Utilization of Underground and Overhead Power Lines in the City of New York

Prepared by:

Office of Long-Term Planning and Sustainability
Office of the Mayor
City of New York

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I. Background

Pursuant to the terms of City Council Introduction No. 985-A, codified as Local Law 13, the Mayor's Office of Long-Term Planning and Sustainability (OLTPS) has undertaken a study of the feasibility of the potential utilization of underground power lines in the City as a replacement or supplement to the overhead radial lines now in use in wide areas of New York City.[1] As was suggested in the local law, OLTPS has in large measure drawn upon the knowledge of City's principal electric utility, Consolidated Edison (Con Edison), and reports prepared by the New York State Department of Public Service (DPS) for much of the information relating to the elements of the electrical distribution system that serves New York.

In the wake of Hurricane Sandy in late 2012, the City Council took note of the widespread and in many cases protracted power outages that occurred in certain areas of the City. Accordingly, the Mayor's Office was asked to provide an evaluation of the relative merits of relocating components of the City's overhead electrical grid to underground locations as a means of potentially mitigating the effects of severe weather events in the future. Specifically, OLTPS was asked to examine the feasibility of undergrounding distribution lines, and to evaluate the areas in the City that would be most advantageous for such an approach.

The City Council asked that to the extent possible, general electric system information be supplemented with data that is disaggregated by borough, community district, or other segments of the utility service territory, as determined by OLTPS. In practice, we have found that below the borough or county level, political subdivisions such as community districts do not lend themselves to separate forms of outage or service data. Rather, Con Edison maintains electrical system statistics disaggregated on a

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[1] This study was prepared under the direction of OLTPS Director Sergej Mahnovski, PhD. by Michael Delaney and Candice Tsay. OLTPS is grateful for the help of its outside counsel, Couch White, in helping to prepare this document. Consolidated Edison was also instrumental in providing technical assistance and background materials, and the authors appreciate the company's participation in advancing this project.

borough basis in accordance with reporting requirements and regulations established by the New York State Public Service Commission (PSC).

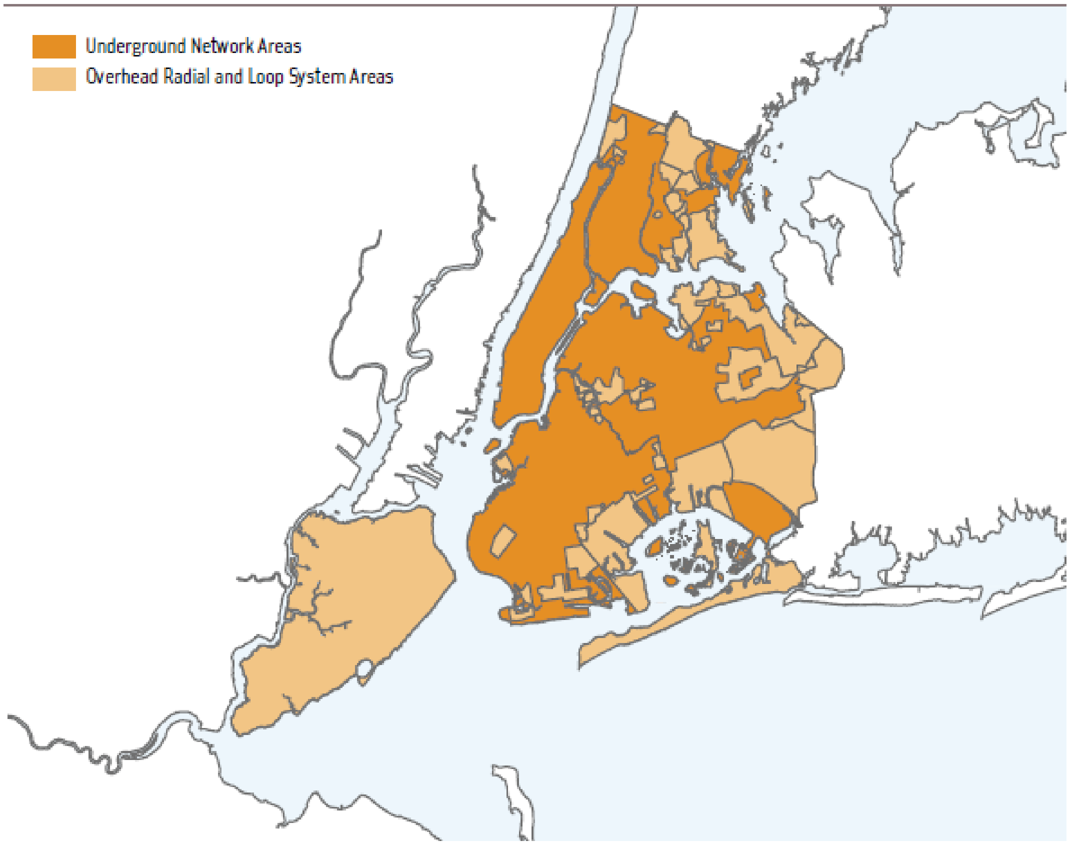
On June 11, 2013, the City of New York published *A Stronger, More Resilient New York,* a detailed analysis of the effects of Hurricane Sandy on eleven (11) infrastructure and service sectors and five (5) affected communities, including dedicated chapters on the utility and refined products infrastructures. The utilities section of the report assessed the causes of electric, gas, and steam service outages during Hurricane Sandy and its aftermath, and produced a number of recommendations to improve the resiliency of these systems on several fronts, addressing regulatory frameworks, utility infrastructure investments, and emerging customer-side solutions. Altogether, the recommendations focused on implementation of strategies to prevent or minimize the impacts of severe weather events, and to allow for more rapid restoration of service in the event of power outages.

Acting upon these recommendations, the Mayor's Office has taken immediate steps to enable implementation of recommended projects. In fact, as early as May 31, 2013, the City filed testimony from numerous expert witnesses addressing a number of system resilience issues in the pending Con Edison electric rate case before the PSC. In addition, beginning in September 2013, the City has also been an active participant in the PSC's Con Edison Resiliency Collaborative, which was established to allow parties in the rate case to reach consensus on Con Edison's proposed near-term storm hardening plans and other important climate change resiliency topics. Within the collaborative, the City has been leading development of a cost-benefit model that that uses detailed climate information and quantifies potential risks of customer outages due to hurricanes and other major storms. The City's efforts in the Resiliency Collaborative and in the rate case are focused on identifying the best outcomes for ratepayers and ensuring that those measures that are implemented are both impactful and cost-effective.

II. Initial Findings

Currently, 86% of electric load and 82% of customers in New York City are served by underground distribution networks.[2] As shown in Figure 1, throughout Manhattan and other high density areas in the boroughs, utility customer load is served by underground distribution networks. These are dense grids that can serve customers over multiple pathways that offer system redundancy and thereby heighten reliability. However, in some areas of relatively lower building density in the Bronx, Brooklyn, Queens and Staten Island, electric distribution lines and equipment are placed overhead in non-network configurations that provide fewer redundancies, but are also considerably less also costly to maintain and repair.

Figure 1.Electric distribution systems



Source: Con Edison, LIPA

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[2] *A Stronger, More Resilient New York*, by the City of New York, page 108

Reproduced from *A Stronger, More Resilient New York*, page 109

Table 1. Miles of overhead wire by Borough[3]

Area	Miles of overhead wire	% of all installed wire, underground and overhead
Bronx	2,667	20%
Brooklyn	3,538	12%
Manhattan	0	0%
Queens	6,968	22%
Staten Island	7,140	72%
Total:	**20,313**	

Based on recent customer outages due to windstorms, snowstorms, hurricanes and other weather-related events, the City Council has raised new questions raised about potential vulnerabilities in the overhead distribution system, and has expressed interest in converting overhead system elements to underground facilities as a way to increase the reliability of the system during severe weather events. The principal presumed advantage of moving an existing overhead system underground would be to reduce the frequency of customer outages. However, while it is true that underground grid elements are far less exposed to the elements, and are generally subject to fewer interruptions of service, there are a number of countervailing considerations that make a decision concerning the subject addressed by Local Law 13 more complicated than it may first appear.

The initial consideration is that of cost – the potentially prohibitive expense of moving electric service underground in one of the most densely populated areas of the country. Con Edison and a consulting firm that it retained recently attempted through a study of representative electric feeder lines

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[3] See Appendix A at page 38.

to quantify the expected overall cost of converting the existing overhead system to an underground configuration.

Clough Harbour & Associates LLP (CHA) was originally retained in 2007 by Con Edison to provide professional engineering services to evaluate the feasibility of converting existing overhead electric distribution system in Westchester County, Bronx, Brooklyn, Queens and Staten Island to an underground distribution grid (the distribution system in Manhattan is entirely underground, which is primarily a function of the very high density of the electric load, or demand, in that borough). In early 2013, Con Edison asked CHA to provide an update of the 2007 study with the most recent information on technical developments affecting overhead and underground lines, and also to reflect the most current estimated costs for implementation of various measures. The study authored by CHA and provided to OLTPS by Con Edison is attached hereto as Appendix A.[4]

The estimate that CHA arrived at for undergrounding averaged some $8.29 million per mile for the Bronx/Westchester, and $7.81 million per mile for Staten Island. Given the very large scale of the overhead or radial system, with a total of more than 20,000 miles of overhead cable in the City alone,[5] the aggregate expense of a wholesale conversion would translate into an estimated total Con Edison system cost of $27.2 billion for Bronx/Westchester County combined, $3.2 billion for Brooklyn, $5.6 billion for Queens, and $6.9 billion for Staten Island, or a total service territory cost of some $42.9 billion to convert all electric overhead lines to underground feeders. For New York City alone, the corresponding cost would be as much as $18.5 billion. To provide a frame of reference, Con Edison's entire capital investment budget for all its system-wide infrastructure improvements is approximately

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[4] *Feasibility Report: Underground Electric Utilities,* prepared by CHA for Consolidated Edison Company of New York in May 2013, and referenced herein as the CHA Report.

[5] See Table 1 on page 2 above.

$1.5 billion annually. The analysis also indicates these costs would translate into a significant increase in the typical residential customer bill.[6]

One driver for the high cost for conversion is the challenge associated with finding a suitable route in which to install new underground facilities due to the high population density of New York City, as well as the multiple competing uses for underground space. Although the costs per mile for overhead to underground conversion calculated in the CHA Report did not extend to specific feeders in the Bronx, those costs are expected to be somewhat higher overall due to the relative degree of building concentration in that borough. More expensive street opening and restoration measures would almost certainly be required in the Bronx than in other areas of the City such as Staten Island that are characterized by lower levels of population density.

As an illustration of the work needed to complete a transformation from overheads to subterranean facilities, the proposed underground installations on the Con Edison system would utilize concrete encased duct banks, manholes and vaults with installed transformer and switching equipment. Installations of these duct lines can be challenging in many areas given the urban nature of the affected locations, and the many underground facilities already in place in these areas. Submersible transformers and other commercial transformers would be installed in Con Edison vaults, and could offer switching flexibility and relative ease of accessibility. Secondary systems in older residential areas might be fed from submersible transformers that would feed additional circuits. Multiple home services would be served from these manhole locations, and secondary conduits crossing streets would feed service boxes that would reach multiple services on the opposite side of the street. In newer residential areas, below grade transformers would feed secondary service boxes on the street with interconnecting cable and conduit runs.

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[6] Appendix A at page 36

To the extent that a reduction in adverse aesthetic and visual effects of overhead systems is a desired result, that may not be achievable because the electric utility poles currently in use serve multiple functions, including support for hardwire telephone service, cable television lines, and other fiber facilities. The physical removal of poles would therefore depend on placing these infrastructure elements underground as well, at a considerable additional expense.[7]

A recent study recently issued by a national utility industry trade group, the Edison Electric Institute (EEI),[8] attached hereto as Appendix B, found that over the last ten years, at least eleven studies or reports have been generated by various states on the merits of undergrounding overhead electric lines as a means of dealing with the impact of large storms. To date, however, no state utility commission has recommended wholesale undergrounding of the utility infrastructure. EEI conducted surveys of consumers' willingness to pay for underground infrastructure, and found that residents typically were willing to pay an additional 0-10% on the monthly retail bill for enhanced security from undergrounding. However, the EEI study also found that the capital cost associated with undergrounding entire utility systems would, on average, double residential retail bill charges.

The principal benefits and challenges to undergrounding were examined in the EEI Report.[9] The perceived value of undergrounding includes both heightened reliability and improved aesthetics. Possible problems associated with undergrounding include costs, operation and maintenance concerns including longer repair times, and a lessened longevity of components – potentially only 30 years for underground system elements versus as long as 50 years with overhead facilities.

The EEI Report in Chapter 6 at pages 29 through 33 also examined the issue of expected costs for undergrounding distribution systems. While the EEI treatment is national in scope, it tends to confirm the

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[7] The CHA Report suggests that such a course would result in an increase of more than $23 billion, thereby causing the total cost of undergrounding to increase to more than $66 billion for the entire Con Edison service territory.

