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IAH

George Bush Intercontinental Airport

Utilities Master Plan

International Terminal Redevelopment Program (ITRP)

FINAL

HOUSTON AIRPORTS

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Table of Contents

VOLUME I

APPENDIX A PROPOSED TERMINAL BUILDING PHASING PLAN FIGURES

APPENDIX B SITE UTILITY FIGURES

Table of Contents - Continued

Chapter 1 | Executive Summary

Chapter 1: Executive Summary

A. PROBLEM STATEMENT

The Utilities Master Plan includes recommendations to HAS, that improve the airport's (IAH) utility infrastructure, to meet the needs of the future 2030 terminal upgrades program while integrating as much of the following as reasonable and applicable:

1. Improve reliability
2. Increase redundancy
3. Renew/Upgrade aged systems
4. Reduce operating and maintenance costs
5. Allow adequate access
6. Conserve resources (Energy and water)
7. Reduce undesirable emissions
8. Make it resilient

Recent condition assessment studies show much of the existing IAH utility infrastructure has less than 15 years remaining life, specifically in Terminals A, B, C & D. (Refer to **Appendix D** for electrical condition assessment discussion). The IAH future 2030 terminal upgrades program will replace much of this infrastructure. For example, the Mickey Leland International Terminal (MLIT) project will replace building infrastructure in Terminals C & D North. Three new piers are planned to replace Terminal B North and Terminal A is to be renovated. In 2002, building renovations began in Terminal E and the Federal Inspection Services (FIS). As a result Terminal E infrastructure is currently in the best condition as compared to the other terminal buildings.

Terminals B & C Core utility systems are in need of upgrades. These facilities will benefit from site utility system upgrades planned to meet the demands of the 2030 terminal program. Site utilities include electrical, domestic water, fire protection, chilled water, heating water, sanitary, storm and natural gas, to within 5'-0" of the buildings. These site utilities are planned for upgrades due to a combination of old age, capacity deficiency, lack of reliability and simple interference issues with the new construction regarding project expansion plans.

B. RECOMMENDATIONS

Recommend an integrated, phased and centralized approach to upgrading the utility infrastructure at IAH, where applicable. Refer to **Appendix C** for Range of Magnitude Cost Estimates for recommended utilities enabling projects that support new Terminal B1, MLIT and Future Terminal upgrades. Early out enabling utilities projects (needed to support Terminal B1) include the following:

B.1 Site Utilities:

1. Utility Corridor (Utilidor): Construct a utilidor between the west edge of existing Terminal C North to the west edge of Terminal A North, along the southern edge of the North Terminal buildings. The utilidor provides a path for 12.5kV, IT, Chilled & Heated Water and Fire Protection/Domestic Water. It also provides all the benefits listed in items 1 – 8, in the problem statement, above.

2. Electrical: Construct an electrical receiving station, with capacity equal to 40 MW, for the purpose of centrally locating a point of connection on airport in which Centerpoint Energy (CNP) hands off power to HAS to serve IAH Terminal Infrastructure. The proposed location is the Terminal C-Core greenfield. The station avoids the need for separate CNP substations, located landside, for each terminal complex. HAS to distribute the 12.5kV feeders, from the Receiving Station to the new Terminals. This Station will help reduce future infrastructure costs as well as provide a power distribution plan for the IAH terminal area. Include Supervisory Control and Data Acquisition (SCADA) system to monitor, control and trend electrical equipment regarding status and power usage.

3. Fire Protection (FP) & Domestic Water (DW): HAS to install a combined central FP/DW storage tank, pump station and loop distribution system. The system to be design to provide water flow and pressures needed to meet the peak fire protection requirements of IFC 2012 and the domestic requirements of Texas Commission on Environmental Quality (TCEQ), Chapter 290. This approach avoids individual fire pumps, storage tanks and hydropneumatic systems per building.

4. Chilled & Heating Water: HAS to install new direct buried distribution branch line crossings in North Terminal Road to serve Terminal B1 and loop the piping in the Utilidor to provide a redundant back feed path.

5. Jet Fuel: HAS to replace the existing fuel distribution mains, hydrant and hardstand lines with a new distribution system, to the north of Terminal B1, to upgrade the piping system, meet the NFPA 415 building separation distances and improve the ability to isolate leaks.

6. Triturator: HAS to Replace Environmental Lift Station at North Terminal A with a Triturator sized to support the additional load from Terminal B1.

7. Emergency Power: HAS to install 2MW emergency generator with sound enclosure, diesel fuel tank and 12.5kV transfer switch in area near C-Garage. Generator to provide emergency power to Terminal complex based on priority sequence of control scheme. Control scheme to shed loads above 2MW to protect generator system.

Chapter 2 | Introduction

Chapter 2: Introduction

A. Utility Master Plan Goal

The goal of this Utility Master Plan (UMP) is to provide the Houston Airports System (HAS) with recommendations, narrative descriptions, tables, cost information and exhibits to describe the projects needed to define how best to improve the airport's (IAH) utility infrastructure to meet the needs of the planned 2030 terminal upgrades. These projects, together with the terminal upgrades, will ultimately benefit IAH by attracting new profitable international flight activity and improve the airport's economic stability.

The following UMP objectives are provided:

1. Estimate future utility demand requirements
2. Provide a phased forecast
3. Develop alternatives to meet utility demands
4. Prepare Recommendations

B. Background

International air travel is on the rise and IAH wants to add more flights to improve the airport's economic stability. Particularly regarding travel to Latin America where demand is way up. IAH is well positioned geographically to add new international flights. However, airport terminal upgrades will be needed in order to accommodate the anticipated growth. See **Appendix A**.1 for a color coordinated IAH Terminal Building Phasing plan. Terminal expansion plans include the following:

1. United Terminal B North Phase II (B Pier) – June 2016
2. New Mickey Leland International Terminal (D1 & D2 Piers) – June 2020
3. United Terminal B North Phase III (two additional piers and FIS) – June 2025
4. Upgrades to Terminal A – June 2030

C. Utility Data

C.1 Terminal Area Assumptions:

Gross building floor areas were obtained for Terminals A – E (See **Appendix A.2, IAH Peak Utility Demands**). The IAH Master Plan, dated December 21, 2012, was used to determine existing terminal areas. United Airlines (Mr. David Brandenburg, email dated 4/1/14), provided input on the Terminal B Piers. MLIT and updated FIS areas were based on area takeoffs, from May 2014 planning drawings. Per Airlines meeting, dated May 6, 2014, it was noted that there is no difference between the new and renovated building floor areas regarding the proposed MLIT.

C.2 Peak Demand Unit Assumptions:

Peak demand unit assumptions were based on a combination of information including past IAH Central Utility Plant design data, current operating conditions, ASHRAE unit data, code information and plumbing fixture count estimates. The peak demand units are shown in **Appendix A.2**. For example, chilled and heating water units were estimated at 230 SF/ton and 25 BTU/SF respectively. The units were multiplied with building gross areas and then adjusted with a diversity factor. The diversity factor helped bring the calculated loads more in line with the overall cooling and heating loads provided by HAS, which came from hourly trends in 2013.

Natural gas unit assumption was based on the previous 90% Terminal D design, which assumed natural gas powered emergency generators. Emergency generators are not currently part of the space planning needs for the MLIT given the good reliability of Centerpoint Energy's four feeders, two coming from two separate substations, and the double-ended distribution design serving each terminal. However, emergency generators provide an alternative means of electrical backup if needed in the future. Domestic water, roof leader sizing and sanitary units were based on the 2012 International Plumbing code and estimated fixture units. Fire protection was based on the 2012 International Fire code.

C.3 Summary Peak Demands:

Summary peak demands were estimated using the terminal areas and peak demand units. See **Appendix A.2** for a list of utility peak demands and A.3 for backup information. A reasonable diversity factor was included to represent the fluctuation in passengers due to varying gate activity. It is understood that not all gates will be occupied simultaneously. Peak demands are used to determine if existing utility systems have adequate capacity to meet these future loads.

D. Situation

IAH is restricted by the number of international flights they can add due to limitations in the airport's existing gates and infrastructure. Infrastructure limitations include inadequate utility capacity, reduced system reliability, aging equipment and insufficient terminal space. IAH is in danger of losing new international flights to other airports if they do not act.

Chapter 3 | Methodology

Chapter 3: Methodology

Find creative solutions by treating utility infrastructure as integrated, networked and smart systems rather than isolated individual projects. Combine creative design and new approaches, with modern technologies, that enable HAS to reimagine the airport's future utility infrastructure. Review the condition assessment studies to determine which utilities have reached their useful life. Estimate existing and future demand needs to determine gaps. Build an existing, high level, utilities 3-demensional (3D) model to determine new infrastructure project interference issues and to present new alternative solutions.

A. Approach to Peak Demands Analysis

Refer to Section, Utility Data, Summary Peak, for the approach to estimating the peaks for each utility system. Peak demands will be organized in the following groups:

1. Base Case – Mickey Leland International Terminal (MLIT), Term B1 is an enabling project for MLIT
2. Short Term – Base Case plus Term B (Single Pier)
3. Long Term – Short Term plus two more Piers on Term B & Renovate Terminal A

B. Approach to Distribution Analysis

Site utility distribution systems will be evaluated. Chilled and heating water system flows will be modeled using Pipe Flo software. Other utility distribution systems will be reviewed per code based on estimated peak flow rates and available line pressures and voltages including aviation fuel, natural gas, fire protection/domestic water, storm and information technology.

C. Approach to Condition Assessment

Refer to **Appendix B.3** for electrical systems condition assessment.

D. Approach to Base Case and Alternatives Analysis

Alternatives will be compared against the base case utility infrastructure systems. Base case assumes "status quo" approach. Range of magnitude construction cost estimates will be organized in three project groups as follows:

1. Enabling Projects
2. MLIT Projects
3. Future Projects

Chapter 4 | Enabling Projects

Chapter 4: Enabling Projects

The Utilities Master Plan involves the projects that support the IAH future 2030 terminal upgrades program. Enabling projects are organized into three project groups as follows:
- Terminal B1
- MLIT
- Future

Refer to **Appendix C** for range of magnitude (ROM) cost estimates.

A. Terminal B1

Utility infrastructure projects needed to be constructed early in order to support Terminal B1 are listed as follows:

1. Electrical:

a. Utility Distribution:

i. Base Case: Direct buried duct bank, 12 each 6 in PVC conduits, from CNP North Terminal Road Vault to new substation located at midpoint of Terminal B1.
1. Earthwork
2. Duct bank
3. Utility Interferences/Relocations

ii. Alt: Part direct buried duct bank and part new Utility Corridor. Install direct buried duct bank with 12 each 6 in PVC conduits, from a Central Receiving Station, at C Garage, across the North Terminal Road. Intercept the new Utility Corridor and run 12 each, 6 in PVC conduits to the west to Terminal B.
1. Earthwork
2. Duct bank across North Terminal Road
3. Duct bank inside Utility Corridor
4. Utility Corridor (Box Culvert) between C-B Connector and West of Terminal B1
5. Utility Interferences/Relocations

b. Receiving Station:

i. Base Case: Dedicated 12.5 kv Substation at Terminal B1 (5 MW, $5M).

ii. Alt: 12.5 kv Central Receiving Station at C Garage
1. 12,000 sf 3-hour rated Critical Facility
2. 2,000 sf parking, access
3. Subgrade Vault (4000 sf), below Critical Facility, for 4 each incoming CNP circuits, 2 from IT and 2 from GR
4. HAS Switchgear room inside Critical Facility

2. Fire Protection (FP)/Domestic Water (DW):

a. Utility Distribution:

i. Base Case: Direct buried ductile iron pipe, run one line from each existing City lines (16 in & 12 in), located in North Terminal Road, to Terminal B water tank fill pumps.
1. Earthwork
2. Two each 10 in ductile iron pump suction lines, from North Terminal Road City line connections, to tank/pumps
3. Utility Interferences/Relocations in North Terminal Road crossing and tank footprint areas

ii. Alt: Part direct buried pipe and part Utility Corridor. Run 16 in direct buried ductile iron pipe across North Terminal Road. Intercept Utility Corridor, convert to 16 in Schedule 40 Carbon Steel and install 16 in Tee. Reduce to 12 in welded Schedule 40 Carbon Steel and run west to Terminal B. Cap off Tee to east.
1. Earthwork
2. Two each 10 in ductile iron pump suction lines, from North Terminal Road City line connections, to tanks/pumps
3. 16 in ductile iron across North Terminal Road
4. Transition to carbon steel inside Utility Corridor
5. Utility Corridor (Included in Electrical)
6. Utility Interferences/Relocations in North Terminal Road crossing and tank footprint areas

b. Water Storage & Booster Pump System:

i. Base Case: New Zone Water Storage System
1. Two each, 400,000 Gallon tanks near Terminal B complex
    a. Tanks sized for B1, B2, B3, A & B-Core
2. One each, 1500 gpm pump
3. One each, future space for 1500 pump
4. Two each, 500 gpm pumps
5. Two each, 500 gpm tank fill pump
6. Two each, future spaces for 500 gpm pumps
7. Pump House
8. Electrical
9. Earthwork
10. Controls

ii. Alt: New Central Water Storage System
1. Two each, 500,000 Gallon Tanks at C Garage site
    a. Tanks sized for B1, B2, B3, A & MLIT, B-Core & C-Core
2. One each, 1500 gpm pump
3. One each, future space for a 1500 gpm pump
4. Two each, 500 gpm pumps
5. Two each 500 gpm tank fill pumps
6. Two each, future spaces for 500 gpm pumps
7. Pump House
8. Electrical
9. Earthwork
10. Controls

3. Chilled Water (CW)/Heating Water (HW):

a. Utility Distribution:

i. Base Case: Direct buried supply & return piping to & from existing Utility Tunnel, across North Terminal Road, to & from Terminal B1. Perma Pipe XTRU-THERM® pre-insulated piping system, 12 in CHW and 6 in HW schedule 40 welded carbon steel carrier pipe, foam insulation, HDPE jacket.

ii. Alt: Part direct buried pipe and part new Utility Corridor. Run direct buried 18 in CHW and 8 in HW Schedule 40 welded carbon steel in Perma Pipe XTRU-THERM® pre-insulated piping system across the North Terminal Road. Intercept Utility Corridor and install 12 in CHW and 6 in HW Schedule 40 welded carbon steel, insulated pipe with metal jacket to Terminal B1.

4. Jet Fuel:

a. Utility Distribution

i. Base Case: Replace existing with new ASTM A53, Grade B, Schedule 40 Carbon Steel, interior and exterior epoxy coated, around Terminal B1 and make connections to existing North Terminal C fuel lines.
ii. Alt: Same as base case.

5. Information Technology:

a. Utility Distribution

i. Base Case: Run in building between B-C Connector to Terminal B
1. Install eight each, 6 in conduits for IT inside building
2. Install UPS system
3. No emergency generators are included in Terminal B

ii. Alt: Run IT in Utility Corridor from B-C Connector to Terminal B
1. Install eight each, 6 in conduits for IT in Utility Corridor
2. Install one each, cable tray, 24 in W x 9 in D
3. Install one each, 2 MW Emergency Generator at Central Receiving Station (C Garage)
4. Install four each, 6 in conduits from 2 MW Emergency Generator at Central Receiving Station (C Garage) to Terminal B

6. Triturator:

Replace Environmental Lift Station at North Terminal A with Triturator to support Terminal B1.

7. Emergency Power:

Install a 2 MW, diesel fueled, emergency generator with sound enclosure and UL2085 base tank. Locate system near FP/DW pump station and distribute four each 6 in conduits in utilidor to Terminals.

B. MLIT

Utility infrastructure projects needed to be constructed early in order to support MLIT are listed below. The following list assumes the enabling projects for Terminal B1 were installed.

1. Electrical:

a. Utility Distribution:

i. Base Case: Direct buried duct bank, 12 each 6 in PVC conduits, from CNP North Terminal Road Vault to new substation located at near Terminal D1, landside.
1. Earthwork
2. Duct bank
3. Utility Interferences/Relocations

ii. Alt: Part direct buried duct bank and part new Utility Corridor. Install direct buried duct bank with 12 each 6 in PVC conduits, from the Central Receiving Station, at C Garage, across the North Terminal Road. Intercept the new Utility Corridor and run 12 each 6 in PVC conduits to the east to MLIT Substation.
1. Earthwork
2. Duct bank across North Terminal Road
3. Duct bank inside Utility Corridor
4. Extend Utility Corridor (Box Culvert) east, from C-B Connector to MLIT
5. Utility Interferences/Relocations

b. Receiving Station:

i. Base Case: Add dedicated 12.5 kv Substation at Term MLIT (10 MW, $10M)
ii. Alt: Add four new dedicated CNP circuits to Existing 12.5 kv Central Receiving Station at C Garage, for a total of eight, four from IT and four from GR

2. Fire Protection (FP)/Domestic Water (DW):

a. Utility Distribution:

i. Base Case: Direct buried ductile iron pipe, run one line from each existing City lines (16 in & 12 in), located in North Terminal Road, to Terminal MLIT water tank fill pumps.
1. Earthwork
2. Two each 10 in ductile iron pump suction lines, from North Terminal Road City line connections, to tank/pumps
3. Utility Interferences/Relocations in North Terminal Road crossing and tank footprint areas

ii. Alt: Connect to existing 16 in tee in new Utility Corridor, reduce to 12 in welded Schedule 40 Carbon Steel and run east to serve MLIT.
1. Connect to existing 16 in in Utility Corridor and run 12 in Schedule 40, welded carbon steel to MLIT
2. Utility Corridor (Included in Electrical)

b. Water Storage & Booster Pump System:

i. Base Case: New Zone Water Storage System
1. Two each, 300,000 Gallon tanks near MLIT
   a. Tanks sized for MLIT
2. One each, 1500 gpm pump
3. One each, future space for 1500 pump
4. Two each, 500 gpm pumps
5. Two each, 500 gpm tank fill pump
6. One each, future spaces for 500 gpm pumps
7. Pump House
8. Electrical
9. Earthwork
10. Controls

ii. Alt: Existing Central Water Storage System Upgrades
1. One each, 1500 gpm pump
2. Two each, 500 gpm pumps
3. Electrical
4. Controls

3. Chilled Water (CW)/Heating Water (HW):

a. Utility Distribution:

i. Base Case: Install 20 in CHW and 8 in HW, across North Terminal Road, to serve MLIT mechanical room.
ii. Alt: Intercept Terminal B 18 in CHW and 8 in HW supply and return lines in Utility Corridor and run east to tie into the new lines serving MLIT to form a loop. Connect to existing 16 in CHW & 8 in HW serving existing Terminal D and route west to tie into 20 in CHW and 8 in HW prior to MLIT mechanical room.

4. Jet Fuel:

a. Utility Distribution

i. Base Case: Replace existing with new ASTM A53, Grade B, Schedule 40 Carbon Steel, interior and exterior epoxy coated, around Terminal B1 and make connections to existing North Terminal C fuel lines.

ii. Alt: Same as base case.

5. Information Technology:

a. Utility Distribution

i. Base Case: Run in building between Terminal B & MLIT

1. Install 8 each, 6 in conduits for IT in building
2. Install UPS system
3. No emergency generators are included in MLIT

ii. Alt: Run IT in Utility Corridor from Terminal B & MLIT

1. Install 8 each, 6 in conduits for IT in Utility Corridor
2. Install 1 each, cable tray, 24 in W x 9 in D
3. Install 4 each, 6 in conduits from 2 MW emergency generator at Central Receiving Station (C Garage) to MLIT

6. Sanitary:

Install new lift station and respective piping to direct flow to the east end of MLIT and to the existing FIS lift station.

C. Future

Utility infrastructure projects needed to be constructed early in order to support new Terminals B2 & B3 and the renovation of Terminal A, B Core, C Core and FIS, are listed below. The following list assumes the enabling projects for Terminal B1 & MLIT were installed.

1. Electrical:

a. Utility Distribution:

i. Base Case: Direct buried duct bank, 12 each 6 in PVC conduits, from CNP North Terminal Road Vault to three each new substations located near Terminals B2, B3 & A, landside.

1. Earthwork
2. Duct bank
3. Utility Interferences/Relocations

ii. Alt: Extend duct bank to the west to Terminals B2, B3 & A. Intercept the new Utility Corridor and run 12 each 6 in PVC conduits to the west Substations.

1. Earthwork
2. Duct bank inside Utility Corridor
3. Extend Utility Corridor (Box Culvert) west, from Terminal B1.
4. Utility Interferences/Relocations

b. Receiving Station:

i. Base Case: Add dedicated 12.5 kv Substations at Terminals B2, B3 & A (5 MW, 5 MW & 10 MW)

ii. Alt: Pull 8 CNP circuits to the west to serve the Terminals B2, B3 and A

2. Fire Protection (FP)/Domestic Water (DW):

a. Utility Distribution:

i. Base Case: Tie into Terminal B Water Storage system and extend direct buried force main to Terminals B2, B3 & A.

1. Earthwork
2. Extend 12 in ductile iron force main to the west.
3. Utility Interferences/Relocations in North Terminal Road

ii. Alt: Tie into Terminal B Water Storage system and extend carbon steel force main in Utility Corridor to Terminals B2, B3 & A.

1. Connect to existing 16 in in Utility Corridor and run 12 in Schedule 40, welded carbon steel to Terminals B2, B3 & A
2. Utility Corridor (Included in Electrical)

b. Water Storage & Booster Pump System:

i. Base Case: Existing Terminal B Water Storage System Upgrades.

1. One each, 1500 gpm pump
2. Two each, 500 gpm pumps
3. Electrical
4. Controls

ii. Alt: Same as Base Case.

3. Chilled Water (CW)/Heating Water (HW):

a. Utility Distribution:

i. Base Case: Direct buried supply & return piping to & from existing Utility Tunnel, across North Terminal Road, to & from Terminal B2. Perma Pipe XTRU-THERM® pre-insulated piping system, 12 in CHW and 6 in HW schedule 40 welded carbon steel carrier pipe, foam insulation, HDPE jacket.

ii. Alt: Same as Base Case except loop back to Terminal B1 piping in Utility Corridor.

b. Jet Fuel:

i. Utility Distribution

1. Base Case: Replace existing with new ASTM A53, Grade B, Schedule 40 Carbon Steel, interior and exterior epoxy coated, around Terminal B1 and make connections to existing North Terminal C fuel lines.
2. Alt: Same as base case.

4. Information Technology:

a. Utility Distribution:

i. Base Case: Run in building between Terminal B1 & B2, B3 & A

1. Install eight each, 6 in conduits for IT in building
2. Install UPS system
3. Install Two each 200 kw emergency generators in MLIT

ii. Alt: Run IT in Utility Corridor from Terminal B1 & B2, B3 & A

1. Install eight each, 6 in conduits for IT in Utility Corridor
2. Install one each, cable tray, 24 in W x 9 in D

3. Extend four each, 6 in conduits from 2 mw emergency generator junction box at Terminal B1 to B2, B3 & A

5. Central Utility Plant:

a. HAS to replace existing boilers 4 and 5, with new 16,000 MBH heating water generators. (Boilers 4 & 5 to be demolished in 2023, seven years before the end of their expected service lives).

b. HAS to replace the three steam driven chillers (two each, 3300 ton units, CH-6 & 8 and one each, 1000 ton unit, CH-1) with new electric drive chillers as follows: one each, 3000 ton, CH-10, one each, 1000 ton, CH-11, and one each, 2,500 ton, CH-12. (Steam driven chillers to be demolished in 2023, two years before their expected end of service life).

