Attachment 1

Storm Resiliency Program Analysis and Acceleration Proposal

Storm Resiliency Program Analysis and Acceleration Proposal

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February 28, 2018

1. Storm Resiliency Program Overview

In 2012, Unitil embarked on a pilot study to test the effectiveness of performing targeted vegetation management to reduce effects of storm events on the electric system. This is known as the Storm Resiliency Program (SRP) today. This pilot was initiated after the Unitil Service territory in New Hampshire was met with 2 large events in 2011, Hurricane Irene and the October Snowstorm and had sustained other frequent major storm events over the past 4 years.

The 2011 October Snowstorm caused widespread damage and prolonged outages and was ranked as the 3rd largest event in the state's history[7] at the time. The Commission's Regulated Utilities' Preparation and Response Report indicated customers expressed frustration with costs incurred with the outages.

> *"Customers also expressed frustration with the personal costs incurred as a result of multi-day outages. For residential customers, those costs are driven in part by the purchase of fuel for generators; lodging and meals for those who cannot remain in their homes; lost wages for those who work from home; and spoiled food with the loss of refrigeration. Business customers experienced revenue losses, as well. Without electricity, many customers in New Hampshire lack water, as well as heat."*[8]

In after-storm meetings with towns and annual emergency preparedness meetings, Unitil also saw that customers expressed a desire for something to be done. Customer's increased reliance on technology coupled with the economic cost of service interruption and safety aspect contributes to the changing expectation of uninterrupted service. Certain towns even expressed support for more tree work to be done.

The Company designed a plan to perform vegetation management activities on appropriate circuits and critical sections of these circuits over a ten year time period. The design was for critical 3-phase sections of a selected circuit, from the substation out to the first protection device, to have tree exposure reduced by removing all overhanging vegetation or pruning "ground to sky." Intensive hazard tree review and removal was conducted on these critical sections. In cases where the customer count was over 500 customers at the first protection device, overhang and hazard tree removal was continued to the second protection device. From that point, hazard tree inspection and removal was conducted out to the third protection device or along remaining three phase lines.

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[7] NH PUC "The October Snowstorm – New Hampshire's Regulated Utilities' Preparation and Response" November 20,2012, Appendix E p55

[8] NH PUC "The October Snowstorm – New Hampshire's Regulated Utilities' Preparation and Response" November 20,2012, Section VI p38

The SRP work has the ability to prevent tree related failures and subsequent electric incidents. This reduction in incidents reduces damage to the electric infrastructure and the need for crews to respond, reducing overall storm costs.

However, tThere are also a number of additional benefits associated with a tree exposure reducing Storm Hardening program, including:

- Preserving municipal critical infrastructure
- Minimizing the dependence on mutual aid and off system resources
- Minimizing the total number of resources required to restore service
- Shortening the duration of major events
- Minimizing the overall cost of restoration
- Reducing economic loss to municipalities, businesses, and customers
- Most cost effective solution vs. other alternatives
- Minimal bill impact on a per-customer basis

The Company believes that reliable electric service is essential to the economic well-being of the businesses and industries we serve, and to the welfare of those who live and work in our communities. Interruptions to electric service are both expensive to repair, and expensive to the businesses and individuals who rely on electricity for commercial and household purposes. To cite one example, a 2004 study conducted by Lawrence Berkeley National Laboratory (Berkeley Lab) (funded by the Office of Electricity Delivery and Energy Reliability of the U.S. Department of Energy) estimated that electric power outages and blackouts cost the nation about $80 billion annually. Of this, $57 billion (73 percent) was attributed to losses in the commercial sector and $20 billion (25 percent) in the industrial sector.[9] In subsequent studies performed by Berkeley Lab in 2009 and 2015 provided extensive data on the cost of customer interruptions, including estimates of the average cost of electric interruptions (in 2008 and 2013 dollars respectively) broken down by customer type, outage duration, time of day, day of week, and other variables.[10]

To test the validity of the program as designed, a pilot of the program was implemented in 2012 and 2013 which was met with positive results, acceptance, and praise from customers[11]. With the Commission's support, in 2014 the storm resiliency pilot program became a full Storm Resiliency

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[9] Understanding the Cost of Power Interruptions to U.S. Electricity Consumers, Kristina Hamachi LaCommare and Joseph H. Eto, September 2004.

[10] Estimated Value of Service Reliability for Electric Utility Customers in the United States, Michael J. Sullivan, Ph.D., et al, June 2009.
Updated Value of Service Reliability Estimates for Electric Utility Customer in the United States, Michael J. Sullivan, Ph.D., et al, January 2015.

[11] Unitil "2013 Storm Resiliency Pilot Program Results – Addendum to the: Storm Resiliency Pilot Program 2012 Cost Benefit Analysis" January 24, 2014

Program, occurring in tandem with the vegetation management program. Including the pilot years, six years of storm resiliency work have been implemented to date.

2. Storm Resiliency Program Analysis

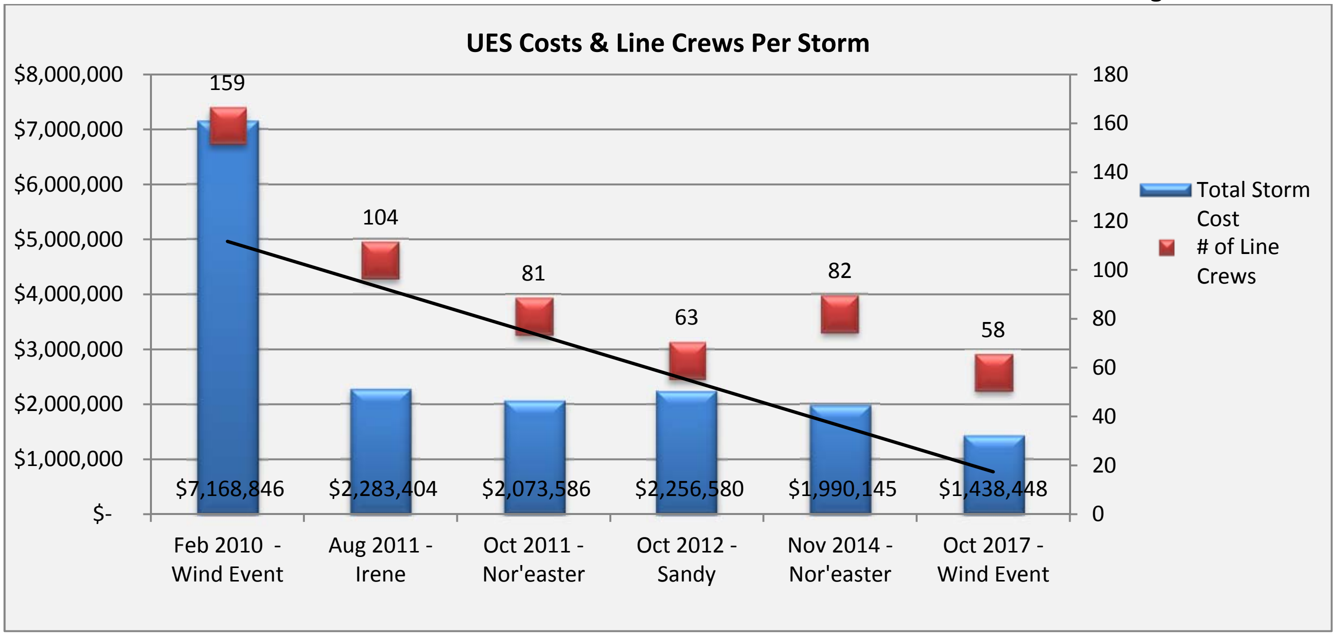
The SRP's objective is to enhance the reliability of electric feeders out to the first protective device to support the concept of bringing "normalcy" back to the community as soon as possible after a storm event. It is the realization of this concept that we would like to explore further.

As an initial matter, it's difficult to prove what might have happened had the Company not undertaken the SRP. However, by trending storm data over the past several years, there is sufficient empirical evidence to conclude that the program is meeting its stated objectives. Those objectives include:

- Improve the reliability of treated circuits out to the first protected device
- Reduce the cost of storms
  - Shorten restoration time
  - Fewer resources needed to restore
- Enhance customer relations by improving power availability during events that previously caused power interruptions

Company has reviewed the biggest storm events to impact New Hampshire over the past 7 years (see Chart 1). The data shows a decline in resources needed and thereby a decline in the overall cost of the restoration. The Company is of the opinion that there is a break point as how fast restoration can occur after the onset of an event, given the activities that have to be performed prior and during restoration such as the public safety phase. The Company believes, however, that restoration times in general have been reduced by approximately 1-2 days such that the type of storms that would have formerly taken 5-6 days to recover from are now are being restored in 4-5 days. The key is that we can now restore with fewer resources as a result of fewer damage locations related to trees, a direct result of the SRP.

Chart 1



In addition to the cost and resource trends in major storms, there is evidence of decline in outages under normal conditions and as a result of minor storms. This can be seen by studying the sections of circuit where the SRP has been performed. The Company compared Pre-SRP (year SRP performed and previous 4 years) and Post-SRP (years after SRP – varies from 5 to 1 depending on the circuit) “tree related” outages on all SRP circuit sections. The areas where SRP ground-to-sky and intensive hazard tree removal were completed had a 74% reduction in tree related outages per year, and a 99.9% reduction in outages per mile per year.[12] See Table 1 below. There were only 15 outages on Post-SRP areas compared to 554 tree-related events in this time period. Outages on the ground-to-sky portions of SRP circuits Post-SRP accounted for only 2.7% of the tree related outages on the SRP circuit over the same time period, versus 7.5% (152 of 2,031) tree related outages for the five years prior to the SRP being performed.

Table 1

Areas of Ground to Sky – Not Including “Major Events”

	PRE-SRP	POST-SRP	% Reduction
Outages Per Circuit Per Year	1.23	0.32	74%
Outages Per Mile Per Year	0.3107	0.0002	99.9%
Average Customer Minutes of Interruption per year	1,795,684	669,883	63%
Average Customer Minutes of Interruption per year per mile	368,527	108,819	71%

[12] Excluding major events and sub-transmission data

In major events, the reduction in outages is not quite as pronounced, due to the lack of data being collected during storm events, and lack of opportunity to collect the data. Without data showing locations of tree-related trouble, an outage affecting a large amount of customers Pre-SRP could be related to numerous cases of tree damage, and that same outage Post-SRP could be related to only one case of tree damage. However, both events appear as a similar, single outage on the circuit. Setting aside discrepancies in the outage data, attempting to compare Pre-SRP major events and Post-SRP major events is difficult due to the fact that in many of the events, individual outage data (or even circuit level data) is not available. The February 25, 2010 wind storm, August 28, 2011 Hurricane Irene, October 31, 2011 Nor'easter, and October 29, 2012 Sandy do not have outage data for comparison. In these events it was not feasible to collect individual outage data. Perhaps the ability to be able to collect circuit and outage level data in recent major events, such as the October 29, 2017 wind storm, speaks to the reduction in trouble locations and damage on the system due to SRP efforts. At the present, the best measure of SRP effectiveness in a storm can be seen in a reduction of the overall storm restoration duration and the number of resources required shown in Chart 1.

3. Storm Resiliency Program Proposal

Due to the positive impact the SRP has had on major storm event resources, restoration, and cost, the Company is proposing to accelerate the program. The original SRP plan was for a 10 year time frame, which put the initial cycle of SRP wrapping up in 2021. The Company is proposing to accelerate the plan by one year, completing an additional one-third mileage during 2018, 2019, and 2020. This would increase spending by $474,333 for these three years, bringing the total SRP spend for each of these years to $1,897,333.

This would have a minimal bill impact on a per customer basis, as an average customer would see an increase of only $0.24.

By using the outage per mile per year results seen to date (Table 1 above), the impact of accelerating the SRP work can be estimated, for the actual areas and customers in the acceleration circuits. We have seen a reduction in outages per mile per year of 99%. If we accelerate 13.6 miles of work in 2018, as proposed, and see the average reduction in outage of 99%, using the past five year history we would expect to reduce the outages on these two circuits by anywhere from 1 to 2 outages, reducing customer interruptions anywhere from 1,073 to 1,273 customer interruptions, and reducing customer minutes of interruption from 53,604 to 64,604 CMI for the acceleration portion only. There are 2,015 customers served on these two circuits that would see an improvement in their reliability two years in advance.

In 2019, we would expect to see a similar reduction in outages and customer interruptions, including the additional accelerated miles in 2019 – bringing the estimated reduction in outages per mile to 3, reducing customer interruptions by an estimate of 2,546 and customer-minutes of interruption by as much as 129,208 for the accelerated circuits in 2018 and 2019 only.

