ELECTRIC SYSTEM STUDY & CAPITAL IMPROVEMENTS PLAN

BRECKENRIDGE PUBLIC UTILITIES

BRECKENRIDGE PUBLIC UTILITIES BRECKENRIDGE, MINNESOTA

Prepared by
DGR Engineering

December 2018

DGR Project No. 425402

DGR ENGINEERING

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CAPITAL IMPROVEMENTS PLAN

FOR

BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

December 2018

I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Signature: ________________________________
Troy W. Metzger, P.E.

Date: ____________ License No. 46371

DGR Project No. 425402

DGR Engineering
1302 South Union Street
Rock Rapids, IA
(712) 472-2531
dgr@dgr.com

Table of Contents

Electric System Study & Capital Improvements Plan

Breckenridge Public Utilities, Breckenridge, Minnesota

EXECUTIVE SUMMARY

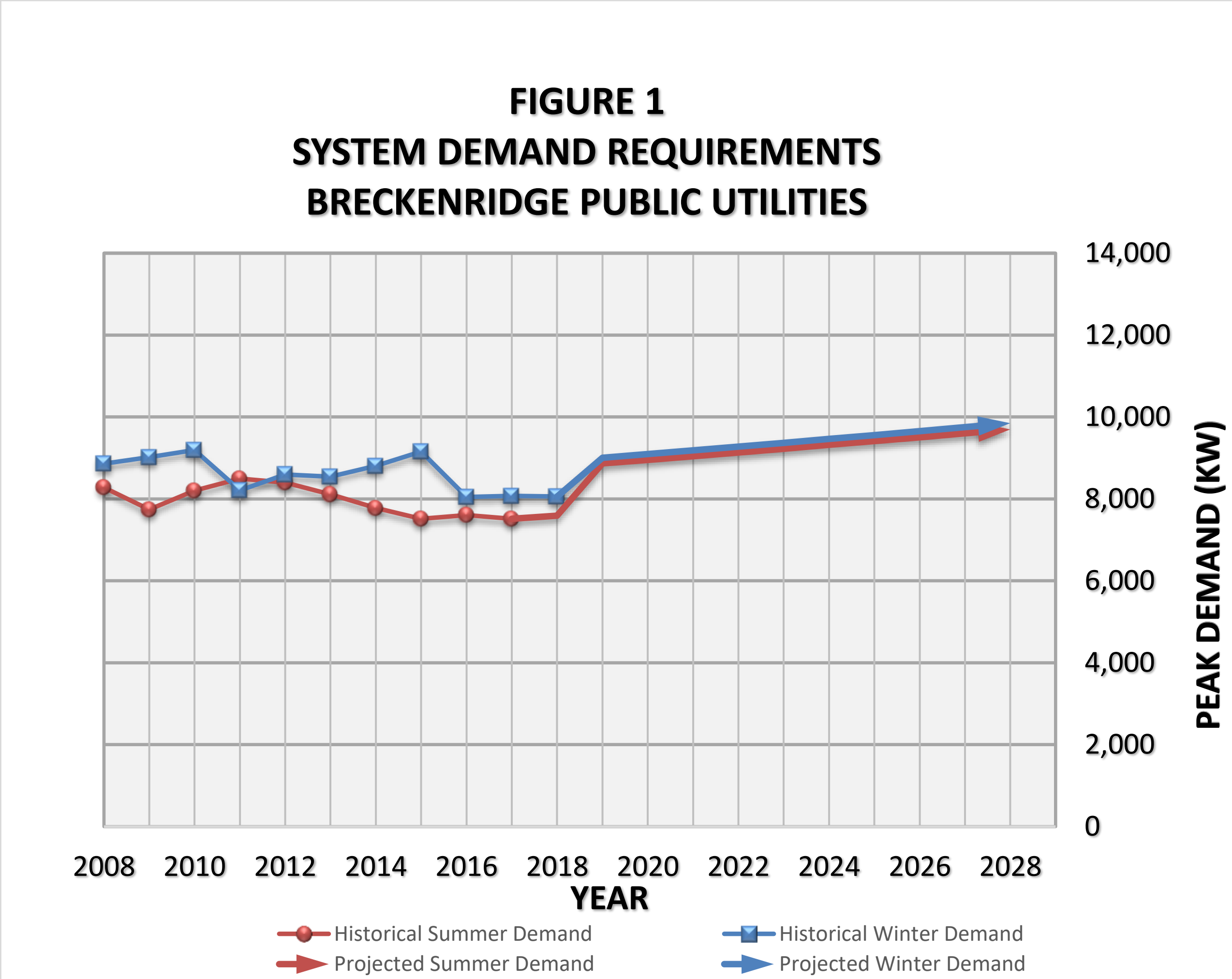
Breckenridge Public Utilities (BPU) of Breckenridge, Minnesota owns and operates an electric system that provides electric service to the citizens of Breckenridge. DGR Engineering (DGR) was commissioned to perform a system evaluation and planning study for BPU.

The study performed by DGR confined itself to the "internal" BPU system, defined as the electrical facilities within Breckenridge and in the immediately adjacent areas. This report outlines an analysis of BPU's system and presents recommended capital improvements to eliminate deficiencies. The Capital Improvements Plan (CIP) recommended covers a ten (10) year period and provides cost estimates for fiscal planning.

LOAD GROWTH AND EXISTING SYSTEM

Over the past ten (10) years, BPU's system has experienced an average decrease of approximately 0.8% for the summer peak and winter peak demand loading levels. This decline can be attributed to implementation of a load management system by BPU and increased efficiency of electrical equipment such as lighting, appliances, and air conditioning; which reduces the overall electric load on the system. The overall system peak of 8,074 kW was established in the winter of 2017 during a period of low temperatures. While the winter and summer peaks have been declined over the past ten (10) years, they look to be steadying in recent years as shown in Figure 1 on the next page.

The projections for 2019 to 2028 are based on a 1.0% annual growth rate for both the summer and winter after the addition of 700 kW (summer) and 350 kW (winter) for the new assisted living. Based on the load growth projections, the peak system demand will increase from a level of 8,074 kW in 2017 to a level of near 9,302 kW by 2028, which can be seen in Figure 1. After consultation with BPU staff, the summer and winter projections were based off the 2017 peak as it is believed to be the "system normal" as compared to the variable winter peaks BPU has experienced in prior years.



BPU's electric system consists of 41.6 kV transmission lines, three (3) load-serving substations and fourteen (14) 4.16 kV distribution feeders.

The internal transmission system consists of a 2.17 mile-long looped 41.6 kV transmission line which connects to Otter Tail Power Company's (OTP) 41.6 kV transmission system north & south of the city. This line is the source for the Water Plant Substation, while a separate 0.03 mile-long tap off OTP's transmission line serves the Twito Substation. A 0.15 mile-long radial 41.6 kV transmission line connects to OTP's line on the east side of the city and sources the South Substation. In total, BPU owns approximately 2.35 miles of 41.6 kV transmission line.

BPU takes delivery of power at transmission voltage at three (3) substations, all of which are owned by BPU: the Twito Substation is located on the north side of the city, the Water Plant Substation is located near the center of the city and the South Substation is located in on the south east portion of the city.

The existing distribution system provides electric service throughout Breckenridge at a system voltage of 4.16 kV. The 4.16 kV system consists of fourteen (14) circuits. Four (4) circuits are sourced by the Twito Substation. Six (6) circuits are sourced from the Water Plant Substation, while the last four (4) circuits are sourced from the South Substation. The distribution system has both overhead and underground sections. The majority of the distribution system is constructed in overhead fashion and has been in place for many years. The underground portion of the system is generally newer and located in newer areas of the city.

DESIGN CRITERIA

The following is a list of criteria used in evaluation of the performance of the electric system and the design of future improvements.

Criterion #1 Provide "N-1" (single contingency) level of reliability for all transmission, substation, and distribution facilities.

Criterion #2 Provide ANSI "Class A" voltage service to all customers, under normal or emergency conditions.

Criterion #3 Do not exceed thermal limitations of facilities on the electric system, under normal or emergency conditions.

Criterion #4 Design a system that is flexible in terms of operational characteristics.

Criterion #5 Develop a system that is expandable, so that load growth can be accommodated in an orderly manner.

EXISTING SYSTEM DEFICIENCIES

Due to modest system growth, and aging infrastructure, the following deficiencies have been identified:

- The Water Plant Substation transformer is 59 years old and is nearing the end of its useful life.
- The South Substation transformer is 46 years old and creeping toward the end of its useful life.
- Voltage violations on Water Plant Substation Circuit B and South Substation Circuits A and D under system intact peak loading. This situation will worsen under anticipated future load growth.
- The South Plant Substation transformer is nearing capacity overload during contingency peak loading circumstances and experiences overloading in these scenarios under the ten-year loading levels.
- Inability to handle an outage of the Water Plant Substation during peak loading periods without poor voltage conditions, overloading distribution circuits and overloading the South Substation Transformer. This situation will worsen under anticipated future load growth.
- Inability to handle an outage of the South Substation during peak loading periods without poor voltage conditions and overloading distribution circuits. This situation will worsen under anticipated future load growth.
- Inability to handle an outage of the Twito Substation during peak loading periods without poor voltage conditions on the distribution circuits. This situation will worsen under anticipated future load growth on the north side of the city.
- In some circuits, single-phase "disconnects" or "cutouts" are used to tie lines together during outage conditions, which has the potential of damaging three-phase equipment down line of the tie point.

- Cables with open concentric neutrals should be replaced with jacketed conductor to prevent voltage issues and outages that result from the neutral conductor corroding away and causing cable failure.

- Some sections of the 41.6 kV transmission line consist of older original construction and don't include a static wire for lightning protection.

CAPITAL IMPROVEMENTS PLAN SUMMARY

The following table summarizes the recommended improvements and associated costs necessary to begin resolving the system deficiencies:

CIP Component	Estimated Cost
Recommended Improvements (2019-2028)	
Phase 1 Distribution Improvements	$ 6,120,000
Phase 2 Distribution Improvements	4,750,000
Phase 3 Distribution Improvements	4,560,000
Total – 10 Year – CIP:	**$ 15,430,000**

Post CIP Period Improvements: Additional improvements may be required after the 10-year CIP period. These items were intentionally left out of the 10-year CIP plan due to their costs and the sequence of construction that was required to complete them. These improvements include rebuilding BPU's existing 41.6 kV transmission system to 69 kV specifications, which includes adding a fourth wire to be used as lightning protection.

1. INTRODUCTION AND SCOPE:

Breckenridge Public Utilities (BPU) of Breckenridge, Minnesota owns and operates an electric system that provides electric service to the citizens of Breckenridge. DGR Engineering (DGR) was commissioned to perform a system evaluation and planning study for BPU.

The study performed by DGR confined itself to the "internal" BPU system, defined as the electrical facilities within Breckenridge and in the immediately adjacent areas. This involved review and analysis of the segments of BPU's electric system, from the high-voltage 41.6 kV transmission system that brings power to the community, through the 4.16 kV distribution facilities that distribute the energy to consumers.

This report outlines an analysis of BPU's system and presents recommended capital improvements to eliminate deficiencies. The Capital Improvements Plan (CIP) is intended to assist BPU staff in proper planning and prioritization of capital improvements. The CIP recommended covers a ten (10)-year period and provides cost estimates for fiscal planning.

All of the staff members at DGR who participated in this study wish to acknowledge the contributions and insight of BPU staff during the study. All BPU staff were more than willing to find necessary data, provide input, and be helpful throughout the study process.

2. LOAD GROWTH PROJECTIONS:

2.1. General: The projected system load and the desired level of service dictate the level of capital expenditures required in order to provide adequate service to all customers. This section discusses the historical and projected system loading requirements.

2.2. System Demand Requirements: Table 1 lists the historical and projected peak power demands for the BPU electric system. For the past ten (10) years, BPU's system demand has peaked during the winter months. This historical load data was furnished by BPU, which was initially obtained by BPU from their power provider, Missouri River Energy Services (MRES).

Over the past ten (10) years, BPU's system has experienced an average decrease of around 0.8% for the summer peak and winter peak demand loading levels. This decline can be attributed to implementation of a load management system by BPU and increased efficiency of electrical equipment such as lighting, appliances, and air conditioning; which reduces the overall electric load on the system. The overall system peak of 8,074 kW was established in the winter of 2017 during a period of low temperatures. While the winter and summer peaks have declined over the past ten (10) years, they look to be steadying in recent years.

