voltage system, either to provide voltage support or eliminate thermal overloads, would be equally difficult.

4.3.9 Impact of Improved Connecticut Transfer Capability on the New York–New England Interface

This section presents the results of a parallel transfer analysis conducted by the working group that evaluated the impact of each SNE transmission reinforcement upgrade option on the ability of the New England bulk transmission system to export to and import from New York. The intent was to determine whether any option particularly enhances or has an adverse impact on this capability.

In the simulation analysis performed by the working group, generation in New York was chosen to aggravate, as much as possible, a potential clockwise loop flow through New England. In this analysis, generation was scaled up at Gilboa (NY) (near the Berkshire–Alps 345 kV tie with New England) and scaled down at Bowline (NY) (south of Long Mountain to the Pleasant Valley 345 kV tie with New England). As most New York generation was on line in the base case, Roseton (NY) generation had to be scaled up to provide coverage for New York exports, despite its beneficial impact on countering any clockwise loop flow.

Generation in eastern New England was chosen to represent a homogeneous source or sink point across all three eastern regions: Maine, Boston, and Southeast Massachusetts. Because most existing generation was on line in the base case, some older retired units had to be scaled up to provide coverage for eastern New England exports.

The main transfer analysis was first performed as described in the preceding paragraph. The following sensitivity analyses were then performed:

- Replacing output from Millennium with Seabrook
- Replacing output from Mystic with West Springfield and Berkshire Power
- Changing the New York source and sink subsystems to represent a "best-case loop-flow scenario." Generation was scaled up at Bowline and scaled down at Bethlehem (Albany area) and Athens.

The results of the analysis show the following:

- Except for Option E, the HVDC option, all options either maintain the transfer capability with New York or improve it.
- Except for the Option E, the HVDC option, all options perform similarly.
- The HVDC option marginally limits imports from New York. However, the transfer-response factor on the limiting element is low (5.9%), and the limiting element (Bear Swamp autotransformer) is a known issue, which will be fixed as part of the central and western Massachusetts upgrades.
- In all instances, exports to New York are limited by the overload of the E131 line from Bear Swamp to the E131 tap. This limiting element also is a known issue, which will also be fixed as part of the central and western Massachusetts upgrades.
- None of the sensitivity runs identified any significant difference in performance among Options A, B, C, or D.

4.3.10 Input from Operations Personnel

The working group presented the details of the Interstate options to Operations personnel from ISO New England, CONVEX, and REMVEC at a joint Planning-Operations meeting. The operators, who were not presented with any information concerning cost, environmental, or routing impacts, preferred Option A for the following reasons:

- It best alleviates the angular difference between Rhode Island and Connecticut, thus removing all the operating complexities related to taking lines out of service in the area.
- Alleviating the angular differences will eliminate the need for the SPS that takes the Lake Road units out of service for certain contingencies to avoid possible shaft damage.
- The new Killingly substation serving eastern Connecticut can receive support from the rest of New England even with the 347 line out of service.

4.4 Interstate Component Conclusion

The comparison of the Interstate options indicates that all options meet the design objectives for satisfying the reliability criteria for the projected New England transmission system. Each option offers different advantages and disadvantages compared with the other options in terms of system performance. These differences will be combined with cost, siting, and construction-related factors to determine the optimal solution for the identified needs.

Section 5
Rhode Island Component Options

As discussed in Section 2, Rhode Island now is overly dependent on limited transmission lines or autotransformers to serve its needs, which could result in thermal overloads and voltage problems during contingency conditions. Causal factors include high load growth (especially in southern Rhode Island and the coastal communities), unit availability, and planned and unplanned transmission outages. The Rhode Island 115 kV system is constrained when a 345 kV line is out of service; an outage of any one of a number of 345 kV transmission lines results in limits to power transfer capability into Rhode Island. For line-out conditions, the next critical contingency involving the loss of a 345/115 kV autotransformer or a second 345 kV line would result in numerous thermal and voltage violations.

To address the identified reliability issues, three new 345 kV facilities were found to be necessary to support the Greater Rhode Island area and to better integrate it with the rest of the New England system. Generally, these improvements would bring a third source into Rhode Island. **This sentence has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.** The improvements also would extend a second source into the load center in southern Rhode Island and add a new source into a 115 kV load center located just east of the Rhode Island border. Several options were evaluated for each of these facilities, which are described in the following sections.

5.1 Rhode Island Recommendations

Figure 5-1 displays the recommended improvements for Rhode Island to increase the ability to move power into West Farnum, creating a stronger tie to the rest of New England; extend another 345 kV path to the southern part of the state; and add a new 345 kV injection point into the load center from the east.

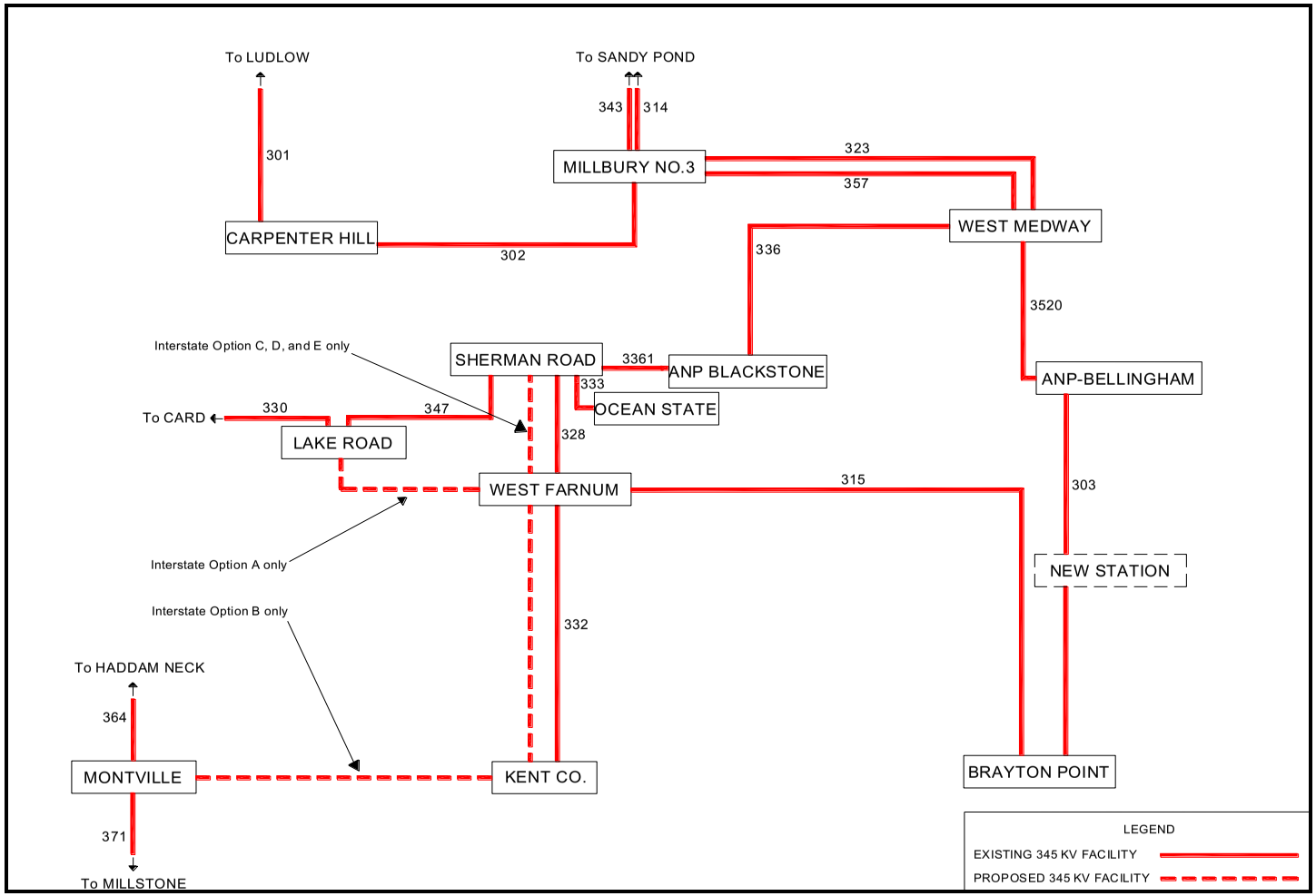

Figure 5-1: Rhode Island upgrades.

5.2 Overview of Rhode Island Options

This section further describes the three areas of Rhode Island needing improvement and the options that were considered for each. The solutions to these three problems are as follows:

- A new 345 kV line from West Farnum to Kent County (recommended with all Interstate options over two other options)
- A new 345 kV line from Sherman Road to West Farnum (recommended with Interstate Options C, D, and E but not needed for Interstate Option A and which brings new lines in from Lake Road, CT, and Millbury, MA) or Interstate Option B (which brings a new line in from Montville, CT)
- A new 345/115 kV substation and transformer (recommended with all Interstate options over one other option)

5.2.1 New 345 kV Line from West Farnum to Kent County (Recommended with All Interstate Options)

A new 345 kV line from West Farnum to Kent County is needed to support the southwestern Rhode Island area if the existing 345 kV line (line 332) is lost, especially if either the FPLE Rise or Manchester Street generation plant is out of service. This recommended line would be critical when line 332 is out of service and an additional key southwestern Rhode Island element is lost (an N-1-1 contingency condition).

Several alternatives to this recommendation were developed, analyzed, and subsequently eliminated. One option was to add a new 345 kV line from Brayton Point to Franklin Square to Kent County. This option was a part of an original Interstate option that the working group is no longer pursuing; the full 345 kV portion of this option was Montville–Kent County–Hartford Ave.–Franklin Square–Brayton Point. This option attempted to resolve some of the transmission bottlenecks by interconnecting the three Greater Rhode Island stations of Brayton Point, Hartford Avenue, and Kent County with a new 345 kV line. Other modifications associated with this option follow:

- Convert the E105 and F106 115 kV cables from Hartford Ave. to Franklin Square to a single 345 kV cable
- Remove the 115 kV W4/K15 and X3 lines and move the Swansea substation to the E-183E line (to make space available for the new 345kV line)
- Feed all of Phillipsdale from E183W (also to make space for the new 345 kV line)

The analysis showed that this option tended to push too much power from Brayton Point to West Farnum and Kent County and thus heavily overloaded transmission system elements in Rhode Island. For certain contingencies under some dispatch scenarios, very low voltages were observed on the Rhode Island 115 kV system that would be difficult to mitigate. Additional 345 kV lines and 345/115 kV transformers (along with significant 115 kV upgrades) would be required for second-contingency conditions. As a result, the working group concluded that these improvements do not provide a viable option compared with the recommended second 345 kV line between West Farnum and Kent County.

Another option developed and analyzed for the Rhode Island component was to add two new 115 kV cables from Franklin Square to Sockanosset. Although these cables strengthen the 115 kV

transmission system that connects the Providence area to southwestern Rhode Island, this option does not perform as well under N-1-1 (line-out) system conditions. When the existing 345 kV line from West Farnum to Kent County (line 332) is out of service, various second contingencies cause significant 345/115 kV transformer and 115 kV line overloads, along with very low 115 kV voltages. The working group concluded that these two 115 kV cables do not provide a viable option compared with the second 345 kV line between West Farnum and Kent County.

5.2.2 New 345 kV Line from Sherman Road to West Farnum (Recommended with Interstate Options C, D, E)

A new 345 kV line into Rhode Island is needed to respond to the contingency condition when both line 328 (from West Farnum to Sherman Road) and line 315 (from Brayton Point to West Farnum) are out of service. In the case of Interstate Options C, D, and E, this second-contingency condition would leave all of Rhode Island without a 345 kV connection and could result in very low voltages or voltage collapse for certain dispatch scenarios.

For Interstate Option A (Lake Road to West Farnum and Millbury to West Farnum) and Interstate Option B (Montville to Kent County), this new 345 kV line segment from Sherman Road to West Farnum is not needed because Rhode Island second-contingency support is afforded by the Interstate options themselves.

5.2.3 New 345/115 kV Substation and Transformer (Recommended with All Interstate Options)

The working group also recommends that a new 345/115 kV substation and transformer be located about 1.5 miles south of the existing South Wrentham substation. This new substation will interconnect the 345 kV 303 line and the 115 kV C-181 and D-182 lines and provide transformation from 345 kV to 115 kV. This substation will off-load the existing Brayton Point 3A/3B transformer pair and also eliminate 115 kV contingency low-voltage conditions in the surrounding area of this new substation.

One option developed for this aspect of the Rhode Island component was to add a new 345/115 kV transformer at Brayton Point substation. This transformer would off-load the existing Brayton Point 3A/3B transformer pair, but it would not eliminate the 115 kV contingency low-voltage conditions in the area surrounding South Wrentham substation. The working group also found that the addition of a 345/115 kV transformer at Brayton Point would increase the 115 kV fault current to a value above the 63 kA rating of the existing Brayton Point 115 kV breakers. (The combination of the additional 345/115 kV transformer at Brayton Point and a proposed 115 kV line from Brayton Point substation to Somerset substation—proposed as a part of a separate study of the Somerset Area—would raise the 115 kV fault current above 63 kA.)

Appendix A contains a full list of all the recommended Greater Rhode Island area upgrades.

5.3 Rhode Island Component Conclusion

The recommended items for the Rhode Island component (along with the additional Rhode Island area upgrades listed in Appendix A) will fully address the Rhode Island area reliability issues and coordinate with the three other component upgrades.

Section 6
Connecticut East–West Component Options

This section presents the three final options for the Connecticut East–West component, as follows, and compares the transfer improvements for each option relative to each of the Interstate options:

- **Connecticut East–West Option A—**a 345 kV line from Manchester to Southington
- **Connecticut East–West Option B—**a 345 kV line from Manchester to Scovill Rock with a tap to the New Berlin 345 kV substation
- **Connecticut East–West Option C—**a 345 kV line from North Bloomfield to Frost Bridge

As discussed in Section 2, the ability to move power into Connecticut currently is limited and could eventually result in the bulk transmission system's inability to serve load under many probable system conditions. Connecticut-area power-transfer capabilities will not meet the area's requirements as early as 2009. If improvements are not made by 2016, the deficiency for this area under "generator unavailability conditions" (i.e., when the largest unit plus a historical average amount of other generation is out-of-service) and under N-1 conditions is expected to be greater than 1,500 MW, assuming a transfer limit of 2,500 MW and no new capacity additions. On the basis of planning assumptions that added 500 MW of generation and retired 204 MW within the Connecticut area, a deficiency of approximately 1,100 MW will occur by 2016 for N-1 conditions, and 1,200 MW for N- 1-1 conditions.

The amount of power that can be delivered from eastern Connecticut to western Connecticut is limited by transmission security criteria violations. These violations, which can cause thermal constraints, limit the Connecticut east–west power transfers across the central part of Connecticut. The movement of power from east to west in conjunction with higher import levels to serve Connecticut results in overloads of transmission facilities located within Connecticut.

The most practical solutions to eliminate the second-contingency transmission security violation when trying to move power from eastern to western Connecticut were found to be new 345 kV line additions. Of the four solutions initially selected, only one failed to be a viable option—a possible 345 kV line from Montville to Haddam Neck, which was eliminated because of poor system performance that could not easily be corrected. Accordingly, the three options previously described were retained for further consideration and analysis.

6.1 Description of Connecticut East–West Options

Figure 6-1 to Figure 6-3 are 345 kV one-line diagrams depicting each option of the final three Connecticut East-West components.

Figure 6-1 depicts Connecticut East–West Option A, adding a 345 kV line from Manchester to Southington. This option creates a link from the Manchester substation (which has ties to Massachusetts, to Rhode Island, and to the Millstone Plant) to the Southington substation, which serves as a source into the southwestern Connecticut load pocket.

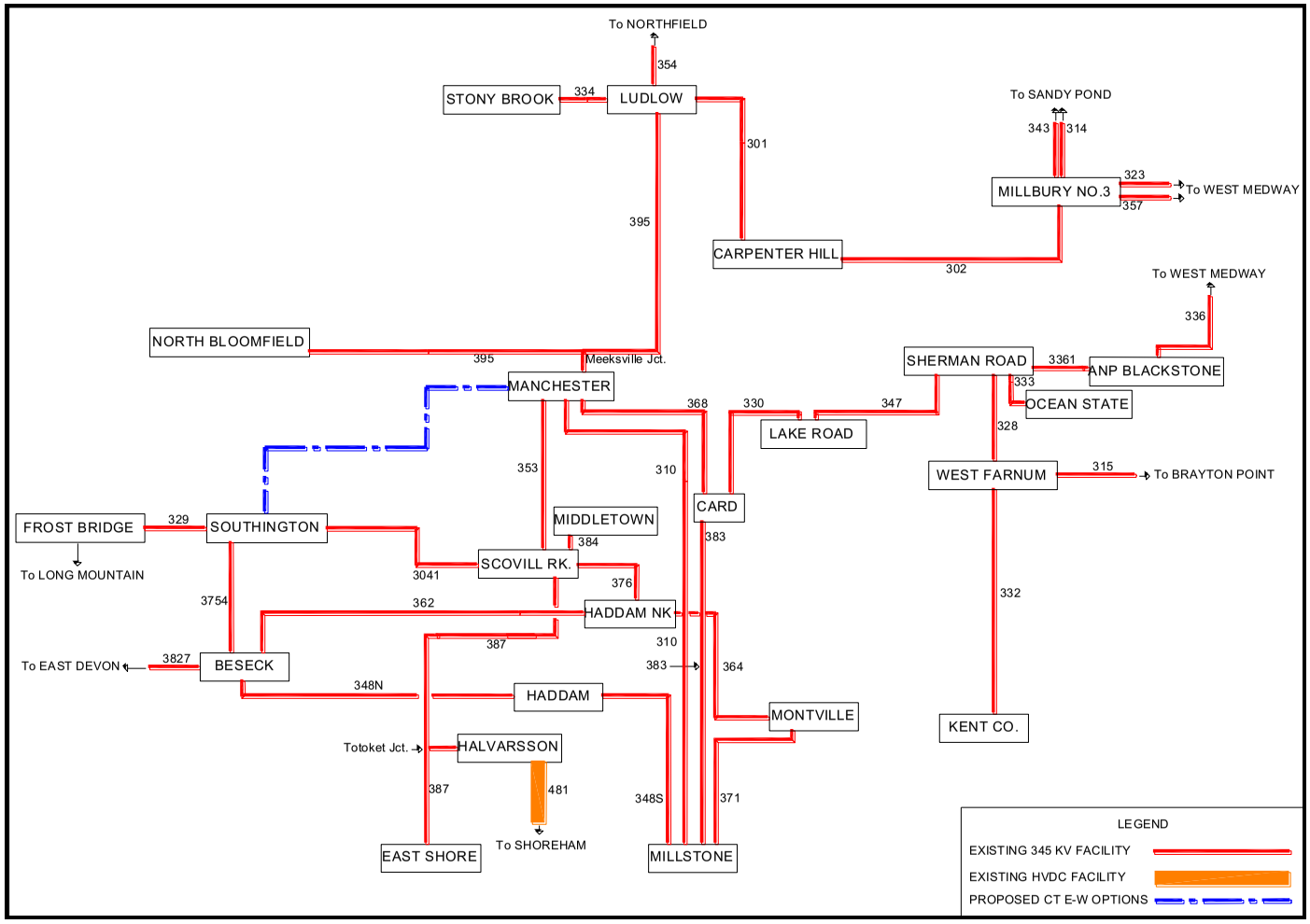

Figure 6-1: Connecticut East–West Option A—345 kV line from Manchester to Southington.

Figure 6-2 depicts Connecticut East–West Option B, adding a 345 kV line from Manchester to Scovill Rock with a tap to a new 345 kV substation in Berlin. This option also taps the Manchester substation but ties it into the Scovill Rock substation as opposed to the Southington substation. Because this line does not extend sufficiently far in a westerly direction, additional stress is placed on the 115 kV system through Hartford, and accordingly, the Berlin 345/115kV autotransformer must provide support to the area's 115 kV system.

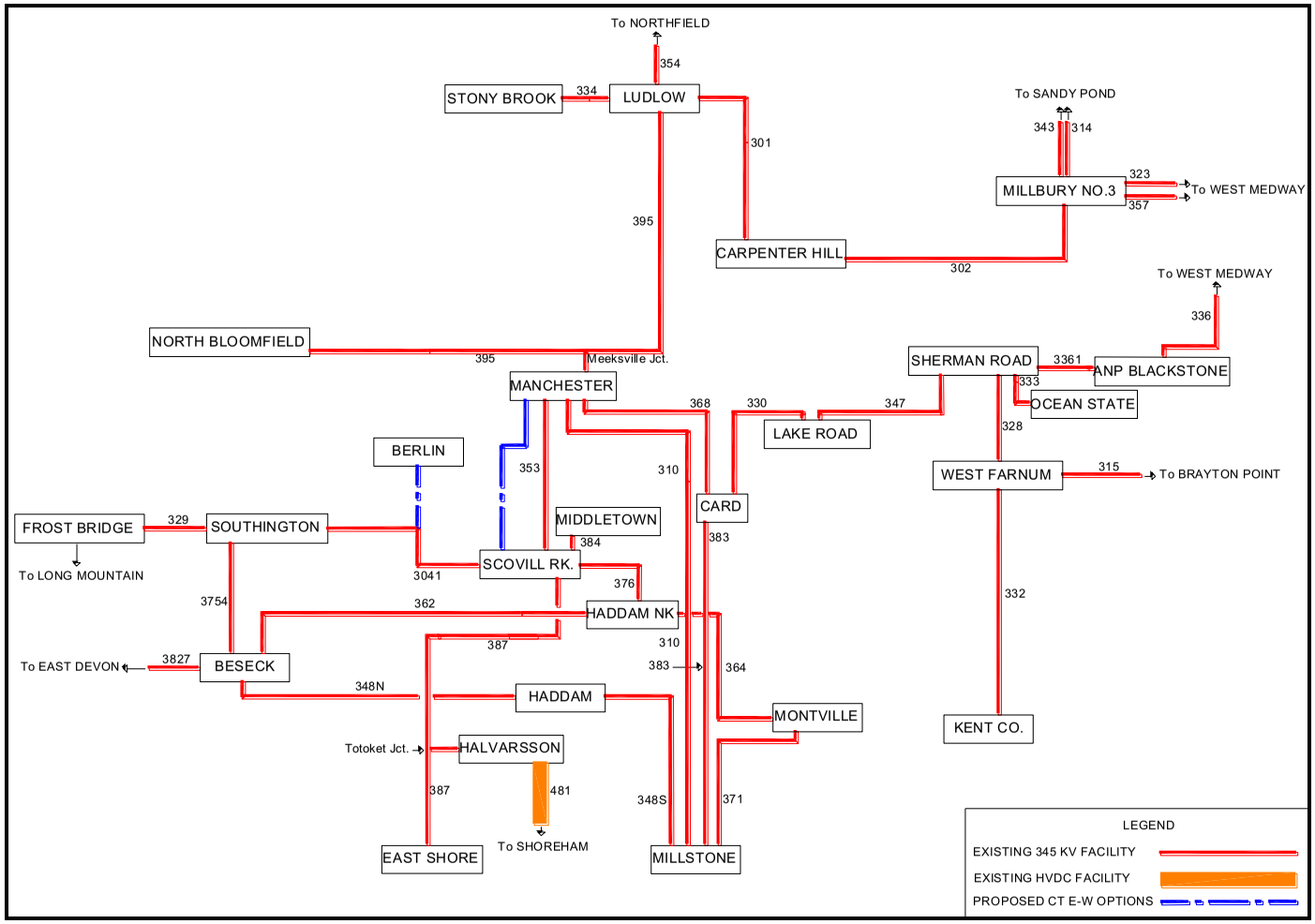

Figure 6-2: Connecticut East–West Option B—345 kV line from Manchester to Scovill Rock with a tap to a new 345 kV substation in Berlin.