[8] *Out of Sight, Out of Mind 2012, An Updated Study on the Undergrounding of Overhead Power Lines*, Edison Electric Institute (January 2013), referenced herein as the EEI Report

[9] *EEI Report* at Chapter 5, "Benefits and Challenges of Undergrounding," at pages 25-28

general findings from CHA concerning projected undergrounding costs on the Con Edison system. The latter show accompanying expenses to be considerably higher in the City; however, this is not unexpected when typical costs incurred in New York are compared to nationwide averages that include many suburban and rural areas as well as more complex urban settings.

In the face of daunting cost estimates such as those analyzed by both CHA and the electric utility industry at large, a careful evaluation must be made of the expected benefits of undergrounding, as well as the inevitable trade-offs that could accompany any such initiative. Approaches other than wholesale conversion of the overhead system, such as a more targeted or selective approach, potentially could realize many of the expected benefits at a fraction of the cost of full conversion. There are also less costly improvements that could be made to the overhead system on a much greater scale to markedly increase its resilience and resistance to storm damage. For more on the latter, see the discussion in Section VI.

Both of these approaches are under current consideration for implementation by Con Edison, and the remainder of this report will discuss a number of possible steps other than wholesale undergrounding that can be taken to enhance the City's electric grid, and improve its resilience to storms, as well as other hazards such as heat waves.

III. Performance During Major Storms

The EEI Report referenced above examined various reliability indices to determine trends between 2003 and 2011. National data compiled for an earlier EEI study in 2009 did not reveal any distinct trends of increasing or decreasing averages in number of events, length of events, or number of customers affected by storms. In contrast, the most recent EEI Report showed an increasing trend toward a greater number of storms over the full period of 2003 through 2011. The new report reviewed the categories of storms that are the most frequent, those that affect the greatest number of customers, and those that cause the largest number of customer outage hours. Hurricanes and major tropical storms, as well as other summer weather disturbances such as local thunderstorms, and winter storms with complicating factors such as snow and ice loading made up 95% of all the external events that adversely affected utility infrastructure.

The New York State Department of Public Service (DPS) has similarly taken note of a tendency in recent years toward more severe storm events affecting utility facilities, both on overhead lines that are typically exposed to adverse weather conditions, and on underground networks in coastal areas that can be subject to inundation events. For example, overall customer hours of interruption rose each year between 2009 and 2012. The most recent study, the DPS *2012 Electric Reliability Performance Report*, discusses these developments, and is attached hereto as Appendix C.

The recent trend of a high number of outages from major storms in New York State, which included the effects of Hurricane Irene in August 2011, as well as an October 2011 storm that had a heightened impact due to heavy snow loading on trees that still had extensive foliage, was highlighted in late October of 2012 with the effects of Hurricane Sandy. In fact, according to DPS, Sandy alone caused nearly a quarter of the total number of customer interruption hours that have been experienced in New York State in the last 23 years.[10]

Overall, in 2012, three major storm[11] events occurred in the Con Edison service areas. Such events affect the overhead system primarily due to downed trees or tree branches. Hurricane Sandy was clearly an outlier in terms of the areas impacted on both the underground and overhead systems, the number of customer outages, and the time needed for restoration.

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[10] *2012 DPS Electric Reliability Performance Report* (issued June 2013), identifying Sandy as responsible for more than 23% of all the electric system outage hours that have occurred in New York since 1989, at page 2. The *Report* at pages 11-12 also reflects the rising storm service interruption numbers attributable to storms in the years 2009 through 2012. This is generally consistent with the national EEI findings discussed above, which identify a national trend toward increased storm events in the nine-year period from 2003 through 2011. See EEI Report, Appendix B hereto at page 10.

[11] According to Rules and Regulations of the PSC, 16 NYCRR Part 97, a major storm is a period of adverse weather during which service interruptions affect at least 10% of the customers in an operating area and/or result in customers being without electric service for at least 24 hours.

Table 2. 2012 Major storms in Con Edison service areas:[12]

Major storm	Areas affected	Number of outages and average duration (system-wide)[13]
July 18, 2012	Queens	3,366 customers for 3.38 hours
September 18-19, 2012	Bronx	1,822 customers for 6.94 hours
	Westchester	25,457 customers for 8.34 hours
October 29, 2012 (Hurricane Sandy and Nor'easter Athena)	All areas	1,221,945 customers for 93.96 hours

IV. Applicable Reliability Metrics

The principal metrics used by the New York Public Service Commission, and by the electric utility industry generally to measure electric system reliability are the following:

System Average Interruption Frequency Index (SAIFI) – measures the average number of interruptions experienced by customers, defined as the customers affected divided by the total number of customers served by the utility. A similar measure of outage frequency is expressed as the number of interruptions per year per 1,000 customers.

Customer Average Interruption Duration Index (CAIDI) – the average length of the interruption experienced by a customer who loses service, as measured in minutes.

System Average Interruption Duration Index (SAIDI) – the average length of an interruption experienced by the average customer, measured in minutes or customer hours, divided by the number of customers served. In mathematical terms, this index equates to SAIFI multiplied by CAIDI.

Traditionally, utility regulators measure day-to-day reliability by excluding major storms. The NYS PSC considers performance during major storms separately from the traditional reliability metrics, and evaluates both metrics side by side in its reports. In addition, it should be noted that the PSC has recently developed new procedure that establishes a range of standards to measure New York utilities'

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[12] Con Edison data in the *2012 Annual Report on Electric Service and Power Quality*, submitted to DPS on(March 31, 2013

[13] Note that these totals include Westchester County.

preparation for, and response to, major storms. One of the City's key recommendations in *A Stronger, More Resilient New York* (Initiative #3), called for regulators to establish performance metrics for climate risk response. Accordingly, the City is supportive of the PSC's efforts in this regard.

Historically, industry data has generally shown that while underground distribution systems experience fewer overall interruptions, those that do occur often last longer than those on overhead systems due to the challenges of diagnosing and repairing subterranean facilities that are out of view. Performing these tasks is inherently more complex compared to doing the same on aboveground facilities. To some degree, this differential may be diminishing due to the higher degree of automation now increasingly being built into underground grid elements to permit greater system visibility, and to facilitate more rapid repairs.[14] Nevertheless, the recognized difference in restoration times between the two systems remains.

This is reflected in Table 2, which shows 2012 reliability performance data gathered by DPS. In 2012, Con Edison's non-network system, primarily overhead in nature, had significantly higher outage frequency than did the company's network system. However, in comparison to the rest of the state, where overhead non-network systems predominate,[15] Con Edison's non-network performance was far superior in terms of frequency of outages, and near- and below-average in terms of outage duration.[16] The data also shows that the outage durations of the network system consistently trends worse than those of the non-network system. Based on this information, and the five-year average that includes data from 2007-2012, it follows that one of the potential trade-offs involved in relocating overhead lines underground will likely be an increased duration of outages when they do occur.

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[14] See *CHA Report* at pages 12-13

[15] Con Edison's extensive network system is unique, as it was built to accommodate the City's exceptional concentration and density of load, which is on a scale not found elsewhere in the State, or indeed, anywhere else in the United States.

[16] However, it should be noted that a blended assessment that examines SAIFI and CAIDI together yields a somewhat different and more favorable result for Con Edison customers.

Table 2. Con Edison's Reliability Performance:[17]

	2012		5-yr average	
	Frequency	Duration	Frequency	Duration
	SAIFI	CAIDI	SAIFI	CAIDI
Con Edison non-network	0.36	2.02	0.40	1.93
Con Edison network	0.012	6.33	0.020	6.28
Con Edison system-wide	0.10	2.39	0.12	2.44

Table 3. Statewide Performance without Con Edison:

	2012		5-yr average	
	Frequency	Duration	Frequency	Duration
	SAIFI	CAIDI	SAIFI	CAIDI
All NYS electric utilities except Con Edison	0.85	1.87	0.90	1.84

V. Considerations Relevant to Undergrounding Distribution System Elements

Underground systems are by their nature insulated from certain risks such as falling trees and limbs, and vehicular accidents, and also offer superior protection from atmospheric hazards such as lightning strikes and ice loading. These benefits, however, are not realized without exposure to other possible risks, and potential equipment failures due to environmental conditions. Such hazards include exposure to wet and humid conditions within underground vaults and manholes, and the adverse effects on electrical components of salt and other corrosive chemicals applied to roads to counteract the effects of adverse winter weather conditions. Such hazards can shorten the life expectancy of buried electrical distribution equipment, and contribute to the lower equipment life expectancy mentioned above.

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[17] Data herein is drawn from the *2012 Electric Reliability Performance Report*. Network systems are generally underground; non-network or radial systems are generally overhead. The reliability metrics shown exclude the effects of major storms.

Underground equipment in the closely confined spaces typically encountered in New York City is also generally more prone to potentially damaging thermal loading during heat waves than are open air facilities, such as overhead radial lines. This is of particular concern in New York City as it experiences what has been termed an urban heat island effect, in which the densely-built environment amplifies retention of heat, particularly at night, and causes sustained temperature levels to be higher compared to adjacent suburban or rural areas. Moreover, in the most critical summer demand periods, temperature stresses such as those resulting from prolonged heat waves are likely to occur with considerably more frequency than major storms.

In addition, as was seen dramatically in lower Manhattan during and after Hurricane Sandy, storm surges, flooding and other sources of water intrusion can clearly compromise even the most robust underground electric circuits. To the extent flooding events remain, as expected, a continuing concern in the future, the limitations of going to an expensive underground system in areas with any appreciable coastal exposure are apparent.

Moreover, although diagnoses of problems on radial overhead systems can usually be made very rapidly as the pole-mounted portion of the system is by definition open to view, this was not the case in the wake of the Hurricane Sandy, where large portions of the Manhattan underground network were brought back into service far faster than many outer borough areas served by overhead electric lines. This anomaly was largely a function of two circumstances: the sheer scale of the destruction of overhead lines caused by a major storm felt over a wide geographic area, which necessitated a lengthy period of restoration and repair,[18] and in contrast, the fact that for ten separate and distinct area networks that

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[18] The broad scope of the harm inflicted by two of the largest storm events to affect the company's system in many years – Hurricane Irene in 2011, and Sandy in 2012 – is illustrated by the significant damage to more than 1000 utility poles and 1000 transformers in the two events combined. The latter storm was of course particularly destructive, with a period of power loss experienced by some 70% of Con Edison customers served by overhead distribution lines.

suffered a blackout in Manhattan, there was only one critical point of failure – the loss due to East River flooding of essential equipment at Con Edison's East 13th Street electric facility that supplied electricity to most of those networks.[19]

Once the facilities at the complex were brought back on line, the principal underground networks in central to lower Manhattan were quickly reenergized, as they had not themselves suffered any significant damage. The only exception to this general pattern was in relatively low-lying underground service locations such as the Seaport and Battery areas that faced direct inundation and widespread damage caused by storm surge – much of it due to flooded electrical equipment located on customers' premises that prevented restoration of power even after the Con Edison facilities were brought back on line.

VI. Alternatives to Full Electrical System Undergrounding in the City

Given some of the clear trade-offs presented by undergrounding the overhead system in New York City, a more nuanced approach that looks to selective use of undergrounding as one strategy in a range of improvements is likely to show the greatest promise, and to be far more cost competitive compared to the wholesale installation of underground circuits.

A potentially beneficial avenue to address the resiliency of overhead utility distribution infrastructure is a strategic approach that utilizes three principal elements: a) the targeted use of undergrounding in certain areas, b) the strengthening of overhead poles and lines, and c) the wider use of a sectionalized or segmentation approach on both underground and overhead systems. The latter course would limit the adverse effects of outages by reducing their geographic reach, and keeping more utility customers in service when outages do occur. Such a strategy offers the prospect of holding costs far

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[19] Two underground area networks in lower Manhattan, Bowling Green and Fulton, were preemptively taken out of service by Con Edison as Sandy approached due to their relatively low elevation, and their recognized potential vulnerability to storm surge. A third area, the Liberty network serving the World Trade Center, was taken out of service by the company when Hudson River water began to inundate the WTC construction site and its environs.

lower than those that would be required for universal undergrounding, while realizing many comparable benefits in achieving enhanced system reliability.

For example, Con Edison has already begun a process of identifying those geographic areas that historically have proven to have been materially affected in nearly all windstorms of major significance, whether due to the presence of mature trees or other forms of vegetation found in those regions, greater wind velocities in particular areas, or perhaps other reasons. Such recognized areas of heightened vulnerability should logically be focus locations for the prudent expenditure of company resilience investment funds. A process is now ongoing to identify and categorize those areas, and to develop optimal approaches to treating their predominant concerns. Attached hereto as Appendix D is an excerpt from a June 2013 Con Edison document, the *Post Sandy Enhancement Plan*, that addresses storm hardening, and examines a number of methods to bolster the strength of overhead lines, including the use of recent technological developments. It also identifies system segments in several neighborhoods that appear to lend themselves to innovative strategies and methods.[20]

Going forward, Con Edison strategy identifies two primary goals: fortifying utility infrastructure to reduce the incidence of outages, and an enhanced restoration process to permit more rapid return of electric power to utility customers who have suffered power losses. Among the principal methods proposed to be used are: enhanced tree clearance programs and selective undergrounding to reduce risk of tree contacts, installation of stronger components such as new pole designs and more resilient cable to better withstand tree impacts, and reduction in the number of customers served from each overhead circuit along with installation of automated switches, isolation devices, and sacrificial components to mitigate the effects of damage.