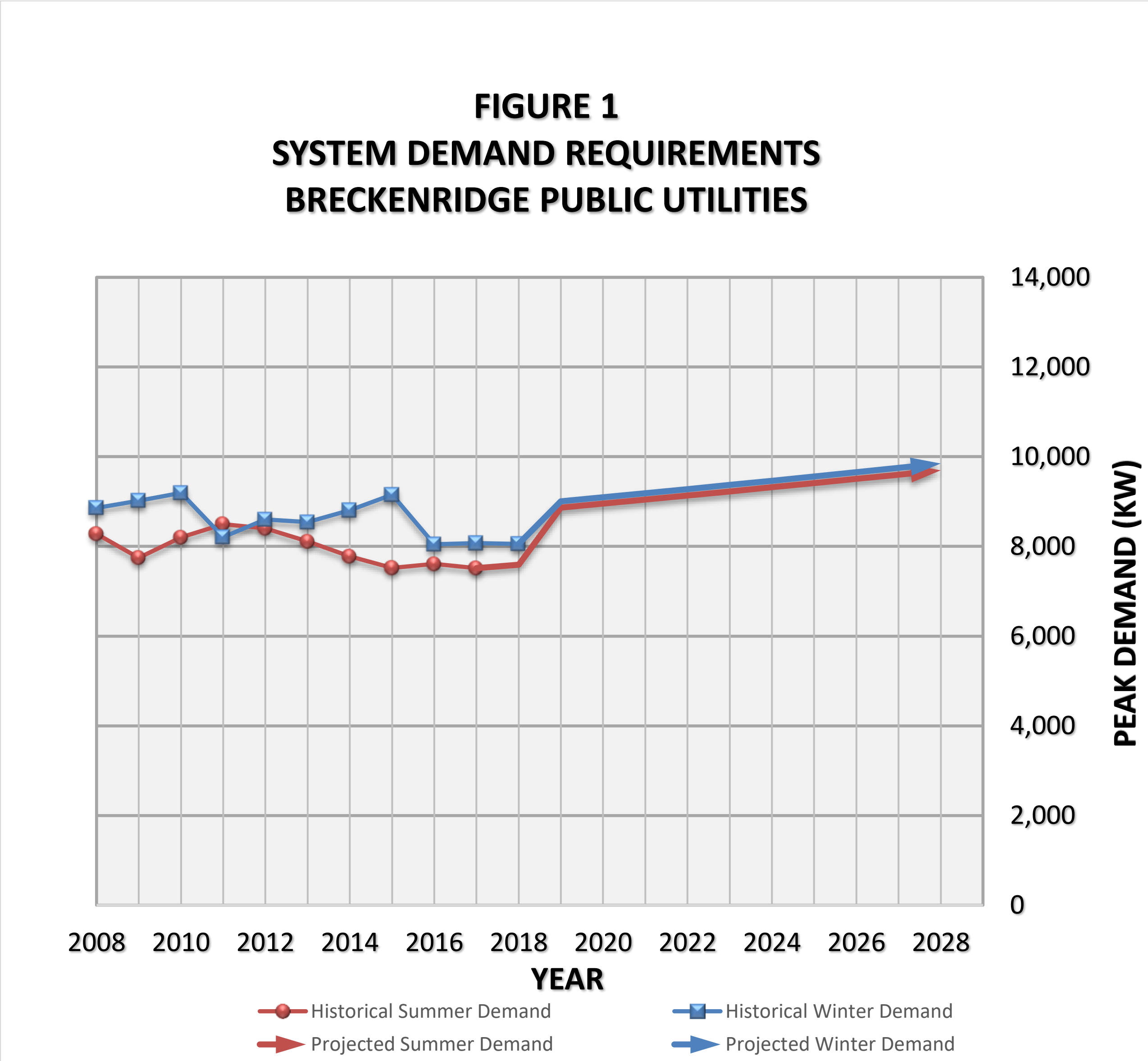
After consultation with BPU staff, the summer and winter projections were based off the 2017 peak as it is believed to be the "system normal" as compared to the variable winter peaks BPU has experienced. The projections for 2019 to 2028 are based on a 1.0% annual growth rate for both the summer and winter after the addition of the new assisted living load (700 kW summer and 350 kW winter) and the new water treatment plant (500 kW). A 1.0% growth rate was chosen to accommodate known future loads such as a new apartment building (100 kW) and residential additions on the north and east portions of the city. These areas are identified in Figure 5 in Appendix A. Based on the load growth projections, the peak system demand will increase from a level of 8,074 kW in 2017 to a level of near 9,848 kW by 2028. BPU staff should be aware that if the load were to grow at a rate substantially higher than this projection, certain improvements over and above those included in this study may be required.

TABLE 1
HISTORIC LOAD DATA AND PROJECTIONS
BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

	Year	Summer Peak Demand (kW)	Winter Peak Demand (kW)
HISTORICAL	2008	8,280	8,857
	2009	7,743	9,016
	2010	8,204	9,193
	2011	8,496	8,209
	2012	8,403	8,599
	2013	8,112	8,540
	2014	7,778	8,807
	2015	7,518	9,156
	2016	7,609	8,047
	2017	7,515	8,074

	Year	Summer Peak Demand (kW)	Winter Peak Demand (kW)
PROJECTIONS:	2018	7,590	8,057
	2019	8,866	9,005
	2020	8,955	9,095
	2021	9,044	9,186
	2022	9,135	9,278
	2023	9,226	9,370
	2024	9,318	9,464
	2025	9,411	9,559
	2026	9,506	9,654
	2027	9,601	9,751
	2028	9,697	9,848

Figure 1 shown below illustrates graphically the load projections shown in Table 1.



2.3. System Energy Requirements and Losses: Table 2 lists the historical energy requirements, sales, and losses and the projected energy purchases for the BPU electric system. Figure 2 is a graph of the historical and projected energy requirements for the system. Sales projections are based on a 54.5% load factor, which is defined as the ratio of the average energy (kWh) to peak demand (kW) calculated over a 1-hour period. Historical energy data was furnished by BPU, but initially obtained by BPU from MRES.

Utilizing total system energy requirements and sales data, the difference, or system energy losses, can be calculated. These are shown graphically in Figure 3 as a percentage of requirements. The historical losses show an average of 8.0% during the time frame of 2008 through 2017. We consider this loss percentage to be above the typical average (~4-7%) for a municipal system with a similar makeup of BPU. Losses could be improved by converting the existing 4.16 kV system to 12.47 kV. A reduction in system energy losses corresponds to real dollars being saved by BPU.

TABLE 2
HISTORIC ENERGY DATA AND PROJECTIONS
BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

	Year	Energy Requirements (MWh)	Energy Sold (MWh)	Losses (%)	Annual Load Factor (%)
HISTORICAL:	2008	46,936	43,075	8.23%	60.49%
	2009	46,354	42,531	8.25%	58.69%
	2010	45,094	41,637	7.67%	56.00%
	2011	44,047	41,123	6.64%	59.18%
	2012	43,012	38,922	9.51%	57.10%
	2013	45,449	42,115	7.34%	60.75%
	2014	44,949	40,761	9.32%	58.26%
	2015	40,911	37,509	8.32%	51.01%
	2016	39,521	36,826	6.82%	56.07%
	2017	39,935	36,659	8.20%	56.46%

	Year	Energy Requirements (MWh)
PROJECTIONS:	2018	40,933
	2019	42,990
	2020	43,420
	2021	43,855
	2022	44,293
	2023	44,736
	2024	45,183
	2025	45,635
	2026	46,092
	2027	46,552
	2028	47,018

Figure 2 shown below illustrates graphically the energy projections shown in Table 2.

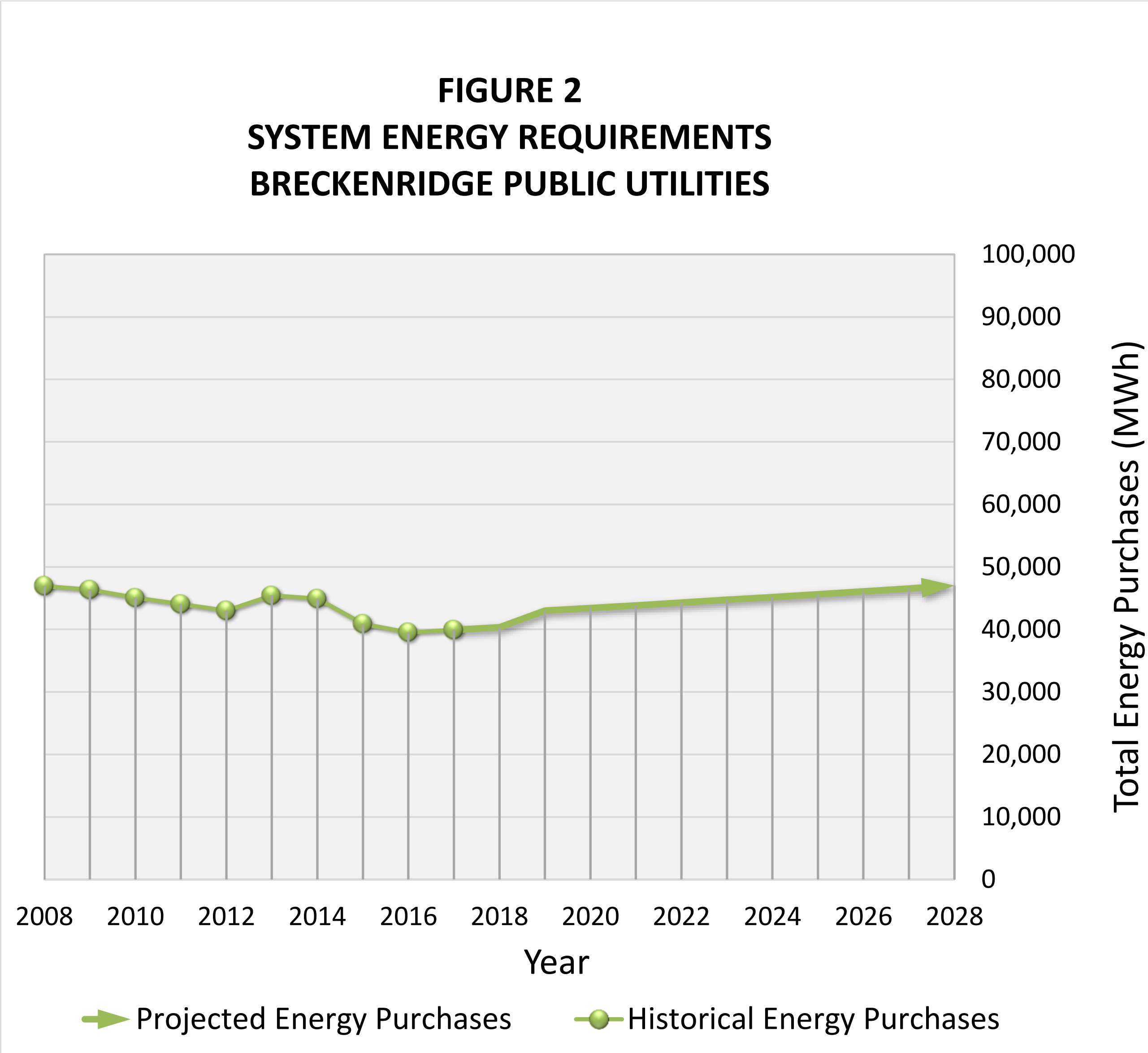
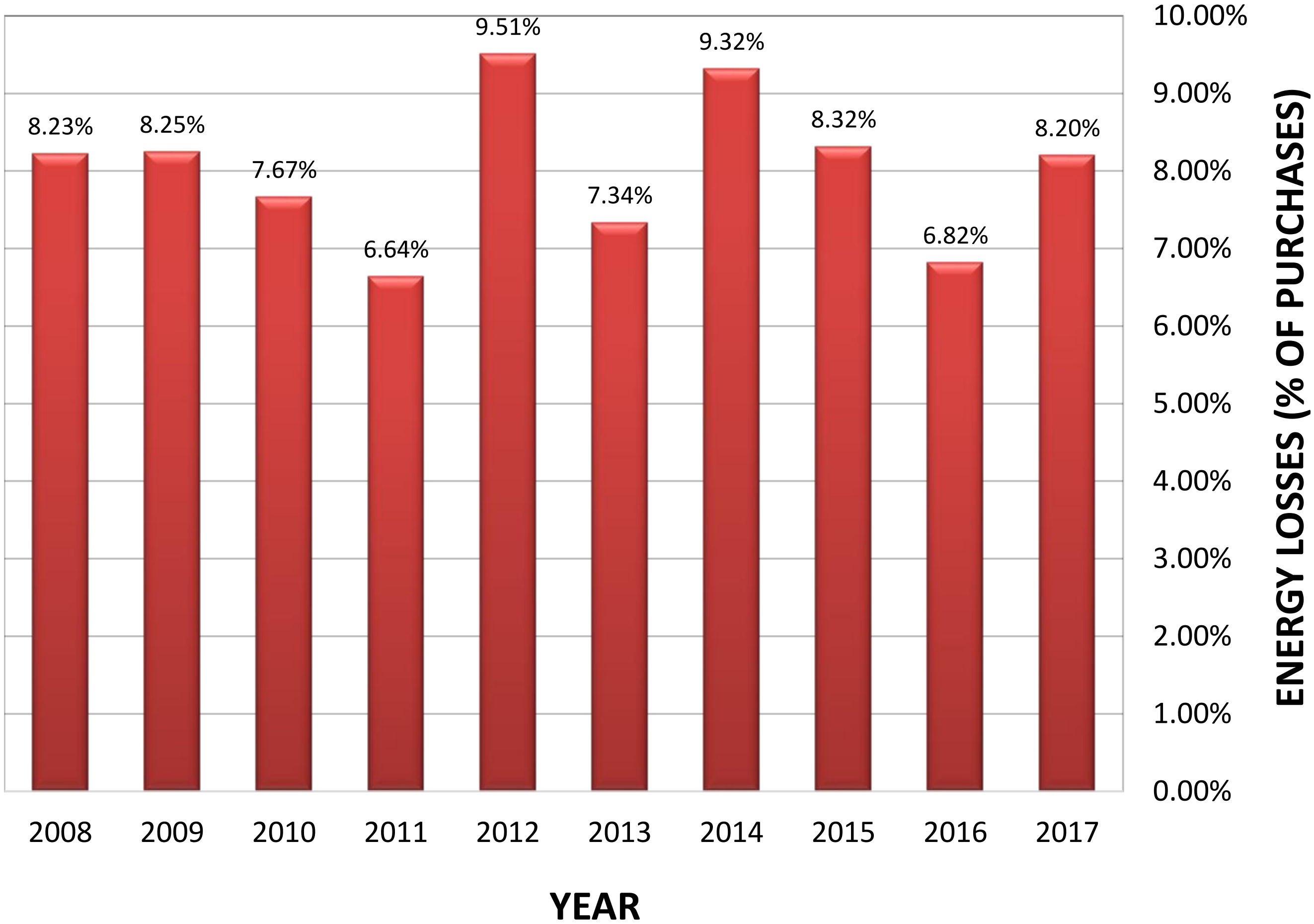


Figure 3 shown below illustrates graphically the losses shown in Table 2.