Figure 6-3 depicts Connecticut East–West Option C, adding a 345 kV line from North Bloomfield to Frost Bridge. This option makes use of the new Springfield 345 kV supply into North Bloomfield by further extending the 345 kV line from North Bloomfield to the Frost Bridge substation. The Frost Bridge substation, similar to the Southington substation, serves as a source into the southwest Connecticut load pocket.

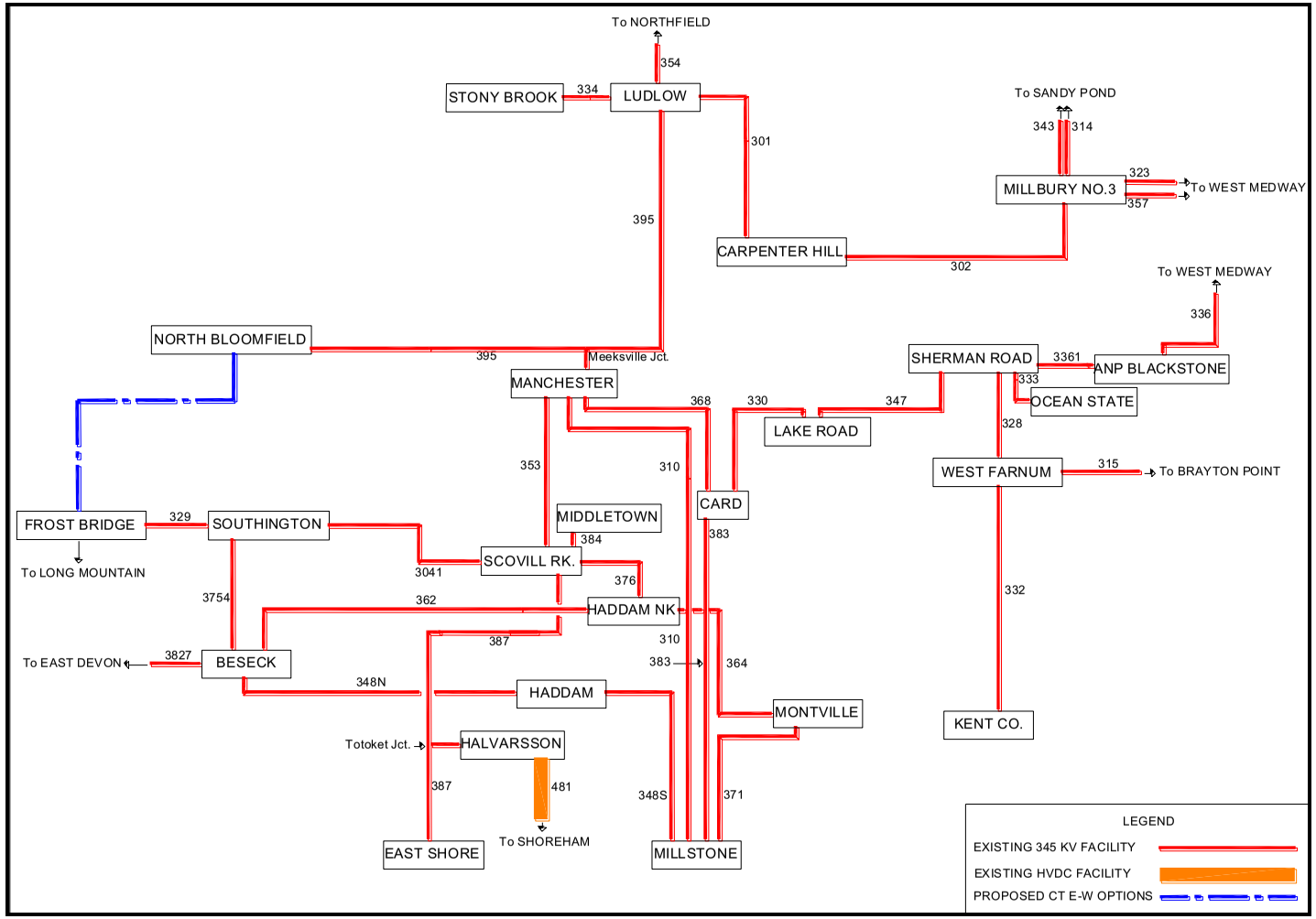

Figure 6-3: Connecticut East–West Option C—345 kV line from North Bloomfield to Frost Bridge.

6.2 Comparison of Connecticut East–West Options

Table 6-1 displays the results of the second-contingency transfer-capability analysis into western Connecticut. Estimating western Connecticut load at 18% to 20% of New England load results in a required transfer capability for 2012 of roughly 2,750 to 3,350 MW under second-contingency system conditions. These figures show that all three options selected with any of the four AC Interstate options will satisfy the 2012 needs. With load growing at about 100 MW per year in western Connecticut, however, Option C can result in a longer lifetime by seven years.

Table 6-1
Connecticut East–West 2012 N-1-1 Transfer Capability (MW)

Interstate Option	CT East–West Option A	CT East–West Option B	CT East–West Option C
A	3,493	3,560	4,117
B	3,744	3,576	3,947
C	3,781	3,461	3,834
D	3,928	3,586	4,291

The working group presented the details of the Connecticut east-west options to Operations personnel from ISO New England and CONVEX at a joint Planning-Operations meeting. The operators, who were not presented with any information concerning cost, environmental, or routing impacts, preferred Option C for the following reasons:

- It provides a solid 345 kV path into the Connecticut 345 kV grid west of the Southington substation. (This is considered beneficial because Southington is an old substation, and upgrades over the years have created some operating issues.) Operators would prefer that new facilities stay clear of the Southington substation
- Option B requires a fifth autotransformer installation at Southington, which is not considered advantageous.
- It allows a greater degree of flexibility in northwestern Connecticut for future development possibilities (e.g., transmission expansion, generator leads, etc.).

6.3 Connecticut East–West Component Conclusion

In summary, three of the four options to eliminate the second-contingency transmission security constraints in central Connecticut met reliability criteria standards for 2012 and beyond. Connecticut East–West Option C achieves higher transfer capabilities regardless of which Interstate option is selected. This option should therefore maintain reliability standards farther into the future. However, Connecticut East–West Options A and B also are viable.

Section 7
Springfield Component Options

As discussed in Section 2, the Springfield, Massachusetts, area has significant transmission reliability concerns, including thermal overloads and voltage problems under numerous contingency scenarios. The severity of these problems increases as the system attempts to move power into Connecticut from the rest of New England. In the Springfield area, local double-circuit tower outages (DCT), stuck-breaker outages, and single-element outages result in severe thermal overloads and low-voltage conditions. **This sentence has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.**

A wide range of transmission reinforcement options were considered to alleviate thermal and voltage problems in the Springfield area. These options included extensive 115 kV reinforcements, additional 345/115 kV transformers, new 345 kV lines, new bulk power sources, and phase shifters. Some of the reinforcement options investigated did not fully meet the area reliability requirements or were not considered to be effective long-term solutions. Other options were not sufficiently compatible with the overall SNE transmission reinforcement plans.

The working group determined that three 345 kV expansion options would fully meet the reliability requirements of the Springfield area and be consistent with the long-term expansion plans for southern New England. Each of the 345 kV options has a number of 115 kV variations, resulting in 12 distinct options. A complete listing of the upgrades that are part of these 12 options can be found in Appendix A.

7.1 Description of the Springfield 345 kV Options

The Springfield area option expansion plans include three 345 kV transmission reinforcement options that are highly compatible with the overall southern New England bulk transmission reinforcement plans. These options are as follows:

- A new 345 kV line from Ludlow to Agawam and from Agawam to North Bloomfield
- A new 345 kV line from Ludlow to North Bloomfield
- A new 345 kV line from Ludlow to Manchester

Each of the above options reinforces the electrical connection between western Massachusetts and Connecticut, which provides benefits to both the Springfield and Connecticut areas. These 345 kV options along with their associated 115 kV reinforcements all meet the required reliability standards.

7.1.1 Springfield Option A—345 kV Line from Ludlow to Agawam to North Bloomfield

This option consists of building new 345 kV lines from Ludlow to Agawam and Agawam to North Bloomfield with 345/115 kV transformation at Agawam. Springfield Option A provides another bulk transmission supply point for the Springfield area. The Springfield area requires other 115 kV transmission reinforcements to meet reliability requirements. Figure 7-1 is a 345 kV one-line diagram of Springfield Option A.

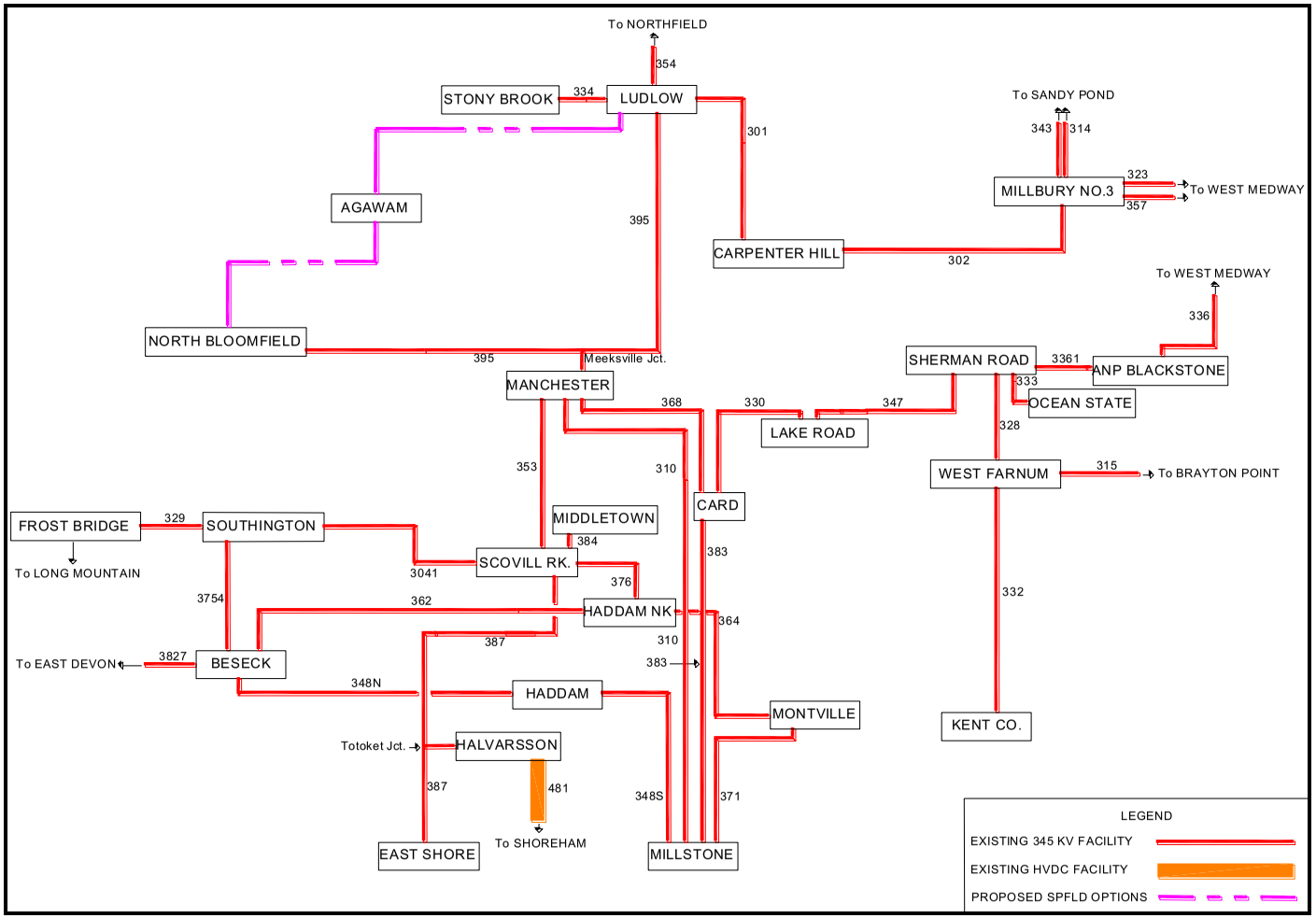

Figure 7-1: Springfield Option A—345 kV line from Ludlow to Agawam to North Bloomfield.

7.1.2 Springfield Option B—345 kV line from Ludlow to North Bloomfield

Springfield Option B includes building a new 345 kV line from Ludlow to North Bloomfield. It is primarily a backup to the existing 345 kV line 395, decreasing the amount of power being wheeled through the Springfield 115 kV system.[11] Springfield Option B requires phase shifters at North Bloomfield on the 115 kV ties between western Massachusetts and Connecticut to further restrain the power flow through the Springfield area. The Springfield area requires other 115 kV transmission reinforcements to meet reliability requirements. Figure 7-2 depicts the 345 kV portion of Springfield Option B.

[11] *Wheel through* refers to the transmission of power through an area to supply load in another area.

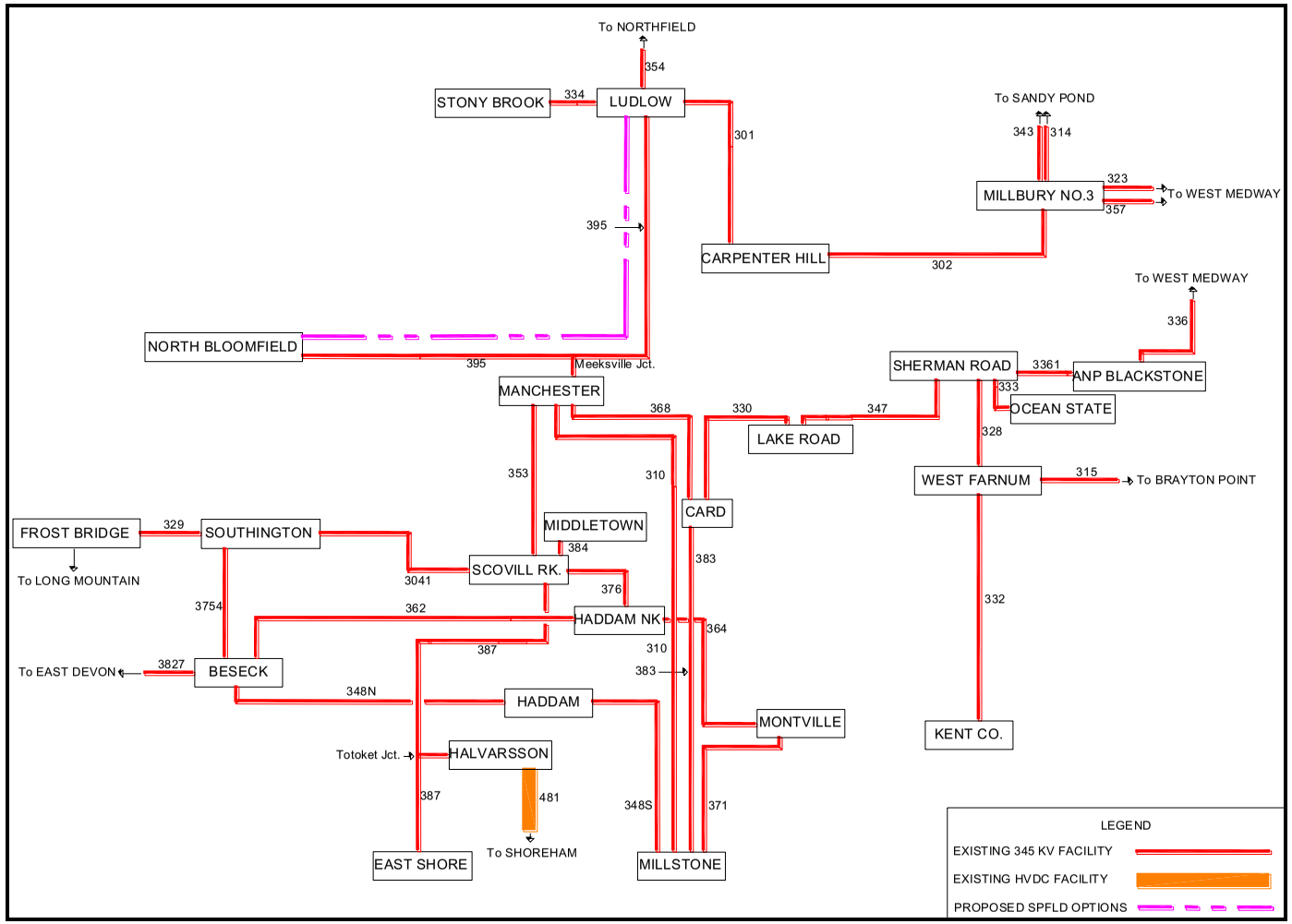

Figure 7-2: Springfield Option B—Ludlow to North Bloomfield 345 kV line.

7.1.3 Springfield Option C—Ludlow to Manchester 345 kV Line

Springfield Option C consists of building a new 345 kV line from Ludlow to Manchester. It also primarily is a backup to the existing 345 kV line 395, decreasing the amount of power being wheeled through the Springfield area. Springfield Option C requires the installation of phase shifters at North Bloomfield on the 115 kV ties between western Massachusetts and Connecticut to further restrain the power flow through the Springfield area. The Springfield area requires other 115 kV transmission reinforcements to meet reliability requirements. Figure 7-3 depicts Springfield Option C.

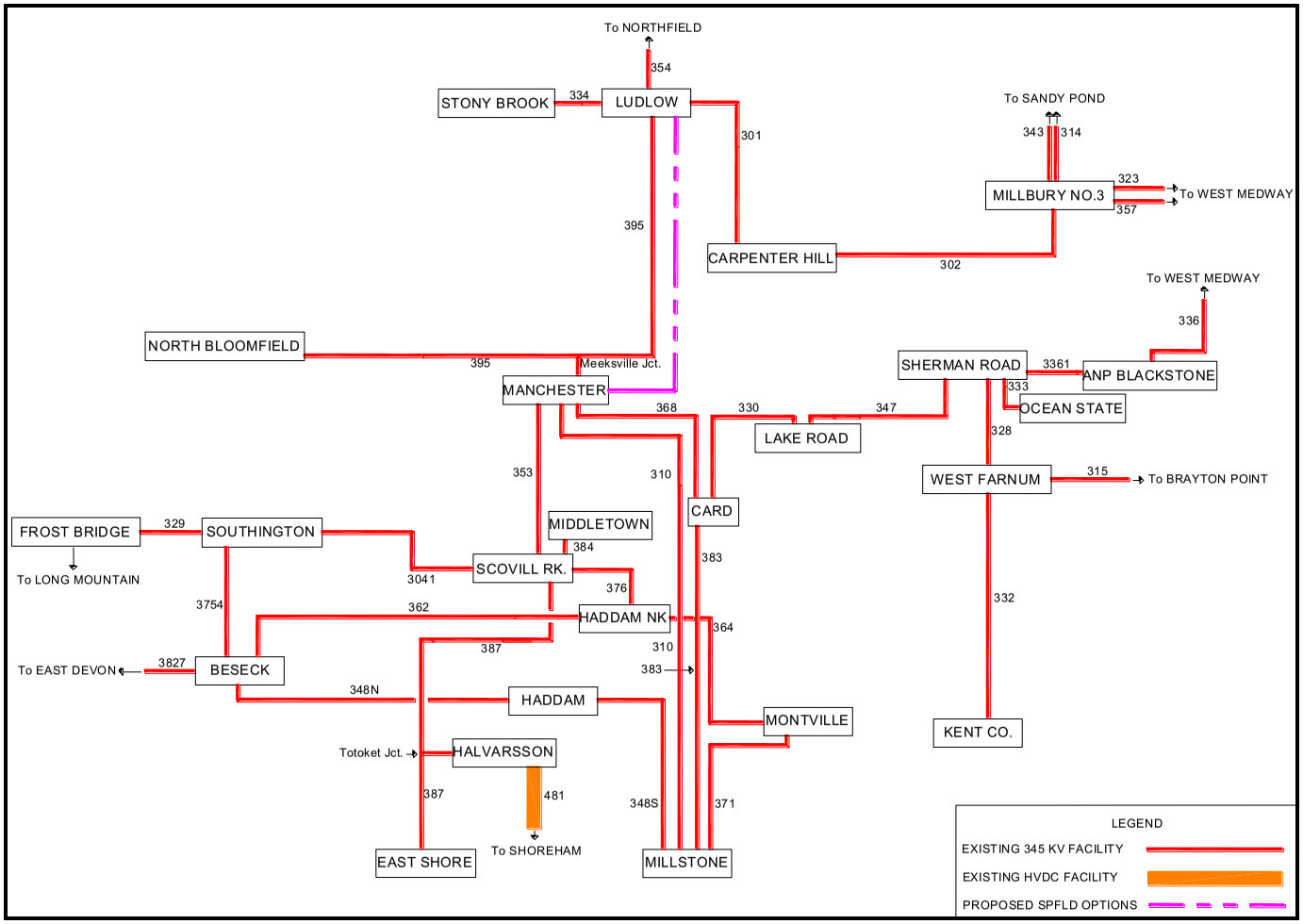

Figure 7-3: Springfield Option C—Ludlow to Manchester 345 kV line.

7.2 Comparison of Springfield Options

The three Springfield area 345 kV options (A, B, and C) and their various associated 115 kV reinforcement options were formulated into a total of 12 transmission reinforcement options. The following subsections discuss the features, benefits, and disadvantages of these options. Appendix A provides a complete list of reinforcements for each option.

The capital letter in each option name (A, B, or C) refers to the 345 kV solution that serves as the backbone of the option. The number and small letter following the capital letter signify the varying 115 kV improvements associated with each of the 345 kV options. Sequential numbers that appear to be missing were assigned to alternatives that were previously eliminated.

7.2.1 Springfield Option A Variations

Eight variations of Springfield Option A remained after the elimination process.

7.2.1.1 Springfield Option A Variation 3a

The major system improvements of this option, in addition to the new 345 kV lines from Ludlow to Agawam and Agawam to North Bloomfield, include three 345/115 kV autotransformers at Agawam, three 115 kV phase shifters in series with the Agawam autotransformers, and the replacement of both 115 kV cables from Breckwood to West Springfield and from Breckwood to East Springfield. This option also would separate the 115 kV ties between western Massachusetts and Connecticut in the South Agawam–North Bloomfield area.

The benefits of this option are as follows:

- Less 115 kV work would be required.
- Phase shifters would facilitate more power flow through the Agawam autotransformers, which would further limit power flow through the Springfield area system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield-area 115 kV system.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The North Bloomfield 2A substation would be more reliable.

One disadvantage of this option is the possibility that additional studies may need to be conducted periodically to optimize the phase-shifter settings.

7.2.1.2 Springfield Option A Variation 3b

This option is similar to the 3a variation except that it ties the Stonybrook 115 kV station into the Springfield 115 kV system. It also allows the output of the Stonybrook plant to be injected directly into the Springfield load pocket as opposed to passing it through the Ludlow 345 kV substation and down the autotransformers.

Variation 3b of Springfield Option A has the following additional benefits:

- The Stony Brook fast-start units would improve the area's non-spinning reserves.[12]
- The severity of extreme contingencies would be reduced or minimized because the Stony Brook–Fairmont lines are on a right-of-way separated from the other Springfield lines.