Chapter 5

Utility Systems

Chapter 5: Utility Systems

Utility systems are reviewed for existing conditions and future demands (load) in this section. An evaluation narrative is provided for each utility system to address existing conditions and or future demand shortfall issues.

A. Electrical

1. Existing

Terminal A Core

• The electrical services to the Terminal A Core building originate at CenterPoint's Basement Level vault with six, 500 kVA/277 V transformers. Three single phase 277 V transformers are arranged in a wye configuration for a 1,500 kVA, three-phase, four-wire wye 277 V/480 V electrical service transformer. The two 1,500 kVA transformers are configured in parallel for redundancy.

• The electrical service to the Terminal A Core building is a single bus to a main switchgear lineup. The main switchgear is a single main switchgear lineup in the tunnel level main electrical room and does not include a dual main or tie breakers.

North

• The electrical services to the Terminal A North Concourse include four, 1,500 kVA transformers. Two, 12.47 kkV-480/277 V transformers serve a switchgear lineup with a main-tie-main configuration. This is typical of two switchgear lineups. Each transformer is supplied from a CenterPoint auto transfer switch (ATO) allowing the service to transfer between the two different 12.47 kV distribution lines. The ATOs are normally configured with one ATO supplying one main of a main-tie-main lineup from a circuit from one CenterPoint substation and the other ATO supplying the other main of a main-tie-main lineup from a circuit from the other CenterPoint substation. The CenterPoint ATOs are programmed for automatic operation and the building main switchgear ties are a manual operation.

• Terminal A North Concourse switchgear lineup number one consists of switchgear SWGR1A and SWGR1B. Terminal A North Concourse switchgear lineup number two consists of switchgear SWGR2A and SWGR2B.

South

• The electrical services to the Terminal A South Concourse include two, 2,000 kVA and two, 1,500 kVA transformers. Two, 12.47 kV-480/277 V transformers serve a switchgear lineup with a main-tie-main configuration. This is typical of two switchgear lineups. Each transformer is supplied from a CenterPoint auto transfer switch (ATO) allowing the service to transfer between the two different 12.47 kV distribution lines. The Terminal A South Concourse west transformer ATOs are normally configured with one ATO supplying one main of a main-tie-main lineup from a circuit from one CenterPoint substation and the other ATO supplying the other main of a main-tie-main lineup from a circuit from the other CenterPoint substation. The Terminal A South Concourse east transformer ATOs are normally configured with both ATOs supplying both mains of the main-tie-main lineup from a circuit from one CenterPoint substation. The CenterPoint ATOs are programmed for automatic operation and the building main switchgear ties are a manual operation.

• The Terminal A South Concourse switchgear lineup number one consists of switchgear SWGR1A and SWGR1B and is supplied from 2,000 kVA transformers. The Terminal A South Concourse switchgear number two consists of switchgear SWGR2A and SWGR2B and is supplied from 1,500 kVA transformers.

Terminal B Core

• The electrical services to the Terminal B Core building originate at CenterPoint's Basement Level Vault with six, 500 kVA, 277 V transformers. Three single phase, 277 V transformers are arranged in a wye configuration for a 1,500 kVA, three-phase, four-wire wye 277 V/480 V electrical service transformer. The two 1,500 kVA transformers are configured in parallel for redundancy.

• The electrical service to the Terminal B Core building is a single bus to a main switchgear line up. The main switchgear is a single main switchgear lineup in the tunnel level main electrical room and does not include a dual main or tie breakers.

FS5

• Flight Station 5 is supplied by electrical service from the Terminal B Core building and from supplemental electrical service dedicated to the flight station. The supplemental electrical service to the Terminal B Flight Station 5 is a pad-mounted 1,000 kVA, three-phase, four-wire wye 277 V/480 V electrical service transformer. The transformer is supplied from the Terminal B Core building basement level vault. The original 750 kVA transformer was upgraded with the addition of the building extension for the airfield level facility for bus service to transfer passengers to airfield level boarding ramps. The main switchboard is a single main configuration and does not include a dual main or tie breakers. The main switchboard is located in an electrical room on the airfield level. The 14 month peak load history from the electrical utility transformer indicated a peak load in July 2012 of 636 kVA. The peak load corresponds to 64% of the transformer rating and 38% of the switchboard rating.

FS6

• Flight Station 6 is supplied by electrical service from the Terminal B Core building and from supplemental electrical service dedicated to the flight station. The supplemental electrical service to the Terminal B Flight Station 5 is a pad-mounted 750 kVA, three-phase, four-wire wye 277 V/480 V electrical service transformer. The transformer is supplied from the Terminal B Core building basement level vault. The original 750 kVA transformer was not upgraded when the Flight Station 5 transformer was upgraded. The transformer is connected to two secondary feeders to supply two main distribution switchboards. Switchboard DP does not have a main breaker and includes seven distribution breakers which exceed the NEC six handle rule. Switchboard DPN-A is located on the apron at Flight Station 6 and includes a 1,600 ampere main in a single main configuration. The Flight Station 6 switchboards do not include dual main breakers or tie breakers. The 14 month peak load history from the electrical utility transformer indicated a peak load in July 2012 of 785 kVA. The peak load exceeds the transformer rating and corresponds to 105 percent of the transformer rating. The load to the two switchboards cannot be determined from the utility peak data, but 785 kVA corresponds to 944 amps and the two switchboards are each rated for 1,600 amps.

Terminal C Core

• The electrical services to the Terminal C Core building originate at CenterPoint's Vault with two, 2,500 kVA, 277 V/480 V transformers and two, 277 V/480 V transformers. One 2,500 kVA transformer supplies SWGR-N Service 3 main to the 3,000 A busway, to MSB-1 and one, 3,000 kVA transformer supplies SWGR-N Service

1 main The two mains are connected in a main-tie-main configuration. Another 2,500 kVA transformer supplies SWGR-S Service 2 main to the 3,000 A busway to MSB-2 and one 3,000 kVA transformer supplies SWGR-S Service 4 main These two mains are also connected in a main-tie-main configuration. The main-tie-main switchgear includes a kirk key system manual tie and the vault includes an automatic transfer primary control system. The normal configuration is for one primary circuit from one substation to supply power to two transformers, each of which supply one main of SWGR-N and one main of SWGR-S. The other primary circuit from the other substation normally supplies power .

North

• The Terminal C North Concourse is supplied from both electrical service from the Terminal C Core building and from supplemental electrical service dedicated to the North Concourse. The supplemental electrical service to the Terminal C North Concourse is a pad-mounted 750 kVA three-phase four-wire wye 277 V/480 V electrical service transformer. The 277 V/480 V pad-mounted transformer is supplied from a CenterPoint manual transfer switch (MTO) allowing the service to transfer between two different 12.47 kV primary circuits. The CenterPoint MTOs operate manually; however, CenterPoint can provide ATOs for automatic operation. The transformer is a radial distribution and supplies two switchboards. The main switchboard is a single main lug only configuration with output fused switches and does not include a dual main or tie breakers.

• The Terminal C North Concourse is also supplied from a second supplemental electrical service with a pad mounted 3,000 kVA three–phase, four-wire wye, 2.4 kV/4.16 kV electrical service transformer. The 2.4 kV/4.16 kV pad-mounted transformer is supplied from a CenterPoint manual transfer switch (MTO) allowing the service to transfer between two different 12.47 kV primary circuits. The CenterPoint MTOs operate manually; however, CenterPoint can provide ATOs for automatic operation. The 4,160 V switchgear is a radial supplied main lug only configuration and does not include a dual main or tie breakers. The 4,160 V switchgear also supplies three unit substations rated for 2,000 kVA, 1,500 kV North A, and 1,000 kVA.

South

• The Terminal C South Concourse is supplied from both electrical service from the Terminal C Core building and from supplemental electrical service dedicated to the South Concourse. The supplemental electrical service to the Terminal C South Concourse is a pad-mounted 750 kVA three-phase, four-wire wye, 277 V/480 V electrical service transformer. The 277 V/480 V pad-mounted transformer is supplied from a CenterPoint manual transfer switch (MTO) allowing the service to transfer between two different 12.47 kV primary circuits. The CenterPoint MTOs operate manually; however, CenterPoint can provide ATOs for automatic operation. The transformer is a radial distribution and supplies two switchboards. The main switchboard is a single main lug only configuration with output fused switches and does not include a dual main or tie breakers.

• The Terminal C South Concourse is also supplied from a second supplemental electrical service with a pad mounted 5,000 kVA three-phase, four-wire wye, 2.4 kV/4.16 kV electrical service transformer. The 2.4 kV/4.16 kV pad-mounted transformer is supplied from a CenterPoint manual transfer switch (MTO) allowing the service to transfer between two different 12.47 kV primary circuits. The CenterPoint MTOs operate manually; however, CenterPoint can provide ATOs for automatic operation. The 4,160 V switchgear is a radial supplied main lug only configuration and does not include a dual main or tie breakers. The 4,160 V switchgear supplies multiple unit substations for 277 V/480 V service to distribution switchboards and panel boards.

• The electrical services to the Terminal C Parking Garage (United Airlines Baggage Sorting West) includes two, 3,000 kVA 12.47 kV-480/277 V transformers serving switchboard lineup GSWGA with a main-tie-main configuration. Each transformer is supplied from a CenterPoint manual transfer switch (MTO) allowing the service to manually transfer between the two different 12.47 kV distribution lines. The MTOs are normally configured with one MTO supplying one main of a main-tie-main lineup from a circuit from one CenterPoint substation and the other MTO supplying the other main of a main-tie-main lineup from a circuit from the other CenterPoint substation. One side of the GSWGA lineup supplies the original garage switchboard GSWSB1 as well as a feeder to the FIS Building.

• The electrical services at 3860 North Terminal Road to United Airlines Baggage Sorting East in the Terminal C Parking Garage includes two, 2,500 kVA 12.47 kV/480/277 V transformers serving switchgear lineup SB1BSA/SB1BSB with a main-tie-main configuration. Each transformer is supplied from a CenterPoint auto transfer switch (ATO) allowing the service to transfer between the two different 12.47 kV distribution lines. The ATOs are normally configured with one ATO supplying one main of a main-tie-main lineup from a circuit from one CenterPoint substation and the other ATO supplying the other main of a main-tie-main lineup from a circuit from the other CenterPoint substation. One side of the GSWGA lineup supplies the original garage switchboard GSWSB1 as well as a feeder to the FIS Building.

Terminal D (MLIT)

The electrical service to the Terminal D Vault is supplied from two separate substations. Each feeder from CenterPoint (CNP) feeds automatic throw over equipment (ATO) between the two CNP feeders. During normal operating conditions, the first substation circuit feeds one side of a 15 kV rated main-tie-main switchgear with the second substation circuit feeding the other side. The 15 kV rated switchgear serves three double-end, 480 V substations (MSGR A, MSGR B, and MSGR C). The voltage is stepped down to 480 V via 12.47 kV-480/277 V transformer on the primary side of each unit substation main

Switchgear MSGR A is a main-tie-main configuration with kirk-key interlock. The main breakers are rated at 4,000 A and the tie breaker is rated for 2,000 A. This switchgear serves switchboard SWBD A1 and switchboard SWBD A2.

Switchgear MSGR B is a main-tie-main configuration with kirk-key interlock. The main breakers are rated at 4,000 A and the tie breaker is rated for 2,000 A. This switchgear serves switchboard SWBD B1 and switchboard SWBD B2.

Switchgear MSGR C is a main-tie-main configuration with kirk-key interlock. The main and tie breakers have a frame size of 1,600 A and a trip setting of 800 A. This switchgear serves switchboard SWBD C1 and switchboard SWBD C2.

Terminal E

The electrical services to Terminal E originate at CenterPoint's 3,000 kVA transformers. Two 12.47 kV-480/277 V transformers serve a switchgear lineup with a main-tie-main configuration. This is typical of four switchgear lineups. A total of eight CenterPoint transformers feed Terminal E. CenterPoint feeds the transformers from two 12.47 kV distribution lines each fed from a different substation. Each transformer is served by a manual transfer switch allowing the service to transfer between the two different 12.47 kV distribution lines.

There are two main switchgear rooms with each housing two switchgear lineups. Switchgear 1 and 2 are located in Room E1.109B and switchgear 3 and 4 are located in Room E1.401. Each switchgear lineup consists of two 5,000 ampere main breakers and one 5,000 ampere tie.

FIS Building

The electrical services to the FIS Building originate at CenterPoint's 2,000 kVA transformers. Two, 12.47 kV-480/277 V transformers serve a switchgear lineup with a main-tie-main configuration. This is typical of two switchgear lineups. A total of four CenterPoint transformers feed the FIS Building. CenterPoint feeds the transformers from two 12.47 kV distribution lines each fed from a different substation. Two transformers are served by an auto transfer switch allowing the service to transfer between the two different 12.47 kV distribution lines with a total of two ATOs serving the building.

The FIS building CenterPoint ATOs each supply two transformers and each transformer supplies one main of each of the two main-tie-main lineups. The ATOs are normally configured such that one main from each of the two switchgear lineups is supplied from a circuit from one CenterPoint substation and the other main is supplied from a circuit from the other CenterPoint substation.

Switchgear lineup number 1 consists of switchgear MSGR MSA and MSGR MSB and is a main-tie-main configuration with kirk-key interlock. The main breakers are rated at 4,000 A and the tie breaker is rated for 4,000 A.

Switchgear lineup number 2 consists of switchgear MSGR MSC and MSGR MSD and is a main-tie-main configuration with kirk-key interlock. The main breakers are rated at 4,000 A and the tie breaker is rated for 4,000 A.

CUP

The electrical utility service to the facility is a 12 kV primary service. The original 1965 480 V utility service to the Central Utilities Plant was replaced in 1988 and the 1988 12 kV switchgear MV-SWGR-1 and 2 resupplied the utility company transformers to provide 4.16 kV to electric chillers and 277 V/480 V to pumps, cooling towers, boilers, lighting, and the remainder of the facility equipment. The electric utility transformers were transferred from electric utility ownership to HAS ownership. A second 12 kV switchgear MVSWGR A and B was added in 1999 with the Central Utilities Plant expansion project (HAS 424B) to supplement the power at the central plant and power additional chillers, pumps, cooling towers, and other loads for the remainder of the facility equipment.

The 12 kV feed to the CUP can support an expanded plant load of 5,000 tons of cooling equipment but this could max out the infrastructure. Other infrastructure configured predominately for 12 kV distribution is adequate for current loads. However, in order to supply a new terminal or major expansion of existing terminals, the infrastructure will need to be upgraded to accommodate dual 35 kV feeds throughout the airport.

2. Load Analysis

Terminal A Core

As the load on the building has increased, the building load has exceeded the capacity of one transformer bank and both transformer banks are required to support the current load. The 14 month peak load history from the electrical utility indicated a peak load in June 2013 of 1,732 kVA. The peak load corresponds to 58% of the transformer rating with both transformers in service in the normal configuration, but corresponds to 115% of the transformer rating with only one transformer in service confirming that the transformers are not currently redundant. Previous 14 month peak load history from the electrical utility provided for HAS Project 634 indicated a peak load of 2,010 kVA. This previous peak load corresponds to 67% of the transformer rating with both transformers in service in the normal configuration but corresponds to 134% of the transformer rating with only one transformer in service confirming that the transformers are not currently redundant.

a. Capacity Planning

It is recommended that dual transformers and dual selector switches, in a main-tie-main or main-tie-tie-main configuration be provided, in addition to new larger 1750 kVA transformers for a truly redundant system that allows for future expansion or remodel.

North

Terminal A North Concourse switchgear lineup number one consists of switchgear SWGR1A and SWGR1B. The 14 month peak load history from one electrical utility transformer indicates a peak load in May 2013 of 480 kVA or 32% of the transformer rating and 19% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in August 2012 of 526 kVA or 35% of the transformer rating and 21% of the switchgear rating. The sum of the two peak loads is 1,006 kVA or 67% of one transformer rating and 40% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

Terminal A North Concourse switchgear lineup number two consists of switchgear SWGR2A and SWGR2B. The 14 month peak load history from one electrical utility transformer indicates a peak load in March 2013 of 678 kVA or 45% of the transformer rating and 27% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in March 2013 of 740 kVA or 49% of the transformer rating and 30% of the switchgear rating. The sum of the two peak loads is 1,418 kVA or 95% of one transformer rating and 57% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers. These loads indicate that the transformer redundancies may be compromised with less than 5% of additional load whether from load growth or from variations in the equipment load that may not be captured in a 14 month peak load history.

b. Capacity Planning

It is recommended that the 1,500 kVA transformers feeding Terminal A North be upgraded to 1,750 kVA transformers in order to be truly redundant and allow for future expansion and renovation.

South

The Terminal A South Concourse switchgear lineup number one consists of switchgear SWGR1A and SWGR1B and is supplied from 2,000 kVA transformers. The 14 month peak load history from one electrical utility transformer indicates a peak load in July 2013 of 362 kVA or 18% of the transformer rating and 15% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in June 2013 of 517 kVA or 26% of the transformer rating and 21% of the switchgear rating. The sum of the two peak loads is 879 kVA or 44% of one transformer rating and 35% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The Terminal A South Concourse switchgear number 2 consists of switchgear SWGR2A and SWGR2B and is supplied from 1,500 kVA transformers. The 14 month peak load history from the electrical utility transformer indicated a peak load in July 2012 of 636 kVA. The peak load corresponds to 64% of the transformer rating and 38% of the switchboard rating. The 14 month peak load history from one electrical utility transformer indicates a peak load in July 2013 of 467 kVA or 31% of the transformer rating and 19% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in August 2013 of 401 kVA or 27% of the transformer rating and 16% of the switchgear rating. The sum of the two peak loads is 868 kVA or 58% of one transformer rating and 35% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

c. Capacity Planning

The existing capacity is sufficient to handle existing loads with true redundancy, as well as sufficient capacity for future renovations and expansion.

Terminal B

As the load on the building has increased, the building load has exceeded the capacity of one transformer bank and both transformer banks are required to support the current load. The 14 month peak load history from the electrical utility indicated a peak load in August 2012 of 2,199 kVA. The peak load corresponds to 73% of the transformer rating with both transformers in service in the normal configuration but corresponds to 147% of the transformer rating with only one transformer in service confirming that the transformers are not currently redundant.

d. Capacity Planning

It is recommended that dual transformers and dual selector switches, in a main-tie-main or main-tie-tie-main configuration be provided, in addition to new larger 2,250 kVA transformers for a truly redundant system that allows for a future expansion or remodel.

Terminal C Core

The 14 month peak load history from one electrical utility transformer indicates a peak load of 965 kVA or 32% of the transformer rating and 23% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load of 171 kVA or 7% of the transformer rating and 4% of the switchgear rating. The sum of the two peak loads is 1,136 kVA or 45% of one transformer rating and 27% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The 14 month peak load history from the third electrical utility transformer indicates a peak load of 419 kVA or 17% of the transformer rating and 10% of the switchgear rating. The 14 month peak load history from the fourth electrical utility transformer indicates a peak load of 1,284 kVA or 43% of the transformer rating and 31% of the switchgear rating. The sum of the two peak loads is 1,703 kVA or 68% of one transformer rating and 41% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

e. Capacity Planning

The existing capacity is sufficient to handle existing loads with true redundancy, as well as sufficient capacity for future renovations and expansion.

North

The 14 month peak load history from the first supplemental electrical utility transformer indicated a peak load in August 2013 of 207 kVA. The peak load corresponds to 28% of the transformer rating and 21% of the switchboard rating.

The 14 month peak load history from the second supplemental electrical utility transformer indicated a peak load in August 2013 of 1,425 kVA. The peak load corresponds to 48% of the transformer rating and 16% of the switchboard rating.

f. Capacity Planning

The existing capacity is sufficient to handle existing loads, as well as sufficient capacity for future renovations and expansion. However, there is no redundancy built into the system. It is recommended that a second transformer be added for redundancy.

South

The 14 month peak load history from the first supplemental electrical utility transformer, for the South Terminal, indicated a peak load in May 2013 of 204 kVA. The peak load corresponds to 27% of the transformer rating and 20% of the switchboard rating.

The 14 month peak load history from the second supplemental electrical utility transformer for the South Terminal indicated a peak load in August 2013 of 2,257 kVA. The peak load corresponds to 45% of the transformer rating and 16% of the switchboard rating.

g. Capacity Planning

The existing capacity is sufficient to handle existing loads, as well as having sufficient capacity for future renovations and expansion. However, there is no redundancy built into the system. It is recommended that a second transformer be added for redundancy.

Terminal C Parking Garage

The 14 month peak load history, for the electrical services to the Terminal C Parking Garage (United Airlines Baggage Sorting West), from one electrical utility transformer indicates a peak load in November 2012 of 1,031 kVA or 34% of the transformer rating and 25% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in September 2012 of 557 kVA or 19% of the transformer rating and 13% of the switchgear rating. The sum of the two peak loads is 1,588 kVA or 53% of one transformer rating and 38% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The 14 month peak load history for the electrical services to 3860 North Terminal Rd. (United Airlines Baggage Sorting East) from one electrical utility transformer indicates a peak load in May 2013 of 895 kVA or 36% of the transformer rating and 27% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in May 2013 of 1,318 kVA or 53% of the transformer rating and 40% of the switchgear rating. The sum of the two peak loads is 2,213 kVA or 89% of one transformer rating and 67% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers. As the load on the building has increased, the building load is approaching the capacity of one transformer to support the current load in the tie configuration.

h. Capacity Planning

The existing capacity is sufficient to handle existing loads with true redundancy, as well as sufficient capacity for future renovations and expansion.

Terminal D (MLIT)

The 14 month peak load history from the electrical utility transformers indicated a peak load in June 2013 of 2,696 kVA. The peak load corresponds to 10 of the switchgear rating.

i. Capacity Planning

The existing capacity is sufficient to handle existing loads, as well as sufficient capacity for future renovations and expansion.

Terminal E

The 14 month peak load history from the first electrical utility transformer indicated a peak load in August 2012 of 930 kVA. The peak load corresponds to 31% of the transformer rating and 22% of the switchboard rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in October 2012 of 1,322 kVA or 44% of the transformer rating and 32% of the switchgear rating. The sum of the two peak loads is 2,252 kVA or 75% of one transformer rating and 54% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The 14 month peak load history from the third electrical utility transformer indicated a peak load in October 2012 of 1,239 kVA. The peak load corresponds to 41% of the transformer rating and 30% of the switchboard rating. The 14 month peak load history from the forth electrical utility transformer indicates a peak load in April 2013 of 1,050 kVA or 35% of the transformer rating and 25% of the switchgear rating. The sum of the two peak loads is 2,289 kiva or 76% of one transformer rating and 55% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The 14 month peak load history from the fifth electrical utility transformer indicated a peak load in August 2013 of 898 kVA. The peak load corresponds to 30% of the transformer rating and 22% of the switchboard rating. The 14 month peak load history from the sixth electrical utility transformer indicates a peak load in August 2012 of 1,269 kVA or 42% of the transformer rating and 31% of the switchgear rating. The sum of the two peak loads is 2,167 kVA or 72% of one transformer rating and 52% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The 14 month peak load history from the seventh electrical utility transformer indicated a peak load in August 2012 of 1,143 kVA. The peak load corresponds to 38 % of the transformer rating and 27% of the switchboard rating. The 14 month peak load history from the eighth electrical utility transformer indicates a peak load in August 2013 of 684 kVA or 23% of the transformer rating and 16% of the switchgear rating. The sum of the two peak loads is 1,827 kVA or 61% of one transformer rating and 44% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

j. Capacity Planning

The existing capacity is sufficient to handle existing loads with true redundancy, as well as sufficient capacity for future renovations and expansion.