In 2020, again the impact of the past two years of acceleration would be realized, plus the additional final year of acceleration, bringing the reduction in outages to an estimate of 4 to 5 outages avoided on the SRP acceleration circuits. The estimated customer impact of the acceleration project in 2020 is estimated to be 3,819 customer interruptions avoided and as much as 193,812 customer-minutes of interruption avoided.

Over all three years of the acceleration project, a total estimated reduction of 6 outages could be realized, equating to a customer impact of 7,638 customer interruptions and 687,624 customer minutes of interruption avoided years in advance, on the accelerated circuits.

4. Conclusion

Unitil embarked on a Storm Pilot Program in 2012 and 2013 in response to the increasing trend of costly and devastating storm events and the need to shorten the response time and event duration. The initial success of the targeted vegetation pilot and anticipated future savings and economic benefits to customers led to approval of the continuance of storm pilot work as an annual Storm Resiliency Program. The Company has seen a clear decline in resources needed in major storms, and a decline in the overall cost of restoration since the SRP program has been in effect. While difficult to quantify, the customer impact of shorter duration events, or the avoidance of events, has been the biggest benefit. The ability to return to normal service conditions more quickly after an event, and allow affected customers to get back to school and to work, and minimize the economic impact that storm events have on customer’s lives is the real benefit. Accelerating the SRP program will bring that benefit more quickly to more customers.

Attachment 2

UES – Capital

Reliability Study 2017

Unitil Energy Systems - Capital

Reliability Study

2017

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Feb 7, 2018

Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES-Capital system from January 1, 2016 through December 31, 2016. The scope of this report will also evaluate individual circuit reliability performance over the same time period. The outage data from the following storm has been excluded from these analyses: July ‘16 wind/thunder storm from 07/23/2016 00:00 to 07/24/2016 00:00.

The following projects are proposed from the results of this study and are focused on improving the worst performing circuits as well as the overall UES-Capital system reliability. These recommendations are provided for consideration and will be further developed with the intention to be incorporated into the 2018 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
8X3	Install Fuse Saver on Lane Rd.	$9,000
22W3	Install Sectionalizers on Birchdale Rd.	$10,000
BOW JUNCITON	Install an Auto-Transfer Scheme	$100,000
396 LINE	Install and Auto Sectionalizing scheme	$40,000

Note: estimates do not include general construction overheads

Reliability Goals

The annual corporate system reliability goals for 2016 were set at 176-151-126 SAIDI minutes. These were developed through benchmarking Unitil system performance with surrounding utilities.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire Capital system is used to identify future capital improvement projects and/or operational enhancements which may be required in order to achieve and maintain these goals.

Outages by Cause

This section provides a breakdown of all outages by cause code experienced during 2016. Chart 1 lists the number of interruptions, and the percent of total interruptions, due to each cause. For clarity, only those causes occurring more than 5 times are labeled. Chart 2 details the percent of total customer-minutes of interruption due to each cause, only those causes contributing greater than 2% of the total are labeled.

Chart 1
Number of Interruptions by Cause

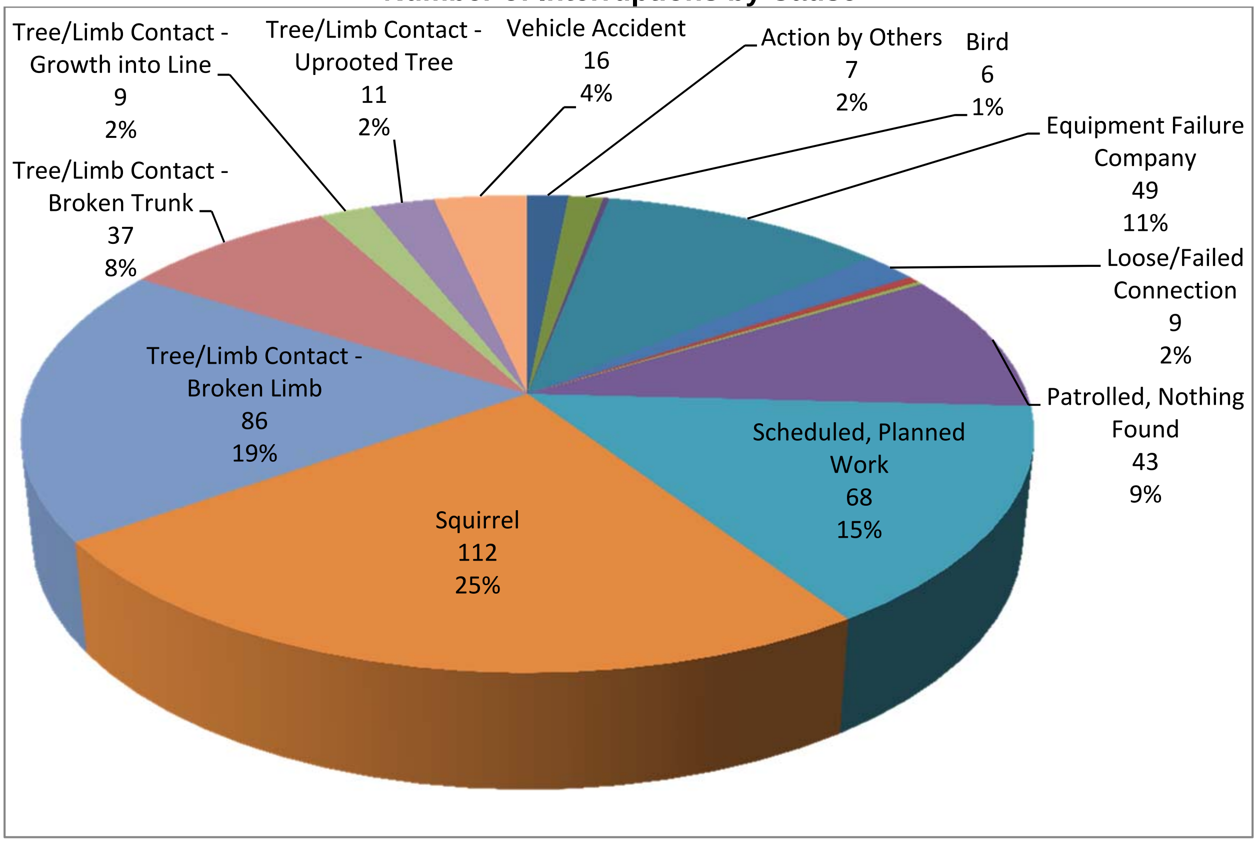
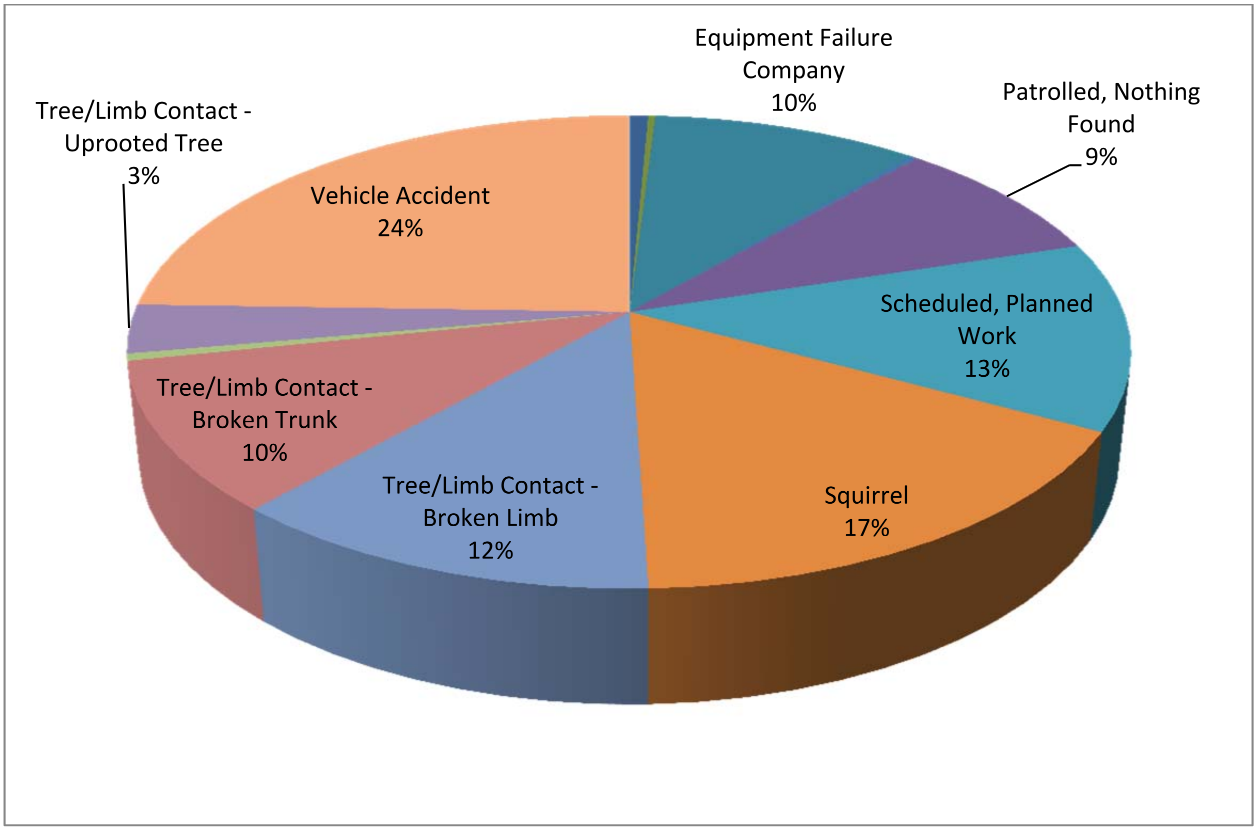


Chart 2
Percent of Customer-Minutes of Interruption by Cause



10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2016 through December 31, 2016 are summarized in Table 1 below.

Table 1
Worst Ten Distribution Outages

Circuit	Date/Cause	Customer Interruptions	Cust-Min of Interruption	SAIDI	SAIFI
C4X1	10/27/2016 Vehicle Accident	2,638	181,571	6.04	0.088
C22W3	07/09/2016 Vehicle Accident	1,608	148,318	4.94	0.054
C15W1	07/26/2016 Tree/Limb Contact - Broken Trunk	1,299	87,712	2.92	0.043
C21W1A	06/15/2016 Equipment Failure Company	282	78,114	2.6	0.009
C4X1	07/29/2016 Vehicle Accident	282	70,782	2.36	0.009
C2H2	10/09/2016 Vehicle Accident	389	68,757	2.29	0.013
C16X4	04/15/2016 Civil Emergency (fire,flood,etc.)	1,063	60,733	2.02	0.035
C13W3	11/27/2016 Patrolled, Nothing Found	675	59,376	1.98	0.022
C13W1	06/26/2016 Squirrel	282	56,400	1.88	0.009
C13W3	01/04/2016 Equipment Failure Company	282	47,088	1.57	0.009

Note: This table does not include substation, sub-transmission or scheduled planned work outages.

Sub-transmission Line and Substation Outages

This section describes the contribution of sub-transmission line and substation outages on the UES-Capital system from January 1, 2016 through December 31, 2016.

All substation and sub-transmission outages ranked by customer-minutes of interruption during the time period from January 1, 2016 through December 31, 2016 are summarized in Table 2 below.

Table 3 shows the circuits that have been affected by sub-transmission line outages. The table illustrates the contribution of customer minutes of interruption for each circuit affected by a sub-transmission outage.

Table 2
Sub-transmission and Substation Outages

Line/Substation	Date/Cause	Customer Interruptions	Cust-Min of Interruption	SAIDI	SAIFI
Line 33	06/02/2016 Operator Error/System Malfunction	1,178	24,131	0.80	0.039
Bow Junction Substation	07/10/2016 Squirrel	1,721	296,879	9.88	0.057
Line 396X1	10/06/2016 Action by Others	1,136	90,685	3.02	0.038

Table 3
Contribution of Sub-transmission and Substation Outages

Circuit	Substation / Transmission Line Outage	Cust-Min of Interruption	% of Total Circuit CMI	Circuit SAIDI Contribution	Number of Events
C33X3	Line 33	21	100%	21.13	1
C33X4	Line 33	1,372	100%	20.18	1
C33X5	Line 33	63	100%	15.71	1
C33X6	Line 33	20	100%	4.10	1
C6X3	Line 33	22,655	89%	20.28	1
C7W3	Bow Junction Substation	230,728	93%	254.11	1
C7W4	Bow Junction Substation	66,151	86%	84.92	1
C17X1	Line 396X1	40	100%	20.00	1
C18W2	Line 396X1	90,645	49%	75.79	1

Worst Performing Circuits

This section compares the reliability of the worst performing circuits using various performance measures. All circuit reliability data presented in this section includes subtransmission or substation supply outages unless noted otherwise.