7.2.1.3 Springfield Option A Variation 6a

In addition to the new 345 kV lines from Ludlow to Agawam and Agawam to North Bloomfield, which is inherent to the Option A variations, this variation includes the following measures:

- Replacing the Breckwood–East Springfield 115 kV cable
- Adding a new 115 kV cable from East Springfield to Clinton
- Eliminating the three-terminal lines at East Springfield Junction (lines 1254 and 1723)
- Installing a breaker-and-one-half substation configuration at Fairmont
- Separating and rebuilding double-circuit lines from Ludlow to East Springfield
- Separating and rebuilding the double-circuit lines from East Springfield to Fairmont
- Separating the western Massachusetts/Connecticut 115 kV ties

No phase shifters would be installed with this variation, and one of the Agawam autotransformers would be replaced with a third autotransformer at Ludlow.

The benefits of this option are as follows:

- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield-area 115 kV system.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The North Bloomfield 2A substation would be more reliable.

One disadvantage of this option would be that the flexibility to restrain power flow through the Springfield area, which variable phase shifters provide, would not be available.

7.2.1.4 Springfield Option A Variation 6b

This option is similar to the 6a variation except that it ties the Stonybrook 115 kV station into the Springfield 115 kV system, as in the 3b variation (Section 7.2.1.2), instead of separating and rebuilding the double-circuit 115 kV lines from Ludlow to East Springfield to Fairmont.

This option has the following benefits:

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[12] *Non-spinning* (non-synchronized) operating reserves are off-line, fast-start resources that can be electrically synchronized to the system and quickly reach rated capability. *Spinning* (synchronized) operating reserve is generation that already is on line, is synchronized to the system, and can increase output.

- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield-area 115 kV system.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The Stony Brook fast-start units would improve the area's non-spinning reserves.
- The severity of extreme contingencies would be reduced or minimized because the lines from Stony Brook to Fairmont would be on a right-of-way separated from the other Springfield lines.
- The North Bloomfield 2A substation would be more reliable.

Similar to Option 6a, one disadvantage of Option 6b would be that the flexibility to restrain power flow through the Springfield area, which variable phase shifters provide, would not be available.

7.2.1.5 Springfield Option A Variation 6c

This option is similar to the 6b variation except that it installs a third 115 kV cable from West Springfield to Clinton and a new 115 kV line from Ludlow to Fairmont as opposed to tieing the Stonybrook 115 kV station into the Springfield 115 kV system.

The benefits of the 6c variation of Springfield Option A are as follows:

- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield area 115 kV system.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The North Bloomfield 2A substation would be more reliable.

Similar to 6a and 6b, one disadvantage of this option would be that the flexibility to restrain power flow through the Springfield area, which variable phase shifters provide, would not be available.

7.2.1.6 Springfield Option A Variations 8a, 8b, and 8c

These options are very similar to the 6a, 6b, and 6c variations except that the third Ludlow 345/115 kV autotransformer and the Fairmont substation work is replaced with a 115 kV line from Stonybrook to Ludlow. Accordingly, the benefits and the disadvantage are similar also.

7.2.2 Springfield Option B Variations

Three variations of Springfield Option B remained after the elimination process.

7.2.2.1 Springfield Option B Variation 7a

In addition to adding the new 345 kV line from Ludlow to North Bloomfield, the major system improvements of this option include adding phase shifters at North Bloomfield on the western Massachusetts/Connecticut 115 kV tie lines, replacing the cable from Breckwood to East Springfield, adding a new cable from East Springfield to Clinton, eliminating the three-terminal lines at East Springfield Junction (lines 1254 and 1723), installing a breaker-and-one-half substation configuration at Fairmont, and separating and rebuilding the double-circuit lines that run from Ludlow to East Springfield and from East Springfield to Fairmont.

The benefits of the 7a variation of Springfield Option B are as follows:

- Phase shifters would help restrain the power flow through the Springfield-area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The North Bloomfield 2A substation would be more reliable.

The disadvantages of this option are that another 345 kV connection into the Springfield load center would not be provided. Additionally, to avoid future problems and system upgrades, operating studies may need to be conducted periodically for properly adjusting the phase-shifter setting of the variable phase shifter.

7.2.2.2 Springfield Option B Variation 7b

This option is similar to the 7a variation except that it ties the Stonybrook 115 kV station into the Springfield 115 kV system, as in the 3b and 6b variations of Option A, instead of separating and rebuilding the double-circuit 115 kV lines that run from Ludlow to East Springfield to Fairmont. This option also adds a third 115 kV cable from West Springfield to Clinton.

The option has the following benefits:

- Phase shifters would help restrain the power flow through the Springfield area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Fairmont substation would be more reliable and better able to provide voltage support in to the surrounding area.
- The North Bloomfield 2A substation would be more reliable.
- The Stony Brook fast-start units would improve the area's non-spinning reserves.
- The severity of extreme contingencies would be reduced or minimized because the lines from Stony Brook to Fairmont would be on a right-of-way separated from the other Springfield lines.

The disadvantages of the 7b variation of Springfield Option B are the same as those for the 7a variation.

7.2.2.3 Springfield Option B Variation 7c

This option is similar to the 7b variation except that it installs a new 115 kV line from Ludlow to Fairmont as opposed to tieing the Stonybrook 115 kV station into the Springfield 115 kV system.

The benefits of this variation of Springfield Option B are as follows:

- Phase shifters would help restrain the power flow through the Springfield-area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The North Bloomfield 2A substation would be more reliable.

The disadvantages of this option are the same as for the 7a and 7b variations of Option B.

7.2.3 Springfield Option C Variation

Only variation 5b of Springfield Option C was deemed to be viable.

In addition to the new 345 kV line from Ludlow to Manchester, the major system improvements of this option include adding 115 kV phase shifters at North Bloomfield in series with each of the three western Massachusetts/Connecticut tie lines, replacing the 115 kV cable from Breckwood to East Springfield, and adding a new 115 kV cable from East Springfield to Clinton and a third 115 kV cable from West Springfield to Clinton. The three-terminal lines at East Springfield Junction (lines 1254 and 1723) would be eliminated, and a breaker-and-one-half substation configuration would be installed at Fairmont. This option ties the Stonybrook 115 kV station into the Springfield 115 kV system.

The benefits of this variation are as follows:

- The phase shifters would help restrain the power flow through the Springfield-area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Stony Brook fast-start units would improve the area's non-spinning reserves.
- The severity of extreme contingencies would be reduced or minimized because the lines from Stony Brook to Fairmont would be on a right-of-way separated from the other Springfield lines.

The disadvantages of the 5b variation of Springfield Option C are that the Hartford area would require additional 115 kV reinforcements, including underground cable circuits; the North Bloomfield 2A substation would not be more reliable; and another 345 kV connection into the Springfield load center would not be provided. Additionally, to avoid future problems and system upgrades, operating studies may need to be conducted periodically for properly adjusting the phase-shifter setting of the variable phase shifter.

7.2.4 Input from Operations Personnel

The working group presented the details of the Springfield options to Operations personnel from ISO New England and CONVEX at a joint Planning Operations meeting. The operators, who were not presented with any information concerning cost, environmental, or routing impacts, preferred Option A, variation 6b (installing a Ludlow–Agawam–North Bloomfield 345 kV line and a 115 kV tie to the Stony Brook generating station with no phase shifters at either Agawam or North Bloomfield) for the following reasons:

- It relies less on the smaller-conductor 115 kV lines heading north out of North Bloomfield.
- The operation of phase-shifters would be burdensome (i.e., they would require daily adjustments) and add an unknown degree of operating complexity.
- It offers a 345 kV source to Agawam and provides an injection point more centrally located in the Springfield load pocket.
- It reduces reliance on the Ludlow autotransformers, which are roughly 40 years old and have a known design deficiency.
- Separating the Connecticut and Massachusetts 115 kV feeds at North Bloomfield is desired as a result of all the operating problems experienced with this through the years.
- A tie to Stony Brook allows power from Stony Brook to flow to the Springfield load center directly, even with the Ludlow substation out of service. (Currently, Stony Brook ties radially into Ludlow.)
- A tie to Stony Brook provides a redundant path for power flowing on the 345 kV to enter the Springfield 115 kV system.
- Currently, all power to the 115 kV system in this area comes through the Ludlow substation. The tie to Stony Brook will allow some power to flow directly to the 115 kV system from the generator, reducing reliance on the Ludlow autotransformers, which are roughly 40 years old and have a known design deficiency.
- Stony Brook autotransformers are single-phase banks, which can be replaced more quickly than three-phase banks at Ludlow providing greater reliability.

7.3 Springfield Component Conclusion

A wide range of transmission reinforcement options were considered to remedy problems in the Springfield area. The 12 options developed were selected for their ability to meet area reliability requirements. They all provide reliability and supply benefits to both Springfield and Connecticut and are compatible with the long-term expansion of the southern New England electric transmission system.

All the Springfield area reinforcement options include a new 345 kV connection between western Massachusetts and Connecticut as well as other associated 115 kV reinforcements to bring the Springfield area electric system into compliance with reliability standards. The main differences among these options are whether they provide another area bulk supply point, eliminate the weak western Massachusetts/Connecticut 115 kV ties, or use phase shifters to restrain power being wheeled through the area.

Section 8
Option Relationships and the Selection of the Preferred Options

Selecting a long-term option to upgrade a complex, integrated transmission grid extending over three states is a difficult and complicated process. Various relationships and points of distinction exist due to the behavior of the transmission grid over a wide range of system conditions. For example, system conditions in one area might affect the performance in an adjacent area, and solving this area's criteria violations may actually eliminate its dependence on the adjacent area. The following list explains these relationships and points of distinction among the options of the four components of the NEEWS plan.

- **Interstate Component**—The selection of the preferred Interstate option of the five available options is totally independent of which of the other components' improvements are selected. Because the Interstate option can be selected independent of any of the other components' improvements, it can be selected during the first stage of the NEEWS selection process.

- **Rhode Island Component**—Because some improvements in the Rhode Island component depend on the Interstate option selected, the Rhode Island component improvements will be selected and eliminated as a result of the Interstate option selected. The remaining improvements of the Rhode Island component are independent of any other component's selection process and can be selected during the first stage of the selection process.

- **Connecticut East–West Component**—The improvements in this component are independent of the preferred selections for any of the other components. However, some 115 kV improvements are needed in the Hartford area, which depend on the preferred options for the Springfield and Connecticut East–West components.

- **Springfield Component**—Although a number of the improvements for this component are primarily needed to address existing system conditions, they have been designed to consider the other components. These improvements are independent of the preferred Interstate component and can be selected during the first stage of the selection process. One exception is that if Interstate Option D is selected, additional Springfield upgrade(s) will be required.

Section 9
Next Steps

The next part of the overall process is for the participating transmission owners to analyze the environmental, cost, constructability, and routing aspects of each option within each component. After this information is gathered and formulated, selections can be made on the basis of all pertinent information.

Appendix A
Listing of Reinforcements by Components

Table A-1
Interstate Component Reinforcements

Interstate Reinforcements	Interstate Option Designation				
	A	B	C	D	E
Build 345 kV circuit, Card–Lake Road	X				
Build 345 kV circuit, Lake Road–W. Farnum	X				
Build 345 kV circuit, W. Farnum–Millbury	X				
Build 345 kV circuit, Montville–Kent County		X			
Build 345 kV circuit, Manchester–Carpenter Hill			X		
Build 345 kV circuit, Carpenter Hill–Millbury			X	X	
Build 345 kV circuit, Ludlow–Carpenter Hill				X	
Build 345 kV circuit, Manchester–Meekville Junction; Split 395 to attach new line				X	
Reconductor line 395, Ludlow–Manchester with bundled 1272 ACSR				X	
Build a HVDC bipole, Millbury–Southington					X
Build a Connecticut East–West solution, see alternate table	X	X	X	X	
Separate line 310, Card–Manchester, and line 368, Card–Millstone	X	X	X	X	X
Replace terminal equipment on line 368 at Manchester	X	X	X	X	X
Replace terminal equipment on line 1272 at Bunker Hill	X	X	X	X	X
Place 14.4 MVAR capacitor at Killingly 115 kV substation	X	X	X	X	X
Loop line 310 from Millstone to Manchester into Card	X	X	X	X	
Replace terminal equipment on line 353 at Manchester	X	X	X	X	
Replace terminal equipment at both terminals on line 376, Haddam Neck–Scovill Rock	X	X	X	X	
Reconductor 345 kV line 3361, Sherman Rd. to ANP Blackstone		X			
Upgrade terminal equipment on Sherman Rd.–ANP Blackstone line 3361	X		X	X	
Upgrade terminal equipment on Sherman Rd.–W. Farnum line 328		X			
Reconductor 345 kV line 347, Sherman Rd. to CTX Border	X			X	
Upgrade terminal at W. Farnum and reconductor line T-172N on W. Farnum–W. Farnum tap	X	X	X	X	X
Reconductor Carpenter Hill–Belchertown 301 line		X			

Interstate Reinforcements	Interstate Option Designation				
Reconductor Millbury–Carpenter Hill 302 line		X			
Reconductor W. Charlton–Little Rest W-175		X			X
Reconductor Little Rest–Palmer W-175		X	X		

Table A-2
Rhode Island Component Reinforcements

Rhode Island Reinforcements	Interstate Option Designation				
	A	B	C	D	E
Build 345 kV circuit, Kent County to W. Farnum	X	X	X	X	X
Install one additional 345/115 kV autotransformer at Kent County	X	X	X	X	X
Install one additional 345/115 kV autotransformer at Kent County	X	X	X	X	X
Build 345/115 kV substation that connects line 303 with lines C-181 and D-182 (including a 345/115 transformer and a 115 kV capacitor bank)	X	X	X	X	X
Build 345 kV circuit, Sherman Rd. to W. Farnum (2nd line)			X	X	X
Uprate Drumrock terminals on Drumrock to Amtrak I-187 line	X	X	X	X	X
Uprate Drumrock terminals on Drumrock–Kilvert line J-188	X	X	X	X	X
Uprate Brayton terminal on line E-183E from Brayton to Merxman Jct.	X	X	X	X	X
Uprate Chartley Pond terminal on line C-181S from Brayton to Chartley Pond	X	X	X	X	X
Uprate breakers and switch on Kent County T3 345/115kV autotransformer	X	X	X	X	X
Uprate Hartford Ave. terminal on Johnston–Hartford Ave. S-171S		X			
Uprate Hartford Ave. terminal on Johnston–-Hartford Ave. T-172S		X	X		X
Reconductor Johnston–Hartford Ave. S-171S; uprate Hart Ave. terminal	X		X	X	X
Reconductor Johnston–Hartford Ave. T-172S; uprate Hart Ave. terminal	X			X	
Upgrade Kent County terminal on G-185N line from KentT1 to Kent County	X	X	X	X	X
Upgrade Kent County terminal on K-189 line, KentT7–Kent County	X	X	X	X	X
Upgrade both terminals and reconductor Pawtucket–Somerset T7 line	X	X	X	X	X
Upgrade bus work disconnects and breakers on W. Farnum T174 345/115kV autotransformer	X	X	X	X	X
Upgrade breakers on W. Farnum T175 345/115kV autotransformer	X	X	X	X	X
Upgrade terminal at W. Farnum on the S-171N W. Farnum–W. Farnum tap	X	X	X	X	X
Reconductor Drumrock–Kent County G-185N	X	X	X	X	X
Reconductor MPLP–Depot St. C-129		X		X	
Reconductor Medway–Depot St. D-130		X	X	X	X
Upgrade terminal equipment Brayton Pt.–Warren E-183		X			

Rhode Island Reinforcements	Interstate Option Designation				
	A	B	C	D	E
Upgrade terminal equipment Mink St.–Wampanoag E-183		X			
Upgrade terminal equipment Wampanoag–Phillipsdale E-183		X			
Upgrade terminal equipment Phillipsdale–Franklin Sq. E-183	X	X	X	X	X
Upgrade Franklin Sq. 115 kV breakers Phillipsdale–Fr. Sq. E-183		X			
Upgrade terminal equipment at South Wrentham	X	X	X	X	X
Reconductor Somerset–Swansea W4		X	X	X	X
Install two 63 MVAR 115 kV capacitors at Kent County	X		X	X	X

Table A-3
Connecticut East–West Component Reinforcements

Connecticut East–West Reinforcements	Connecticut East–West Option Designation		
	A	B	C
Build 345 kV circuit, Manchester–Southington	X		
Build 345 kV circuit, Manchester–Scovill Rock		X	
Tap 362 line at Has Brook Junction; build 3-breaker ring bus		X	
Build 345 kV circuit, Hans Brook Junction–Berlin		X	
Add three 200 MVA single-phase transformers at Berlin		X	
Build 345 kV circuit, North Bloomfield–Frost Bridge			X
Add three 200 MVA single-phase transformers at Southington	X	X	
Increase reactor size from 4 to 6.67 ohms on line 1910, Southington–Todd	X		
Increase reactor size from 4 to 6.67 ohms on line 1950 line, Southington–Canal	X		
Reconductor line 1810 from Southington to Chippen Hill with 795 ACSR	X	X	
Replace terminal equipment at Chippen Hill on line 1810	X	X	
Reconductor line 1783 from North Bloomfield to Northeast Simsbury with 954 ACSR		X	
Replace terminal equipment on line 362 at Haddam Neck		X	
Add three 200 MVA single-phase transformers at Frost Bridge			X
Reconductor line 1777 from North Bloomfield to Bloomfield with 795 ACSR	X	X	
Reconductor line 1786 from East Hartford to the tap with 1590 ACSR			X
Reconductor line 353 from Kleen Energy to Scovill Rock with bundled 954 ACSR			X

Table A-4
Springfield Component Reinforcements

	Springfield Option Designation											
Springfield Reinforcements	**3a**	**3b**	**5b**	**6a**	**6b**	**6c**	**7a**	**7b**	**7c**	**8a**	**8b**	**8c**
Associated 345 kV Option:	**A**	**A**	**C**	**A**	**A**	**A**	**B**	**B**	**B**	**A**	**A**	**A**
345 kV												
Build Ludlow–Agawam 345 kV circuit #1	X	X		X	X	X				X	X	X
Build Agawam–N. Bloomfield 345 kV circuit #1	X	X		X	X	X				X	X	X
Build Ludlow–Manchester 345 kV circuit #1			X									
Build Ludlow–North Bloomfield 345 kV circuit							X	X	X			
Transformers												
Install Agawam 345/115 kV transformer #1	X	X		X	X	X				X	X	X
Install Agawam 345/115 kV transformer #2	X	X		X	X	X				X	X	X
Install Agawam 115 kV phase shifters circuit #s 1–2 (in series with transformer)	X	X										
One spare 115 kV phase shifter	X	X	X				X	X	X			
Replace N. Bloomfield 345/115 kV transformer #1 (CT)	X	X		X	X	X	X	X	X	X	X	X
Install N. Bloomfield 345/115 kV transformer #2 (CT)	X	X		X	X	X	X	X	X	X	X	X
Install N. Bloomfield–S. Agawam phase shifters #s 1–2			X				X	X	X			
Add N. Bloomfield–Southwick phase shifter			X				X	X	X			
Reconnect Ludlow 345/115 kV transformer #1 into bay	X	X	X	X	X	X	X	X	X	X	X	X
Reconnect Ludlow 345/115 kV transformer #2 into bay	X	X	X	X	X	X	X	X	X	X	X	X
Install Ludlow 345/ 115 kV transformer #3				X		X	X			X		X
115 kV												
Rebuild/reconductor Ludlow–Shawinigan				X						X		
Separate/rebuild E. Springfield–Orchard-Ludlow and E. Springfield–Ludlow				X			X			X		

	Springfield Option Designation											
Springfield Reinforcements	**3a**	**3b**	**5b**	**6a**	**6b**	**6c**	**7a**	**7b**	**7c**	**8a**	**8b**	**8c**
Associated 345 kV Option:	**A**	**A**	**C**	**A**	**A**	**A**	**B**	**B**	**B**	**A**	**A**	**A**
Separate or rebuild W. Springfield–Agawam circuit #s 1 & 2	X	X										
Upgrade West Springfield–Agawam circuit #s 1 & 2				X		X				X		
Rebuild S. Agawam–Silver circuit #s 1 & 2 **or** add circuit # 3			X				X	X	X			
Rebuild Silver–Agawam circuit #s1 & 2 **or** add circuit # 3			X				X	X	X			
Replace Breckwood–W. Springfield cable circuit	X	X										
Replace Breckwood–E. Springfield cable circuit	X	X	X	X	X	X	X	X	X	X	X	X
Replace Breckwood reactors	X	X	X	X	X	X	X	X	X	X	X	X
Rebuild/reconductor Woodland–Pleasant line circuit #1	X		X	X	X	X	X	X	X	X	X	X
Rebuild Agawam–Piper Rd. circuit #1	X	X			X							
Install new Clinton–E. Springfield cable circuit			X	X	X	X	X	X	X	X	X	X
Clinton reactor			X	X	X	X	X	X	X	X	X	X
Install 3rd Clinton– W. Springfield cable circuit			X			X		X	X			
Upgrade Ludlow–E. Springfield circuit #1						X						X
Build new Stony Brook–Ludlow 115 kV line		X									X	
Build new 115 k lines 1 and 2, Stony Brook–Five Corners		X	X		X			X			X	
Rebuild 115 kV lines 1 and 2, Five Corners–Fairmont		X	X		X			X			X	
Build new 115 kV line, Ludlow–Fairmont						X			X			X
Disconnect CT/WMASS 115 kV ties	X	X		X	X	X				X	X	X
Reconductor E. Springfield Jct.–Fairmont N.											X	
Separate/Rebuild 1254/1723	X									X		
Undo 3-terminal line 1254/1723; rebuild lines from E. Springfield Jct. to Fairmont			X	X	X	X	X	X	X			
Separate/Rebuild (Fairmont–Shawinigan)/ (Fairmont– E. Springfield)			X	X			X	X				
Reconductor E. Springfield Jct.–Shawinigan											X	X

	Springfield Option Designation											
Springfield Reinforcements	**3a**	**3b**	**5b**	**6a**	**6b**	**6c**	**7a**	**7b**	**7c**	**8a**	**8b**	**8c**
Associated 345 kV Option:	**A**	**A**	**C**	**A**	**A**	**A**	**B**	**B**	**B**	**A**	**A**	**A**
Reconductor Fairmont–Shawinigan					X	X						
Upgrade E. Springfield Jct.–Chicopee											X	
Reconductor E. Springfield Jct.–Piper Rd.	X	X									X	X
Reconductor Fairmont–Piper Rd.					X	X						
Upgrade Fairmont S.–Holyoke			X		X	X					X	
Upgrade Pineshed–Fairmont N.												X
Upgrade Blandford–Granville Jct.	X	X	X	X	X	X	X	X	X	X	X	X
Upgrade Southwick–N. Bloomfield							X		X			
Upgrade Pleasant–Blandford			X	X	X	X	X			X	X	X
Create breaker-and-one-half substation configuration at Fairmont			X	X	X	X	X	X	X			
Build second underground 115 kV line, Northwest Hartford–Southwest Hartford	X	X	X	X	X	X	X	X	X	X	X	X
Build second underground 115 kV line, Southwest Hartford–South Meadow	X	X	X	X	X	X	X	X	X	X	X	X
Build a new 115 kV line from Manchester to East Hartford with 2% or 2.65 ohm reactor	X	X	X	X	X	X	X	X	X	X	X	X
Build a new 115 kV line from Manchester to South Meadow with a 1.5 ohm reactor			X									
Reconductor line 1783 from Farmington to Newington with 556 ACSR			X									
Reconductor line 1785 from Berlin to Newington with 795 ACSR			X									
Add 1% or 1.5 ohm reactor on line 1704			X									
Add 1% or 1.5 ohm reactor on line 1722			X									

Appendix F

Assessment of Non-Transmission Alternatives to the NEEWS Transmission Projects: Rhode Island Reliability Project

Prepared for:

National Grid

Prepared by:

ICF International

August 2008

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EXECUTIVE SUMMARY

I. Introduction

The Rhode Island Reliability Project (the "Project") is a transmission upgrade project which has been proposed by National Grid to alleviate transmission constraints in the greater Rhode Island area. The Rhode Island Reliability Project consists of a set of transmission upgrades in the Rhode Island area that are designed to eliminate major constraints and reinforce limiting elements in the area. The Project is part of the larger New England East-West Solution (NEEWS) which, in addition to the Rhode Island Reliability Project, includes three other major transmission projects:

- Interstate Reliability Project
- Greater Springfield Reliability Project
- Central Connecticut Reliability Project

The four NEEWS projects were selected in combination as the most effective approach to address the five major weaknesses which ISO New England (ISO-NE), the regional transmission organization (RTO) serving the New England electricity market, identified in its *2007 Regional System Plan*.[1] The geographical location of the weaknesses is shown in Exhibit ES-1 as are the four projects which comprise NEEWS. Each of the four projects includes the installation of a new 345 kV line among other components, and each individually addresses at least one of the key weaknesses that ISO-NE identified. The four projects have been designed to be complementary. Therefore, the benefits of the NEEWS projects as a whole, far exceeds that of the four component projects if considered individually. The Rhode Island Reliability Project is designed specifically to alleviate Rhode Island's dependence on limited transmission lines and autotransformers.

