APPENDIX L

UES-CAPITAL 2020-2024 DISTRIBUTION SYSTEM PLANNING STUDY

Unitil Energy Systems - Capital

Distribution System Planning Study 2020-2024

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1. Executive Summary

This study is an evaluation of the Unitil Energy Systems Capital (UES-Capital) electric distribution system. The purpose of this study is to identify when system load growth is likely to cause main elements of the distribution system to reach their operating limits, and to prepare plans for the most cost-effective system improvements. The timeframe of this study is the winter and summer peak load periods over the next five years, from the summer of 2020 through the summer of 2024.

Circuit	Year	Project	Cost
Various	2020	Fuse Changes	Minimal
18W2	2020	Configuration Change for Overloaded Recloser	$105,839
7T2	2020	Bow Junction High Side Fuse Replacement	$155,515
21W1A/P	2020	Downtown Underground Restoration	Completed in 2019
22T1	2022	Iron Works Rd High Side Fuse Replacement	$157,105
24H1	2022	Configuration Change for Overloaded Conductor	$47,875

2. System Configuration

The UES-Capital operating system takes service from Eversource Energy. 34.5 kV service is taken at Garvins Substation and at Penacook Substation via the 3122 and 317 lines (fed from Eversource Energy's Oak Hill Substation). 115kV service is taken at Broken Ground Substation via the T1 & T2 lines from Eversource Energy's Curtisville Substation.

The 34.5kV subtransmission system serves 16 distribution substations which serve distribution circuits at 34.5 kV, 13.8 kV, and 4.16 kV. The distribution system is equipped with various circuit ties that permit load swap between circuits.

3. Study Focus

This study is primarily focused on the 34.5, 13.8 and 4.16 kV distribution substations and circuits. System modifications are based upon general distribution planning criteria. An evaluation of the 34.5 kV subtransmission system is made under a separate electric system planning study.

The first objective of this distribution planning study is to identify and correct specific conditions that do not meet design or operating criteria. The second objective is to develop and communicate a master plan for the development of a robust and efficient distribution system to accommodate long-term improvement and expansion throughout and beyond the study years. Recommendations are based on system adequacy, reliability and economy among available alternatives.

4. Load Projections

A five year history of summer and winter peak demands for each individual circuit was developed from the monthly peak demand readings. A linear regression analysis was performed on the historical loads to forecast future peak demands for substation transformers, circuits and other major devices. Attempts were made to take into account known significant load additions, shifts in load between circuits, etc. Large (>500KVA) DG interconnections were taken into account. In some instances, the peak loads did not present a confident trend over the historical period, so estimates were made using the best available information and knowledge of the circuit. In general, one standard deviation was added into these forecasts to account for differences from year to year in the severity of summer heat and other varying factors.

This methodology does not directly forecast future DG interconnections or other DER projects/initiatives such as energy efficiency programs. Rather the impact of DG and other DER programs are inherent in the historical regression analysis by offsetting most recent peak loads thereby reducing projected growth rates at the circuit level. It is recognized that the reduction in circuit growth rates will lag DG interconnections and other DER projects implemented in a given year. However, since load forecasts are completed annually, the timing of projects identified in the planning process is continually reviewed and updated. In addition, during the annual capital budget development process, a more detailed review of the most recent circuit peak loads, known load additions and interconnection applications either in study or recently processed is performed in order to ensure the timing of investments in system improvement projects is appropriate.

The following table shows the five circuits with the highest estimated growth rates.

Ranking	Circuit	Average Annual Growth Rate (%) 2020-2024	Loading Increase 2020-2024 (KVA)
1	24H1	3.17	253
2	14H2	3.1	288
3	18W2	2.17	421
4	22W3	1.79	478
5	16H3	1.51	121

The projection analysis can be referenced in Appendix A.

5. Rating Analysis

A detailed review of the limiting factors associated with each circuit was completed. The limiting factors included current transformers (CT), protection device settings, switches, circuit exit conductors, regulators, and transformers. Overall circuit ratings are based upon the most restrictive of these limiting elements. The distribution system circuit limitations can be referenced in Appendix B. Summer and winter peak load projections for the five year study period, listed in Appendix A, were compared to these circuit ratings.

Projected loads reaching certain thresholds prompted a closer assessment of the conditions. Shading, as shown below, has been added to the projection analysis to provide a visual representation of potential problem areas. The analysis of circuits and transformers reaching 90% or higher of the normal rating is described in the following section.

Legend

loading < 50% of Normal Limit
50% ≤ loading ≤ 90% of Normal Limit
90% < loading ≤ 100% of Normal Limit
100% of Normal Limit < loading

The details of this review are provided in Section 6 of this report. In the five year period of this study, a single substation transformer and a single distribution circuit are projected to be loaded over 90% of the normal limit. There are 29 of 49 circuits and 12 of 19 transformers that are projected to be in the 50-90% loading section. Two high-side protective fuses are projected to be loaded over 90% of the normal limit.

6. Transformer and Circuit Loading Analysis

Transformer and circuit loadings have been compared to the limiting circuit elements. The monthly per phase transformer load readings are added together and then converted to kVA. In order to maintain some conservatism, those transformers and circuits which have reached 90% of the limiting factor have been highlighted and will be discussed later in the section. The threshold of 90% was taken to account for phase loading imbalance.

This section details the findings resulting from the analysis described in Section 5 as well as an analysis of stepdown transformer loadings and a review of circuit load phase imbalance. Individual project descriptions, justification, predicted benefits and associated cost estimates intended to address each of the identified issues are included in Section 8.

6.1. Substation Transformer Loadings

There are no substation transformers that are projected to be loaded above 90% of its protective rating.

There are two protective fuses on the primary side of two substation transformers that are projected to be above 90% of their protective ratings. The Bow Junction FA7T1 fuse is projected to be above 90% of its protective rating in 2020. The Iron Works Rd FA22T1 fuse is projected to be above 90% of its protective rating in 2022.

6.2. Distribution Circuit Loadings

There are no circuits that are projected to be above 90% loading of its lowest rated element.

6.3. Distribution Stepdown Transformer Loadings

The Summer Normal Limit used for distribution stepdown transformer loading analysis is 120% of the nameplate rating. This is based upon the “Normal Life Expectancy Curve” in ANSI/IEEE C57.91-latest. The ambient temperature assumed is 30°C (86°F).

There are no stepdown transformers that are loaded above 120% of their nameplate rating.

6.4. Phase Imbalances

All of the circuits within the UES-Capital service territory were reviewed for phase balance. The individual phase loading for each circuit was averaged over a timeframe of January 2018 through December 2018. Circuits and substation transformers were ranked based upon the worst average phase imbalances (greatest deviation from the average).

In general, the goal for phase balancing is 10%. The following is a list of circuits where the imbalance is greater than 20%, which is considered severe. The circuits below will be looked at in more detail to determine the severity of the problem and Engineering Work Requests (EWRs) will be issued to reduce the phase imbalances if required. It is important to note that the phase imbalance experienced by transformers will be reduced as the circuits fed from that transformer are balanced. The values listed below are an absolute seasonal average and do not take diversity factor into consideration.

Circuit	% Imbalance	Solution	Expected % imbalance
1H4	50%	• Transfer 59 kVA from phase A to phase B • Transfer 104 kVA from phase A to phase C	<5%
13W1	42%	• Transfer 14 kVA from phase A to phase B • Transfer 47 kVA from phase A to phase C	<5%
14H1	42%	• Transfer 11 kVA from phase B to phase A • Transfer 18 kVA from phase B to phase C	<5%
15W2	40%	• Transfer 16 kVA from phase A to phase C • Transfer 2 kVA from phase B to phase C	<5%
4W3	28%	• Transfer 16 kVA from phase A to phase C • Transfer 74 kVA from phase B to phase C	<5%
2H2	28%	• Transfer 102 kVA from phase A to phase B • Transfer 58 kVA from phase A to phase C	<5%
24H1	22%	• Transfer 19 kVA from phase A to phase B • Transfer 55 kVA from phase A to phase C	<5%

7. Circuit Analysis Results

Circuit analysis is completed for the UES-Capital distribution system on a three year rotating cycle, where each circuit is reviewed once every three years. Windmil circuit analysis is used to identify potential problem areas. The circuit analysis performed includes voltage drop, load flow, and protection analysis. Milsoft Windmil software is used to model the system impedances and loads to identify potential problems areas. All identified problems should be followed up with verification from field measurements. Solutions to the deficiencies noted below are detailed in Section 8.

The following is a list of the circuits analyzed in 2019. Other circuits not shown on this listing were reviewed for planning purposes. However, those circuits were not part of the three year cycle.

Substation	Circuit	Substation	Circuit
Hazen Dr	24H1	Hollis	8H1
	24H2		8H2
Iron Works Rd	22W1	Bow Junction	7X1
	22W2		7W3
	22W3		7W4
Bow Bog	18W2	Terrill Park	16H1
			16H3
			16X4

7.1. Voltage Concerns

Voltage drop analysis is performed to identify areas where the primary voltage on the circuit may be outside of a pre-determined acceptable range. The acceptable range used for this analysis is 117-125 V on a 120 V base on the circuit primary conductor. The following table summarizes the areas where voltage is expected to be outside of this range. The table is sorted by circuit and year.

Circuit	Year	Voltage	Location
2H1	2020	114.7	Tremont St, Concord
13W1	2020	116.6	Borough Rd, Canterbury
2H2	2020	116.0	Ridge Rd, Concord
6X3	2020	116.4	Dunbarton Rd, Concord
8X3	2020	116.5	Copperline Dr, Epsom
15H3	2024	116.6	Technical Institute Dr, Concord

7.2. Overload Conditions

The following table summarizes distribution equipment which is expected to be loaded above 80% of normal limits during the five year study period. The table is sorted by circuit and year.

Circuit	Year	Overload Amps	Device	Location
2H1	2020	81%	Fuse	P.30 N. State St, Concord
13W2	2020	83%	Fuse	P.1 Sweatt St, Boscawen
14H2	2020	92%	Fuse	P.3 Kimball St, Concord
15W1	2020	84%	Fuse	P.61 Mountain Rd, Concord
18W2	2020	99%	Fuse	P.75 Brown Hill Rd, Bow
18W2	2020	91%	Recloser	P.1 Dunbarton Center Rd, Bow
24H1	2020	180%	Fuse	P.12 East Side Dr, Concord
2H2	2020	105%	Solid	P.58 Rumford St, Concord
14H2	2021	83%	Fuse	P.14 Spruce St, Concord
14H2	2021	81%	Fuse	P.20 West St, Concord
22W3	2022	91%	Conductor	Iron Works Rd Circuit Exit
24H1	2022	92%	Conductor	Hazen Dr, Concord
14H2	2023	82%	Fuse	P.2 Broadway, Concord
24H2	2023	82%	Fuse	P.4 Prescott St, Concord
24H1	2024	80%	Fuse	P.13 East Side Dr, Concord

7.3. Protection Concerns

Analysis is performed on the circuits to identify protective devices that violate Unitil’s distribution protection sensitivity and coordination criteria. EWR’s or capital budget projects are issued to address the concerns identified. The analysis identified 11 fuse replacements, 1 fuse additions, and 3 substation settings change requests.

7.4. Underground Circuit Concerns

Analysis is performed on the Concord Downtown Underground System to identify violations of Unitil’s underground mainline restoration criteria. The Concord Downtown Underground System is comprised of Storrs Street substation, Montgomery Street substation and the circuits which they supply. Capital budget projects were developed and estimated to address the concerns identified.

The following analysis was performed with the five year projected loads. The columns detailing the number of switching steps identify how many steps it takes to traditionally restore all load, depending on the fault location.