FIGURE 3
SYSTEM ENERGY LOSSES
BRECKENRIDGE PUBLIC UTILITIES



3. EXISTING SYSTEM ANALYSIS:

3.1. General: The analysis of the existing system consisted of site visits, review of historical records, and analysis in our office. Meetings were held with operating personnel to receive their input covering the electrical system. The study work included a review of the transmission, substation, and distribution components of the electric system. Each of these areas will be discussed in this section. Figures 6 and 7 in Appendix A illustrate BPU's existing electric system.

3.2. Power Supply Arrangement: BPU is a member of Missouri River Energy Services (MRES) and receives a base allocation of power from the Western Area Power Administration (WAPA). Supplemental power is purchased as required through the MRES arrangement.

3.3. Transmission: BPU is currently served by Otter Tail Power Company (OTP) via its 41.6 kV looped transmission lines in the area. At the north end of BPU's territory, BPU line commences at a structure on the OTP 41.6 kV line near the intersection of Grace Ave and Main Street by the Twito Substation. This line section traverses along the west edge of the city and terminates at OTP's transmission line on the south edge of Breckenridge, for a total distance of approximately 2.17 miles long. The Water Plant Substation taps this line near the middle of the line segment just outside the substation yard.

From a separate 41.6 kV OTP line that travels east and west along Grace Ave, a 0.03-mile radial tap feeds the Twito Substation. Additionally, a 0.15-mile radial tap connects to OTP's 41.6 kV line in the southeast corner of Breckenridge and sources the South Substation. The majority of BPU's line segments are original construction and consist of the older "crossarm" type construction with no static wire installed. All BPU-owned transmission facilities generally appear to have been maintained well and are in decent condition.

3.4. Substations: BPU takes delivery of power at transmission voltage at three (3) substations; the Twito Substation, Water Plant Substation and the South Substation, all of which are owned by BPU. The existing system one-line diagram, shown in Figure 6 of Appendix A, illustrates the electrical configuration of the substations.

The Twito Substation is located on the north side of the city and is comprised of one (1) transformer that provides 4.16 kV distribution service and serves approximately 25% of the overall electric system load. Room for expansion at the site is feasible. There is room for expansion to the south of the existing substation as well as to the east. The power transformer has a top-end capacity of 6,250 kVA at 65°C ONAF cooling and is normally used to serve most of the load north of Otter Tail River. This transformer was manufactured in 1989 and therefore it likely has less than half of its useful life remaining. The transformer is protected on the 41.6 kV side by fuses.

The 4.16 kV side of the Twito substation is connected to three (3) single-phase voltage regulators with bypass switches. These regulators were manufactured in 2013 and connect to a lineup of open-air bus which feeds the individual circuits. Three (3) phase reclosers and bypass switches are installed on each circuit to provide fault protection on the distribution system. There are three (3) Kyle type "WE" recloser estimated to be 30 years old and one (1) newer ABB "OVR" recloser. The circuits exit the substation via underground cable.

The Water Plant Substation is located near the west central part of the city and is comprised of one (1) transformer that provides 4.16 kV distribution service and serves approximately 37.5% of the overall electric system load. Room for physical expansion at the site is not feasible. The power transformer has a top-end capacity of 9,375 kVA at 65°C ONAF cooling and is normally used to serve most of the electric load south of the Otter Tail River and on the west side of the city. This transformer was manufactured in 1970 and is near the end of its useful life. The transformer is also protected on the 41.6 kV side by fuses.

Similar to the Twito Substation, the 4.16 kV side of the Water Plant substation is connected to three (3) single-phase voltage regulators with bypass switches. These regulators were manufactured in 2014 and connect to a lineup of open-air bus that feeds the individual circuits. Three (3) phase reclosers and bypass switches are installed on each circuit to provide fault protection on the distribution system. All six (6) circuits have ABB type "VR 3S" recloser that are 20 years old. The circuits exit the substation via underground cable.

The South Substation is located on the south east side of the city and is comprised of one (1) transformer that provides 4.16 kV distribution service and serves approximately 37.5% of the overall electric system load. Room for physical expansion at the site is feasible. There is room for expansion to the north of the existing substation as well as to the east. The power transformer has a top-end capacity of 6,250 kVA at 65°C ONAF cooling and is normally used to serve most of the load on the south and east portions of the city. This transformer was manufactured in 1973 and is also reaching the end of its useful life. The transformer is protected on the 41.6 kV side by fuses.

Again, like the previous substation sites discussed, the South Substation's 4.16 kV bus is connected to three (3) single-phase voltage regulators with bypass switches. These regulators appear to be less than 10 years old and connect to a lineup of open-air bus that feeds the individual circuits. Three (3) phase reclosers and bypass switches are installed on each circuit to provide fault protection on the distribution system. There are four (4) Kyle type "VWE" recloser that are 21 years old. The circuits exit the substation via underground cable.

In general, it is our opinion that the high-side fuse protection and open-air 4.16 kV low-side bus layouts in each BPU substation are design limitations. Utilizing fuses for high-side protection, instead of a circuit switcher or circuit switcher, isn't recommended as they can be slow to operate, which increases the exposure to the substation transformer. The open-air bus design increases the probability of substation outages due to its exposure to weather or invasive varmints.

3.5. Distribution: The existing distribution system provides electric service throughout Breckenridge at a system voltage of 4.16 kV. The 4.16 kV system consists of fourteen (14) circuits; four (4) fed from the Twito Substation, (6) fed from the Water Plant Substation and four (4) fed from the South Substation.

The distribution system has both overhead and underground sections. The majority of the distribution system is constructed in overhead fashion, with the underground construction located particularly in newer areas of the city. Figure 7 in Appendix A is a circuit diagram of the existing distribution system, and depicts the areas served by each distribution circuit.

The physical condition of the existing 4.16 kV distribution system is average in general. No obvious problems with construction methods were observed. The backbone of the 4.16 kV distribution system is largely made up of #2 CU, 1/0 CU and 4/0 ACSR overhead circuits, with some 4/0, 500 MCM and 750 MCM aluminum underground circuits. We believe that in an effort to increase reliability, underground circuitry should be considered for new construction as much as possible.

The overhead sections are the oldest parts of the system and are in need of eventual replacement. In addition, many segments of the system cannot be backfed during certain outage conditions. Rather than spending large amounts of money on repairs for this system, due to its age and electrical limitations, we recommend that BPU convert the 4.16 kV system to 12.47 kV underground construction. This will be discussed more in following report sections.

In general, BPU has made an effort to loop mainline circuits. Loops provide multiple sources of feed for easy switching and backup during fault conditions, and should be constructed and maintained whenever practical. There are some areas for improvement on the distribution system regarding loop and tie points.

In three-phase switching locations where single-phase disconnect switches or fused cutouts are used to tie lines together during outage conditions, BPU should consider installing and using group-operated three-phase switches in lieu of cutouts. It is not good practice to use single-phase disconnect switches or cutouts for three-phase switching as each phase must be tied in individually, which is hard on three phase equipment down-line of the tie point.

Several areas of the 4.16 kV underground system consists of older cable that was manufactured with an open concentric neutral. Cable constructed in this fashion is notorious for causing voltage issues and outages and should be replaced with jacketed concentric neutral cable to improve reliability.

The distribution system also contains many sectionalizing devices. A coordination study is being completed independently to determine correct relay settings and fuse sizes for coordination of equipment throughout the system. After the new equipment settings and sizes are implemented, the system will do a better job of isolating faults to smaller areas, and provide better protection to equipment. In addition, fuse inventory will be reduced, and consistency will be maintained throughout the system.

3.6. Voltage and Capacity Analysis: A load flow analysis of the distribution system was performed using the Milsoft WindMil® computer modeling program. This program is a commercial product that can perform load flow, short-circuit, and other analysis of a modeled electrical system. In particular, we wanted to analyze the voltage level and capacity constraints of the system under existing and projected peak loading conditions. This model was constructed based on the mapping information for BPU's electric system. Load data by substation and circuits and for large power consumers was collected from BPU staff. We feel the model provides an accurate tool for analyzing various every-day scenarios such as the loss of specific pieces of equipment, different switching scenarios, effects of load growth on the system, and available fault currents to a particular site. The ability to integrate GIS mapping data also exists within this software platform. As such, we recommend that BPU make use of this tool as the need arises, and that any significant future GIS mapping updates be updated in the computer model as well.

Our computer analysis indicates that BPU experiences low voltage conditions on areas of the distribution system, even with no outage conditions present. In particular, the voltage condition on areas of the primary system exceeds American National Standard Institute (ANSI) limits for Class A voltage service during more heavily loaded periods. This situation will further deteriorate as load grows, since voltage drop is directly proportional to load current.

Under emergency scenarios such as the loss of a distribution feeder or substation bus during heavily loaded periods, unacceptable voltage conditions arise on areas of the primary system that exceed American National Standard Institute (ANSI) limits for Class A voltage service. This situation will further deteriorate as load grows, since voltage drop is directly proportional to load current. These deficiencies suggest the need for system modifications, especially when considering anticipated load growth on the system.

Under normal peak operating conditions, the system transformation capacity and relative loading is shown in the following Table 3:

TABLE 3
SUBSTATION CAPACITIES

Substation	Maximum Transformer Capacity	2017 Winter Loadings	Projected 2028 Winter Loadings
Twito Transformer	6,250 kVA	8,335 kVA	10,405 kVA
Water Plant Transformer	9,375 kVA		
South Transformer	6,250 kVA		
Total	21,875 kVA		

It is apparent that at both current and projected load levels, the source substations have adequate capacity under normal operating conditions. However, during the loss of one of the transformers, capacity issues emerge, which will be discussed in the following section and is highlighted in the analysis tables shown in Appendix B.

3.7. System Deficiencies: The following are deficiencies found in analysis of the existing system under existing and projected loading:

3.7.1. The Water Plant Substation transformer is 59 years old and is nearing the end of its useful life.

3.7.2. The South Substation transformer is 46 years old and creeping toward the end of its useful life.

3.7.3. Voltage violations on Water Plant Substation Circuit B and South Substation Circuits A and D under system intact peak loading. This situation will worsen under anticipated future load growth.

3.7.4. The South Plant Substation transformer is nearing capacity overload during contingency peak loading circumstances and experiences overloading in these scenarios under the ten-year loading levels.

3.7.5. Inability to handle an outage of the Water Plant Substation during peak loading periods without poor voltage conditions, overloading distribution circuits and overloading the South Substation Transformer. This situation will worsen under anticipated future load growth.

3.7.6. Inability to handle an outage of the South Substation during peak loading periods without poor voltage conditions and overloading distribution circuits. This situation will worsen under anticipated future load growth.

3.7.7. Inability to handle an outage of the Twito Substation during peak loading periods without poor voltage conditions on the distribution circuits. This situation will worsen under anticipated future load growth on the north side of the city.

3.7.8. In some circuits, single-phase "disconnects" or "cutouts" are used to tie lines together during outage conditions, which has the potential of damaging three-phase equipment down line of the tie point.

3.7.9. Cables with open concentric neutrals should be replaced with jacketed conductor to prevent voltage issues and outages that result from the neutral conductor corroding away and causing cable failure.

3.7.10. Some sections of the 41.6 kV transmission line consist of older original construction and don't include a static wire for lightning protection.

The case study summaries, in Appendix B, depict the results of the detailed analysis of the system intact and the emergency/contingency scenarios for the existing system with existing loads and for the existing system with projected 2028 loads.

4. DESIGN CRITERIA:

4.1. General: The criterion for proper design of electric utility systems is developed in the following paragraphs. All criteria are important and all efforts were made to satisfy them in the design of the system plan.