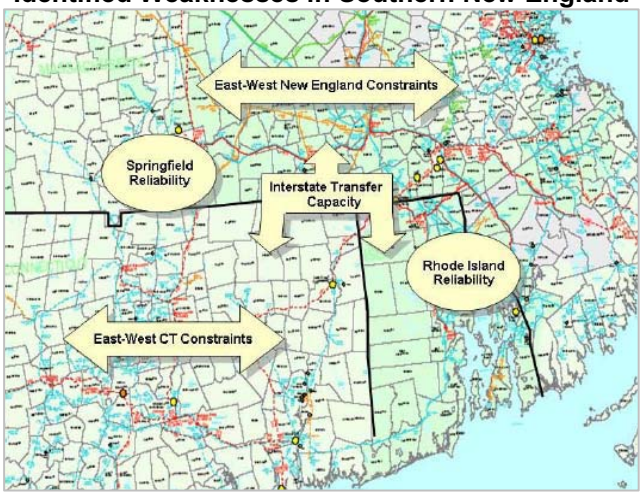
ICF Resources LLC (ICF) was retained by Northeast Utilities and National Grid to prepare an analysis considering the potential for alternative resources, on both the supply and demand side, to displace or defer the need for the Rhode Island Reliability Project (the "Project") and the other NEEWS projects.

To perform the analysis of the effect of non-transmission alternatives on the Rhode Island Reliability Project, ICF has considered the addition of demand resources (including distributed generation), traditional generation supply, and combined heat and power supply options and examined the impact of a large total combined penetration of these resources on the overall reliability of the area as determined through power-flow modeling analysis at peak conditions for pre- and post-Rhode Island Reliability Project cases. In addition, given the synergies inherent among the four projects, ICF has examined a similar set of power-flow cases, pre- and post-NEEWS, for the impact on the local Rhode Island constraints as well as the system. While the first set of cases isolates the direct impact of the Rhode Island Reliability Project, the latter provides an assessment of the interaction of the Project with the other components of NEEWS.

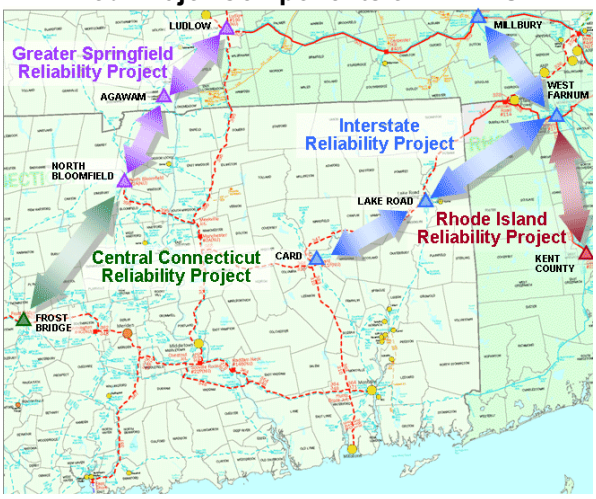
[1] "2007 Regional System Plan," October 18, 2007, ISO New England.

Exhibit ES-1
Identified Weaknesses in Southern New England and the Four Major Components of NEEWS

Identified Weaknesses in Southern New England



Four Major Components of NEEWS



Sources: ISO New England's "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008; and Northeast Utilities web site: http://www.transmission-nu.com/residential/projects/NEEWS/default.asp#

This report is focused on the Rhode Island Reliability Project solution. The remainder of this Executive Summary will briefly describe ICF's approach for analyzing alternatives to the Project, conducting the power-flow analysis, and conclusions of the power-flow analysis.

II. Background

In terms of reliability, ISO-NE is obligated to meet, at a minimum, the electric industry reliability standards set by the North American Electric Reliability Corporation (NERC), the electric reliability standards development and enforcement body for North America. NERC has established rules and criteria for all geographic areas in North America. The performance of the New England transmission system is also governed by reliability standards and criteria established by the Northeast Power Coordinating Council, Inc. (NPCC), and ISO-NE. NPCC is one of eight regional entities under NERC. As the regional entity for Northeastern North America (that is, New England, New York and eastern Canada), NPCC sets rules and criteria particular to the Northeast. ISO-NE has also developed rules and criteria specific to New England.

The reliability standards address both local (Area Transmission Requirements) and regional (Transmission Transfer Capability) concerns. The Area Transmission Requirements specify that the transmission system be capable of delivering power to consumers under anticipated outage conditions. Transmission Transfer Capability addresses the need for the transmission system to be capable of transferring power within the ISO-NE region and between ISO-NE and its neighbors. The standards define

the system conditions and contingencies that must be evaluated when performing a reliability assessment of the transmission grid.[2] These standards were incorporated in ICF's study.

As part of its regional transmission planning process, ISO-NE evaluates whether any areas within its footprint or border regions may violate NERC standards within the 10-year planning horizon. In the *2007 Regional System Plan*, ISO-NE highlighted concern over future reliability violations within Southern New England. Encompassing the states of Connecticut, Massachusetts and Rhode Island, Southern New England represents 80% of New England's load.[3] During the last 10 years, various drivers such as strong load growth and increased generation have begun to strain the existing transmission system in this region. Despite planned upgrades in key load pockets, local and regional reliability violations may occur as early as 2009.[4] Furthermore, local and regional reliability are often interrelated and "individual solutions in one area must be evaluated to ensure that they do not produce unintended consequences in another area."[5]

Given the complex and interdependent nature of the Southern New England transmission network and the long lead time needed to implement transmission solutions, ISO-NE explored this issue focusing on the system's reliability needs for 10 years from 2007 to 2016 with a focus on the summers of 2009 and 2016. ISO-NE created a reference case simulation for its analysis which included currently planned transmission upgrades expected to be online by 2009.[6] With increasing demand growth, the ISO-NE simulations identified violations of reliability criteria during the study horizon with respect to stability, steady state, and fault-current scenarios.[7] The results of these studies show that by 2009, "area transmission capabilities will be inadequate to meet NERC…reliability standards and criteria for the projected load and generation conditions in the Connecticut, Springfield, and Rhode Island areas."[8]

ISO-NE formed a working group which included National Grid, and Northeast Utilities to conduct the studies necessary to analyze the system upgrade options to the transmission problems identified in the 2007 RSP for the southern New England region. The studies show that by 2009, load deficits occur for Connecticut and Springfield even in normal operating conditions and for Rhode Island during emergency conditions. By 2016, however, deficits occur for all three areas during normal operating conditions.[9] A

[2] ISO New England Planning Procedure No. 3, Reliability Standards for the New England Area Bulk Power Supply System, October 13, 2006

[3] "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008, ISO New England, page 2.

[4] "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008, ISO New England, page 11.

[5] "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008, ISO New England, page ii.

[6] The Reference Case included the following planned transmission improvements: Southwest Connecticut Phase I and II Projects; Boston 345 kV Transmission Reliability Project; Northeast Reliability Interconnection Project; Northwest Vermont Reliability Projects; Central Massachusetts Reliability Projects; Southwest Rhode Island Reliability Projects; Barbour Hill Reliability Projects; and Killingly Reliability Project.

[7] The results of this analysis by ISO New England can be found in "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008.

[8] "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008, ISO New England, page 31.

[9] "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008, ISO New England, page 11.

load deficit is the amount of load unable to be served reliably because of transmission constraints.[10]

ISO-NE concludes that these deficits and the five weaknesses "demonstrate a need to construct new transmission facilities to significantly improve the reliability of the transmission grid serving Connecticut, Rhode Island, and western Massachusetts. Given the lead times necessary for permitting and other pre-construction activities, as well as the time required for construction itself, these problems constitute needs that should be addressed now."[11]

In a separate report, ISO-NE identified potential solutions and assessed each option based on system performance characteristics.[12]

III. Rhode Island Reliability Project

Rhode Island has only two 345-kV line connections to the New England 345-kV transmission system. Kent County Substation, a key Rhode Island load serving substation, has only one 345-kV line connecting to it. Additionally, Rhode Island has limited generation connected to the 115-kV system. This combination of limited 345-kV connections and limited generation connected to the 115 kV system makes Rhode Island vulnerable to line and equipment overloads and area voltage violations under contingency conditions (particularly for N-1-1 second contingency conditions).

The Rhode Island Reliability Project proposes the following reinforcements to address these reliability problems:

- A new 345- kV line from West Farnum Substation to Kent County Substation
- An additional 345/115-kV autotransformer at Kent County Substation
- Various transmission line upgrades and substation terminal equipment upgrades.

These upgrades would change the system configuration at Kent County Substation from one 345-kV line and two 345/115-kV autotransformers to a new configuration of two 345-kV lines and three 345/115-kV autotransformers. [13]

Additional support for the Rhode Island area is offered through a proposed new 345-kV line from Millbury #3 Substation to West Farnum Substation which is part of the NEEWS Interstate Reliability project. Though it is not directly included in the Rhode Island Reliability Project, when the two projects are combined, additional local Rhode Island benefits are anticipated.

[10] Note that references to Connecticut, Springfield and Rhode Island do not refer to state or city boundaries or coincide with definitions used by ISO New England for operational purposes. The names refer to areas specifically delineated for the above referenced needs analysis.

[11] "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008, ISO New England, page 31.

[12] The results of ISO New England's analysis are found in "New England East–West Solutions, Report 2, Options Analysis."

[13] There is one existing autotransformer and one planned outside of the Project additions. Together with the autotransformer included in the project, this will result in a total of three autotransformers by 2013.

Several upgrades to the current transmission system configuration are already in well advanced stages of planning or are under construction. Since these projects will certainly have an impact on the system in 2013[14], it was important to ensure that they were included in the analysis. The specific modifications included are:

- Install a 345/115-kV autotransformer and two 115-kV, 72-MVAR capacitors at Kent County Substation and reinforce the substation
- Make terminal upgrades at Drumrock Substation (I-187 & J-188)
- Reconductor a 115-kV line (T7) from Somerset, MA to Pawtucket, RI with terminal upgrades at Pawtucket Substation
- Upgrade 115-kV terminal equipment at West Farnum Substation
- Install a new 115-kV line from Brayton Point, MA to Somerset, MA
- Install a new 345/115-kV Substation in Plainville, MA.

IV. Analytical Approach and Key Assumptions

IV.1. Assessment of Alternatives to Transmission under Reliability Planning

Transmission lines and systems are designed to provide reliable power delivery from source to the distribution delivery point supporting the end-user. Reductions in end-use demand, or less centralized placement of generation may reduce the utilization of lines on the transmission system. In assessing the potential for alternative resources to displace or defer the Project, ICF considered three distinct options:

1. Combined Heat and Power Resources ("CHP"): These reflect the resources that would be located on site, typically at larger industrial or commercial locations with both steam and electric power needs, and would be used as the primary source of power for that location such that there is no direct demand from the location for regional generation sources and hence no demand for transmission services.
2. Demand-Side Management ("DSM") Resources: Demand-Side Management resources represent a large block of options that tend to reduce the demand for system generation and transmission services either through direct reductions in the load, or the addition of generation as a distributed source, i.e. distributed generation. Demand reductions may either be passive, such as energy efficiency programs that are tied to use of highly efficient equipment , or they may be active. Active resources reflect loads that can be responsive to system conditions or prices such as interruptible load contracts or distributed/emergency generators.
3. Generation: Generation resources located closer to the load demand centers may also help reduce the overall load on the transmission system.

These three options alone, or in combination have the potential to in some circumstances defer or displace upgrades to the existing transmission system while

[14] 2013 is the year used in the ICF power-flow analysis. This reflects the year that the facilities are expected to be in-service.

maintaining the same level of reliability. However, they may not offer the same certainty offered through transmission projects. For example, in order to provide reliability benefits, active demand resources must be dispatched. Many of these resources can only be called on for short periods of time, and may take 30 minutes or longer to respond, if they do respond. Hence, they do not offer the same certainty as the transmission lines or components which are always present and have a very high availability.

IV.2. Reliability Planning Criteria and Power-Flow Approach

The performance of the New England transmission system is governed by reliability standards and criteria established by NERC, the Northeast Power Coordinating Council, Inc. (NPCC), and the ISO-NE. Operating within these standards ensures that electric power customers in New England will be served with reliable electric power. Similar to the ISO-NE Southern New England Transmission Reliability study[15], ICF's study was designed to test the operation and reliability of the New England transmission system under these standards and criteria.

Both NPCC and ISO-NE standards establish that the electric transmission system must pass specific tests to comply with the established reliability criteria. These tests take into account historical data and occurrences and include an examination of Area Transmission Requirements and Transmission Transfer Capability.

Once the set of reasonable alternatives was established, the reliability assessment for the Rhode Island Reliability Project was carried out by comparing the performance of the local area and broader regional transmission system with and without the Project under various conditions. ICF modeled the New England transmission system under normal and emergency conditions for both cases. The emergency conditions tested included possible N-1 and N-1-1 contingency conditions and further considered the same contingencies under a generation stress case. The analysis was conducted for the year 2013 to coincide with the planned in-service date of the Project.

Chapter One provides additional details on the analytical approach to the alternatives assessment and power-flow modeling.

IV.3. Key Assumptions for the Alternatives Analysis

Combined Heat and Power Resources: The decision on the type of CHP resource to add and location of the resource was based on an assessment of technical potential and the economics of various CHP options. A review of the technical potential was conducted on a state level through assessing the potential locations which currently are not served by CHP sources. ICF utilized its own projections for forward market prices to assess the economics of the CHP options in combination with market surveys of the penetration rates for the equipment. The resulting additions in the state of Rhode Island were 31 MW of CHP.

[15] "Southern New England Transmission Reliability Report 1 Needs Analysis," January 2008, ISO New England.

Demand-Side Management Resources: ICF projected DSM savings based on publicly available projections for the maximum technically achievable DSM and the market information revealed through the ISO-NE Forward Capacity Auction (FCA) process. The FCA has been very successful at attracting demand resources in the New England market area. Roughly 2,500 MW of demand resources cleared in the first Forward Capacity Auction for 2010/2011. The second auction has yet to occur, but demand resources have already submitted to qualify to participate in that auction. The total of demand resources cleared in the first FCA and those showing interest in the second FCA is just over 4,200 MW. This total represents approximately 12% of the peak capacity requirement in the 2011/12 commitment period throughout New England. The Rhode Island resources that were selected in the 2010/2011 auction amounted to 165.4 MW or 8.5% of the expected Rhode Island state summer peak load in 2010. We assume that the total committed demand resources in Rhode Island will grow at the same rate as the technical potential found in other sources such as the January 2008 Connecticut IRP and the growth in resources submitting to the FCA between auction periods, which yields an annual growth rate of 17%. This assumed growth rate results in a total of 265 MW of peak DSM in Rhode Island in 2013 and a peak penetration of DSM resources of 15% of peak load in Rhode Island.

New Generation Assets: Supply-side resources were also reviewed to ensure that adequate supply was maintained for generation planning purposes. The options considered included traditional generation supply such as combined cycles, combustion turbines, fossil steam units, nuclear units, and renewable units. The decision on the type of resource necessary to add to maintain adequate reserves was based on a high level assessment of the economics of these options. The requirement that load-serving entities face in much of New England to satisfy renewable portfolio standard obligations was also considered in the decision. The resulting additions in the Rhode Island area were 196 MW of renewable generation.

As described above and analyzed, the total resources available as generation or demand side options were examined in combination to determine the total penetration of these resources under aggressive penetration assumptions. This approach resulted in a total amount of resource additions which were included in all cases. Another approach was also examined. This second approach considered the following question: Given the system in its existing configuration, what total amount of demand reductions would be necessary to achieve the benefits identified from the Project under the already assumed level of aggressive penetration?

IV.4. Key Assumptions for the Power-Flow Modeling

The starting point for the non-transmission alternatives analysis was the 2012 power-flow planning case from ISO-NE. This information was provided to ICF under confidentiality restrictions by Northeast Utilities so as to protect Critical Energy Infrastructure Information (CEII) in accordance with FERC requirements. Since the study year for the alternatives analysis was 2013, there were several modifications that were made to the case to reflect 2013 conditions. These modifications were reflected in

both the pre- and post-project implementation cases and additional stressed generation scenarios.

The key assumptions for the power-flow modeling include:

- **Load Projections:** The original power-flow case provided was based on a 2006 vintage forecast for load growth. ISO-NE released a revised forecast in April 2008[16] which was adopted for purposes of this analysis. To modify the peak load input, the load at each node was scaled by the ratio of the 2006 and 2008 vintage forecasts. In compliance with standard transmission reliability planning methods, ICF used the extreme weather peak demand forecast (also known as the 90/10 forecast). Under the 90/10 forecast, the Rhode Island zonal peak demand is estimated to be 2,965 MW in 2013 based on the 2008 vintage forecast. The values used in the original power-flow were 2,940 MW for the 2012 year, nearly an identical match to the 2013 demand predicted by the current 2008 forecast. The same approach was applied to all areas within New England. Additional factors and assumptions affecting load projections include:

    - **Dispatchable DSM Resources:** For modeling purposes, the dispatchable DSM resources such as the emergency generators and demand response are assumed to be reserved for emergency conditions and are not removed from the ISO-NE peak load projection in the power-flow cases.[17] Thus, the Rhode Island peak load is only decremented by 113 MW to account for the non-dispatchable DSM resources for the power-flow analysis, accounting for about 43% of the total Rhode Island DSM projection. Since the ISO-NE load projections are at the generator level, load decrements for DSM include reserve margin requirements and transmission losses.

    - **Transmission Losses:** The ISO-NE load projections are based at the generator bus-bar and hence include both transmission and distribution losses. In contrast, power-flow load inputs reflect the load at the distribution transfer point rather than at the generator level. As such, we have adjusted the ISO-NE load projections to remove transmission losses to reflect the distribution load levels. This allows for the power-flow to internally determine the transmission sector losses.

- **Existing Generating Capacity:** ICF relied on the generation capacity for existing units as provided directly in the power-flow case. The capacity included in the power-flow case reflects the maximum summer-rated capacity for each unit. Modifications were then made to first establish a view of system dispatch under normal peak-day conditions such that system operations were not stressed for the Reference Case. Additional modifications were made to ensure that adequate supply resources were available to satisfy the expected realized peak load in 2013.

[16] "2008-2017 Forecast Report of Capacity, Energy, Loads, and Transmission," April 2008, ISO New England.

[17] ISO-NE views dispatchable DSM as supply side resources

- **Forced Outage Rate and Spinning Reserves:** From the dispatch perspective, forced outages and spinning reserves were accounted for in the dispatch. The forced outage rate assumed for Rhode Island was 7 percent of the total zonal capacity. To implement the forced outage in the power-flow model, ICF turned off selected generation units to reach 7 percent of the total capacity such that these units were assumed to not be available to meet system demand. The same forced outage rate assumption was used for each zone in New England. A spinning reserve requirement of approximately 15 percent of total capacity was also implemented in the power-flow model across New England. This represents generation capacity that is made available to respond to system contingencies and reflects roughly the largest generation contingency in each zone. The 15 percent spinning reserve was implemented in each load zone with the exception of the SEMA/Rhode Island area. Since the SEMA/Rhode Island area is a net exporting region, it is expected that all generation units within that area will be operating at their available capacities on a peak summer day.

- **Generation Asset Lifetime:** Assumptions regarding the useful life of existing generating assets were also made. ICF assumed that any non-hydro asset within New England that reached the age of 60 years by 2013 would retire. No generators in Rhode Island were affected by this retirement assumption.

V. Conclusions

Based on the results of the analysis performed for this study that included projected new generation, DSM, and CHP resources, the Rhode Island Reliability Project was determined to be critical to the reliable operation of the New England transmission grid, and in particular, the Rhode Island transmission system. Non-transmission alternatives to the Rhode Island Reliability Project were not found to be satisfactory or sufficient in nature to displace or defer the need for the Project. This conclusion is supported by results of the power-flow analysis which indicate that, despite the addition of generation, DSM, and CHP resources previously described, numerous transmission facility overloads and substation voltage violations could still potentially occur under contingency conditions.

This was evident in both the reference case, with generation facilities under normal operation, and the generation outage scenarios. The analysis further demonstrated that the transmission reinforcements from the Rhode Island Reliability project would improve the performance of the system in the area of study and resolve the line overloads and voltage violations.

It should be noted that these conclusions are based on conservative assumptions used to generate the Reference Case. Less conservative assumptions would result in greater line overloads and voltage violations than were determined in this study. The conservative nature of these assumptions is focused on both the supply and the demand side including the following:

- ISO-NE has an admitted history of under-forecasting peak demand. Based on studies conducted by the ISO itself, the average forecast error for the fifth year (the relevant year for our study) is biased to a 4.2% under estimate of peak.
    - This under-forecasting seems to be a continuing trend on its face given that the peak projections for the 2008 weather normal forecast are not only below the 2007 forecast but are well below the 2006 forecast as well.
- ICF's analysis under the Reference Case reflects a normal peak-day operation for the system assuming that adequate spinning reserves are maintained and further that no active demand resources are called on. These conditions do not reflect the standard which suggests that transmission planning be performed under stress conditions. ICF further examines several generation stress cases in comparison to the Reference Case.
- Several generation units in New England which have been targeted by environmental groups as high polluters and are considered somewhat at risk of closure based on tightening of environmental regulations have not been assumed to retire or turndown. These units include five plants in Connecticut and five in Massachusetts.[18, 19]
- ICF's assumed generation outages do not reflect the extreme generation outage conditions which have occurred on occasion in New England. Thus the equipment overloads and voltage violations found under ICF's cases can be reasonably expected to occur under such extreme conditions.