Worst Performing Circuits in Past Year

A summary of the worst performing circuits during the year of 2016 is included in the tables below. Table 4 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption. The SAIFI and CAIDI for each circuit are also listed in this table. Table 5 provides detail on the major causes of the outages affecting these circuits. Customer-minutes of interruption are given for the six most prevalent causes during 2016.

Circuits having one outage contributing more than 75% of the Customer-Minutes of interruption were excluded from this analysis.

Table 4
Worst Performing Circuits by Customer-Minutes

Circuit	Customer Interruptions	Worst Event (% of CI)	Cust-Min of Interruption	Worst Event (% of CMI)	SAIDI	SAIFI	CAIDI
C4X1	3,287	80%	276,811	66%	146.38	1.738	84.21
C21W1A	1,130	25%	252,669	31%	892.82	3.993	223.6
C22W3	2,385	67%	215,821	69%	136.51	1.509	90.49
C13W3	2,143	27%	186,166	24%	117.09	1.348	86.87
C18W2	2,386	48%	185,878	49%	155.42	1.995	77.9
C8X3	2,205	9%	177,913	12%	62.34	0.773	80.69
C15W1	1,930	67%	147,366	60%	147.96	1.938	76.36
C13W1	880	55%	69,392	44%	140.76	1.785	78.86
C4W3	797	19%	65,268	32%	47.5	0.58	81.89
C4W4	716	43%	37,756	44%	16.49	0.313	52.73

Note: all percentages and indices are calculated on a circuit basis

Table 5
Circuit Interruption Analysis by Cause

Circuit	Customer-Minutes of Interruption / # of Outages					
	Vehicle Accident	Squirrel	Scheduled, Planned Work	Tree/Limb Contact - Broken Trunk	Tree/Limb Contact - Broken Limb	Equipment Failure Company
C4X1	250,327 / 2	0 / 0	260 / 2	75 / 1	6,463 / 3	9,741 / 3
C21W1A	0 / 0	0 / 0	181,887 / 5	0 / 0	0 / 0	70,782 / 1
C22W3	148,633 / 2	10,265 / 12	2,620 / 4	7,536 / 2	24,281 / 8	8,492 / 3
C13W3	36,311 / 4	13,035 / 15	70 / 1	22,734 / 9	11,126 / 13	30,807 / 8
C18W2	818 / 1	24,043 / 15	224 / 3	10,325 / 1	25,814 / 7	1,182 / 3

C8X3	586 / 3	50,500 / 26	1,320 / 4	22,866 / 9	38,686 / 25	8,304 / 4
C15W1	21,382 / 1	14,860 / 5	0 / 0	87,917 / 2	22,613 / 5	544 / 1
C13W1	0 / 0	33,222 / 6	2,927 / 2	20,553 / 7	2,759 / 4	871 / 1
C4W3	0 / 0	11,777 / 3	550 / 3	4,881 / 1	33,402 / 3	7,946 / 5
C4W4	0 / 0	11,630 / 7	1,195 / 6	16,782 / 2	2,523 / 2	3,780 / 3

Worst Performing Circuits of the Past Five Years (2012 – 2016)

The annual performance of the ten worst circuits in terms of SAIDI and SAIFI for the past five years is shown in the tables below. Table 6 lists the ten worst circuits ranked by SAIDI performance. Table 7 lists the ten worst performing circuits ranked by SAIFI.

The data used in this analysis includes all system outages except those outages that occurred during the 2016 July wind/thunder storm, 2014 November Cato Snowstorm, and 2012 Hurricane Sandy.

Table 6
Circuit SAIDI

Circuit Ranking (1=worst)	2016		2015		2014		2013		2012	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	C21W1A	892.82	C21W1A	803.71	C15W2	794.83	C16H1	1524.26	C13W2	817.42
2	C7W3	272.49	C34X2	399.45	C22W3	729.57	C375X1	1018	C13W1	425.04
3	C34X2	244.8	C13W3	357.44	C35X1	573.63	C37X1	861.07	C211P	381.91
4	C37X1	176.22	C375X1	318.05	C24H1	570.48	C13W2	744.95	C211A	270
5	C18W2	155.42	C14H2	288.1	C24H2	545.14	C13W1	739.74	C8X3	244.17
6	C15W1	147.96	C16X4	281.37	C22W1	534.36	C16X5	720.5	C18W2	223.12
7	C4X1	146.38	C16H1	281.3	C22W2	512.65	C8X3	708.72	C7W3	193.84
8	C13W1	140.76	C7W3	281.18	C15W1	499.87	C13W3	609.67	C34X2	165
9	C22W3	136.51	C16H3	280.82	C7W3	444.56	C24H1	524.03	C15W1	152.67
10	C13W3	117.09	C16X5	280.05	C38W	441.97	C18W2	521.3	C15W2	135.36

Table 7
Circuit SAIFI

Circuit Ranking (1=worst)	2016		2015		2014		2013		2012	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	C21W1A	3.993	C21W1A	6.356	C24H1	7.143	C13W2	7.068	C13W2	9.52
2	C37X1	2.418	C16X4	5.023	C24H2	6.987	C16X5	5.5	C13W1	4.858
3	C18W2	1.995	C16H1	5.02	C15W2	6.597	C37X1	5.412	C21W1P	3.037
4	C15W1	1.938	C16X5	5	C22W3	5.832	C13W1	5.405	C7W3	2.458
5	C13W1	1.785	C16X6	5	C3H1	4.251	C22W3	4.849	C18W2	2.386
6	C1X7P	1.778	C375X1	5	C22W1	4.034	C4W3	4.574	C6X3	2.283
7	C4X1	1.738	C16H3	4.998	C38W	4.022	C13W3	4.547	C8X3	2.25
8	C22W3	1.509	C7W3	4.85	C22W2	4	C7W3	4.547	C15W1	2.053
9	C7W3	1.396	C13W3	4.567	C7W3	3.982	C18W2	4.337	C22W1	2
10	C13W3	1.348	C18W2	4.127	C14X3	3.5	C16H1	4.12	C13W3	1.834

Improvements to Worst Performing Circuit (2014-2016)

Projects completed from 2014 to 2017 that are expected to improve the reliability of the worst performing circuits are included in table 8 below.

Table 8
Improvements to Worst Performing circuits

Circuits	Year of Completion	Project Description
21W1A	2016	Completed work to allow energized transfer for planned work (added cable, added junctions, moved switchgear)
		Replaced fault indicator system
15W1	2014	Forestry Review
	2015	Cycle Pruning / Hazard Tree Mitigation
	2016	New Hydraulic Recloser Installation
18W2	2014	Forestry Review / Installed Animal Guards in problem areas
	2015	Fuse Addition / Sectionalizer Installations
	2016	Cycle Pruning
4X1	2014	Fuse Changes/Additions
	2014	Cutout Replacements
22W3	2014	Forestry Review / Installed Animal Guards in problem area

Circuits	Year of Completion	Project Description
	2015	Cycle Pruning / Hazard Tree Mitigation / Installed Animal Guards in problem areas / Fuse savings implemented in problem areas
13W3	2014	Hazard Tree Mitigation / Mid Cycle Review
37X1	2014	Fuse Changes/Additions
13W1	2014	Cycle Pruning
	2015	Fuse Changes/Additions
8X3	2015	Hazard Tree Mitigation / SRP / Mainline One Bolt Connectors Replaced / Replaced Insulators that are well known for higher than normal failure rate / Fuse Addition
	2016	Sectionalizer Installation
7W3	2015	Cycle Pruning / Hazard Tree Mitigation
375 Line[13]	2015	Cycle Pruning / Clearing zone expanded
	2016	ROW tree clearing zone expanded

Tree Related Outages in the Past Year (1/1/16-12/31/16)

This section summarizes the worst ten performing circuits by tree related outages during 2016.

Table 9 shows the ten worst circuits ranked by the total number of Customer-Minutes of interruption caused by tree related faults on the circuit. The number of customer-interruptions and number of outages are also listed in this table. Circuits having less than three outages were excluded from this table.

All streets on the Capital System with three or more tree related outages are shown in Table 10 below. The table is sorted by number of outages and customer-minutes of interruption and does not include major events.

[13] The 375 Line work will improve reliability performance on 16H1,16H3, 16X4, 16X5, 16X6 and 375X1

Table 9
Worst Performing Circuits – Tree Related Outages

Circuit	Customer Minutes of Interruption	Number of Customers Interrupted	No. of Interruptions
C15W1	110,529	1,628	7
C8X3	81,508	1,033	38
C13W3	54,011	542	29
C22W3	38,883	434	11
C4W3	38,283	398	4
C18W2	36,192	414	9
C13W1	29,551	299	15
C4W4	19,305	355	4
C4X1	15,877	124	5
C37X1	10,456	155	4

Table 10
Multiple Tree Related Outages by Street

Circuit	Street, Town	# Outages	Customer-Minutes of Interruption	Number of Customer Interruptions
C13W3	North Water St, Boscawen	6	10,100	114
C13W1	Morrill Rd, Canterbury	4	7,758	120
C8X3	New Orchard Rd, Epsom	3	8,097	83

Failed Equipment in the Past Year

This section is intended to clearly show all equipment failures throughout the year of 2016. Chart 3 shows all equipment failures throughout the study period. Chart 4 shows each equipment failure as a percentage of the total failures within this same study period. Chart 5 shows the top four types of failed equipment within the study period with five years of historical data.