Violation	Year	% Rating	Fault Location	# Traditional Switching Steps To Restore Load	% Rating	# Additional Switching Steps To Restore Load
21W1A Cable - 21T1 to MH15 (165A)	2020	110	21W1P - MH15 to MH16	3	106	2
	2020	110	21W1P - MH16 to MH17	3	104	4
	2020	110	21W1P - MH17 to MH23	3	104	4
	2020	110	21W1P - MH23 to MH25	3	100	6
22W1 - S/S Regulators (180A)	2020	140	21W1P - 23T1 to MH25	2		
21W1P Cable - 23T1 to MH25 (165A)	2020	106	21W1A - MH15 to MH16	3		
	2020	104	21W1A - MH16 to MH17	3		
	2020	104	21W1A - MH17 to MH23	3		
	2020	100	21W1A - MH23 to MH25	3		

Note that the first loading violation occurs in the year 2020. Based upon the historical load data, full circuit restoration cannot occur during the months of May through October in 2020.

8. Detailed Recommendations

The following sections detail system improvement projects to address the deficiencies listed above. All cost estimates provided in this report are without general construction overheads.

8.1. Overload Concerns

To address overload concerns, several fuse replacements will be scheduled for 2020. Projects to address fuse overloads listed in years after 2020 are not detailed here. All other overload concern projects are detailed here.

13W2 – Pole 1 Sweatt St, Concord:

The 75N fuse is expected to be loaded at 83% of its continuous current rating in 2020.

Proposed Solution:

Replace the 75N fuse with a 95N fuse.

Estimated Cost: Minimal

14H2 – Pole 3 Kimball St, Concord:

The 10N fuse is expected to be loaded at 92% of its continuous current rating in 2020.

Proposed Solution:

Replace the 10N fuse with a 25N fuse.

Estimated Cost: Minimal

<u>15W1 – Pole 61 Mountain Rd, Concord:</u>

The 50N fuse is expected to be loaded at 84% of its continuous current rating in 2020.

Proposed Solution:

Replace the 50N fuse with a 65N fuse. Replace the 50N fuses at Pole 10 Country Club Ln, Concord with 65N fuses as well. The fuses on Country Club lane are normally open and act as the backup supply to the residential underground.

Estimated Cost: Minimal

<u>24H1 – Pole 12 East Side Dr, Concord:</u>

The 25N fuse is expected to be loaded at 180% of its continuous current rating in 2020.

Proposed Solution:

Replace the 25N fuses with 75N fuses.

Estimated Cost: Minimal

<u>2H1 – Pole 30 N. State St, Concord:</u>

The 50N fuse is expected to be loaded at 81% of its continuous current rating in 2020.

Proposed Solution:

Replace the 50N fuses with 75N fuses.

Estimated Cost: Minimal

<u>2H2 – Pole 58 Rumford St, Concord:</u>

The 300A Solid Blades are expected to be loaded at 105% of their continuous current rating in 2020.

Proposed Solution:

Remove the cutouts and solid blades. Install 600A in-line disconnects in the same area.

Estimated Cost: Minimal

18W2 – Pole 1 Dunbarton Rd, Bow

A hydraulic recloser on P.1 Dunbarton Rd, Bow and single phase fuse on P.75 Brown Hill Rd, Bow are expected to be loaded at 91% and 99% of their continuous current ratings, respectively, in 2020.

Proposed Solution:

Install a second phase on Dunbarton Rd, Bow totaling 6,643ft. Also, install an additional 100A, V4L hydraulic recloser at P.1 Dunbarton Rd, Bow.

Estimate: Alternate selected

Alternate Solution:

Extend 22W3 1200ft to connect with 18W2 along Brown Hill Rd, Bow. Install a regulator at Pole 16 Brown Hill Rd, Bow. Replace approximately 350ft of 1/0 ACSR with 336 AAC on Iron Works Rd, Concord. This solution also encompasses the future necessary upgrades for 22W3 on Iron Works Rd.

Estimate: $105,839

22W3 – Iron Works Rd, Concord

The 1/0 ACSR on Iron Works Rd is expected to be loaded at 91% of its continuous current rating in 2022.

Proposed Solution:

Replace approximately 350ft of 1/0 ACSR with 336 AAC.

Estimate: Encompassed in 18W2 solution

24H1 – Hazen Dr, Concord

The 1/0 ACSR on Hazen Dr is expected to be loaded at 92% of its continuous current rating in 2022. Two solutions have been developed due to the master plan for the area. Ultimately, the goal is to convert Loudon Rd to 34.5kV from Hollis to Bridge St. This will connect the Broken Ground capacity with the main UES Capital sub-transmission system. As such, the following solutions take into account the future plans so as to not hinder them.

Proposed Solution:

Replace approximately 2000ft of 1/0 ACSR with 336 AAC. Insulate the area to 15kV. This solves the loading issue while also improving tie capability. The new constraint is the recloser trip limit at the substation, an increase of approximately 100A of circuit tie carrying capacity. The loading after reconductoring is 41% of the continuous current rating of 336 AAC.

The Hazen Dr substation will no longer be in service when the mainline conversion occurs. Reinsulating this portion of the line allows for 34.5 to 13.8kV step down transformation, increasing the area (compared to 34.5 to 4.16kV) a set of step down transformers can serve.

Estimate: Alternate selected

Alternative Solution:

Transfer load from 24H1 to 8H1. Install a switch at P.5 East Side Dr. Transfer the 24H1 load from that point to 8H1 via 8H1J24H1. This load transfer eliminates the loading violation; however it does not improve circuit tie capability. Additional switching steps will need to be added to be able to tie 8H1 and 8H2. The loading after this transfer is 68% of the continuous current rating of 1/0 ACSR on 24H1 and 76% of the current rating of the current transformer at the Hollis S/S.

In regards to the master plan, this solution does not have much of an effect on it, but more importantly, it does not hinder it.

Estimate: $47,875

8.2. Low Voltage Concerns

All low voltage concerns are solved by putting existing capacitors into service during seasonal switching.

8.3. Substation Transformer Loading Solutions

<u>Bow Junction Substation</u>

Replace the substation transformer high-side protective fuses with a high side recloser.

Estimate: $155,515

<u>Iron Works Rd Substation</u>

Replace the substation transformer high-side protective fuses with a high side recloser.

Estimate: $157,105

8.4. Underground Circuit Restoration Solutions

The following four options have been identified as potential solutions to the Concord Downtown Underground restoration violation.

<u>Option 1: Install an Additional Circuit</u>

This solution is to install a new run (~1700ft) of 1/0 Al conductor from 23T1 to MH25. A new underground switch will be required in MH25. This new conductor will serve as an alternate to both 21W1P and 21W1A, depending on the circuit where a fault occurs. This will require the removal of abandoned conductor.

Loading after Project Completion:

New Conductor restoring 21W1P = 58% of 1/0Al rating
New Conductor restoring 21W1A = 52% of 1/0Al rating

Challenges:

This new conductor would run from the Montgomery St substation, but would not be a new circuit unless a new circuit position was created at Montgomery St. This solution utilizes a capped T-body at the origin of 21W1P. The new conductor will also use the only spare conduit in some of the ductbanks.

Benefits:

This option allows the downtown underground to be fully isolated with complete restoration ability, which is part of the master plan. It also will require removing all the abandoned cable.

Limitations: None

Estimate: $750,000

<u>Option 2: Replace 21W1P and 21W1A</u>

This solution is to replace the existing mainline of 21W1P and 21W1A with 350Cu from their respective origins to MH25, approximately 3,550ft of total replacement. Additionally, all 200A mainline connections will need to be replaced with 600A connectors.

Loading after Project Completion:

Total loading after restoration = 44% of 350Cu rating

Challenges:

This project will take a long time to complete with tap cutovers and switching time. Copper conductor is more costly than aluminum. The mainline connectors will be much larger, in some cases, than what currently exists. Some manholes may be too small to house the larger conductor and connectors.

Benefits:

The existing conductor and connections are reaching their manufactured lifetime or have already passed it. Replacing it will prevent failures due to material breakdown. It also presents an opportunity to clean up the manholes.

Limitations: Physical space in manholes.

Estimate – Project determined to be not operationally feasible; requirement of 600A t-body connectors does not work with physical limitations of existing manholes

Option 3: Shift 21W1P Overhead Load to 22W1

21W1P does not currently serve any load along the underground manhole path. This circuit's entire load is overhead construction at the end of the circuit. This project shifts the overhead load from 21W1P to 22W1. 22W1 cannot accommodate the added load under peak, so several sections of 1/0 ACSR and the substation regulators will need to be replaced.

Loading after Project Completion:

21W1A and 21W1P combined = 52% of 1/0Al rating
22W1 = 49% of 336AA rating and 52% of regulator rating
22T1 = 90% of transformer rating

Challenges:

The first major challenge is that this project would drive a new transformer at Iron Works Rd substation as no significant amount of load can be transferred to another circuit.

Benefits:

The downtown underground will be able to self-restore all year long. A new transformer at Iron Works Rd, or wherever it is determined to go, will further along the master plan.

Limitations:

The transformer capacity would limit the ability to carry this transferred load.

Estimate: $1,880,000

Option 4: Shift 21W1P Overhead Load to Gulf St

With the conversion of the Gulf St substation to 13.8kV, one of the new circuits, designated here as 3W4, will be close to the 21W1P overhead load. This project will consist of converting approximately 1000ft of 1H2 on Warren St and Green St to 13.8kV, transferring that to 3W4, and then tying 3W4 with 21W1P. In addition to reconductoring to 336AA and reinsulating to 15kV, two new switches will also be installed.

Loading after Project Completion:

21W1P and 21W1A combined = 52% of 1/0 Al rating
3W4 = 67% of substation regulator rating
3T3 = 69% of substation transformer rating
3W4 carrying 22W1 = 102% of 336AA spacer rating
3T3 carrying 22W1 = 96% of substation transformer rating

Challenges:

This circuit configuration heavily loads the Gulf St transformer under peak while tied. 3W4 would be a very large circuit.

Benefits:

This circuit configuration allows for increased tie capability. It does not add much exposure to 3W4 as the majority of the added load is downline of a recloser. The downtown underground can self-restore all year.

Limitations:

3W4 cannot carry 22W1 all year, however it does increase the amount of time during the year that it can back it up compared to the current tie with 21W1P

Estimate – Planning determined that a 13.8kV circuit should not be normally loaded above ~6MW.

<u>Option 5: Additional Transformer and 13.8kV Circuit at Gulf St</u>

Instead of installing a 4kV transformer and retaining a single 4kV circuit at Gulf St, install a second 34.5Y/19.92kV to 13.8Y/7.97kV, 10/14MW transformer at Gulf St. This will require the conversion of 3H2 to 13.8kV. This is approximately 7,000ft of conversion, which includes reinsulating and reconductoring, as well as distribution transformer replacements.

Loading after Project Completion:

3W4: 3,299KVA – 28% of regulator rating
3W5: 2,470KVA – 21% of regulator rating
3T3: 6,769KVA – 54% of mobile rating
3W2: 4,766KVA – 41% of regulator rating
3T2: 4,766KVA – 38% of mobile rating
3W2 carrying 22W1 – 8,456KVA – 72% of regulator rating

Challenges:

The timeline of ordering another 13.8kV transformer in time for summer loading 2020 may not work. This does not address some of the condition-based concerns in the downtown underground.

Benefits:

21W1P and 21W1A are able to completely back the other up. No single circuit is loaded above 6MW under normal conditions. Shifting load does not overload other circuits or equipment. A major component to the master plan is accomplished.

Limitations: None

Estimate: $1,600,000

9. Circuit Tie Analysis

A detailed analysis was performed on ten mainline distribution circuit ties in the UES-Capital System. The circuit ties were evaluated using 2020 projected summer peak loads and were evaluated for loading and voltage violations. It is understood that marginal low voltage, coordination and protection sensitivity concerns may exist while circuits are tied. For the purpose of this review all elements were allowed to operate up to their long term emergency ratings while circuits are tied.

Detailed results of this analysis can be found in appendix E.

A full district circuit tie analysis was performed and included in this report.

Projects to create additional circuit ties or increase circuit tie capability will be identified and justified as part of the UES-Capital Reliability Study.