The conservative nature of these assumptions further reinforces the conclusions above given that even under these conservative assumptions, the reliability of the system must be addressed through the proposed transmission upgrade. The conservative nature of these assumptions is further elaborated on in Chapter One.

[18] The five Connecticut plants are Bridgeport Harbor, New Haven Harbor, Norwalk Harbor, Middletown, and Montville. The five plants in Massachusetts include Brayton Point, Salem Harbor, Canal, Mount Tom and Mystic. Brayton Point, though located in Massachusetts is electrically in the Rhode Island zone and is approximately 1100 MW.

[19] The conservative nature of this assumption is further supported by NRG's recent interrogatory response filed with the Connecticut Energy Advisory Board (CEAB), Docket F-2008 NRG Energy Inc.'s Responses to Interrogatories of the CEAB, dated July 8, 2008, in which NRG indicated that the retirement of Norwalk Harbor, Montville, and Middletown should be expected if prevailing market conditions continue.

CHAPTER ONE: OPTIONS FOR AND ASSESSMENT OF TRANSMISSION SYSTEM ALTERNATIVES

1.1 Rhode Island Reliability Project Background

Rhode Island has only two 345-kV line connections to the New England 345-kV transmission system. Kent County Substation, a key Rhode Island load serving substation, has only one 345-kV line connecting to it. Additionally, Rhode Island has limited generation connected to the 115-kV system. This combination of limited 345-kV connections and limited generation connected to the 115 kV system makes Rhode Island vulnerable to line and equipment overloads and area voltage violations under contingency conditions (particularly for N-1-1 second contingency conditions).

The Rhode Island Reliability Project proposes the following reinforcements to address these reliability problems:

- A new 345-kV line from West Farnum Substation to Kent County Substation
- An additional 345/115-kV autotransformer at Kent County Substation
- Various transmission line upgrades and substation terminal equipment upgrades.

These upgrades would change the system configuration at Kent County Substation from one 345-kV line and two 345/115-kV autotransformers to a new configuration of two 345-kV lines and three 345/115-kV autotransformers.

The Project is part of the larger New England East-West Solution (NEEWS) which, in addition to the Rhode Island Reliability Project, includes three other major transmission projects:

- Interstate Reliability Project
- Greater Springfield Reliability Project
- Central Connecticut Reliability Project

These four projects were selected in combination as the most effective approach to address major transmission system weaknesses which ISO New England (ISO-NE), the regional transmission organization (RTO) serving the New England electricity market, identified in its 2007 Regional System Plan[20]. The Rhode Island Reliability Project is designed specifically to alleviate Rhode Island's dependence on single transmission lines or autotransformers for reliability. However, there are significant synergies resulting from the combined implementation of the four NEEWs projects which further reinforce the transmission system. For example, additional support for the Rhode Island area is offered through a proposed new 345-kV line from Millbury #3 Substation to West Farnum Substation which is part of the NEEWS Interstate Reliability project. Though it is not directly included in the Rhode Island Reliability Project, when the two projects are combined, additional local Rhode Island benefits will be obtained.

[20] "2007 Regional System Plan," October 18, 2007, ISO New England.

ICF was retained by Northeast Utilities and National Grid, the sponsors of the NEEWS projects, to prepare an analysis considering the potential for alternative resources, on both the supply and demand side, to displace or defer the Rhode Island Reliability Project.

1.2 Options for Non-Transmission Alternatives to the Rhode Island Reliability Project

Transmission and distribution lines and systems are designed to provide reliable power delivery from source to end-user. As demand for electrical energy grows, utilization of a transmission system also grows and upgrades may be required to continue to serve load reliably over time. Alternatively, additional generation sources nearby the load demand areas, or reductions in the load at key demand areas may alleviate the load on the transmission system and help to defer or displace transmission upgrades otherwise necessary. In assessing the potential for alternative resources to displace or defer the Project, ICF considered three distinct options:

1. **Combined Heat and Power Resources:** These reflect the resources that would be located on site, typically at larger industrial or commercial locations with both steam and electric power needs, and would be used as the primary source of power for that location such that there would no longer be any direct demand from the location for regional generation sources and hence no demand for transmission services.
2. **Demand-Side Resources:** Demand-Side Management resources represent a large block of options that tend to reduce the demand for system generation and transmission services either through direct reductions in the load, or the addition of generation as a distributed source. Demand reductions may be passive, such as energy efficiency programs which may rely on replacing older less efficient equipment with newer more efficient equipment. In this case, all else equal, to provide the same function from the equipment, less energy would be consumed. Demand resources may also be active resources. Active resources reflect loads such as interruptible load contracts that can be responsive to system conditions or prices. Additionally, distributed or emergency generators are considered responsive demand resources in this analysis.
3. **Generation:** Generation resources located closer to the load demand centers may also help reduce the overall load on the transmission system. Local generation sources will help reduce the transmission load provided that they are appropriately sized and that they are operating at the time of need. It should be noted that a generator that is sized too large may have an undesired effect through creating additional constraints in trying to move generation in the opposite direction of traditional flows and hence impacting the overall system directional flows and utilization. So although they may help alleviate a constraint in one area, generation resources may result in constraints in other areas.

These three options alone, or in combination have the potential to, in some circumstances, defer or displace the need for upgrades to the existing transmission system while maintaining the same level of reliability. However, the benefits from transmission upgrades in terms of reliability are likely to be much more reliable and dependable than any of the options. Outages on the transmission system tend to be shorter than that of generation assets when both types of facilities are adequately maintained, and in particular are less frequent than distributed generation options. Even more so, the reliability benefits of the savings from demand resources are much less predictable than the benefits of generation or transmission options. The duration of active demand-side resources tends to be somewhat short-lived, such that if the transmission system overloads are greater than 3 to 5 hours, the demand resources may no longer be available. Further, transmission provides additional benefits beyond strict reliability considerations such as helping to reduce losses and also helping to move ouput from lower cost resources located in non-local areas to the local demand centers. Such additional benefits may not be available from the non-transmission alternatives.

1.3 Approach to Considering Non-Transmission Alternatives to the Rhode Island Reliability Project

In order to assess the potential for CHP, DSM, or generation options to defer or displace the Project in 2013, ICF considered the potential for each separately. The evaluation first considered the potential for CHP resources and DSM resources in isolation from each other. Once this was determined, ICF considered the potential for generation resources. Each of these analyses is described in detail in the chapters which follow. In summary, the expected potential in each of these areas based on both the technical potential and the economic potential were considered. Once these data were estimated, the expected resource potential was input into a power-flow case for 2013. Assuming that these resources were available, we examined if a reliability need established by ISO-NE in their transmission planning process continued to exist. Additionally, ICF used a second approach in which we examined the total load reduction that would be necessary to achieve the same or similar reliability levels as exist with the Project. That is, within a power-flow case which did not contain the upgrades associated with the Project, the load levels were decremented until a reasonably close reliability level to that of the Project was achieved.

1.4 Approach to Power-Flow Reliability Analysis

Power-flow studies are important in the operation and planning of the transmission grid. The studies are based on detailed models of the power system that include representations of generation units, load, transmission facilities, substations and other components. Computer simulations using powerful software models are then used to determine the performance of the system under various conditions. The results of such simulations include power flows or loading on transmission lines, dispatch of generation units, and voltages at substations. Power-flow simulations can be used to analyze variations in system performance due to changes in configuration. For example, in

ICF's study, simulations were used to determine how the power flowing on transmission lines would change if other key transmission lines were taken out of service.

ICF's study was designed to test the operation of the New England transmission system under the ISO-NE standards and criteria, which require that the system reliably continue to serve its load during anticipated transmission facility outages. The standards and criteria also require that the New England transmission system maintain adequate capability to transfer power within New England and between New England and neighboring markets.

The reliability assessment for the Project was carried out by comparing the performance of two separate configurations of the New England regional transmission system. The first case, referred to as the Pre-RIRP Case, represents the New England transmission system assuming the Project, as well as the other components of the NEEWS, is not implemented. The second case, referred to as the Rhode Island Case represents the transmission system assuming the Project was implemented. Both cases were developed from power-flow models of the New England transmission system and were representative of a summer peak demand period in 2013.

To determine the ability of the system to continue to serve its load during anticipated facility outages, ICF performed a detailed power-flow analysis of the system assuming both normal and emergency conditions. Normal conditions imply that all generation and transmission facilities continue to operate as expected on a peak summer day. First, ICF assessed system performance under normal conditions assuming no unplanned failure of a transmission element such as a transmission line, a transformer, a circuit breaker, or a pair of transmission lines on a multiple circuit transmission tower. Next, the process was repeated for the unexpected failure of key transmission elements.

A similar analysis was then conducted to evaluate system performance under emergency conditions, that is, following the outage of a single transmission element a second element was then considered to fail. In this analysis, the transmission system was first allowed to adjust the flows of power following the single element loss.

System performance was measured by monitoring transmission lines for overloads, and transmission substations for voltage violations. To continue to operate reliably, the power-flowing on each transmission line should remain below the emergency ratings of the line. If a line exceeds its limit, operator action may be taken to relieve the overload; if the overload persists, protective devices in the network may activate to take the line out of service in order to prevent damage to the line. Emergency actions taken by operators or automatic measures to relieve one line's overload could overload other transmission system elements, worsen system conditions, and result in severe power outages or a blackout. It is therefore important to ensure that the system is designed to operate within limits under anticipated emergencies. Similarly, substation voltages must remain within acceptable limits specified by the operator.

Furthermore, ICF assessed the ability of the system to operate reliably if selected generation facilities in the study area were out of service. In each case a generation

unit was taken out of service and other generation facilities adjusted to replace the lost output. The performance of the system was then examined as described above.

The loss of a single transmission element is referred to as an N-1 contingency. The loss of a single transmission component followed by the loss of a second component is referred to as N-1-1 contingency.

A detailed discussion of the power-flow cases and input assumptions is provided in Chapter Five.

CHAPTER TWO: COMBINED HEAT AND POWER RESOURCE ALTERNATIVES

Combined Heat and Power ("CHP") resources reflect the resources that would be located on site, typically at larger industrial or commercial locations with both steam and electric power needs, and would be used as the primary source of power for that location such that there would no longer be any direct demand from the location for regional generation sources and hence no demand for transmission services.

The potential for CHP resources in New England was determined as a multi-step process which included first assessing the technical potential, then assessing the economic break-even point, and finally assessing the market penetration based on user adoption rates and economics.

- *Technical potential* represents the total capacity potential from existing and new facilities that are likely to have the appropriate physical electric and thermal load characteristics that would support a CHP system with high levels of thermal utilization during business operating hours.

- *Economic potential* reflects the share of the technical potential capacity (i.e. the customer base) that would consider the CHP investment economically acceptable according to a procedure that is described in more detail below.

- *Cumulative market penetration* represents an estimate of CHP capacity that will actually enter the market between 2008 and 2023. This value discounts the economic potential to reflect non-economic screening factors and the rate that CHP is likely to actually enter the market.

A detailed discussion of each step is provided below.

2.1 Technical Potential for CHP

The technical potential for CHP is considered in three broad sectors: 1) industrial, 2) commercial/institutional, and 3) multi-family residential. Two different types of CHP market segments were included in the evaluation of technical potential. Both were evaluated for high load factor (80% and above) and low load factor (51%) applications resulting in four distinct market segments that are analyzed. These markets are considered individually because both the annual load factor and the installation and operation of thermally activated cooling has an impact on the system economics.

- **Traditional CHP** – electric output is produced to meet all or a portion of the base load for a facility and the thermal energy is used to provide steam or hot water. Depending on the type of facility, the appropriate sizing could be either electric or thermal limited. Industrial facilities often have "excess" thermal load compared to their on-site electric load. Commercial facilities almost always have excess electric load compared to their thermal load. Two sub-categories were considered:

- **High load factor applications** – This market provides for continuous or nearly continuous operation. It includes all industrial applications and round-the-clock commercial/institutional operations such as colleges, hospitals, hotels, and prisons.

- **Low load factor applications** – Some commercial and institutional markets provide an opportunity for coincident electric/thermal loads for a period of 3,500 to 5,000 hours per year. This sector includes applications such as office buildings, schools, and laundries.

o **Combined Cooling Heating and Power (CCHP)** – All or a portion of the thermal output of a CHP system can be converted to air conditioning or refrigeration with the addition of a thermally activated cooling system. This type of system can potentially open up the benefits of CHP to facilities that do not have the year-round thermal load to support a traditional CHP system. A typical system would provide the annual hot water load, a portion of the space heating load in the winter months and a portion of the cooling load during the summer months. Two sub-categories were considered:

- **Low load factor applications** – These represent markets that otherwise could not support CHP due to a lack of thermal load.

- **Incremental high load factor applications** – These markets represent round-the-clock commercial/institutional facilities that could support traditional CHP, but with cooling, incremental capacity could be added while maintaining a high level of utilization of the thermal energy from the CHP system. All of the market segments in this category are also included in the high load factor traditional market segment, so only the incremental capacity for these markets is added to the overall totals.

The following basic steps were used to estimate the technical potential in these sectors for the four types of CHP segments:

1. **Identify applications where CHP provides a reasonable fit to the electric and thermal needs of the user.** Target applications were identified based on reviewing the electric and thermal energy (heating and cooling) consumption data for various building types and industrial facilities. Data sources include the DOE EIA *Commercial Buildings Energy Consumption Survey (CBECS),* the DOE *Manufacturing Energy Consumption Survey (MECS)* and various market summaries developed by DOE, Gas Technology Institute (GTI), and the American Gas Association. Existing CHP installations in the commercial/institutional and industrial sectors were also reviewed to understand the required profile for CHP applications and to identify target applications.

2. **Quantify the number and size distribution of target applications.** Once applications that could technically support CHP were identified, the iMarket, Inc. *MarketPlace Database* and the *Major Industrial Plant Database* (MIPD) from His

Inc.[21] were utilized to identify potential CHP sites by Standard Industrial Classification (SIC) code or application, and location (county). The SIC code is a United States government system for classifying industries by a four-digit code. The *MarketPlace Database* is based on the Dun and Bradstreet financial listings and includes information on economic activity (8 digit SIC), location (metropolitan area, county, electric utility service area, state) and size (employees) for commercial, institutional and industrial facilities. In addition, for select SICs limited energy consumption information (electric and gas consumption, electric and gas expenditures) is provided based on data from Wharton Econometric Forecasting (WEFA). MIPD has detailed energy and process data for 16,000 of the largest energy-consuming industrial plants in the United States. The *MarketPlace Database* and MIPD were used to identify the number of facilities in target CHP applications and to group them into size categories based on average electric demand in kiloWatt-hours.

3. **Estimate CHP potential in terms of MW capacity.** Total CHP potential was then derived for each target application based on the number of target facilities in each size category. It was assumed that the CHP system would be sized to meet the average site electric demand for the target applications unless thermal loads (heating and cooling) limited electric capacity. There are two distinct applications and two levels of annual load making for four market segments in all. In traditional CHP, the thermal energy is recovered and used for heating, process steam, or hot water. In cooling CHP, the system provides both heating and cooling needs for the facility. High load factor applications operate at 80% load factor and above; low load factor applications operate at an assumed average of 4500 hours per year (51%) load factor. The high load factor cooling applications are also applications for traditional CHP, though the cooling applications have 25-30% more capacity than traditional. These differences are directly accounted for in the analysis.

4. **Estimate the growth of new facilities in the target market sectors***.* The technical potential included economic projections for growth through 2023 by means of state by state 15-year growth factors. The growth factors used in the analysis for growth between the present and 2023 by individual sector are shown in Exhibit 2-1. These growth projections were used in this analysis as an estimate of the growth in new facilities. In cases where an economic sector is declining, it was assumed that no new facilities would be added to the technical potential for CHP. Note, existing CHP is subtracted from the identified sites to determine the remaining incremental technical market potential.

[21] IHS (NYSE: IHS) is a leading global source of energy, product lifecycle management, environmental and security information.

Exhibit 2-1
New England State CHP Growth Projections Through 2023

State	15 year average annual growth
CT	1.193%
MA	1.028%
ME	1.367%
NH	1.834%
RI	1.153%
VT	1.217%

The technical market potential does not consider screening for economic rate of return, or other factors such as ability to retrofit, owner interest in applying CHP, capital availability, natural gas availability, and variation of energy consumption within customer application/size class. The technical potential as outlined is useful in understanding the potential size and size distribution of the target CHP markets in the state. The estimated technical potential by county and size of unit is provided in Exhibit 2-2.

Exhibit 2-2
Rhode Island CHP Technical Potential by County and Size of Unit, 2013

	Size Range Capacity Totals (MW)					
County	**50-500 kW**	**500-1 MW**	**1-5 MW**	**5-20 MW**	**>20 MW**	**Total**
Bristol	4.9	10.2	5.8	0.0	0.0	21.0
Kent	18.3	24.2	24.1	0.0	61.3	127.9
Newport	11.5	13.2	10.9	0.0	0.0	35.6
Providence	58.0	105.7	134.1	39.9	23.9	361.6
Washington	15.0	19.9	13.2	21.2	0.0	69.2
Total	107.7	173.3	188.1	61.0	85.3	615.3

2.2 Economic Potential for CHP

Economic potential is determined by an evaluation of the competitiveness of CHP versus purchased fuel and electricity. The projected future fuel and electricity prices and the cost and performance of CHP technologies determine the economic competitiveness of CHP in each market. CHP technology and performance assumptions appropriate to each size category and region were selected to represent the competition in that size range (Exhibit 2-3). Additional assumptions were made for the competitive analysis. Technologies below 1 MW in electrical capacity are assumed to have an economic life of 10 years. Larger systems are assumed to have an economic life of 15 years. Capital related amortization costs were based on a 10% discount rate. Based on their operating characteristics (each category and each size bin within the category have specific assumptions about the annual hours of CHP operation (80-90% for the high load factor cases with appropriate adjustments for low load factor facilities), the share of recoverable thermal energy that gets utilized (80%-90%), and the share of useful thermal energy that is used for cooling compared to

traditional heating. The economic figure-of-merit chosen to reflect this competition in the market penetration model is simple payback.[22] While not the most sophisticated measure of a project's performance, it is nevertheless widely understood by all classes of customers.

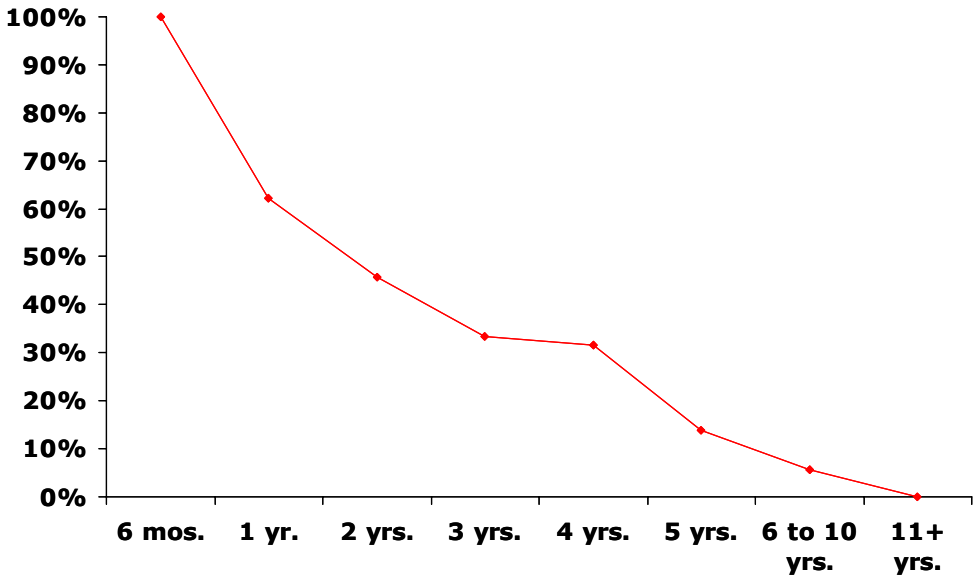
Exhibit 2-3
Technology Competition Assumed within Each CHP Size Category

Market Size Bins	Competing Technologies
50 – 500 kW	100 kW Recip Engine
	70 kW Microturbine
	150 kW PEM Fuel Cell
500 - 1,000 kW	300 kW Recip Engine (multiple units)
	70 kW Microturbine (multiple units)
	250 kW MC/SO Fuel Cell (multiple units)
1 – 5 MW	3 MW Recip Engine
	3 MW Gas Turbine
	2 MW MC Fuel Cell
5 - 20 MW	5 MW Recip Engine
	5 MW Gas Turbine
20 – 100 MW	40 MW Gas Turbine

Rather than use a single payback value, such as 3-years or 5-years as the determinant of economic potential, we have based the market acceptance rate on a survey of commercial and industrial facility operators concerning the payback required for them to consider installing CHP. Exhibit 2-4 shows the percentage of survey respondents that would accept CHP investments at different payback levels[23]. As can be seen from the figure, more than 30% of customers would reject a project that promised to return their initial investment in just one year. A little more than half would reject a project with a payback of 2 years. This type of payback translates into a project with an ROI of between 49-100%. One possible explanation for rejecting a project with such high returns is that the average customer does not believe that the results are real and is protecting himself from this perceived risk by requiring very high projected returns before a project would be accepted. Another possible explanation is that the facility is very capital limited and is rationing its capital raising capability for higher priority projects (market expansion, product improvement, etc.).

[22] Simple payback is the number of years that it takes for the annual operating savings to repay the initial capital investment.
[23] "Assessment of California CHP Market and Policy Options for Increased Penetration", California Energy Commission, July, 2005.

Exhibit 2-4
Customer Payback Acceptance Curve



Source: *Primen's 2003 Distributed Energy Market Survey*

For each market segment, the economic potential represents the technical potential multiplied by the share of customers that would accept the payback calculated in the economic competition module.

ICF considered 2 cases for economic penetration, the first assumed existing active state incentives continued to be in place going forward while the second case applied incentives throughout New England.[24] The results of the economic potential for CHP in Rhode Island for each case are shown in Exhibit 2-5.

Exhibit 2-5
Rhode Island Economic Potential for CHP Resources by Size, 2013

Case	50-500 kW	500kW-1,000kW	1-5 MW	5-20 MW	>20 MW	All Sizes
	(MW)					
Base Incentive Case	4	9	51	24	41	130
High Incentive Case	11	32	86	38	41	208

Detailed discussions of the assumptions driving the economic analysis are presented below. The primary drivers of the economic analysis are the electric prices and gas prices that the equipment installation would avoid, and the equipment cost itself.

[24] Currently Connecticut offers a $400-500 per customer incentive. Rhode Island does not have an active incentive program.

2.2.1 Electric Prices

- Initial year price estimates are from EIA average retail price by state. Each additional year is calculated using the output of the ICF Integrated Planning Model™ (IPM®) model generation weighted industrial prices and then modified as described below for use in the CHP market penetration model. The industrial average prices for each 5-year period are shown in Exhibit 2-6.

- The electricity price assumptions for the high load factor CHP applications were as follows

  – 50-500 kW – 115% of the industrial average price
  – 500-1000 kW – Industrial average price
  – 1-5 MW – 90% of industrial average price (to reflect higher voltages and lower prices as customer size increases above the average industrial size used by EIA)
  – 5-20 MW – 81% of industrial average price
  – >20 MW – 81% of industrial average price

- Price adjustments for customer load factor were defined as follows:

  – High load factor – 90% of the estimated value
  – Low load factor – 100% of the estimated value
  – Peak cooling load – 150% of the estimated value

- For a customer generating a portion of its own power with CHP, standby charges are estimated at 15% of the defined average electric rate except for Connecticut where standby charges are waived as part of an ongoing incentive program. In the other New England states, when considering CHP, only 85% of a customer's rate can be avoided.