Chart 3
Equipment Failure Analysis by Cause

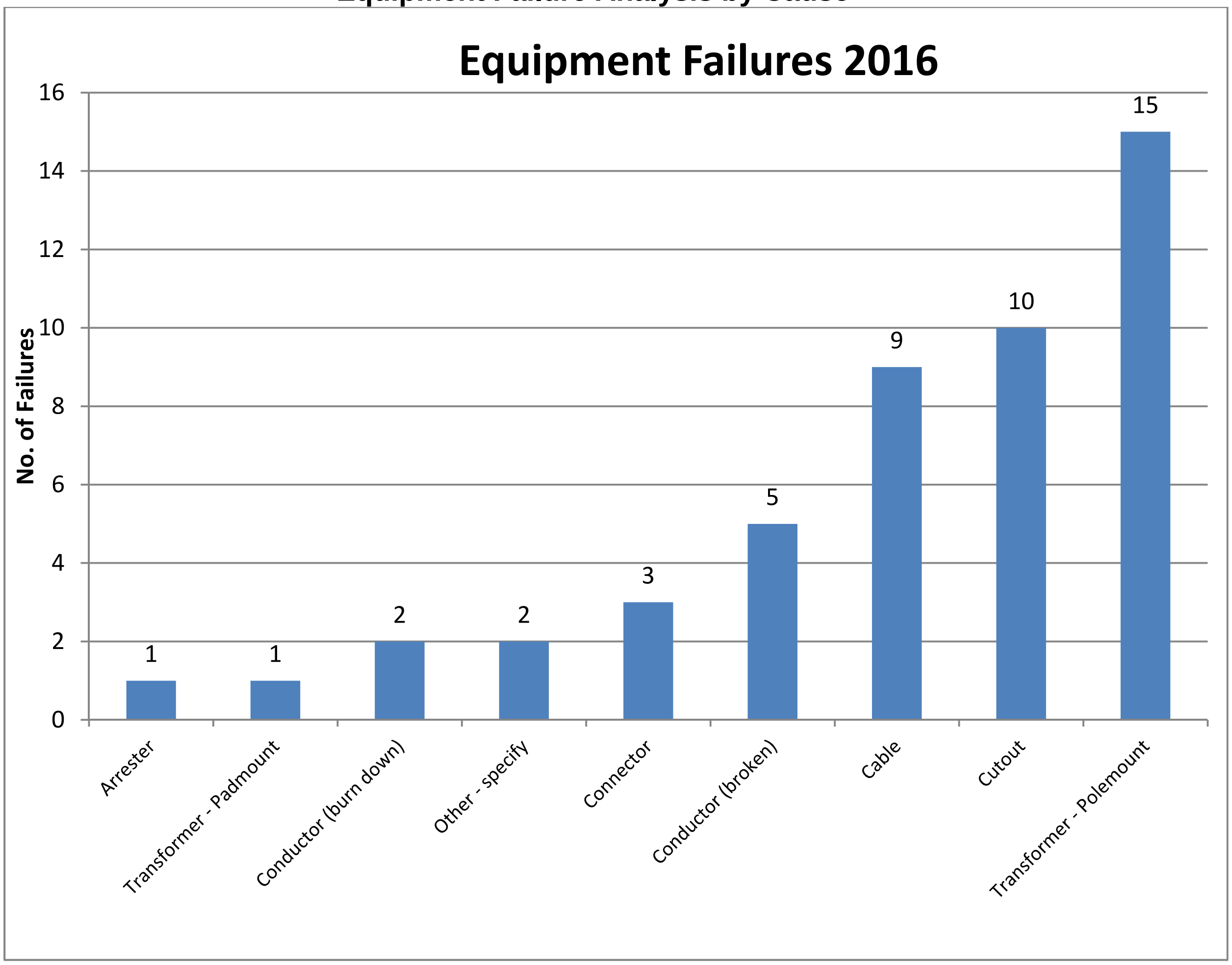


Chart 4
Equipment Failure Analysis by Percentage of Total Failures

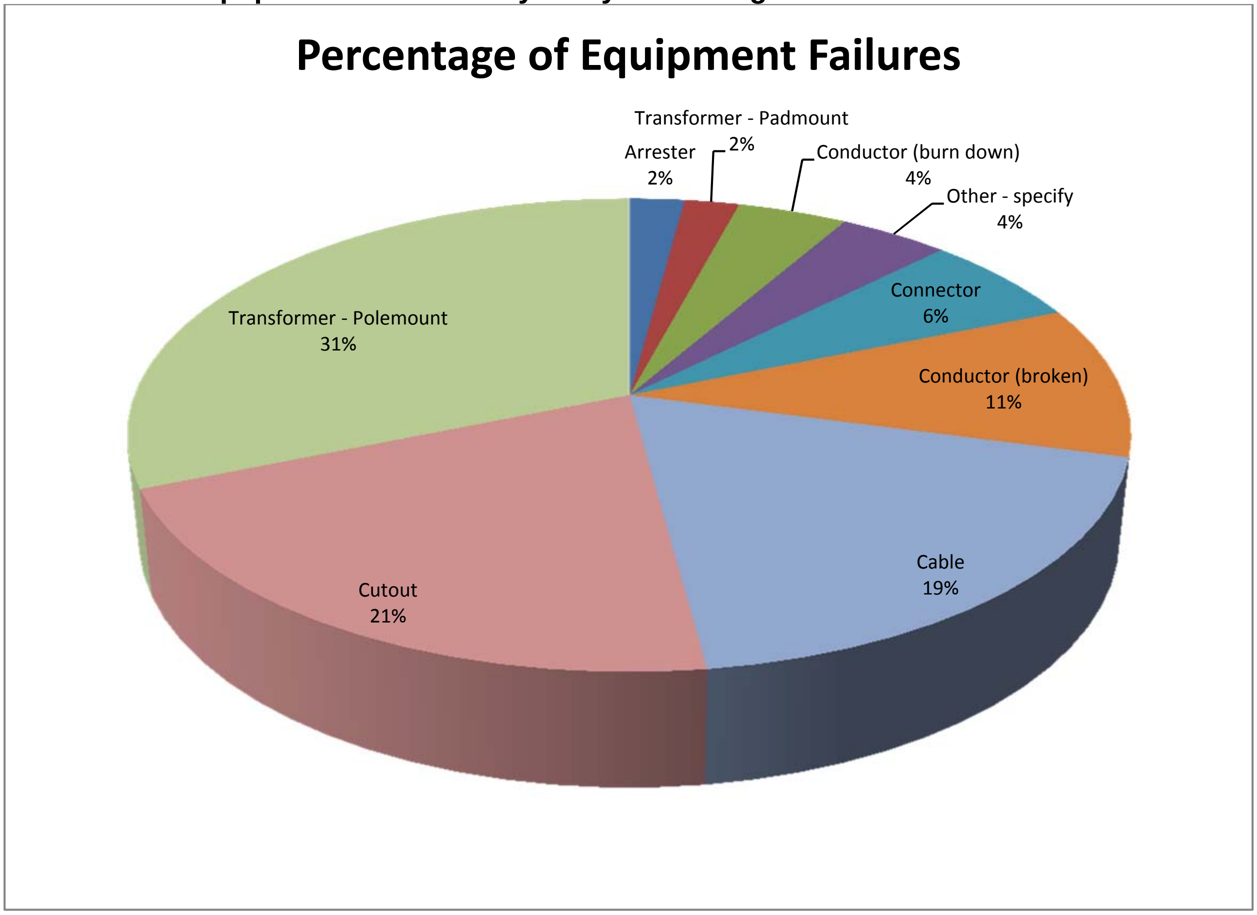
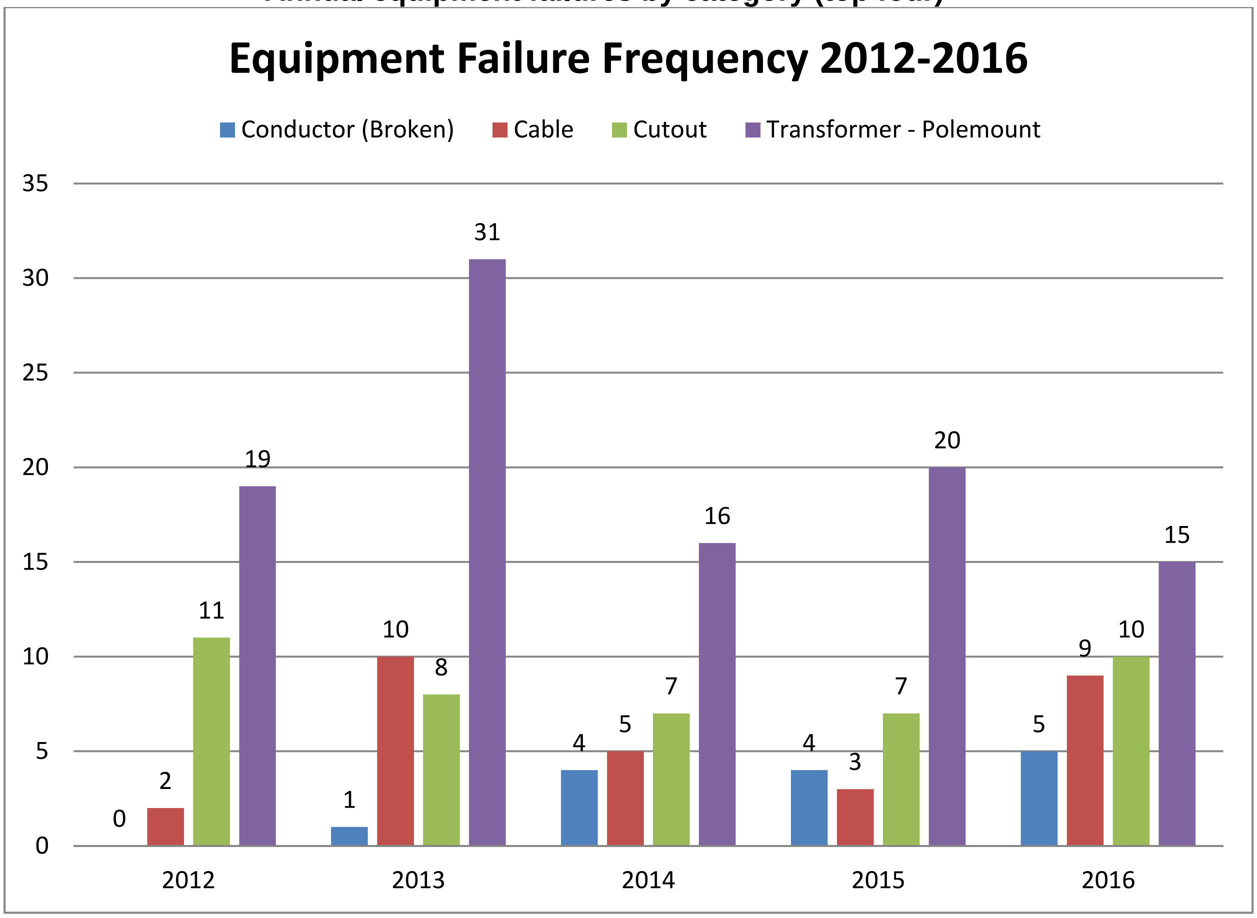


Chart 5
Annual equipment failures by category (top four)



Multiple Device Operations in the Past Year (1/1/15-12/31/15)

Table 11 below is a summary of the devices that have operated three or more times in 2016. All exclusionary events are removed in this table.

Table 11
Multiple Device Operations

Circuit	Number of Operations	Device	Customer Minutes	Customer Interruptions
C8X3	7	Fuse, Pole 11, Old Town Rd, Epsom	7,638	119
C18W2	5	Fuse, Pole 34, Putney Rd, Bow	11,487	165
C22W3	4	Fuse, Pole 1, Rocky Point Dr, Bow	8,534	120
C8X3	4	Fuse, Pole 1, Smith Sanborn Rd, Chichester	21,009	308
C13W3	3	Fuse, Pole 1, North Water St, Boscawen	9,863	111
C13W3	3	Fuse, Pole 10, Terrace Hill Rd, Boscawen	2,465	48
C18W2	3	Fuse, Pole 1, Allen Rd, Bow	19,369	283
C8X3	3	Fuse, Pole 16, Highland Dr, Chichester	3,341	30
C15W1	3	Fuse, Pole 65, East Side Dr, Concord	6,710	114
C4W4	3	Trans. Breaker, Pole 10, Hutchins St, Concord	1,924	23
C4W3	3	Fuse, Pole 158, Mountain Rd, Concord	975	9
C21W1A	3	Recloser, Substation, Storrs St, Concord	174,270	846

Other Concerns

This section is intended to identify other reliability concerns that would not necessarily be identified from the analysis above.

Narrow subtransmission ROW expansion

The UES-Concord subtransmission system has some areas where the Right Of Way (ROW) is narrow, thus, even after pruning trees to the edge of the ROW we leave our system vulnerable to damage by falling trees. Historically, Unitil has experienced noticeably more outages, due to falling trees, on lines that are in narrow ROW in comparison to lines in larger ROW. Unitil has been able to successfully expand ROW tree lines in 2015 and will continue these efforts in 2016. This effort is expected to allow effective tree mitigation in the problem areas.

13.8kV Underground Electric System Degradation

The 13.8kV underground electric system has been experiencing connector and conductor failures at an average rate of 0.8 per year for the last 5 years. This does not include scheduled replacement of hot terminations identified by inspection; hot terminations have been identified and replaced regularly, without causing outage. In 2015, a study on this system was completed. It identified age and use of 200A connectors may be a contributing factor to failures. Energized transfer capability is being built into this underground system to reduce the number of outages experienced by customers, during equipment replacement.

Alternate Mainline for Large 34.5kV Circuits

Circuit 8X3 has the largest customer exposure on the capital system at 2,764 customers with an 11.5MVA peak, in 2014. This circuit has no alternate feeds to restore customers during mainline outages.

Building an alternate mainline to reduce customer exposure and allow an alternate feed during contingency scenarios is the ultimate goal for this area. Three alternatives where reviewed. One involved constructing a pole line outside of UES territory, one involved double circuiting, and the final involved rebuilding Horse Corner Rd. The Horse Corner Rd route is preferred because it will create an alternate pole line and does not involve joint construction with Eversource.

One Bolt Connector Replacement

One bolt connectors on primary conductor are required to be installed on stirrups, by existing construction standards. Surveys have found many one bolt connectors installed directly on primary conductor. It has been found that stranded conductor can become damaged by single bolt connectors directly connected, reducing the conductor's thermal and mechanical strength. This damage has been found to be most drastic on 34.5kV energized conductor. Due to recent outages and noticeable damage found on 34.5kV circuits, it has become a priority to replace these connectors on 34.5kV energized mainline. Significant work was done in 2015 to mitigate this problem on circuits 6X3, 7X1, 8X5 and 8X3. Work is planned to continue on circuits 8X5 and 8X3 in 2016.

URD's Utilizing Direct Buried Cable of 1970's vintage

Direct buried cable URD's are failing at an increasing rate, about 1-3 failures per year as of 2015. When a direct buried cable fails, Unitil splices a small section of new cable into the run of aged cable. The remaining aged cable in that area is just as susceptible to failure, so additional failures persist more frequently. When cable in conduit fails, entire runs of cable are replaced, preventing this issue. This can't be done easily for direct buried due to cost and digging permissions. Some options to help mitigate this problem: one is to improve dielectric strength of existing cable with cable injection; two is to reduce the operating voltage of a URD and three replace runs of direct buried cable with conduit and new conductor. Option one and two are not ideal because aged direct buried cable typically has other concerns such as a degrading neutral. Option three is preferred and is being done now but it is expensive and requires implementing multiyear plans to reduce the impact of this cost.