10. Master Plan

This section describes a long range master plan for the UES-Capital system. The purpose of this plan is to provide strategic direction for the development of the electric distribution system as a whole. It does not, in and of itself, represent a cost-benefit justification for major system investments. Instead, it is intended to guide design decisions for various individual projects incrementally towards broader system objectives. The concepts detailed below should be considered in all future designs of the system, including designing the system for future grid modernization initiatives. It is expected that this Master Plan will be modified, adjusted, and refined as system challenges and opportunities evolve.

This master plan has been separated into two different parts. The first part of the plan consists of an overview map of the UES-Capital distribution system. The second part of the master plan consists of more detailed future considerations. At this time some of these future considerations are not detailed.

10.1. Master Plan Map

The map in Appendix F identifies existing and future main line backbones at 34.5 kV, 13.8 kV and 4.16 kV. The map should be used as a tool when designing system improvement projects. Sections of conductor which have been identified as backbones should be constructed to 336.4 AA open wire conductor or equivalent and the appropriate insulation level should be used, even if conditions do not require it at the time of construction. Underground mainline conductor spans will be constructed or replaced with 350 kcmil CU, even if conditions do not require it at the time of construction.

10.2. Future Considerations

10.2.1. Bow Junction, Iron Works Rd and Bow Bog Substation Area

When load levels grow beyond the transformation capacity in this area, upgrade options include adding capacity at Bow Bog Substation, adding capacity at Bow Junction Substation or adding capacity at Iron Works Substation. Replacements will be with delta-wye transformers instead of wye-wye transformers for protection reasons.

Upgrades to mainline construction on Clinton St, Silk Farm Rd, and Iron Works Rd improve the circuit tie capability of 22W1 and 22W3.

Upgrades to mainline construction on Iron Works Rd, Silk Farm Rd, Albin Rd, Bow Center Rd, Logging Hill Rd, Grandview Rd, and Robinson Rd improve the circuit tie capabilities between 18W2 and 22W3, 7W3 and 22W3, and 7W3 and 18W2.

Extending three phase mainline construction along Page Rd and White Rock Hill Road will create a new tie between 18W2 and 22W3. Upgrades to Iron Works Rd, Silk Farm Rd, Clinton St, and Birchdale Rd are also necessary.

Extending three phase mainline construction along Woodhill Rd, South Bow Rd, and Allen Rd will create a loop within 18W2, which is otherwise a radial circuit with circuit ties that have limited restoration capability.

Extending three phase mainline construction along River Rd and Route 3A will create a loop within 7W3, which is otherwise a radial circuit with ties that have limited restoration capability.

Upgrades to mainline construction along Iron Works Rd improve the circuit tie capabilities between 7W4 and 22W2.

Upgrades to mainline construction along South St and Clinton St improve the circuit tie capabilities between 7W4 and 22W1.

10.2.2. Montgomery St and Storrs St Substations

Montgomery St and Storrs St are planned to remain in a wye-wye configuration. This will be an islanded system that will be dead-tie only. Circuit configuration changes will eventually restore 22W1 from Gulf St.

An additional circuit in the downtown underground or upgrading the existing circuits to 350MCM Cu will allow the downtown underground to serve as a looped system. If the path of upgrading the existing cable is taken, then the mainline connections need to be upgraded to 600A connectors as well. The additions and/or upgrades allow switching between 21W1A and 21W1P all year.

10.2.3. Bridge St, Gulf St, and Langdon Ave Area

When additional transformer capacity is needed in this area, a second 13.8kV transformer will be installed at Gulf St (replacing the existing 4.16kV transformer) and at least one 13.8kV transformer will be installed at Bridge St, replacing all the 4.16kV circuits in the area.

There are four 13.8kV circuits planned for Gulf St. Two circuits are planned to extend north/northwest towards Bridge St and 22W1. The other two circuits are planned to extend south/southwest towards Bow Junction and 22W2. The 4.16kV circuits from Langdon Ave will be converted to 13.8kV and transferred to the Gulf St substation, leaving Langdon Ave as a sub-transmission switching point and a single 34.5kV distribution circuit.

10.2.4. Pleasant St

To create restoration capability for 6X3, 2H2 on Penacook St and Rumford St and 6X3 on Washington St, Pine St, and Warren St will be converted to 34.5kV. A new tie for this circuit will be built at the 33 Line on Little Pond Rd. The master plan map provides the geographic visual. For reliability exposure, it is advantageous to split this large circuit into two pieces, with the tie in the middle at Washington St and Rumford St.

10.2.5. West Concord Substation

When this substation requires additional transformation capacity, a new 13.8kV transformer will be installed, replacing the 4.16kV transformer. 2H2 will be transferred according to 10.2.4. 2H1 and 2H4 will be converted to 13.8kV. 2H1 will tie with the planned 13.8kV at Bridge St. 2H4 will tie with 4W4, creating the only tie 4W4 has with a circuit from a different substation.

10.2.6. Penacook and Boscawen Substations

When additional capacity is required in the Penacook Substation area, install an additional transformer.

The Boscawen Substation is currently served radially via the 37 line from Penacook. In order to create a backup for this substation, 13W2 will be converted from 13.8kV to 34.5kV. Additionally, a new tie between the converted circuit and 4X1 will be created near the Village St Bridge. There is a four-conduit ductbank already installed to tie the two circuits.

When additional capacity is required in the Boscawen Substation area, one or both of the 13.8kV transformers should be replaced with higher capacity transformers.

Due to the radial nature of 13W3, a loop internal to 13W3 can be achieved by extending three phase mainline on N. Water St. and a transfer scheme at the intersection of Old Turnpike Rd and Rabbit Rd.

With additional capacity at Penacook and Boscawen, a new tie between 4W3 and 13W1 can be created by eliminating the 37X1 circuit. It exists currently as a single phase, 13.8kV circuit served from a 37 line tap. Mainline upgrades will be required on Carter Hill Rd, South West Rd, and Mountain Rd, as well as three phase line extensions on South West Rd and Mountain Rd to connect the two circuits. This will allow an otherwise radial 13W1 and partly radial 4W3 to have greater restoration capabilities.

10.2.7. Hollis, Hazen Dr, and Terrill Park Dr Area

When additional capacity is required in this area, or system planning determines Loudon Rd is going to be the path to connect Broken Ground and Bridge St, convert all substations to 34.5kV distribution circuit positions. Two 34.5kV distribution circuits will tie the Hollis and Terrill Park substations and connect to the 38 line at the Hazen Dr substation. All three substations will no longer have any transformation. The mainline of Loudon Rd, Airport Rd, Terrill Park Dr, Hazen Dr, and East Side Dr will be converted to 34.5kV. All other laterals or groups of laterals can be stepped down to 4.16kV.

10.2.8. Broken Ground, 15W2, and 8X3

From Broken Ground, a path to tie into the northern system loop is through West Portsmouth. As such, 15W2 can be converted to 34.5kV and be a supply from Broken Ground to West Portsmouth.

8X3 stands a UES-Capital's largest circuit, which also happens to be a radial circuit. The master plan map shows how a new circuit served from Hollis or Broken Ground can be built without utilizing the same pole line as 8X3. The new circuit will be built by converting and upgrading to three-phase mainline along Horse Corner Rd, Lane Rd, Mill House Rd, Short Falls Rd, Black Hall Rd, and Dover Rd. The new circuit ties will be built at Horse Corner Rd and Dover Rd and Black Hall Rd and Dover Rd. The new circuit can be built in pieces over several years.

11. Conclusion

The projects identified in this study attempt to address all of the system constraints that have been identified. The future of the UES–Capital system will rely predominantly on where load enters the system and growth occurs. In the future, projects will continue to focus on improving system voltages and loading constraints to support long term system growth and improve system reliability. Implementation of the master plan will enable the system to grow towards one common vision in a direct and cost effective manner. It is recognized that this study is a living document and it will be continually updated as the system's needs change or new system deficiencies are identified.

Appendix A

Summer and Winter Load Forecasts

UES-Capital
5-Year Load Forecast
2020-2024

Summer Peak Loads (three-phase kVA)						
		5 Year Projected Summer Peak Load (kVA)				
Distribution Element	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Bridge Street 1T1 Xfmr	4,426	4,478	4,529	4,580	4,631	4,682
1H3	1,608	1,623	1,637	1,652	1,667	1,682
1H4	998	1,008	1,017	1,026	1,035	1,044
1H5	1,678	1,687	1,695	1,703	1,712	1,720
Bridge Street 1T2 Xfmr	5,498	3,613	3,656	3,700	3,743	3,786
1H1	2,452	2,475	2,498	2,520	2,543	2,565
1H2	1,196	1,217	1,237	1,257	1,277	1,298
1H6	2,018	0	0	0	0	0
Bridge Street 1X7P	2,303	2,327	2,351	2,375	2,399	2,423
Bridge Street 1X7A	2,513	2,537	2,560	2,583	2,606	2,629
West Concord 2T1 Xfmr	3,671	3,704	3,738	3,772	3,806	3,840
2H1	1,439	1,452	1,465	1,479	1,492	1,505
2H2	1,850	1,867	1,884	1,901	1,918	1,935
2H4	1,189	1,200	1,211	1,222	1,233	1,244
Gulf Street 3T1 Xfmr	3,311	3,313	3,315	3,316	3,318	3,320
3H1	1,865	1,882	1,899	1,916	1,933	1,951
3H2	1,395	1,408	1,420	1,433	1,446	1,459
Gulf Street 3T2 Xfmr	0	0	0	0	0	0
3H3	0	0	0	0	0	0
Gulf Street 3T3 Xfmr	0	6,877	7,006	7,071	7,136	7,200
3W4	0	4,407	4,490	4,531	4,573	4,614
3W5	0	2,470	2,516	2,540	2,563	2,586
Penacook 4X1	6,220	6,277	6,335	6,392	6,449	6,507
Penacook 4T3 Xfmr	8,572	8,651	8,730	8,809	8,889	8,968
4W3	3,442	3,473	3,505	3,537	3,569	3,600
4W4	5,065	5,112	5,159	5,206	5,252	5,299
Pleasant Street 6X3	10,005	10,097	10,189	10,282	10,374	10,466
Bow Junction 7X1	2,577	2,592	2,606	2,621	2,635	2,650
Bow Junction 7T2 Xfmr	9,583	9,693	9,802	9,912	10,021	10,131
7W3	6,842	6,896	6,949	7,003	7,057	7,110
7W4	2,834	2,860	2,887	2,913	2,939	2,965
Hollis 8T1 Xfmr	2,246	2,267	2,288	2,309	2,329	2,350
8H1	1,224	1,235	1,246	1,257	1,269	1,280
8H2	1,124	1,127	1,130	1,133	1,136	1,139
Hollis 8X3	12,298	12,411	12,525	12,638	12,752	12,865
Hollis 8X5	8,945	8,971	8,997	9,023	9,049	9,075
Boscawen 13T1 Xfmr	3,785	3,852	3,919	3,987	4,054	4,121
13W1	1,454	1,467	1,481	1,494	1,507	1,521
13W2	2,533	2,556	2,579	2,603	2,626	2,650
Boscawen 13T2 Xfmr	4,852	4,873	4,895	4,916	4,938	4,959
13W3	4,852	4,873	4,895	4,916	4,938	4,959
Boscawen 13X4	2,917	2,944	2,971	2,998	3,024	3,051
Langdon Street 14T1 Xfmr	1,782	1,843	1,905	1,966	2,028	2,089
14H1	342	345	349	352	355	358
14H2	1,499	1,571	1,643	1,715	1,787	1,859
Langdon 14X3	712	721	729	738	746	755
West Portsmouth 15T1 Xfmr	3,531	3,564	3,596	3,629	3,661	3,694
15W1	2,878	2,915	2,953	2,990	3,028	3,065
15W2	682	688	694	700	707	713
West Portsmouth 15T2 Xfmr	529	533	538	543	548	553
15H3	529	533	538	543	548	553
Terrill Park 16T1 Xfmr	2,467	2,489	2,512	2,535	2,558	2,580
16H1	1,233	1,245	1,256	1,267	1,279	1,290
16H3	1,446	1,476	1,506	1,536	1,566	1,597
Terrill Park 16X4	2,801	2,827	2,852	2,878	2,904	2,930
Terrill Park 16X5	1,602	1,616	1,631	1,646	1,661	1,675
Terrill Park 16X6	308	311	313	316	319	322