4.2. System Reliability: In general, BPU should adopt a policy to maintain "N-1" or "single contingency" design, on all transmission, substation, and distribution facilities. "Single contingency" design is defined as the ability to operate the system at peak load with the loss of any single major system component. The electric customers have undoubtedly come to expect that electric service be available at all times, except for minor weather-related outages. We feel that it is important that the electric system be able to survive the loss of any one piece of equipment or line section, and still be able to carry peak load while providing Class A service.

4.3. Voltage Levels: Voltage levels at the consumer's premises should be maintained within ANSI limits for Class A service at all times. ANSI voltage limits are as follows:

Maximum Voltage	126 volts
Minimum Voltage	110 volts
Maximum Daily Voltage Swing	8 volts

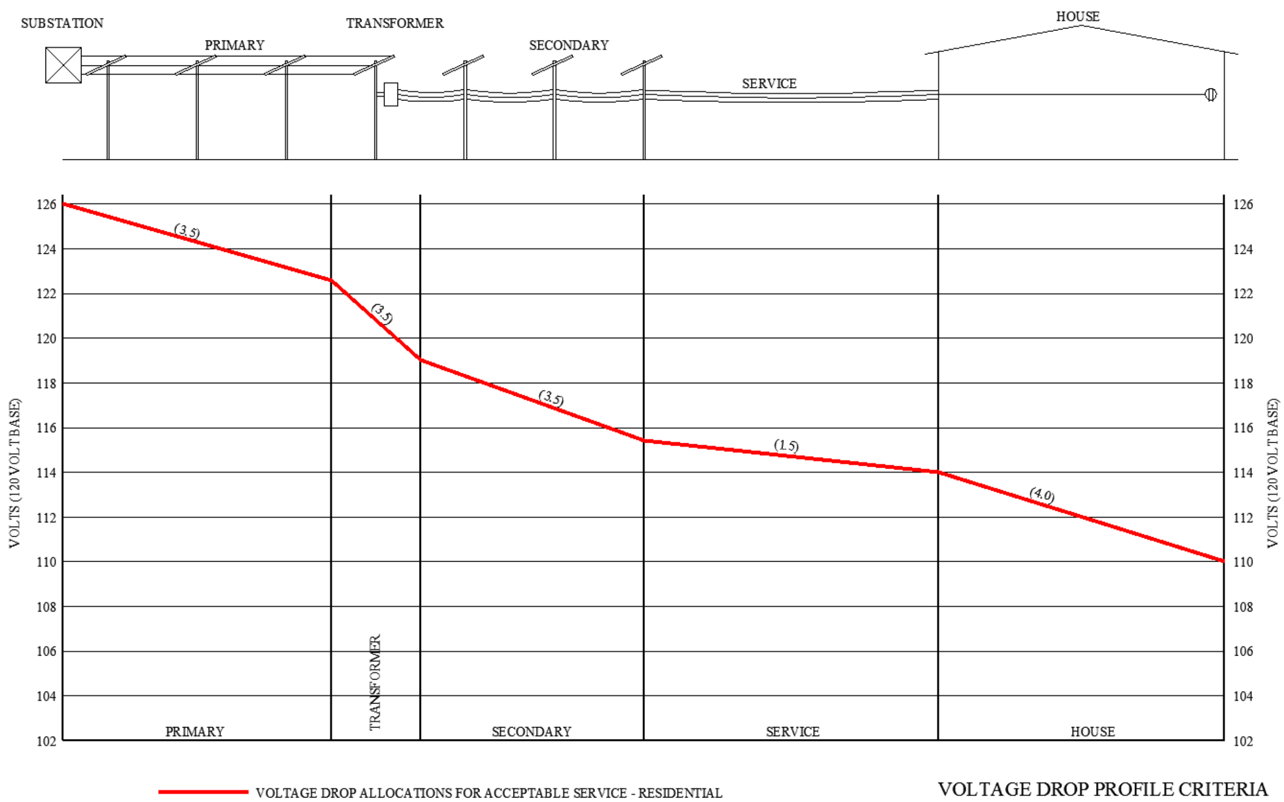
The figures given above are the maximum and minimum voltages that any customer could experience at utilization equipment, and still be in compliance with ANSI standards. In addition, no customer could experience a difference (swing) of more than 8 volts in any 24 hour period, without violating ANSI standards.

Voltage drop is a natural occurrence on an electric system. Voltage drop through the various pieces of electrical equipment must be accommodated and included in the planning process. In order for the voltage drop to not exceed that allowed by standards, the following components of drop in the various portions of the system are assumed:

Primary Circuits	3.5 volts
Distribution Transformers	3.5 volts
Secondaries	3.5 volts
Services	1.5 volts
Customer Wiring	4.0 volts
	16.0 volts

The voltage drop profile in Figure 4 illustrates the allowable voltage drop components listed previously. The specific portion of the assigned voltage drop that is controllable directly by a utility is that portion assigned to primary circuits. Hence, planning is done to ensure that voltage drop on primary circuits does not exceed 3.5 volts, under the assumption that the other components of drop will be present.

FIGURE 4
VOLTAGE DROP PROFILE CRITERIA



VOLTAGE DROP PROFILE CRITERIA

In addition to the voltage criteria developed above, consideration of equipment thermal capacity was used in evaluation of the system. This criterion requires that all equipment, including substation transformers and distribution lines be kept within published thermal limits at all times, during both normal and emergency operations, so as not to become overloaded.

4.4. Flexibility and Expandability: Future system improvements should be designed to provide an optimum number of combinations of circuit configurations for serving existing loads as well as future system development. This is accomplished by designing multiple tie and switching points between distribution circuits, as well as providing sufficient distribution circuits themselves. A flexible system will allow the ability to transfer loads from circuit to circuit.

The system should also be designed to be expandable, such that new loads can be added to it without major upheaval to the existing system. Sufficient capacity must be available in substations and lines to handle the addition of a reasonably large load without scrambling to provide facilities for it. This does not mean, however, that the system should be overbuilt, but it does mean that reasonably sufficient capacity should exist to handle new loads.

5. CAPITAL IMPROVEMENTS PLAN:

5.1. General: The Capital Improvements Plan (CIP) describes in general the improvements to the system recommended over the next ten (10) years to eliminate the system deficiencies identified in the previous sections of this report and to satisfy the planning criteria listed in the foregoing section. The following sections detail the proposed capital improvements for BPU's electric system.

5.2. Recommended Improvements – General: It is recommended to complete a conversion of the distribution system voltage from 4.16 kV to 12.47 kV to help correct the distribution voltage and capacity violations previously discussed and highlighted in Appendix B. Using 12.47 kV as the system voltage will decrease overall system losses and improve voltage conditions during large loading levels and during the loss of a circuit or substation. A 12.47 kV system will be able to handle future load growth much easier than the existing 4.16 kV system. A 4.16 kV system requires 3 times the current that a 12.47 kV system requires to carry the same amount of power. This higher level of current uses most of the capacity available on BPU's distribution circuits to a point that the distribution system will not be able to adequately handle growth. Using a 12.47 kV system will lessen the burden on the distribution lines and open up more capacity in the distribution system.

If BPU were to elect to stay at the 4.16 kV distribution voltage, an exorbitant number of new distribution feeders and/or a new substation location would need to be added to correct the voltage and capacity violations realized. It is estimated that $5-8 million would need to be invested in the 4.16 kV distribution system to satisfy the analysis criteria to meet just the existing system peak. Even more investment would need to be made to satisfy the peak under the 10-year loading scenario. For this reason and to provide for an electric system that has room to grow in the future, it is our recommendation to proceed with the distribution voltage conversion to 12.47 kV option.

5.3. Recommended Improvements – Phase 1: The improvements recommended for Phase 1 are shown in Figure 8 in Appendix A, and are described in this section.

5.3.1 Construction Description – Phase 1: Construction in this Phase includes the following items:

- Build a new substation with a 69/41.6 kV high side and 12.47 kV low side adjacent to the existing South Substation.
- Convert the 4.16 kV system south of the railroad to underground 12.47 kV and transfer to the new substation.
- Install two (2) 12.47-4.16 kV satellite step-down transformers at tie points with the existing 4.16 kV system north of the railroad.
- Replace cable that is open concentric with jacketed concentric neutral cable south of the railroad.

5.3.2 Timing of Phase 1: The improvements in Phase 1 have been assigned to be constructed in the 2019 to 2021 timeframe. These improvements are the first step toward correcting deficiencies that currently exist on the system.

Discussion of Phase 1: The substation work proposed in Phase 1 involves building a new substation either north or east of the existing South Substation. The construction method proposed for the new substation will be drastically different than the other substations on BPU's system. The new substation will have a new control building to house a new lineup of switchgear and control panels. A relayed circuit interrupter is proposed to protect the new 10/14 MVA power transformer. A circuit interrupter is a three-phase device that is electrically operated. The device takes the place of power fuses and allows electronic relaying of the transformer for better protection. Since the device is a three-phase gang-operated device, it will prevent any single phasing of customers on the system. Also, the power transformer will be ordered with a dual rating on the high-side, 69 kV and 41.6 kV. The other high-side equipment would also be insulated for 69 kV. This will allow for a quick and smooth transition in the future when OTP increases the system voltage to 69 kV.

The proposed substation design has several advantages over typical rural substation designs. For one, this design features enclosed equipment, which includes the secondary bushings of the transformer, power cable, and metalclad switchgear breakers. In addition to being more aesthetically pleasing, the enclosed equipment on the secondary side greatly reduces the possibility of outages due to less exposure to weather and varmints. This design will increase the reliability of BPU's system. Other work necessary to construct the new substation will include site work, ground grid, conduit, foundations, steel structures, buswork, fencing, control wiring, power cabling, and a DC power system.

The distribution work in Phase 1 will consist of converting the 4.16 kV system south of the railroad from overhead 4.16 kV to 12.47 kV underground. The distribution conversion work in this phase, and in the following phases, includes the construction of mainline circuitry that has switching equipment as needed throughout the system to allow for more safe and expedient switching capabilities on the system. Also, the distribution system design will include the installation of conduit for the primary cables, which matches BPU's current design standard. The conversion of this portion of the 4.16 kV system to 12.47 kV will begin to eliminate the deficiencies associated with poor voltage and backfeeding of the existing 4.16 kV system. In addition, system energy losses will be lowered as a result.

5.3.3 Cost of Phase 1: The construction costs in this CIP are 4th quarter 2018 estimates and include labor, materials, engineering, and contingencies, and assume Contractor-built facilities. Costs for any required land, right-of-way, permitting, and distribution removals is not included, and costs for future work are not escalated to include the effects of inflation. The cost estimates are intended for budgetary uses only.

Phase 1 cost estimates are as follows:

South Substation Rebuild	Estimated Cost
10/14 MVA, 69/41.6 kV-12.47 kV transformer	$ 575,000
69 kV circuit switcher, control panel	112,000
15 kV switchgear (1M, 4F)	225,000
Steel, 69 kV buswork, foundations, ground grid, site work, conduit, ductbank, fence, mobilization	460,000
Control building, AC/DC wiring, control wiring, and power cables	238,000
Contingencies & engineering	290,000
Subtotal:	$ 1,900,000

Distribution Improvements	Estimated Cost
Install two satellite step-down transformers to tie the 12.47 kV and 4.16 kV systems	$ 100,000
Convert and bury 4.16 kV system south of the railroad to 12.47 kV underground	3,570,000
Contingencies & engineering	550,000
Subtotal:	$ 4,220,000

Total – Phase 1: $ 6,120,000

5.4. Recommended Improvements – Phase 2: The improvements recommended for Phase 2 are shown in Figure 8 in Appendix A, and are described in this section.

5.4.1 Construction Description – Phase 2: Construction in this Phase includes the following items:

- Convert the 4.16 kV system north of the railroad and south of the Otter Tail River to underground 12.47 kV and transfer to the new substation.

- Move the two (2) 12.47-4.16 kV satellite step-down transformers to tie points with the existing 4.16 kV system north of Otter Tail River.
- Replace cable that is open concentric with jacketed concentric neutral cable.

5.4.2 Timing of Phase 2: The improvements in Phase 2 have been assigned to be constructed in the 2022 to 2024 timeframe.

5.4.3 Discussion of Phase 2: The Phase 2 distribution improvements recommended will continue to correct the deficiencies that exist on the system. Work during this phase will consist mainly of converting the 4.16 kV circuits fed from the Water Plant Substation to 12.47 kV and feeding them from the new South Substation. This eliminates the need for the aging Water Plant transformer that will be more than past its useful life at this time.

5.4.4 Cost of Phase 2: The construction costs in this CIP are 4th quarter 2018 estimates and include labor, materials, engineering, and contingencies, and assume Contractor-built facilities. Costs for any required land, right-of-way, permitting, and distribution removals is not included, and costs for future work are not escalated to include the effects of inflation. The cost estimates are intended for budgetary uses only.

Phase 2 cost estimates are as follows:

Distribution Improvements	Estimated Cost
Relocate the two satellite step-down transformers to tie the 12.47 kV and 4.16 kV systems	$ 20,000
Convert and bury 4.16 kV system north of the railroad and south of Otter Tail River to 12.47 kV 12.47 kV underground	4,100,000
Contingencies & engineering	630,000
Subtotal:	$ 4,750,000
Total – Phase 2:	**$ 4,750,000**

5.5. Recommended Improvements – Phase 3: The improvements recommended for Phase 3 are shown in Figure 8 in Appendix A, and are described in this section.