As noted, one of the main components of Con Edison's storm hardening program is the installation of sectionalizing equipment on both overhead and underground elements of its distribution

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[20] See Con Edison *Post Sandy Enhancement Plan*, at pp. 36-42 (issued June 20, 2013)

system. The planned improvements would divide circuits into smaller segments, and reduce the number of customers served by each segment, thereby minimizing adverse effects when problems occur - whether unexpected, or planned as preventive measures, as in the case of the preemptive network shutdowns used by Con Edison to protect vulnerable underground networks. In the overhead system areas across the four outer boroughs, the improvements would result in a significant reduction in the number of customers served by each individual segment to no more than 500. This would contrast favorably with the current pattern, in which perhaps twice as many customers may be on a single circuit, and are thus vulnerable to a single point of failure.

Another major component of the company’s strategy is upgrading auto-loop circuits in targeted areas that historically have experienced a disproportionate number of electrical outages during storms. The auto-loop configuration forms loops in which feeders can be fed from either end thus affording greater redundancy than standard radial configurations. A mix of measures including the extension of new supply feeders, reductions in loop sizes, and installation of stronger overhead poles and cables is expected to result in material reliability improvements.

One of the new measures that Con Edison is seeking to pilot at approximately 1,000 locations in the targeted auto-loops is the use of breakaway overhead cable connections that would disconnect when struck from above by a load exceeding 500 pounds, such as a falling tree or large limb. Rather than causing a live wire or its attached pole to break, as often occurs now in such a circumstance, the distribution lines would break off without unduly straining the pole or its attached wires. Importantly, such breakaway cables are also designed to fall to the ground in a de-energized state, thus preventing the electrocution risk that sometimes accompanies fallen overhead wires today. Moreover, the avoidance of harm to adjacent facilities would materially reduce customer restoration times. While promising, these new lines need to be tested in practice to determine the extent to which they actually perform as designed.

As mentioned above, selective undergrounding is another piece of Con Edison's overall overhead system hardening strategy. As reflected in the cost estimates from the CHA study, undergrounding twenty-five (25) miles of cable in Con Edison's City and Westchester service areas, or about 0.07% of a total of 34,000 miles of overhead wire system-wide, would require a budget of some $200 million. In comparison, the cost to reduce overhead circuit segment size, a measure that is intended to bring significant reliability benefits system-wide, affecting most overhead system customers, totals approximately $23 million.

Meanwhile, Con Edison's capital investment plan to build flood barriers, elevate equipment, and install pumping equipment at 19 substations across all five boroughs that are at risk for coastal flooding, and each of which serves tens or hundreds of thousands of customers, totals approximately $210 million. Therefore, given the significant cost of converting overhead equipment to underground circuits and the relatively small number of customers that would benefit from such upgrades, the recommended, cost effective approach to undergrounding would be to selectively target areas where relocation of lines underground would be the superior strategy over other resiliency alternatives. Accomplishing this will require analysis by Con Edison to establish criteria for prioritizing the overhead segments and circuits within each community that offer the greatest reliability benefit and cost effectiveness. It is thus prudent to call on Con Edison to undertake such a planning exercise, and to budget a reasonable time for completing the analysis in preparation for implementation of needed system upgrades in the coming years.

VII. Conclusion

As the foregoing discussion indicates, there are many competing considerations related to the wider use of underground electrical infrastructure. Moreover, those considerations extend to a number of concerns beyond the well-understood cost issues.

With the exception of the Rockaways area served by the Long Island Power Authority, the City's entire electric distribution system is exclusively owned and operated by Con Edison. The company is subject to comprehensive regulation and oversight by the Public Service Commission. However, the City of New York plays a vital role in its own right in assuring that safe and reliable electric service is provided to all New Yorkers, and further, to ensure that such service remains affordable.

Accordingly, the City is actively engaged with the Public Service Commission and Con Edison in helping to shape expectations for the future form of the electrical grid, including a host of resilience and reliability measures. Very significant capital investments will clearly be needed, and our future advocacy efforts will in part focus on the optimal degree of undergrounding to realize the energy goals that are central to ensuring the City's future electric system reliability.

FEASIBILITY REPORT: UNDERGROUND ELECTRIC UTILITIES

CON EDISON
WESTCHESTER COUNTY, BRONX,
BROOKLYN, QUEENS & STATEN ISLAND
OVERHEAD FEEDER CONVERSIONS

RYE, NEW YORK

May 2013

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I. EXECUTIVE SUMMARY

CHA Consulting, Inc. (CHA) was retained by Consolidated Edison Company of New York, Inc. (ConEd) to provide professional engineering services to evaluate the feasibility of converting their existing overhead electric distribution system in Westchester County, Bronx, Brooklyn, Queens and Staten Island to underground distribution systems in 2007. In 2013, ConEd contracted with CHA to provide an update of the 2007 study such that the data would reflect current costs. The primary basis for the 2007 study was the result of field evaluation of several representative feeders identified by ConEd, including the following:

Table A

Feeder Designation	Feeder Type	Feeder Location
17W42	13kV Express	Westchester County
Bowman Loop	13kV Auto-Loop	Westchester County
13U1 and 36U4	4kV Primary Grid	Westchester County
5R10 and 5R29	13 kV Express / Auto Loop	Staten Island
272	4kV Primary Grid	Staten Island
33R08	33 kV Express	Staten Island

Based on a review of feeder designations with ConEd engineering personnel, CHA recognizes that ConEd categorizes their overhead distribution feeders into the following feeder types:

- **13kV Open Wire Loop**: A predominantly overhead radial system consisting of open wire distribution to residential and small commercial loads. A loop is supplied by either two or three 13kV supply feeders with an arrangement of automatic switches called vacuum reclosers that provide fault isolation and redundant supply sources.
- **Automatic Transfer Switch (ATS)**: A pad-mounted device which automatically switches between two 13kV supply feeders and supplies large residential or commercial loads with pad-mounted transformers or residential developments with an underground residential distribution (URD) system.
- **Isolated Networks**: An underground system consisting of two or more vault type transformers that have their secondary paralleled through automatic switches called network protectors. These systems are used to supply large commercial or residential buildings.

- **4kV Distribution**: This system consists of a group of unit substations supplied by 13kV feeders. The unit substations supply between two to five 4kV distribution feeders. These 4kV feeders, which are tied to other unit substations forming a network type system, supply residential and small commercial customers from either overhead, underground, or pad-mounted transformers.
- **Secondary Network**: Essentially an underground secondary grid supplied by underground vault type transformers through automatic switches called network protectors. These transformers are supplied by various 13kV distribution feeders which provide redundancy while one or more of the feeders are out of service. Residential and small commercial customers are supplied by this secondary grid.

The perceived advantages of placing an existing overhead system underground are believed to primarily reduce the frequency of customer outages. Based on our study of the sample feeders in both Westchester County and Staten Island, the projected cost for converting the existing overhead system to an underground system are on average $8.29M per mile for Westchester County / Bronx and $7.81M per mile for Staten Island. These per mile costs translate to a total electric cost of $27.2B for Westchester County / Bronx, $3.2B for Brooklyn, $5.6B for Queens and $6.9B for Staten Island, for a total cost of $42.9B to convert all electric overhead feeders to underground feeder systems.

As indicated in Table A above, the feeders that were used for the basis of this feasibility study were located throughout Westchester County and Staten Island. The costs per mile for overhead to underground conversion that were calculated as the basis of this study did not include feeders in the Bronx. Based on the construction requirements in the Bronx, Brooklyn and Queens, the costs per mile are anticipated to be greater than those presented in this report. Not only would restoration work in the Bronx, Brooklyn and Queens be greater than that in Westchester County and Staten Island, but finding a suitable “lane” to install new underground facilities would be extremely difficult. Once this “lane” is found and the underground facilities were designed and installed, a more complete roadway restoration would be required than in Westchester County or Staten Island.

While the above costs represent those associated with converting the electric system only, the same estimating procedures were applied to the remaining overhead facilities on the existing pole line structures. The true improvement to the aesthetic and visual impacts of the existing pole line structures can only be fully realized when the entire overhead utility system is placed underground. With the vast number of cable television (CATV) and private fiber companies and private customers that currently occupy the existing pole lines, the additional costs to underground these networks and thus allow the removal of the existing pole lines from the streets would cost approximately $23.5B for Westchester County, Bronx, Staten Island, Queens and Brooklyn. When this cost is added to the estimated $42.9B, a total combined conversion cost to completely underground all the overhead utilities in Westchester County, Bronx, Staten Island, Queens and Brooklyn is estimated to be $66.4B.

In summary, the costs presented in this report are considered by CHA to be realistic for a system that could be built to replicate the operational flexibility of the existing overhead system. This flexibility is required to allow ConEd the operational flexibility (i.e., switching) to allow quick response to outages. Likewise, the costs are based on an evaluation of study feeders in Westchester County and Staten Island.

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1.0 INTRODUCTION

The following report summarizes the results of a field investigation and overall system-wide feasibility for the conversion of existing overhead electrical distribution systems throughout Westchester County, Bronx, Brooklyn, Queens and Staten Island, New York. Clough Harbour & Associates LLP (CHA) was retained to complete an extensive field investigation of several representative feeders identified by ConEd, including the following:

Feeder Designation	Feeder Type	Feeder Location
17W42	13kV Express	Westchester County
Bowman Loop	13kV Auto-Loop	Westchester County
13U1 and 36U4	4kV Primary Grid	Westchester County
5R10 and 5R29	13 kV Express / Auto-Loop	Staten Island
272	4kV Primary Grid	Staten Island
33R08	33kV Express	Staten Island

Throughout Westchester County, Bronx, Brooklyn, Queens and Staten Island, New York, the majority of the electric distribution lines are constructed overhead on wooden pole lines to facilitate economical construction and maintenance practices. Based on recent weather patterns and the perceived increase in customer outages due to wind storms and other severe weather-related outages, customers tend to become increasingly aware of the overhead distribution system and its perceived lack of reliability. In light of these types of circumstances and issues, customers tend to request that the overhead systems be converted to underground to increase the reliability of the system, and at the same time increase the aesthetics of the area and eliminate the visual impact of the overhead facilities.

According to the 2012 EEI Study "Out of Sight, Out of Mind, An Updated Study on the Undergrounding of Overhead Power Lines", found that the growth rate and additional miles of line built were greater for underground distribution facilities than overhead facilities. The distribution rate of underground investment has been consistently above 25% until the recession years of the late 2000's. Approximately 80% of the nation's electrical grid, however, has been built with overhead power lines. Would reliability be improved if more of the existing overhead lines were placed underground as well? This report will examine the major issues associated with undergrounding existing overhead power lines (i.e., design parameters, reliability issues, costs, etc.).

2.0 SYSTEM DESIGN PARAMETERS

CHA extensively reviewed the study feeders in the field to determine the optimum method for conversion to underground construction. Potential options for underground systems include the following:

1. Direct burial primary cable with pad-mounted switchgear and transformers and pull-boxes for splicing, where required.
2. Primary cable installed in PVC conduits with pad-mounted switchgear and pull-boxes for splicing, where required.
3. Primary cable installed in concrete encased conduits with pad-mounted switchgear and pad-mounted transformers and pull-boxes for splicing, where required.
4. Primary cable installed in concrete encased conduits with submersible transformers and switches located in manholes and vaults.
5. A hybrid of items 3 and 4 above (i.e., pad-mount installations where right-of-way may be reasonably obtained).
6. A complete network system.

Based on our extensive field review, direct burial primary cable and direct burial primary cable in PVC conduit were regarded as infeasible. The representative study feeders are located in a largely urban environment which precludes these options. Based on the field review it was also determined that the installation of a largely pad-mounted system was highly problematic. Due to the narrowness of the public right-of-way and also the lack of space on private right-of-way for pad-mounted equipment, it was decided that the design would utilize vault type equipment (i.e. submersible transformers, switches, etc.). The added complication with the lack of space on private right-of-way is the ability to obtain the private right-of-way from the current landowners in the area. Indeed, in many areas facilities (i.e., manholes and vaults) will need to be installed in the streets, rather than utilizing sidewalk installations for these structures. All transformer vaults required would be in strict compliance with Con Ed specifications for transformer vaults.

Several assumptions were required by CHA to develop realistic cost estimates for the study feeders that could then be applied to all other feeders within the study area. The pertinent assumptions that were required for this study with respect to each feeder are provided in the following table:

Table 1

Feeder Number and Relevant Design Assumptions (Westchester County)

Design Criteria	**Feeder Numbers**					
	17W42 Express	**17W33**	**17W42**	**Bowman Loop**	**13U1**	**36U4** [a]
1-Phase Vacuum Switches		12	6		4	2
Feeder Tie Switches (210)	1		1	1	2	2
Feeder Switches (422) (PMH-9)		29	3	10	3	6
Feeder Switches (431) (PMH-11)	3	14	6	9	3	5
Feeder Switches (440)		1	1	2		
Vacuum Recloser		2	3	3		
Service Entrances (Feet Private / Feet Public) [b]		250’ / 100’	250’ / 100’	250’ / 100’	100’ / 100’	100’ / 100’
Percent of Services Requiring Service Boxes (%)		25%	25%	25%		
Maximum Manhole Spacing (Feet)	500’				450’	450’

Superscript Notes:

a 3-phase padmount transformers could potentially be utilized on this feeder.

b Service entrance lengths were based on field review and an estimate of the lengths required on both the public and private rights of way.