UES-Capital
5-Year Load Forecast
2020-2024

		5 Year Projected Summer Peak Load (kVA)				
Distribution Element	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Bow Bog 18T2 Xfmr	2,344	2,449	2,555	2,660	2,765	2,870
18W2	2,344	2,449	2,555	2,660	2,765	2,870
Storrs Street 21T1 Xfmr	2,095	2,114	2,133	2,153	2,172	2,191
21W1P	2,213	2,257	2,301	2,345	2,389	2,433
21W1A	2,142	2,154	2,165	2,176	2,187	2,198
Iron Works Road 22T1 Xfmr	8,572	8,651	8,730	8,809	8,889	8,968
22W1	3,734	3,768	3,803	3,837	3,872	3,906
22W2	208	218	228	238	248	258
22W3	4,751	4,871	4,990	5,110	5,230	5,349
Montgomery Street 23T1 Xfmr	2,213	2,257	2,301	2,345	2,389	2,433
21W1P	2,213	2,257	2,301	2,345	2,389	2,433
21W1A	2,142	2,154	2,165	2,176	2,187	2,198
Hazen Drive 24T1 Xfmr	1,282	1,345	1,409	1,472	1,535	1,599
24H1	1,282	1,345	1,409	1,472	1,535	1,599
Hazen Drive 24T2 Xfmr	1,703	1,719	1,735	1,751	1,766	1,782
24H2	1,703	1,719	1,735	1,751	1,766	1,782
24H3	1,703	1,719	1,735	1,751	1,766	1,782
33 Line - Little Pond Rd	171	173	174	176	177	179
37X1 37X1	374	377	381	384	388	391

Winter Peak Loads (three-phase kVA)						
	5 Year Projected Winter Peak Load (kVA)					
Distribution Element	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**
Bridge Street 1T1 Xfmr	3,994	4,031	4,067	4,104	4,141	4,178
1H3	1,479	1,493	1,506	1,520	1,534	1,547
1H4	866	874	882	890	898	906
1H5	1,413	1,420	1,427	1,434	1,441	1,448
Bridge Street 1T2 Xfmr	4,467	2,936	2,971	3,006	3,041	3,077
1H1	2,090	2,109	2,128	2,147	2,167	2,186
1H2	988	1,005	1,022	1,038	1,055	1,072
1H6	1,219	0	0	0	0	0
Bridge Street 1X7P	2,232	2,253	2,273	2,294	2,315	2,335
Bridge Street 1X7A	2,251	2,271	2,292	2,313	2,334	2,354
West Concord 2T1 Xfmr	3,137	3,166	3,195	3,224	3,253	3,282
2H1	1,165	1,176	1,187	1,197	1,208	1,219
2H2	1,762	1,778	1,794	1,810	1,827	1,843
2H4	1,130	1,141	1,151	1,162	1,172	1,183
Gulf Street 3T1 Xfmr	2,636	2,637	2,639	2,640	2,641	2,643
3H1	1,395	1,408	1,420	1,433	1,446	1,459
3H2	1,245	1,254	1,262	1,271	1,280	1,288
Gulf Street 3T2 Xfmr	854	0	0	0	0	0
3H3	854	0	0	0	0	0
Gulf Street 3T3 Xfmr	0	6,189	6,306	6,364	6,422	6,480
3W4	0	3,966	4,041	4,078	4,115	4,153
3W5	0	2,223	2,265	2,286	2,307	2,327
Penacook 4X1	7,570	7,639	7,709	7,779	7,849	7,919
Penacook 4T3 Xfmr	7,657	7,782	7,906	8,030	8,154	8,278
4W3	2,955	2,982	3,009	3,036	3,064	3,091
4W4	4,415	4,456	4,497	4,538	4,578	4,619
Pleasant Street 6X3	7,042	7,107	7,172	7,237	7,302	7,367
Bow Junction 7X1	1,469	1,475	1,481	1,487	1,493	1,499
Bow Junction 7T2 Xfmr	7,526	7,595	7,665	7,734	7,803	7,873
7W3	5,252	5,300	5,349	5,397	5,446	5,494
7W4	2,960	2,994	3,028	3,062	3,095	3,129
Hollis 8T1 Xfmr	2,621	2,642	2,662	2,683	2,703	2,724
8H1	1,661	1,676	1,691	1,707	1,722	1,737
8H2	1,028	1,037	1,047	1,056	1,066	1,075
Hollis 8X3	10,147	10,240	10,334	10,428	10,521	10,615
Hollis 8X5	7,813	7,885	7,957	8,029	8,101	8,173
Boscawen 13T1 Xfmr	2,980	3,014	3,047	3,081	3,114	3,148
13W1	1,216	1,226	1,237	1,247	1,257	1,268
13W2	2,112	2,136	2,160	2,184	2,207	2,231
Boscawen 13T2 Xfmr	4,278	4,317	4,357	4,396	4,436	4,475
13W3	4,278	4,317	4,357	4,396	4,436	4,475
Boscawen 13X4	2,579	2,602	2,626	2,650	2,674	2,698
Langdon Street 14T1 Xfmr	1,545	1,552	1,559	1,566	1,573	1,580
14H1	289	291	294	297	299	302
14H2	1,386	1,434	1,482	1,529	1,577	1,625
Langdon 14X3						
West Portsmouth 15T1 Xfmr	2,443	2,466	2,488	2,511	2,533	2,556
15W1	2,208	2,228	2,248	2,269	2,289	2,310
15W2	430	434	438	442	446	450
West Portsmouth 15T2 Xfmr	440	445	449	453	457	461
15H3	440	445	449	453	457	461
Terrill Park 16T1 Xfmr	1,918	1,936	1,954	1,972	1,989	2,007
16H1	940	948	957	966	974	983
16H3	1,251	1,268	1,286	1,303	1,320	1,338
Terrill Park 16X4	2,422	2,444	2,466	2,489	2,511	2,533
Terrill Park 16X5	0	0	0	0	0	0
Terrill Park 16X6						

UES-Capital
5-Year Load Forecast
2020/21-2024/25

		5 Year Projected Winter Peak Load (kVA)				
Distribution Element	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**
Bow Bog 18T2 Xfmr	2,435	2,457	2,480	2,502	2,525	2,547
18W2	2,725	2,732	2,739	2,746	2,753	2,761
Storrs Street 21T1 Xfmr	1,293	1,351	1,409	1,467	1,525	1,583
21W1P	0	0	0	0	0	0
21W1A	1,762	1,778	1,794	1,810	1,827	1,843
Iron Works Road 22T1 Xfmr	7,013	7,078	7,143	7,208	7,272	7,337
22W1	2,857	2,884	2,910	2,936	2,963	2,989
22W2	204	206	208	209	211	213
22W3	3,945	3,981	4,018	4,054	4,090	4,127
Montgomery Street 23T1 Xfmr	1,851	1,868	1,885	1,902	1,919	1,937
21W1P	1,851	1,868	1,885	1,902	1,919	1,937
21W1A	1,772	1,788	1,804	1,821	1,837	1,853
Hazen Drive 24T1 Xfmr	1,371	1,371	1,371	1,371	1,371	1,371
24H1	1,371	1,371	1,371	1,371	1,371	1,371
Hazen Drive 24T2 Xfmr	1,500	1,502	1,505	1,507	1,510	1,512
24H2	1,500	1,502	1,505	1,507	1,510	1,512
24H3	1,500	1,502	1,505	1,507	1,509	1,512
33 Line - Little Pond Rd	157	158	160	161	163	164
37X1 37X1	433	449	465	481	497	513

Appendix B

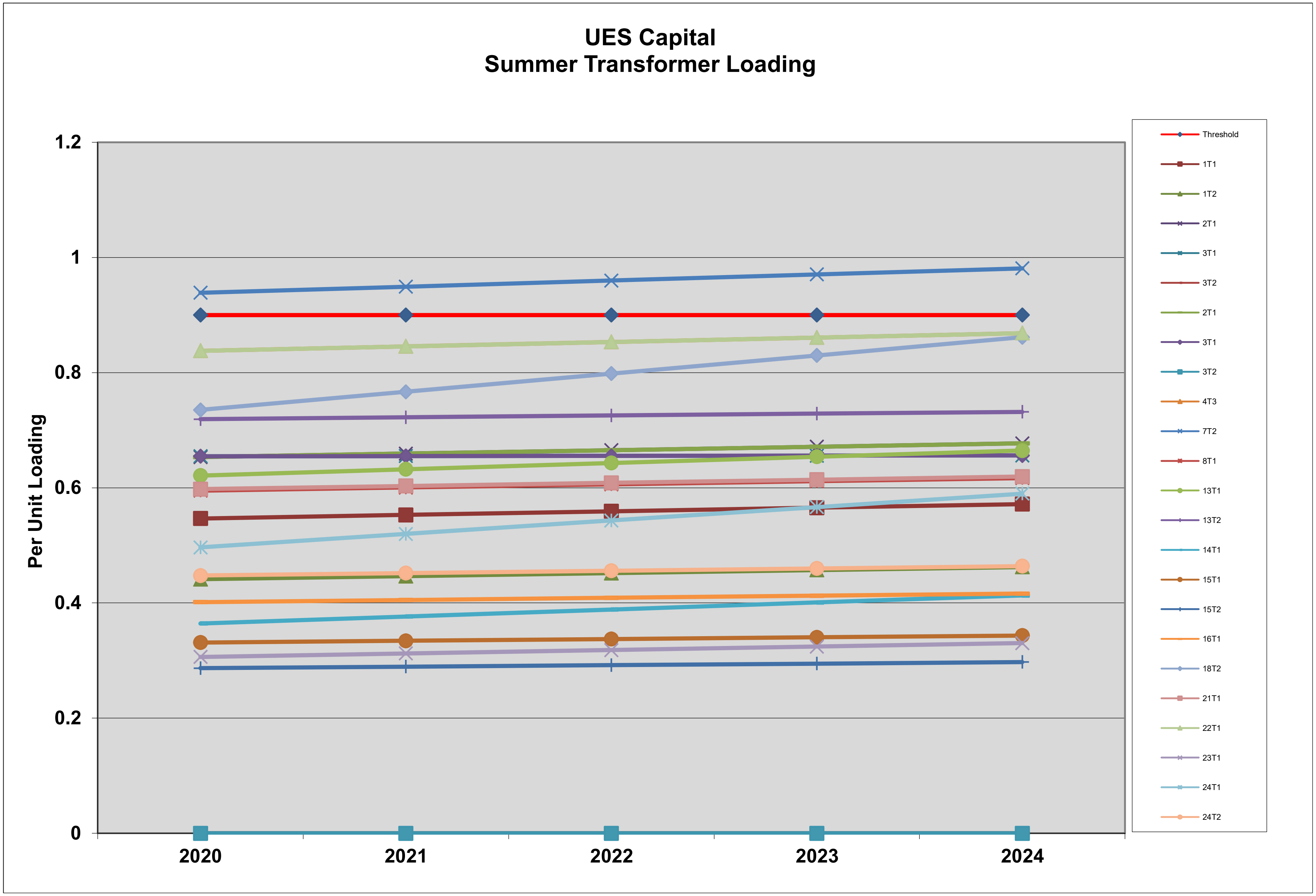
Distribution Circuit Ratings and Limitations