5.5.1 Construction Description – Phase 3: Construction in this Phase includes the following items:

- Build a new substation at 69/41.6 kV high side to 12.47 kV low side adjacent to the existing Twito Substation.
- Convert the 4.16 kV system north of the Otter Tail River to underground 12.47 kV and transfer to the new Twito Substation.
- Replace cable that is open concentric with jacketed concentric neutral cable.

5.5.2 Timing of Phase 3: The improvements in Phase 3 will be scheduled to construct in the 2025 to 2028 timeframe. These improvements are the final steps toward correcting deficiencies that currently exist on the system.

5.5.3 Discussion of Phase 3: The substation work involves building a new substation either south or east of the existing Twito substation. The design of this substation would be identical to the one described in the previous Phase 1 section for the new South Substation.

This phase will complete the conversion of the distribution system to 12.47 kV, and will involve converting the remaining 4.16 kV system from to 4.16 kV to 12.47 kV underground construction design. With this conversion complete, the capacity and voltage violations highlighted in this report will be mitigated.

5.5.4 Cost of Phase 3: The construction costs in this CIP are 4th quarter 2018 estimates and include labor, materials, engineering, and contingencies, and assume contractor-built facilities. Costs for any required land, right-of-way, permitting, and distribution removals is not included, and costs for future work are not escalated to include the effects of inflation.

Phase 3 cost estimates are as follows:

Twito Substation Rebuild	Estimated Cost
10/14 MVA, 69/41.6 kV-12.47 kV transformer	$ 575,000
69 kV circuit switcher, control panel	112,000
15 kV switchgear (1M, 4F)	225,000
Steel, 69 kV buswork, foundations, ground grid, site work, conduit, ductbank, fence, mobilization	460,000
Control building, AC/DC wiring, control wiring, and power cables	238,000
Contingencies & engineering	290,000
Subtotal:	$ 1,900,000

Distribution Improvements	Estimated Cost
Convert and bury 4.16 kV system south of the railroad to 12.47 kV underground	$ 2,300,000
Contingencies & engineering	360,000
Subtotal:	$ 2,660,000

Total – Phase 3:	**$ 4,560,000**

5.5. Cost Summary:

Phase	Estimated Cost
Phase 1 Improvements (2019-2021)	$ 6,120,000
Phase 2 Improvements (2022-2024)	4,750,000
Phase 3 Improvements (2025-2028)	4,560,000
Total – 10 – Year CIP:	**$ 15,430,000**

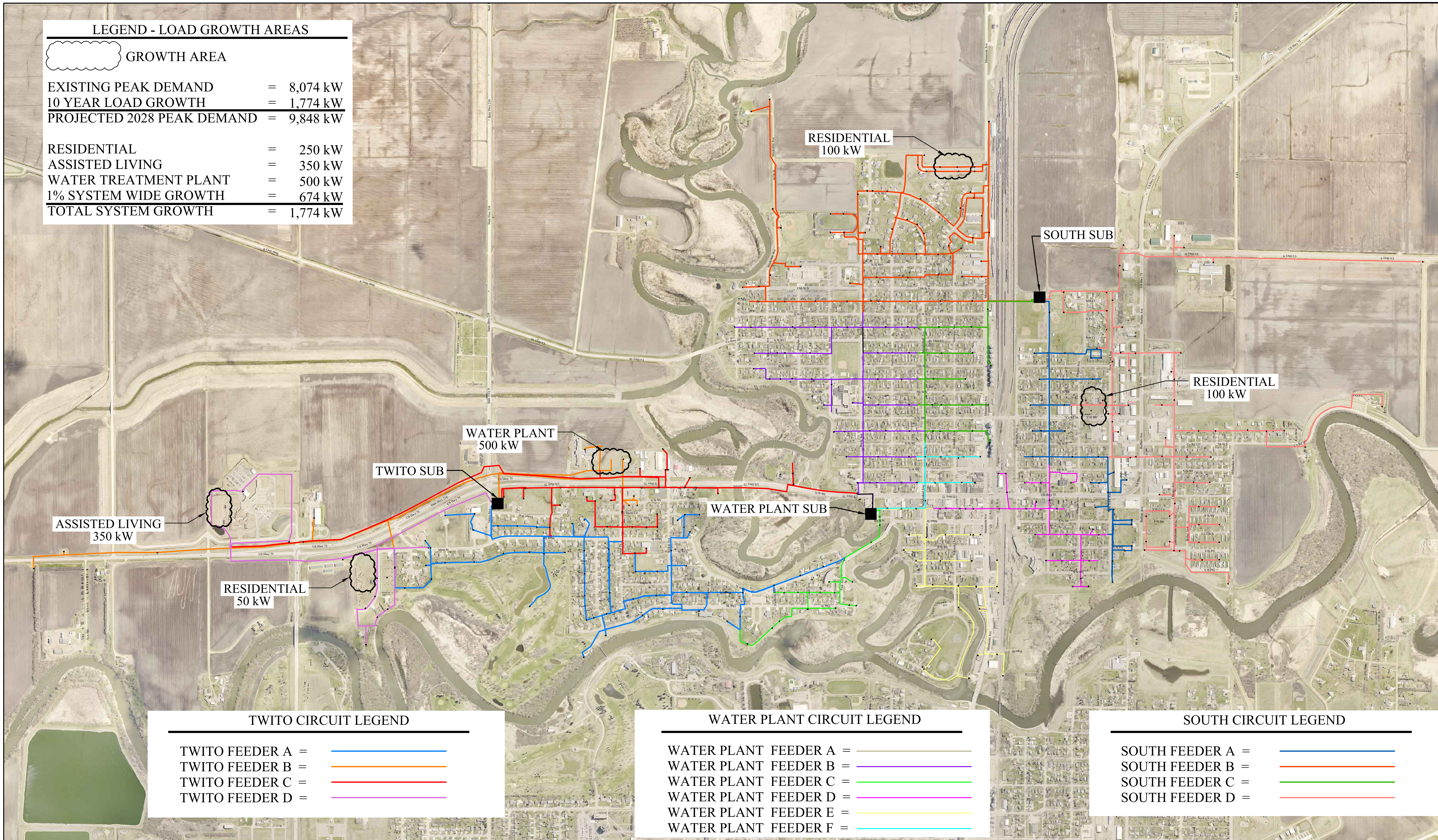
5.6. Post CIP Period Improvements: Additional improvements may be required after the 10-year CIP period. These items were intentionally left out of the 10-year CIP plan due to their costs and the sequence of construction that was required to complete them. These improvements include rebuilding BPU's existing 41.6 kV transmission system to 69 kV specifications, which includes adding a fourth wire to be used as lightning protection. An estimated cost for these improvements is estimated to be $900,000.

5. RECOMMENDATIONS AND CONCLUSIONS:

It is our opinion that continuous planning is important, and we believe that this plan should be formally reviewed, preferably every three (3) to five (5) years, but no more than seven (7) years, to ascertain its relevance and to make appropriate adjustments. A relatively minor amount of analysis and planning done on a frequent basis means that large scale comprehensive planning efforts based at lengthy intervals are not required. This allows the system to be flexible and to adjust to changing system conditions. It also tends to provide the right amount of capacity at the right time as system loads change. We believe that BPU should commit to this planning method and make it a practice in their operation.

We recommend that BPU adopt this capital improvements plan as its basis for future system development. We further recommend that the system improvements be authorized, so that they can be completed in the time frame proposed. We acknowledge the input of BPU staff in preparation of this study and look forward to implementation of the improvements contained herein.