Table 2

Feeder Number and Relevant Design Assumptions (Staten Island)

Design Criteria	**Feeder Numbers**			
	5R10	**5R29**	**272** [a]	**33R08** [b]
1-Phase Vacuum Switches	8	3		
Feeder Tie Switches (210)	3	3	6	
Feeder Switches (422) (PMH-9)	18	3	4	
Feeder Switches (431) (PMH-11)	4	3	12	3
Vacuum Recloser	3	3		
Service Entrances (Feet Private / Feet Public) [c]	100’ / 100’	100’ / 100’	100’ / 100’	
Maximum Manhole Spacing (Feet)	450’		450’	500’

Superscript Notes:

a Automatic single phase sectionalizing devices on a three-phase system.

b West Service Road could be a direct burial system.

c Service entrance lengths were based on field review and an estimate of the lengths required on both the public and private rights of way.

As previously discussed, the proposed underground installation would utilize concrete encased ductbanks, manholes and vaults with both transformer and switch vault-type equipment. The ductbanks would generally consist of concrete encased 6 or 9 way, 5” Schedule 40 ducts with a minimum of 30”cover. Ductlines would vary in configuration depending on whether the installation was for a mainline application or a tap/spur from the mainline. For mainline application a 9 way ductline would be the typical application and for a tap from the mainline a 6 way ductline would typically be installed. Installations of these ductlines would be difficult in many areas given the urban nature of the locations to be undergrounded and the many existing underground facilities in these areas.

Manholes would be 7’X14’X7’ to allow for multiple medium voltage primary and secondary cables, adequate cable training and splicing room. Transformers and switches would be installed in H20 design loading concrete vaults. To the extent practicable the vaults could be located in sidewalk or grassy areas for access and allow for operability above grade if required. However, due to the severe congestion observed in many areas, street vaults would be utilized as well. Depending on location, these vaults would either be cast in place or precast units. Placement of both manholes and vaults would be problematic given the locations of the many existing underground facilities in these areas and the urban nature of the areas. The utilization of precast vaults could provide significant savings in locations where adequate crane access could be provided. It would be very important to develop standard drawings for both switch and transformer vault specifications to ensure that costly multiple variations of the vaults are not required. See typical drawing (Attachment I) for a typical vault configuration. A suitable head structure would need to be designed to meet Con Ed’s standards for the precast application. Smaller precast concrete vaults would be utilized for single phase submersible transformer installations.

CHA would propose to utilize single phase submersible transformers similar to existing ConEd standards and three phase underground commercial transformers installed in vaults similar to ABB UCT types. The three phase underground commercial transformers are designed for either loop feed or radial dead-front applications. Transformer protection is normally provided by bayonet fusing. These units could be installed in ConEd vaults and would offer switching flexibility and easy accessibility coupled with the pre-requisite level of safety to operating personnel. These units would be utilized in lieu of pad-mounted transformers (See Attachment J for a manufacturer’s cut sheet for this equipment). Again due to the urban nature of the commercial areas and existing landscaping, walkways in the residential areas etc, determining locations for these transformers would be extremely problematic. Stainless steel units for both the three phase and single phase applications will provide a great degree of corrosion protection and provide a long term life for these vault installed units.

For three phase switching and protection of the system, vault style stainless steel SF6 switch and interrupter units would be utilized similar to S&C Vista equipment rather than pad mounted switch and fuse equipment. The Vista equipment, Model 211 with one load break switch and one fault interrupter, could be utilized as an intermediate feeder recloser, as a midpoint tie recloser or a tie recloser to an adjacent feeder. Additional units (322, 422, etc.) would provide additional sectionalizing points, but also provide overcurrent protection for three phase transformers and three phase loops that feed single phase loops.). This state of the art underground switching equipment is available in a maximum short circuit rating of 25,000 amperes symmetrical. For applications in excess of this rating, current limiting reactors at the affected stations or other fault limiting techniques would need to be employed to limit the available fault current level.

The installation of series reactors on some of the Westchester County feeders would add a small percentage (on the order of a percent or two) to the overall electric conversion costs for Westchester County. These reactors would be required on all four bank substations to limit the fault current to a 25,000 ampere design level.

The 600 or 900 ampere three phase fault interrupter is controlled by a microprocessor –based overcurrent control. The gear may be setup as a vault installation although manhole style units are also available. Large windows provide a clear view of the open gap and grounded positions (See Attachment K for a manufacturer’s cut sheet for this type of application). For single phase switching and protection of single phase transformers or single phase URD loops, vault style fault interrupters may be utilized similar to Elastimold type MVT (See Attachment L for a manufacturer’s cut sheet). It is our understanding that ConEd presently utilizes equipment very similar to these units. Alternatively, the Vista switchgear may incorporate a single phase protection feature to protect the single phase loops. The microprocessor-based overcurrent control features special customizable coordinating speed time current curves that provide complete coordination with upstream relays and downstream fuses. Conventional E and K speed curves are available.

Utilization of the fault interrupters for transformer protection will allow the purchase of transformers without bayonet fusing which will also provide greater operational flexibility.

The interconnecting cable system would consist of primarily 15kV EPR insulated and jacketed cables installed in the duct system. The cable system would utilize 600 ampere dead break separable connectors similar to Elastimold (See Attachment L for typical cut sheets). Splices that can be disconnected would be utilized in the mainline in conjunction with junction points to allow for sectionalizing and testing during fault conditions. Additionally, test point mounted fault indicators will be utilized in the manhole system to provide fault location information. Equipment mounted fault indicators at the switchgear and transformers would also be provided. These fault indicators would be bi-directional units that would provide reliable fault indication in closed loop, paralleled or networked distribution systems. They would still provide accurate indication not only when a fault occurs but also once a successful circuit reconfiguration has been made from an alternate source. These units would be equipped with fiber optic eye activation and may also be configured for communication through the fiber optic network. Power Delivery Products manufactures fault indicators that would meet the requirements and is a present supplier of Con Ed for overhead fault indicator applications. (See Attachment M for fault indicator information) For the URD system, 200 ampere loadbreak separable connectors and fault indicators would be utilized here as well. Installation of these components would aid fault location, isolation, and restoration.

See Figures 1, 2, 3, and 4 which are schematic outlining typical system one-line diagrams. The aforementioned switch with a circuit configuration of 211 would be utilized as the typical sectionalizing device. This unit has 2 bays, one with a 600 amp or 900 amp load interrupter switch and the other with the aforementioned microprocessor-controlled vacuum interrupter. Additional units (322, 422) provide additional sectionalizing points and also provide overcurrent protection for the transformers.

Depending on circuit configuration and degree of automation required, certain units would be installed with motor operators and communication capability. This equipment, in conjunction with an appropriate control methodology similar to S&C Intelli TEAM, could replicate Con Ed’s standardized automatic loop schemes. IntelliTEAM automatic restoration system uses distributed intelligence and peer to peer communications to dynamically track system conditions on the underground system to detect and isolate a fault anywhere on the loop and restore service to unaffected sections (See Attachment N for a manufacturer's cut sheet for this application). Attachment O provides product literature related to communication devices utilized for the S&C IntelliTEAM product. Attachment P provides product literature related to the universal interface module for the IntelliTEAM product. A fiber optic interconnection would also need to be installed in the ductline to provide the communication capability for the automated units.

The IntelliTEAM works with S&C Automatic Switch Controls to improve service reliability for the distribution system. The IntelliTEAM can be utilized to serve the entire Westchester County, Bronx, Brooklyn, Queens and Staten Island overhead systems. No central monitoring or SCADA control is required although SCADA is fully supported.

IntelliTEAM proceeds without delays inherent in a dispatcher operated or centrally controlled system. Real time currents and voltages are monitored throughout the system and this information is used to make smart switching decisions before breaker or recloser lockout. Unlike time coordinated restoration systems, IntelliTEAM's logic can automatically restore service under multiple configurations. Depending on the number of automated switches utilized, the feeder may be broken up into several sections, typically 4 or 5, to restore power to the unaffected sections during a fault condition in a section. Providing automated functionality at the additional units by adding fault interrupter bays would allow for restoration of service to the entire feeder thru feeder ties with only a cable section or transformer left out of service.

There are many operational and safety features inherent in this proposed system. All routine operating tasks (i.e. switching, voltage testing, and grounding) can be accomplished by a single person. The three position (closed-open-ground) load interrupter switches are manually operated and provide three pole live switching of 600 or 900 ampere three phase circuits. These switches also provide a visible gap when open and internal grounding without exposure to medium voltage or the need to manipulate elbows.

The 600 amp or 900 amp fault interrupter features vacuum interrupters in series with the manually operated three position (closed-open- ground) disconnection for isolation and internal grounding of each phase.

Large windows provide a clear view of the open gap, ground position and ground bus allowing the operator to easily confirm the position of the load interrupter switch and disconnect of the fault interrupter. Additionally a potential indication with test feature can be utilized. This feature includes an LCD display to indicate presence of voltage on each phase with provisions for low voltage phasing.

Cable testing for faults can be performed through the back of an elbow or a feed-through insert thus eliminating the need for different cable handling parking stands.

In short, although the new proposed switching equipment represents a major change from existing operating procedures, a transition to new operating procedures should easily be made given the capabilities and safety features provided with this equipment.

Secondary systems in older residential areas would be fed from submersible URD transformers that would feed secondary manholes. Multiple secondary home services would be served from these manholes. Additionally, secondary conduits crossing the street would feed service boxes with manhole covers which would serve multiple services on the opposite side of the street. In newer residential areas below grade transformers would feed secondary service boxes on the same side of the street with interconnecting cable and conduit runs to the opposite side of the street where service boxes would feed two services.

For the light commercial areas (i.e., non network), a commercial subsurface transformer vault would serve a large services' manhole on the near side of the street which would be interconnected with a service manhole on the opposite side of the street. A three phase crab system is proposed for installation in these manholes, typically an 11-15 way crab to provide capability for future loads. The crab system would also allow for connecting multiple secondary cables rated at 600V and would also provide disconnect capability. Additional interconnecting manholes with crab systems could be interconnected for loads located several hundred feet or more from the first secondary manhole.

As noted above, the proposed underground installation would utilize vault-type equipment rather than pad-mounted installations. CHA proposes to utilize single phase submersible transformers per existing ConEd standards and three phase underground subsurface transformers installed in vaults similar to the ABB UCT types. These three phase underground commercial transformers are designed for loopfeed dead-front applications or radial feed applications. The units are stainless steel and are economical for this application. Transformer protection is typically provided by bayonet fusing but the fusing provided by the SF6 interrupters would be the standard utilized.

These units could be installed in ConEd vaults and will offer the switching flexibility and easy accessibility coupled with a pre-requisite level of safety to operating personnel. These installations would be utilized in lieu of pad-mounted switches and pad-mounted transformers (see Attachment J for a manufacturer’s cut-sheet for this type of application).These transformer vault installations would also utilize non metallic cable racking to minimize future vault corrosion problems (See Attachment Q - Underground Devices spec sheet)

CHA reviewed the study feeders for a potential network application, but concluded that the load density did not support this type of application. Additionally, the study feeders did not have a heavy concentration of three phase customers. The CST style transformers provide an economical solution for vault installed transformers.

3.0 SYSTEM RELIABILITY

The 2004 Edison Electric Institute (EEI) Study entitled “Out of Sight, Out of Mind” concluded that “When compared to overhead power systems, underground power systems tend to have fewer power outages, but the duration of these outages tends to be much longer. The bottom line – reliability benefits associated with burying existing overhead power lines are uncertain and in most instances do not appear to be sufficient to justify the high price tag that undergrounding carries” The report further states that “on average, underground circuits in Virginia and Long Island experience only 20 percent to 25 percent of the outages that overhead circuits experience”. Further, however, “data suggest underground outages in Virginia take approximately 2.5 times longer to repair than overhead outages”.

Per an updated 2009 EEI study, “Out of Sight, Out of Mind Revisited, An Updated Study on the Undergrounding of Overhead Power Lines”, over the last 10 years, at least 11 state studies or reports have been generated due to the outage impact of unusually large storms. Yet to date, no state utility commission has recommended wholesale undergrounding of the utility infrastructure.

This revised report examined various reliability indices to determine trends from 2003 to 2008. This data does not reveal any trends of increasing or decreasing averages in number of events, length of events or number of customers impacted by storms for this period. The report also reviewed the categories of storms that are the most frequent, those that affect the most customers, and those that caused the largest number of customer hours. Hurricanes/Tropical Storms, Summer Storms and Winter Storms make up 95% of all the events recorded.

This revised report also examined the reliability of overhead and underground electrical systems. For CAIDI it was found that underground distribution systems typically has a slight advantage over an overhead distribution system. SAIDI data indicates that the average customer experiences significantly fewer minutes of outage from underground system outage events and SAIFI data shows that underground electrical systems contribute significantly fewer interruptions to the average customer outage experience.

Examining utility infrastructure cost data, it was found that there has been an increase in number of miles of underground distribution line with underground cables now comprising 18% of total in service lines. Additionally industry spending in underground distribution has nearly doubled from $2.7 Billion in 1999 to $4.5Billion in 2008 such that the level of investment is approximately 26-27% of all dollars.