Single Phase Underground Loop-Feed at Court St

Identified Concern
The single-phase underground cable at Court St that is used as a redundant feed for several customers on North State St is left un-energized because it doesn't normally feed customers. There is a concern that if there is a fault on this section of cable, it could take out Circuit 21W1A. With the cable left un-energized, we wouldn't know if there was a problem with the cable until it was energized.
Recommendation
Install an interrupter in the single phase loop out of MH22.

Recommended Reliability Improvement Projects

This following section describes recommendations on circuits, sub-transmission lines and substations to improve overall system reliability. The recommendations listed below will be compared to the other proposed reliability projects on a system-wide basis. A cost benefit analysis will determine the priority ranking of projects for the 2018 capital budget. All project costs are shown without general construction overheads

Circuit 18W2: Install Reclosers in Both Directions out of Bow Bog Substation

Identified Concerns

Circuit 18W2 has been in the list of 10 worst circuits in regards to SAIDI and SAIFI for three of the last five years. In the past five years since 2012, the 18W2 recloser has operated four times due to faults on the mainline.

Recommendations

Install a Recloser in Northern Direction out of Bow Bog Substation

Estimated Project Cost (without construction overheads): $ 64,000
Estimated Annual Savings – Customer Minutes: 43,804, Customer Interruptions: 674

Install a Recloser in Southern Direction out of Bow Bog Substation and a Sectionalizer on Allen Rd.

Estimated Project Cost (without construction overheads): $ 68,000
Estimated Annual Savings – Customer Minutes: 4,616, Customer Interruptions: 71

Circuit 18W2: Install Fuse in Blevens Rd Tap

Identified Concerns

The fuse a P.34 Putney Rd. in Bow had five operations in 2016. Three of the operations were due to squirrels. One was due to a broken limb and one was patrolled and nothing found.

Recommendations

Install a fuse in the Blevens Rd tap.

Estimated Project Cost (without construction overheads): minimal
Estimated Annual Savings – Customer Minutes: 256, Customer Interruptions: 4

Circuit 18W2: Replace Low-Side Step-Down fuse with Recloser on Smith-Sanborn Rd

Identified Concern

The fuse a P.1 Smith-Sanborn Rd. in Chichester had four operations in 2016. Two of the operations were due to squirrels. One was due to a broken limb and one was patrolled and nothing found.

Recommendation

Replace low-side step-down fuse with a 70A V4L hydraulic recloser and the hi-side fuse with a 65K fuse. Also, install fusing at the two unfused downline taps.

Estimated Project Cost: $12,000
Estimated Annual Savings – Customer Minutes of Interruption: 1,267, Customer Interruptions: 20

Circuit 13W3: Replace North Water St Fuse with Sectionalizer

Identified Concern

The fuse at P.1 North Water St. in Boscawen had three operations in 2016 that were all tree related.

Recommendation

Replace the fuse at P.1 North Water St. with a sectionalizer and install a fuse about half-way down the North Water St. tap.

Estimated Project Cost: $8,000

Estimated Annual Savings – Customer Minutes of Interruption: 1,732, Customer Interruptions: 27

Build Circuit-Tie Between 8X3 and 8X5

Identified Concern

The fuse at P.1 North Water St. in Boscawen had three operations in 2016 that were all tree related.

Recommendation

Replace the fuse at P.1 North Water St. with a sectionalizer and install a fuse about half-way down the North Water St. tap.

Estimated Project Cost: $8,000
Estimated Annual Savings – Customer Minutes of Interruption: 1,732, Customer Interruptions: 27

Miscellaneous Circuit Improvements to Reduce Recurring Outages

Identified Concerns & Recommendations

The following concerns were identified based on a review of Tables 10 & 11 of this report; Multiple Tree Related Outages by Street and Multiple Device Operations respectively.

Mid-Cycle Forestry Reviews

The areas identified below experienced three or more tree related outages in 2016. It is recommended that a forestry review of these areas be performed in 2017 in order to identify and address any mid-cycle growth or hazard tree problems.

- C13W3, North Water Street, Boscawen
- C13W1, Morrill Road, Canterbury
- C8X3, New Orchard Road, Epsom

Animal Guard Installation Recommendations

The area identified below experienced three or more patrolled nothing found / animal outages in 2016. It is recommended that an animal protection review is performed in 2017 in order to identify locations in which animal protection can prevent outages due to animals.

- C8X3, Old Town Road, Epsom
- C18W2, Putney Road, Bow
- C8X3, Hillview Drive, Chichester
- C8X3, Smith Sanborn Road, Chichester
- C13W3, Terrace Hill Road, Boscawen

Conclusion

During 2015, tree related outages still present the largest problem in the UES-Capital System, compared to other causes. Although compared to previous years, the worst performing circuits have seen a dramatic decrease in Customer Minutes of Interruption from tree related outages. Enhanced tree trimming efforts are still being implemented, which is expected to improve reliability for most of the worst performing circuits identified in this study. Motor Vehicle Accidents have caused about 3 times as many customer minutes of interruption, in 2015, as the two previous years. This cause will be reviewed next year to determine if this elevated level of interruption persists.

Recommendations developed from this study are mainly focused on reducing the impact of multiple permanent outages and improving reliability of the sub transmission system. This report is also intended to assist Unitil Forestry in identifying areas of the system that are being frequently affected by tree related outages to allow proactive measures to be taken. In addition, new ideas and solutions to reliability problems are always being explored in an attempt to provide the most reliable service possible.

Attachment 3

UES - Seacoast

Reliability Study 2017

Unitil Energy Systems – Seacoast

Reliability Study
2017

Prepared By:

Jake Dusling
Unitil Service Corp.
August 21, 2017

1 Executive Summary

The purpose of this document is to report on the overall reliability performance of the UES-Seacoast system from January 1, 2016 through December 31, 2016. The scope of this report will also evaluate individual circuit reliability performance over the same time period.

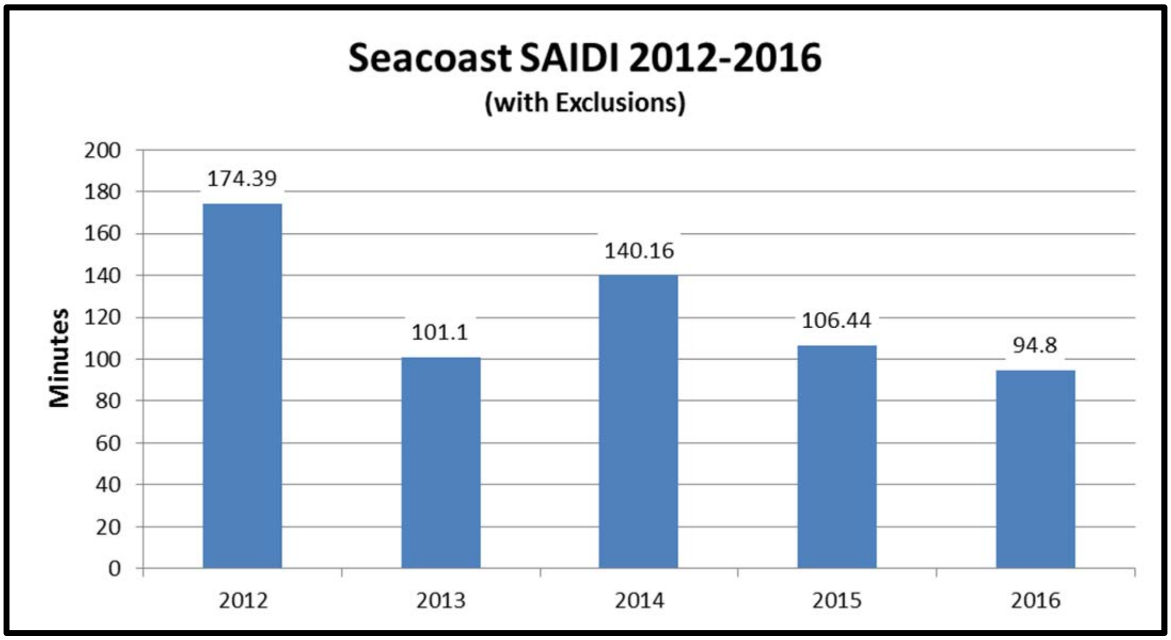
The following projects are proposed from the results of this study and are focused on improving the worst performing circuits as well as the overall UES-Seacoast system reliability. These recommendations are provided for consideration and will be further developed with the intention to be incorporated into the 2018 budget development process.

Circuit / Line / Substation	Proposed Project	Cost ($)
13W2	Replace V4L Reclosers and Relocate Downline	$225,000
19X2/11X1/11X2	Distribution Automation Scheme	$190,000
43X1	Install Recloser – Exeter Road	$75,000
3346 Line	Automatic Restoration Scheme	$160,000
3347 Line Tap	Recloser Replacements	$125,000
Timberlane S/S	Installation of Motor Operated Switches with SCADA Control	$30,000

Note: estimates do not include overheads

UES-Seacoast SAIDI was 94.80 minutes in 2016 after removing all Major Event Days. Chart 1 below shows UES-Seacoast SAIDI over the past five years.

Chart 1
Annual UES-Seacoast SAIDI



2 Reliability Goals

The annual corporate system reliability goals and UES-Seacoast reliability goals have been set at 175-143-111 SAIDI minutes and 128.3-110.6-92.9 SAIDI minutes, respectively. These were developed through benchmarking Unitil system performance with surrounding utilities.

Individual circuits will be analyzed based upon circuit SAIDI, SAIFI, and CAIDI. Analysis of individual circuits along with analysis of the entire Seacoast system is used to identify future capital improvement projects and/or operational enhancements which may be required in order to achieve and maintain these goals.

3 Outages by Cause

This section provides a breakdown of all outages by cause code experienced during 2016. Chart 2 lists the number of interruptions due to each cause. For clarity, only those causes occurring more than 10 times are labeled. Chart 3 details the percent of total customer-minutes of interruption due to each cause. Only those causes contributing greater than 2% of the total are labeled.