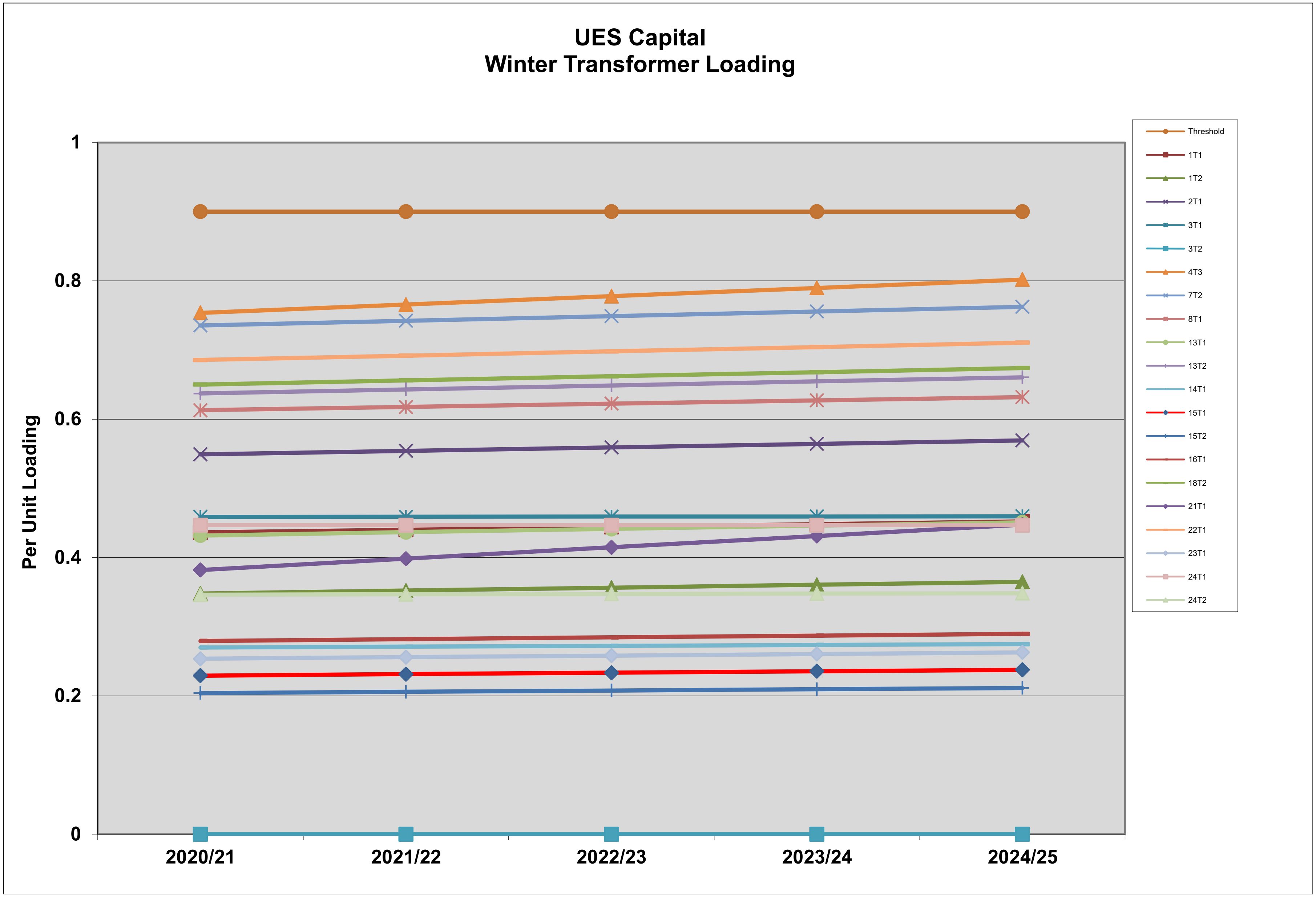
	Voltage	Breaker or Recloser						Current Transformer		Switch		Fuse		Regulator		Conductor		Transformer		Overall		Overall		Limiting	
Distribution Element	Base	Continuous Rating		Trip Level		Load Enchroachment		Present Tap Selection		Continuous Rating		Limit		Limit		Rating		Rating		Rating		Rating		Element	
	(kV)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (kVA)	LTE (kVA)	Normal (Amps)	LTE (Amps)	Normal	LTE
Bridge Street 1T1 Xfmr	4.16											1493	1493					1137	1171	8,190	8,436	1137	1171	Xfmr	Xfmr
1H3	4.16	560	560	414	448									480	480	325	325			2,342	2,342	325	325	Wire	Wire
1H4	4.16	560	560	296	320									480	480	500	607			2,133	2,306	296	320	Relay Set	Relay Set
1H5	4.16	600	600	444	480									480	480	415	415			2,990	2,990	415	415	Wire	Wire
Bridge Street 1T2 Xfmr	4.16											1493	1493					1137	1171	8,190	8,436	1137	1171	Xfmr	Xfmr
1H1	4.16	560	560	414	448									480	480	531	645			2,986	3,228	414	448	Relay Set	Relay Set
1H2	4.16	560	560	414	448									480	480	325	325			2,342	2,342	325	325	Wire	Wire
1H6	4.16	560	560	414	448									480	480	531	645			2,986	3,228	414	448	Relay Set	Relay Set
Bridge Street 1X7P	34.5	560	560											160	160	165	165			9,561	9,561	160	160	Reg	Reg
Bridge Street 1X7A	34.5											180	180			165	165			9,860	9,860	165	165	Wire	Wire
West Concord 2T1 Xfmr	4.16							800	800			1090	1090					787	811	5,670	5,764	787	800	Xfmr	CT
2H1	4.16	600	600	311	336									480	480	283	336			2,039	2,421	283	336	Wire	Relay Set
2H2	4.16	600	600	444	480									480	480	500	620			3,199	3,459	444	480	Relay Set	Relay Set
2H4	4.16	560	560	296	320									480	480	373	451			2,133	2,306	296	320	Relay Set	Relay Set
Gulf Street 3T1 Xfmr	4.16											1090	1090					702	716	5,060	5,160	702	716	Xfmr	Xfmr
3H1	4.16	600	600	311	336									480	480	500	620			2,239	2,421	311	336	Relay Set	Relay Set
3H2	4.16	600	600	311	336									480	480	373	451			2,239	2,421	311	336	Relay Set	Relay Set
Gulf Street 3T2 Xfmr	4.16											597	597					573	587	4,130	4,230	573	587	Xfmr	Xfmr
3H3	4.16	560	560	370	400											325	385			2,342	2,774	325	385	Wire	Wire
Gulf Street 3T3 Xfmr	13.8																								
3W4	13.8																								
3W5	13.8																								
Penacook 4X1	34.5	560	560	243	262							441	441			531	645			14,504	15,680	243	262	Relay Set	Relay Set
Penacook 4T3 Xfmr	13.8							600	600			432	432					521	530	10,326	10,326	432	432	Fuse	Fuse
4W3	13.8	400	400	296	320									240	240	415	415			5,737	5,737	240	240	Reg	Reg
4W4	13.8	400	400	296	320			400	400					394	459	283	336			6,764	7,649	283	320	Wire	Relay Set
Pleasant Street 6X3	34.5	800	800											241	281	500	620			14,413	16,815	241	281	Reg	Reg
Bow Junction 7X1	34.5	560	560	178	192			600	600							247	294			10,613	11,473	178	192	Relay Set	Relay Set
Bow Junction 7T2 Xfmr	13.8											432	432					516	529	10,326	10,326	432	432	Fuse	Fuse
7W3	13.8	800	800	355	384			600	600					394	459	531	645			8,490	9,178	355	384	Relay Set	Relay Set
7W4	13.8	800	800	444	480			600	600					589	668	531	645			10,613	11,473	444	480	Relay Set	Relay Set
Hollis 8T1 Xfmr	4.16											746	746					529	540	3,810	3,890	529	540	Xfmr	Xfmr
8H1	4.16	600	600	355	384			300	300	300	300					500	620			2,162	2,162	300	300	CT	CT
8H2	4.16	600	600	355	384			300	300	300	300					531	645			2,162	2,162	300	300	CT	CT
Hollis 8X3	34.5	560	560	370	400									668	668	373	451			22,110	23,902	370	400	Relay Set	Relay Set
Hollis 8X5	34.5	560	560	370	400									668	668	373	451			22,110	23,902	370	400	Relay Set	Relay Set
Boscawen 13T1 Xfmr	13.8											329	329					259	264	6,200	6,320	259	264	Xfmr	Xfmr
13W1	13.8	560	560	207	224			300	300	600	600			240	240	382	472			4,953	5,354	207	224	Relay Set	Relay Set
13W2	13.8	560	560	207	224			300	300	600	600			240	240	370	438			4,953	5,354	207	224	Relay Set	Relay Set
Boscawen 13T2 Xfmr	13.8											284	284					343	353	6,776	6,776	284	284	Fuse	Fuse
13W3	13.8	560	560	281	304			600	600	600	600			440	514	531	645			6,721	7,266	281	304	Relay Set	Relay Set
Boscawen 13X4	34.5	560	560	252	272							182	182			247	294			10,864	10,864	182	182	Fuse	Fuse
Langdon Street 14T1 Xfmr	4.16											1090	1090					702	716	5,060	5,160	702	716	Xfmr	Xfmr
14H1	4.16	560	560	414	448									480	480	463	562			2,986	3,228	414	448	Relay Set	Relay Set
14H2	4.16	560	560	414	448									480	480	537	653			2,986	3,228	414	448	Relay Set	Relay Set
Langdon 14X3	34.5											36	36							2,151	2,151	36	36	Fuse	Fuse
West Portsmouth 15T1 Xfmr	13.8											450	450					520	528	10,756	10,756	450	450	Fuse	Fuse
15W1	13.8	600	600	229	248									240	240	240	289			5,483	5,737	229	240	Relay Set	Reg
15W2	13.8	600	600	296	320									240	240	531	645			5,737	5,737	240	240	Reg	Reg
West Portsmouth 15T2 Xfmr	4.16											363	363					258	268	1,860	1,930	258	268	Xfmr	Xfmr
15H3	4.16															240	289			1,729	2,082	240	289	Wire	Wire
Terrill Park 16T1 Xfmr	4.16											1090	1090					860	877	6,200	6,320	860	877	Xfmr	Xfmr
16H1	4.16	560	560	296	320									480	480	340	411			2,133	2,306	296	320	Relay Set	Relay Set
16H3	4.16	560	560	414	448									480	480	531	645			2,986	3,228	414	448	Relay Set	Relay Set
Terrill Park 16X4	34.5	560	560	207	224															12,381	13,385	207	224	Relay Set	Relay Set
Terrill Park 16X5	34.5											81	81							4,840	4,840	81	81	Fuse	Fuse
Terrill Park 16X6	34.5											101	101							6,023	6,023	101	101	Fuse	Fuse
Bow Bog 18T2 Xfmr	13.8																	139	141	3,332	3,375	139	141	Xfmr	Xfmr
18W2	13.8	560	560	148	160			600	600	200	200	252	252			165	165			3,538	3,824	148	160	Relay Set	Relay Set
Storrs Street 21T1 Xfmr	13.8											148	160					377	388	3,538	3,824	148	160	Fuse	Fuse
21W1P	13.8									600	600					165	165			3,944	3,944	165	165	Wire	Wire
21W1A	13.8															165	165			3,944	3,944	165	165	Wire	Wire
Iron Works Road 22T1 Xfmr	13.8											432	432					521	530	10,326	10,326	432	432	Fuse	Fuse
22W1	13.8	560	560	207	224									240	240	247	294			4,953	5,354	207	224	Relay Set	Relay Set
22W2	13.8	560	560	207	224									240	240	531	645			4,953	5,354	207	224	Relay Set	Relay Set
22W3	13.8	560	560	296	320			300	300					394	459	531	645			7,075	7,171	296	300	Relay Set	CT
Montgomery Street 23T1 Xfmr	13.8							600	600			308	308					377	388	7,368	7,368	308	308	Fuse	Fuse
21W1P	13.8									600	600					165	165			3,944	3,944	165	165	Wire	Wire
21W1A	13.8															165	165			3,944	3,944	165	165	Wire	Wire
Hazen Drive 24T1 Xfmr	4.16											582	582					376	383	2,710	2,760	376	383	Xfmr	Xfmr
24H1	4.16	560	560	355	384											247	294			1,780	2,118	247	294	Wire	Wire
Hazen Drive 24T2 Xfmr	4.16											940	940					533	544	3,840	3,920	533	544	Xfmr	Xfmr
24H2	4.16	1200	1200	355	384											385	385			2,559	2,767	355	384	Relay Set	Relay Set
24H3	4.16	1200	1200	355	384											385	385			2,559	2,767	355	384	Relay Set	Relay Set
33 Line - Little Pond Rd	13.8											237	237	120	140	141	168	17	17	400	400	17	17	Xfmr	Xfmr
37X1	34.5															364	364			21,751	21,751	364	364	Wire	Wire