The benefits and challenges to undergrounding were also examined. The perceived value of undergrounding included reliability, aesthetics, increased customer acceptance and satisfaction, etc. Problems of undergrounding included costs, operation and maintenance issues including longer repair times, and failure issues with system longevity potentially only 30 years for UG versus 50 years for OH facilities.

The Edison Electric Institute recently issued an updated “Out of Sight, Out of Mind 2012” in January 2013. This report contrary to the 2009 report showed an increasing trend for more storms over the 2003-2011 time-frame. The data also shows an increasing trend for customers experiencing an outage over this period. And although customer hours of interruption increased, customers out per storm and average outage hours per storm decreased.

The report also indicated that an underground distribution system had a slight advantage over an overhead system for the CAIDI index. This too was a variation from the initial 2004 report (It should be noted however that many of these underground installations are of the URD type and not the manhole and ductline underground configuration contemplated for this study.) The data also indicated a significant advantage for SAIFI for an underground system. Thus for the SAIDI index an average customer experienced significantly fewer minutes of outage from an underground system outage event each year of the study.

The study found that the growth rate and additional miles of line built were greater for underground distribution facilities than overhead facilities. The distribution rate of underground investment has been consistently above 25% until the recession years of the late 2000’s.

The EEI report also provided an updated table of State conversion reports. Noteworthy data points were the District of Columbia report with a cost of $3.5M /mile and EEI's 2012 estimate of $5M /mile.

Per past studies the consensus therefore was that although the underground system would experience fewer interruptions, these interruptions could last longer than those experienced on an overhead system. However recent EEI information indicates that CAIDI for underground failures has improved such that outage times for both overhead and underground systems are similar. The key to the reliability of the new system however, would be proper selection of individual reliable equipment components (i.e., cable, transformers, switches, etc.). ConEd would need to evaluate available technologies and specify the required equipment based on extensive engineering and operating evaluations. Even then failure rates would not be available but would be determined over the installed life of the equipment.

With respect to estimates of the impact on ConEd's SAIFI and CAIDI rates, the effect on the indices would also largely be determined by the level of automation employed. Without automation of switchgear, it is expected that the indices would experience the typical decrease in SAIFI yet could experience an increase in CAIDI due to the longer durations for cable fault locating and repair depending on the degree of automation employed and also potentially the longer times for switchgear and transformer failures.

However, with automation of the switchgear, marked improvements in both SAIFI and CAIDI could be experienced. Feeders could be sectionalized into four or more primary sections such that for a failure to a section, the remaining sections could be restored quickly. Attachment R provides case study data relative to reliability indices with the installation of IntelliTEAM. Preliminary pricing provided by S&C for the IntelliTEAM option on these types of feeder configurations are provided in Attachment S. Utilizing automation at all transformer tap points could minimize outages further such that the system would only experience a prolonged outage due to transformer or secondary cable failures. Primary three phase cable failures would ideally be isolated through automatic switching and single phase cable failures could be loop sectionalized thus optimizing both the SAIFI and CAIDI indices. Equipment and material used for the system would need to be engineered to provide long life cycles. Failure rates of the three phase switches and transformers contemplated for the system are unknown at this time and failure rates will be determined unfortunately over the life of the installation. Cable and accessory failure modes can be controlled by strict adherence to specifications for cable and accessory equipment. Con Ed should be able to capitalize on various existing cable system failure rates in determining the requirements of the new system. A stringent specification development should provide for an expected cable life in excess of *forty* years.

Construction of the new underground system would also pose reliability issues during construction. Extensive interruptions would be incurred as individual customers are "cutover" to the new system. Large groups of customers may be affected as sections of new underground circuitry are energized and overhead sections are retired out.

Unlike hybrid systems with some portions remaining overhead, the new system would be immune to tree and vehicular accidents and should also offer superior lightning protection. These benefits, however, are not realized without some potential downsides and potential equipment failures due to other environmental conditions. These environmental conditions include, among others, exposure to wet and humid conditions within vaults and manholes and road salt and sand during winter conditions. These environmental conditions can shorten the life expectancy of the electrical distribution equipment. As noted, however, the utilization of stainless steel for both the switches and transformers, jacketed EPR cable, molded splices, nonmetallic cable racking etc, should provide a long life.

4.0 ENVIRONMENTAL HEALTH AND SAFETY CONCERNS

Construction of the new underground systems will require a highly trained and skilled workforce knowledgeable in all current OSHA and ConEd Health and Safety rules. This large of an undertaking will require rigid adherence to all electric operating procedures. All required switching, tagging, and grounding provisions are paramount to the safety and welfare of personnel. The ongoing requirement of cutovers from the new underground system will require strict observance of all Lockout/Tagout Markup Rules.

During construction, extensive trenching will be required for installation of the new ductline and service conduits. Large excavations will be required for manholes and transformer vaults. All OSHA rules will need to be rigidly adhered to in order to protect both the public and the workers during this construction.

The completed underground system as noted should inherently incorporate safety measures to ensure that the installed system may be safely constructed, operated and maintained. A major consideration that should be extensively reviewed and incorporated into the design of the new system is the capability to operate the switches above grade to the extent practicable. The design of the system, should also allow for ease of sectionalizing the system during normal and emergency conditions, to allow for personnel to de-energize, test de-energize and ground. Personnel should be provided the capability of working at all times between grounds per OSHA requirements.

Upon the construction of a completed underground system, an on-going maintenance issues could be the pumping of manhole water with the potential presence of transformer oil. State of the art transformer oil detection sensors with redundant feature, however, should ensure that oil is not pumped to the sewer system.

5.0 GEOTECHNICAL CONCERNS

CHA geotechnical engineers reviewed the existing feeder routes for each of the study feeders in both Westchester County and Staten Island to complete a review of each feeder from a geotechnical perspective and potential exposure to rock during excavation of the proposed underground feeder installations.

For the Westchester County feeder routes, CHA evaluated the four subject feeder routes versus the Surficial Geologic Map of New York State – Lower Hudson Sheet (Caldwell 1989). Areas mapped as bedrock stipple were considered as full bedrock areas. An estimate of 20% bedrock was assigned to areas mapped as till to account for the potential for the presence of shallow bedrock or boulders in the glacial till areas. Based on this review, the following approximate percentages have been applied to the study feeders, and then these percentages were applied to total ductbank length to develop a total length of ductbank that is in soil versus rock.

Table 3

Rock Percentage as a Function of Length by Feeder Number (Westchester County)

Feeder Name / Number	Feeder Location	Approximate Breakdown of Surficial Materials Mapped Along Feeder Routes		Estimated Percentage of Total Feeder Length to Encounter Rock
		Rock Type	Percent	
Bowman Loop	Town of Harrison	Till	80%	31%
		Till w/ Bedrock Stipple	15%	
		Kame	5%	
17W42	Town of Harrison	Till	80%	31%
		Till w/ Bedrock Stipple	15%	
		Kame	5%	
13U1	City of Yonkers	Till	100%	20%
36U4	City of Yonkers	Till	80%	36%
		Bedrock	20%	

For the Staten Island feeder routes, CHA evaluated the four subject feeder routes versus the Surficial Geologic Map of New York State – Lower Hudson Sheet (Caldwell 1989) and the Geologic Map of New York – Lower Hudson Sheet (Fisher, et al 1970). An estimate of 20% bedrock was assigned to areas mapped as till or till moraine over bedrock formations to account for the presence of shallow bedrock or boulders in these areas. An estimate of 2% bedrock was assigned to areas mapped as till, till moraine, or artificial fill over coastal deposits to account for the potential for the presence of boulders in these soil deposits. The chance of encountering bedrock in the coastal deposit areas was considered very low.

Table 4

Rock Percentage as a Function of Length by Feeder Number (Staten Island)

Feeder Name / Number	**Feeder Location**	**Approximate Breakdown of Surficial Materials Mapped Along Feeder Routes**		**Estimated Percentage of Total Feeder Length to Encounter Rock**
		Rock Type	**Percent**	
5R10	Staten Island	Till or Till Moraine Underlain by Raritan Coastal Deposits	100%	2%
5R29	Staten Island	Till or Till Moraine Underlain by Raritan Coastal Deposits	100%	2%
33R08	Staten Island	Till or Till Moraine Underlain by Raritan Coastal Deposits	70%	2%
		Artificial Fill over Raritan Coastal Deposits or Stockton Formation	30%	
272	Staten Island	Till or Till Moraine Underlain by Stockton Formation or Serpentine	100%	20%

Depending on the competency of the bedrock encountered during excavation for the ductbank construction, specialized equipment may be required for the installation work. The competency of the bedrock will determine the excavation methods required for each particular feeder and this will only be able to be determined during the ductbank design process. Should competent bedrock be encountered, more expensive construction methods would have to be implemented to remove the bedrock.

6.0 MUNICIPALITY CONCERNS

All existing municipal street lighting systems will need to be converted to underground ornamental systems. Existing street lighting contracts would need to be reviewed, however municipalities would obviously resist the large required increase in their rates for the new systems. Due to the purchase of ornamental standards, conduit installation, and cable installation, costs per new ornamental light could exceed $20,000 and necessitate huge rate increases for the municipalities. Some municipalities when faced with these increases could opt for retirement of their street lighting system or pursue customer owned systems. The advent of new LED lighting designs would also need to be addressed. For a large scale change-out to LED lighting, the municipalities may at this time opt to own and install such a new system.

7.0 DOT CONCERNS

As previously mentioned, much of the construction will unfortunately be required to be installed within the street limits. This construction causes long term disturbances to traffic flow, pedestrian traffic, and general public access. The required construction will be governed by Part 131 of the NYSDOT Rules and Regulations, Accommodation of Utilities within State Highway Right of Way. Attachment T provides a copy of the NYSDOT Part 131. Attachment U provides a copy of the Highway Design Manual: Chapter 13 – Utilities (Revision 41). For purposes of this study, CHA has not been in direct contact with NYSDOT, but the following contacts would be made should any of the projects proceed into further evaluation and/or design:

- Mr. Joseph Schiraldi, PE
  NYSDOT Resident Engineer
  Southern Westchester County
  Saw Mill River Road
  Valhalla, NY 10595
  Phone: (914) 592-6557

- Mr. Michael McBride, PE
  NYSDOT Resident Engineer
  Northern Westchester County
  85 Route 100
  Katonah, NY 10536
  Phone: (914) 232-3060

ConEd will be required to submit an appropriate permit application for all work required within the public right-of-way. Construction procedures requiring maintenance of traffic flow will be extremely difficult due to locations of the proposed work within the road right-of- way. Because of the street location of the new facilities, conflicts with other utilities (i.e., gas, water, sewer etc.) will be a major concern. Based on the magnitude of the existing utilities that currently exist within the right-of-way, extensive efforts will be required to locate these existing utilities prior to design of any new ductbank facilities for the electric system. This would require extensive involvement by underground utility locating companies as well as ConEd's existing survey resources. The additional work required by ConEd's survey and engineering departments will be extensive and likely require additional in-house resources to meet this demand. The Maintenance & Protection of

Traffic Plans (MPT Plans) required by this type of construction will be much more involved than the traditional MPT Plans that ConEd prepares for their existing overhead facility construction.

Extensive work will be conducted in the road shoulder areas provided these utility conflicts can be avoided. Alternatively, construction may be required in the middle of the existing roadways. Sheeting will be required in many areas due to the depth of the facilities. Pavement cuts, concrete base cut back and pavement replacement will be required (See Attachment V for a typical trench installation within existing asphalt pavement). Due to the open-cut nature of most of the construction work for this project, traffic disturbances will be unavoidable. The impact to traffic patterns will be on the order of those experienced with any major road work in the area. Depending on the ability to locate a new ductbank within the road right-of-way, traffic could be interrupted in both travel directions, or only a single direction. Full road closures would need to be avoided as much as possible, but there may be instances where this would be unavoidable.

8.0 HISTORIC SITES / LANDMARK AREAS

As outlined in our proposal, CHA utilized geographic information system (GIS) mapping techniques to evaluate the study feeders with regards to the presence of several geographic based features within the study areas. The features that were summarized and presented on the GIS mapping include the following:

- Toxic Chemical Storage or Release Point
- RCRA Regulated Facilities
- SPDES Discharge Locations
- Tax Parcel Lines
- Historic Sites
- NYSDEC Wetland Areas
- Federal Wetland Areas
- Presence / Absence of Bedrock

Relative to the presence of Historic Sites and Landmark Areas, the following table summarizes the presence of these sites near the study feeders.

Table 5

Historic Sites / Landmark Areas

Feeder Name / Number	Feeder Location	Number of Historic Sites / Landmark Areas in Relative Proximity of Feeder	General Location of Historic Site
Bowman Loop	Town of Harrison	2	North of I-95, south of existing feeder South of Boston Post Road, south of existing feeder
17W42	Town of Harrison	0	N/A
13U1	City of Yonkers	2	West of existing feeder East of existing feeder
36U4	City of Yonkers	1	West of existing feeder
5R10	Staten Island	0	N/A
5R29	Staten Island	1	East of existing feeder, along Amboy Rd
33R08	Staten Island	0	N/A
272	Staten Island	1	Along Watchogue Road, south of feeder

As summarized in the above table, there are not many historic or landmark features that are in close proximity to the study feeders. Although the number of historic sites / landmark areas in relative proximity to the study feeders are not great, there are several of these sites within the overall land mass of Westchester County, the Bronx, and Staten Island as follows:

➢ Westchester County	186 Sites
➢ Bronx	48 Sites
➢ Staten Island	45 Sites

Based on the ability to permit disturbances to these features, however, every effort would need to be made during the design process to avoid impacts to these areas. On a feeder by feeder basis, the requirement to avoid impacts to historic and landmark features could add to the actual conversion cost for individual feeders.