Chart 2
Number of Interruptions by Cause

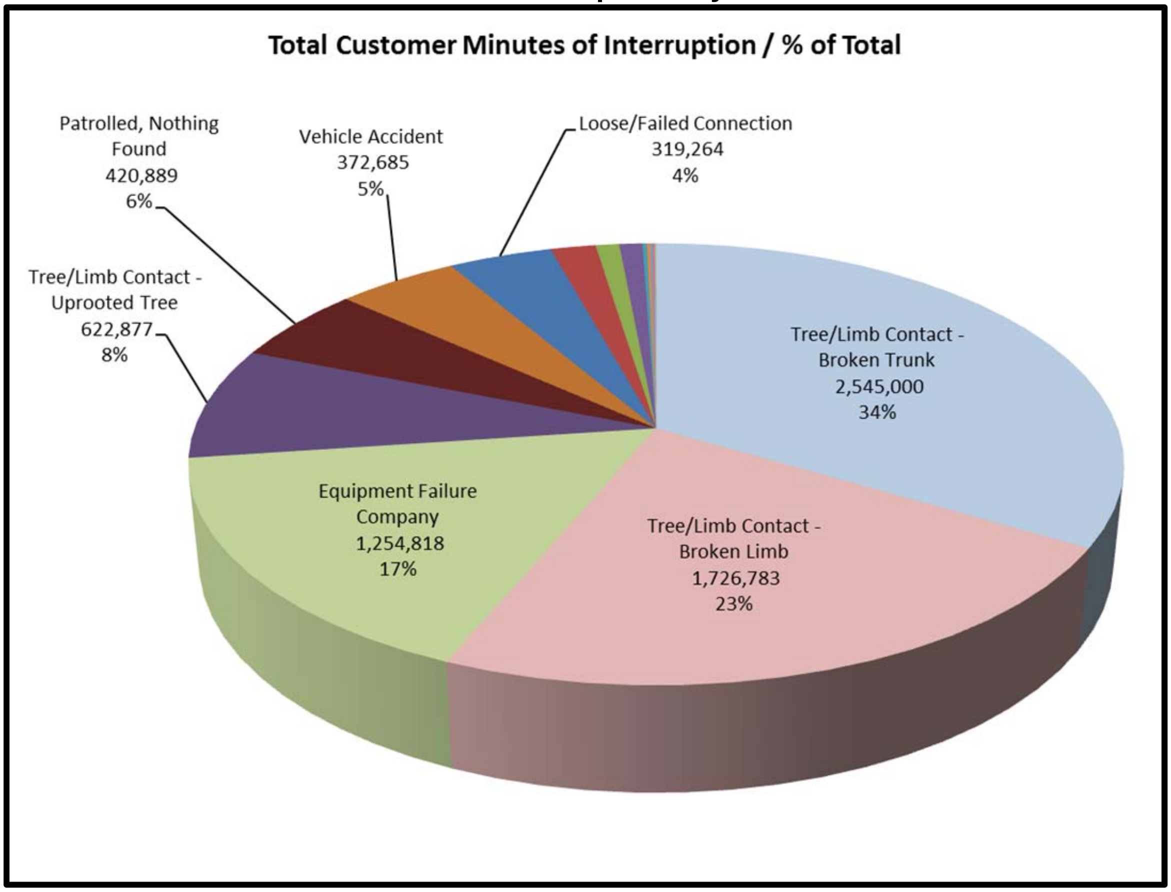
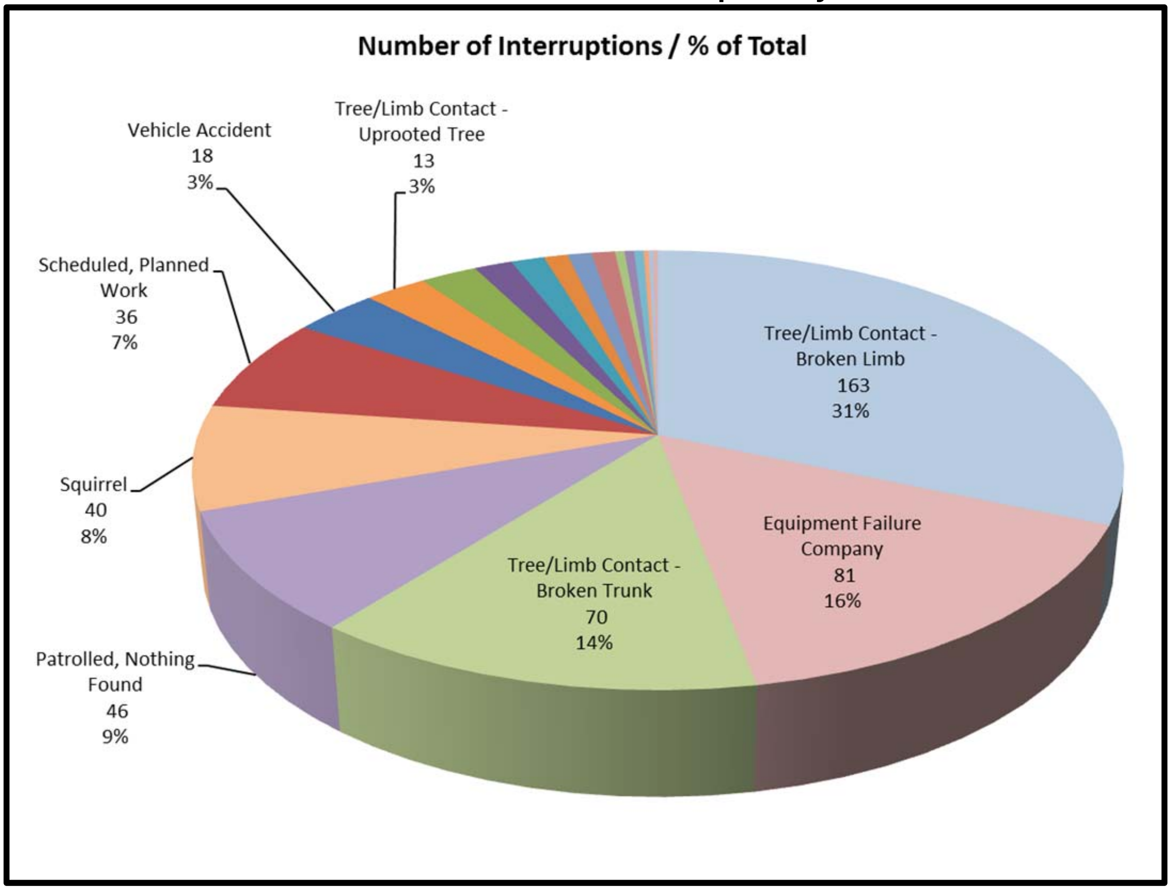


Chart 3
Customer-Minutes of Interruption by Cause



4 10 Worst Distribution Outages

The ten worst distribution outages ranked by customer-minutes of interruption during the time period from January 1, 2016 through December 31, 2016 are summarized in Table 1 below.

Table 1
Worst Ten Distribution Outages

Circuit	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	UES Seacoast SAIDI (min.)	UES Seacoast SAIFI
7W1	10/31/16 Equipment Failure Company	1,213	451,054	9.69	0.026
3H3	2/3/16 Equipment Failure Company	1,061	253,091	5.44	0.023
54X1	2/5/16 Tree/Limb Contact – Broken Trunk	1,457	149,755	3.22	0.031
43X1	12/29/16 Tree/Limb Contact – Broken Trunk	1,862	140,053	3.01	0.040
58X1	7/17/16 Tree/Limb Contact – Broken Limb	725	99,071	2.13	0.016
58X1	9/4/16 Vehicle Accident	569	92,557	1.99	0.012
22X1	12/24/16 Patrolled, Nothing Found	1,909	86,064	1.85	0.041
21W2	10/28/16 Patrolled, Nothing Found	692	78,277	1.68	0.015
6W1	8/14/16 Tree/Limb Contact – Broken Limb	362	76,929	1.65	0.008
13W2	6/12/16 Tree/Limb Contact – Broken Trunk	647	68,354	1.47	0.014

Note: This table does not include outages that occurred at substations or on the subtransmission system or outages that occurred during excludable events.

5 Subtransmission and Substation Outages

This section describes the contribution of subtransmission line and substation outages on the UES-Seacoast system.

All substation and subtransmission outages ranked by customer-minutes of interruption during the time period from January 1, 2016 through December 31, 2016 are summarized in Table 2 below.

Table 3 shows the circuits that have been affected by subtransmission line and substation outages. The table illustrates the contribution of customer-minutes of interruption for each circuit affected.

In aggregate, subtransmission line and substation outages accounted for 20% of the total customer-minutes of interruption for UES-Seacoast.

Table 2
Subtransmission and Substation Outages

Trouble Location	Description (Date/Cause)	No. of Customers Affected	No. of Customer Minutes	UES Seacoast SAIDI (min.)	UES Seacoast SAIFI
3345 Line	7/23/16 Tree/Limb Contact – Broken Trunk	3,224	499,472	10.73	0.069
3356 Line	2/5/16 Tree/Limb Contact – Broken Trunk	5,776	376,614	8.09	0.124
3343 Line	7/23/16 Tree/Limb Contact – Broken Trunk	3,299	332,900	7.15	0.071
3343 Line	4/5/16 Loose/Failed Connection	3,687[14]	316,663	6.80	0.079

[14] The 3343 line was in an abnormal configuration at the time of this outage.

Table 3
Contribution of Subtransmission and Substation Outages

Circuit	Trouble Location	Customer-Minutes of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution	Number of Events
13W1	3345 Line	88,090	52.6%	81.72	1
13W2		249,128	39.4%	153.03	1
13X3		33,951	84.5%	144.47	1
5H1		29,463	89.2%	130.37	1
5H2		70,342	88.0%	160.97	1
5X3		28,497	95.0%	160.10	1
21W1	3356 Line	94,323	39.5%	68.85	1
21W2		96,669	31.0%	66.62	1
56X1		25,480	17.5%	34.81	1
56X2		8,549	14.0%	97.15	1
58X1		151,593	10.2%	68.50	1

Contribution of Subtransmission and Substation Outages

Circuit	Trouble Location	Customer-Minutes of Interruption	% of Total Circuit Minutes	Circuit SAIDI Contribution	Number of Events
27X1	3343 Line	66,608	45.7%	127.85	2
27X2		68,588	97.6%	164.48	2
43X1		308,177	51.0%	158.04	2
28X1		71,124	93.5%	140.28	1
54X1		46,410	22.1%	43.46	1
54X2		88,655	75.6%	190.25	1

6 Worst Performing Circuits

This section compares the reliability of the worst performing circuits using various performance measures. All circuit reliability data presented in this section includes exclusionary events, subtransmission or substation supply outages unless noted otherwise.

6.1 Worst Performing Circuits in Past Year (1/1/16 – 12/31/16)

A summary of the worst performing circuits during the time period between January 1, 2016 and December 31, 2016 is included in the tables below.

Table 4 shows the ten worst performing circuits ranked by the total number of customer-minutes of interruption. The SAIFI and CAIDI for each circuit are also listed in this table.

Table 5 provides detail on the major causes of the outages on each of these circuits. Customer-minutes of interruption are given for the six most prevalent causes[15].

Circuits having one outage contributing more than 75% of the customer-minutes of interruptions were excluded from this analysis.

[15] Six most prevalent causes determined from UES-Seacoast system wide data, not individual circuit data.

Table 4
Worst Performing Circuits Ranked by Customer-Minutes

Circuit	Customer Interruptions	Worst Event (% of CI)	Cust-Min of Interruption	Worst Event (% of CMI)	SAIDI	SAIFI	CAIDI
58X1	6,056	36%	1,489,819	36%	673.21	2.737	246.01
13W2	4,128	39%	632,721	39%	388.65	2.536	153.28
43X1	7,603	29%	604,154	27%	309.82	3.899	79.46
23X1	1,825	28%	332,905	56%	350.06	1.919	182.41
21W2	3,832	37%	311,342	31%	214.57	2.641	81.25
22X1	4,249	45%	303,736	28%	149.55	2.092	71.48
6W2	1,555	59%	251,486	39%	274.55	1.698	161.73
21W1	3,643	38%	238,832	39%	174.33	2.659	65.56
6W1	1,593	33%	217,101	35%	247.83	1.818	136.28
54X1	2,021	72%	209,979	71%	196.61	1.892	103.90

Note: all percentages and indices are calculated on a circuit basis

Table 5
Circuit Interruption Analysis by Cause

Circuit	Customer – Minutes of Interruption / # of Outages					
	Tree/Limb Contact - Broken Trunk	Tree/Limb Contact - Broken Limb	Equipment Failure Company	Tree/Limb Contact - Uprooted Tree	Patrolled, Nothing Found	Vehicle Accident
58X1	567,303 / 12	235,470 / 13	19,947 / 5	539,647 / 2	8,144 / 4	117,758 / 2
13W2	338,903 / 4	269,770 / 15	1,915 / 4	0 / 0	18,108 / 6	1,425 / 1
43X1	302,426 / 2	50,214 / 10	14,678 / 7	2,139 / 1	3,899 / 1	48,739 / 1
23X1	100,038 / 4	56,161 / 4	0 / 0	5,839 / 1	9,296 / 1	180 / 1
21W2	99,472 / 3	8,201 / 3	25,025 / 4	30,204 / 2	87,836 /2	34,637 / 1
22X1	83,749 / 5	43,696 / 13	48,629 / 6	0 / 0	86,064 / 1	41,434 / 2
6W2	2,704 / 1	186,876 / 12	100 / 1	0 / 0	1,412 / 2	0 / 0
21W1	94,365 / 2	136,093 / 13	2,386 / 3	0 / 0	1,498 / 1	0 / 0
6W1	52,927 / 6	146,284 / 7	52 / 1	375 / 1	540 / 3	6,478 / 1
54X1	149,755 / 1	5,253 / 6	0 / 0	0 / 0	8,141 / 1	0 / 0

6.2 Worst Performing Circuits of the Past Five Years (2012 – 2016)

The annual performance of the ten worst circuits in terms of SAIDI and SAIFI for each of the past five years is shown in the tables below. Table 6 lists the ten worst performing circuits ranked by SAIDI and Table 7 lists the ten worst performing circuits ranked by SAIFI.

The data used in this analysis includes all system outages except those outages that occurred during excludable events in 2016, the 3342/3353 Line Outage in 2014 and Hurricane Sandy in 2012.