Distribution Element	Voltage Base	Breaker or Recloser						Current Transformer		Switch		Fuse		Regulator		Conductor		Transformer		Overall		Overall		Limiting	
		Continuous Rating		Trip Level		Load Enchroachment		Present Tap Selection		Continuous Rating		Limit		Limit		Rating		Rating		Rating		Rating		Element	
	(kV)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (Amps)	LTE (Amps)	Normal (kVA)	LTE (kVA)	Normal (Amps)	LTE (Amps)	Normal	LTE
Bridge Street 1T1 Xfmr	4.16											1493	1493					1282	1347	9,240	9,702	1282	1347	Xfmr	Xfmr
1H3	4.16	560	560	414	448									480	480	325	325			2,342	2,342	325	325	Wire	Wire
1H4	4.16	560	560	296	320									480	480	653	731			2,133	2,306	296	320	Relay Set	Relay Set
1H5	4.16	600	600	444	480									480	480	415	415			2,990	2,990	415	415	Wire	Wire
Bridge Street 1T2 Xfmr	4.16											1493	1493					1171	1171	8,436	8,436	1171	1171	Xfmr	Xfmr
1H1	4.16	560	560	414	448									480	480	694	777			2,986	3,228	414	448	Relay Set	Relay Set
1H2	4.16	560	560	414	448									480	480	325	325			2,342	2,342	325	325	Wire	Wire
1H6	4.16	560	560	414	448									480	480	694	777			2,986	3,228	414	448	Relay Set	Relay Set
Bridge Street 1X7P	34.5	560	560											160	160	165	165			9,561	9,561	160	160	Reg	Reg
Bridge Street 1X7A	34.5											180	180			165	165			9,860	9,860	165	165	Wire	Wire
West Concord 2T1 Xfmr	4.16							800	800			1090	1090					910	960	5,764	5,764	800	800	CT	CT
2H1	4.16	600	600	311	336									480	480	369	405			2,239	2,421	311	336	Relay Set	Relay Set
2H2	4.16	600	600	444	480									480	480	696	778			3,199	3,459	444	480	Relay Set	Relay Set
2H4	4.16	560	560	296	320									480	480	486	543			2,133	2,306	296	320	Relay Set	Relay Set
Gulf Street 3T1 Xfmr	4.16											1090	1090					798	838	5,750	6,040	798	838	Xfmr	Xfmr
3H1	4.16	600	600	311	336									480	480	696	778			2,239	2,421	311	336	Relay Set	Relay Set
3H2	4.16	600	600	311	336									480	480	486	543			2,239	2,421	311	336	Relay Set	Relay Set
Gulf Street 3T2 Xfmr	4.16											597	597					647	679	4,302	4,302	597	597	Fuse	Fuse
3H3	4.16	560	560	370	400											424	464			2,666	2,882	370	400	Relay Set	Relay Set
Gulf Street 3T3 Xfmr																									
3W4																									
3W5																									
Penacook 4X1	34.5	560	560	243	262							441	441			694	777			14,504	15,680	243	262	Relay Set	Relay Set
Penacook 4T3 Xfmr	13.8							600	600			432	432					584	584	10,326	10,326	432	432	Fuse	Fuse
4W3	13.8	400	400	296	320									240	240	415	415			5,737	5,737	240	240	Reg	Reg
4W4	13.8	400	400	296	320			400	400					476	476	369	405			7,075	7,649	296	320	Relay Set	Relay Set
Pleasant Street 6X3	34.5	800	800											291	291	696	778			17,416	17,416	291	291	Reg	Reg
Bow Junction 7X1	34.5	560	560	178	192			600	600							322	354			10,613	11,473	178	192	Relay Set	Relay Set
Bow Junction 7T2 Xfmr	13.8											432	432					575	575	10,326	10,326	432	432	Fuse	Fuse
7W3	13.8	800	800	355	384			600	600					476	476	694	777			8,490	9,178	355	384	Relay Set	Relay Set
7W4	13.8	800	800	444	480			600	600					668	668	694	777			10,613	11,473	444	480	Relay Set	Relay Set
Hollis 8T1 Xfmr	4.16											746	746					598	634	4,310	4,570	598	634	Xfmr	Xfmr
8H1	4.16	600	600	355	384			300	300	300	300					696	778			2,162	2,162	300	300	CT	CT
8H2	4.16	600	600	355	384			300	300	300	300					694	777			2,162	2,162	300	300	CT	CT
Hollis 8X3	34.5	560	560	370	400									668	668	486	543			22,110	23,902	370	400	Relay Set	Relay Set
Hollis 8X5	34.5	560	560	370	400									668	668	486	543			22,110	23,902	370	400	Relay Set	Relay Set
Boscawen 13T1 Xfmr	13.8											329	329					292	304	6,980	7,260	292	304	Xfmr	Xfmr
13W1	13.8	560	560	207	224			300	300	600	600			240	240	530	591			4,953	5,354	207	224	Relay Set	Relay Set
13W2	13.8	560	560	207	224			300	300	600	600			240	240	483	528			4,953	5,354	207	224	Relay Set	Relay Set
Boscawen 13T2 Xfmr	13.8											284	284					384	403	6,776	6,776	284	284	Fuse	Fuse
13W3	13.8	560	560	281	304			600	600	600	600			525	525	694	777			6,721	7,266	281	304	Relay Set	Relay Set
Boscawen 13X4	34.5	560	560	252	272							182	182			322	354			10,864	10,864	182	182	Fuse	Fuse
Langdon Street 14T1 Xfmr	4.16											1090	1090					798	838	5,750	6,040	798	838	Xfmr	Xfmr
14H1	4.16	560	560	414	448									480	480	605	677			2,986	3,228	414	448	Relay Set	Relay Set
14H2	4.16	560	560	414	448									480	480	702	787			2,986	3,228	414	448	Relay Set	Relay Set
Langdon 14X3	34.5											36	36							2,151	2,151	36	36	Fuse	Fuse
West Portsmouth 15T1 Xfmr	13.8											450	450					584	610	10,756	10,756	450	450	Fuse	Fuse
15W1	13.8	600	600	229	248									240	240	312	348			5,483	5,737	229	240	Relay Set	Reg
15W2	13.8	600	600	296	320									240	240	694	777			5,737	5,737	240	240	Reg	Reg
West Portsmouth 15T2 Xfmr	4.16											363	363					303	321	2,180	2,310	303	321	Xfmr	Xfmr
15H3	4.16															312	348			2,248	2,507	312	348	Wire	Wire
Terrill Park 16T1 Xfmr	4.16											1090	1090					962	1001	6,930	7,210	962	1001	Xfmr	Xfmr
16H1	4.16	560	560	296	320									480	480	443	495			2,133	2,306	296	320	Relay Set	Relay Set
16H3	4.16	560	560	414	448									480	480	694	777			2,986	3,228	414	448	Relay Set	Relay Set
Terrill Park 16X4	34.5	560	560	207	224															12,381	13,385	207	224	Relay Set	Relay Set
Terrill Park 16X5	34.5											81	81							4,840	4,840	81	81	Fuse	Fuse
Terrill Park 16X6	34.5											101	101							6,023	6,023	101	101	Fuse	Fuse
Bow Bog 18T2 Xfmr	13.8																	158	167	3,780	3,980	158	167	Xfmr	Xfmr
18W2	13.8	560	560	148	160			600	600	200	200	252	252			165	165			3,538	3,824	148	160	Relay Set	Relay Set
Storrs Street 21T1 Xfmr	13.8											148	160					433	459	3,538	3,824	148	160	Fuse	Fuse
21W1P	13.8									600	600					165	165			3,944	3,944	165	165	Wire	Wire
21W1A	13.8															165	165			3,944	3,944	165	165	Wire	Wire
Iron Works Road 22T1 Xfmr	13.8											432	432					582	611	10,326	10,326	432	432	Fuse	Fuse
22W1	13.8	560	560	207	224									240	240	322	354			4,953	5,354	207	224	Relay Set	Relay Set
22W2	13.8	560	560	207	224									240	240	694	777			4,953	5,354	207	224	Relay Set	Relay Set
22W3	13.8	560	560	296	320			300	300					476	476	694	777			7,075	7,171	296	300	Relay Set	CT
Montgomery Street 23T1 Xfmr	13.8							600	600			308	308					430	451	7,368	7,368	308	308	Fuse	Fuse
21W1P	13.8									600	600					165	165			3,944	3,944	165	165	Wire	Wire
21W1A	13.8															165	165			3,944	3,944	165	165	Wire	Wire
Hazen Drive 24T1 Xfmr	4.16											582	582					426	450	3,070	3,240	426	450	Xfmr	Xfmr
24H1	4.16	560	560	355	384											322	354			2,320	2,551	322	354	Wire	Wire
Hazen Drive 24T2 Xfmr	4.16											940	940					602	636	4,340	4,580	602	636	Xfmr	Xfmr
24H2	4.16	1200	1200	355	384											385	385			2,559	2,767	355	384	Relay Set	Relay Set
24H3	4.16	1200	1200	355	384											385	385			2,559	2,767	355	384	Relay Set	Relay Set
33 Line - Little Pond Rd	13.8											237	237	145	145	184	203	17	17	400	400	17	17	Xfmr	Xfmr
37X1	34.5															694	777			41,470	46,430	694	777	Wire	Wire

Appendix C

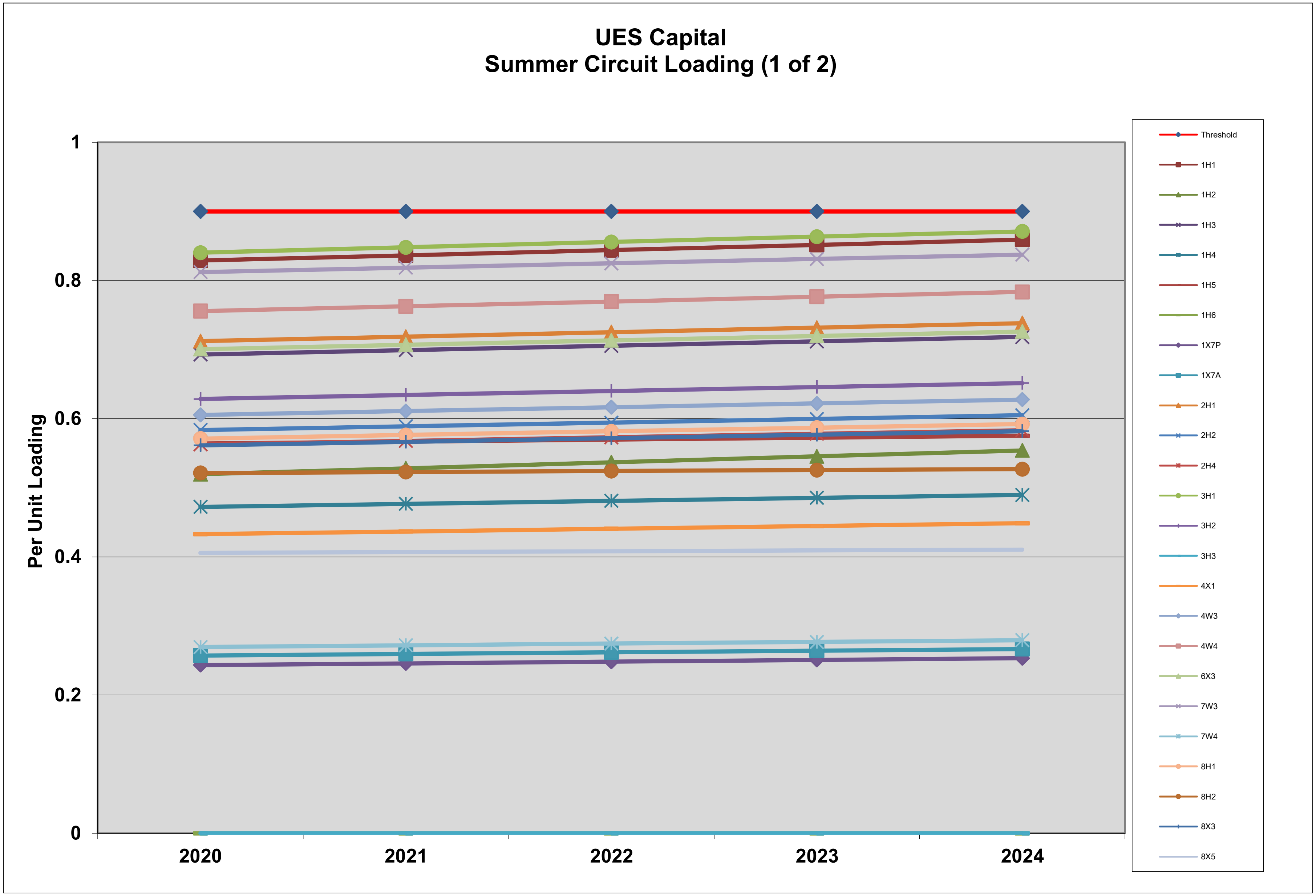
Transformer Loading Charts
(In Per Unit)