Exhibit 2-6
Input Price Forecast: Industrial Electric Price Estimation

Average Industrial Price	5 Year Average Prices $/kWh		
	2013	2018	2023
CT	$0.114	$0.106	$0.116
MA	$0.128	$0.119	$0.132
ME	$0.087	$0.081	$0.089
NH	$0.114	$0.106	$0.118
RI	$0.123	$0.114	$0.127
VT	$0.081	$0.075	$0.084

2.2.2 Natural Gas Prices

- The natural gas price assumptions are based on the forecast for delivered ISO-NE prices by state with estimated markups for other markets.

- Electric Sector and CHP price – equal to the ISO-NE 5-year average price for each state and 5-year time period
- Commercial Customer – -- $1.10/MMBtu (boiler fuel) above ISO-NE price
- Industrial Customer from City Gate -- $0.60/MMbtu (boiler fuel) above ISO-NE price

- The gas price assumptions are shown in Exhibit 2-7.

Exhibit 2-7
Natural Gas Price Assumptions ($/MMBtu)

Year	2013			2018			2023		
State	EG/ CHP	Ind.	Comm.	EG/ CHP	Ind.	Comm.	EG/ CHP	Ind.	Comm.
CT	$8.09	$8.69	$9.19	$7.24	$7.84	$8.34	$7.84	$8.44	$8.94
MA	$8.09	$8.69	$9.19	$7.24	$7.84	$8.34	$7.84	$8.44	$8.94
ME	$8.28	$8.88	$9.38	$7.43	$8.03	$8.53	$8.04	$8.64	$9.14
NH	$8.20	$8.80	$9.30	$7.35	$7.95	$8.45	$7.96	$8.56	$9.06
RI	$8.09	$8.69	$9.19	$7.24	$7.84	$8.34	$7.84	$8.44	$8.94
VT	$8.13	$8.73	$9.23	$7.27	$7.87	$8.37	$7.88	$8.48	$8.98

2.2.3 CHP Technology Cost and Performance

The CHP system itself is the engine that drives the economic savings. The cost and performance characteristics of CHP systems determine the economics of meeting the site's electric and thermal loads. A representative sample of commercially and emerging CHP systems was selected to profile performance and cost characteristics in combined heat and power (CHP) applications. The selected systems range in capacity from approximately 100 – 20,000 kW. The technologies include gas-fired reciprocating engines, gas turbines, microturbines and fuel cells. The appropriate technologies were allowed to compete for market share in the penetration model. In the smaller market sizes, reciprocating engines competed with microturbines and fuel cells. In intermediate sizes (1 to 20 MW), reciprocating engines competed with gas turbines.

Cost and performance estimates for the CHP systems were based on work being undertaken for the EPA.[25] The foundation for these updates is based on work previously conducted for NYSERDA[26], on peer-reviewed technology characterizations that ICF[27] developed for the National Renewable Energy Laboratory[28] and on follow-on

[25] EPA CHP Partnership Program, Technology Characterizations, December 2007 (under review).
[26] *Combined Heat and Power Potential for New York State*, Energy Nexus Group (later became part of EEA), for NYSERDA, May 2002.
[27] ICF's Energy and Environmental Analysis (EEA) group.
[28] "Gas-Fired Distributed Energy Resource Technology Characterizations", NREL, November 2003, http://www.osti.gov/bridge

work conducted by DE Solutions for Oak Ridge National Laboratory.[29] Additional emissions characteristics and cost and performance estimates for emissions control technologies were based on ongoing work conducted for EPRI.[30] Data is presented for a range of sizes that include basic electrical performance characteristics, CHP performance characteristics (power to heat ratio), equipment cost estimates, maintenance cost estimates, emission profiles with and without after-treatment control, and emissions control cost estimates. The technology characteristics are presented for three years: 2005, 2010, 2020. The 2007-2010 estimates are based on current commercially available and emerging technologies. The cost and performance estimates for 2010-2015 and 2015-2020 reflect current technology development paths and currently planned government and industry funding. These projections were based on estimates included in the three references mentioned above. NOx, CO and VOC emissions estimates in lb/MWh are presented for each technology both with and without aftertreatment control (AT). Which system is applicable in any size category (e.g., with aftertreatment or without) is a function of the specific emissions requirements assumptions for each scenario. The installed costs in the following technology performance summary tables are based on typical national averages.

Exhibits 2-8 through 2-11 show the CHP technology cost and performance assumptions. For the cooling markets an additional amount is added to cover the cost of absorption chillers. This cost is a fitted function based on the amount of heat available that varies from $50/kW for the large systems to over $500/kW for the smallest systems analyzed.

[29] "Clean Distributed Generation Performance and Cost Analysis", DE Solutions for ORNL. April 2004.
[30] "Assessment of Emerging Low-Emissions Technologies for Distributed Resource Generators", EPRI, January 2005.

Exhibit 2-8
Reciprocating Engine Cost and Performance Characteristics

CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
100 kW	Installed Costs, $/kW	$2,210	$1,925	$1,568
	Heat Rate, Btu/kWh	12,000	10,830	10,500
	Electric Efficiency, %	28.4%	31.5%	32.5%
	Thermal Output, Btu/kWh	6100	5093	4874
	O&M Costs, $/kWh	0.022	0.013	0.012
	NO_x Emissions, lbs/MWh (w/ AT)	0.10	0.15	0.15
	CO Emissions w/AT, lb/MWh	0.32	0.60	0.30
	VOC Emissions w/AT, lb/MWh	0.10	0.09	0.05
	PMT 10 Emissions, lb/MWh	0.11	0.11	0.11
	SO_2 Emissions, lb/MWh	0.0068	0.0064	0.0062
	After-treatment Cost, $/kW	incl.	incl.	incl.
800 kW	Installed Costs, $/kW	$1,640	$1,443	$1,246
	Heat Rate, Btu/kWh	9,760	9,750	9,225
	Electric Efficiency, %	35.0%	35.0%	37.0%
	Thermal Output, Btu/kWh	2313	3791	3250
	O&M Costs, $/kWh	0.013	0.01	0.009
	NO_x Emissions, lbs/MWh (w/ AT)	0.5	1.24	0.93
	CO Emissions w/AT, lb/MWh	1.87	0.45	0.31
	VOC Emissions w/AT, lb/MWh	0.47	0.05	0.05
	PMT 10 Emissions, lb/MWh	0.10	0.01	0.01
	SO_2 Emissions, lb/MWh	0.0068	0.0057	0.0054
	After-treatment Cost, $/kW	300	190	140
3000 kW	Installed Costs, $/kW	$1,130	$1,100	$1,041
	Heat Rate, Btu/kWh	9,492	8,750	8,325
	Electric Efficiency, %	35.9%	39.0%	41.0%
	Thermal Output, Btu/kWh	3510	3189	2982
	O&M Costs, $/kWh	0.011	0.0083	0.008
	NO_x Emissions, lbs/MWh (w/ AT)	1.52	1.24	0.775
	CO Emissions w/AT, lb/MWh	0.78	0.31	0.31
	VOC Emissions w/AT, lb/MWh	0.34	0.10	0.10
	PMT 10 Emissions, lb/MWh	0.01	0.01	0.01
	SO_2 Emissions, lb/MWh	0.0057	0.0051	0.0049
	After-treatment Cost, $/kW	200	130	100
5000 kW	Installed Costs, $/kW	$1,130	$1,099	$1,038
	Heat Rate, Btu/kWh	8,758	8,325	7,935
	Electric Efficiency, %	39.0%	41.0%	43.0%
	Thermal Output, Btu/kWh	3046	2797	2605
	O&M Costs, $/kWh	0.009	0.008	0.008
	NO_x Emissions, lbs/MWh (w/ AT)	1.55	1.24	0.775
	CO Emissions w/AT, lb/MWh	0.75	0.31	0.31
	VOC Emissions w/AT, lb/MWh	0.22	0.10	0.10
	PMT 10 Emissions, lb/MWh	0.01	0.01	0.01
	SO_2 Emissions, lb/MWh	0.0054	0.0049	0.0047
	After-treatment Cost, $/kW	150	115	80

Exhibit 2-9
Microturbine Cost and Performance Characteristics

CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
60 kW	Installed Costs, $/kW	$2,739	$2,037	$1,743
	Heat Rate, Btu/kWh	13,891	12,500	11,375
	Electric Efficiency, %	24.6%	27.3%	30.0%
	Thermal Output, Btu/kWh	6308	3791	3102
	O&M Costs, $/kWh	0.022	0.016	0.012
	NO_x Emissions, lbs/MWh (w/ AT)	0.15	0.14	0.13
	CO Emissions w/AT, lb/MWh	0.24	0.22	0.20
	VOC Emissions w/AT, lb/MWh	0.03	0.03	0.02
	PMT 10 Emissions, lb/MWh	0.22	0.20	0.19
	SO_2 Emissions, lb/MWh	0.0079	0.0074	0.0067
	After-treatment Cost, $/kW			
250 KW	Installed Costs, $/kW	$2,684	$2,147	$1,610
	Heat Rate, Btu/kWh	13,080	11,750	10,825
	Electric Efficiency, %	2.6%	29.0%	31.5%
	Thermal Output, Btu/kWh	4800	3412	2625
	O&M Costs, $/kWh	0.015	0.013	0.012
	NO_x Emissions, lbs/MWh (w/ AT)	0.43	0.24	0.13
	CO Emissions w/AT, lb/MWh	0.26	0.26	0.24
	VOC Emissions w/AT, lb/MWh	0.03	0.03	0.02
	PMT 10 Emissions, lb/MWh	0.18	0.18	0.16
	SO_2 Emissions, lb/MWh	0.0070	0.0069	0.0064
	After-treatment Cost, $/kW	500	200	90

Exhibit 2-10
Fuel Cell Cost and Performance Characteristics

CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
200 kW PAFC in 2005 150 kW PEMFC in outyears	Installed Costs, $/kW	$6,310	$4,782	$3,587
	Heat Rate, Btu/kWh	9,480	9,480	8,980
	Electric Efficiency, %	36.0%	36.0%	38.0%
	Thermal Output, Btu/kWh	4250	3482	3281
	O&M Costs, $/kWh	0.038	0.017	0.015
	NO_x Emissions, lbs/MWh (w/ AT)	0.06	0.05	0.04
	CO Emissions w/AT, lb/MWh	0.07	0.07	0.07
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.00	0.00	0.00
	SO_2 Emissions, lb/MWh	0.0057	0.0056	0.0053
	After-treatment Cost, $/kW	n.a.	n.a.	n.a.
300 kW MCFC	Installed Costs, $/kW	$5,580	$4,699	$3,671
	Heat Rate, Btu/kWh	8,022	7,125	6,920
	Electric Efficiency, %	42.5%	47.9%	49.3%
	Thermal Output, Btu/kWh	1600	1723	1602
	O&M Costs, $/kWh	0.035	0.02	0.015
	NO_x Emissions, lbs/MWh (w/ AT)	0.1	0.05	0.04
	CO Emissions w/AT, lb/MWh	0.07	0.05	0.04
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.00	0.00	0.00
	SO_2 Emissions, lb/MWh	0.0057	0.0042	0.0041
	After-treatment Cost, $/kW	n.a.	n.a.	n.a.
1200 kW MCFC	Installed Costs, $/kW	$5,250	$4,523	$3,554
	Heat Rate, Btu/kWh	8,022	7,110	6,820
	Electric Efficiency, %	42.5%	48.0%	50.0%
	Thermal Output, Btu/kWh	1583	1706	1503
	O&M Costs, $/kWh	0.032	0.019	0.015
	NO_x Emissions, lbs/MWh (w/ AT)	0.05	0.05	0.04
	CO Emissions w/AT, lb/MWh	0.04	0.04	0.03
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.00	0.00	0.00
	SO_2 Emissions, lb/MWh	0.0044	0.0042	0.0040
	After-treatment Cost, $/kW	n.a.	n.a.	n.a.

Exhibit 2-11
Gas Turbine Cost and Performance Characteristics

CHP System	Characteristic/Year Available	2007-2010	2010-2015	2016-2020
3000 KW GT	Installed Costs, $/kW	$1,690	$1,560	$1,300
	Heat Rate, Btu/kWh	13,100	12,650	11,200
	Electric Efficiency, %	26.0%	27.0%	30.5%
	Thermal Output, Btu/kWh	5018	4489	4062
	O&M Costs, $/kWh	0.0074	0.0065	0.006
	NOx Emissions, lbs/MWh (w/ AT)	0.68	0.38	0.2
	CO Emissions w/AT, lb/MWh	0.55	0.53	0.47
	VOC Emissions w/AT, lb/MWh	0.03	0.03	0.02
	PMT 10 Emissions, lb/MWh	0.21	0.20	0.18
	SO_2 Emissions, lb/MWh	0.0070	0.0069	0.0069
	After-treatment Cost, $/kW	210	175	150
10 MW GT	Installed Costs, $/kW	$1,298	$1,342	$1,200
	Heat Rate, Btu/kWh	11,765	10,800	9,950
	Electric Efficiency, %	29.0%	31.6%	34.3%
	Thermal Output, Btu/kWh	4674	4062	3630
	O&M Costs, $/kWh	0.007	0.006	0.005
	NO_x Emissions, lbs/MWh (w/ AT)	0.67	0.37	0.2
	CO Emissions w/AT, lb/MWh	0.50	0.46	0.42
	VOC Emissions w/AT, lb/MWh	0.02	0.02	0.02
	PMT 10 Emissions, lb/MWh	0.20	0.18	0.17
	SO_2 Emissions, lb/MWh	0.0069	0.0064	0.0059
	After-treatment Cost, $/kW	140	125	100
40 MW GT	Installed Costs, $/kW	$972	$944	$916
	Heat Rate, Btu/kWh	9,220	8,865	8,595
	Electric Efficiency, %	37.0%	38.5%	39.7%
	Thermal Output, Btu/kWh	3189	3019	2892
	O&M Costs, $/kWh	0.004	0.004	0.004
	NO_x Emissions, lbs/MWh (w/ AT)	0.55	0.2	0.1
	CO Emissions w/AT, lb/MWh	0.04	0.04	0.04
	VOC Emissions w/AT, lb/MWh	0.01	0.01	0.01
	PMT 10 Emissions, lb/MWh	0.16	0.15	0.15
	SO_2 Emissions, lb/MWh	0.0054	0.0052	0.0051
	After-treatment Cost, $/kW	90	75	40

2.3 Market Penetration Analysis

ICF has developed a CHP market penetration model that estimates cumulative CHP market penetration in 5-year increments. For this analysis, the forecast periods are 2013, 2018, and 2023. The target market is comprised of the facilities that make up the economic market potential. Based on this calculated economic potential, a market diffusion model is used to determine the cumulative market penetration for each 5-year time period.

The estimation of market penetration includes both a non-economic screening factor and a factor that estimates the rate of market penetration (diffusion.) The non-economic screening factor was applied to reflect the share of each market size category (i.e., applications of 50 to 500 kW, applications of 500 to 1,000 kW, etc) within the economic potential that would be willing and able to consider CHP at all. These factors range from 32% in the smallest size bin (50-500 kW) to 64% in the largest size bin (more than 20 MW.) These factors are intended to take the place of a much more detailed screening that would eliminate customers that do not actually have appropriate electric and thermal loads in spite of being within the target markets, do not use gas or have access to gas, do not have the space to install a system, do not have the capital or credit worthiness to consider CHP investment, or are otherwise unaware, indifferent, or hostile to the idea of adding CHP. The specific value for each size bin was established based on an evaluation of EIA facility survey data and gas use statistics from the iMarket database.

The rate of market penetration is based on a *Bass diffusion curve* with allowance for growth in the maximum market. This function determines cumulative market penetration for each 5-year period. Smaller size systems are assumed to take a longer time to reach maximum market penetration than larger systems. Cumulative market penetration using a Bass diffusion curve takes a typical S-shaped curve. In the generalized form used in this analysis, growth in the number of ultimate adopters is allowed. The curves shape is determined by an initial market penetration estimate, growth rate of the technical market potential, and two factors described as *internal market influence* and *external market influence*.

The cumulative market penetration factors reflect the economic potential multiplied by the non-economic screening factor (maximum market potential) and by the Bass model cumulative market penetration estimate.

Exhibit 2-12
Rhode Island Market Penetration for CHP Resources by Size, 2013

Case	50-500 kW	500kW-1,000kW	1-5 MW	5-20 MW	>20 MW	All Sizes
	(MW)					
Base Incentive Case	0	1	5	4	12	23
High Incentive Case	1	3	9	7	12	31

For purposes of the analysis considered herein, the penetration projections for the High Incentive Case are used.

CHAPTER THREE: DEMAND SIDE ALTERNATIVES

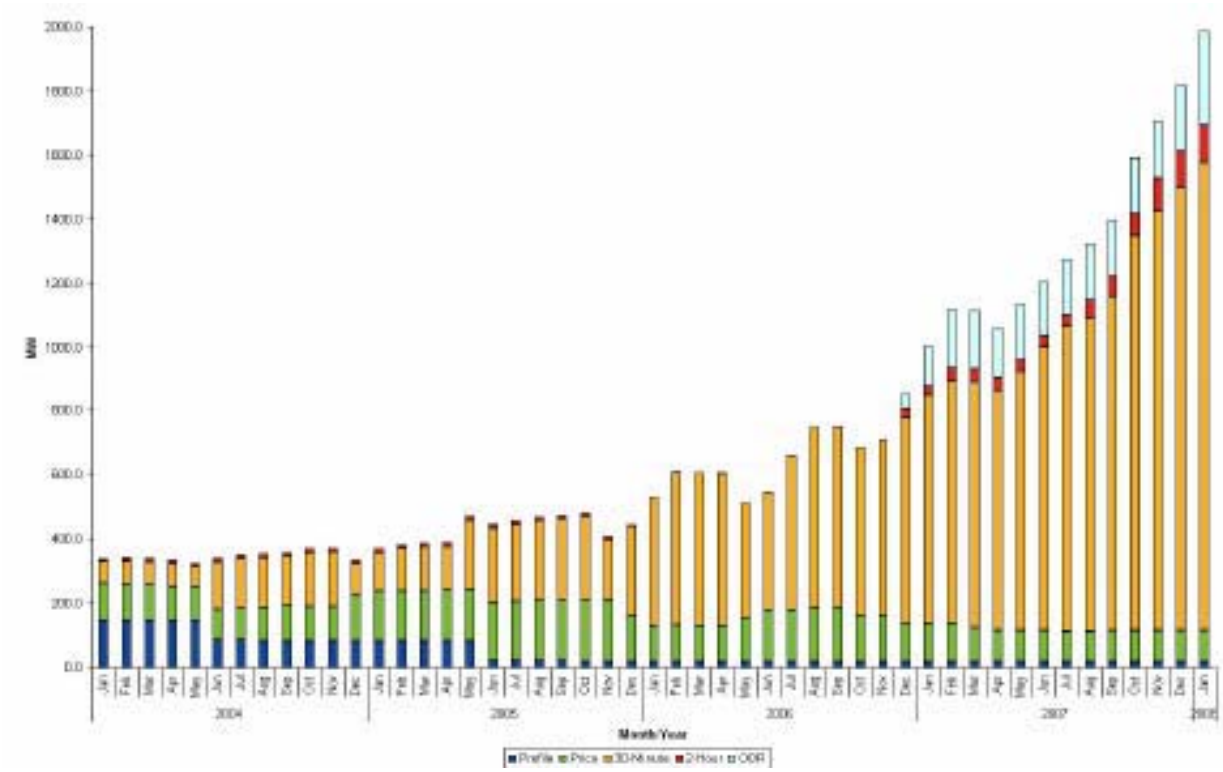
Demand side resources represent a large block of resource options that tend to reduce the demand for system generation and transmission services either through direct reductions in the load, or the addition of generation as a distributed source, i.e. distributed or emergency generation. Demand reductions may either be passive, such as energy efficiency programs that are tied to use of highly efficient equipment, or they may be active. Active resources reflect loads such as interruptible load contracts or distributed/emergency generators that can be responsive to system conditions or prices. Active resources are considered dispatchable by ISO-NE, though the performance of active resources programs, particularly non-generation specific programs, has not been tested under conditions in which they would be frequently called on, such as the large penetration levels considered in this analysis.

For this analysis, ICF projected DSM savings based on publicly available projections for the maximum technically achievable DSM and the market information revealed through the ISO-NE Forward Capacity Auction (FCA) process.

3.1 Background on Demand Resources in New England

Demand side resources have expanded considerably in the last several years. Exhibit 3-1 provides an overview of the growth in demand resources enrolled with ISO-NE between January 2004 and January 2008. As can be seen, there has been significant growth in 30-minute responsive reserves and Other Demand Resources (ODRs). ODRs reflect energy efficiency, emergency generation, and load management resources that can participate in the recently initiated forward capacity market in New England.

Exhibit 3-1
Demand Resources Enrolled with ISO-NE January 2004 – January 2008



This growth reflects an unprecedented amount of demand resources participating in the market. To participate as real-time resources, the demand resources must offer reductions as individual or grouped resources with a minimum reduction of 100 kW. They must be able to respond to real time capacity deficiency instructions from the system operator within either 30-minutes or 2-hours of the system operator's request, depending on the resource classification. Further, the resources need to offer a guaranteed 2 hour minimum reduction time. Resources will be compensated through both an energy and capacity mechanism. The energy mechanism reflects the greater of the real-time wholesale price of a guaranteed minimum of $0.50/kWh for 30-minute response and $0.35/MWh for 2-hour response. The capacity payment reflects a monthly payment ($/kW) based on the Forward Capacity Market Settlement Agreement.

To date, demand resources have performed well and have enhanced system reliability. However, the number of hours that the resources have been called on has been very limited. With the increasing volume of Demand Resources participating in the wholesale electricity markets, new planning and operational challenges are emerging. The 2010/2011 Forward Capacity Auction resulted in over 2,500 MW of demand resource capacity cleared, which reflected roughly 70 percent of the total resources which bid in that same auction. Resources submitting in the 2011/2012 forward capacity market reflect 4,218 MW or roughly 14% of the anticipated peak load. This continued growth is alarming from an overall resource adequacy and reliability planning standpoint, given that as demand resources grow in proportion to total resources, they will be relied upon to maintain system reliability. As demand response resources

replace generation, there will be fewer generators available to satisfy the load and reserve requirements. Further, load reductions from demand response resources will be called upon more frequently to maintain the reserve requirements for a given expected load level. That is, as demand resources grow and displace generation resources, demand reductions will be called to perform in more hours.

Given that there is no history of performance, and the expectation for the initial auctions would not have accounted for the expansion in number of hours a demand resource is called to perform, there is a large question regarding the ability of the resources to perform for extended periods at more frequent rates.

Analysis performed by ISO-NE showed that if a total of 4,218 MW of demand resources cleared for the 2011/2012 period, demand resources would be required to be active in more than 200 hours under the 50/50 load growth projection for that resource year. In a case with roughly the 2,500 MW available from the 2010/2011 auction, the number of hours the resources would be called on was roughly 50. This reflects not only a quadrupling of the hours of need, but also implicit in this is the fact that the resources would be needed for longer durations under peak conditions. That is, the resources would be called on in consecutive peak days for a longer period of days (for example 7 consecutive days instead of 2 days) which places an extra performance burden on the load reduction resources.