Table 6
Circuit SAIDI

Circuit Ranking (1 = worst)	2016		2015		2014		2013		2012	
	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI	Circuit	SAIDI
1	3H2	463.53	6W1	429.20	19X3	581.05	6W1	384.28	56X2	590.69
2	7W1	375.29	58X1	371.96	6W1	550.41	27X1	300.82	13W2	556.17
3	3H3	255.03	47X1	362.03	43X1	513.14	47X1	275.19	13W1	383.59
4	54X2	249.35	6W2	306.70	54X1	479.86	18X1	255.15	2X2	376.99
5	6W1	241.11	51X1	201.87	1H3	406.51	21W1	242.80	58X1	339.87
6	43X1	226.55	22X1	172.38	22X1	345.20	13W2	212.92	7X2	317.63
7	21W2	214.57	56X2	138.86	6W2	336.08	59X1	197.65	47X1	297.13
8	17W2	210.69	17W2	136.96	20H1	299.78	22X1	136.57	43X1	296.43
9	58X1	203.82	27X1	126.50	51X1	297.15	15X1	128.33	23X1	292.58
10	54X1	196.61	3W4	97.95	18X1	262.63	43X1	122.34	15X1	263.38

Table 7
Circuit SAIFI

Circuit Ranking (1 = worst)	2016		2015		2014		2013		2012	
	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI	Circuit	SAIFI
1	43X1	2.94	47X1	3.82	6W2	4.70	18X1	3.40	56X2	7.39
2	3H2	2.86	22X1	3.22	20H1	4.36	21W1	3.25	13W2	5.77
3	21W2	2.64	6W1	2.87	43X1	4.13	27X1	2.98	23X1	5.69
4	17W2	2.31	51X1	2.51	51X1	3.82	6W1	2.95	43X1	4.22
5	21W1	2.20	58X1	2.35	6W1	3.23	47X1	2.55	6W1	4.06
6	58X1	2.11	2X3	2.18	19X3	3.22	13W2	2.48	13W1	3.92
7	22X1	1.92	17W2	1.86	18X1	2.84	43X1	2.42	15X1	3.89
8	27X1	1.92	13X3	1.47	21W1	2.67	7X2	1.98	59X1	3.64
9	54X1	1.89	13W1	1.44	47X1	2.67	56X1	1.96	21W1	3.20
10	6W1	1.72	21W2	1.43	11X1	2.64	54X1	1.91	58X1	3.13

6.3 System Reliability Improvements (2016 and 2017)

Vegetation management projects completed in 2016 and planned for 2017 that are expected to improve the reliability of the 2016 worst performing circuits are included in table 8 below. Table 9 below details electric system upgrades that are scheduled to be completed in 2017 or were completed in 2016 that were performed to improve system reliability.

Table 8
Vegetation Management Projects on Worst Performing Circuits

Circuit(s)	Year of Completion	Project Description
58X1	2017	Planned Reliability Analysis Details
	2016	Hazard Tree Mitigation
		Planned Mid-Cycle Pruning
13W2	2017	Hazard Tree Mitigation
	2016	
		Planned Mid-Cycle Pruning
43X1	2016	Planned Cycle Pruning
		Hazard Tree Mitigation
21W2	2017	Hazard Tree Mitigation
		Planned Mid-Cycle Pruning
22X1	2016	Planned Cycle pruning (Carryover from 2015)
		Hazard Tree Mitigation
21W1	2017	Hazard Tree Mitigation
		Planned Mid-Cycle Pruning
6W1	2016	Reliability Analysis Details
54X1	2017	Planned Cycle Pruning
		Hazard Tree Mitigation
	2016	Storm Resiliency Program
3H2	2016	Planned Cycle Pruning
7W1	2016	Planned Cycle Pruning
3H3	2016	Planned Cycle Pruning
54X2	2017	Planned Cycle Pruning
		Hazard Tree Mitigation
	2016	Storm Resiliency Program
17W2	2016	Planned Mid-Cycle Pruning
27X1	2016	Hazard Tree Mitigation

Circuit(s)	Year of Completion	Project Description
		Planned Mid-Cycle Pruning
56X1	2017	Planned Cycle Pruning
		Hazard Tree Mitigation
	2016	Storm Resiliency Program

Table 9
Electric System Improvements Performed to Improve Reliability

Circuit(s)	Year of Completion	Project Description	Justification
22X1	2017	Relocation of Mainline	2016 DPB Project
47X1	2017	Circuit 47X1 – Install Devices and Implement Pulsefinding Scheme	2017 DRB Project
3343 and 3354 Lines	2017	Replace subtransmission tap switches with motor operated switches and connect to SCADA at Munt Hill Tap, Shaw’s Hill Tap, Willow Road Tap, East Kingston substation and New Boston Road Tap	2015 DRB Project
3341, 3352, 3351 and 3362 Lines	2017	Install in-line motor operated switches with automatic sectionalizing and SCADA control and status in the vicinity of Merrill’s Pit	2015 DRB Project
54X1	2016	Recloser additions to split circuit 54X1 into two circuits, 54X1 and 54X1	2015 DRB Project
Plaistow Substation	2016	Upgrades at Plaistow substation to accommodate a large customer includes the installation of reclosers on the 3345 and 3356 lines to supply the 3358 lines. Reclosers will be configured for automatic restoration of the 3358 line upon loss of the 3356 line.	2016 SPN Project

7 Tree Related Outages in Past Year (1/1/16 – 12/31/16)

This section summarizes the worst performing circuits by tree related outages during the time period between January 1, 2016 and December 31, 2016.

Table 10 shows these circuits ranked by the total number of customer-minutes of interruption. The number of customer-interruptions and number of outages are also listed in this table. This table does not include tree related outages on the subtransmission system. Circuits having two or less tree related outages were excluded from this table.

The UES-Seacoast subtransmission system experiences three tree related interruptions that accounted for 12,299 customer interruptions and 1,208,985 customer-minutes of interruption.

All streets on the Seacoast system with three or more tree related outage are shown in table 11 below. The table is sorted by number of outages and customer-minutes of interruption.

Table 10
Worst Performing Circuits – Tree Related Outages

Circuit	Customer-Minutes of Interruption	Number of Customers Interrupted	No. of Interruptions
58X1[16]	1,190,827	2,645	26
13W2[1]	359,684	2,258	19
23X1[17]	323,086	1,449	12
6W2[2]	247,022	1,471	14
6W1[1]	199,586	1,402	13
43X1[1]	194,447	2,181	14
54X1[1]	155,008	1,545	7
21W1[1]	136,135	2,189	13
22X1[1]	127,445	744	18
56X1[1]	119,128	360	4

[16] Pruning is planned or has been completed on this circuit (refer to table 8 for details)
17 Refer to section 11 for recommendations in this area.

Table 11
Tree Related Outages by Street

Circuit	Street	Town	# Outages	Customer-Minutes of Interruption	No. of Customer Interruptions
28X1[18]	Exeter Rd	Hampton Falls	8	4,081	53
58X1[19]	South Main St	Plaistow	5	145,147	334
6W21[1]	North Rd	Kingston	5	68,444	328
13W1[1]	North Main St	Plaistow	5	12,568	159
58X1[2]	Forest St	Plaistow	4	317,150	327
23X1[1]	Mill Lane	Hampton Falls	3	292,979	1,242
13W2[2]	Pond St	Newton	3	148,983	643
43X1[2]	Willow Rd	East Kingston	3	140,303	1,864
6W2[1]	Main St	Kingston	3	102,758	193
22X1[2]	Long Pond Rd	Danville	3	27,094	137
43X1[2]	Pickpocket Rd	Exeter	3	26,556	121
17W1[2]	Cusack Rd	Hampton	3	16,451	149
58X1[2]	Main St	Atkinson	3	13,022	179
59X1[2]	Kensington Rd	Hampton Falls	3	10,056	104
59X1[2]	Crank Rd	Hampton Falls	3	9,551	56
13W2[2]	Quaker St	Newton	3	7,446	64
51X1[2]	Winnicut Rd	Stratham	3	4,223	58
23X1[1]	Woodman Rd	South Hampton	3	4,120	36

8 Failed Equipment

This section is intended to clearly show all equipment failures throughout the study period from January 1, 2016 through December 31, 2016. Chart 3 shows all equipment failures throughout the study period. Chart 4 shows each equipment failure as a percentage of the total failures within this same study period. The number of equipment failures in each of the top three categories of failed equipment for the past five years are shown below in Chart 5.