FIS

The 14 month peak load history from one electrical utility transformer indicates a peak load in August 2013 of 679 kVA or 34% of the transformer rating and 20% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicates a peak load in January 2013 of 539 kVA or 27% of the transformer rating and 16% of the switchgear rating. The sum of the two peak loads is 1,218 kVA or 61% of one transformer rating and 37% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The 14 month peak load history from the third electrical utility transformer indicates a peak load in March 2013 of 614 kVA or 31% of the transformer rating and 18% of the switchgear rating. The 14 month peak load history from the fourth electrical utility transformer indicates a peak load in September 2012 of 533 kVA or 27% of the transformer rating and 16% of the switchgear rating. The sum of the two peak loads is 1,147 kVA or 57% of one transformer rating and 34% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

k. Capacity Planning

The existing capacity is sufficient to handle existing loads, as well as sufficient capacity for future renovations and expansion. However, in order for there to be true redundancy built into the system, it is recommended that a second feeder from CenterPoint be provided from a separate substation.

CUP

The 14 month peak load history from the first electrical utility transformer indicated a peak load in August 2013 of 2,321 kVA. The peak load corresponds to 12% of the switchgear rating. The 14 month peak load history from the second electrical utility transformer indicated a peak load in August 2012 of 1,087 kVA. The peak load corresponds to 6% of the switchgear rating. The sum of the two peak loads is 3,408 kVA or 18% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The 14 month peak load history from the third electrical utility transformer indicated a peak load in June 2013 of 4,327 kVA. The peak load corresponds to 30% of the switchgear rating. The 14 month peak load history from the forth electrical utility transformer indicated a peak load in August 2013 of 3,975 kVA. The peak load corresponds to 28% of the switchgear rating. The sum of the two peak loads is 8,302 kVA or 58% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

l. Capacity Planning

The proposed plan to replace the existing steam driven chillers with electrical centrifugal chillers would increase the existing peak demand by 2MVA. In addition the plant peak chilled water load is projected to grow an additional 6.8MVA. Adding these two demands equals 8.8MVA of new load on the Plant.

The additional load of 8.8MVA Is not a problem for HAS's existing electrical Infrastructure. However, Center Point's (CNP) infrastructure can only handle 4.8MVA and will need to be upgraded to meet this demand. 2MVA corresponds to 18% of the switchgear rating on transformer one, and 12% on transformer two. The combined impact is 30% of the switchgear rating when the tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

The proposed final projected additional load of 6.8MVA can also be divided up evenly between transformers one and two, resulting in a proposed peak load of 5,721 kVA on transformer one, or 30% of the switchgear rating, and a proposed peak load of 6,487 kVA on transformer two, or 36% of the switchgear rating. The sum of the two peak loads is 12,208 kVA or 67% of the switchgear rating when the switchgear tie breaker is closed and the switchgear is supplied from one of the two redundant transformers.

Center Point's the existing 12 kV feed to the CUP can only support an expanded plant load of 5,000 tons of cooling equipment, or an additional 4.8MW. Therefore, although the existing 12 kV Infrastructure can easily handle the replacement of the existing steam driven chillers to electrical centrifugal chillers, the proposed final projected load of 6.8 MVA will require a significant upgrade to the existing 12 kV underground infrastructure by Center Point.

B. Fire Protection (FP) and Domestic Water (DW)

1. Existing

The City of Houston, Public Works, provides water to IAH. Public Works has stated that they can't guarantee more than 35 psi pressure under normal operations to customer meters. On 5/29/2014, City of Houston Managing Engineer, Kira Smith, wrote, "we are not able to guarantee more than 35 psi under normal operations to customer meters and we do not have jurisdiction downstream of a meter." Water pressures at the airport have been reported well below 35 psi. This is a problem for both fire protection and domestic water systems that require adequate flow and pressure to meet code requirements.

A 6 in water line services Terminal C. The 6 in line branches from the existing 12 in ductile iron water line, located in North Terminal Road, just south of Terminal C.
An 8 in PVC line provides water to Terminal D. The 8 in line branches from the existing 16 in water line, located in North Terminal Road, just south of Terminal D. A 4 in water line, branching from the 16 in main around Gate D3, runs north and feeds an apron environmental drainage network with 2 in and 1.5 in water lines. The 8 in line supplies water to a City of Houston required surge tank located in the Basement Level (74) main mechanical room.

The Basement Level (74) surge tank serves both the fire pump and the domestic water booster pumps. The fire pump is electrically driven (200 hp) and has a capacity equal to 1,500 gpm (140 psi). A 15 gpm jockey pump provides firewater to a complete standpipe and automatic sprinkler system. The Fire Department Pumper Truck Connections (FDC) are located landside, near the east entrance of Terminal D. Two fire pump test station connections are located adjacent to the FDCs.

Unlike Terminal D, no fire sprinkler protection system is installed in Terminal C. Evidence of a stand pipe system was observed on the airside, located just west of the C Pier, which included a single hose cabinet, with a 11/2 in hose, 100 ft in length. The cabinet pressure gage indicated 180 psig static pressure. A 6 in line provides the existing Terminal C water supply. The 6 in line branches from the existing 12 in ductile iron water line loop located at the North Terminal Road, just south of Terminal C. The existing 12 in line serves the fire hydrants located landside, along the sidewalk in front of Terminal C.

1. Load Analysis

a. Fire Protection Requirements: Per Table B105.1 of the 2012 International Fire Code (IFC), the maximum fire flow for Type IIIA construction for buildings over 166,501 square feet = 6,000 gpm for 4 hour duration. In addition, IFC B105.2 includes an exception which states that a reduction of 75% is allowed with an approved automatic sprinkler system. Therefore, per the IFC, fire flow for Terminal buildings larger than 166,501 sf equals 1,500 gpm for 4 hour duration. Estimated storage tank size for FP is 1,500 gpm 60 min/hr x 4 hrs x 1.1 = 396,000 gallons.

As a check, paragraph 4.5.5 Water Supply from NFPA 415, Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways, 2013 Edition, states that water supply must be adequate to supply the maximum calculated sprinkler demand plus a minimum of 500 gpm for hose streams. Using 0.2 gpm/remote area (Ordinary Hazard, Group 2, Baggage Handling) the requirement is 1,500 sf x 0.2 gpm/sf + 27% overspray equals 381 gpm. Adding 500 gpm for hose stream equals 881 gpm which is less than 1500 gpm per IFC.

The Design Team must confirm the following prior to design of fire protection requirements for Terminals at IAH:
1. Local City of Houston Amendments do not have more severe requirements.
2. The Terminal project will have an approved automatic sprinkler system.

b. Domestic Water Requirements:
Per email dated 5/29/14, from Managing Engineer of City of Houston Department of Public Works and Engineering, Kira Smith, she states, "I talked with James Beauchamp at Texas Commission on Environmental Quality (TCEQ) this morning, who manages the group that activates and deactivates public water systems. He said that you are not considered a public water system unless you add disinfection or other treatment facilities. You meet the Chapter 290 exception requirements cited below if you simply re-pressurize. However, if Plumbing Codes or other City of Houston standards require you to install disinfection, then you would no longer meet the exception requirements." The design team will need to confirm if the Plumbing Codes or other City of Houston standards require IAH to install disinfection.

The 290 exception is as follows:
(a) General applicability. This subchapter shall apply to all public water systems as described in each section, unless the system:
(1) consists only of distribution and storage facilities (and does not have any production and treatment facilities);
(2) obtains all of its water from, but is not owned or operated by, a public water system to which such standards apply;
(3) does not sell water to any person;
(4) is not a carrier which conveys passengers in interstate commerce; and
(5) is subject to plumbing restrictions and inspections by the public water system which provides the water.

City of Houston regulations link: https://www.tceq.texas.gov/rules/indxpdf.html

HAS Direction:
1. Confirm that IAH storage and pumping system does not "trigger" or constitute a separate public water system as per Texas Code.
2. Confirm storage requirements (potential minimum 24-hours peak flow volume).

Response:
1. IAH storage and pumping system meets the exception criteria listed in chapter 290, listed above. The design team will need to confirm that plumbing codes or other City of Houston standards do not require disinfection. If disinfection is required, a combined DW/FP storage/booster pump system would need to meet the "full" requirements of 290. Requirements include a certified operator to ensure water quality is maintained by treatment, monitoring residual tank displacement or both.
2. The reference to minimum 24-hours peak flow volume comes from Section 290-45, Table A: Maximum daily domestic water demand/minimum capacity. See estimated DW example calculation below, which indicates storage equal to 657,534 GPD for the airport.

RE: 290.41. WATER SOURCES:
Water quality. The quality of water to be supplied must meet the quality criteria prescribed by the commission's drinking water standards contained in Subchapter F of this chapter (relating to Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements for Public Water Systems).

RE: 290-43 WATER STORAGE:
Capacity. The minimum clearwell, storage tank, and pressure maintenance capacity shall be governed by the requirements in §290.45 of this title (relating to Minimum Water System Capacity Requirements).

Facility security. All potable water storage tanks and pressure maintenance facilities must be installed in a lockable building that is designed to prevent intruder access or enclosed by an intruder-resistant fence with lockable gates. Pedestal-type elevated storage tanks with lockable doors and without external ladders are exempt from this requirement.

RE: 290-44 WATER DISTRIBUTION
Minimum pressure requirement. The system must be designed to maintain a minimum pressure of 35 psi at all points within the distribution network at flow rates of at least 1.5 gallons per minute per connection. When the system is intended to provide firefighting capability, it must also be designed to maintain a minimum pressure of 20 psi under combined fire and drinking water flow conditions.

When service is to be provided to more than one pressure plane or when distribution system conditions and demands are such that low pressures develop, the method of providing increased pressure shall be by means of booster pumps taking suction from storage tanks.

EXCEPTION: Where booster pumps are installed to take suction directly from the distribution system, a minimum residual pressure of 20 psi must be maintained on the suction line at all times. Such installations must be equipped with automatic pressure cut-off devices so that the pumping units become inoperative at a suction pressure of less than 20 psi. In addition, a continuous pressure recording device may be required at a predetermined suspected critical pressure point on the suction line in order to record the hydraulic conditions in the line at all times. If such a record indicates critical minimum pressures, less than 20 psi, adequate storage facilities must be installed with the booster pumps taking suction from the storage facility. Fire pumps used to maintain pressure on automatic sprinkler systems only for fire protection purposes are not considered as in-line booster pumps.

RE: 290.45. MINIMUM WATER SYSTEM CAPACITY REQUIREMENTS
The executive director will require additional supply, storage, service pumping, and pressure maintenance facilities if a normal operating pressure of 35 pounds per square inch (psi) cannot be maintained throughout the system, or if the system's maximum daily demand exceeds its total production and treatment capacity. The executive director will also require additional capacities if the system is unable to maintain a minimum pressure of 20 psi during firefighting, line flushing, and other unusual conditions.

Table A: The maximum daily domestic water demand/minimum capacity for Airports is 6 gallons per day (GPD). The number of passengers that traveled through IAH in 2012 was 40,000,000 (40 MAP). That equates to a daily average equal to 109,589 passengers. Multiplying 40 MAP by 6 GPD equals to 657,534 GPD max daily domestic water demand.

Although elevated storage is the preferred method of pressure maintenance for systems of over 2,500 connections, it is recognized that local conditions may dictate the use of alternate methods utilizing hydropneumatic tanks and on-site emergency power equipment.

2. Evaluation
a. Base Case: Install zoned FP/DW combined systems within the central terminal area to serve Terminal projects as they are constructed. The base case requires multiple sites to locate tanks and pumps. The central terminal area is tight for space. In addition, installing multiple tanks and pumps will result in higher operating and maintenance costs than one central system that could serve all the terminals.

b. Alternative 1: Install a central FP/DW combined system with tank storage and booster pump station, sized to serve the airport Terminal buildings. This alternative provides the water capacity at the pressure needed for both FP and DW. The design team will need to confirm that plumbing codes or other City of Houston standards do not require disinfection.

c. Alternative 2: Install a dedicated tank storage and booster pump station for a hybrid FP/Gray Water system. Both the FP/GW system and the DW system would be separately-metered by the City. However, only the FP/GW system would have storage tanks and re-pressurization. The FP/GW system could potentially supply the toilets with the high pressure requirements. The remaining DW requirements would be supplied from the City water main as currently done with a meter and a backflow preventer.

This Alternative 2 would require dual piping to restrooms to supply gray water to toilets and domestic water to lavatories. Some of the potable water equipment would require booster pumps to meet the pressure needs due to the low City water pressure.

3. Project Phasing & Temporary Infrastructure
The combined FP/DW storage tanks and pump station is intended to support the water needs of the new Terminal C North project. During this initial phase only one 1500 gpm fire pump and a base number of domestic pumps would be needed, with additional pumps added as the distribution system is constructed to serve other Terminals in the future.

4. Recommendations
Recommend constructing the 1 million gallon FP/DW combined water system. Tanks to be sized at 500,000 gallons each. Fire pumps to be sized at 1500 gpm. Domestic water pumps to Include variable frequency drives to vary flow. Design team to determine optimal pump sizes and controls and meet minimum storage tank throughput requirements for water quality (3 days) throughout the year.

C. Chilled and Heating Water

SYSTEM ANALYSIS

As the Airport expands, the CUP capacity will need to increase to match the future heating and cooling loads. In analyzing this future growth and development of IAH, the following three options were considered.

- Base Case - Remove the existing steam boilers, Boiler 4 and Boiler 5 in 2023 in advance of the end of their service life, in the boiler room at the existing CUP to utilize the space for future hot water boilers.
- Alternate 1 – Plant Expansion – Provide additional space at the existing CUP to accommodate future plant growth.
- Alternate 2 - Satellite Plant – Provide additional space at a remote location relative to the existing CUP.

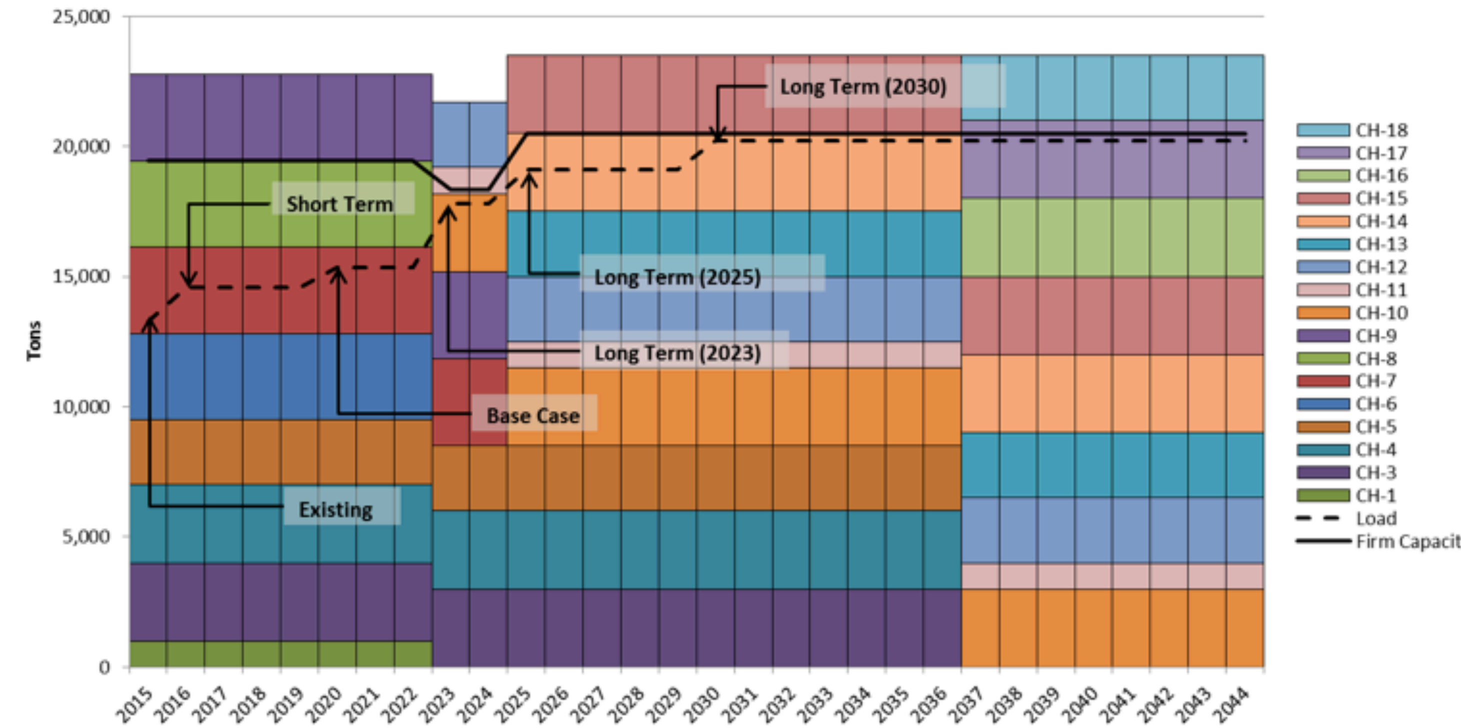
Only results for the Base Case are shown for the capacity analysis. The hydraulic model is primarily focused on the Base Case. However, a full build out satellite plant option has been provided to demonstrate the hydraulic benefits over the Base Case and Alternate 1. The Base Case and Alternate 1 are considered to be hydraulically identical. Annual cost estimates are included for all cases.

CENTRAL UTILITIES PLANT CAPACITY ANALYSIS

Currently, assets of the Central Utilities Plant provide enough firm capacity to be able to maintain N+1 redundancy for both chilled and hot water in support of Terminal B Pier B1, and MLIT D1 and D2 Facilities. In order to maintain this level of redundancy, the total installed capacity must be great enough to meet the peak load demands if the largest piece of production equipment is out of service (N+1 redundancy). The plant will not have adequate firm capacity throughout the entire 30 year analysis, requiring additional capacity to be installed for any load expansion beyond new facilities B1, D1 and D2. The capacity planning provided herein assumes that no additional plant space is required outside of the existing Central Utilities Plant. In this case, Boilers 4 and 5 are demolished in 2023, 7 years before the end of their expected service lives. As discussed below, operating the steam boilers solely to produce chilled water is inefficient compared to electrically driven units and utilizing existing plant space provides the lowest capital cost option. Without steam capacity, all steam driven chillers are likewise demolished in 2023, two years before their expected end of service life. Due to the size of the steam driven chillers and their surface condensers, it is assumed that electric chillers of equal or less capacity as well as one 2,500T electric chiller can be installed in their place. Additionally, this case assumes that two 16,000 MBH hot water boilers are installed in place of the steam boilers to serve future loads.

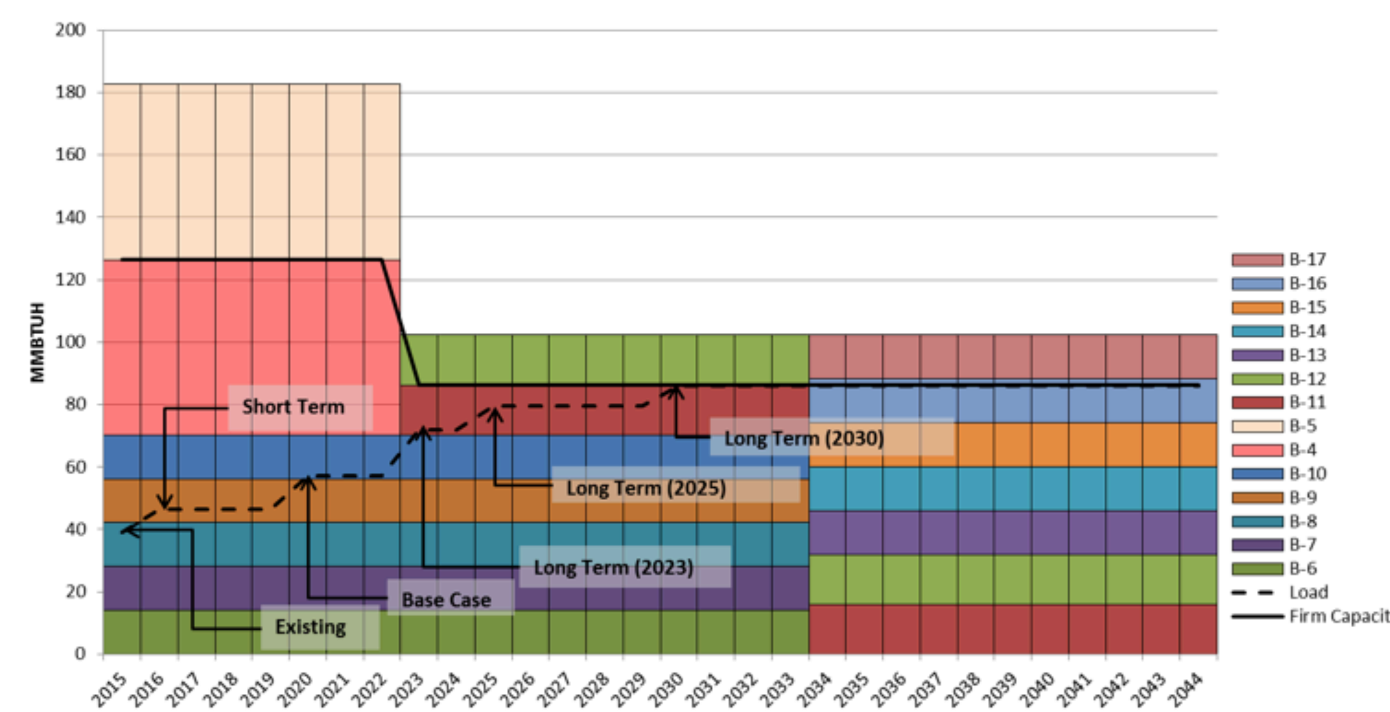
As seen in the figure to the top right, in order for the Airport to maintain N+1 redundancy for chilled water production at the Long Term phase, an additional 2,500T chiller must be installed.

Figure 1: Chiller Capacity Roadmap, Graphical



As seen in the figure and table below, in order for the Airport to maintain N+1 redundancy for hot water production at the Long Term (2023) phase, additional boiler capacity must be installed.

Figure 2: Boiler Capacity Roadmap, Graphical



The existing distribution system at IAH was originally installed in 1965 with several modifications and expansions occurring as recently as 2013. The system ranges in age from approximately 1- 50 years old. Visual inspections of the system revealed several instances of removed or deteriorating insulation and some external corrosion on pipe. However, the overall condition of the piping system and the remaining service life of the piping system is dependent on use, system maintenance and water treatment. The best way to effectively evaluate this without major disruptions to the system is through non-destructive examination (NDE).