9.0 IMPACTS TO OTHER UTILITIES

Construction will rigidly adhere to Industrial Code Rule 53 (13NYCRR Part 53). All existing underground facilities shall be maintained and protected by and at the expense of ConEd. These utility conflicts with the proposed alignment of the new underground installation will be extensive and significantly add to the construction costs.

Also, ConEd's program to underground existing overhead facilities would "strand other utilities (i.e., cable and telephone companies) which would then have to assume 100% of pole costs if electric lines are undergrounded, per the EEI report "Out of Sight, Out of Mind?". EEI also reports in their recent report that costs of undergrounding these other utilities can add approximately 25% to total undergrounding costs. The most likely scenario is that ConEd would sell its pole plant interest to the phone company joint owners and retire out the primary and secondary on the poles. The telephone, cable television (CATV), and private fiber would remain on the pole line. Thus, the truly aesthetic benefit of undergrounding the electric lines would be substantially negated. If these communication facilities relocated underground, they would need to construct their own ductline to relocate underground in that their facilities would not be allowed to jointly occupy the electrical ductline constructed for ConEd's facilities.

As described above, there are several utilities that would be affected by the conversion of the overhead feeder system to an underground feeder system. These utilities include, but are not limited to the ones listed in the following table.

Table 6

Cable & Fiber Companies Potentially Impacted

Company Name	Company Type	Company Address	Company Contact
Cable Vision	CATV	111 Stewart Avenue Bethpage, NY 11714	Sasraz Ali (516) 803-2300
Time Warner	CATV	701-717 MacQuesten Park North Mount Vernon, NY 10552	Brian Kelley General Manager (914) 699-3630 ext. 600
Westchester County Dept. of Transportation	Private Fiber	Liberty Line Buses 100 East 1st Street Mount Vernon, NY 10550	John Demila (914) 813-7770 (914) 813-7776

IBM Research Center	Private Fiber	P.O. Box 218 Yorktown Heights, NY 10598	George DeSimone (914) 945-1145
MCI Telecommunications	Private Fiber	2400 North Glenville (MT 2314) Richardson, TX 75082	Judy Miller (972) 729-7844
MCI-Metro	Private Fiber	6929 North Lakewood Avenue Mail Drop 2-1 Tulsa, OK 74117	Christine Wilkinson (918) 590-2809
Town of Greenburgh-DPW	Private Fiber	P.O. Box 205 Elmsford, NY 10523	Albert Regula (914) 993-1573
Iona College	Private Fiber	715 North Avenue New Rochelle, NY 10801	George Fountaine (914) 633-2458
Tuckahoe Housing Auth.	Private Fiber	4 Union Place Tuckahoe, NY 10707	Eric DeEsso (914) 961-3373
Westchester ARC	Private Fiber	121 Westmoreland Avenue White Plains, NY 10601	Lisa Dinapoli (914) 428-8330
Village of Croton Public Works	Private Fiber	One Van Wyck Street Croton-on-Hudson, NY 10520	Fred Sorenson (914) 271-3775
Mamaroneck Union Free School District	Private Fiber	1000 West Boston Post Road Mamaroneck, NY 10543	Bill Koulouris (914) 220-3000
Engelhard Corporation	Private Fiber	1057 Lower South Street Peekskill, NY 10566	Chris Magerhans (914) 737-2554
AboveNet Communications, Inc.	Private Fiber	360 Hamilton Avenue White Plains, NY 10601	Laura Srancomano (914) 421-6749
Elantic Telecom	Private Fiber	2134 West Laburnum Avenue Richmond, VA 23227	Karl Dawson (804) 422-4354
Neon Communications, Inc.	Private Fiber	2200 West Park Drive Westborough, MA 01581	Maureen Borinski (508) 616-7800
Consolidated Edison Communications, Inc.	Private Fiber	29-76 Northern Boulevard Long Island City, NY 11101	Paul Corona (718) 752-7509
Bayer Diagnostics	Private Fiber	511 Benedict Avenue Tarrytown, NY 10591	Louis Malaver (914) 631-8000
Entergy Nuclear Indian Point 2, LLC.	Private Fiber	440 Hamilton Avenue White Plains, NY 10601	Michael Slobodien (914) 272-3352
FiberTech Networks, LLC.	Private Fiber	140 Allens Creek Road Rochester, NY 14618	James Baase (585) 697-5103
AT&T Local Service	Private Fiber	33 Thompson Street, 9th Floor New York, NY 10007	Joyce Newman (212) 513-2055
NYSDOT Hudson Valley, Inc.	Private Fiber	244 Westchester Avenue White Plains, NY 10604	John LiMazi (914) 949-6384
Hudson Valley Data Network	Private Fiber	263 Route 17K Suite 2003 Newburgh, NY 12550	Jack Weishaupt (845) 567-6367
Tarrytown Union Free School District	Private Fiber	200 North Broadway Sleepy Hollow, NY 10591	Andrew Labella (914) 332-8620
Elmsford Union Free School District	Private Fiber	98 South Goodwin Avenue Elmsford, NY 10523	Mark Barone (914) 592-8550

10.0 URBAN AREAS

As previously noted, construction in urban areas is extremely problematic due to the required concrete ductbank construction largely within the road right-of-way, conflicts with other utilities, and the requirement to maintain traffic flow. These urban areas require concrete encased ductline and manhole and vault installation. Pad-mount design and construction is precluded except where there may be existing installations. This work will be very capital intensive requiring a large manpower contingent coupled with many pieces of construction equipment (i.e., excavating equipment, cranes, concrete trucks, etc.). Significant disruption to traffic patterns and local business and residences are to be expected.

11.0 CONSTRUCTION ACCESS

Access to customer rights-of-way is expected to be very difficult necessitating the installation of facilities largely on the public right-of-way. Where required, however, easements will need to be obtained from customers for locations of equipment on private property. Negotiations of these easements will slow the engineering and construction of the system, thus delaying the conversion project.

Access to NYSDOT roadways is governed by Part 131. At locations of the Metro North Railroad crossings, jack and bore techniques would typically be employed to provide the required conduit and cable system. Horizontal directional drilling would also be reviewed for application on a case by case basis. Typical construction would require the installation of a carrier pipe(s). The required number of conduits would then be assembled and pulled within the casing pipe utilizing bore spacers and then grouted with a weak mix concrete for thermal considerations. Utilization of this construction technique would be very expensive. ConEd would need to abide by all required municipality permitting and would need to provide proposed construction drawings to the appropriate authorities for required permitting in advance of all construction.

12.0 WORK PRACTICES

CHA reviewed ConEd's "General Instructions Governing Work on System Electrical Equipment" and "General Instructions Governing Work on Overhead and Underground Residential Distribution Equipment". Construction of the new proposed underground system would require some work practice modifications for ConEd. The use of subsurface transformers with loadbreak elbows and switch and fuse provisions and subsurface SF6 switches would necessitate new operating procedures and instructions. Extensive employee training would also be required. A transition would need to be made to splicer / mechanic type classifications in the Westchester County, Bronx, and Staten Island districts from a largely line person classification that constructs, operates, and maintains these systems presently. Over time these districts' crew makeup would need to be more like those that work on the Manhattan underground system.

13.0 MATERIAL AND EQUIPMENT ACQUISITION

Material and equipment specifications and acquisition are vital to the new underground system design. It is very important that consistent standards for material and equipment be developed. Standard designs will ensure not only cost effectiveness but reliability and safety. ConEd would need to ensure that appropriate quality measures are specified for the new cable, transformers, switchgear, etc. to ensure adequate reliability, serviceability, and life expectancy of the equipment. Given the large quantities of these types of equipment required, it would be necessary to qualify multiple manufacturers, and thus competition should be ensured. Manageable lead times for manufacture and delivery hopefully will be a byproduct of the process. Because of the large demand and scheduling issues inherent with a project of this magnitude, purchase costs are expected to increase significantly for these items over the period of installation.

14.0 DISPOSAL OF EQUIPMENT

Con Ed will need to comply with all regulations for the disposal of existing overhead oil-filled equipment. Given ConEd's prior change-out of these equipments to non-PCB classification, it is not anticipated that disposal will be overly burdensome. All transformers will be evaluated and many depending on age and physical condition could be potentially reused. Disposal of oil filled transformers will be in compliance with "Environmental Specification for the Disposal of Oil filled Pole Transformers from Service Centers ES-083", "Management of Drained or Oil Filled Non PCB and PCB- Contaminated Equipment Other than Transformers ES-022", and "Removal and Disposal of PCB and PCB – Contaminated Transformers Other than Pole Transformers ES-046".

Retirement of pole plant will need to conform to ConEd's policies and procedures for disposal of treated wood products (i.e. "Disposal of Non Hazardous Solid Waste ES-035A"). This would also include excavation materials from the new construction.

15.0 MANPOWER

Estimates for construction of one mile of underground conversion are estimated at approximately 30,000 man-hours, or 15 full-time equivalents (FTE's) per year per mile of converted line. Based on a total mileage of approximately 5,200 miles for the Westchester County, Bronx, Brooklyn, Queens and Staten Island districts, a workforce of 7,800 FTE's would be required per year for 10 years to completely underground these areas. In addition to the field workforce, additional supervision and administrative support personnel will be required to direct this large workforce. The additional supervision and administrative support could be on the order of an additional 10% to 15% of the workforce (i.e., 780 to 1,170 FTE's).

This level of required manpower per year is additionally problematic given the current availability of skilled labor resources in the metro New York area and the Northeast in general. Highly trained and skilled electrical contractors are required to meet this manpower need. This demand on available construction resources could drive up prices considerably. This includes engineering personnel to design and coordinate the project and labor and equipment for construction, etc.

Additionally, upon completion of the installed system it is expected that a contingent of mechanics and splicers will be required to provide additional construction, operation, and maintenance for the new system on an on-going basis. Con Ed would need to develop detailed new training programs for these personnel to ensure that all construction, operation, and maintenance activities strictly comply with the new electric operating procedures that would need to be developed.

16.0 PROJECT COSTS

In the 2007 estimate, CHA extrapolated the data from the study feeders to all Westchester County, Bronx, and Staten Island feeders, the total estimated cost of the electric underground conversion is \$25.8B. The estimate in 2013 dollars for Westchester County, Bronx, and Staten Island is \$34.1B, which is a 32.2 percent increase. When the data is extrapolated from the study feeders to all of Westchester County, Bronx, Brooklyn, Queens and Staten Island, the total the electric underground conversion is \$42.9B.

Several previous studies have been completed by other New York State utilities to evaluate the potential costs associated with converting overhead distribution systems to underground distribution systems. Based on a report produced by Navigant Consulting in March 2005, entitled “A Review of Electric Utility Undergrounding Policies and Practices”, the following observations were reported:

- Almost all jurisdictions investigating undergrounding existing overhead systems have concluded that the cost to underground all existing overhead distribution facilities is prohibitive. Cost estimates for underground construction are estimated at ten times the cost of overhead construction varying from \$0.5M to several million dollars per mile.
- A preliminary study performed for the Long Island Power Authority (LIPA) by KeySpan Energy (Keyspan) in 2005 estimates the cost to underground the Long Island distribution system, primary main, primary branch and secondary lines at \$24.8B. These estimated costs exclude the cost to convert services and third party attachments and are based on an estimated average per mile cost of \$5.4M for a typical mile of primary main and \$1.7M per mile for a typical primary branch line. This cost per mile is greater than the industry average due to a decision to employ a looped, rather than radial, distribution system design. The looped system is standard for the LIPA system and avoids some of exceptionally long restoration times for faults occurring on the underground system.
- There are substantial additional costs to convert homes and businesses to underground service.
- The primary driver for undergrounding existing overhead power lines continues to be aesthetic considerations, not reliability or economic benefits.

- The New York State Public Service Commission (PSC) has detailed undergrounding regulations that mainly apply to new construction in residential subdivisions.
- While underground systems are more reliable than overhead systems under normal weather conditions they are not impervious to damage. In general, it is believed that underground systems suffer only about half the number of outages as an overhead system. The repair time, however, for underground systems can be from 60% longer to three to four times longer than for overhead systems when damage does occur.
- Underground lines have proven to have a shorter useful life than overhead lines and they are more susceptible to corrosion than overhead lines and can be damaged by flooding, tree root infiltration, rodents, and other companies excavating and tearing up the lines.
- Underground lines connecting to overhead lines are still vulnerable to lightning strikes. Unless the entire line is underground, the overhead portions are still susceptible to the weather conditions previously discussed that affect the overhead lines.
- Burying existing overhead power lines does not completely protect consumers from storm-related power outages. During storms, conditions such as flooding, falling objects onto surface-mounted equipment, and over-voltages caused by lightning can cause the loss of power on underground systems. This is not to mention the potential impact from long-term system outages associated with major storms that allow moisture to seep into the system which can ultimately cause cable failures upon system re-energization.