Additional performance concerns exist for the demand resources, even beyond the extreme cases of need. Under conditions with heavy penetration of demand resources they would not only be called on in peak months, but would also be called on in shoulder periods to compensate for planned outages of generation units. This places an extra performance burden on the demand resources to reduce load in periods where the ability to do so might be limited. That is, the consumption levels may already be low when not driven up by weather conditions. Therefore, the ability to get the resource to respond on a timely basis could be limited.

These issues with demand resources reflect uncertainties which will need to be carefully considered and addressed going forward. Further, this calls into doubt the ability of demand resources, at such high penetration levels, to act as critical resources which would be able to provide surety of performance. Hence, the reliability benefit of demand resources at such penetration levels needs to be discounted for planning purposes.

3.2 Demand Side Resource Projections and Power-flow Assumptions

Demand resources as used here-in reflect measures that result in verifiable reductions in end-use consumption of electricity. These resources include both passive and active resources. Passive demand resources (Passive DR) save energy (MWh) during peak hours, are not dispatchable and may include on-peak and seasonal peak FCM resources. Active demand resources (Active DR) are designed to reduce peak loads (MW). These active resources can reduce load based on real-time system conditions or ISO instructions. They include critical peak, Real-Time Demand Response (RTDR), and Real-Time Emergency Generation (RTEG) in the FCM.

The FCM auction has been very successful at attracting demand resources in New England. Roughly 2,500 MW of demand resources cleared in first FCA (2010/2011). Of these, 700 MW or 31% represent Passive DR and 1,579 MW or 69% represent Active DR.

The second auction has yet to occur, but resources have submitted to qualify to participate. The total of demand resources in first FCA and those showing interest in the second FCA is over 4,200 MW. This represents approximately 14% of the peak requirement in the 2011/12 commitment period. Active resources reflect approximately 9% of the peak requirement.[31]

ICF has relied on the results of the first FCA and show of interest in the second as a basis for determining the DSM projections for 2013 used in the power-flow analysis. Further, where publicly available, ICF utilized current projections for resource potential for specific areas. Most publicly available projections were somewhat dated and inconsistent with the FCA results; however, the Connecticut 2008 Integrated Resource Plan did have analysis which was relied on as a basis for the Connecticut projections. The aggressive case growth assumptions in the Connecticut IRP reflected the highest growth rates of other technical studies for DSM potential in the New England area that were found in the public domain.

The Connecticut IRP presented two cases, a Reference Case, and a DSM Focus Case. The DSM Focus case reflects the more aggressive of the two and was relied on for this analysis as a conservative assumption for the power-flow analysis. That is, the aggressive DSM penetration has a more significant effect on reducing the need for transmission capacity and hence reflects a conservative assumption from the perspective of transmission planning. Exhibit 3-2 presents the DSM focus case from the Connecticut IRP. The resources labeled EE reflect non-dispatchable or passive energy efficiency resources while those labeled DR reflect active resources as per the descriptions above.

Exhibit 3-2
DSM Focus Case Connecticut January 2008 IRP (MW)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
UI EE	10	13	24	38	57	81	107	131	157	182	208	234
UI DR	20	42	92	103	108	113	118	118	119	120	121	122
CLP EE	36	50	96	154	224	308	401	501	594	668	723	768
CLP DR	346	380	447	453	476	496	506	506	506	506	506	506
Total	410	484	658	748	865	998	1131	1257	1376	1476	1558	1630

Page D-15, Table D-4 CT IRP January 1, 2008, The Brattle Group.

Under the aggressive case (DSM Focus Case), DSM resources grow in total by 134% between 2008 and 2013, reflecting a 19% annual average growth in each of the next

[31] 14% reflects the share of the 2008 CELT/RSP ISO-NE forecast for peak. 9% is ISO-NE's estimate, which is believed to be based on the 2007 CELT/RSP forecast.

five years. This aggressive growth target was applied to the Rhode Island FCA auction results for the 2010/2011 period to determine the 2013 potential in the state. Active and passive resources were assumed to grow at the growth rates applicable to energy efficiency and demand response respectively. These results were cross-referenced with the implied resource base submitting interest in the 2011/2012 forward capacity auction such that the auction results are reflected for 2011/2012 and the IRP growth rate applied thereafter. The resulting DSM trajectories for total, passive and active demand resources are shown in Exhibit 3-3.

Exhibit 3-3
Rhode Island Projections for Demand Resources (MW)

Resource Type	2010	2011	2012	2013	2014	2015	2016
Total Resources	165	211	231	265	296	326	351
Passive Resources	46	65	83	113	144	174	199
Active Resources	120	146	148	152	152	152	152

2010 and 2011 results estimated based on share of resource type to total in 2010/2011 auction results and estimates of the 2011/2012 auction.
CT 2012 forward results based on DSM Focus case in 2008 IRP. All other areas assumed to remain flat in 2012 and grow at same rate as CT DSM Focus case as percent of peak thereafter.

These projections reflect the resources netted up for reserve margin and transmission losses (i.e., generation side) and hence these values reflect the distribution side load. The reserve margin gross-up used by ISO-NE for 2010/2011 was 14.3% and for 2011/2012 16.1%. ICF assumed the 2011/2012 gross up for later years.

Further discussion on the Connecticut IRP assumptions is provided in the next section.

3.3 Review of Demand Resource Plan in the January 2008 Connecticut Integrated Resource Plan

In January, 2008, the Brattle group published an Integrated Resource Plan (IRP) for Connecticut. Within this IRP, demand-side resource options were evaluated for their ability to meet future resource gaps.[32] Two levels of DSM efforts were considered. The "Reference Level" represents current and planned expenditures by the state and was identified within the study as already being "aggressive". The "DSM-Focus Level" represents a significant expansion beyond this reference scenario and assumes that the programs would:

- promote the most efficient cost-effective equipment available,
- accelerate early retirement programs,
- achieve operational efficiencies by integrating program design and delivery, and,
- coordinate with other state-wide initiatives.

[32] Integrated Resource Plan for Connecticut, The Brattle Group, January 1, 2008.

This scenario was identified as a "very ambitious program that is unprecedented in New England" and would result in an actual reduction of demand below current levels by 2018. As an illustration of the aggressive nature of the estimate, it anticipates savings from emerging technologies not yet available to the mass market, such as LED general task lighting and heat-pump water heaters.

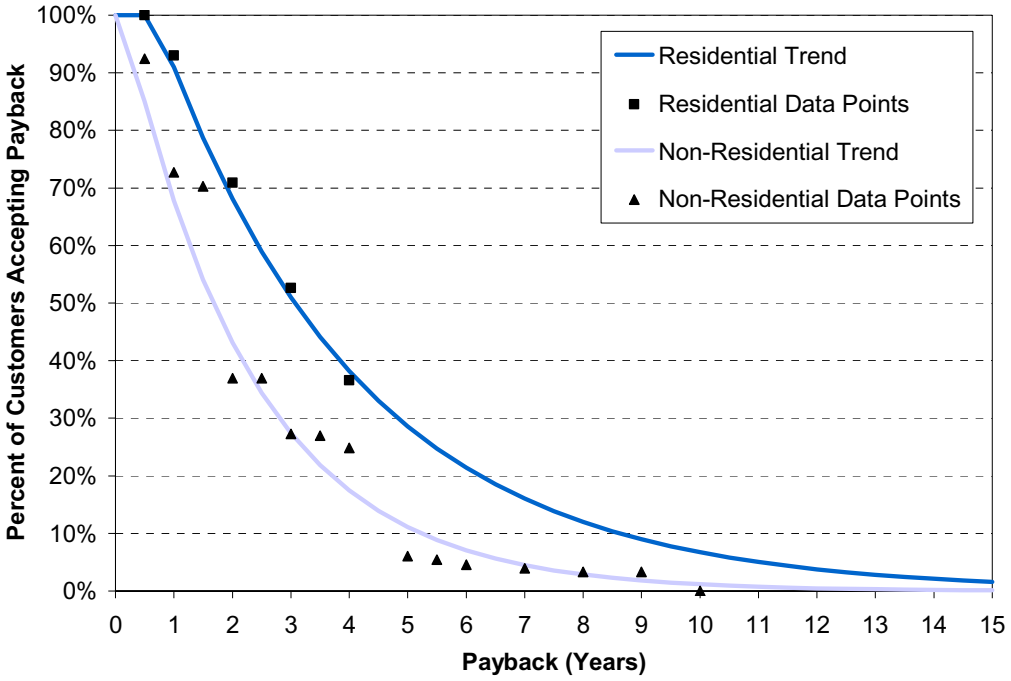
While the methodology used to develop this aggressive level is not highly detailed, the report indicates that one of the principal sources of the estimate was a study completed by GDS Associates[33]. This study was completed with the express purpose of estimating the long-term maximum achievable cost-effective potential within Connecticut and formed the foundation for the IRP's estimate. It arrives at this estimate by first estimating technical potential (i.e., all measures for which it is technically feasible to install them), then maximum achievable potential (i.e., 80% of technically feasible potential), and finally maximum achievable cost-effective potential (i.e., achievable potential that meets the TRC test).

The assumption that 80% of technically feasible potential is achievable is very aggressive and reflective of the study's philosophy that this value represents what "would be adopted given unlimited funding, and by determining the maximum market penetration that can be achieved with a concerted, sustained campaign involving highly aggressive programs and market intervention". ICF's typical estimate of achievable potential varies by measure and study, but generally ranges from 5% to 45%. Among the factors considered in our approach for determining achievable potential is the customers' stated willingness to pay for a measure based solely upon its payback period.

Exhibit 3-4 shows the payback acceptance curves used by ICF and the data points used to derive them. The curve shows the percentage of consumers willing to pursue an energy-saving project at a given payback period. The complete curve was developed by a regression through the collected data points. The implication of the curve is that willingness to pursue a project drops off very quickly as the payback period rises. Though the vast majority of consumers would be willing to pursue a project with a payback of 1 year, only half are willing to accept a project with a 3-year payback.

[33] *Independent Assessment of Conservation and Energy Efficiency Potential for Connecticut and the Southwestern Connecticut Region*, **Final Report for the Connecticut ECMB, GDS Associates, Inc. and Quantum Consulting, June 2004**

Exhibit 3-4
Payback Acceptance Curves



Based upon this curve alone, substantial program incentives would be required to pay down payback periods to 0.5 to 1.5 years to achieve 80% of technical potential, and one would have to assume that participation is driven solely by payback period. More typical payback targets are 2 years. Also, as evidenced by the fact that much of the market has not transitioned to highly cost-effective fluorescent lighting, not all decisions are based upon payback alone. For these reasons, assuming that achievable potential is 80% is very aggressive.

In all, the IRP recognizes that the "DSM-Focus Level" scenario is an extremely aggressive level. As the study notes, the DSM ramp up rate is unprecedented, estimating a tripling of DSM activity in five years. Due to the GDS report's definition of achievable potential, its assumption of unlimited funding and highly aggressive marketing for cost-effective measures, the IRP's reliance upon emerging technologies to achieve savings, and the expectation that the scenario will result in eliminating more than 100% of load growth (an achievement that ICF is not aware of having occurred with any other utility), ICF considers this a highly-aggressive estimate of DSM potential.

Supply-side resources were also reviewed to ensure that adequate supply was maintained for generation planning purposes. The options considered included traditional generation supply such as combined cycles, combustion turbines, fossil steam units, nuclear units, and renewable units. The decision on the type of resource necessary to add to maintain adequate reserves was based on a high level assessment of the economics of these options. New generation capacity is primarily required to meet demand and reserve margin requirements and to satisfy the state level Renewable Portfolio Standards (RPS).[34] Some existing New England generation capacity is also expected to retire by 2013 due to changing market conditions and age of the units. Such retirements may be due to cost of operating aging units exceeding energy and capacity revenues, new technologies displacing aging fleets, or other factors. Details of the analysis are provided below.

4.1 Generation Capacity Additions

Generation additions for 2013 were based on public announcements for committed capacity and an assessment of basic capacity requirements based on a needs review. In assessing the need for new generation to meet demand requirements, consideration was first given to the DSM and CHP penetration within the market. That is, the peak load was considered after deducting the DSM and CHP resources which would serve to reduce the load requirements. Once the decremented load was determined, a basic analysis was performed to ensure that there would be adequate supply resources available to satisfy a reserve margin requirement. This was particularly important because increasing penetration of demand resources will reduce the need for generation capacity. For most of the New England market, ICF determined that due to the expected demand reduction from DSM and CHP, economic generation addition would comprise in large part minimal amounts of renewable energy sources which contribute to the state level RPS needs. This result is consistent with the New England forward capacity market auctions which reflect a depressed price for generation given the addition of significant demand resources. That is, the ability of the market to attract new generation at the prices cleared in the first capacity auction is extremely low relative to the capital required to construct such assets.

The Rhode Island RSP zonal load is expected to be under 3 GW at peak, and is further reduced by DSM and CHP installations. The current supply is over 4.5 GW of capacity, implying that there is more than a 50% reserve available and no additional local supply is needed to satisfy the reserve requirement.

In addition to looking at the reserve requirements, ICF reviewed requirements in the New England states for renewable generation resources (Renewable Portfolio Standards). Several of the New England states require that the load serving entities

[34] Renewable Portfolio Standards require that load serving entities supply a certain share of their load through renewable resources. If the load serving entities are not in compliance with these standards, a financial penalty is applicable.

serve a portion of their load through renewable resources and this percentage increases over time. Given that most states allow for the renewable resources to be located in neighboring areas, ICF evaluated the renewable need for New England as a whole. Further, we considered alternate compliance standards in the individual states which allow the load serving entities to pay a financial penalty rather than sourcing all or part of their requirement through renewable sources. To the extent that using renewable supply was more economic than the financial penalties for non-compliance, ICF determined the amount of renewable capacity which would be required in New England to satisfy the overall need.

This analysis was performed using ICF's Integrated Planning Model ™ (IPM®). IPM® is a widely used tool which simulates the operations of the power grid to optimally solve for dispatch, generation additions and retirements, compliance decisions, and power prices over time. Decisions on the timing and zonal location of new renewable resources are optimally made within IPM® based on the economics of the options available. Available options reflect options that are supported through the geographical and ambient conditions within the individual zones. ICF utilized its own capital and operating cost assumptions to consider the tradeoff between alternative compliance (or financial penalties) and new renewable capacity decisions.

The resulting need indicated approximately 196 MW of new renewable capacity would be needed in the Rhode Island zone by 2013 to help satisfy RPS requirements.

In order to locate these additions appropriately for power-flow purposes, ICF reviewed the current announced capacity additions in the New England queue and selected sites which most closely reflected the additions. The ISO queue for the Rhode Island zone is shown in Exhibit 4-1 below. Note that the Rhode Island RSP zone includes parts of southeastern Massachusetts and northwestern Connecticut. The 196 MW of renewable generation was sited at the West Kingston Substation in Washington County since this queue request had an expected in service date prior to 2013.

Exhibit 4-1
ISO-NE Generation Queue for Rhode Island Zone

Request Date	Project Type	Fuel Type[1]	Summer Net MW	County	State	Projected Commercial Operation Date	Proposed Point of Interconnection
2/26/2007	Combined Cycle	NG	320	Providence	RI	6/1/2012	345 kV RISE Substation
2/27/2007	Combined Cycle	NG	411	Windham	CT	5/31/2012	CL&P 345 kV Lake Road substation
4/13/2007	Gas Turbine	NG	100	Norfolk	MA	6/1/2011	345 kV NEA Bellingham substation
5/15/2007	Gas Turbine	NG	158.5	Worcester	MA	6/1/2010	ANP Blackstone 345 kV substation
5/15/2007	Gas Turbine	NG	158.5	Worcester	MA	6/1/2010	ANP Milford 115 kV substation
10/25/2007	Steam Turbine Capacity Uprate	BIT	190	Bristol	MA	6/302012	Brayton Point 345 kV Switchyard
11/2/2007	Combined Cycle	LFG	82	Providence	RI	9/1/2010	NGRID 115 kV S171 line
12/5/2007	Combined Cycle	NG	285	Newport	RI	6/1/2012	115 kV Tiverton Substation
5/7/2008	Combined Cycle	NG	551	Providence	RI	6/1/2009	115 kV RISE Substation
5/7/2008	Combined Cycle	NG,DFO	303.3	Norfolk	MA	6/1/2010	345 kV NEA Bellingham Substation
5/8/2008	Wind	WND	450	N/A	RI	12/31/2013	Brayton Point 345 kV bus or Dexter 115 kV bus
5/8/2008	Wind	WND	450	N/A	RI	12/31/2013	Kent County 345 kV bus or Davisville 115 kV bus
5/27/2008	Wind	WND	347	Washington	RI	12/1/2012	West Kingston Substation

1, NG = Natural Gas; BIT = Bituminous coal; LFG = Landfill gas; DFO = Distillate fuel oil; and WND = Wing.

4.2 Generation Capacity Retirements

Generation capacity retirement decisions were based on two main criteria:

1. the ability of generation units to meet their fixed and variable operating costs given expected market conditions, and
2. the age of the unit.

The former criteria (cost recovery) was specifically applied to generation facilities currently under Reliability Must-Run (RMR) contracts with ISO-NE since a reasonable

estimate of their operating cost can be derived from publicly available market data as described below. Further these units have a documented history of inability to support their costs directly through the historic energy and capacity market prices which they have received through market sources alone. Given that the RMR contracts that these units operate under expire at the end of the forward capacity market transition period (2010) then these units would be forced to earn full compensation through the market assuming no other regulatory source was available. As the initial forward market capacity clearing prices have indicated prices well below the Cost of New Entry (CONE), any RMR unit which is known to have a regulated payment above the CONE was considered to retire by 2013. No units in Rhode Island were affected by this assumption; only units in Connecticut and Massachusetts are affected.

The latter criteria (age) was applied to all non-hydro units that will reach 60 years of operation before or in 2013. We assume these units are retired for purposes of the 2013 power-flow case. This assumption is consistent with that in ISO-NE's system planning process. Under this assumption, a total of 207 MW in New England will reach age of 60 by 2013 and retire. No units in Rhode Island are affected by this assumption.

The approach using these two criteria results in a conservative estimate of capacity retirements for several reasons. Rather than considering the operating costs for all units, we limit the review to only those units that are currently on RMR contracts. These units represent only a small amount of the total capacity which may be at risk of not being able to recover operating costs through realized market pricing. In particular, those units which are exposed to increasing cost requirements related to compliance with stricter air emissions standards such as carbon reduction programs, are also at risk. Coal generation facilities in particular face these environmental risks, though other types of generators are affected as well. Estimates for the expected carbon allowance prices range from roughly $5/ton to over $100/ton by 2013; this range is based on the severity and timing of the policies as well as the ability of resources to reduce carbon emission through control equipment (or reduction in output). Within the Rhode Island RSP zone, the facility most at risk due to possible tightening of air emission control policies is the Brayton Point[35] facility which includes over 1,100 MW of coal generation.

[35] Brayton Point is located physically in Somerset Massachusetts but is in the Rhode Island RSP zone.

CHAPTER FIVE: KEY ASSUMPTIONS FOR THE POWER-FLOW MODELING

This chapter provides additional detail regarding the overall assumptions used in the power-flow model. The power-flow case was based on the 2012 power-flow planning case from ISO-NE. The basic assumptions were updated to include more recent information available since the creation of that power-flow and also to reflect the alternative assumptions described in the previous three chapters. Note, the case was also updated to reflect the 2013 year rather than the 2012 year.

The key assumptions for the power-flow modeling include:

- Peak Load Characterization
  - 2013 Peak Demand Projection
  - Transmission Loss Adjustment
  - DSM and CHP Adjustments
- Supply Side
  - Existing Generating Capacity
  - Forced Outage Rate and Spinning Reserves
  - Capacity Additions and Retirements
  - Additional Dispatch Related Assumptions
  - Stressed Generation Capacity Case

5.1 Peak Load Characterization

5.1.1 2013 Peak Demand Projection

The ISO-NE load growth forecast issued in April 2008 is the source for the demand data used in this analysis. ISO-NE provides a reference load forecast that is characterized as having a 50 percent chance of being exceeded. An extreme weather peak demand forecast is also provided by ISO-NE that is characterized as having a 10 percent chance of being exceeded. In compliance with standard transmission reliability planning, ICF uses the extreme weather peak demand forecast (also known as the 90/10 forecast). Under the 90/10 forecast, the Rhode Island sub-area peak demand is estimated to be 2,965 MW in 2013.

ICF believes that relying on the ISO-NE projection for the 2013 year is a conservative assumption based on ISO-NE's own statements that indicate that their load projections for 1, 3, and 5 years into the future have been below the actual realized load growth on a consistent basis. The average forecast error ISO-NE has documented for the fifth year (the relevant year for our study) is biased to a 4.2% under estimate of peak. For the Rhode Island 90/10 case, this implies 125 MW of additional demand at peak, or a peak load of 3,090 MW rather than 2,965 MW.

5.1.2 DSM and CHP Adjustments

For power-flow modeling purposes, DSM and CHP resources are decremented from the peak demand level used in the model. The dispatchable DSM resources such as the emergency generators and demand response are assumed to be reserved for emergency conditions and are not removed from the ISO-NE peak load projection in the power-flow cases.[36] Thus, the Rhode Island peak load is only decremented by 113 MW to account for the non-dispatchable DSM resources for the power-flow analysis, accounting for about 43% of the total Rhode Island DSM projection. CHP resources are removed in total, reflecting an additional 31 MW decrement in peak demand. After accounting for the CHP and DSM resources, the power-flow peak modeling characterization is 2,821 MW for the Rhode Island zonal peak.

5.1.3 Transmission Loss Adjustments

The ISO-NE load projections are based at the generator bus-bar and hence include both transmission and distribution losses. In contrast, power-flow load inputs reflect the load at the distribution transfer point rather than at the generator level. As such, we have adjusted the ISO-NE load projections to remove transmission losses to reflect the distribution load levels. This allows for the power-flow to internally determine the transmission sector losses.

5.2 Supply Side Characterization

To establish a starting point for the Reference Case scenarios considered in the analysis, ICF first established a view of system dispatch under normal peak day conditions such that system operations were not stressed. This starting point dispatch utilizes the existing generation resources as reported by ISO-NE, and includes the ISO-NE typical generation unit forced outage rate and spinning reserve requirement.

5.2.1 Generation Capacity

ICF relied on the generation capacity for existing units as provided directly in the power-flow case. The capacity included in the power-flow case reflects the maximum summer-rated capacity for each unit. Additional modifications were made to account for capacity additions and retirements by 2013.

5.2.2 Forced Outage Rate and Spinning Reserve

The required forced outage rate in each zone is 7 percent of total capacity within the zone. To implement the forced outage in the power-flow model, ICF turned off selected generation units within each zone, to reach 7 percent of the total capacity. These units were considered not available to meet system demand.

[36] ISO-NE views dispatchable DSM as supply side resources

A spinning reserve requirement of 15 percent of total capacity was also implemented in the power-flow model. This represents generation capacity that is made available to respond to system contingencies. The 15 percent spinning reserve was implemented in each load zone with the exception of Rhode Island. Since Rhode Island is a net exporting region, it is expected that all generation units within that area will be operating at their available capacities on a peak summer day.

5.2.3 Capacity Additions and Retirements

Capacity additions and retirements as described in Chapter Four were incorporated into the power-flow cases.

5.2.4 Additional Dispatch Related Assumptions

Other unit specific dispatch requirements were modeled. For example, nuclear generation facilities are expected to operate at their full output on a typical summer peak day. Therefore in the model, all nuclear units throughout New England were fully dispatched. These assumptions did not affect generation dispatch in the Rhode Island area.