HYDRUALIC DISTRIBUTION ANALYSIS

The IAH hot water and chilled water systems were modeled and analyzed using Pipe Flow Expert software. The chilled water and hot water systems were each modeled in several scenarios to capture the increasing load and capacity of the Airport from a representation of the existing system to a full future build out over 16 years. The following load scenarios were developed for both hot water and chilled water flow models:

1) Existing, 2014– Model Baseline

2) Short Term, 2016 (Terminal B1 - East)

3) Base Case, 2020 (Terminal D1, Central Processor and Terminal D2)

4) Long Term 1, 2023 (Terminal B2)

5) Long Term 2, 2025 (Terminal B3)

6) Long Term 3, 2030 (Terminal D3)

7) Long Term 3 with Satellite Plant, 2030

CHILLED WATER RESULTS

In the Existing, Short Term, and Base Case flow model scenarios, no pressure or velocity issues have been identified. In the long term scenarios, high velocity issues greater than 10 ft/s occur in two locations. The first section is the 20" tie-in piping near the "Christmas Tree" connection and is over 10 feet/second (ft/s) as early as 2025 and increases to over 11.5 ft/s by 2030. The second section where high velocities occur is located in the utility tunnel south of Pump Room B. Project 621 added two 2,070 gpm chilled water pumps within the tunnel to supply Terminal B south. The velocity in the 14" piping between the suction of these pumps and the CUP is approximately over 10 ft/s by 2025 and increases to over 11 ft/s by 2030.

While the velocity in these lines increases over a recommended maximum velocity of 10 ft/s, the instances are minimal due to load variances in the system. Table 7, F22.3 (2009 ASHRAE Handbook), states that water piping systems can minimize erosion while operating up to 12 ft/s if the normal operation is below this point for a minimum of 4,000 hours per year. However, these should be testing locations for non-destructive testing as discussed above. Replacement is not recommended unless warranted by testing results.

HOT WATER RESULTS

In the Existing, Short Term and Base Case flow model, no pressure or velocity issues have been identified in the distribution system. However, in the Base Case and Long Term models the header within the Central Utilities Plant is undersized to utilize all five existing hot water boilers. The velocities within the 10" main header exceed the 10 ft/s baseline and reach approximately 10.9 ft/s. Similar to the chilled water discussion above, the high velocities within the plant header are only experienced for a few hours though out the year and do not appear to be a major issue worth replacing. However, these locations should be verified with non-destructive testing. Following removal of the steam boilers in 2023, and installation of additional capacity, these flow issues will be resolved within the plant header. Installing additional capacity in a Satellite Plant would also relieve the main headers of velocity issues. No issues related to pressure have been identified from the flow model.

CAPACITY COST ESTIMATES

The following section provides rough order of magnitude (ROM) cost estimates for each option analyzed. The cost estimates include capacity additions and capacity replacements to maintain firm capacity throughout the 30 year analysis. The estimates do not include capital required for distribution piping replacement as a result of age. This is considered equal in all cases and replacement would be dependent of the results of an NDE.

BASE CASE

The first option for utility growth is removing the existing steam boilers, Boiler 4 and Boiler 5, and installing new 16,000 MBH boilers in this space in 2023. Ideally all boilers, including the existing boilers, could be moved in the existing steam boiler room to achieve code compliance by separating combustion assets from refrigeration assets. ASHRAE 15 and NFPA 85 state that special consideration and safety measures concerning refrigerant monitoring and combustion control is required to co-locate boilers and chillers within a common space. However, additional design would be required to confirm that the existing five hot water boilers and the future boilers could fit within the existing steam boiler space. Relocating the existing five boilers would have operational benefits, but these benefits are not considered to be great enough to warrant the capital cost required to relocate the existing assets and the cost is not carried forward in this analysis. All future boiler capacity is evaluated to be located within the steam boiler room. With the removal of the steam boilers, the three steam driven chillers will have to be replaced with electrical driven chillers to serve the chilled water load to maintain firm capacity. The removal of these steam driven chillers in 2023 would be two years earlier than the end of their expected service life. The table below shows the 30 year capital investments for this scenario. All costs provided are in 2014 dollars and do not account for inflation.

Table 1 Base Case ROM - Capital Cost Roadmap

Year	Equipment Costs	Plant/ Building Costs	Demolition Costs	Misc.	Subtotal	Total Costs
2022	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
2023	$3,666,800	$-	$383,964	$480,000	$4,530,764	$7,416,460
2025	$4,642,500	$-	$171,200	$450,000	$5,263,700	$8,593,540
2032	$795,000	$-	$39,750	$-	$834,750	$1,347,787
2033	$180,000	$-	$9,000	$-	$189,000	$305,159
2034	$1,055,000	$-	$52,750	$-	$1,107,750	$1,788,573
2035	$1,296,000	$-	$64,800	$-	$1,360,800	$2,197,148
2037	$4,122,500	$-	$206,125	$-	$4,328,625	$6,988,998
2038	$180,000	$-	$9,000	$-	$189,000	$305,159
2044	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
Total	**$21,170,520**	**$-**	**$1,198,225**	**$930,000**	**$23,298,745**	**$37,814,012**

ALTERNATIVE #1 - CENTRAL UTILITIES PLANT EXPANSION

The second option considered is to expand the Central Utilities Plant. Construction is limited to the west due to the water facility and control building and limited to the east due to the new control building constructed in Project 621. Therefore, the proposed location for expansion is to the east at the current parking lot location between Jetero Boulevard and Mecom Road. This will require the construction of a new building which will be in close proximity to the chilled water, hot water and electrical distribution network. It is recommended that the CUP expansion be completed by 2023 with one new 16,000 MBH hot water boiler installed and an additional installed in 2025 to increase the hot water capacity. The existing CUP would have enough installed capacity with the steam boilers to operate through 2030. However, based on load increases in 2023 the steam boilers would no longer be utilized solely as emergency back-up assets and would be required to carry a percentage of the hot water load. The time of construction of the expansion is driven by the required space for extra hot water capacity. In this option, the replacement of the steam driven chillers can be completed as capacity is required, assuming the steam boilers are still operational. Based on capacity planning, the three steam driven chillers will need to be replaced with electric chillers in 2025. The table below shows the thirty year capital investments for this scenario. All costs provide are in 2014 dollars and do not account for inflation.

Table 2 Alternate 1 ROM - Capital Cost Roadmap

Year	Equipment Costs	Plant/Building Costs	Demolition Costs	Misc.	Subtotal	Total Costs
2022	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
2023	$241,400	$4,631,923	$-	$240,000	$5,113,323	$9,281,999
2025	$8,067,900	$-	$555,164	$690,000	$9,313,064	$15,182,187
2032	$795,000	$-	$39,750	$-	$834,750	$1,347,787
2033	$180,000	$-	$9,000	$-	$189,000	$305,159
2034	$1,055,000	$-	$52,750	$-	$1,107,750	$1,788,573
2035	$1,296,000	$-	$64,800	$-	$1,360,800	$2,197,148
2037	$4,122,500	$-	$206,125	$-	$4,328,625	$6,988,998
2038	$180,000	$-	$9,000	$-	$189,000	$305,159
2044	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
Total	**$21,170,520**	**$4,631,923**	**$1,198,225**	**$930,000**	**$27,930,668**	**$46,268,198**

ALTERNATIVE #2 – SATELLITE PLANT

The final option considered is to build a new satellite plant at another location from the existing CUP. This will provide the additional chilled water and hot water capacity required while also improving redundancy and reliability. The proposed satellite plant location is east of Terminals E and the FIS, along the road connecting S Terminal Road and Will Clayton Parkway. It is recommended that the satellite plant is completed by 2023 with one new 16,000 MBH hot water boiler. By 2025, an additional hot water boiler, two new 2,500 ton chillers and a 1,000 ton chiller will be installed in the satellite plant to accommodate the increased chilled water load as well as alleviate high velocity issues in the chilled water system. The table below shows the thirty year capital investments for this scenario. All costs provide are in 2014 dollars and do not account for inflation.

The figure below compares the relative costs associated with each option and their total over the 30 year analysis. As shown, the satellite option requires the most capital up front and long term, but provides the most operational flexibility. The option of utilizing the existing CUP building requires the least capital up front and the least cost over the life of the analysis.

Table 3 Alternate 2 ROM - Capital Cost Roadmap

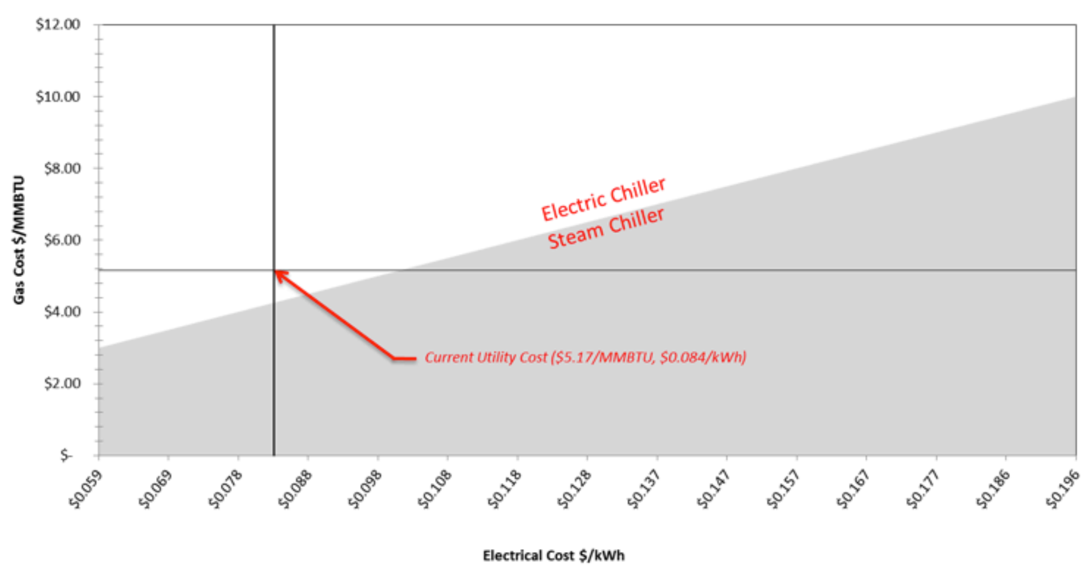
Year	Equipment Costs	Plant/Building Costs	Demolition Costs	Misc.	Subtotal	Total Costs
2022	$1,763,280	$-	$130,818	$-	$1,894,098	$3,058,211
2023	$311,400	$8,267,788	$-	$240,000	$8,819,188	$16,031,201
2025	$9,130,980	$-	$555,164	$690,000	$10,376,144	$16,898,636
2032	$515,000	$-	$39,750	$-	$554,750	$895,699
2033	$180,000	$-	$9,000	$-	$189,000	$305,159
2034	$1,055,000	$-	$52,750	$-	$1,107,750	$1,788,573
2035	$1,296,000	$-	$64,800	$-	$1,360,800	$2,197,148
2037	$4,122,500	$-	$206,125	$-	$4,328,625	$6,988,998
2038	$180,000	$-	$9,000	$-	$189,000	$305,159
2044	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
Total	**$21,170,520**	**$8,267,788**	**$1,198,225**	**$930,000**	**$31,566,533**	**$52,904,378**

STEAM VERSUS ELECTRIC CHILLER ANALYSIS

IAH has a combination of steam and electric chillers at the CUP. The following analysis has been completed in support of the base case plant expansion option (removal of steam Boiler 4 and Boiler 5), showing the economical disadvantages of operating the steam driven chillers over the electrical chillers. This analysis is only reflective of the natural gas and electrical utility costs. Additional Operations and Management (O&M) costs occur by having to operate and maintain the steam turbine drives and boilers that are predominately used for chilled water production.

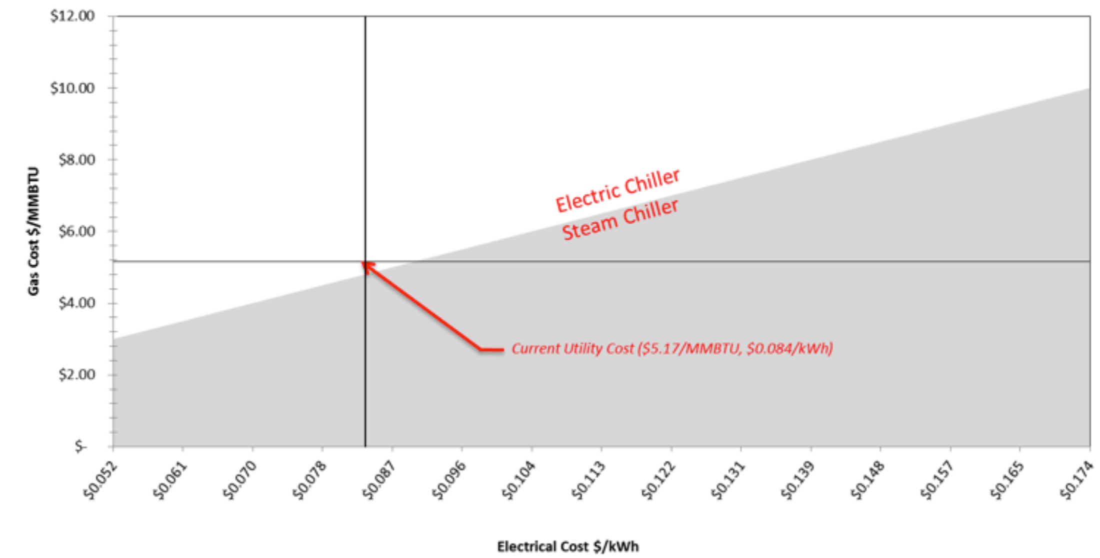
Depending on utility rates at any given time, it may be more economical to operate one versus the other assuming the Airport load does not require the operation of all chillers at the plant. The charts below show the breakeven line for running the Trane electric chillers versus the steam driven chillers and the York electric chillers versus the steam driven chillers given various electricity and natural gas costs. At the current average utility costs, it is more economically viable to operate the either the York or the Trane electric chillers over the steam driven chillers. At a current natural gas rate of $5.17/MMBtu, the electricity costs would need to increase to at least $0.10 kWh for steam driven chillers to be more cost effective than the Trane electric chillers and increase to at least $ .089/kWh for steam driven chillers to be more cost effective than the York electric chillers. At the current electricity rate or $0.084/kWh, the natural gas costs would need to decrease to $4.27/MMBtu for steam driven chillers to be more cost effective than the Trane electric chillers and $4.81/MMBtu for the York electric chillers.

Table 1 York Steam Driven Chiller vs. Trane Electric Chiller



*Assumed Trane chiller efficiency of .558 kW/Ton as published in the PN621 Equipment Schedule
**Assumed Steam Driven Chiller steam consumption of 8.16 lb/Ton

Table 2 York Steam Driven Chiller vs. York Electric Chiller



*Assumed Trane chiller efficiency of .629 kW/Ton as published in the PN621 Equipment Schedule
**Assumed Steam Driven Chiller steam consumption of 8.16 lb/Ton

These results show significant margin reflecting the benefits of the electric chillers in lieu of the steam driven chillers. Further, when considering the added O&M cost burden of steam driven equipment, the margin widens.

LOW TEMPERATURE HOT WATER ANALYSIS

The current peak hot water distribution temperature from the CUP is approximately 200°F. The 200°F distribution hot water is decoupled from the Terminals with a shell and tube heat exchanger. The Terminal side loop provides a maximum of 180°F hot water to air handling units (AHUs). Potential issues with reducing the overall supply temperature from the CUP and on the terminal side of the heat exchanger occur within existing air handlers, heat exchangers and distribution from the CUP. Maintaining a designed heat output from existing AHUs while lowering the supply temperature would also require lowering the leaving water temperature to maintain the overall temperature differential. Maintaining the temperature differential would be important to not overflow the coils and not to impose higher pressure drops in the system. However, the AHU would experience a minor derate in overall airside capacity due to a lower temperature hot water supplied. Additionally, lowering the Terminal side supply temperatures would reduce the performance of the heat exchanger. The heat exchangers would need to be replaced to maintain the Terminal side loads and the CUP return temperature of 155°F.

Lowering the hot water supply temperature while serving the same heat load creates a degree of concern with the distribution hot water return temperature. Lower return temperatures promote better heat transfer and thus better efficiencies but too much heat transfer from the flue gas can cause condensation of harmful sulfuric acid onto the boiler tubes. If the Airport decides to lower the hot water supply temperature, the operational temperature differential will also have decrease. Potential exists to lower the supply temperature; however the return temperature is on the bottom edge of acceptable return temperatures to remain from condensing in the boilers and causing internal damage. In the case of maintaining this hot water return temperature limit while lowering the hot water supply temperature, it can be understood that at best, an X% change in supply-return temperature difference results in a 1/X% change in pumping capacity. Increasing pumping capacity results in additional power consumption and a potential for high pipeline velocities. It may also require the installation of additional hot water pumps and may require upsizing the Terminal-side hot water heat exchangers to avoid unacceptable pressure losses. Although reducing the existing supply temperatures of existing terminals is not recommended due to the requirement of some additional design considerations and potential equipment replacement; the potential to design new terminals at a lower hot water supply temperature does exist. Lower supply temperatures also promote potential energy savings options.

COMBINED HEAT AND POWER SYSTEM ANALYSIS

Combined Heat and Power (CHP) is a system utilizing a prime mover such as a combustion turbine generator or a reciprocating engine to produce electricity. The waste heat from that prime mover is then used to produce hot water or steam to be utilized in the central heating supply. CHP can greatly increase the overall efficiency of the system, reduce the amount of purchased utilities, and reduce regional emissions. The efficiency and cost effectiveness of the system varies depending on the facility loads and utility costs; therefore a CHP analysis is necessary to determine its feasibility.

Three prime movers were selected for the CHP analysis; Centaur 50, Mercury 50, and the Jenbacher 624. Each prime mover is coupled with a heat recovery unit (HRU). The selection was based on the ability to maximize operation while utilizing the assumed hot water loads.

Table 1 Centaur 50 w/ Duct Fired HRU

Maximum Electrical Generating Capacity	5.0	MW
Nominal Turbine Heat Rate (HHV)	13,164	Btu/kWh
Nominal CHP Efficiency	66.3	%
Maximum Unfired Hot Water Production	22.4	MMBtu/hr
Additional Fired Hot Water Production	25.7	MMBtu/hr

Table 2 Mercury 50 w/ Duct Fired HRU

Maximum Electrical Generating Capacity	5.1	MW
Nominal Turbine Heat Rate (HHV)	9,951	Btu/kWh
Nominal CHP Efficiency	65.5	%
Maximum Unfired Hot Water Production	10.5	MMBtu/hr
Additional Fired Hot Water Production	32.6	MMBtu/hr

Table 3 Jenbacher 624 w/ HRU

Maximum Electrical Generating Capacity	4.3	MW
Nominal Engine Heat Rate (HHV)	7,401	Btu/kWh
Nominal CHP Efficiency	89.3	%
Maximum Total Hot Water Production	13.9	MMBtu/hr

* Nominal calculations completed at 55 F

Duct-firing is limited to the turbine generator exhausts because the excess air in the reciprocating engine by Jenbacher does not produce the same level of excess oxygen in the exhaust as its turbine counterparts. The electrical and thermal output for each prime mover was estimated across a range of loads (50-100%) and a range of ambient temperatures, corresponding to those experienced in Houston, TX. These outputs were used to calculate an hourly load profile for the prime mover throughout the year, as well as the excess hot water and electrical demand.

All three options where analyzed based on annual utility cost savings. Annual utility cost savings were compared to the base case cost, in which the entire 6 MW load would be satisfied by grid electricity and the entire hot water demand would be supplied by a boiler. The figure below compares the total annual utility costs for each prime mover compared to the base case.

Table 1 CHP Annual Savings

	Annual Fuel Costs	Annual Electrical Savings	Total Savings	Savings/MW
C50	$1,194,380	$829,005	$188,422	$19.03
M50	$2,001,773	$2,837,181	$1,389,206	$40.99
J624	$1,372,033	$2,604,678	$1,786,442	$57.41

*All cost/savings are incremental to the Base Case
**Annual O&M costs are based on Long Term Service Agreements (LTSA) to cover the maintenance of the prime mover.

Figure 2 Total Annual Utility Cost Based on 6 MW Load

The table below provides the incremental costs/savings for each option compared to the base case. Rough Order of Magnitude (ROM) estimates were developed for each option. The ROM estimates assume the CHP equipment and associated infrastructure would be installed adjacent to the existing plant.

Table 2: Calculated CO2 Emissions

		Base Case	Centaur 50	Mercury 50	Jenbacher 624
Typical Emissions Rates					
*Utility Equivalent Generation	lb/MWh	1,223	1,223	1,223	1,223
CHP Production	lb/MMBtu		117	117	117
Operating Profiles					
**Utility Generation Required	MWh	54,137	45,561	20,852	23,713
CHP Fuel Consumption	MMBtu	0	136,580	345,572	233,341
Annual Emissions Totals					
Annual Equivalent CO2 Emissions	Tons	30,032	32,523	29,908	25,539
Equivalent CO2 Reduction (Regional)	Tons		-2,491	125	4,494
Automobile Reduction	Cars		-453	23	816

*Based on eGRID 2010 ERCOT subregion

**Includes 3% distribution loss

The results show that the J624 and the M50 were significantly better options then the C50. This is attributed to their higher ratios of thermal to electricity outputs for equivalent fuel consumptions. These results show that CHP could be a viable option and is recommended for a detailed analysis. A detailed analysis would include developing a capital cost estimate for each option and evaluating the life cycle costs.

In addition to providing cost savings for power and hot water production, two of the three CHP options are estimated to also provide Greenhouse Gas reductions according to the table below. The Centaur 50 option does not provide a carbon offset due to its poor heat rate unlike the Mercury 50 and Jenbacher 624. However, without full knowledge of the Airport's air permits, conclusion of the effect of CHP carbon dioxide emissions cannot be made.

ELECTRICAL INFRASTRUCTURE

In 2013, Jacobs Engineering completed an assessment of the electrical infrastructure at George Bush Intercontinental Airport (IAH). The assessment was completed under Houston Airport Systems (HAS) 715B-LOA-008. The condition assessment evaluated the entire electrical infrastructure from the Center Point Energy service point at the Terminal transformers to the 480V distribution panels. Based on findings in the condition assessment and utilizes the findings from the condition assessment, an overall project phasing plan was developed to effectively correct the deficiencies while minimizing downtime and providing an overall ROM project costs. All equipment costs utilize those provided in the Jacobs study. All recommended projects are grouped and title as provided in the Jacobs study. Additional details, beyond those provided below, to each recommendation can be found in the Jacobs study.

TERMINAL A

Terminal A was originally constructed and opened in 1969. After opening there have been several renovations to reconstruct the north and south concourses. From the assessment report, the Terminal A electrical equipment and distribution system was installed in 1969 and has exceeded its anticipated operation life. Although the equipment is currently operational and in fair condition, it is recommended to replace all outdated equipment. The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Terminal A North Concourse Automatic Transformer Load Study and Upgrade if Required	2A
	2	Terminal A Core Building Switchgear Replacement	1A
	3	Code Issues and Other Deficiencies for Repairs	All
Near Term	4	Terminal A Core Building Manual Transfer Switches	1A
	5	Terminal A Core Building Manual Transfer Switches	1A
Long Term	6	Terminal A North Concourse Switchgear Replacement	2A
	7	Terminal A South Concourse Switchgear Replacement	3A

* Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs

TERMINAL B

According to the electrical infrastructure assessments, Terminal B was one of the initially constructed Terminals at IAH, but only minor renovations have occurred in the late 1990s and early 2000s. From the assessment report, the Terminal A electrical equipment and distribution system was installed in 1969 and has exceeded its anticipated operation life. Although the equipment is currently operational and in good condition, it is recommended to replace all outdated equipment. The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Flight Station 6 Transformer Load Study and Upgrade	2B
	2	Terminal B Core Building Vault and Switchgear Replacement	1B
	3	Code Issues and Other Deficiencies for Repairs	1B
Near Term	4	Critical Equipment Manual Transfer Switches	1B
	5	Replacement of Terminal B Core Building Aging Electrical Infrastructure	1B
Long Term	6	Replacement of Flight Station Aging Electrical Infrastructure	3B
	7	Replacement of Flight Station Switchgear	3B

* Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs.