As outlined above, the perceived advantages of placing an existing overhead system underground are believed to be primarily reducing the frequency of customer outages, but those outages when they do occur can be for a longer duration than the overhead system outages. Based on our study of the sample feeders in Westchester County, Bronx, and Staten Island, the projected cost for converting the existing overhead system to an underground system are on average $8.29M per mile for Westchester County and $7.81M per mile for Staten Island. Attachments W and X provide feeder estimates for the following Westchester County and Staten Island feeders respectively:

- Westchester County: 13U1, 17W31, 17W33, 17W42, 17W42 Express, Bowman Loop and 36U4
- Staten Island: 272, 33R08, 5R10, and 5R29

The development of the conversion costs for each of these feeders was based upon the Unit Rates table provided in Attachment T to ascertain the average costs per mile for each feeder type that is also included in this attachment.

These per mile costs translate to a total electric cost of $27.2B for Westchester County / Bronx, $6.9B for Staten Island, $3.2B for Brooklyn, and $5.6B for Queens, to convert all overhead feeders to underground feeder systems. Attachment Z is a summary by municipality and by feeder for all conversion feeders in Westchester County and the Bronx. Attachment AA is a summary by substation and by feeder for all conversion feeders in Staten Island. Attachment BB is a summary by feeder for all conversion feeders in Brooklyn. Attachment CC is a summary by feeder for all conversion feeders in Queens.

An alternate method to review these costs is to consider the breakdown of these costs on a per item or per material type basis. The 2004 EEI report compared the costs based on seven (7) different criteria, but the following table represents a consolidation of these criteria as follows:

Table 7

Cost Component Relative Percentages

Cost Component	EEI Study (%)	Westchester County / Bronx (%)	Staten Island (%)
Excavation, Installation & Material	51	70	66
Service Connections	14	9	13
Reinstatement	12	6	6
Transformers	12	11	10
Street Lights	7	3	4
Dismantling	4	1	1

Another method to compare the data and cost estimates that we have developed to date is to consider the cost per mile for converting the overhead systems to underground systems. This cost per mile data appears to be becoming an industry standard comparison that most utilities are developing as the basis of the request for undergrounding evaluations. The following table adapted from the recent EEI 2012 report, outlines these costs:

Table 8

State Reports Underground Conversion Cost Comparison

State	Year of Study	Project Information	Cost per Mile
Virginia	2005	Average Cost	$1,195,000
Oklahoma	2008	Average Cost	$1,540,000
Florida	2007	Pensacola Beach	$1,686,235
Maryland	1999	Maximum Cost	$2,000,000
EEI	2009	Maximum Cost	$2,130,000
North Carolina	2003	Maximum Cost	$3,000,000
District of Columbia	2010	Maximum Cost	$3,500,000
EEI	2012	Maximum Cost	$5,000,000

While the above costs represent those associated with converting the electric system only, the same estimating procedures were applied to the remaining overhead facilities on the existing pole line structures. The true improvement to the aesthetic and visual impacts of the existing pole line structures can only be fully realized when the entire overhead utility system is placed underground. With the vast number of cable television (CATV) and private fiber companies that currently occupy the existing pole lines, the additional costs to underground these networks and be able to remove the existing pole lines from the streets would cost approximately $23.5 for Westchester County, Bronx, Staten Island, Queens and Brooklyn.

Additionally, sources indicate that O&M costs for a manhole and duct system can be 4 times the costs of maintaining an overhead system (North Carolina Natural Disaster Preparedness Task Force Report). These costs are largely related to cable failure response, repair and installation. Failures of switchgear and transformer equipment and their subsequent replacement would also be more costly than failure repair on an overhead system. The new system would require the incremental expense associated with stray voltage monitoring.

17.0 CUSTOMER COSTS / IMPACTS

The ConEd “Requirements for Electric Service Installations” specification booklet requires that the customer is responsible for service conduit and cable costs on private property. For the purposes of this conversion estimate, the total cost of the overhead to underground conversion has been included in our estimates. Based on ConEd’s specifications, however, these costs on private property are a customer responsibility and this cost would thus need to be negotiated between ConEd, the municipality requesting the underground conversion, and the private property owners. The impact to customers would not only be to existing customers, but would also impact new customer business. Since the new customers would be served from an underground system instead of overhead, the cost and time associated with getting new customers connected to the system could change dramatically.

In these cases, contractors will need to be retained to install the service conduits in private property and ConEd’s contractors would then install the new service cables from ConEd’s facilities in the street to the customer’s service equipment. Costs for these service cable installations have been approximated at $10,000 for residential services and $25,000 for large commercial services. However, individual service costs would vary depending upon size, distances, topography, etc. Directional boring techniques may have to be utilized for service installations in several locations which could greatly increase the costs of these service installations.

Additionally, it should be noted that in some residential areas customers may be required to convert from 120/240 volt service to 120/208 single phase service which would likely require appliance change-outs. It should be further noted that because of the utilization of large three phase underground transformers, service entrance switchgear change-outs may also be required to meet increased interrupting ratings. Customer costs are very difficult to quantify for these necessary conversions but will add significant costs to the project. These costs are shown within the total conversion costs of the project.

Customer cost impacts are not the only issue that customers will face as a result of the conversion process. Although costs may be of the utmost concern to the customers, they will also be impacted by customer outages. The outages will likely be on the order of hours versus days, but there will likely be multiple outages for each customer throughout the overall construction process.

18.0 CUSTOMER RATE INCREASES

The greatest obstacle to converting the existing Westchester County, Bronx, Queens, Brooklyn and Staten Island overhead electric distribution systems to underground systems is cost. CHA has estimated that the total capital cost, in 2013 dollars, of converting approximately 5,217 miles of existing distribution to underground is $42.9 billion dollars. By comparison, ConEd's transmission and distribution (T&D) net utility plant as of December 31, 2011, is $16.1 billion. Therefore, a complete underground conversion would nearly triple the Company's rate base and create the need for massive rate increases.

Upon completion of the conversion, the impact on the Company's annual distribution revenue requirement of just the additional capital investment is estimated to be $7.24 billion dollars, or 144% higher than the $5.00 billion annual T&D revenues at currently effective rates. In addition to capital costs, there would be some effect on rates of increase in other costs such as operations & maintenance and property taxes. However, in relative terms those costs are not significant when compared with the effect of the capital costs. Therefore, this section focuses on the effect on rates resulting from the capital investment required for the contemplated conversion.

The calculation of the rate base impact and the corresponding increases in revenue requirements are shown in Attachment W. If ConEd decides to go forward with the conversion, it would require multiple years to complete. As shown on line 2, for this analysis the $42.9 billion expenditure has been spread equally over ten years and has been adjusted for inflation at a rate of 5% per year. Therefore, the total capital expenditure over the 10 year period would be $55.7 billion in nominal dollars. It is estimated that $332 million book value of the existing overhead system will be retired with the conversion resulting in net annual additions to plant in service as shown on line 4. The Cumulative additions to rate base are shown on lines 7 through 9. Annual depreciation expense calculated at 3% per year is accumulated on line 10 and subtracted from the net additions to produce the cumulative changes in net utility plan and rate base on a year by year basis. As shown, the conversion would add $52.4 billion to net utility plant by the 10th year. By comparison, ConEd's 2011 net T&D utility plant was $16.1 billion.

The annual revenue requirement associated with the capital investment is the sum of the rate of return requirement, the depreciation expense, and the amortization of the retirement of the existing overhead. A pre-tax rate of return of 11.49% (8.53% after tax return grossed up for income taxes) is used for the return requirement. Depreciation expense is based on a 3% depreciation rate.

For comparison purposes, the additional revenues to support the underground conversion are measured against the Company's T&D revenues from all retail classes based on the T&D rates in effect as of April 1, 2012. The following table shows the annual additions to the revenue requirement and both the year over year and cumulative percentage increases in T&D revenues:

Table 9

Additional Revenue Requirements ($ x 1,000)

Year	Year by Year Additional Revenue ($)	Cumulative Additional Revenue ($)	Total Company T&D Revenues ($)	Year Over Year Percent	Cumulative % vs. Present
Present			$ 5,008,733		
1	$ 347,641	$ 347,641	$ 5,356,374	6.94%	6.94%
2	$ 637,152	$ 984,793	$ 5,993,526	11.90%	19.66%
3	$ 657,890	$ 1,642,683	$ 6,651,416	10.98%	32.80%
4	$ 687,230	$ 2,329,913	$ 7,338,647	10.33%	46.52%
5	$ 721,821	$ 3,051,734	$ 8,060,467	9.84%	60.93%
6	$ 758,141	$ 3,809,875	$ 8,818,608	9.41%	76.06%
7	$ 796,277	$ 4,606,152	$ 9,614,885	9.03%	91.96%
8	$ 836,320	$ 5,442,472	$ 10,451,205	8.70%	108.66%
9	$ 878,365	$ 6,320,836	$ 11,329,570	8.40%	126.20%
10	$ 922,512	$ 7,243,348	$ 12,252,082	8.14%	144.61%

Assuming the increases would be applied equally across all customer classes, the average monthly residential T&D bill would increase from the current level of $58.40 to $142.87 upon completion of the conversion from overhead to underground.

Since the revenue and rate impacts are primarily driven by the capital costs, the extent to which funding is provided by local, state or federal governments would directly affect the rate increases. For example, if 50% of the capital was contributed, the cumulative increase would be 71.44%.

Background Information:

The Company serves slightly more than 3 million retail customers in the Bronx, Brooklyn, Manhattan, Queens, Staten Island, and Westchester County. A breakdown of customers, MWH sales and revenues at April 1, 2012 prevailing rates is as follows;

Table 10

ConEd Summary Background Data ($ x 1,000)

Line	Classification	2010 Customers	2010 Sales (MWhs)	Total Revenue @ 4/1/12 Rate Level	T&D Revenue @ 4/1/12 Rate Level	Energy Supply Revenue
1	SC1	2,714,654	14,614,003	$ 3,665,009	$ 1,902,611	$ 1,762,399
2	SC1 Rate II	2,237	98,937	$ 20,458	$ 8,679	$ 11,780
3	SC2	345,871	2,224,752	$ 586,129	$ 317,185	$ 268,944
4	SC2 Rate II	283	6,517	$ 1,284	$ 508	$ 776
5	SC5 Rate I	9	657	$ 121	$ 44	$ 78
6	SC5 Rate II	5	124,023	$ 18,848	$ 4,417	$ 14,431
7	SC6	3,806	9,748	$ 3,488	$ 2,275	$ 1,213
8	SC8 Rate I	1,829	1,941,451	$ 368,516	$ 139,758	$ 228,759
9	SC8 Rate II	16	112,427	$ 20,659	$ 7,448	$ 13,210
10	SC8 Rate III	42	48,380	$ 8,856	$ 3,174	$ 5,682
11	SC9 Rate I	122,294	17,652,702	$ 3,514,837	$ 1,422,557	$ 2,092,280
12	SC9 Rate II	686	9,963,090	$ 1,750,694	$ 578,799	$ 1,171,895
13	SC9 Rate III	1,565	881,835	$ 151,369	$ 47,657	$ 103,712
14	SC12 Rate I	441	200,434	$ 33,979	$ 10,347	$ 23,632
15	SC12 Rate II	28	248,736	$ 42,121	$ 12,822	$ 29,298
16	SC13 Rate II	1	8,403	$ 3,282	$ 2,208	$ 1,074
17	Full Service & Retail Access	3,193,767	48,136,095	$ 10,189,650	$ 4,460,489	$ 5,729,161
18						
19	CONED	3,193,767	48,136,095		$ 4,460,489	
20	NYPA & EDDS	1	10,697,663		$ 548,244	
21	Total	3,193,768	58,833,758		$ 5,008,733	

A substantial portion of the distribution system serving those customers is underground. All of the distribution system in Manhattan is underground and a portion of the Brooklyn and Queens distribution is underground. However, relatively most of Staten Island and Westchester County are served from overhead facilities. A breakdown of the miles of line by area is as follows:

Table 11

ConEd Miles of Wire by Area (2007)

Area	Underground Cable (Miles)	Overhead Cable (Miles)
Bronx	10,570	2,667
Brooklyn	26,578	3,538
Manhattan	20,408	0
Queens	24,292	6,968
Staten Island	2,754	7,140
Westchester	6,570	15,195
Total:	**91,172**	**35,508**

By any measure, the conversion of overhead distribution to underground is cost prohibitive. Spread over the entire system, the $42.9 billion is $13,431 per customer. By comparison, the Company's 2011 T&D net utility plant was $5,040 per customer. The $42.9 billion is $16,777 per customer when averaged over the 2,557,000 customers of Staten Island, Westchester County, Bronx, Brooklyn and Queens. The installed cost of the plant alone would require $7.2 billion dollars in additional annual T&D revenues by the 10th year of a ten year conversion plan.

19.0 IMPLEMENTATION SCHEDULE

A detailed implementation schedule would need to be determined for this large project. It is recommended that those feeders exhibiting the poorer reliability statistics and /or feeders with aged infrastructure be the first candidates for conversion. Based on our manpower estimates, a timetable of 13 years or more would be required for completion of the entire conversion project. Difficulties would be initially encountered in obtaining the necessary skilled contractor labor to complete the required work on an annual basis.