18 Refer to section 11 for recommendations in this area.

19 Forestry work was completed on this circuit in 2016 and/or is scheduled on this circuit in 2017.

Chart 3
Equipment Failure Analysis by Cause

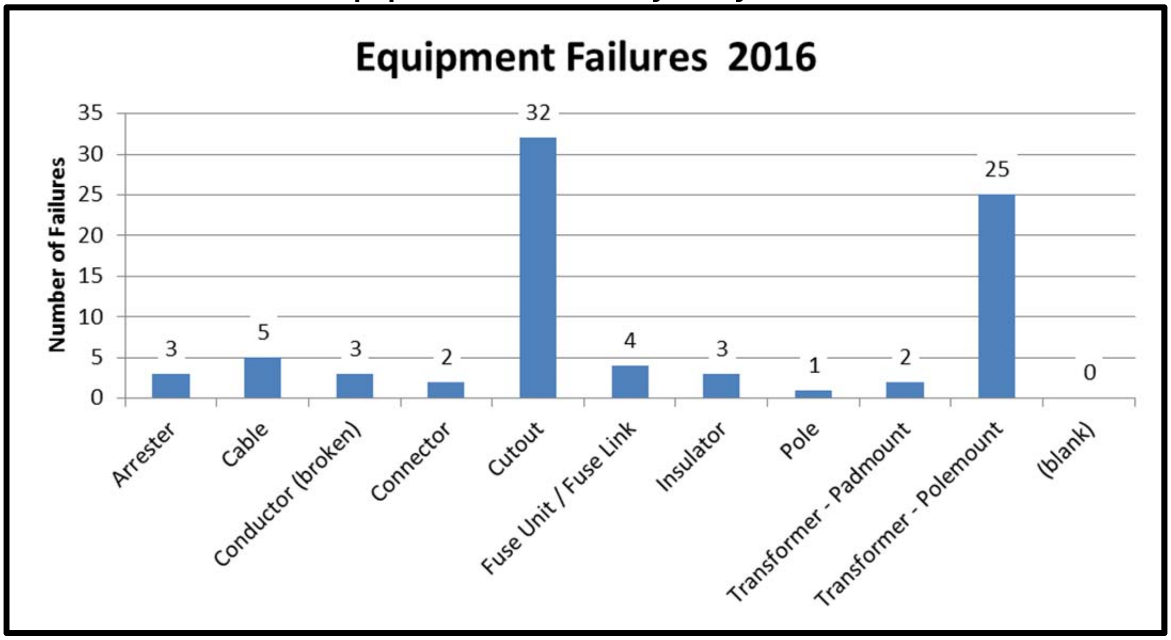


Chart 4
Equipment Failure Analysis by Percentage of Total Failures

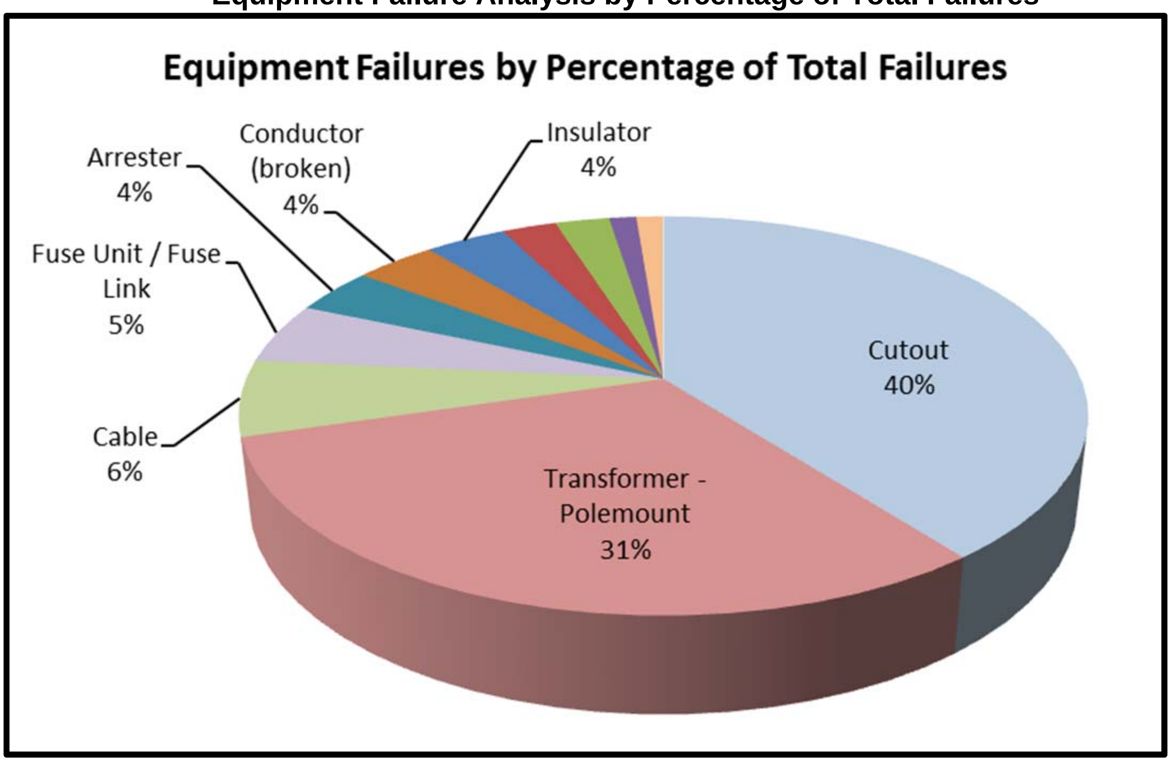
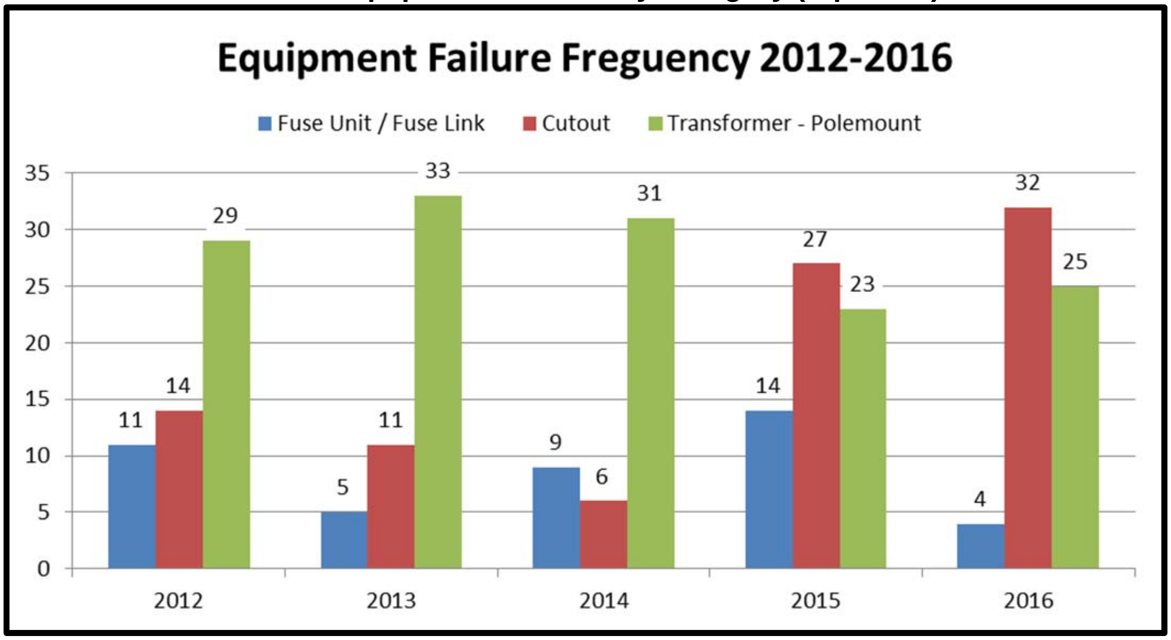


Chart 5
Annual Equipment Failures by Category (top three)



9 Multiple Device Operations in Past Year (1/1/16 – 12/31/16)

A summary of the devices that have operated four or more times from January 1, 2016 to December 31, 2016 are included in table 12 below.

Table 12
Multiple Device Operations

Circuit	Number of Operations	Device	Customer-Minutes	Customer-Interruptions
58X1[20]	4	Fuse – Pole 52/28 Main Street, Atkinson	11,202	140
28X1[1]	4	Fuse – Pole 12/160 Exeter Road, Hampton Falls	387	4
23X1[21]	4	Recloser – Pole 142/31 Mill Lane, Seabrook	302,276	1,608

[20] Operations and Forestry performed a detailed review of the area and observed good tree clearance.
21 Refer to section 11 for recommendations in this area.

10 Other Concerns

This section is intended to identify other reliability concerns that would not be identified from the analyses above.

10.1 Recloser Replacements

Power factor testing has identified that the solid dielectric material used for the poles on a specific type/vintage recloser degrades over time leading to premature failure. In follow up discussions with the manufacturer, they acknowledged that the solid dielectric material used for the recloser poles could prematurely degrade resulting in a dielectric failure.

Unitil has experienced two (UES-Seacoast and FG&E) failures of this type/vintage of recloser in 2011 and removed two others from service due to the appearance of tracking.

Based on this information, a multi-year replacement program began in 2013 to replace all reclosers of this vintage. There are currently two reclosers in service on the UES-Seacoast system, both at the 3347 Line tap.

It is recommended that this program continue in 2017.

11 Recommendations

This following section describes recommendations on circuits, sub-transmission lines and substations to improve overall system reliability. The recommendations listed below will be compared to the other proposed reliability projects on a system-wide basis. A cost benefit analysis will determine the priority ranking of projects for the 2017 capital budget. All project costs are shown overheads.

11.1 Miscellaneous Circuit Improvements to Reduce Recurring Outages

11.1.1 Identified Concerns & Recommendations

The following concerns were identified based on a review of Tables 10 and 11 of this report; Multiple Tree Related Outages by Street and Multiple Device Operations respectively.

<u>Mid-Cycle Forestry Review</u>
The areas identified below experienced three or more tree related outages in 2016. It is recommended that a forestry review of these areas be performed in 2017 in order to identify and address any mid-cycle growth or hazard tree problems.

- 6W2 – North Road, Kingston
- 6W2 – Main Street, Kingston
- 23X1 – Mill Lane, Seabrook

- 28X1 – Exeter Road, Hampton Falls
- 13W1 – North Main Street, Plaistow
- 23X1 – Woodman Road, South Hampton

11.2 Circuit 13W2 – Replace V4L Reclosers and Relocate Downline

11.2.1 Identified Concerns

Circuit 13W2 is typically one of the worst performing circuits on the UES-Seacoast system and is the second circuit on the 2016 list.

11.2.2 Recommendation

This project will consist of replacing the two existing sets of 140A V4L reclosers on circuit 13W2 with electronically controlled reclosers. This will allow the existing reclosers to be relocated to Peaslee Crossing Road and Thornell Road. Two additional sets of 100A V4L reclosers will be installed on Highland Street and Pond Street. The existing 13W2 recloser control at Timberlane substation will most likely need to be replaced to accommodate this project.

The new reclosers will benefit approximately 1,100 customers.

- Estimated annual customer-minutes savings = 53,451
- Estimated annual customer-interruption savings = 660

Estimated Project Cost: $225,000

11.3 Circuit 19X2 – Distribution Automation Scheme with Portsmouth Ave

11.3.1 Identified Concerns

On average one subtransmission outage per year causes an outage to Portsmouth Ave substation or Exeter Switching Station.

Additionally, Portsmouth Ave substation is supplied from the 3347 line, which is a radial line that typically experiences damage during major events.

11.3.2 Recommendation

This project will consist of replacing the 11X2J19X2 tie switch with a recloser and the installation communication infrastructure between the new recloser, the 19X2 recloser at Exeter Switching and Portsmouth Ave substation.

A distribution automation scheme will be implemented that will restore the 1,700 customers on circuits 11X1 and 11X2 via circuit 19X2 for the loss of the 3347 line. Additionally, for a fault on the 3352 or 3362 line the 600 customers supplied by circuit 19X2 will automatically be restored via circuit 11X2.

- Estimated annual customer-minutes savings = 64,182
- Estimated annual customer-interruption savings = 792

Estimated Project Cost: $175,000

11.4 Circuit 43X1 – Recloser Installation

11.4.1 Identified Concerns

Circuit 43X1 was one of the worst performing circuits in 2016 and has been on the worst performing SAIDI circuit list four of the last five years.

A detailed protection review of circuit 43X1 indicated that the installation of a new recloser and relocating the existing 150 QA fuses is expected to improve overall circuit reliability.

11.4.2 Recommendation

This project will consist of replacing the 150 QA fuses at pole 55 Exeter Road with an electronically controlled recloser, with the intent of relocating the 150 QA fuses to the vicinity of pole 64 Exeter Road.

The new recloser will benefit approximately 1,400 customers and the new fuse location is expected save approximately 650 customer interruptions per year.

This project is the first step to implanting a distribution automation scheme with circuit 19X3.

- Estimated annual customer-minutes savings = 44,649
- Estimated annual customer-interruption savings = 1,102

Estimated Project Cost: $75,000

11.5 3346 Line – Automatic Restoration Scheme

11.5.1 Identified Concerns

The 3346 line in an unprotected subtransmission tap off the 3342 line with an alternate source of the 3353 line.

11.5.2 Recommendation

This project will consist of installing two reclosers at the 3346 line, replacing the 46J42 and 46J53 switches.

An automation scheme would be implemented to automatically restore the 3346 line for loss of the 3342 line.

Additionally, the new reclosers will be set to operate for faults on the 3346 line.

- Estimated annual customer-minutes savings = 59.528
- Estimated annual customer-interruption savings = 1,253

Estimated Project Cost: $160,000

11.6 Recloser Replacements

11.6.1 Identified Concerns

Unitil has experienced premature failures of a specific type/vintage of recloser due to insulation breakdown of the poles.

This will be the final year of a multi-year project to replace the reclosers of the identified type/vintage.

11.6.2 Recommendation

This project will consist of replacing the remaining two reclosers on the UES-Seacoast system.

- Two (2) at 3347 Line Tap

Below is a summary of the reliability benefit for this project:

Recloser	Customers of Exposure
3347A	5,350
3347B	7,900

- Estimated annual customer-minutes savings = 104,992
- Estimated annual customer-interruption savings = 1,296

Estimated Project Cost: $125,000

11.7 Installation of Motor Operated Switches at Substations and Subtransmission Taps

11.7.1 Summary

Unitil acquired several motor operated switches in 2014. It was determined that many of these switches would be used to replace the existing manually operated switches that connect substations and distribution taps to the UES-Seacoast subtransmission system.

Reference the document titled Motor Operated Switch Installation – Project Justification, dated February 24th, 2015 for additional information.

11.7.2 Switches Proposed for Replacement – 2018

Based on the project justification document referenced above the following switches are proposed for replacement in 2018.

Location	Switches to be Replaced	Cost (w/o OH's)	Special Details
Timberlane S/S	J1356 J1345	$30,000	Pre-Existing SCADA Site
Total	**2 Switches**	**$30,000**	

12 Conclusion

The UES-Seacoast system has been greatly affected by outages involving tree contact and equipment failures A more aggressive tree trimming program began in 2011 and has started to reduce the number and impact of tree related outages.

In 2012 three circuits on the UES-Seacoast benefited from a storm resiliency pruning (SRP) pilot, which consisted of ground to sky trimming and hazard tree removal. Due to the success of this pilot, five additional UES-Seacoast circuits had SRP performed in 2014 and an additional six circuits were completed in 2016.

The recommendations in this report are aimed at reducing the duration and customer impact of outages, improving the reliability of the subtransmission system and mitigating damage to distribution mainlines and subtransmission lines during major events. This report is also intended to assist Unitil Forestry in identifying areas of the system that are being frequently affected by tree related outages to allow proactive measure to be taken.

Attachment 4

Reliability Project Listing

2017 Budget Versus Actual Expenditures

Reliability Project Listing
2017 Budget Versus Actual Expenditures

DOC	Bud #	Description	Auth #	Budgeted	Authorized	Actual Exp.
UES Capital	DRBC03	Circuit 22W3: Install Sectionalizers on Birchdale Road	170139	$ 10,157.09	$10,157.09	$ 9,513.63
UES Capital	DRBC01	Bow Junction Substation: Install an Auto Transfer Scheme		$139,612.00	-	
UES Capital	DRBC02	Circuit 8X3: Install a Fusesaver on Lane Road		$ 15,166.00	-	$ 6.940.59
UES Capital	DRBC04	374 Line: Install an Autosectionalizing Scheme		$ 67,324.00	-	
UES Capital	DRCC00	375 Line Automatic Sectionalizing at Terrill Park		$160,643.00	-	
UES Capital	DROC13	Substation Reliability Improvements	170166	$ 0.00	$172,000.00	$ 67,649.27
UES Capital	DROC15	Install 430 ft of conduit and 1/0 Al 35KV URD cable	170155	$ 0.00	$53,829.36	$59,298.95
UES Seacoast	DRBE01	Circuit 47X1 - Install Devices w/ Pulsefinding	171020	$413,510.25	$413,510.25	$417,850.24
UES Capital	DPBC01	Distribution Pole Replacement	170115	$696,640.08	$735,136.91	$753,379.51
UES Seacoast	DPBE01	Distribution Pole Replacements	171024	$653,326.95	$780,000.00	$770,796.75