TERMINAL E

Terminal E was originally constructed by Continental and has had multiple expansions and additions. In 2002, building renovations started on Terminal E and Federal Inspection Services (FIS). After the renovation, the building expanded to almost 800,000 square feet and United Airlines was added to the addition. The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs. Additional details for each Project Phase are provided below.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Egress Door Panic Hardware	1E
	2	Other Deficiencies for Repairs	2E
Long Term	3	Main-Tie-Tie-Main Switchgear	3E
	4	Arc Flash Resistant Switchgear	3E
	5	Manual Transfer Switches	3E

* Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs.

FIS BUILDING

The current Federal Inspection Services (FIS) building was renovated along with the Terminal E/Federal Inspection Services building upgrade. In 2002, HAS started the renovation phases and expanded to about 800,000 square feet. The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Preventative Maintenance	1FIS
	2	Code Issues and Other Deficiencies for Repairs	1FIS
Long Term	3	Replace FIS Building Switchgear of MTTM Configuration	2FIS

* Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs.

D. Jet Fuel

1. Existing

Jet-A fuel is pumped throughout the airport by a transmission system that feeds several distribution lines that in turn serve the various hydrants at each parking position.

System pressure fluctuates between 180 pound force per square inch gauge (psig) at the fuel farm and 120 psig at the cargo area. The transmission and distribution system consists of the following elements:

- Three, 18 in fuel lines supply fuel from the fuel farm to the airport Main Fuel Vault located on the west side of Terminal A.

- Five lines (three, 14 in and two, 12 in) run out of the Main Fuel Vault to airside north and serve Terminals A North, B North, and C North.

- Five lines (three, 14 in and two, 12 in) run out of the Main Fuel Vault to airside south and serve Terminals A South, B South, and C South.

- Four lines (two, 14 in and two, 12 in) serve Terminals D/E

- Two lines (two, 12 in) continue to the east to serve the Cargo Facility

The transmission main lines are connected to fuel valve manifolds, located above ground, at each terminal. Main line system high point vents and low point drains are located at these manifolds. Separate hydrant distribution lines run from these manifolds to serve each gate. Fuel lines also branch off the main lines to serve aircraft parked at the hardstand positions. These manifolds include motor operated double block and bleed valves that isolate the hydrant and hardstand distribution lines closed upon activation of the emergency fuel shut-off (EFSO) button.

The fuel distribution system includes the hydrant fuel pits, high point vents, low point drains, isolation valve vaults, motor operated isolation valves, cathodic protection, emergency fuel shut-off (EFSO), and a dedicated drainage system. Each aircraft parking position is served by two hydrant fuel pits. Fuel trucks with pumps connect to the fuel pits and transfer fuel to the aircraft. All of the fuel pits are plumbed together. The fuel pits are designed to drain into the stormwater system and eventually to a lift station vault (Environmental Lift Stations). The common drain line is closed off at the last fuel pit prior to the lift station vault. The isolation valve vaults have sump pumps to collect stormwater and fuel spills. These vaults are pumped out periodically. Pipeline integrity leak detection is performed at the fuel farm using pressure charts to determine loss of pressure over the system (loss of fuel). There is no separate leak detection system, such as Hansa Consult or Vista, being used. Global Cathodic Protection is the current testing firm for the corrosion control system. That system consists of impressed current test stations, and sacrificial anode beds located airside, near each manifold.

The emergency fuel shut-off (EFSO) system is a safety system to shut off the flow of fuel in case of an emergency. It consists of emergency push buttons at each gate and input/output (I/O) control boards located in electrical rooms within each terminal. The hydrant gate EFSO is connected parallel to the hardstand system. In the event of an EFSO activation, all four motor operated valves (MOV) will close, thus stopping the flow of fuel to the hydrants and hardstand system.

Fuel is stored in above ground vertical tanks at the fuel farm. The combined capacity of those tanks is 13 million gallons. The average daily fuel consumption ranges between 1.6 and 1.8 million gallons per day (mgd), according to Allied Aviation, the airline consortium fuel operator. The fuel farm has 16 hydrant pumps rated at 1,000 gpm/each and four lead (high pressure) pumps with a flow of 600 gpm for a total peak flow rate equal to 18,400 gpm. Each pump has a filter separator sized to match the pump flow. Peak daily demand is 4,500 gpm. Estimated current Terminal D demand is 2,800 gpm for six wide-body and six narrow-body aircraft. The existing hydrant fuel trucks are rated to flow at a maximum of 800 gpm.

2. Load Analysis

ESTIMATE FUEL CONSUMPTION FOR IAH PASSENGER GATES

Peak Flow Estimate Approach based on gates:

Number of EXISTING gates at IAH:
- Terminal A - serves a number of domestic airlines and short haul flights, with gates 1 to 34
- Terminal B - serves several domestic airlines, with gates 50 to 91
- Terminal C - serves domestic airlines, with gates C14 to C48
- Terminal D - serves all of the airport's international airlines, with gates D1 to D12

Total Existing Gates: 121

Projected number of gates at IAH in 2030:
- Terminal A - 0 Net New Gates
- Terminal B - 13 Net New Gates = Add B1 (11) + B2 (11) + B3 (11) - 20 gates for demo of B-North
- Terminal C - 2 Net New Gates (A380)
- Terminal D - 2 Net New Gates (A380)

Total Net New Gates in 2030: 17

Total Gates: 138

1. Aircraft Layout Assumptions:
   a. Estimated number of Group III (B737) aircraft is 100
   b. Group IV: 30
   c. Group V: 4
   d. Group VI: 4

Desired velocity in Hydrant main is between 6 and 7ft/sec

Group III Aircraft Typical (B737) Gate Turnaround time (30 Minute Average)

00:00 Chocks (5 service cars already waiting for the plane to stop)
00:01 Start to take bags out
00:01 Doors open
00:02 Passengers starting to leave the plane
00:07 New passengers start to board
00:15 Finished loading bags for the new flight
00:20 Last passenger boards
00:31 Push back

Group IV Aircraft Typical (B767) Gate Turnaround time (45 Minute Average)
00:00 Chocks (5 service cars already waiting for the plane to stop)
00:01 Start to take bags out
00:01 Doors open
00:02 Passengers starting to leave the plane
00:12 New passengers start to board
00:20 Finished loading bags for the new flight
00:30 Last passenger boards
00:45 Push back

Group V Aircraft Typical (B747 & B777) Gate Turnaround time (60 Minute Average)
00:00 Chocks (5 service cars already waiting for the plane to stop)
00:01 Start to take bags out
00:01 Doors open
00:02 Passengers starting to leave the plane
00:14 New passengers start to board
00:30 Finished loading bags for the new flight
00:40 Last passenger boards
01:00 Push back

Group VI Aircraft Typical (A380) Gate Turnaround time (105 Minute Average)
00:00 Chocks (5 service cars already waiting for the plane to stop)
00:01 Start to take bags out
00:01 Doors open
00:05 Passengers starting to leave the plane
00:35 New passengers start to board
00:45 Finished loading bags for the new flight
01:15 Last passenger boards
01:45 Push back

PEAK FUEL RATE CALCULATIONS

Group III (Boeing 737)
6,000 gal = Uplift for each aircraft
600 gpm = Fuel acceptance rate from one hydrant pit/hydrant cart
6,000 gal /600 gal/min =10 min fueling duration
30 min = Gate turn-around time
10 min /30 min = 33 % Gate time spent fueling

Group IV (Boeing 767)
15,000 gal = Uplift for each aircraft
800 gpm = Fuel acceptance rate from one hydrant pit/hydrant cart
16,000 gal /800 gal/min =20 min fueling duration
45 min = Gate turn-around time
20 min /45 min = 44 % Gate time spent fueling

Group V (Boeing 747 & 777)
30,000 gal = Uplift for each aircraft
1,400 gpm = Fuel acceptance rate from two hydrant pits/hydrant carts
30,000 gal /1,200 gpm = 22 min fueling duration
60 min = Gate turn-around time
22 min /60 min = 37 % Gate time spent fueling

Group VI (A380)
50,000 gal = Uplift for each aircraft
1,600 gpm = Fuel acceptance rate from two hydrant pits/hydrant carts
50,000 gal /1,200 gpm = 32 min fueling duration
105 min = Gate turn-around time
32 min /105 min = 30 % Gate time spent fueling

Hydrant System Flow Rate
100 Aircraft * 33% = 33 Number of aircraft simultaneously fueling
33 Aircraft *600 = 19,800 gpm Hyd system flow rate for Group III aircraft
30 Aircraft * 44% = 13 Number of aircraft simultaneously fueling
13 Aircraft *800 = 10,400 gpm Hyd system flow rate for Group IV aircraft
4 Aircraft * 37% = 2 Number of aircraft simultaneously fueling
2 Aircraft *1400 = 2800 gpm Hyd system flow rate for Group V aircraft
4 Aircraft * 30% = 2 Number of aircraft simultaneously fueling
2 Aircraft *1600 = 3,200 gpm Hyd system flow rate for Group VI aircraft

Total Fuel Flow equals 36,200 gpm x diversity factor.
Current Peak Flow equals 4500 gpm

Projected 2030 Peak Flow is 36,200 gpm x 25% = 9,000 gpm

3. Evaluation
The fuel farm has 16 hydrant pumps rated at 1,000 gpm/each and four lead (high pressure) pumps with a flow of 600 gpm for a total peak flow rate equal to 18,400 gpm. The fuel distribution mains are sized to meet the total peak fuel farm flow rate. No additional capacity Is needed at the fuel farm or in the hydrant distribution system

4. Project Phasing and Temporary Infrastructure
The hydrant distribution system will need to be phased to accommodate the new Terminal B and MLIT work. A new set of fuel mains are planned to be constructed to the north, to clear the new Terminal B and MLIT Piers. The existing fuel mains are located too close to the new construction and will need to be demolished.
Per NFPA 415 (2013), 4.1.5 Glazing Material–Covered Openings Facing the Ramp:

Where potential fuel spill points are located less than 100 ft (30.5 m) horizontally from glazing material–covered openings in airport terminal building walls facing the airport ramp, they shall be provided with an automatically activated water spray system in accordance with 4.1.5.3.1 or an automatically activated, listed fire shutter system in accordance with 4.1.5.3.2. (See Annex C.)

5. General Definitions

The points on or around the aircraft or airport ramp where fuel can be released. These points include fueling hydrants, fuel servicing vehicles, fuel tank fill connections, fuel vent openings, and fuel dump valves.

Per NFPA 407 (2012), Section 4.4.10 Fuel Servicing Hydrants, Pits, and Cabinets:

Fueling hydrants, cabinets, and pits shall be located at least 15.2 m (50 ft) from any terminal building, hangar, service building, or enclosed passenger concourse (other than loading bridges).

6. Recommendations

Install new fuel mains to the north, to clear the new Terminal B and MLIT Piers. Connect to Cargo on the east side of MLIT. Phase the work to accommodate Terminal B first, followed by MLIT.

E. Sanitary and Grease Vaults

1. Existing

Sanitary and grease vault systems at IAH are in need of replacement. Per the Sanitary Sewer Report, prepared by Amani Engineering in June 2010, the overall condition of the sanitary waste system in Terminals C and D, including the grease system, are in poor condition. That report confirmed the poor condition of the sanitary system and the need to repair sections of the system.

Terminals C and D each have two grease interceptors (1,500 gallons and 750 gallons) located outside on the east and west. Terminal C sanitary sewer system is directly connected to the existing 14 in CI gravity sewer line located to the south of the building and running west.

The existing Terminal D sanitary sewer system is composed of six subsystems listed below.

• Service Lines • Bypass Line
• Collector Line • Transfer Line
• Gate D4 Lift Station • West Lift Station

The service lines are 6 inch lines that carry the building wastewater to a collector line. The collector line is an 8 inch gravity line that runs parallel to the terminal on the apron side. The slope of the 8 inch collector line is not known. However, the collector invert elevation at the lift station has been surveyed during HAS Project 638A and is recorded at 72.03 ft. This invert elevation (72.03 ft) appears to be approximately 2 ft above the terminal basement elevation that is approximately at 70 ft. The collector line discharges into the Gate D4 lift station.

The Gate D4 lift station is a 10 ft diameter, 28 ft deep submersible lift station equipped with two, 3 hp pumps with a firm capacity of 280 gpm. The lift station lifts the Terminal D wastewater load and discharges it into the City of Houston manhole number IC104069 located near Gate D4. Houston Airport System Project 638A is upgrading the lift station. The main structure will remain in its present location with top slab elevation at 95.98 ft and with base elevation of the wet well at 67.98 ft. The pumps will be replaced with two new 5 hp pumps with a firm capacity of 365 gpm at 25 ft TDH (total dynamic head). The electrical control panel and other peripheral equipment will all be upgraded accordingly.

A 12 in cast iron (CI) bypass gravity line, constructed in 1987, carries the wastewater load of a few facilities located to the east of Terminal D. This line runs parallel to the collector line and discharges into the City of Houston manhole number IC104069. The wastewater load coming from the east through this 12 in line, per the HAS Project 638A study, is about 48 gpm. The line grade, per City of Houston Geographic Information System (GIMS), is only 0.117%. That is far less than the minimum City of Houston requirement of 0.26%.

Manhole number IC104069 combines wastewater loads from the 8 in collector line and the 12 in bypass line, a total of 328 gpm per the Project 638A study, and transfers it from airside to roadside via a 12 in DI gravity sanitary sewer pipe transfer line that is sloped at 0.117%. The transfer line discharges into the Terminal D West lift station.

The Terminal D West Lift Station was constructed in 2004 as a part of the International Services Expansion Program. This lift station is an 8 ft diameter, 12 ft deep submersible lift station equipped with two, 3 hp pumps with a firm capacity of 328 gpm. The lift station receives combined wastewater generated from Terminal D plus the bypass line and discharges, via a 6 in force main, to the City of Houston manhole number IC1040E01, located just outside of FIS building.

Project 638A is upgrading the Terminal D West Lift Station. The main structure will remain at its current location with a top slab elevation of 87.42 ft and with a base elevation of the wet well at 75.58 ft. The pumps will be replaced with two new 10 hp pumps with a firm capacity of 425 gpm at 21 ft TDH. The electrical control panel and other peripheral equipment will be upgraded accordingly.

Design of new sanitary sewer system for the new Terminal D (MLIT) shall consider the following three principal lessons learned from the existing conditions.

• Simplified Network: Existing sanitary sewer network is a complex and hard to maintain system resulting from several modifications through past decades.
• Non-ferrous Pipes: Existing sanitary sewer lines are cast iron. HAS Project 638 investigations from 2010 show that the existing CI lines are all heavily deteriorated.
• Depth: Existing collector line is higher than the terminal basement. New system shall be deep enough to safely cover all levels of the new terminal.

2. Load Analysis

a. Per the UMP projected utility demand tables (2030 Growth Plan) airport sanitary peak demand is 11,488 gpm. This peak does not include diversity or Terminal E. Projected growth for new Terminal B and MLIT is 990 gpm and 717 gpm respectively. Grease waste is included.

3. Evaluation

b. Base Case: Maintain North Terminal sanitary flow to the west. Upsize existing sanitary main, at MLIT and Terminal B, to meet 2030 capacity growth. Install grease vaults, landside, to collect food concession's grease. Some grease vaults may be needed on airside depending on the location of the respective concessions in the Terminal buildings.

c. Alternatives: Keep existing sanitary system In place at Terminal B. Install new sanitary main to serve MLIT and gravity flow to the east. Install a new lift station on the east side to collect MLIT sanitary and pump to the existing lift station at the FIS. Separate grease vaults will be needed, similar to the base case.

- Alternative 1: Utilize existing Terminal D West Lift Station:

o Discard lift station at Gate D-4.
o Collect D1 load and discharge into Terminal D-west lift station, which is planned to be upgraded by HAS Project 638A.
o Abandon existing 12-inch and eight-inch CI lines.
o Carry load of the MLIT via a new 8-inch to 12-inch line flowing from west to east, in place of the existing eight-inch collector.
o Construct a new lift station east of the new terminal building per City of Houston Standard Submersible Lift Stations.
o Construct a new force main from the new lift station to the City of Houston Lift Station No. 3.
o The new lift station shall have enough reserve capacity for a future East Pier.

- Alternative 2: Demo both existing Lift Stations at Terminal D

Keep existing sanitary system In place at Terminal B. Install new sanitary main to serve MLIT and gravity flow to the east. Install a new lift station on the east side to collect MLIT sanitary and pump to the existing lift station at the FIS. Separate grease vaults will be needed, similar to the base case.

o Discard both lift stations near gate D4 and Terminal D West.
o Abandon existing 12 inch and eight inch CI lines.
o Combine loads from MLIT via a new 12 inch line flowing west to east in place of the existing eight inch collector.
o Construct a new lift station, per City of Houston Standard Submersible Lift Stations, at east of the new terminal.
o Construct a new force main from the new lift station to the City of Houston Lift Station No. 3.
o The new lift station shall have enough reserve capacity for a future East Pier.

4. Project Phasing and Temporary Infrastructure

The base case will need multiple phases to upsize the existing sanitary main running to the west from Terminal B. Temporary infrastructure is planned to allow replacement of portions of the existing main.

The Alternative also needs to be phased. The existing lift station, at Terminal D, will be used to temporarily route sanitary from the west portion of MLIT to the south. This will allow the new sanitary main to be installed to the east, along with the new lift station.

Grease vaults will be phased in locations located as near to the food concessions as possible.

5. Recommendations

Recommend installing a new lift station to the east of MLIT. In addition, redirect the sanitary flow, from MLIT, to the east. This will offload the existing sanitary system, which gravity flows to the west, freeing up available capacity for new Terminal B.

New six inch sanitary lines will be needed at each level for the new terminal buildings. An estimated five sanitary drops, at each level, will connect to the common main line outside the building.
A minimum of two new grease vaults are estimated for Terminal D, one located on each side (west and east) of the terminal. Main sanitary waste piping system to be sized with 10 to 15-percent extra capacity at peak flow conditions. Service Sinks, Floor Drains, Floor Sinks and buried waste shall be 2 in minimum. All kitchen waste shall be routed to an approved grease vault. Grease vaults to be precast concrete vault, two compartment, 9,000 gal capacity minimum, with grease retaining baffles; four 24 in diameter access covers and frames, traffic pattern designed to withstand H-20 wheel loadings per AASHTO; gas and watertight.

F. Storm

1. Existing

IAH terminal buildings include roof leaders to storm drains. The Terminal C roof drains are collected by a network of reinforced concrete pipe (RCP) storm lines ranging from 12 in to 30 in. The system discharges into the three 10 x 5 storm box culverts located just south of Taxiway NA.

The Terminal C apron is served by a contaminated stormwater collection system west, north, and east of the terminal. This system consists of a slotted drain collection system and a dual conveyance system. A slotted drain intercepts potentially contaminated stormwater runoff from the aircraft parking and diverts it to the environmental station located to the north of Terminal B North where it is segregated for treatment or allowed to bypass and flow into the drainage system.

2. Load Analysis

Per the UMP projected utility demand tables (2030 Growth Plan), airport terminal building roof stormwater peak demand is 123,601 gpm. This peak does not include Terminal E. Projected growth for new Terminal B and MLIT is 25,753 gpm and 15,900 gpm respectively.

3. Evaluation

Apron grading and drainage is governed by FAA and NFPA Design Criteria. FAA Advisory Circular 150/5300-13 "Airport Design" states that apron grades for an Aircraft Approach Category C and D apron pavement cannot have a slope in excess of 1%. In addition the apron pavement grades are required to drain away from the terminal building especially in aircraft fueling areas.

NFPA Code 415 "Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways" requires that the minimum apron grade shall be 1%. The apron pavement needs to drain away from the building and no drainage or collection structures can be located within 50 feet of the building face. The 50-foot collection structure criteria is in place to assure that there won't be any surface runoff collection points that could catch on fire located within 50 feet of any building face in the event of a fuel spill.

Currently the existing Terminal D apron satisfies both the FAA's and the NFPA's design requirements. However, construction of the new concourse for Terminal D will impact the existing grading patterns and drainage collection points on the apron that in turn will require modifications to the existing apron pavement.

4. Project Phasing and Temporary Infrastructure

Project phasing is described in the Project Definition Manual for new Terminal B and MLIT. Concept drawings are also provided. Project phasing is planned from west to east, starting with Terminal B

5. Recommendations

In order to meet apron grading criteria, approximately 800 feet of the existing trench drain that runs parallel to the existing Terminal D building face will need to be removed due to the construction of the new terminal concourse. A new set of trench drains will be required to collect stormwater runoff on both the east and west sides of the new concourse. New storm sewer connection points will be required to tie the trench drains into to the existing storm sewers that are located on the north side of the apron.

The overall grading pattern adjacent to the new concourse's building face will need to change from an existing northerly direction of flow pattern to one that drains away from the new concourse in both an east and west direction of flow. Refer to the PDM, Stormwater section for a conceptual grading plan. As shown on this figure, rotating the apron grading plan by 90 degrees will require a significant amount of pavement to be reconstructed.

G. Environmental Lift Stations

1. Existing Conditions

- Because of the rare occurrences of snow (0.087%), snowfall has been omitted from this analysis.
- Based on NOAA data and FAA criteria, the average year has 41 deicing days for the airports operated by the Houston Airport System. This compares to an average of 20 deicing days per year based on actual deicing records.

1.1 Runoff and First Flush:

- Stormwater runoff needs to be collected from deicing areas during a deicing day.
- The largest 30-day rainfall quantity was 8.37 inches, and is the basis for these recommendations.

1.2 Spent Aircraft Deicing Fluid (SADF)

- Wet weather deicing where SADF mixes with stormwater is an inversely proportional intensity versus frost weather deicing where SADF reaches the ground without dilution.
- Current operations are such that before deicing, stormwater inlets are sealed.

1.3 Best Management Practices:

- Current IAH BMP's include eight on-site environmental stations designed for collection and storage of SADF and hydrocarbons.

2. Permit Compliance

- IAH is in possession of a Multi Sector General Permit (MSGP)
- As long as a facility meets the requirements for its Sector Identification Codes (SIC) classification, its stormwater discharges are considered "permitted" under the MSGP.
- Monitoring requirements include: quarterly site inspections, quarterly wet weather visual monitoring, weekly inspection during deicing season, rain gauge monitoring and annual site compliance evaluations.