REFERENCES

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3. Navigant Consulting Prepared for Long Island Power Authority (LIPA). March 2005. “A Review of Electric Utility Undergrounding Policies and Practices”.
4. Infrasource Technology Prepared for Florida Electric Utilities. February 2007. “Undergrounding Assessment Phase I Final Report: Literature Review and Analysis of Electric Distribution Overhead to Underground Conversion”.
5. North Carolina Public Service Commission. November 2003. “Report of the Public Staff To The North Carolina Natural Disaster Preparedness Task Force: The Feasibility of Placing Electric Distribution Facilities Underground”.
6. Edison Electric Institute prepared by Kenneth L. Hall December 2009 “Out of Sight, Out of Mind Revisited, An Updated Study on the Undergrounding of Overhead Power Lines
7. Edison Electric Institute prepared by Kenneth L. Hall January 2013 “Out of Sight, Out of Mind 2012, An Updated Study on the Undergrounding of Overhead Power Lines

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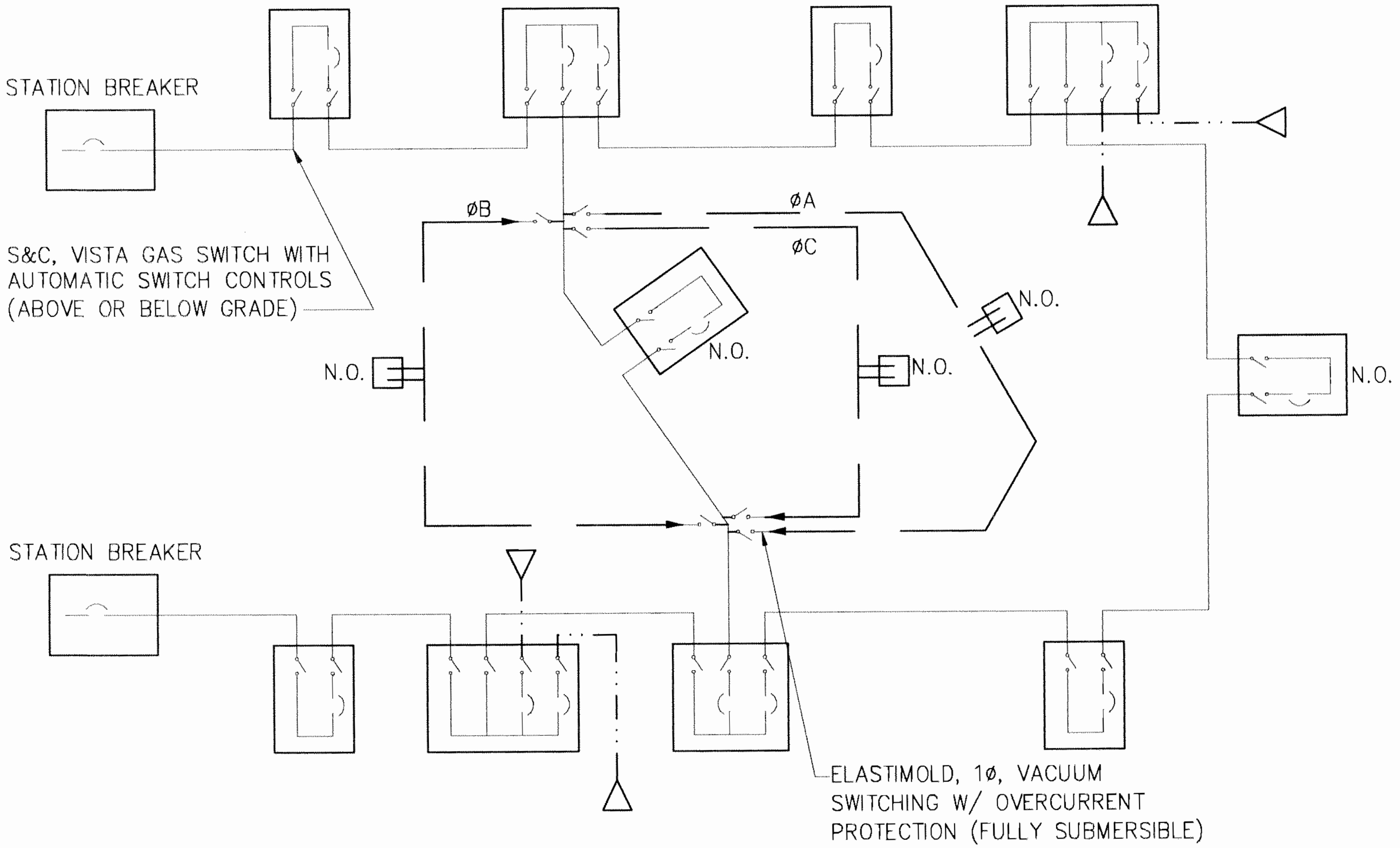

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FIGURE 1

FEASIBILITY REPORT
TYPICAL PRIMARY SINGLE LINE DIAGRAM

PROJECT NO.
16596

7/25/07

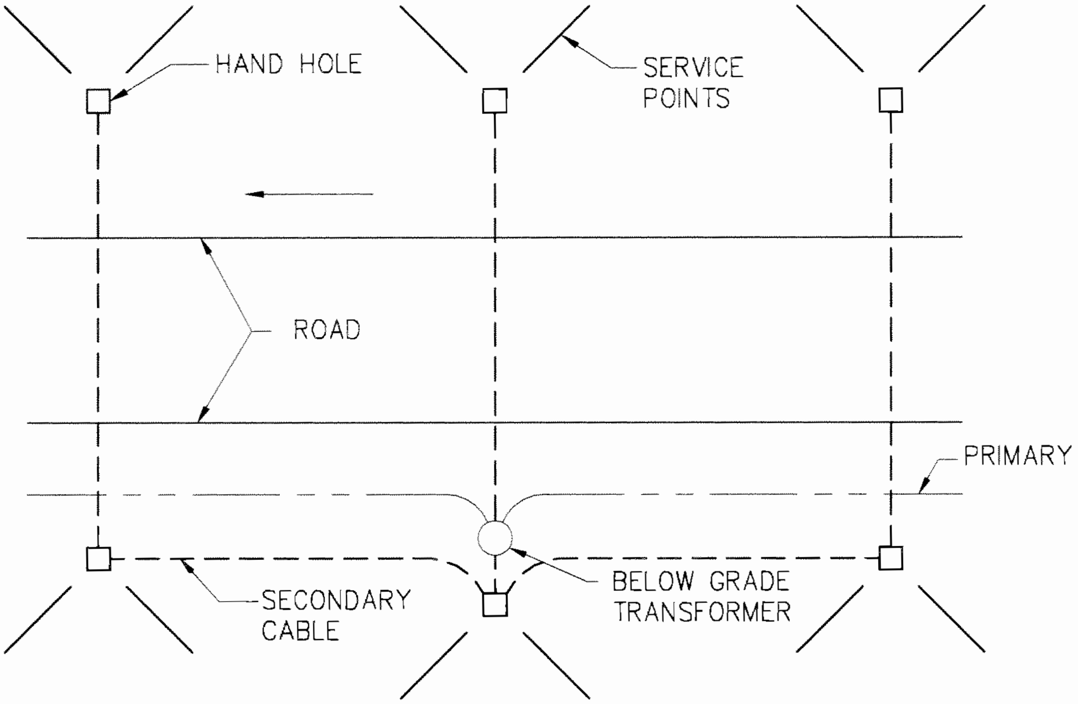

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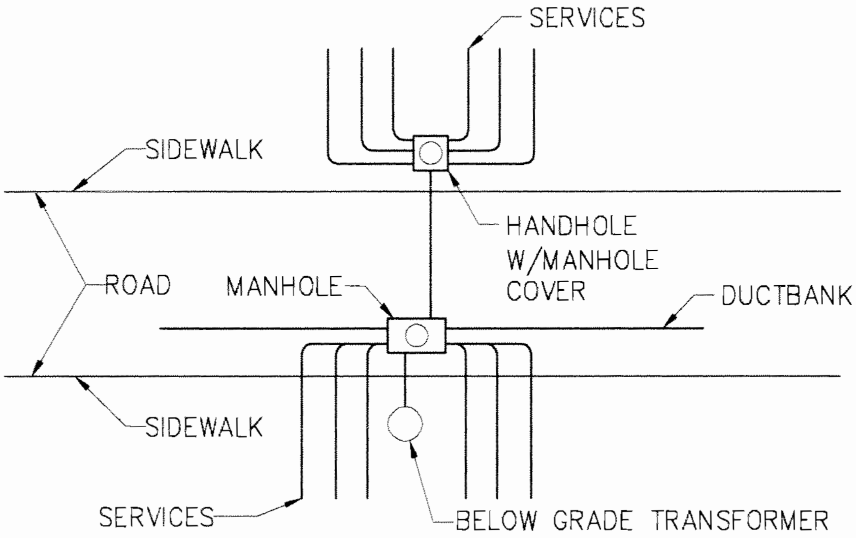
FIGURE 2

FEASIBILITY REPORT
TYPICAL SECONDARY SINGLE LINE DIAGRAM

NEWER RESIDENTIAL AREAS

PROJECT NO.
16596

DATE: 7/25/07



NOTE:
1. DIRECTIONAL BORES MAY BE REQUIRED TO MEET MANY OF THE SERVICE METER LOCATIONS.

2. LOCATION OF BELOW GRADE TRANFORMER WILL VARY BASED ON EXISTING UNDERGROUND UTILITIES.

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FIGURE 3

FEASIBILITY REPORT
TYPICAL SECONDARY SINGLE DIAGRAM

OLDER RESIDENTIAL AREAS

PROJECT NO.
16596

DATE: 7/25/07

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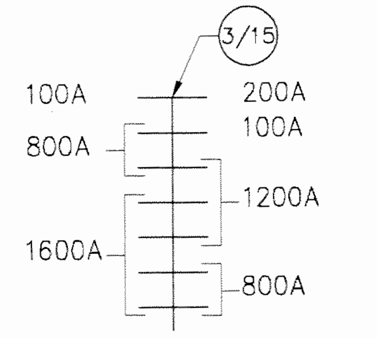
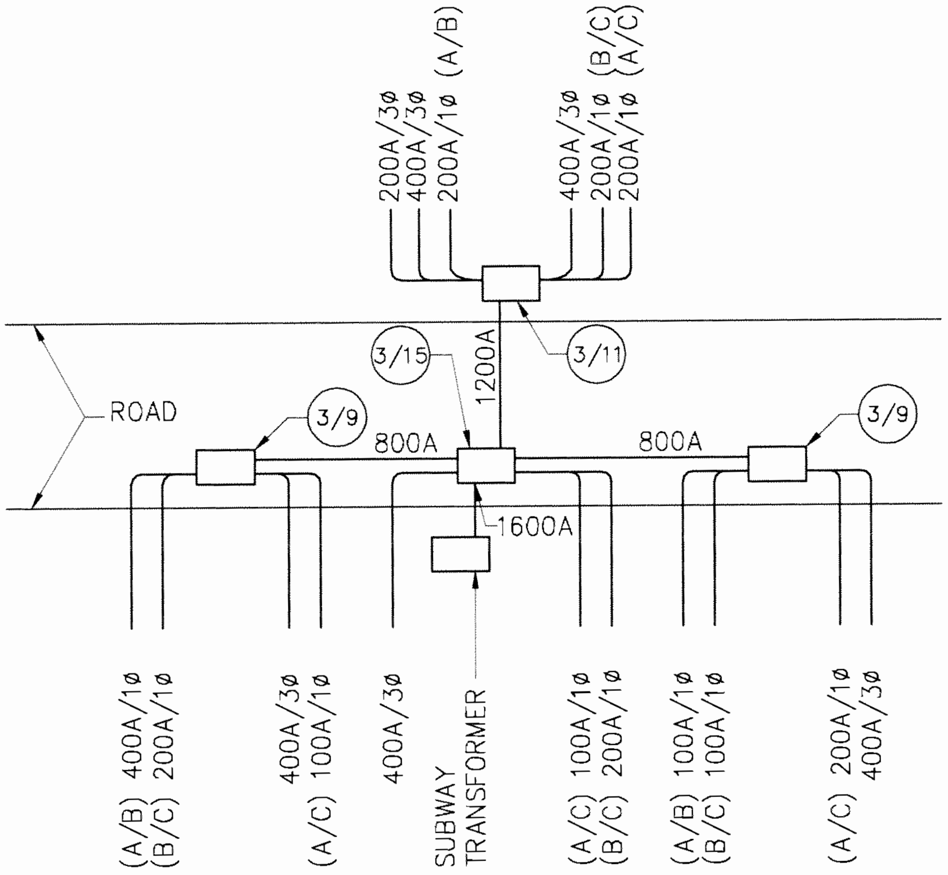


TYPICAL MOLE INSTALLATION



NOTE:

(3/15) REPRESENTS 3 MOLES WITH 15 OUTLETS EACH.

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FIGURE 4
FEASIBILITY REPORT
TYPICAL SECONDARY SINGLE LINE DIAGRAM
LIGHT COMMERCIAL NON-NETWORK AREA

PROJECT NO.
16596

DATE: 7/25/07