APPENDIX A



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P:\04\254\02\DWG\FIG5-8.DWG

REV	DATE	DESCRIPTION
A	12-03-2018	ISSUED FOR REPORT

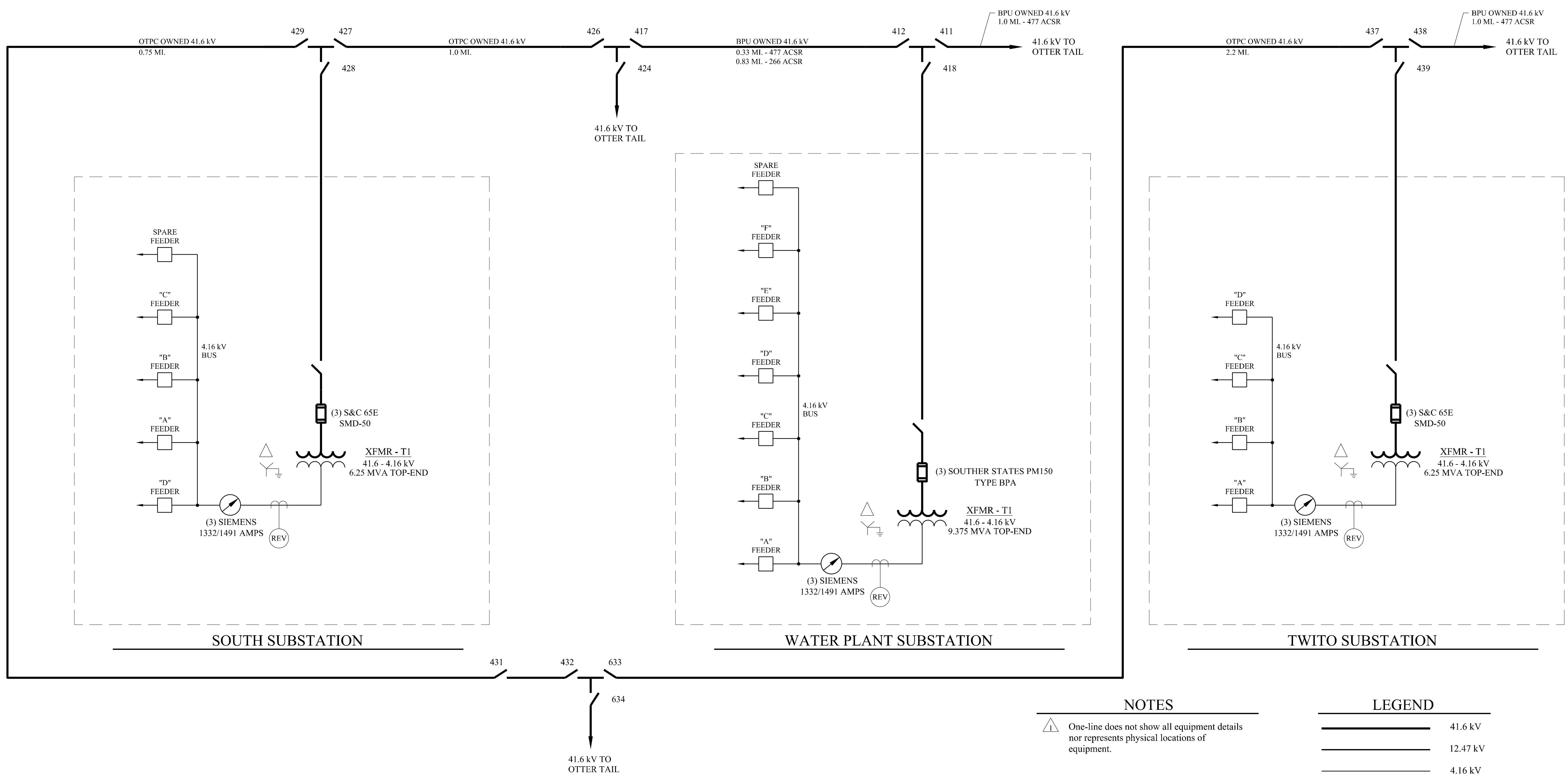
DGR ENGINEERING

Project Manager: TWM
Designer: DSM
Project Number: 425402
Phone: (712) 472-2531

BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

LOAD GROWTH AREAS
ELECTRIC SYSTEM STUDY

SHEET FIGURE 5



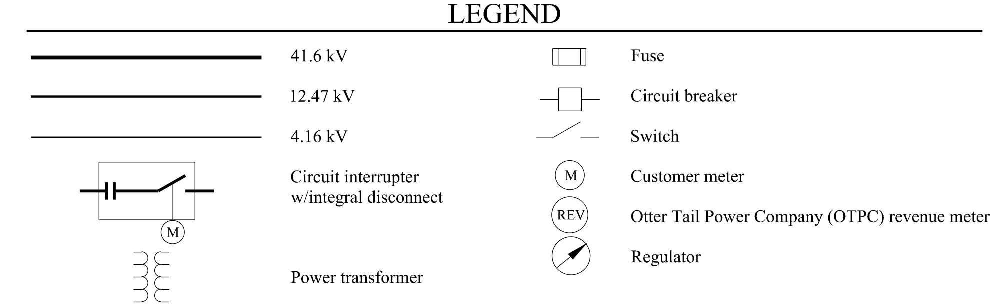
NOTES

1. One-line does not show all equipment details nor represents physical locations of equipment.

LEGEND

41.6 kV	
12.47 kV	
4.16 kV	
2.4 kV	

LEGEND



REV	DATE	DESCRIPTION
A	12-01-2018	ISSUED FOR REPORT

DGR ENGINEERING

Project Manager: TWM
Designer: DSM
Project Number: 425402
Phone: (712) 472-2531

BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

BASIC ONE-LINE DIAGRAM
ELECTRIC SYSTEM STUDY

SHEET FIGURE 6

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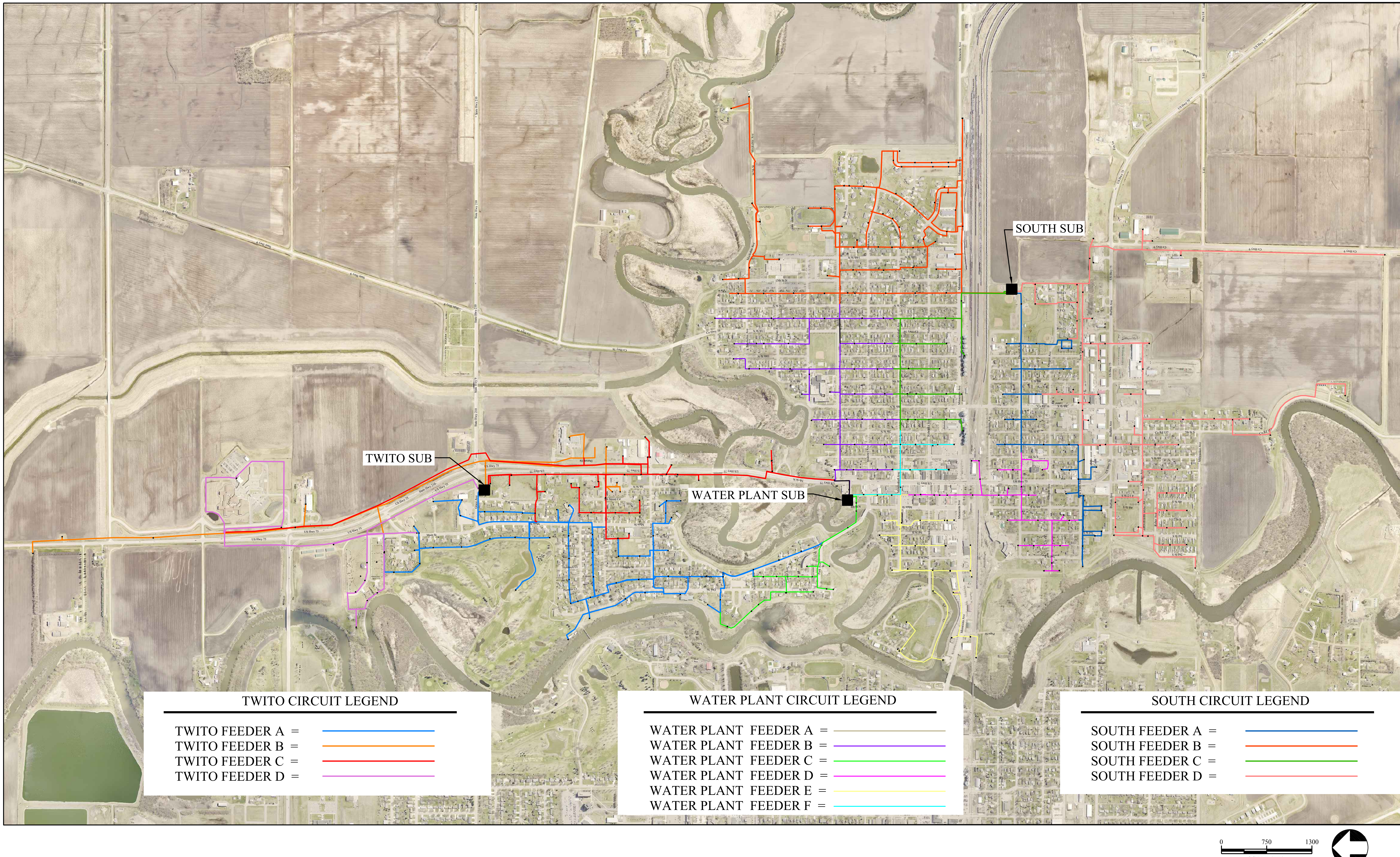
P:\04\254\02\DWG\FIG.6&9.DWG



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P:\04\254\02\DWG\FIG5-8.DWG

REV	DATE	DESCRIPTION
A	12-03-2018	ISSUED FOR REPORT

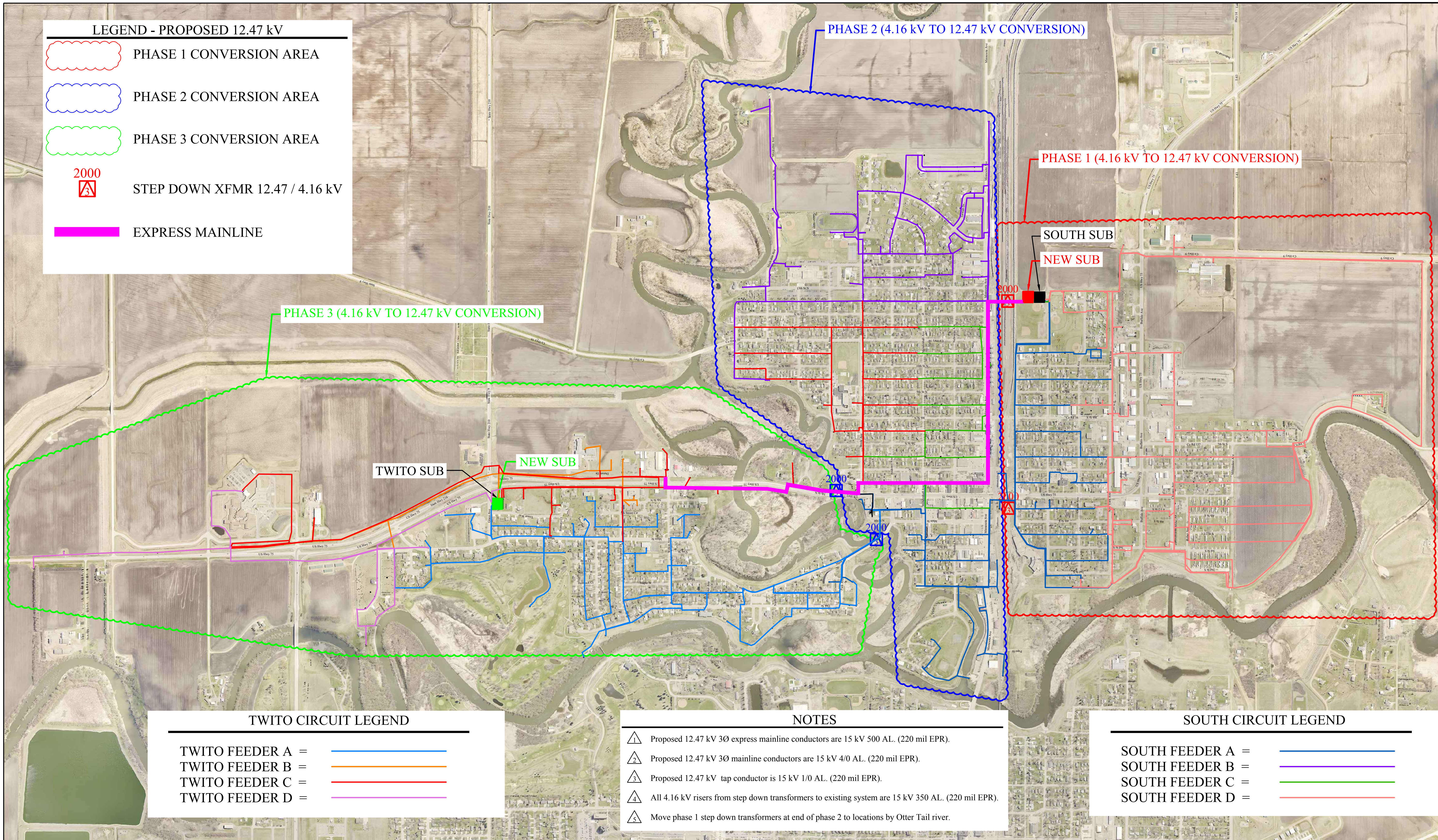
DGR ENGINEERING

Project Manager: TWM
Designer: DSM
Project Number: 425402
Phone: (712) 472-2531

BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

EXISTING - ELECTRIC DISTRIBUTION
ELECTRIC SYSTEM STUDY

SHEET FIGURE 7



NOTES

1. Proposed 12.47 kV 3Ø express mainline conductors are 15 kV 500 AL. (220 mil EPR).
2. Proposed 12.47 kV 3Ø mainline conductors are 15 kV 4/0 AL. (220 mil EPR).
3. Proposed 12.47 kV tap conductor is 15 kV 1/0 AL. (220 mil EPR).
4. All 4.16 kV risers from step down transformers to existing system are 15 kV 350 AL. (220 mil EPR).
5. Move phase 1 step down transformers at end of phase 2 to locations by Otter Tail river.

REV	DATE	DESCRIPTION
A	12-03-2018	ISSUED FOR REPORT

DGR ENGINEERING

Project Manager:	TWM
Designer:	DSM
Project Number:	425402
Phone:	(712) 472-2531

BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

PROPOSED - ELECTRIC DISTRIBUTION
ELECTRIC SYSTEM STUDY

SHEET FIGURE 8

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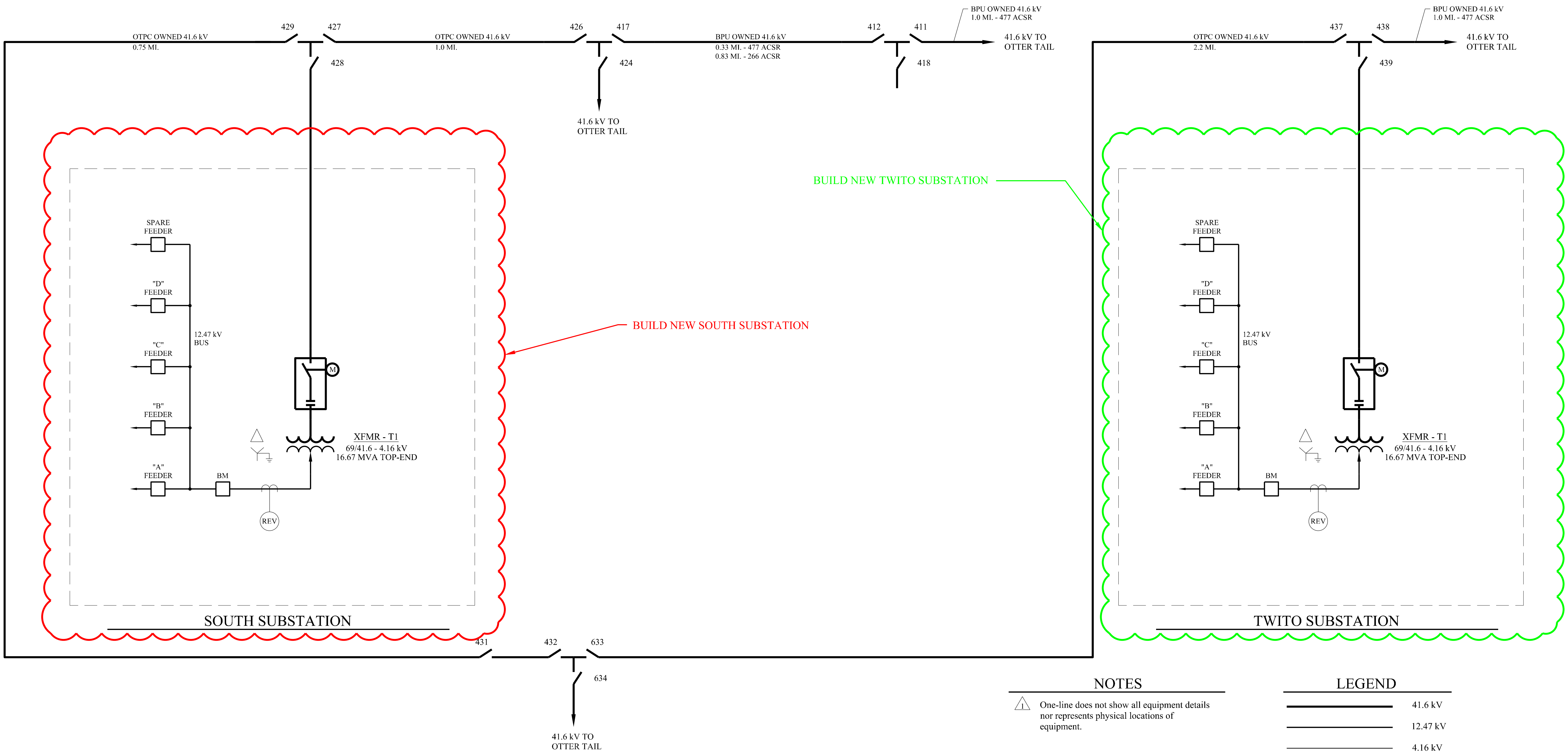
P:\04\254\02\DWG\FIG5-8.DWG