3. Alternatives

3.1 SADF Collection: Option 1 – Upgrades of existing systems

1. Budget $300,000
2. No Infrastructure changes; upgrades only
3. Increases maintenance and labor efforts
4. Increases disposal efforts
5. Least controls over SADF runoff

Option 1 components:

- Upgrades to existing deicing procedures and recovery equipment to maximize effectiveness
- Eliminate frost deicing by spraying or mechanical application
- Eliminate gate deicing
- Evaluate drainage conditions at all deicing locations; confirm that SADF stormwater runoff is being directed to collection points
- Employ commercially available Glycol Recovery Vehicle (GRV) systems to collect SADF contaminated stormwater

3.2 SADF Collection: Option 2 – Construct collection systems and install storage tanks

1. Budget $4,810,000
2. Collection systems and storage tanks at seven existing deicing stations
3. Consider as an interim step to ultimate recommendation of deicing pads incorporated into the future instrumnet flight rule (IFR) hold pads.
4. Increases disposal efforts/costs
5. Moderate controls over SADF runoff

Option 2 components:

- Construction of additional infrastructure at existing deicing areas
- Install underground storage tanks and electronic diversion valves at each deicing area
- Install trench drains at wet weather deicing locations
- Eliminates the need for portable booms
- Valves can be electronically activated
- Flushing requires water truck
- Storage tanks emptied by pump trucks

3.3 SADF Collection: Option 3 – Construction of dedicated deicing pads

1. Budget $5,200,000
2. Recommended if integrated with future IFR hold pads.
3. Least cost effective
4. Greatest controls over SADF runoff

Option 3 components:
- New hold pads constructed at runway ends
- Install new underground storage tanks
- Install new dual valves, electronically operated
- Tanks emptied by pump trucks
- Operations to determine number of deicing positions on the IFR hold pads

3.4 SADF Treatment and Disposal Options:

Option 1: Publicly Owned Treatment Works (off site) – may not be capable of treating the volume and chemical complexity of IAH discharges

Option 2: Above Ground Engineered Wetlands (on site) – sheet flow approach not desired for airports due to wildlife attraction

Option 3: Sub Surface Engineered Wetlands (on-site) – requires less land area than above ground but may require additional oxygen supplies to maintain performance. Also may require retention or surge ponds (not desirable due to wildlife attraction).

Option 4: Off-site Private Entities – Conveys SADF to an off-site facility for processing/disposal; airport maintains some liability.

Option 5: Anaerobic Digestion (on-site) – difficult to sustain without year round waste load

Option 6: Physical Treatment by Evaporation – Cost prohibitive without end demand for product

Option 7: Physical Treatment by Filtration – Cost prohibitive due to complex mechanical processes, initial costs and maintenance requirements

3.5 Petroleum Hydrocarbon Collection Options:

1) Repair existing Environmental Stations as recommended in Brown and Caldwell 2008 report. Budget $2,400,000 at that time, Current budget estimated at $4 Million.

2) Install storm sewer water treatment units: decommission existing environmental stations and install 9 new stormwater treatment unit pollutant removal systems. These stormwater treatment units have no mechanical or electrical parts.

Utilize existing trench drains to route flows. Budget for all 9 units $1,640,000.

CP&Y/HNTB recommends a multi-step set of improvements to IAH's deicing procedures and facilities. In the short term, SADF collection Option 2 in conjunction with SADF Treatment and Disposal Option 1 should be implemented.

Hydrocarbon collection should be accomplished through the implementation of petroleum hydrocarbon Option 2, the installation of Stormwater Treatment Units (Stormceptors).

3.6 Recommendations

HNTB recommends a multi-step set of improvements to IAH's deicing procedures and facilities. In the short term, SADF collection Option 2 in conjunction with SADF Treatment and Disposal Option 1 should be implemented.

Hydrocarbon collection should be accomplished through the implementation of petroleum hydrocarbon Option 2, the installation of Stormwater Treatment Units (Stormceptors).

H. Triturator

1. Existing

Aircraft waste from restrooms is blue due to a blue dye used to pre-charge the toilets during service/draining. Aircraft waste is collected from toilets and wash basins and pumped into biffy trucks. The waste is dumped into a wet well with grinder pumps that reduce the waste to fine particles and discharge the waste to sanitary.

2. Load Analysis

a. Aircraft peak waste demand, on the North Terminal side, is estimated to increase by 20 gates with the addition of new Terminals Piers B1, B2 & B3.

3. Evaluation

b. Base Case: The existing triturator, located in the area of concern of the New Terminal B, will need to be demolished. Install a new triturator east of MLIT.

c. Alternatives: Replace the existing Environmental Lift Station, located north of North Terminal A Pier, with a new triturator.

4. Project Phasing and Temporary Infrastructure

The new triturator will need to be phased with the construction of Terminal B. Temporary aircraft waste disposal will need to be planned if the new triturator is not completed in time for the opening of Terminal B.

5. Recommendations

The preferred plan, to dispose of aircraft restroom waste, is to collect it in trucks and transport to a triturator, where it will be disposed of to sewer through grinder pumps.

Location of the triturator is planned to replace an existing environmental lift station located north of North Terminal A Pier. Grinder pumps will be located in the wetwell to allow for truck deliveries to dump their tanks by gravity. The waste runs through the grinder pumps and discharges to the existing sewer line.

I. Natural Gas

1. Existing

CenterPoint Energy (CNP) supplies natural gas to IAH. They own and maintain the lines upstream of the gas meters. CNP's gas mains run north on JFK Boulevard to the Central Utility Plant and to South and North Terminal Roads. The main line is 4 in in South Terminal Road and reduces to 2 in in North Terminal Road. Line pressure is between 30 psig and 40 psig. CNP provides meters that reduce line pressure down to 5 psig, 3 psig, or 4 ounces.

Terminals D and C are served by two natural gas meters. At Terminal D, the natural gas meter/regulator is located at Level 88, on the east end of the terminal. The beginning pipe size is 4 in and reduces to a 3 in pipe around column line eight on the Departure Level (total developed length is approximately 1,100 ft). The entire natural gas line is encased in a 6 in steel sleeve. The as-built drawings indicate the meter/regulator is sized for 1,750 cf/hour at 4 ounce pressure.

2. Load Analysis

Per the UMP projected utility demand tables (2030 Growth Plan) airport terminal building natural gas peak demand, for concessions, is estimated at 75,292 CFH, not including the Central Utility Plant boilers, diversity or Terminal E. Projected growth for new Terminal B and MLIT is 10,757 CFH and 7,792 CFH respectively. Terminal B and MLIT make up about 24% of the concessions gas demand.

3. Evaluation

CenterPoint Energy (CNP) operates and maintains the natural gas mains and branch lines to and including the airport building meters. CNP delivers service gas at multiple pressures including 5 psig, 2 psig and 5 ounces. Per April 2014 meeting with CNP, new branch lines and meters will be provided by CNP to Terminal B and MLIT as needed. If existing branch lines are adequate, CNP will replace the meters only. CNP main line service pressure varies between 20 psig and 30 psig.

4. Project Phasing and Temporary Infrastructure

Natural gas lines and meters will be phased In during construction of Terminals B and MLIT by CNP.

5. Recommendations

CNP to provide natural gas branch lines and meters to new Terminals. Design to confirm service pressure and CFH so that CNP can size piping, meters and pressure reducing stations.

J. Pre-Condition Air (PCA)

1. Existing

IAH uses point-of-use PCA at most of the terminal gates except Terminal D. Terminal D has a zone glycol system, which is located in the basement. This system feeds glycol coolant to all gates, except Gate D12A. Power for this system comes from the normal building power supply. This system is at the end of its life.

The Terminal D system cannot provide sufficient sub cooled liquid (20°F to 25°F) to adequately cool wide-body or larger aircraft. The PCA units have been de-rated to 60 tons because of this, although their capacity is 120 tons. This item is linked to the glycol system deficiencies and it was estimated in 2011 that it would require an $11 million upgrade with no additional capacity to continue to provide aircraft cooling with this system. In 2012, new PCA units were placed on the Passenger Boarding Bridges for Gate D12A to accommodate the A380 aircraft using that gate. HAS is currently working to replace the glycol system completely and place stand-alone PCA units on all Passenger Boarding Bridges.

2. Load Analysis

a. Capacity Planning

The size of the PCA unit installed at each gate is directly impacted by the type of aircraft being serviced at that gate. Listed below are the recommended PCA heating and cooling load requirement ranges for the 5 categories of aircraft that will be services at IAH.

Table A - General PCA Cooling & Heating Loads

Aircraft Type	Cooling Load (Tons)	Heating Load (Btuh)
Commuter	15 - 25	110,000
Group III	30 - 45	215,000
Group IV	60 - 75	450,000
Group V	90 - 100	660,000
Group VI	120	800,000

Table B - Load Analysis for Mickey Leland Terminal

MLIT Aircraft Type	Quantity	Cooling Load (Tons)	Power (2.3 KV A/T)
Group III	2	90	207
Group IV	9	675	1553
Group V	0	0	0
Group VI	4	480	1104
Subtotals:	15	1245	2864

Table C - Load Analysis for Terminal (United)

Terminal B Aircraft Type	Quantity	Cooling Load (Tons)	Power (2.3 KV A/T)
Group III	10	450	1035
Group IV	1	75	173
Subtotals:	11	525	1208

3. Evaluation

b. Base Case

There are three main PCA system types available for application at IAH. They Include, Central, Zoned and Point-of-Use. The following definitions are provided.

Central System - The central system type includes a single dedicated mechanical plant to serve the needs of each Terminal at IAH. This type of plant would consist of low temperature chillers (20°F, glycol-water supply), primary and secondary distribution pumps and cooling towers. PCA is delivered to the aircraft via air handling units hung from the Passenger Boarding Bridges (PBBs). The AHUs must be specially designed to deliver air at sub-freezing temperatures and at a high static pressure in order to cool the aircraft properly. Heating will be provided through the use of electric resistance heating coils. The specialty AHUs are hung from the underside of the PBB at the bridge rotunda column and deliver air to the aircraft via an across-the-bridge ducted air delivery system. Plant capacity can be constructed and increased in phases in order to meet the needs of each Terminal as they are upgraded through the 2030 phasing program.

PROS:
1. Best PCA type to take advantage of energy savings related to the diversity in aircraft gate activity.
2. Great option for thermal energy storage systems.
3. Long equipment life; low operating and maintenance cost as compared to the Point-of-Use type PCA.

CONS:
1. Ideally, the central system would be located near the the Terminal buildings and the airport Central Utility Plant. However, the existing CUP is located across a runway to the south, away from the Terminal buildings.
2. The central system requires significant real estate.
3. IAH electrical rates are flat and are not attractive for a thermal energy storage system.
4. Highest first cost alternative and longest runs of distribution piping.

Zoned PCA System - The zoned system includes multiple PCA mechanical plants to serve the needs of all the Terminal Facilities. An estimated four zoned system is suggested, two serving the North Terminals and two serving the South Terminals. PCA is delivered to the aircraft the same way as described in the Central PCA system section, above. The zoned system scenario can be Implemented in phases In order to meet the needs of each Terminal as they are upgraded through the 2030 phasing program.

PROS:
1. Next best PCA type to take advantage of energy savings related to the diversity in aircraft gate activity.
2. Good option for thermal energy storage systems.
3. Long equipment life; low operating and maintenance cost as compared to the Point-of-Use type PCA.

CONS:
1. Space Is a premium in the Terminal area. Need to find four areas of space to locate the zoned chillers, pumps and electrical gear within the terminal area.
2. IAH electrical rates are flat and are not attractive for a thermal energy storage system.
3. High first cost alternative and long runs of distribution piping.

Point-Of-Use System - The POU PCA system type requires the use of all unitary DX packaged air conditioning units located at each gate. Each POU unit is self-contained and comes equipped with multiple compressors, a blower, motor, heating and cooling coils and a control package. The POU units all require 60 Hz power to be routed from the Terminal Buildings to each gate to power the units.

PROS:
1. Least first cost alternative.
2. Least amount of space requirements.
3. Very flexible regarding changing out PCA POU units to match different aircraft type, If needed.
4. Simple cost method for charging the airlines, since each gate has one PCA POU, versus the cost sharing involved with a zoned or central system where multiple gates and carriers are involved.

CONS:
1. Highest amount of operating and maintenance costs.
2. Lowest equipment life, particularly regarding the compressors.
3. Requires higher amounts of electrical power at each gate, than the central or zoned systems, because power is needed for the DX system.
4. POU AHU's are heavier than central and zoned AHUs because of the added weight of the DX system.

c. Alternatives

Base Case - POU PCA System
The base case is POU for all gates. The POU units have an estimated replacement life of 7-10 years as compared to 20-25 years for the central and zoned PCA systems. All of the components within the POU units will require ongoing maintenance. Toward the end of the useful life of these units, the costs for repair and replacement of compressors and fan motors will be very high.

Alternative 1 - Central System
This Alternative installs a new Central PCA system for the new Terminal C and MLIT. It maintains the existing POU's at the other Terminal gates until they reach their remaining life. The Central PCA system "footprint" will be designed to cover all North and South Terminal gates and be phased to replace those gates over the airport's 2030 growth program.

Alternative 2 - Zoned System
This Alternative installs one zoned plant to meet the demands of new Terminal C and MLIT. It maintains the existing POU's at the other Terminal gates until they reach their remaining life. Up to three more zoned plants will be built to cover all North and South Terminal gates and be phased to replace those gates over the airport's 2030 growth program.

Evaluation - The inherent difference between the three types of PCA systems is that centralized systems (Central & Zone) are customized for the particular airport facility and must be carefully designed for that facility similar to the Terminal Building's central HVAC system. The POU approach utilizes standard off-the-shelf units located at each gate and powered by the buildings electrical power distribution system. The following additional differences are provided:

• System Performance: Centralized systems can deliver subfreezing air from the PCA air handling unit because they can deliver 20°F glycol-water from the chillers. At George Bush Intercontinental Airport, the normal daily high temperature peaks at 95.0°F (35.0°C) on 5–12 August, with a normal of 102.4 days per year at or above 90°F (32°C) and 3.5 days per year at or above 100°F (38°C). The average relative humidity ranges from over 90 percent in the morning to around 60 percent in the afternoon. Centralized systems can deliver 28°F air from the AHU. The air picks up about 30°F of heat between the AHU and the plane nozzles. Once the air leaves the AHU it runs through the ductwork, across the ramp and through the aircraft. This results in A 58°F supply temperature to the passengers, which will adequately cool down a heat soaked aircraft in less than 15 minutes.

POU's can't meet the performance of centralized systems and will not be able to cool a heat soaked aircraft to the required comfort level temperatures. A POU unit will only supply air at 35°F (AHU leaving temperature). Adding 30°F equals 65°F supply air to the passengers.

• Glycol-Water Distribution: Centralized systems will require a 2-pipe distribution system. Piping may be able to be routed in the existing IAH utility tunnels. POU's are self-contained and do not require any distribution piping.

• Maintenance Requirements: Maintenance for centralized systems is done in one main location or a few zoned locations. Chiller maintenance is typically performed by well trained personnel. The gate equipment is relatively simple, including a blower motor, cooling coil and modulating valve per AHU. Chiller equipment have life expectancies between 20 to 25 years.

POU units are located at each gate and equipment consists of a blower motor, cooling coil, multiple compressors, capacitors and a refrigeration valve, all of which are susceptible to failure. The weak links in the system are the compressors, capacitors and refrigerant valves. POUs are light weight, commercial construction which have life expectancies of 7 to 10 years.

• Power Consumption: Centralized systems take advantage of aircraft activity diversity since they supply multiple gates and all gates will not demand the peak load simultaneously. This means that the overall capacity and electrical rating of the CUP centralized system can be much smaller than the sum of the ratings of the individual POU units. Additionally, the gate equipment for a centralized system requires only 60 - 100 Amps per AHU versus 400 - 600 Amps for the POUs. See power comparison below assuming 121 gates with Group IV average PCA loads.

Number of gates at IAH:
• Terminal A - serves a number of domestic American airlines and short haul flights, with gates 1 to 34
• Terminal B - serves several domestic / American airlines, with gates 50 to 91
• Terminal C - serves domestic / American airlines, with gates C14 to C48
• Terminal D - serves all if the airport's international airlines, with gates D1 to D12

Table D - PCA Power Consumption Comparison

PCA System Type	Power Requirement (kVA)
Central System w/35% Diversity	7,306
Zone System w/50% Diversity	10,437
POU PCA Units	= 121 Gates x 75T x 2.3 = 20,873

4. Project Phasing and Temporary Infrastructure

All three types of PCA systems can be phased into IAH. The POU type is the least disruptive to Infrastructure since they primarily impact each Passenger Boarding Bridge and can be phased respectively. Centralized systems, however, require significant infrastructure considerations including where to run the distribution piping and where to locate the chiller plant. Given the first two projects are to be installed along North Terminal Road, on the east side, it will be cost effective to find an area near these two projects to install the chiller plant along with a utility tunnel to run the piping. The area near C-Garage fits this description; however, both the CenterPoint Energy Receiving Station and the combined FP/DW storage tanks/pump station are planned for this same site. Infrastructure coordination and system commissioning, for the centralized system, will require more effort than the POU type because of the chiller plant, and more extensive controls and electrical systems. The centralized system may also require temporary infrastructure in the event the chiller plant was not ready.

5. Recommendations

POUs are currently planned for both new Terminal projects, Terminal C and MLIT. This study recommends a full life cycle cost analysis be performed to determine which type of PCA system has the best Net Present Value. Given the advantages of the centralized systems over the POUs, as described In the Evaluation section above, and the potential available space near C-Garage for a chiller plant, an economic analysis is warranted. The accuracy of the economic analysis will depend on the Terminal C and MLIT gate activity projections.

K. 400 Hz

1. Existing

IAH uses zone type 400 Hz power systems at the aircraft gates. This is typical for each terminal building. For example, Terminal D has a zone type system that consists of motor generators in the basement with electrical distribution to 90 kVA, 400 Hz boxes, at each gate. This service is not adequate for the 747-400/800, 777-200 LR/300 ER, and A3 40, which require two, 90 kVA receptacles. In addition, the B787 and A380 aircraft have two, 180 kVA receptacles. Diesel power ground service equipment (GSE) is used to supplement the 400 Hz system.

CenterPoint Energy provides 60 Hz power to the terminal buildings. The 60 Hz power is converted to 400 Hz using the motor generators. The 400 Hz power is fed underground to the apron and distributed to the gates in a system of duct banks and manholes. In the Terminal D example, nine empty 2.5 in conduit spares are available. However, the existing 400 Hz system is at the end of its useful life. Additional gate power will be required to avoid future use of the auxiliary power units (APU) or separate diesel powered ground power units (GPU).

2. Load Analysis

a. Capacity Planning

Using a load of 180 kVA at each Group V aircraft gates, and a load of 360 kVA at each group VI aircraft gates, the total additional load on the MLIT terminal would be 3.4 MW.

3. Evaluation

b. Base Case

Provide individual, stand-alone POU 400 Hz power systems at the aircraft gates, and continue to utilize the mobile

GPUs to help facilitate and additional 400 Hz requirements. Mobile equipment, Ground Power Units (GPU), may be self-propelled or towed, but require storage when not in use and space positioning for use. Towed GPUs weigh approximately 3,000 pounds, and are approximately five feet tall. GPU should be sized to accommodate B787. POU delivery systems are defined as systems where each aircraft service position has a self-contained, independent, power and PC Air unit. This approach is usually economical up to 10 units. At about 10 service points and above, the argument to look at central power and air technologies begins to become more attractive. Note: All wide-body aircraft require dual receptacles for GPU.

c. Alternatives

Provide a zone set of motor generators. Commercial aircraft electrical systems use high frequency power (400 Hz), unlike the 60 Hz power distributed on public power grids. To conserve fuel and reduce emissions, airlines use 400 Hz electricity produced by fixed or mobile equipment to power aircraft at the gate until departure time. Fixed equipment, whether point-of-use equipment installed on the passenger boarding bridge or centralized with distribution over the passenger boarding bridge, requires no space at the gate for the unit

4. Project Phasing and Temporary Infrastructure

In order to facilitate temporary gates, and the shutdown of the existing centralized 400 Hz system, it Is recommended that POU units be utilized at these temporary facilities with GPUs to provide additional power required by Group VI aircraft.

5. Recommendations

The preferred ground power (400 Hz) systems are recommended to be a zone set of motor generators. It is also clear that the operational savings are similar up until 10 service points, and then central system 400Hz begins to become the larger cost savings system. The reason for this is that true central equipment is too large and cumbersome for the less than 10 service points, which means that maintenance and operations costs will be excessive for the capabilities and services received.

L. Ground Service Equipment (GSE) Electrification

1. Existing

IAH currently uses all diesel powered GSE. GSE operations are faced with many cost pressures, compliance issues, and operational challenges caused by competition and growth in the industry, including the rising cost of fuel and pressure to reduce air pollutants. Many airlines, power utilities, and other GSE industry stakeholders are examining the cost-effectiveness of utilizing electric ground support equipment (eGSE) versus gasoline and diesel-fueled internal combustion engine (ICE).

2. Load Analysis

a. Capacity Planning

At a total 30 kW per dual port charger, the additional load on the proposed Infrastructure would be minimal. With a total of 15 dual port chargers the electrical infrastructure would see an increase of 450 kW for the entire MLIT.

3. Evaluation

b. Base Case

The Base case would be to continue utilizing the existing ICE GSE. This ultimately would only require adding a centrally located fueling station and repair dock for the GSE already in use.

c. Alternatives

Provide a total of 15 dual port charging stations at MLIT. In order to reduce crowding at the gates, only one dual port charger would be provided for every two gates. This means that a total of 8 dual port charges would be installed at the gates. The remaining 7 dual port chargers would be installed at a central eGSE charging and maintenance area.

4. Project Phasing and Temporary Infrastructure

Charging stations can be added slowly over time. It is recommended that the 8 charges at the gates be installed as part of the Initial MLIT project. As more ICE GSE are replaced with eGSE additional charges can be added to the central eGSE charging and maintenance area.

Generally, electric baggage tractors and belt loaders are a cost-effective replacement, with a reasonable payback period, over similar performance ICE GSE for most applications. At this time, pushback tractors have a much longer payback period mostly because of the premium capital cost for the eGSE and low fuel-use requirements. When taking into consideration potential cost sharing, conversions of existing equipment, and other variables, payback for all three types of GSE can be shortened and even pushback tractors can be a very cost-effective option.

5. Recommendations

It is our recommendation that one dual port charging station be installed for every two gates as part of the MLIT program, as well as ensuring that the electrical infrastructure is designed to handle the full build-out of 15 dual port charging stations. This will allow the airport to slowly move Into eGSE, without the large upfront capital costs associated with a full switch-over. This will also give the airlines a chance to adapt to the proposed change. As older ICE GSE deteriorates and reaches the end of its life, it can be replaced with eGSE also helping to offset the upfront capital costs by using already allocated GSE funds to facilitate the transition

M. HVAC (Heating and Cooling)

1. Existing

IAH HVAC systems vary per terminal building. Terminal E HVAC is in the best shape with the 2002 renovation. The rest of the airport HVAC systems are in need of replacement and include a mix of systems.

For example, Terminal C North contains a mix of dedicated outside air units, dual duct variable air volume (VAV) air handling units, and constant and variable volume multi-zone units with a hot and cold deck/duct connection. These units supply air to the majority of the building. Most of the air handling units at Terminal C North are located in two mechanical rooms at the Apron Level. Dedicated outside air pretreatment air handling units are also provided in these mechanical rooms. Fan coil units provide service to smaller areas. Exhaust fans are curb mounted on the roof. In general the units are in fair to good condition and most of them are within 10 to 15 years of useful life assuming a maintenance plan is implemented to avoid further deterioration and extend their life.