5.2.5 Stressed Case Generation Characterization

The study also assessed the ability of the system to operate reliably following the loss of selected generation resources in the study area. In each generation outage scenario the system was allowed to adjust following the loss of the generator.

The consideration of generation outage scenarios in this report is limited to the outage of the FPLE RISE generation facility in Rhode Island. This is because this facility is critical to electric transmission reliability in Rhode Island. Under the current system configuration, severe transmission line overloads may occur when the RISE facility is out of service. This type of stress case is necessary to consider for reliability planning purposes and is consistent with the NERC guidelines for such.

CHAPTER SIX: DETAILED RESULTS FOR THE RHODE ISLAND RELIABILITY PROJECT

This section presents the results of the power-flow analysis to determine if non-transmission resources, such as DSM, CHP and new generation capacity, can displace or delay the need for the Rhode Island Reliability Project. The power-flow analysis was conducted on the Pre-RIRP Case and the Rhode Island Case, and the results were compared to determine if the Project would provide reliability benefits above and beyond that of the non-transmission resources. In particular, ICF determined whether reliability violations existed in one or more sections of the transmission grid following the implementation of the non-transmission resources in the Pre-RIRP Case. ICF then evaluated system performance in the Rhode Island Case to determine the ability of the Project to resolve all the violations.

For both the Pre-RIRP Case and the Rhode Island Case, two main system conditions were examined – a Reference Scenario in which all generation facilities were allowed to operate as would be expected during a peak summer period, and a stressed generation case, the RISE Facility Outage Scenario, in which the RISE generation facility was assumed to be out of service. The power flowing on each transmission line, also referred to as the line loading, was measured and compared to the thermal limit or capacity of the line to determine if the power grid would operate reliably and continue to serve all consumers under the conditions that were simulated. For reliable system operation, the loading on each transmission line should remain within the emergency rating of the line. Similarly, substation voltages were measured and compared to the limits required for reliable system operation.

As described in detail below, ICF observed that the implementation of the non-transmission alternatives fail to resolve all the transmission line overloads that may occur in the Rhode Island area under anticipated operating conditions. This is particularly evident under contingency conditions, that is, during periods that one or more transmission facilities are out of service. Further, when the RISE generation facility is out of service, extreme conditions occur in the Pre-RIRP Case. The implementation of the Project resolves the reliability problems since it reinforces the Rhode Island area transmission backbone and also provides redundant transmission capacity across which power can be redistributed in case of a failure of other transmission elements.

In all cases, the contingencies shown in the following tables are those that result in the most severe overload for each monitored elements. The tables do not list all contingencies that impact the monitored element. The model simulation showed that in the Pre-RIRP cases, several different contingencies could cause overloads on the transmission elements shown.

6.1 Reference Scenario Results

Exhibits 6-1 and 6-2 summarize the performance of the Rhode Island area transmission grid in the Reference Scenario for both the Pre-RIRP Case and the Rhode Island Case. In Exhibit 6-1, all transmission elements are assumed to be operating as expected during a peak summer period, while Exhibit 6-2 shows system conditions if one transmission element is out of service. In both cases system performance is assessed after an additional transmission element is allowed to fail to reflect a system contingency, or an emergency condition that occurs during the peak period. This element is labeled Contingency in the two tables. Exhibit 6-1 therefore displays results assuming a single transmission element is unavailable, while Exhibit 6-2 shows results if two transmission elements are unavailable.

The tables list transmission facilities that will be overloaded or heavily loaded under the simulated conditions. A description of the facility is given in the column labeled Monitored Element. In addition, the expected line loading for the selected transmission facility is given as a percentage of the limit of the line.

For example, as shown in Exhibit 6-1, if Line 332[37] goes out of service, the loading on the 115 kV line from Drumrock to West Cranston 72 is expected to increase to its capacity or thermal limit (98% loading) if the Project is not implemented (Pre-RIRP Case). However, if the Project is in service (Rhode Island Case), the loading on the line following the same contingency outage is expected to fall below 50% of its emergency rating. Similar information is shown in the rest of the table.

Exhibit 6-1
N-1 Rhode Island Line Overloads, Reference Case

Line Out of Service	Contingency	Monitored Element				Line Loadings - (%)	
Line Name-ISO	Line Name-ISO	From Bus	From KV	To Bus	To KV	Pre-RIRP 2013	Rhode Island 2013
None	332	Drumrock	115	West Cranston 71	115	103%	52%
None	332	Drumrock	115	West Cranston 72	115	98%	< 50%
None	332	Drumrock	115	Kent Co. T1	115	84%	< 50%
None	332	RISE 171	115	West Cranston 71	115	85%	< 50%
None	332	West Cranston 72	115	RISE 172	115	84%	< 50%
None	332	Franklin Square	115	Hartford Ave.	115	84%	54%

Exhibit 6-1 shows that if the Project is not implemented, the failure of a single transmission element during a peak summer period when all other transmission facilities are operating as expected, will cause heavy loading on several 115 kV transmission lines. Line overloads will, however, be minimal. The severity of the overloads will likely increase as demand increases in subsequent years. The implementation of the Project

[37] Line 332 refers to the 345 kV line from West Farnum Substation to Kent County Substation.

reduces line loadings on all the lines considerably, providing reserve transmission capacity to meet further growth in demand. This is because the Project will provide transmission reinforcements in the Kent County area.

The line overloads are much more severe if at least one transmission element is out of service prior to the failure of another transmission element. As shown in Exhibit 6-2, following the failure of a second line, the Pre-RIRP loadings on several transmission facilities exceed the line capacities by 30% to 60%. Such severe overloads can lead to loss of additional transmission facilities, compromising the ability of the grid to reliably serve demand. The transmission reinforcements from the Project reduce loadings below the line limits and, in addition, provide reserve transmission capacity.

Exhibit 6-2
N-1-1 Rhode Island Line Overloads, Reference Case

Line Out-of-Service	Contingency	Monitored Elements				Line Loadings - (%)	
Line Name-ISO	Line Name - ISO	From Bus	From KV	To Bus	To KV	Pre-RIRP 2013	Rhode Island 2013
332	Drumrock 7289	West Cranston 72	115	RISE 172	115	158%	66%
332	Drumrock 7289	Drumrock	115	West Cranston 72	115	153%	61%
332	Drumrock 7289	RISE 171	115	West Cranston 71	115	156%	65%
332	Drumrock 7289	Drumrock	115	West Cranston 71	115	153%	62%
332	Drumrock 7289	Drumrock	115	Kent Co. T1	115	135%	< 50%
332	Hartford Ave. 725	Franklin Square	115	Hartford Ave.	115	130%	82%
332	Drumrock 7289	Drumrock	115	Kent Co. T7	115	87%	< 50%
332	Drumrock 7289	RISE 172	115	RISE	115	106%	71%
332	Hartford Ave. 7205	RISE 171	115	RISE	115	102%	69%
332	Hartford Ave. 7205	Johnston 171	115	Hartford Ave.	115	80%	< 50%
332	Hartford Ave. 7205	Johnston 172	115	Hartford Ave.	115	80%	< 50%

6.2 RISE Unit Outage Scenario Results

The 550 MW FPLE RISE generation facility is a critical generation unit in Rhode Island. An assessment of system conditions assuming the outage of the RISE generation facility shows severe thermal and voltage violations in Rhode Island in the Pre-RIRP case. For example, following an outage of the RISE generation facility and the loss of line 332, a contingency outage of line S-171S or line T-172S results in a voltage collapse[38] in the Rhode Island area. Operator action to prevent impact to a larger section of the grid may include load shedding.

Exhibits 6-4 and 6-5 summarize the expected system performance if the FPLE RISE generation facility is out of service during a peak summer period. As shown in Exhibit 6-4, if a single transmission element is out of service, several transmission lines will be

[38] Voltage collapse usually occurs when the grid is required to serve more load than the voltage can support. Under such conditions, system voltages decline progressively, and can result in a local or regional blackout.

loaded close to, or just above, their capacities. The 115 kV transmission line from Franklin Square to Hartford Avenue exceeds its emergency rating by 31% in the Pre-RIRP Case.

If a second transmission facility goes out of service, the transmission line overloads become excessive. The line loading for several transmission lines exceed their thermal ratings by more than 60% in the Pre-RIRP Case.

Similar to the Reference Case, the implementation of the Project results in significantly reduced line loadings on all the transmission facilities and resolves the identified transmission reliability issues.

Exhibit 6-3
Location of FPLE RISE Unit

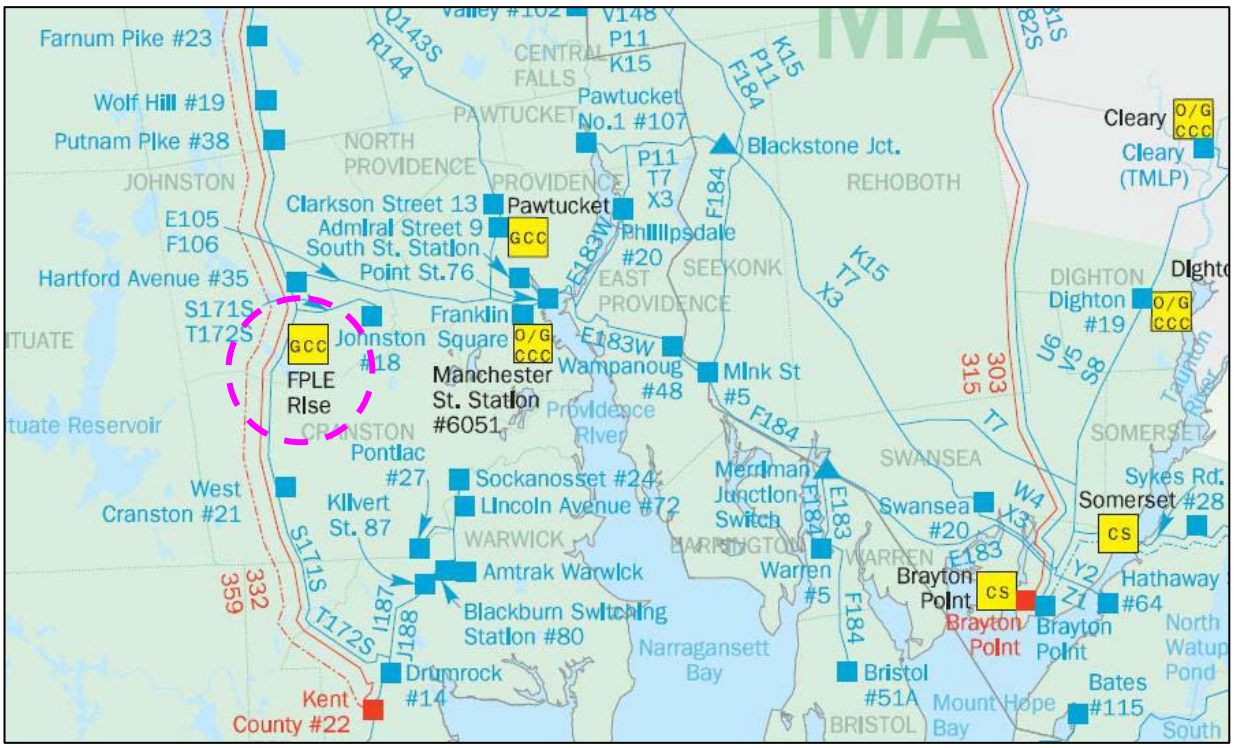


Exhibit 6-4
N-1 Rhode Island Line Overloads, RISE Unit Outage Case

Line Out-of-Service	Contingency	Monitored Elements				Line Loadings - (%)	
Line Name-ISO	Line Name-ISO	From Bus	From KV	To Bus	To KV	Pre-RIRP 2013	Rhode Island 2013
None	332	Johnston 171	115	Hartford Ave.	115	106%	< 50%
None	332	Johnston 172	115	Hartford Ave.	115	105%	< 50%
None	332	Drumrock	115	West Cranston 71	115	97%	< 50%
None	332	Franklin Square	115	Hartford Ave.	115	131%	83%
None	332	Phillipsdale	115	Franklin Square	115	97%	< 50%
None	332	Brayton Point	115	Warren 83	115	98%	52%
None	332	Drumrock	115	West Cranston 72	115	92%	< 50%
None	332	West Farnum	115	West Farnum Tap 1	115	92%	< 50%
None	332	Johnston 171	115	RISE 171	115	82%	< 50%
None	332	West Farnum	345	West Farnum	115	83%	< 50%
None	332	Mink Street 183	115	Wampanoag	115	83%	< 50%
None	332	West Farnum	115	West Farnum Tap 2	115	82%	< 50%
None	332	RISE 171	115	West Cranston 71	115	81%	< 50%
None	332	Mystic CT	115	Whipple Junction	115	76%	< 50%
None	332	West Cranston 72	115	RISE 172	115	80%	< 50%
None	332	Johnston 172	115	RISE 172	115	78%	< 50%

Exhibit 6-5
N-1-1 Rhode Island Line Overloads, RISE Unit Outage Case

Line Out-of-Service	Contingency	Monitored Elements				Line Loadings - (%)	
Line Name-ISO	Line Name - ISO	From Bus	From KV	To Bus	To KV	Pre-RIRP 2013	Rhode Island 2013
332	Hartford Ave. 7205	Johnston 171	115	Hartford Ave.	115	195%	65%
332	Hartford Ave. 7205	Johnston 172	115	Hartford Ave.	115	195%	65%
332	Hartford Ave. 7205	Johnston 171	115	RISE 171	115	172%	51%
332	Hartford Ave. 7205	Johnston 172	115	RISE 172	115	168%	< 50%
332	Drumrock 7289	Drumrock	115	Kent Co. T1	115	120%	76%
332	Hartford Ave. 7205	West Farnum	115	West Farnum Tap 1	115	93%	< 50%
332	Hartford Ave. 7205	Phillipsdale	115	Franklin Square	115	92%	< 50%
332	Hartford Ave. 7205	Brayton Point	115	Warren 83	115	87%	< 50%
332	Hartford Ave. 7205	Mink Street 183	115	Wampanoag	115	85%	< 50%
332	Hartford Ave. 7205	RISE 171	115	West Cranston 71	115	82%	< 50%
332	Hartford Ave. 7205	West Cranston 72	115	RISE 172	115	81%	< 50%
332	Hartford Ave. 7205	Drumrock	115	West Cranston 71	115	80%	< 50%
332	Drumrock 7289	Drumrock	115	Kent Co. T7	115	77%	< 50%
332	Hartford Ave. 7205	West Farnum	115	West Farnum Tap 2	115	79%	< 50%

6.3 Demand-side Reduction Scenarios

The assumptions in the Reference Scenario regarding the penetration of additional demand and supply side resources over time are derived considering an aggressive demand side penetration in combination with a primarily economic driven generation addition.[39] ICF considered an alternate approach to this to determine the total incremental amount of demand side resources which would need to be added in order to provide similar reliability benefits to those achieved in the Reference Case already including both transmission and non-transmission alternatives. This is a step in assessing whether there is a feasible alternative to the transmission solution beyond the penetration level already assumed; hence it supplements the Reference and unit outage cases examined.

Under this scenario, the full quantity of CHP, DSM, and generation resources included in the Reference Case were assumed to be online as a starting point. From this case, the

[39] Generation additions are primarily driven based on ensuring that adequate reserves are maintained over time. The types of resources added are those which would provide the least cost option to maintain reserves. In addition, units which may already be under construction, or units which are had been approved in non-marketed programs (such as the Kleen unit in Connecticut) at the time this analysis began are considered as generation additions.

peak load was then decremented until all line overloads were resolved and similar line flows to the Reference Case with the Project online were achieved.

The findings, based on the power-flow analysis, indicated that the incremental load decrement which would need to be applied as a uniform percentage reduction to all load points in the Rhode Island zone would be between 1,500 MW and 2,000 MW. This reflects roughly 50 to 70 percent of the peak demand projected for the entire Rhode Island sub-area over and above the 5 percent of peak demand already decremented for as active DSM and CHP resources.

Given the importance of the location of load reductions on power-flow and line loadings, we further examined a scenario in which local load reductions were assumed at key load points rather than uniform load reductions. In cases where problems are isolated to specific geographical points, one would expect that a lesser total reduction would be necessary, i.e. one is attacking the problem at the source. Under this scenario, the Drumrock, Kent County and Johnston substations were identified as key contributers to the identified reliability issues, and the assumption was made that all load at these three substations was set to zero. This removed 294 MW of coincident peak load. With this change alone, overloads continued to exist on the system and as such, further uniform decrements were applied to all points in the Rhode Island zone until overloads were addressed. A total of 1,000 MW were required to be decremented through curtailment of other means in addition to the 294 MW site specific load for a total of 1,294 MW load reduction. This still reflects over 40 percent of the 90/10 projected peak load for the Rhode Island zone in 2013. Our conclusion from this analysis was the site specific loads which most contribute to the local line overloads is not significant enough to reduce line overload issues in the area, even in the extreme case where all local load was eliminated.

One final demand decrement scenario, relating to exports to Connecticut, was considered. This export case was analyzed to consider if loop flows and exports to Connecticut may be contributing to the overloads. In this case, a load reduction was applied in Connecticut as well as Rhode Island. Similar to the site specific decrement case, the power-flow results indicated that even with a 1,000 MW reduction in Connecticut, at least 1,000 MW of reduction would be required in Rhode Island as well.

The demand reduction that has been found to be necessary in the Rhode Island zone based on these several cases reflects an unrealistic level of resources. The resulting peak demand in the Rhode Island sub-area would need to be between 800 and 1,500 MW to achieve the reliability benefits of the Project. This reflects a situation where in 2013, the peak load would need to be reduced by 40 to 70 percent of today's peak demand level, a situation not able to be technically achieved.

CHAPTER SEVEN: CONCLUSIONS

It is evident from this study that the Rhode Island Reliability project is critical to the reliable operation of the New England transmission grid, and in particular, the Rhode Island transmission system. This conclusion is supported by results of the power-flow analyses, which indicate that the implementation of non-transmission alternatives alone will not be sufficient to resolve the numerous transmission facility overloads and substation voltage violations that could potentially occur when some key transmission elements are out of service.

The study has shown that the Project will sufficiently resolve the overloads and violations. In addition, the transmission reinforcements from the Project will provide reserve transmission capacity that can be used to redistribute power in the event of a system emergency, and which will also be available to meet future system needs as demand grows in the Rhode Island area.

ICF's study examined a Reference Scenario that reflected summer peak conditions in 2013, assuming all facilities operated as expected. Non-transmission alternatives, including DSM, CHP and new generation capacity, were implemented in this scenario. To a large extent, the grid would be able to serve consumer demand under these conditions if all transmission facilities remained in service. If one of a number of key facilities is out of service, however, the ensuing severe overloads would compromise the integrity of the grid in the Rhode Island area. The Project will provide additional transmission capacity that will resolve these reliability problems. Further, the study has shown that the magnitude of demand-side options necessary to achieve similar reliability benefits to the Project are not feasible.

The study also showed that system conditions worsen considerably if the FPLE RISE Generation facility is out of service, especially if this is coupled with the outage of one of several transmission lines.

Since Rhode Island has limited high voltage (345-kV level) connections to the rest of the New England 345-kV transmission backbone, and limited generation connected to the 115-kV system, the additional 345-kV capacity provided by the Project significantly improves the reliability of the Rhode Island transmission grid.

The conservative nature of the assumptions used in the study further reinforces these conclusions. Even under these conservative assumptions, the reliability of the system must be addressed through the proposed transmission upgrade. Less conservative assumptions would result in greater line overloads and voltage violations than determined in this study.

APPENDIX 1: GLOSSARY OF TERMS

Active demand resources –Dispatchable demand-side resources.

Combined Heat and Power – Systems used typically at industrial or commercial sites to generate electricity and steam/heat for onsite operations and use, thus reducing the load on the generation and transmission system.

Contingency – A situation in which one or more elements of the power system have failed. These elements might include a generating station, transmission line, or a transformer.

Critical peak resources – Active demand-side resources which reduce their load during forecasted peak hours (realized in the day-ahead time frame) and shortage hours (realized in real-time).

Demand resources – A variety of techniques used to reduce electrical demand in order to reduce system-wide generation and transmission requirements. Demand resources are also referred to as **Demand-side Management**. Demand resources can be "active" or "passive."

Distributed generation – Generation resources directly connected to end-use customer load and typically located behind the end-use customer's billing meter. Distributed generation resources may be used for routine energy generation or for emergency use only, and typically have a capacity less than 5 MW.

Distribution-side load – A measure of the system load at the end-user point.

Emergency operating conditions – In this study, emergency operating conditions refer to a system state in which two components of the bulk power system have failed. Compare to **Normal operating conditions.**

Forced outage rate – The percentage of time that a given generating unit is unable to function due to unanticipated breakdown or emergency conditions.

Forward capacity auction (FCA) – The mechanism through which supply and demand resources are bid into and selected to participate in the Forward Capacity Market (FCM). The FCA is held two years prior to the commitment period for which the resources cleared in the market must provide the generating capacity or demand-side resources bid into the auction. In the New England market, commitments of up to five years are available for demand resources and units are paid the market-clearing electricity price during their demand-reduction actions.

Forward capacity market (FCM) – A market designed to procure capacity from willing providers of new generating resources and demand resources already available, but not used, in a system.

Generator bus-bar – Connects a given generator to the step-up transformer.

Load deficit – The amount of load unable to be served reliably.

Market penetration – The measurement of the relationship between the total potential use of a product or technology in a given market and its actual use.

N-1 – Power system state where one component of the bulk power system has failed.

N-1-1 – Power system state where two components of the bulk power system have failed.

Normal operating conditions – In this study, normal operating conditions refer to a system state in which no more than one component of the bulk power system has failed. Compare to **Emergency operating conditions.**

Passive demand resources – A set of demand resources whose use are outside the direct control of the grid operator and not *necessarily* correlated to the relationship between demand and supply of energy in a system. Examples of passive demand resources include energy-efficient equipment, such as refrigerators and air conditioners, and compact fluorescent lights.

Payback – The number of years it takes for the annual operating savings to repay the initial capital investment of a particular technology or upgrade.

Power-flow case – a modeling representation of the physical power system, including generation units, load, transmission facilities, transformers, reactive compensation devices, DC lines, and phase angle regulators.

Real-time demand response – Resources which must reduce their load within 30 minutes of receiving instructions from the ISO, and wait until further instructions come before they may restore usage.

Real-time emergency generation – Distributed Generation Resources which must reduce their load within 30 minutes of receiving instructions from the ISO, and wait until further instructions come before they may restore usage. Limited to 600 MW system-wide in the NE-ISO.

Reliability Must-Run (RMR) – RMR units are generation facilities that are no longer economical to operate on an on-going basis, but that are required for system reliability purposes. These generating facilities enter into RMR agreements with NE-ISO and that provide for payments to the plants so the plant owner will maintain the units in a ready operating state in case the plants are required to maintain the reliability of the power system.

Renewable Standards Portfolio (RSP) – Policies under which many governments at the state level have mandated different levels of renewable generation to electric utilities within certain timeframes.

Spinning reserves – Supply available to serve load in the event of a contingency that are available on short notice, typically around 15 - 30 minutes time.

Substation – A facility containing switches, transformers and other equipment used to switch, change, regulate, and monitor voltage in the electric transmission and distribution system.

Voltage violation – An incident in which the voltage at a substation reaches levels outside of safe operating limits.