PHASE 1 IMPROVEMENTS

PHASE 3 IMPROVEMENTS

NOTES

1. One-line does not show all equipment details nor represents physical locations of equipment.

LEGEND

41.6 kV

12.47 kV

4.16 kV

2.4 kV

LEGEND

41.6 kV

12.47 kV

4.16 kV

Circuit interrupter w/integral disconnect

Power transformer w/LTC

Fuse

Circuit breaker

Switch

Customer meter

Dairyland revenue meter

Regulator

REV	DATE	DESCRIPTION
A	12-01-2018	ISSUED FOR REPORT

DGR ENGINEERING

Project Manager: TWM
Designer: DSM
Project Number: 425402
Phone: (712) 472-2531

BRECKENRIDGE PUBLIC UTILITIES
BRECKENRIDGE, MINNESOTA

PROPOSED - BASIC ONE-LINE DIAGRAM
ELECTRIC SYSTEM STUDY

SHEET FIGURE 9

APPENDIX B

Table of Contents
- Breckenridge Public Utilities
- DGR Project No.: 425402

Scenario Legend

Scenario	Existing System & Loading
0	System Intact
1	Loss of Twito Sub
2	Loss of Water Plant Sub
3	Loss of South Sub

- **Breckenridge Public Utilities**
- **DGR Project No.: 425402**

0	**Scenario Selection**
System Intact	

System Analysis Configuration

Existing System & Loading

80	**= 80% Capacity Warning**
100	**= 100% Capacity Violation**
+3.5	**= +3.5 Voltage Drop Violation**

		Ratings (kVA)			**Phase Amps**			**Max V Drop**						
Scenario	**Transformer**	**Base**	**Top**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
0	Twito Sub Xfmr	5,000	6,250	Twito Sub	283	233	309	1.94	1.49	1.80	1,973	1,892	386	95.91%
0	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	396	509	425	2.12	3.85	1.58	3,188	3,026	618	94.90%
0	South Sub Xfmr	5,000	6,250	South Sub	444	440	439	2.72	4.73	3.72	3,174	3,051	629	96.13%
				TOTALS	1123	1182	1173	2.72	4.73	3.72	8,335	7,969	1,632	95.61%

				Phase Amps			**Max V Drop**						
Scenario	**Circuit**		**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
0		Twito A Feeder	Twito Sub	111	62	125	1.94	0.00	1.60	705	703	(53)	99.72%
0		Twito B Feeder	Twito Sub	48	48	46	1.05	1.05	1.01	342	321	118	93.84%
0		Twito C Feeder	Twito Sub	41	48	46	0.54	0.57	0.49	326	310	102	94.95%
0		Twito D Feeder	Twito Sub	83	75	92	1.64	1.49	1.80	600	558	218	93.14%
0		WP A Feeder	Water Plant Sub	12	12	12	0.01	0.01	0.01	89	81	37	91.09%
0		WP B Feeder	Water Plant Sub	121	178	108	2.12	3.85	1.58	977	957	197	97.94%
0		WP C Feeder	Water Plant Sub	52	51	58	0.77	0.82	1.03	387	348	169	89.96%
0		WP D Feeder	Water Plant Sub	79	115	89	1.26	2.44	1.39	677	674	57	99.65%
0		WP E Feeder	Water Plant Sub	80	111	105	1.09	2.14	1.29	711	647	296	90.93%
0		WP F Feeder	Water Plant Sub	52	42	52	0.39	0.13	0.54	347	319	(138)	91.75%
0		South A Feeder	South Sub	65	76	102	2.40	3.19	3.72	584	519	266	89.00%
0		South B Feeder	South Sub	140	114	118	2.50	2.28	2.58	895	860	248	96.09%
0		South C Feeder	South Sub	122	106	118	2.72	2.23	2.81	831	811	185	97.49%
0		South D Feeder	South Sub	117	144	100	1.87	4.73	0.47	864	861	(71)	99.67%

- Breckenridge Public Utilities
- DGR Project No.: 425402

1	Scenario Selection
Loss of Twito Sub	

System Analysis Configuration

Existing System & Loading

80	= 80% Capacity Warning
100	= 100% Capacity Violation
+3.5	= +3.5 Voltage Drop Violation

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	Transformer	Base	Top	Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
1	Twito Sub Xfmr	5,000	6,250	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	682	737	742	4.39	4.21	8.04	5,181	4,960	1,066	95.73%
1	South Sub Xfmr	5,000	6,250	South Sub	444	440	439	2.72	4.73	3.72	3,174	3,051	629	96.13%
				TOTALS	1126	1177	1181	4.39	4.73	8.04	8,355	8,011	1,694	95.88%

				Phase Amps			Max V Drop						
Scenario	Circuit		Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
1		Twito A Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		Twito B Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		Twito C Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		Twito D Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		WP A Feeder	Water Plant Sub	189	187	202	4.39	4.21	5.15	1,386	1,291	505	93.13%
1		WP B Feeder	Water Plant Sub	121	178	108	2.12	3.85	1.58	977	957	197	97.94%
1		WP C Feeder	Water Plant Sub	161	104	186	4.37	1.21	8.04	1,083	1,072	149	99.05%
1		WP D Feeder	Water Plant Sub	79	115	89	1.26	2.44	1.40	677	674	57	99.65%
1		WP E Feeder	Water Plant Sub	80	111	105	1.09	2.14	1.30	711	647	296	90.93%
1		WP F Feeder	Water Plant Sub	52	42	52	0.39	0.13	0.55	347	319	(138)	91.75%
1		South A Feeder	South Sub	65	76	102	2.40	3.19	3.72	584	519	266	89.00%
1		South B Feeder	South Sub	140	114	118	2.50	2.28	2.58	895	860	248	96.09%
1		South C Feeder	South Sub	122	106	118	2.72	2.23	2.81	831	811	185	97.49%
1		South D Feeder	South Sub	117	144	100	1.87	4.73	0.47	864	861	(71)	99.67%

Switching Procedure:
1. Northern Ave. - Close Cutouts.
2. "A" Circuit on Beede Ave. & Hwy 75 North - Close Switch.
3. Wagner Ave. & Hwy 75 North - Close Switch.

- **Breckenridge Public Utilities**
- **DGR Project No.: 425402**

2	**Scenario Selection**
Loss of Water Plant Sub	

System Analysis Configuration

Existing System & Loading

80	**= 80% Capacity Warning**
100	**= 100% Capacity Violation**
+3.5	**= +3.5 Voltage Drop Violation**

		Ratings (kVA)			**Phase Amps**			**Max V Drop**						
Scenario	**Transformer**	**Base**	**Top**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
2	Twito Sub Xfmr	5,000	6,250	Twito Sub	345	288	379	3.44	1.50	4.01	2,426	2,331	609	96.09%
2	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South Sub Xfmr	5,000	6,250	South Sub	780	906	802	6.38	12.52	8.68	5,968	5,757	1,249	96.46%
				TOTALS	1125	1193	1180	6.38	12.52	8.68	8,395	8,089	1,858	96.36%

			Phase Amps			**Max V Drop**						
Scenario	**Circuit**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
2	Twito A Feeder	Twito Sub	160	104	182	3.44	1.47	4.01	1,069	1,061	133	99.23%
2	Twito B Feeder	Twito Sub	48	48	46	1.05	1.05	1.01	342	321	118	93.84%
2	Twito C Feeder	Twito Sub	54	61	59	0.81	0.92	0.80	416	391	140	94.15%
2	Twito D Feeder	Twito Sub	83	75	92	1.65	1.50	1.80	600	558	218	93.14%
2	WP A Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP B Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP C Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP D Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP E Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP F Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South A Feeder	South Sub	226	321	306	6.38	12.52	8.68	2,049	1,913	733	93.38%
2	South B Feeder	South Sub	267	302	228	5.59	7.40	3.28	1,914	1,844	514	96.33%
2	South C Feeder	South Sub	170	138	167	3.33	2.10	3.74	1,141	1,139	73	99.80%
2	South D Feeder	South Sub	117	144	100	1.88	4.74	0.47	864	861	(71)	99.67%

Switching Procedure:
1. North 7th St. & Mendenhall Ave. - Close Switch.
2. "A" Circuit on Beede Ave. & Hwy 75 North - Close Switch.
3. Tie between "A" & "B" Circuit Beede Ave. & Hwy 75 North - Close Switch.
4. Northern Ave. - Close Cutouts.
5. Mendenhall Ave. ,alley between Main & Hwy 9 - Close Switch.
6. Dacotah Ave. ,alley between 6th & 7th St. - Close Switch.

- Breckenridge Public Utilities
- DGR Project No.: 425402

3	Scenario Selection
Loss of South Sub	

System Analysis Configuration

Existing System & Loading

80	= 80% Capacity Warning
100	= 100% Capacity Violation
+3.5	= +3.5 Voltage Drop Violation

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	Transformer	Base	Top	Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
3	Twito Sub Xfmr	5,000	6,250	Twito Sub	283	233	309	1.94	1.49	1.80	1,973	1,892	386	95.91%
3	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	854	979	871	11.10	19.45	9.34	6,491	6,262	1,536	96.47%
3	South Sub Xfmr	5,000	6,250	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
				TOTALS	1137	1212	1180	11.10	19.45	9.34	8,464	8,154	1,921	96.34%

		Substation	Phase Amps			Max V Drop						
Scenario	Circuit	Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
3	Twito A Feeder	Twito Sub	111	62	125	1.94	0.00	1.60	705	703	(53)	99.72%
3	Twito B Feeder	Twito Sub	48	48	46	1.05	1.05	1.01	342	321	118	93.84%
3	Twito C Feeder	Twito Sub	41	48	46	0.54	0.57	0.49	326	310	102	94.95%
3	Twito D Feeder	Twito Sub	83	75	92	1.64	1.49	1.80	600	558	218	93.14%
3	WP A Feeder	Water Plant Sub	12	12	12	0.01	0.01	0.01	89	81	37	91.09%
3	WP B Feeder	Water Plant Sub	271	302	233	9.16	7.67	6.27	1,935	1,867	509	96.48%
3	WP C Feeder	Water Plant Sub	52	51	58	0.78	0.83	1.03	387	348	169	89.96%
3	WP D Feeder	Water Plant Sub	269	364	296	11.10	19.45	9.34	2,229	2,182	458	97.87%
3	WP E Feeder	Water Plant Sub	80	111	105	1.10	2.15	1.30	711	647	296	90.93%
3	WP F Feeder	Water Plant Sub	170	139	166	3.30	2.47	3.31	1,139	1,138	67	99.83%
3	South A Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
3	South B Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
3	South C Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
3	South D Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%

Switching Procedure:
1. North 7th St. & Mendenhall Ave. - Close Switch.
2. North 12th St. & Beede Ave. - Close Switch.
3. New York Ave , alley between South 6th & 7th St. - Close Switch.
4. Dacotah Ave. ,alley between 6th & 7th St. - Close Switch.
5. Chicago Ave. ,alley between 6th & 7th St. - Close Switch.

Table of Contents
- Breckenridge Public Utilities
- DGR Project No.: 425402

DGR ENGINEERING

Scenario Legend

Scenario	Existing Sys. & Proposed Loading
0	System Intact
1	Loss of Twito Sub
2	Loss of Water Plant Sub
3	Loss of South Sub

- Breckenridge Public Utilities
- DGR Project No.: 425402

0	Scenario Selection
System Intact	

System Analysis Configuration

Existing Sys. & Proposed Loading

80	= 80% Capacity Warning
100	= 100% Capacity Violation
+3.5	= +3.5 Voltage Drop Violation

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	Transformer	Base	Top	Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
0	Twito Sub Xfmr	5,000	6,250	Twito Sub	440	382	492	2.83	2.63	3.39	3,147	3,007	775	95.54%
0	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	437	563	469	2.40	4.32	1.80	3,525	3,346	781	94.92%
0	South Sub Xfmr	5,000	6,250	South Sub	503	507	544	3.09	5.54	4.12	3,733	3,580	877	95.90%
				TOTALS	1380	1453	1505	3.09	5.54	4.12	10,405	9,933	2,434	95.46%

				Phase Amps			Max V Drop						
Scenario		Circuit	Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
0		Twito A Feeder	Twito Sub	122	67	138	2.22	0.00	1.80	778	777	(26)	99.95%
0		Twito B Feeder	Twito Sub	127	127	125	1.26	1.27	1.22	909	859	299	94.45%
0		Twito C Feeder	Twito Sub	46	53	51	0.59	0.64	0.55	360	342	114	94.89%
0		Twito D Feeder	Twito Sub	145	136	178	2.83	2.63	3.39	1,100	1,029	389	93.55%
0		WP A Feeder	Water Plant Sub	14	14	14	0.01	0.01	0.01	99	90	41	91.08%
0		WP B Feeder	Water Plant Sub	135	198	120	2.40	4.32	1.80	1,088	1,058	251	97.30%
0		WP C Feeder	Water Plant Sub	57	57	65	0.85	0.91	1.13	428	385	187	89.94%
0		WP D Feeder	Water Plant Sub	87	128	98	1.47	2.77	1.61	752	746	95	99.19%
0		WP E Feeder	Water Plant Sub	89	123	116	1.21	2.37	1.43	786	715	328	90.91%
0		WP F Feeder	Water Plant Sub	56	43	56	0.48	0.18	0.64	372	352	(121)	94.58%
0		South A Feeder	South Sub	72	84	114	2.65	3.54	4.12	646	575	295	88.96%
0		South B Feeder	South Sub	167	145	147	2.95	2.70	2.98	1,104	1,054	331	95.41%
0		South C Feeder	South Sub	136	119	132	3.09	2.54	3.19	928	897	238	96.65%
0		South D Feeder	South Sub	128	160	151	1.86	5.54	1.67	1,054	1,054	13	99.99%