Building temperature controls, for all terminals and the Central Plant at the airport, currently use or will soon use, Allerton field controllers supervised from a common operator interface maintained by OpenTech Controls Inc. The system is fully BACnet compliant. OpenTech is currently updating the operator interface software for the central plant controls to URVIEW, supplied by Tridium, which will provide enhanced programming and control features. This front-end is intended to be extended in the future to the rest of the airport systems and will be used on new or renovation projects.

The temperature control systems have capability for temperature setback and time of day scheduling of equipment operation but these features have not yet been implemented.
The majority of the HVAC units are controlled through the Building Automation System (BAS). The BAS has multiple sequences and varying setpoints for similar types of units. Several of the pressure readings, displayed within the BAS, were out of tolerance.

In general, the building automation system sensors most likely need to be calibrated to obtain more accurate information.

2. Evaluation

Per the Central Utility Plant and Chilled/Heating Water Distribution sections, the new terminal building space cooling demands will be met. The following list of energy conservation and renewable energy measures are keys to sustainable design. Consider the following steps when designing new Terminal B and MLIT.

1) Expand Energy Efficiency

Meet the requirements of ASHRAE 90.1-2013 Energy Standard for Buildings. New requirements in 2013 include:
• Revised, stricter opaque element and fenestration requirements at a reasonable level of cost-effectiveness
• Improvements to daylighting controls, space-by-space lighting power density limits, and thresholds for top lighting
• Revised equipment efficiencies for heat pumps, packaged terminal air conditioners (PTACs), single package vertical heat pumps and air conditioners (SPVHP and SPVAC), and evaporative condensers
• Improved equipment efficiencies and controls for chillers
• Improved controls for heat rejection and boiler equipment
• Improved requirements for expanded use of energy recovery, small-motor efficiencies, and fan power control and credits
• Clarifications for the use of prescriptive provisions when performing building energy use modeling, and revisions to enhance capturing daylighting when performing modeling calculations

2) Optimizing the Design of the HVAC Systems

Design HVAC systems that are appropriately sized for the loads. Include control schemes to set back temperatures during unoccupied time periods along with optimizing the use of the most energy efficient equipment.

3) Maximizing the Generation of Renewable Energy

Look for opportunities for the utility company to incentivize renewable energy systems on the project. In addition, consider third party Buy-Own-Operate-Maintain strategies for installing large Solar PV arrays.

4) Designing Highly Energy Efficient or Zero Net Energy Buildings

Review ASHRAE standards for High Performance Building Design.

5) Specifying Future-Looking Building Automation Technology

The key to long lasting energy conservation is to maintain the building operations at the "commissioned" level. Many buildings let the HVAC systems drift out of tolerance over time which can waste up to 3% of the system energy per year. Building Automation Systems (BAS) need to include metering and verification technology to help operators recognize when key parameters run outside of commissioned set points. Submeters can track real time energy and demand usage on HVAC equipment. The BAS needs energy trending dashboards to show energy consumption in real time and contrast the data with the commissioned benchmarked data. This information will help establish "demand-shift" strategies to reduce electric bills. HAS can contract the monitoring service remotely or do it in-house. The key is to define the project M&V plan early in the design in order to include key meters and software in the project so energy consumption can be tracked when needed. Meters and instrumentation will need to be maintained within accepted tolerances in order to provide accurate feedback on energy usage.

3. Project Phasing and Temporary Infrastructure

Terminal HVAC systems will be constructed with each building. No temporary infrastructure Is anticipated.

4. Recommendations

Meet the requirements of ASHRAE 90.1-2013 Energy Standard for Buildings. Optimize the Design of the HVAC Systems and make them accessible for maintenance. Maximize the Generation of Renewable Energy, where practical. Consider features of Net Zero Energy Buildings. Specify Future-Looking Building Automation Technology. Perform monitoring and verification of energy systems after commissioning is complete.

N. Information Technology

1. Existing

The existing typical Terminal Information Technology (IT) system is set up in a traditional hub-and-spoke arrangement with the central Main Distribution Frame (MDF) hub, feeding Individual Distribution Frame (IDF) spokes via fiber optic and copper connections (refer to **Appendix C.2** for a schematic of the hub-and-spoke distribution). The existing MDF is in the basement of Terminal D. The MDF room has a new fire suppression system that was installed June 2011. In addition to the IT infrastructure for the existing terminal, the basement houses the PBX system for the entire airport. The main airport fiber optic (FO) loop also utilizes the Terminal D MDF as a go-between when routed between terminals and other ancillary buildings, which means that almost all airport-wide FO pathways land on Terminal D MDF, patch panels, or are routed through Terminal D MDF raceways. Although the majority of the main FO loop system is single mode (SM), some of the fibers are still multimode (MM).

The majority of the existing IDF rooms are served off of central air systems with some rooms having temperature control and some rooms not having control.

Most of the IDF rooms with the exception of the SITA room and MDF room do not have dedicated air handling systems meeting current HAS requirements.

The existing access control system uses a distributed architecture consisting of redundant head-end servers with automated fall over, intelligent field panels (IFP), and contactless smart card readers and access media. The existing access control software application is ProWatch by Honeywell. The head-end system is currently in place and operates on redundant servers located in the Terminal A MDF. The ACC in Terminal A receives all forced door alarms.

Communication between head-end and IFPs is via network switches on a secure VLAN across the common HAS LAN. Standard card readers and access media are iCLASS contactless by HID. HAS utilizes a secure iCLASS

Elite key managed by HID to ensure a unique security format. Current iCLASS products in use include model R10 for mullions, R40, and RK40 (with keypad) card readers, and 16 k smart card credentials. Existing distributed video surveillance system architecture utilizes redundant head-end database servers at the Terminal A MDF and Administration Building, with camera servers and storage arrays located in the respective facility (Terminal D) MDF. HAS holds a DVM site license.

HAS is currently in the process of developing a new consolidated data center adjacent to the existing Administration Building located at 16930 JFK Blvd.

2. Evaluation

a. Base Case

The base case involves leaving the existing IT system as is. New construction or remodels, as is the case with Terminal D, would involve strict adherence to HAS specifications and requirements for all IT infrastructure and equipment.

The existing FO pathways to the existing MDFs would remain, and as the new 1,500 sf Terminal D MDF was relocated, these pathways would be reestablished with splices and hot cuts. Ultimately upgrades to the existing IT infrastructure and equipment would happen slowly, and piecemeal, as new construction or remodels on existing terminals was completed.

Existing FO cables from the existing Terminal D MDF go to the terminal wide MDFs. Infrastructure for these cables will have to be intercepted and rerouted outside the limits of phase 1 work. The existing FO pathways to the existing MDFs would remain, and as the new 1,500 sf Terminal D MDF was relocated, these pathways would be re-established with splices and hot cuts.

Ultimately, upgrades to the existing IT infrastructure and equipment would happen slowly, and piecemeal, as new construction or remodels on existing terminals was completed.

The final build out of the new Mickey Leland International Terminal will have the existing FO connection to the Terminal MDFs routed underground, in the Utility Tunnel, just outside the new terminal on the landside. Fiber optic cables and copper communication lines will be run within cable trays mounted within the utility tunnel. All fiber optic routes will be terminated back in the new MLIT MDF room, located at the base of the new D1 Pier.

The new MDF will house all new termination points for the existing airport FO backbone. These connections will have to be made in a systematic coordinated way, so that no critical systems are allowed to be down longer than one hour, and only during off-peak hours as dictated by HAS. All FO cables that go through the existing Basement Level FIS Connector will have to be rerouted through the new MDF. This will require that all terminations in the existing Terminal D MDF be relocated to the new MLIT FO node, and all FO cables routed through the existing Terminal D MDF will have to be cut, rerouted, and spliced in the new MDF. The designer will be responsible for coordinating each system to be cutover, ensuring that all critical systems have been accounted for prior to any cuts being made.

The existing Brown Shack location, in the Northeast corner of the CTA, adjacent to a secure access point, has above ground splices and termination blocks. This above ground infrastructure is no longer needed and, as part of the scope of this project, will be rerouted underground. A new adjacent manhole will be provided in order to intercept the existing conduit, and provide a splice location for the existing FO cable and copper communication lines. These lines will be pulled from the new manhole at the Brown Shack location all the way back to the new MDF in the MLIT, and terminated in such a manner as to ensure continuity to the previously served systems.

All exterior communications installations will be in accordance with HAS/PDC/Design Division Specifications Section 270543 – Exterior Communication Pathway and Section 2705533 – Identification and Labeling of Communication Infrastructure.

b. Alternatives

In addition to the base case items listed above, the alternative is to include new SM FO backbone connections to all Terminal MDFs from the new MLIT MDF. This would ensure the highest level of connectivity, as well as ensuring that there is no down time to critical IT systems during the cutover. The new MDF will mirror the existing backbone infrastructure in the existing Terminal D MDF in order to avoid all hot cuts.
In addition, new fiber will be run to the new data center being constructed adjacent to the Administration Building. The new fiber would run from the new MLIT Terminal MDF and would include the following:

- Terminal A MDF –144 Fiber, Single Mode Cable with 12 APC fiber connections
- Terminal B MDF –144 Fiber, Single Mode Cable with 12 APC fiber connections
- Terminal C MDF –144 Fiber, Single Mode Cable with 12 APC fiber connections
- Terminal E MDF –144 Fiber, Single Mode Cable with 12 APC fiber connections
- FIS MDF –144 Fiber, Single Mode Cable with 12 APC fiber connections
- FIS Garage MDF –144 Fiber, Single Mode Cable with 12 APC fiber connections
- ASC Building MDF –144 Fiber, Single Mode Cable with 12 APC fiber connections
- New Data Center – 288 Fiber, Single Mode Cable with 24 APC fiber connections

3. Project Phasing and Temporary Infrastructure

Phase 1: United Terminal B1 Pier

Existing FO cables from the existing Terminal D MDF go to Terminal C and Terminal B, through the existing C and B Connectors. These cables will have to be intercepted and rerouted as part of Phase 1 work, prior to the start of demolition.

Phase 2: MLIT

In order to facilitate the cutover from the existing Terminal D MDF to the new MLIT MDF located in D1 Pier, new duct banks will have to be run along the front of the existing Terminal D, to support the cutover, and ensure that there is no down time during critical airport activities. The temporary FO connection to the existing MDF will be routed underground, in six, 4 in conduits, just outside the limits of construction on the landside. This new duct bank will be supported by two, 8 ft by 16 ft manholes at either end, used for fusion splicing the existing cables to the new rerouted extension. All FO routes will be terminated back in the new terminal MDF room, located at the base of the new D1 Pier.

In order to support the new terminal, a new 1,500 sf MDF will have to be constructed early on. This will allow time for the new systems to be tested and commissioned prior to demolition of the existing Terminal D MDF. During construction, and prior to the demolition of the existing MDF, all existing systems, including the fiber optic backbone will have to be cutover to the new MDF. The existing PBX system in the existing Terminal D MDF will have to be systematically cutover to the new MDF as the airport-wide telephone system transitions to VOIP. In addition, the airport FO going through the existing MDF will need to be protected in place until the new Terminal D MDF is operational, and a new FO bypass route is available that can support the systematic cutover of the existing FO system.

The new MDF room will be located at the base of the Terminal D1 Pier. This location will require additional FO duct banks run along the front of the existing Terminal D to allow for the cutover of existing FO and copper trunk lines, allowing for a more expedient cutover. The new MDF will also be a central connection point for all telephone and cable TV connections, including FO converters, Cisco type routers and switches, centralized telephone and fire alarm interface for the PA system, central building management control center, energy management system, wireless network, radio communications, data communications, head units for eVIDS, as well as ACS, and CCTV. With a basic level of service required for the baseline operation of the systems required for the new terminal, the MDF room should be no less than 1,000 sf and be located at the first point of entrance into the terminal for all communications systems. To support the cutover of the existing PBX system an additional 500 sf should be provided. The MDF room will have all systems backed up with a UPS to maintain system power, during brownouts. It is recommended that a centralized UPS system be provided in the main electrical room in order to provide flexibility for future expansion or service redistribution.

The smaller, 250 sf IDFs will house routers for connections to local airline GIDS; connections to airline and passenger WiFi routers; local eVIDS systems; amplifiers; noise sensors and network switches for local PA systems; ACAMS security panels for local doors; CCTV network hubs for signal consolidation and local viewing if required by individual airlines; local fire alarm sub panels; and UPS units to maintain system power during brownouts or during generator start-up. The IDFs will then connect to smaller telecommunications closets located at each gate pod. These closets will be limited to Passenger Boarding Bridge (PBB) support, monitoring systems, and phones. All other systems including ACS, VDGS, CCTV, and PA will be routed back to the nearest IDF room. This is to ensure that when the gate is being utilized for boarding an aircraft, critical systems will still be accessible without disrupting passenger traffic. Each IDF will be connected to the centralized UPS system for emergency power.

Additionally, each IDF and MPOE/MDF will have a dedicated UPS powered air-conditioning unit separate from the terminal cooling system, to allow for whole room cooling during extended blackouts.

Phase 3: United Terminal B2 and B3 Piers

Provide new 144 fiber, single mode cable with 12 APC fiber connections back through the new utility tunnel to the new MLIT MDF, from the new Terminal B2 and B3 Piers MDF, as well as the Terminal B FIS and MDF, Terminal B South MDF, Terminal B Processor MDF, and the Terminal A/B Parking Structure MDF. Each MDF will require its own 144 fiber, single mode cable with 12 APC fiber connections back to the new MLIT Terminal D MDF.

Phase 4: Terminal A Renovation

Provide new 144 fiber, single mode cable with 12 APC fiber connections back through the new utility tunnel to the new MLIT MDF, from the existing Terminal A MDF.

Phase 5: Existing Terminals

Provide new 144 fiber, single mode cable with 12 APC fiber connections back through the new utility tunnel to the new MLIT MDF, from the existing Terminal C MDF, the existing FIS MDF and the existing Terminal E MDF. Each MDF will require its own 144 fiber, single mode cable with 12 APC fiber connections back to the new MLIT Terminal D MDF.

4. Recommendations

It is recommended that HAS provide new SM FO backbone connections to all Terminal MDFs, as well as the ASC Building and the new Data Center adjacent to the Administration Building, from the new MLIT MDF. This would ensure the highest level of connectivity, as well as ensuring that there is no down time to critical IT systems during the cutover.

5. Central Utility Plant:

a. HAS to replace existing boilers 4 and 5, with new 16,000 MBH heating water generators. Boilers 4 and 5 to be demolished in 2023, seven years before the end of their expected service lives.

b. HAS to replace the three steam driven chillers (two each, 3,300 ton units, CH-6 and 8, and one each 1,000 ton unit, CH-1) with new electric drive chillers as follows: one each 3,000 ton, CH-10; one each, 1,000 ton, CH-11; and one each 2,500 ton, CH-12. Steam driven chillers to be demolished in 2023, two years before their expected end of service life.

Chapter 6 | Recommendations

Chapter 6: Recommendations

The Utilities Master Plan (UMP) estimated peak utilities demands out to 2030 for the IAH Terminal Infrastructure with the exception of Terminal E (Refer to **Appendix A.2**). Condition assessment reports were reviewed and one is included in **Appendix D**. The UMP used an integrated, phased and centralized approach to evaluate alternatives to meet the utilities needs of Terminal infrastructure at IAH, where applicable. Range of Magnitude Cost Estimates are provided in **Appendix C**.

The following recommendations are provided to meet the 2030 IAH Terminal Infrastructure utilities demands:

A. Utility Corridor (Utilidor):

A utility corridor (utilidor) is recommended to run the length of North Terminal Road between Terminal A and MLIT. Given the extent of new Terminal Infrastructure work, along North Terminal Road, and the need to replace much of the existing utility systems currently serving the Terminal Complex, a utilidor is an ideal solution for several reasons.

a. The utilidor provides a path for the new12.5 kV, IT, Chilled & Heated Water and Fire Protection/Domestic Water.

b. It also provides all the benefits listed in items 1 – 8, in the Executive Summary.

c. Fewer emergency shutdowns due to the ability to backfeed from two directions and to perform preventative maintenance because the utility systems are accessible versus the direct buried alternative.

B. Electrical:

A 40 MW electrical receiving station is recommended to reduce costs and space required to install separate substations at multiple terminals. A centrally located Receiving Station allows a single point of connection, on airport, in which Centerpoint Energy (CNP) hands off power to HAS to serve IAH Terminal Infrastructure. The proposed location is the Terminal C-Core greenfield.

HAS to distribute the 12.5 kv feeders, from the Receiving Station to the new Terminals. This Station will help reduce future infrastructure costs as well as provide a power distribution plan for the IAH terminal area. A Supervisory Control and Data Acquisition (SCADA) system is planned to monitor, control and trend electrical equipment regarding status and power usage. The SCADA will also manage the combined Fire and Domestic water storage and pump station and 2 mw generator system.

C. Fire Protection (FP) & Domestic Water (DW):

Recommend a combined central FP/DW storage tank, pump station and loop distribution system. The system to be designed to provide water flow at pressures needed to meet the peak fire protection requirements of IFC 2012 and the domestic requirements of Texas Commission on Environmental Quality (TCEQ), Chapter 290. This approach avoids individual fire pumps, storage tanks and hydropneumatic systems per building.

D. Chilled & Heating Water:

Recommend new direct buried distribution branch line crossings in North Terminal Road to serve the new and renovated North Terminals and Core Terminals. Additional piping would be installed in the new Utilidor to increase redundancy by providing backfeed path.

E. Jet Fuel:

Recommend replacing the existing fuel distribution mains, hydrant and hardstand lines with a new distribution system, to the north of the North Terminals, to upgrade the piping system, meet the NFPA 415 building separation distances and improve the ability to isolate leaks.

F. Triturator:

Recommend replacing the existing Environmental Lift Station, at North Terminal A, with a Triturator sized to support the North Terminal Complex.

G. Emergency Power:

Recommend installing a diesel fueled 2 MW emergency generator system to serve the North Terminal and Core Terminal Complex. Generator to be rated at 12.5 kV and include transfer switch, diesel storage tank and controls package in area near C-Garage. Generator to provide emergency power to Terminal complex based on priority sequence of control scheme. Control scheme to shed loads above 2 MW to protect generator system. A single 2 MW generator is planned to provide power to Terminal A Core and also back-up emergency power to Terminals B, C & D, depending on outage location and priority.

H. Storm Water:

In order to meet apron grading criteria, approximately 800 feet of the existing trench drain that runs parallel to the existing Terminal D building face will need to be removed due to the construction of the new MLIT. A new set of trench drains will be required to collect storm water runoff on both the east and west sides of the new concourse. New storm sewer connection points will be required to tie the trench drains into to the existing storm sewers that are located on the north side of the apron. The overall grading pattern, adjacent to the MLIT building face, will need to change from an existing northerly direction of flow pattern to one that drains away from the new terminal in both an east and west direction of flow. Refer to the MLIT PDM, Storm Water section, for a conceptual grading plan B, C & D, depending on outage location and priority.

I. Sanitary Sewer:

Recommend installing a new lift station to the east of MLIT. In addition, redirect the sanitary flow, from MLIT, to the east. This will offload the existing sanitary system, which gravity flows to the west, freeing up available capacity for new Terminal B. New six inch sanitary lines will be needed at each level for the new terminal buildings. An estimated five sanitary drops, at each level, will connect to the common main line outside the building. A minimum of two new grease vaults are estimated for each pier at MLIT, one located on each side (west and east).

Main sanitary waste piping system to be sized with 10 to 15% extra capacity at peak flow conditions. Service Sinks, Floor Drains, Floor Sinks and buried waste shall be 2 in minimum. All kitchen waste shall be routed to an approved grease vault. Grease vaults to be precast concrete vault, two compartment, 9,000 gal capacity minimum, with grease retaining baffles; four 24 in diameter access covers and frames, traffic pattern designed to withstand H-20 wheel loadings per AASHTO; gas and watertight.

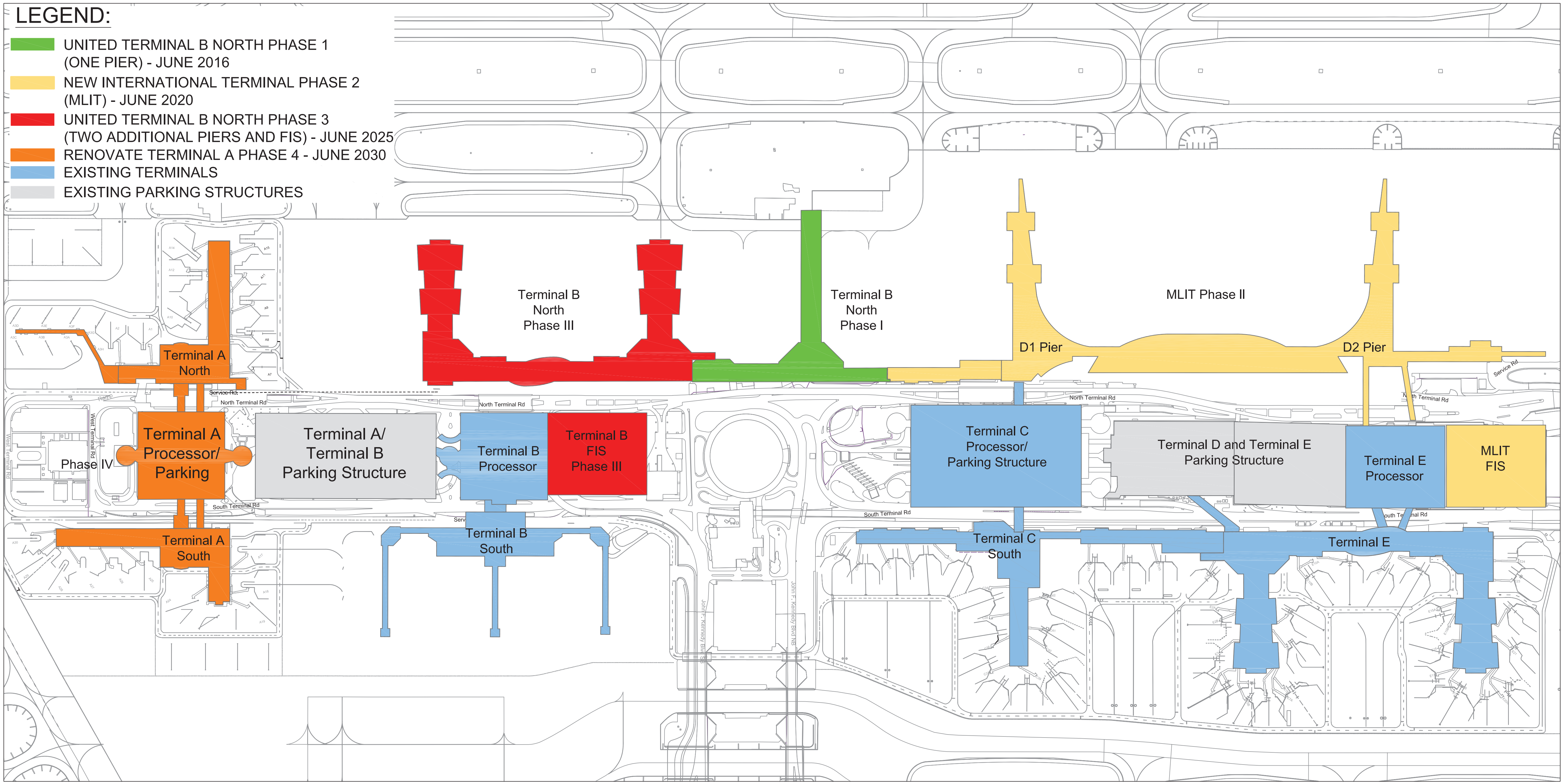
J. Environmental Lift Station:

Recommend a multi-step set of improvements to IAH's deicing procedures and facilities. Refer to Section V.G, Environmental Lift Station. The SADF Collection Option 2 in conjunction with SADF Treatment and Disposal Option 1 is the recommended approach. Hydrocarbon collection should be accomplished through the implementation of petroleum hydrocarbon Option 2, the installation of Storm Water Treatment Units (Stormceptors).