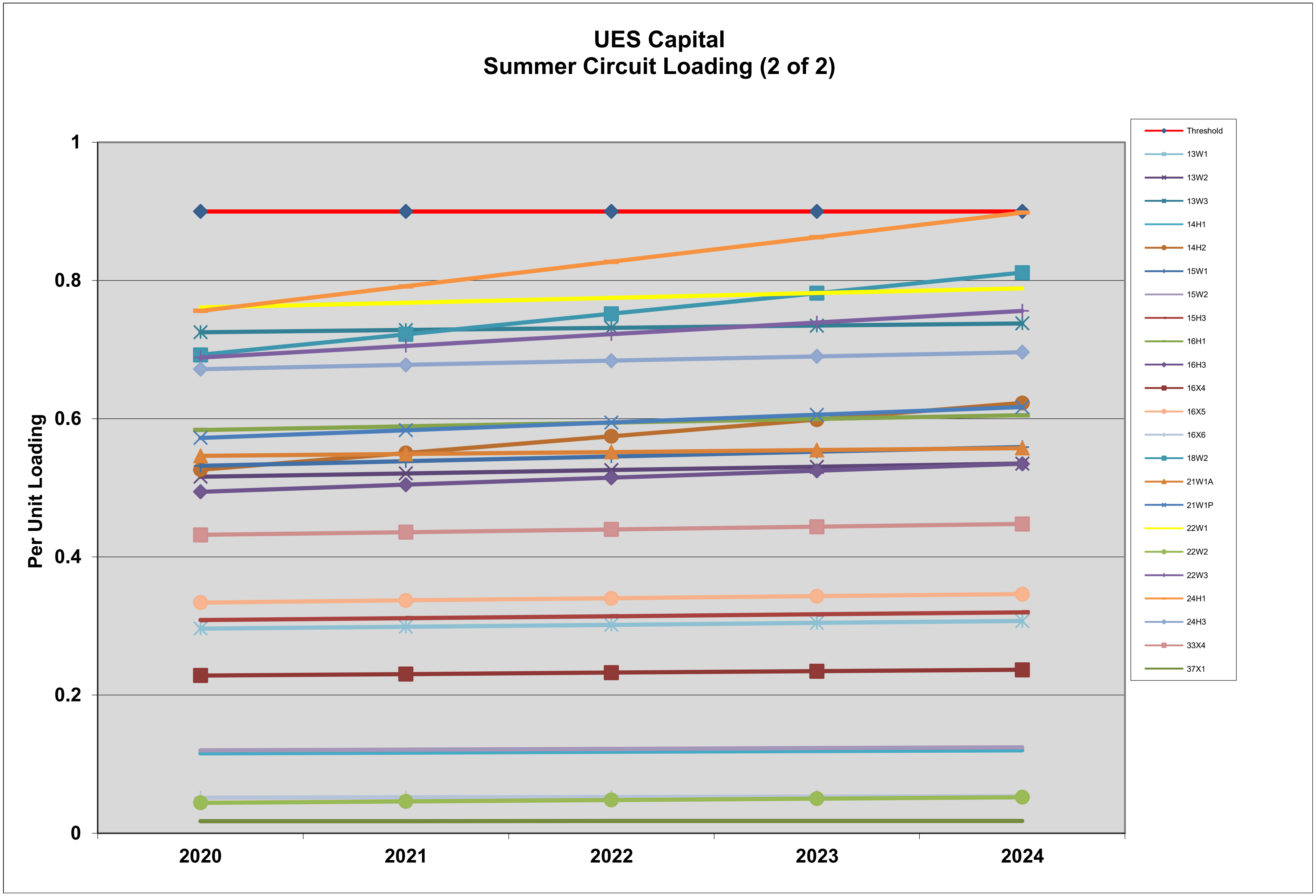

UES Capital
Summer Transformer Loading
Per Unit Loading
1.2
1
0.8
0.6
0.4
0.2
0
2020
2021
2022
2023
2024
Threshold
1T1
1T2
2T1
3T1
3T2
2T1
3T1
3T2
4T3
7T2
8T1
13T1
13T2
14T1
15T1
15T2
16T1
18T2
21T1
22T1
23T1
24T1
24T2

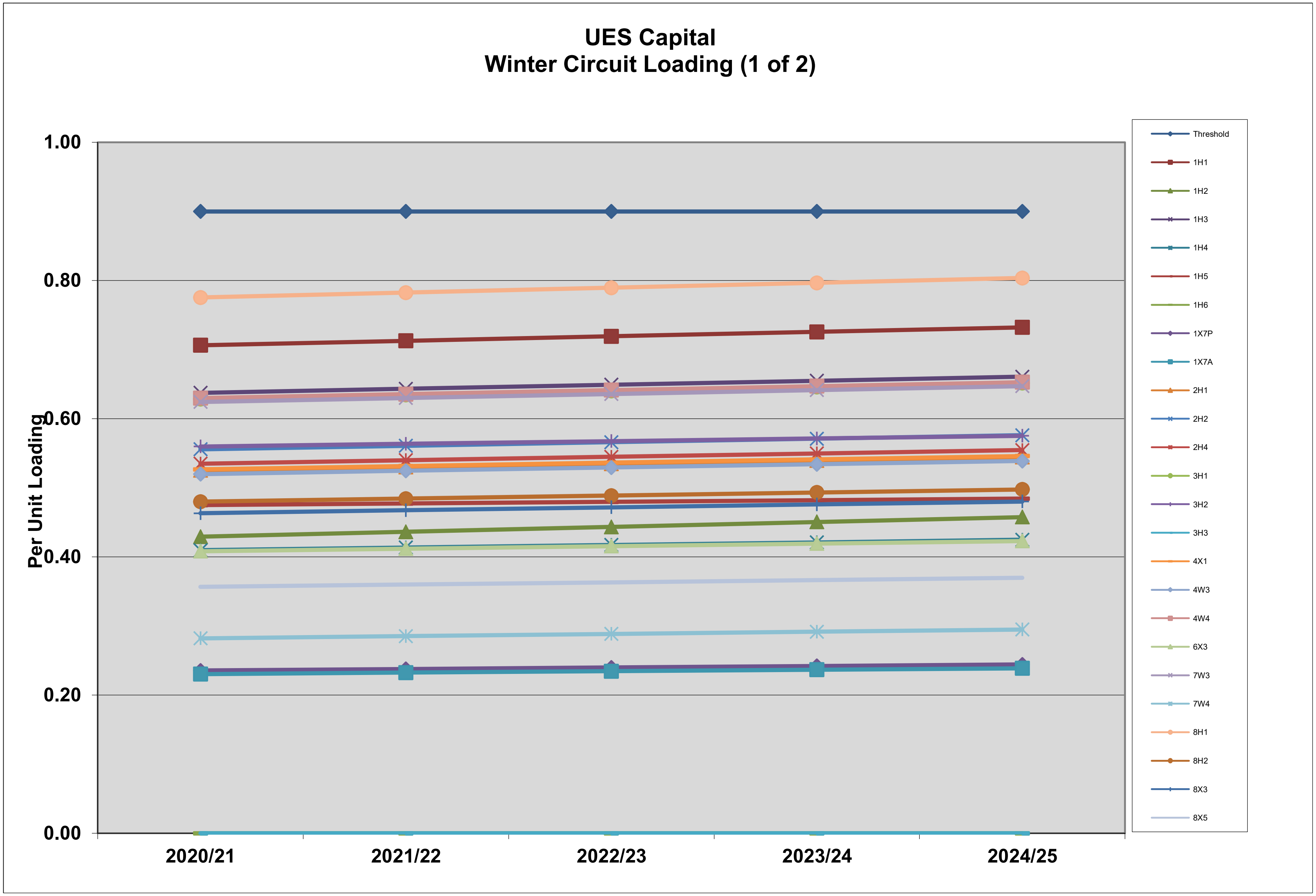

UES Capital
Winter Transformer Loading
Per Unit Loading
1
0.8
0.6
0.4
0.2
0
2020/21
2021/22
2022/23
2023/24
2024/25
Threshold
1T1
1T2
2T1
3T1
3T2
4T3
7T2
8T1
13T1
13T2
14T1
15T1
15T2
16T1
18T2
21T1
22T1
23T1
24T1
24T2

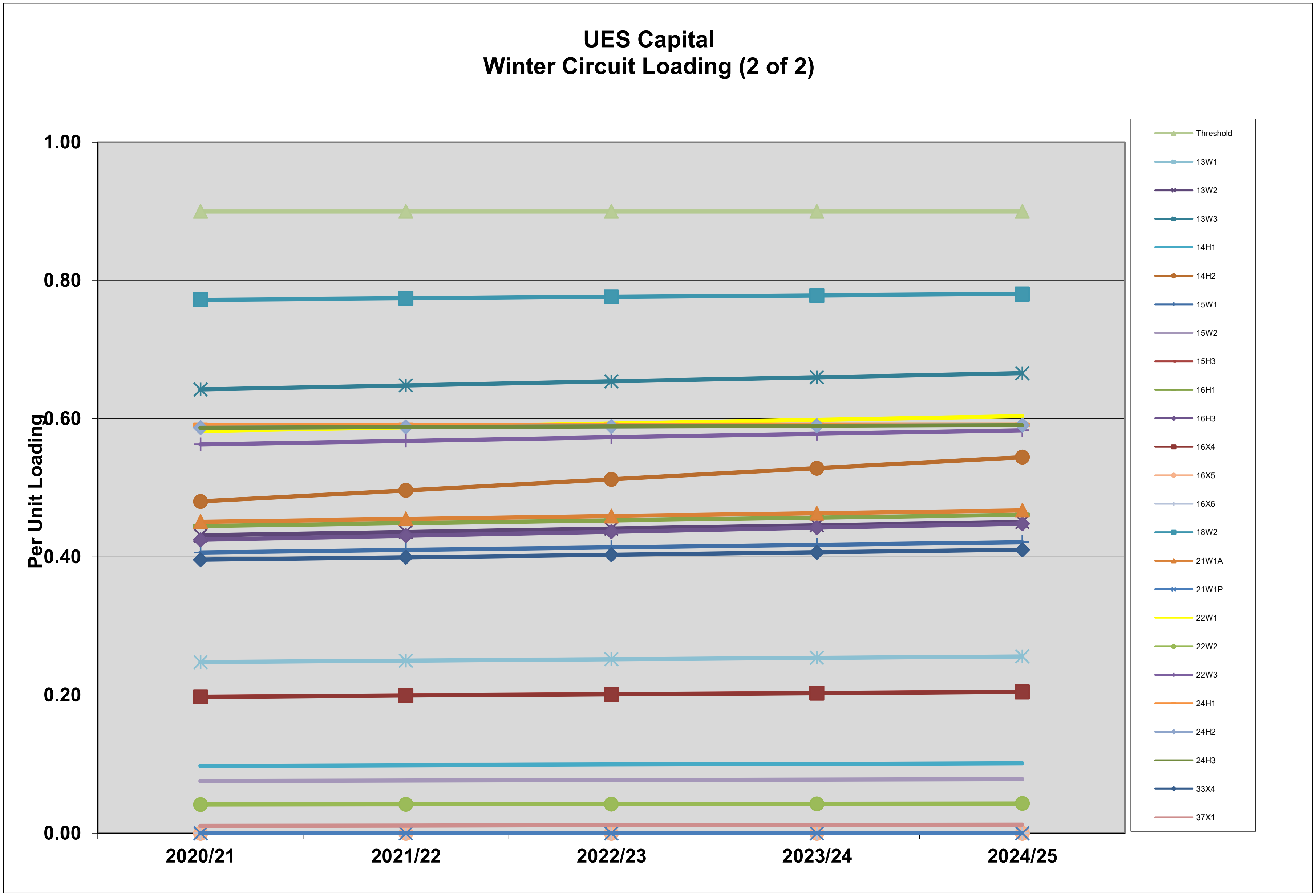
Appendix D

Circuit Loading Charts
(In Per Unit)