- **Breckenridge Public Utilities**
- **DGR Project No.: 425402**

1	**Scenario Selection**
Loss of Twito Sub	

System Analysis Configuration

Existing Sys. & Proposed Loading

80	**= 80% Capacity Warning**
100	**= 100% Capacity Violation**
+3.5	**= +3.5 Voltage Drop Violation**

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	**Transformer**	**Base**	**Top**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
1	Twito Sub Xfmr	5,000	6,250	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	893	952	991	8.50	8.22	10.59	6,802	6,473	1,716	95.17%
1	South Sub Xfmr	5,000	6,250	South Sub	503	507	544	3.09	5.54	4.12	3,733	3,580	877	95.90%
				TOTALS	1396	1459	1535	8.50	8.22	10.59	10,535	10,053	2,593	95.43%

			Phase Amps			Max V Drop						
Scenario	**Circuit**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
1	Twito A Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	Twito B Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	Twito C Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	Twito D Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	WP A Feeder	Water Plant Sub	347	343	391	8.50	8.22	10.59	2,598	2,414	962	92.89%
1	WP B Feeder	Water Plant Sub	135	198	120	2.40	4.33	1.81	1,088	1,058	251	97.30%
1	WP C Feeder	Water Plant Sub	179	116	208	4.96	1.43	9.07	1,205	1,188	201	98.61%
1	WP D Feeder	Water Plant Sub	87	128	98	1.47	2.77	1.62	752	746	95	99.19%
1	WP E Feeder	Water Plant Sub	89	123	116	1.21	2.37	1.44	786	715	328	90.91%
1	WP F Feeder	Water Plant Sub	56	43	56	0.48	0.18	0.64	372	352	(121)	94.58%
1	South A Feeder	South Sub	72	84	114	2.65	3.54	4.12	646	575	295	88.96%
1	South B Feeder	South Sub	167	145	147	2.95	2.70	2.98	1,104	1,054	331	95.41%
1	South C Feeder	South Sub	136	119	132	3.09	2.54	3.19	928	897	238	96.65%
1	South D Feeder	South Sub	128	160	151	1.86	5.54	1.67	1,054	1,054	13	99.99%

Switching Procedure:
1. Northern Ave. - Close Cutouts.
2. "A" Circuit on Beede Ave. & Hwy 75 North - Close Switch.
3. Wagner Ave. & Hwy 75 North - Close Switch.

- **Breckenridge Public Utilities**
- **DGR Project No.: 425402**

2	Scenario Selection
Loss of Water Plant Sub	

System Analysis Configuration

Existing Sys. & Proposed Loading

80	= 80% Capacity Warning
100	= 100% Capacity Violation
+3.5	= +3.5 Voltage Drop Violation

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	**Transformer**	**Base**	**Top**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
2	Twito Sub Xfmr	5,000	6,250	Twito Sub	509	445	570	3.91	2.63	4.54	3,657	3,494	1,024	95.56%
2	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South Sub Xfmr	5,000	6,250	South Sub	880	1031	950	7.18	14.15	9.79	6,868	6,590	1,689	95.96%
				TOTALS	1389	1475	1520	7.18	14.15	9.79	10,525	10,085	2,714	95.82%

		Phase Amps			Max V Drop						
Scenario	**Circuit**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
2	Twito A Feeder	Twito Sub	178	115	202	3.91	1.71	4.54	1,188	1,174	181	98.83%
2	Twito B Feeder	Twito Sub	127	127	125	1.26	1.27	1.22	909	859	299	94.45%
2	Twito C Feeder	Twito Sub	59	67	65	0.90	1.03	0.89	460	433	156	94.09%
2	Twito D Feeder	Twito Sub	145	136	178	2.83	2.63	3.40	1,100	1,029	389	93.55%
2	WP A Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP B Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP C Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP D Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP E Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	WP F Feeder	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South A Feeder	South Sub	253	360	342	7.18	14.15	9.79	2,294	2,128	858	92.74%
2	South B Feeder	South Sub	310	357	270	6.43	8.57	3.84	2,250	2,148	669	95.48%
2	South C Feeder	South Sub	189	153	186	3.89	2.52	4.34	1,269	1,261	148	99.32%
2	South D Feeder	South Sub	128	160	151	1.86	5.55	1.67	1,054	1,054	13	99.99%

Switching Procedure:
1. North 7th St. & Mendenhall Ave. - Close Switch.
2. "A" Circuit on Beede Ave. & Hwy 75 North - Close Switch.
3. Tie between "A" & "B" Circuit Beede Ave. & Hwy 75 North - Close Switch.
4. Northern Ave. - Close Cutouts.
5. Mendenhall Ave. ,alley between Main & Hwy 9 - Close Switch.
6. Dacotah Ave. ,alley between 6th & 7th St. - Close Switch.

- **Breckenridge Public Utilities**
- **DGR Project No.: 425402**

3	**Scenario Selection**
Loss of South Sub	

System Analysis Configuration

Existing Sys. & Proposed Loading

80	**= 80% Capacity Warning**
100	**= 100% Capacity Violation**
+3.5	**= +3.5 Voltage Drop Violation**

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	**Transformer**	**Base**	**Top**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
3	Twito Sub Xfmr	5,000	6,250	Twito Sub	440	382	492	2.83	2.63	3.39	3,147	3,007	775	95.54%
3	Water Plant Sub Xfmr	7,500	9,375	Water Plant Sub	964	1120	1050	11.40	22.83	14.73	7,520	7,198	2,051	95.73%
3	South Sub Xfmr	5,000	6,250	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
				TOTALS	1403	1502	1542	11.40	22.83	14.73	10,667	10,206	2,826	95.67%

			Phase Amps			Max V Drop						
Scenario	**Circuit**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
3	Twito A Feeder	Twito Sub	122	67	138	2.22	0.00	1.80	778	777	(26)	99.95%
3	Twito B Feeder	Twito Sub	127	127	125	1.26	1.27	1.22	909	859	299	94.45%
3	Twito C Feeder	Twito Sub	46	53	51	0.59	0.64	0.55	360	342	114	94.89%
3	Twito D Feeder	Twito Sub	145	136	178	2.83	2.63	3.39	1,100	1,029	389	93.55%
3	WP A Feeder	Water Plant Sub	14	14	14	0.01	0.02	0.01	99	90	41	91.08%
3	WP B Feeder	Water Plant Sub	316	359	278	10.91	10.08	8.06	2,288	2,187	673	95.58%
3	WP C Feeder	Water Plant Sub	57	57	65	0.86	0.92	1.15	428	385	187	89.94%
3	WP D Feeder	Water Plant Sub	299	414	393	11.40	22.83	14.73	2,652	2,563	682	96.64%
3	WP E Feeder	Water Plant Sub	89	123	116	1.22	2.39	1.44	786	715	328	90.91%
3	WP F Feeder	Water Plant Sub	189	154	185	3.80	2.89	3.82	1,267	1,259	141	99.38%
3	South A Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
3	South B Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
3	South C Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
3	South D Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%

Switching Procedure:
1. North 7th St. & Mendenhall Ave. - Close Switch.
2. North 12th St. & Beede Ave. - Close Switch.
3. New York Ave , alley between South 6th & 7th St. - Close Switch.
4. Dacotah Ave. ,alley between 6th & 7th St. - Close Switch.
5. Chicago Ave. ,alley between 6th & 7th St. - Close Switch.

Table of Contents
- Breckenridge Public Utilities
- DGR Project No.: 425402

DGR ENGINEERING

Scenario Legend

Scenario	Proposed 15 kV System & Loading
0	System Intact
1	Loss of Twito Sub
2	Loss of South Sub

- **Breckenridge Public Utilities**
- **DGR Project No.: 425402**

0	**Scenario Selection**
System Intact	

System Analysis Configuration

Proposed 15 kV System & Loading

80	**= 80% Capacity Warning**
100	**= 100% Capacity Violation**
+3.5	**= +3.5 Voltage Drop Violation**

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	**Transformer**	**Base**	**Top**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
0	Twito Sub Xfmr	10,000	16,667	Twito Sub	205	187	221	0.63	0.67	0.58	4,403	4,158	1,441	94.45%
0	Water Plant Sub Xfmr	10,000	16,667	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
0	South Sub Xfmr	10,000	16,667	South Sub	297	284	280	0.70	0.95	0.78	6,189	5,669	2,465	91.60%
				TOTALS	501	471	501	0.70	0.95	0.78	10,592	9,827	3,905	92.78%

				Phase Amps			Max V Drop						
Scenario	**Circuit**		**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
0		Twito A Feeder	Twito Sub	60	39	65	0.36	0.12	0.39	1,178	1,122	358	95.27%
0		Twito B Feeder	Twito Sub	32	32	31	0.11	0.11	0.11	681	649	206	95.32%
0		Twito C Feeder	Twito Sub	64	70	65	0.63	0.67	0.58	1,434	1,334	526	93.04%
0		Twito D Feeder	Twito Sub	49	46	60	0.31	0.29	0.37	1,110	1,053	351	94.87%
0		South A Feeder	South Sub	82	85	75	0.70	0.95	0.78	1,743	1,600	692	91.79%
0		South B Feeder	South Sub	55	47	53	0.50	0.24	0.28	1,118	1,041	407	93.12%
0		South C Feeder	South Sub	85	74	85	0.27	0.17	0.25	1,754	1,554	813	88.60%
0		South D Feeder	South Sub	74	78	67	0.45	0.73	0.51	1,574	1,474	553	93.63%

- Breckenridge Public Utilities
- DGR Project No.: 425402

1	Scenario Selection
Loss of Twito Sub	

System Analysis Configuration

Proposed 15 kV System & Loading

80	= 80% Capacity Warning
100	= 100% Capacity Violation
+3.5	= +3.5 Voltage Drop Violation

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	**Transformer**	**Base**	**Top**	**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
1	Twito Sub Xfmr	10,000	16,667	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	Water Plant Sub Xfmr	10,000	16,667	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1	South Sub Xfmr	10,000	16,667	South Sub	503	471	503	2.01	1.25	2.52	10,627	9,865	3,946	92.83%
				TOTALS	503	471	503	2.01	1.25	2.52	10,627	9,865	3,946	92.83%

				Phase Amps			Max V Drop						
Scenario	**Circuit**		**Substation**	**AØ**	**BØ**	**CØ**	**AØ**	**BØ**	**CØ**	**kVA**	**kW**	**kVAR**	**PF**
1		Twito A Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		Twito B Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		Twito C Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		Twito D Feeder	Twito Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
1		South A Feeder	South Sub	121	107	134	2.01	1.22	2.52	2,606	2,431	938	93.29%
1		South B Feeder	South Sub	104	98	98	0.57	0.57	0.49	2,154	1,972	866	91.57%
1		South C Feeder	South Sub	181	171	197	1.36	1.25	1.87	3,956	3,677	1,461	92.93%
1		South D Feeder	South Sub	97	95	73	0.80	0.94	0.49	1,910	1,785	681	93.43%

- Breckenridge Public Utilities
- DGR Project No.: 425402

2	Scenario Selection
Loss of South Sub	

System Analysis Configuration

Proposed 15 kV System & Loading

80	= 80% Capacity Warning
100	= 100% Capacity Violation
+3.5	= +3.5 Voltage Drop Violation

		Ratings (kVA)			Phase Amps			Max V Drop						
Scenario	Transformer	Base	Top	Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
2	Twito Sub Xfmr	10,000	16,667	Twito Sub	507	474	504	2.75	2.66	2.21	10,686	9,898	4,008	92.62%
2	Water Plant Sub Xfmr	10,000	16,667	Water Plant Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South Sub Xfmr	10,000	16,667	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
				TOTALS	507	474	504	2.75	2.66	2.21	10,686	9,898	4,008	92.62%

			Phase Amps			Max V Drop						
Scenario	Circuit	Substation	AØ	BØ	CØ	AØ	BØ	CØ	kVA	kW	kVAR	PF
2	Twito A Feeder	Twito Sub	155	150	161	2.12	2.66	2.21	3,358	3,138	1,195	93.46%
2	Twito B Feeder	Twito Sub	298	272	276	2.75	2.10	1.99	6,095	5,585	2,439	91.64%
2	Twito C Feeder	Twito Sub	4	6	7	0.01	0.02	0.02	123	121	24	98.15%
2	Twito D Feeder	Twito Sub	49	46	60	0.31	0.29	0.37	1,110	1,053	351	94.87%
2	South A Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South B Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South C Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%
2	South D Feeder	South Sub	0	0	0	0.00	0.00	0.00	-	-	-	0.00%