UES Capital
Summer Circuit Loading (1 of 2)
Per Unit Loading
1
0.8
0.6
0.4
0.2
0
2020
2021
2022
2023
2024
Threshold
1H1
1H2
1H3
1H4
1H5
1H6
1X7P
1X7A
2H1
2H2
2H4
3H1
3H2
3H3
4X1
4W3
4W4
6X3
7W3
7W4
8H1
8H2
8X3
8X5


UES Capital
Summer Circuit Loading (2 of 2)
Per Unit Loading
1
0.8
0.6
0.4
0.2
0
2020
2021
2022
2023
2024
Threshold
13W1
13W2
13W3
14H1
14H2
15W1
15W2
15H3
16H1
16H3
16X4
16X5
16X6
18W2
21W1A
21W1P
22W1
22W2
22W3
24H1
24H3
33X4
37X1


UES Capital
Winter Circuit Loading (1 of 2)
Per Unit Loading
1.00
0.80
0.60
0.40
0.20
0.00
2020/21
2021/22
2022/23
2023/24
2024/25
Threshold
1H1
1H2
1H3
1H4
1H5
1H6
1X7P
1X7A
2H1
2H2
2H4
3H1
3H2
3H3
4X1
4W3
4W4
6X3
7W3
7W4
8H1
8H2
8X3
8X5


UES Capital
Winter Circuit Loading (2 of 2)
Per Unit Loading
1.00
0.80
0.60
0.40
0.20
0.00
2020/21
2021/22
2022/23
2023/24
2024/25
Threshold
13W1
13W2
13W3
14H1
14H2
15W1
15W2
15H3
16H1
16H3
16X4
16X5
16X6
18W2
21W1A
21W1P
22W1
22W2
22W3
24H1
24H2
24H3
33X4
37X1

Appendix E

Circuit Tie Analysis

Circuit Tie	Restoring Circuit	Restored Circuit	Limit of Restoration during Summer Peak	Accepted Planning Violations	Limiting Element w/ Summer Normal Rating	% Peak Loading & Max Per-Phase Amps at S/S when Tie is Usable to Restore Entire Circuit	Accepted Planning Violations
7W3J7W4	7W3	7W4	Open @ P.90 South St	S/S Regulators @ 90% rating - 393A	S/S Regulator Rating - 393A	90% Peak, 391A Per Phase on Circuit	S/S Regulators @ 100% loading
	7W4	7W3	No Limit	None	N/A	N/A	None
7W3J18W2	7W3	18W2	Open @ P.1 Dunbarton Center Rd and P.150-X Woodhill Rd	Solids @ 91% rating - 300A	P.1 Robinson Rd Fuse - 130A	70% Peak, 122A Per Phase on Circuit	Fuse @ 94% loading
	18W2	7W3	Cannot carry at Peak	None	Bow Bog XFMR - 139A	35% Peak, 136A Per Phase on Circuit	XFMR @ 98% loading
7W3J22W3	7W3	22W3	Open @ P.1 Albin Rd	S/S Regulators @ 98% rating - 393A	S/S Regulator Rating - 393A	65% Peak, 331A Per Phase on Circuit	114V on Primary
	22W3	7W3	Open @ P.1 Carriage Rd	Iron Works Rd 1/0 ACSR @ 90% rating - 247A	Iron Works Rd 1/0 ACSR - 247A	56% Peak, 217A Per Phase on Circuit	114V on Primary
7W4J22W1	7W4	22W1	No Limit	Solids @ 95% rating - 300A	P.7 Storrs St Solids - 300A	100% Peak, 301A Per Phase on Circuit	Solids @ 95% loading
	22W1	7W4	Open @ P.23 South St	None	S/S Regulator Rating - 240A	80% Peak, 237A Per Phase on Circuit	2/0 ACSR @ 99% loading
7W4J22W2	7W4	22W2	No Limit	None	N/A	N/A	None
	22W2	7W4	No Limit	None	N/A	N/A	None
18W2J22W3	18W2	22W3	Cannot carry at Peak	None	S/S XFMR - 139A	42% Peak, 136A Per Phase on Circuit	XFMR @ 98% loading
	22W3	18W2	Cannot carry at Peak	None	Iron Works Rd 1/0 ACSR - 247A	70% Peak, 233A Per Phase on Circuit	1/0 ACSR @ 94% loading, 114V on Bow Center Rd
22W1J22W2-1	22W1	22W2	No Limit	None	N/A	N/A	None
	22W2	22W1	No Limit	None	N/A	N/A	None
22W1J22W3-2	22W1	22W3	Open @ P.1 Albin Rd and P.93 Clinton St	None	S/S Regulator Rating - 240A	65% Peak, 238A Per Phase on Circuit	S/S Regulators @ 98% loading
	22W3	22W1	Open @ P.23 Clinton St	Iron Works Rd 1/0 ACSR @ 98% rating - 247A	Iron Works Rd 1/0 ACSR - 247A	69% Peak, 245A Per Phase on Circuit	Trip Limit @ 98% loading
22W2J22W3	22W2	22W3	No Limit	None	N/A	N/A	None
	22W3	22W2	No Limit	Iron Works Rd 1/0 ACSR @ 91% rating - 247A	Iron Works Rd 1/0 ACSR - 247A	100% Peak, 225A Per Phase on Circuit	1/0 ACSR @ 91% loading
8H1J24H1	8H1	24H1	Cannot carry at Peak	None	Hollis 250 CU_UG - 320A	96% Peak, 306A Per Phase on Circuit	250 CU_UG @ 96% loading
	24H1	8H1	Cannot carry at Peak	None	Hazen Dr 1/0 ACSR - 247A	63% Peak, 242A Per Phase on Circuit	1/0 ACSR @ 98% loading, 115V on Primary
8H1J8H2-1	8H1	8H2	Open @ P.34 Pembroke Rd	Hollis 250 CU_UG @ 96% rating - 320A	Hollis 250 CU_UG - 320A	95% Peak, 311A Per Phase on Circuit	250 CU_UG @ 98% loading
	8H2	8H1	Open @ P.43-X Loudon Rd	None	Hollis 250 CU_UG - 320A	95% Peak, 311A Per Phase on Circuit	251 CU_UG @ 98% loading
8H1J8H2-2	8H1	8H2	Open @ P.34 Pembroke Rd	Hollis 250 CU_UG @ 96% rating - 320A	Hollis 250 CU_UG - 320A	95% Peak, 311A Per Phase on Circuit	250 CU_UG @ 98% loading
	8H2	8H1	Open @ P.43-X Loudon Rd	None	Hollis 250 CU_UG - 320A	95% Peak, 311A Per Phase on Circuit	250 CU_UG @ 98% loading
8H2J24H2	8H2	24H2	Cannot carry at Peak	None	Sullivan St 1/0 Al_UG - 165A	50% Peak, 205A Per Phase on Circuit	114V on Primary
	24H2	8H2	Cannot carry at Peak	None	S/S Regulator Rating - 331A	83% Peak, 328A Per Phase on Circuit	S/S Regulators @ 99% loading
16H1J16H3	16H1	16H3	Open @ P.2 Terrill Park Dr	Terrill Park Dr 3/0 AAC @ 97% - 340A	Terrill Park Dr 3/0 AAC - 340A	70% Peak, 271A Per Phase on Circuit	114.5V on Primary
	16H3	16H1	Open @ P.1 Airport Rd	Airport Rd Fuse @ 96% rating - 190A	Airport Rd 125N Fuse - 190A	93% Peak, 361A Per Phase on Circuit	125N Fuse @ 99% loading
16H1J24H2	16H1	24H2	Open @ P.12 and P.13 Loudon Rd	Low Voltage on Loudon Rd - 115.8V	Airport Rd 1/0 ACSR - 247A	42% Peak, 181A Per Phase on Circuit	114V on Primary
	24H2	16H1	Open @ P.1 Airport Rd	None	S/S Regulator Rating - 331A	79% Peak, 329A Per Phase on Circuit	S/S Regulators @ 99% loading
24H301A	24H1	24H3	No Limit	None	N/A	N/A	None
	24H3	24H1	No Limit	None	N/A	N/A	None
24H301B	24H2	24H3	No Limit	None	N/A	N/A	None
	24H3	24H2	No Limit	None	N/A	N/A	None

Appendix F

Master Plan Map


HAZEN DR
EAST SIDE DR
SHEEP DAVIS RD NORTH
ORMOND ST
CANTERBURY RD
BRANCH TPKE
LOUDON RD
PEMBROKE RD
CHENNEL DR
SHEEP DAVIS RD SOUTH
REGIONAL DR
AIRPORT RD
TERRILL PARK S/S
TERRILL PARK DR
OLD TURNPIKE RD
RABBIT RD
OLD TURNPIKE RD
N WATER ST
HIGH ST
GOODHUE RD
DANIEL WEBSTER HWY
CARTER HILL RD
WATER ST
WEST RD
KING ST
DEPOT ST
BOSCAWEN S/S
SOUTH WEST RD
QUEEN ST
N MAIN ST
MACCOY ST
MOUNTAIN RD
VILLAGE ST
PENACOOK S/S
ABBOTT RD
MANOR RD
FISHERVILLE RD
SEVALLS FALLS RD
W PORTSMOUTH S/S
S STATE ST
W CONCORD S/S
W PORTSMOUTH ST
PORTSMOUTH ST
OLD LOUDON RD
LOUDON RD
HOLLIS S/S
DOVER RD
HORSECORNER RD
DOVER RD
LANE RD
PENACOOK ST
COMMERCIAL ST
LITTLE POND RD
SHORT FALLS RD
MILL HOUSE RD
BLACK HALL RD
SHORT FALLS RD
PLEASANT ST
PLEASANT ST S/S
S FRUIT ST
WEST ST
GULF ST S/S
MANCHESTER ST
SOUTH ST
BROADWAY
MAIN ST
HALL ST
GARVINS FALLS RD
CLINTON ST
IRON WORKS RD S/S
IRON WORKS RD
BOW JUNCTION S/S
SILK FARM RD
LOGGING HILL RD
CARTAGE RD
GRANDVIEW RD
ALBIN RD
BIRCHDALE RD
ROUTE 3A
BOW CENTER RD
PAGE RD
WHITE ROCK HILL RD
BOW BOG RD
ROBINSON RD
RIVER RD
BOW BOG S/S
WOODHILL RD
ALLEN RD
SOUTH BOW RD
RUMFORD ST
STICKNEY AVE
MONTGOMERY ST S/S
STORRS ST S/S
CENTER ST
LOUDON RD
WASHINGTON ST
N SPRING ST
S STATE ST
STORRS ST
PINE ST
WARREN ST
PLEASANT ST
THEATRE ST
THOMPSON ST
S SPRING ST
THORNDIKE ST
13.8kV Mainline
13.8kV Mainline - Future
13.8kV Downtown UG
34.5kV Mainline
34.5kV Mainline - Future
34.5kV Sub-T