Appendix A

Proposed Terminal Building Phasing Plan Figures

IAH 2030: TERMINAL PHASING PLAN



IAH 2030: PEAK UTILITY DEMANDS: GROSS Sf CALCULATIONS & UTILITY DEMANDS: TERMINALS A - E

	GROSS BUILDING FLOOR AREA	CHILLED WATER			HEATING WATER			NATURAL GAS		POWER			ROOF DRAINS			DOMESTIC WATER			SANITARY SEWER			FIRE SPRINKLER RISERS	BUILDING AREA SOURCE
		Unit Cooling	Total	Demand Total	Unit Heating	Total	Demand Total	Unit NG	Total	Unit Power	Total	Demand Total	Roof Storm Water	# of 8" dia Rain Leaders	Demand Total	Water Fixture Units	Total Fixture Units	Water Demand	Sewer Fixture Units	Sewer Demand	Sewer Pipe Size	Total	
	TOTAL (sf)	sf/ton	tons	tons	btuh/sf	mbh	mbh	sf/cfh	cfh	watts/sf	kw	kw	gpm		gpm	sf/fu	fu	gpm	sfu	gpm	in dia		
TERMINAL D - MLIT																							
MLIT CENTRAL PROCESSOR	291,243	230	1,266	1,013	25	7,281	5,825	50	5,825	18	5,242	2,621	7,597	11	1,899	250	1,165		582		6	3	HNTB Takeoffs (C.Laaser, 03-27-14))
D1 PIER	268,794	230	1,169	935	25	6,720	5,376	50	5,376	18	4,838	2,419	7,095	10	1,774	250	1,075		538		6	3	HNTB Takeoffs (C.Laaser, 03-27-14))
D2 PIER	268,794	230	1,169	935	25	6,720	5,376	50	5,376	18	4,838	2,419	7,095	10	1,774	250	1,075		538		6	3	HNTB Takeoffs (C.Laaser, 03-27-14))
EAST OF D2	67,312	230	293	234	25	1,683	1,346	50	1,346	18	1,212	606	1,661	2	415	250	269		135		4	1	HNTB Takeoffs=2 x Plan Area (M.Kellegrew)
WEST OF D1	93,466	230	406	325	25	2,337	1,869	50	1,869	18	1,682	841	2,306	3	577	250	374		187		4	1	HNTB Takeoffs=2 x Plan Area (M.Kellegrew)
MLIT FIS	313,000	230	1,361	1,089	25	7,825	6,260	50	6,260	Existing		1,000	7,562	11	1,891	250	1,252		626		6	3	Email from David Brandenburg dated 4/1/14
	1,302,609		5,664	4,531		32,565	26,052		26,052		17,813	9,906	33,315	49	8,329		5,210	520	2,605	1,303		13	
TERMINAL B																							
B/MLIT CONNECTOR	66,640	230	290	232	25	1,666	1,333	50	1,333			600	1,644	2	411	250	267		133		4	1	HNTB Takeoffs (C.Laaser, 03-27-14))
B1 PIER (East)	350,000	230	1,522	1,217	25	8,750	7,000	50	7,000	18	6,300	3,150	6,694	10	1,673	250	1,400		700		6	3	Email to Scott Slaughter, HNTB
B2 PIER (Middle + Bridges)	426,500	230	1,854	1,483	25	10,663	8,530	50	8,530	18	7,677	3,839	7,899	12	1,975	250	1,706		853		8	3	Email to Scott Slaughter, HNTB
B3 PIER (West + Concourse Lvls)	443,779	230	1,929	1,544	25	11,094	8,876	50	8,876	18	7,988	3,994	6,462	9	1,616	250	1,775		888		8	3	Email to Scott Slaughter, HNTB
TERM B FIS	300,281	230	1,306	1,044	25	7,507	6,006	50	6,006			2,600	7,562	11	1,891	250	1,201		601		6	3	Leigh-Fisher IAH MP, Jan 2012: Table C-2
TERM B PROCESSOR	250,038	230	1,087	870	25	6,251	5,001	50	5,001			1,000	8,226	12	2,057	250	1,000		500		6	3	HNTB Takeoffs=1.5x Plan Area (M.Kellegrew)
TERM B SOUTH	264,948	230	1,152	922	25	6,624	5,299	50	5,299			1,000	6,538	10	1,635	250	1,060		530		6	3	HNTB Takeoffs=2 x Plan Area (M.Kellegrew)
	2,102,186		9,140	7,312		52,555	42,044		42,044		21,965	16,183	45,025	66	11,256		8,409	700	4,204	2,102		18	
C-CORE & TERM C SOUTH										Existing Demand Taken in 2013													
TERM C CENTRAL	1,855,272	500	3,711	2,968	15	27,829	22,263	50	37,105			2,300	16,128	24	4,032	500	3,711		1,855		8	6	Leigh-Fisher IAH MP, Jan 2012: Table C-3
TERM C SOUTH	307,890	230	1,339	1,071	25	7,697	6,158	50	6,158			2,000	8,717	13	2,179	250	1,232		616		6	3	Leigh-Fisher IAH MP, Jan 2012: Table C-3
	2,163,162		5,049	4,039		35,526	28,421		43,263		0	4,300	24,845	36	6,211		4,942	680	2,471	1,236		10	
TERMINAL A										Existing Demand Taken in 2013													
TERM A NORTH	222,096	230	966	773	25	5,552	4,442	50	4,442			1,000	6,054	9	1,513	250	888		444		6	2	Leigh-Fisher IAH MP, Jan 2012: Table C-1
TERM A PROCESSOR/PARKING	510,409	500	1,021	817	15	7,656	6,125	50	10,208			1,000	7,582	11	1,895	500	1,021		510		8	3	Leigh-Fisher IAH MP, Jan 2012: Table C-1
TERM A SOUTH	193,665	230	842	674	25	4,842	3,873	50	3,873			1,000	5,416	8	1,354	250	775		387		6	2	Leigh-Fisher IAH MP, Jan 2012: Table C-1
	926,170		2,828	2,263		18,050	14,440		18,523		0	3,000	19,052	28	4,763		2,684	400	1,342	671		8	
TERMINAL E										Existing Demand Taken in 2013													
TERM E PROCESSOR	334,474	230	1,454	1,163	25	8,362	6,689	50	6,689			4,000	7,562	11	1,891	250	1,338		669		8	6	Leigh-Fisher IAH MP, Jan 2012: Table C-5
TERMINAL E	581,986	230	2,530	2,024	25	14,550	11,640	50	11,640			4,000	14,361	21	3,590							6	HNTB Takeoffs=2 x Plan Area (M.Kellegrew)
	916,460		1,454	3,188		8,362	18,329		6,689		0	8,000	21,923	32	1,891		1,338	505	669	334		12	
TOTAL	7,410,587			21,333			129,286		136,572		39,778	41,389	144,160	211	32,450		22,583	2,805	11,292	5,646		57	
DIVERSITY		Demand Load = 80%			Demand Load = 80%			Demand Load = 100%		Demand Load = 50%			Demand Load = 25%			Demand built into Fixture Units			Demand built into Fixture Units			1500 gpm/Riser	
SYSTEM CAPACITY ASSUMPTIONS		1. Average SF/Ton Cooling: ASHRAE Cooling Load Check Figures			1. Average btuh/SF: IAH Terminal D Predesign Calculations 2. Demand: Internal loads supply some of the heat.			1. Natural Gas in IAH Buildings for Concessions. 2. Building heating from heating water generated in Central Utility Building.		1. Watts/SF and Demand percentage from experience with past airport design projects.			1. Max flow uses 4.75" rainfall/ hr, 100 year storm (Int'l Plumb. Code) 2. Rain Leader sizing from Int'l Plumbing Code			1. Average SF per FU: IAH Terminal D Predesign Calcs. 2. Demand from Table E103.3(3), Int'l Plumbing Code			1. Flow rate from paragraph 709.3 of Int'l Plumbing Code. 2. Pipe size from Table 710.1(1) of Int'l Plumbing Code			1. Max Plan Area = 52,000 sf per floor per riser. 2. One sprinkler riser flows at one time.	

Proposed Work Phases

United Terminal B North Phase II (one pier) – June 2016

New International Terminal (MLIT) – June 2020

United Terminal B North Phase III (two additional piers and FIS) – June 2025

Renovate Terminal A – June 2030

DOMESTIC WATER & FIRE PROTECTION

	Gross Building Floor Area	Roof Area	Sprinkler Riser Number
	TOTAL (SF)	TOTAL (SF)	
TERMINAL D - MLIT			
MLIT CENTRAL PROCESSOR	291,243	153,930	3
D1 PIER	268,794	143,760	3
D2 PIER	268,794	143,760	3
EAST OF D2	67,312	33,656	1
WEST OF D1	93,466	46,733	1
MLIT FIS	313,000	153,233	3
	1,302,609	675,072	13
TERMINAL B			
B/MLIT CONNECTOR	66,640	33,320	1
B1 PIER (East)	350,000	135,638	3
B2 PIER (Middle + Bridges)	426,500	160,050	3
B3 PIER (West + Concourse Lvls)	443,779	130,943	3
TERM B FIS	300,281	153,233	3
TERM B PROCESSOR	250,038	166,692	3
TERM B SOUTH	264,948	132,474	3
	2,102,186	912,350	18
C-CORE & TERM C SOUTH			
TERM C CENTRAL	1,855,272	326,808	6
TERM C SOUTH	307,890	176,634	3
	2,163,162	503,442	10
TERMINAL A			
TERM A NORTH	222,096	122,672	2
TERM A PROCESSOR/PARKING	510,409	153,626	3
TERM A SOUTH	193,665	109,754	2
	926,170	386,052	8
TERMINAL E			
TERM E PROCESSOR	334,474	153,233	3
TERMINAL E	581,986	290,993	6
	916,460	444,226	9
TOTAL	7,410,587	2,921,142	57

From International Fire Code - IFC-2012

1. Table B105.1 lists the maximum fire flow for Type III A constucted buildings over 166,501 sf = 6,000 gpm.

2. IFC B105.2 Exception states that a reduction of 75% is allowed with an approved automatic sprinkler system. Therefore fire flow = 1,500 gpm.

3. Paragraph 4.5.5 Water Supply from NFPA 415, Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways, 2013 Edition, states that water supply must be adequate to supply the maximum calculated sprinkler demand plus a minimum of 500 gpm for hose streams.

Fire Water Flow

Automatic Sprinkler System Maximum

(Maximum water flow includes the 500 gpm hose stream allowance.)

From NFPA 13 "Standard for the Installation of Sprinkler Systems"

- 52,000 sf is the maximum floor area on any one floor that can be supplied by any one sprinkler riser.
- Calculation strategy - Divide roof area by 52,000 sf and round up for numbers of sprinkler risers per building.

PLUMBING

PLUMBING ASSUMPTIONS

- Total Water Fixture Units - General 250 sf per Fixture Unit
- Total Water Fixture Units - Parking Garage 500 sf per Fixture Unit
- Cold Water Fixture Units 95% of Total Water Fixture Units
- Hot Water Fixture Units 15% of Total Water Fixture Units
- Sewer Fixture Units 50% of Total Water Fixture Units

Building	Building Area (sf)	Total Water Fixture Units sf per FU	Total Water Fixture Units	Water Demand (gpm)	Cold Water Fixture Units	Cold Water Demand (gpm)	Hot Water Fixture Units	Hot Water Demand (gpm)	Sewer Fixture Units	Sewer Pipe Size	Quantity of Sewer Pipes	Sewer Demand (gpm)
TERMINAL D - MLIT												
MLIT CENTRAL PROCESSOR	291,243	250	1,165		1,107		175		582	6	1	
D1 PIER	268,794	250	1,075		1,021		161		538	6	1	
D2 PIER	268,794	250	1,075		1,021		161		538	6	1	
EAST OF D2	67,312	250	269		256		40		135	4	1	
WEST OF D1	93,466	250	374		355		56		187	4	1	
MLIT FIS	313,000	250	1,252		1,189		188		626	6	1	
	1,302,609		5,210	595	4,950	590	782	180	2,605			1,303
TERMINAL B												
B/MLIT CONNECTOR	66,640	250	267		253		40		133	4	1	
B1 PIER (East)	350,000	250	1,400		1,330		210		700	6	1	
B2 PIER (Middle + Bridges)	426,500	250	1,706		1,621		256		853	8	1	
B3 PIER (West + Concourse Lvls)	443,779	250	1,775		1,686		266		888	8	1	
TERM B FIS	300,281	250	1,201		1,141		180		601	6	1	
TERM B PROCESSOR	250,038	250	1,000		950		150		500	6	1	
TERM B SOUTH	264,948	250	1,060		1,007		159		530	6	1	
	2,102,186		8,409	750	7,988	730	1,261	240	4,204			2,102
C-CORE & TERM C SOUTH												
TERM C CENTRAL	1,855,272	500	3,711		3,525		557		1,855	8	1	
TERM C SOUTH	307,890	250	1,232		1,170		185		616	6	1	
	2,163,162		4,942	590	4,695	565	741	175	2,471			1,236
TERMINAL A												
TERM A NORTH	222,096	250	888		844		133		444	6	1	
TERM A PROCESSOR/PARKING	510,409	500	1,021		970		153		510	8	1	
TERM A SOUTH	193,665	250	775		736		116		387	6	1	
	926,170		2,684	390	2,550	380	403	127	1,342			671
TERMINAL E												
TERM E PROCESSOR	334,474	250	1,338		1,271		201		669	8	1	
TERMINAL E	581,986	250	2,328		2,212		349		1,164	8	1	
	916,460		3,666	480	3,483	460	550	145	1,833			916
SITE TOTAL	7,410,587		24,911	2,805	23,665	2,725	3,737	867	12,455			6,228

Water Demand is found on Table E103.3(3) - TABLE FOR ESTIMATING DEMAND from 2012 edition of International Plumbing Code (IPC). Sewer Flow rate: 1 gpm is equivalent to two fixture units - from paragraph 709.3 of the 2012 International Plumbing Code. Sewer pipe size comes from Table 710.1(1) from page 62 of the 2012 International Plumbing Code. At 1/4" Slope per foot.

STORMWATER

100 YEAR, 1 HOUR RAINFALL INCHES AT 4.75 INCHES PER HOUR BY ICC-IPC (2012) FOR HOUSTON

Building	Roof Area (sf)	100 Year, 1 Hour Rainfall Rate (in/hr)	Rainfall on roof (cu ft per hour)	Roof Storm Water (gpm)	Interior pipe leader sizing (in)	Horizontally Projected Area (sf) for 8" dia vertical leader at 4.75" / hr rainfall	Horizontally Projected Area (sf) for 8" dia horizontal leader 1/4" / ft slope, at 4.75" / hr rainfall	Number of leaders in a terminal building	Horizontal pipe main sizing (in)	Horizontally Projected Area (sf) for 12" dia horizontal leader 1/4" / ft slope, at 4.75" / hr rainfall	Number of horizontal pipes required leaving Terminal
TERMINAL D - MLIT											
MLIT CENTRAL PROCESSOR	153,930	4.75	60,931	7,597	8	24,650	13,860	11	12	39,950	4
D1 PIER	143,760	4.75	56,905	7,095	8	24,650	13,860	10	12	39,950	4
D2 PIER	143,760	4.75	56,905	7,095	8	24,650	13,860	10	12	39,950	4
EAST OF D2	33,656	4.75	13,322	1,661	8	24,650	13,860	2	12	39,950	1
WEST OF D1	46,733	4.75	18,498	2,306	8	24,650	13,860	3	12	39,950	1
MLIT FIS	153,233	4.75	60,655	7,562	8	24,650	13,860	11	12	39,950	4
	675,072			33,315							
TERMINAL B											
B/MLIT CONNECTOR	33,320	4.75	13,189	1,644	8	24,650	13,860	2	12	39,950	1
B1 PIER (East)	135,638	4.75	53,690	6,694	8	24,650	13,860	10	12	39,950	3
B2 PIER (Middle + Bridges)	160,050	4.75	63,353	7,899	8	24,650	13,860	12	12	39,950	4
B2 PIER (West + Concourse Lvls)	130,943	4.75	51,832	6,462	8	24,650	13,860	9	12	39,950	3
TERM B FIS	153,233	4.75	60,655	7,562	8	24,650	13,860	11	12	39,950	4
TERM B PROCESSOR	166,692	4.75	65,982	8,226	8	24,650	13,860	12	12	39,950	4
TERM B SOUTH	132,474	4.75	52,438	6,538	8	24,650	13,860	10	12	39,950	3
	912,350			45,025							
C-CORE & TERM C SOUTH											
TERM C CENTRAL	326,808	4.75	129,362	16,128	8	24,650	13,860	24	12	39,950	8
TERM C SOUTH	176,634	4.75	69,918	8,717	8	24,650	13,860	13	12	39,950	4
	503,442			24,845							
TERMINAL A											
TERM A NORTH	122,672	4.75	48,558	6,054	8	24,650	13,860	9	12	39,950	3
TERM A PROCESSOR/PARKING	153,626	4.75	60,810	7,582	8	24,650	13,860	11	12	39,950	4
TERM A SOUTH	109,754	4.75	43,444	5,416	8	24,650	13,860	8	12	39,950	3
	386,052			19,052							
TERMINAL E											
TERM E PROCESSOR	153,233	4.75	60,655	7,562	8	24,650	13,860	11	12	39,950	4
TERMINAL E	290,993	4.75	115,185	14,361	8	24,650	13,860	21	12	39,950	7
	444,226			21,923							
SITE TOTAL	2,921,142			144,160	8	24,650	13,860	211	12	39,950	73

Rainfall Rate is found on page 88 of 2012 International Plumbing Code (IPC). Water Demand is found on Table E103.3(3) - TABLE FOR ESTIMATING DEMAND from 2012 edition of International Plumbing Code (IPC).

NATURAL GAS

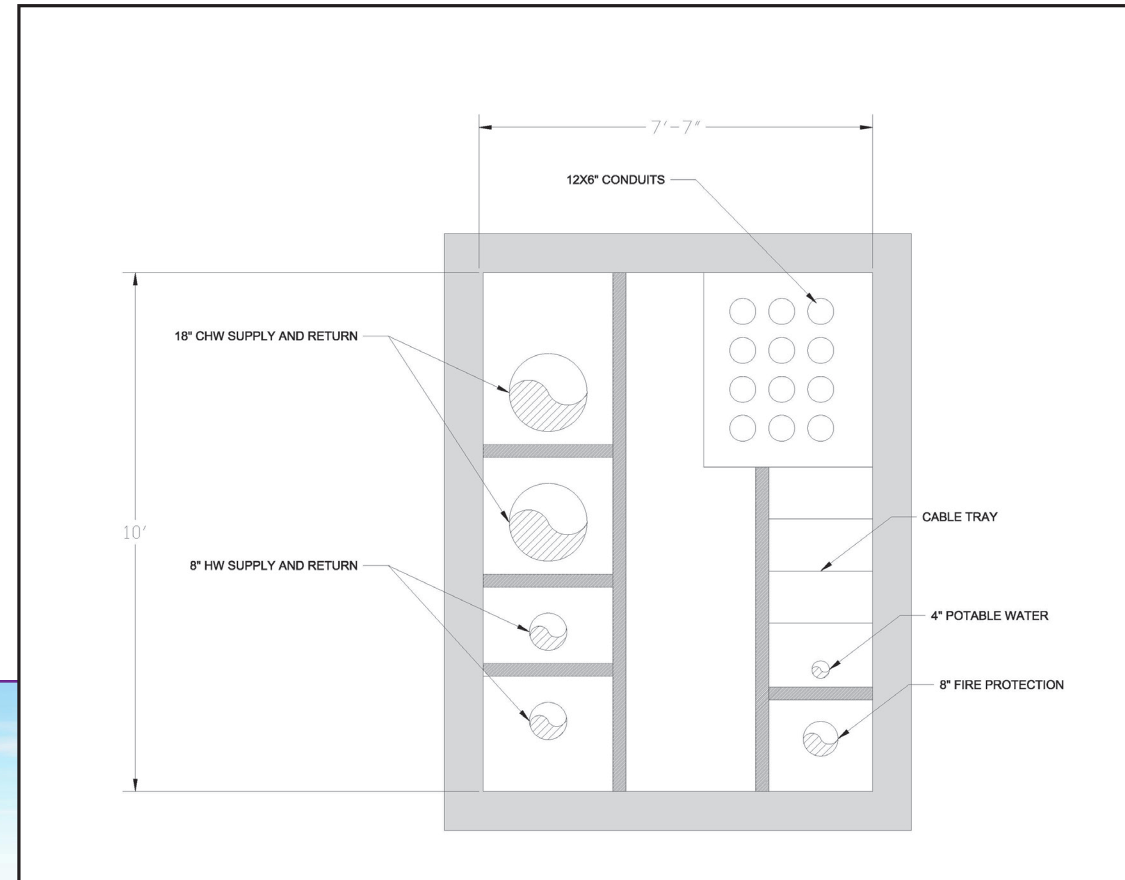
	GROSS BUILDING FLOOR AREA	CONCESSIONS	NATURAL GAS	
		Natural Gas 2 psi	Regulator Size	Gas Usage per sf
	TOTAL (sf)	cfh	cfh	sf/cfh
TERMINAL D - MLIT				
MLIT CENTRAL PROCESSOR	291,243	7,500	7,500	39
D1 PIER	268,794	7,500	7,500	36
D2 PIER	268,794	7,500	7,500	36
EAST OF D2	67,312	7,500	7,500	9
WEST OF D1	93,466	7,500	7,500	12
MLIT FIS	313,000	7,500	7,500	42
	1,302,609	45,000	45,000	
TERMINAL B				
B/MLIT CONNECTOR	66,640		0	
B1 PIER (East)	350,000	7,500	7,500	47
B2 PIER (Middle + Bridges)	426,500	7,500	7,500	57
B3 PIER (West + Concourse Lvls)	443,779	7,500	7,500	59
TERM B FIS	300,281			
TERM B PROCESSOR	250,038	7,500	7,500	33
TERM B SOUTH	264,948	7,500	7,500	35
	2,102,186	37,500	37,500	
C-CORE & TERM C SOUTH				
TERM C CENTRAL	1,855,272	7,500	7,500	247
TERM C SOUTH	307,890	7,500	7,500	41
	2,163,162	15,000	15,000	
TERMINAL A				
TERM A NORTH	222,096	7,500	7,500	30
TERM A PROCESSOR/PARKING	510,409	7,500	7,500	68
TERM A SOUTH	193,665	7,500	7,500	26
	926,170	22,500	22,500	
TERMINAL E				
TERM E PROCESSOR	334,474	7,500	7,500	45
TERMINAL E	581,986	7,500	7,500	78
	916,460	15,000	15,000	
TOTAL	7,410,587	135,000	135,000	55

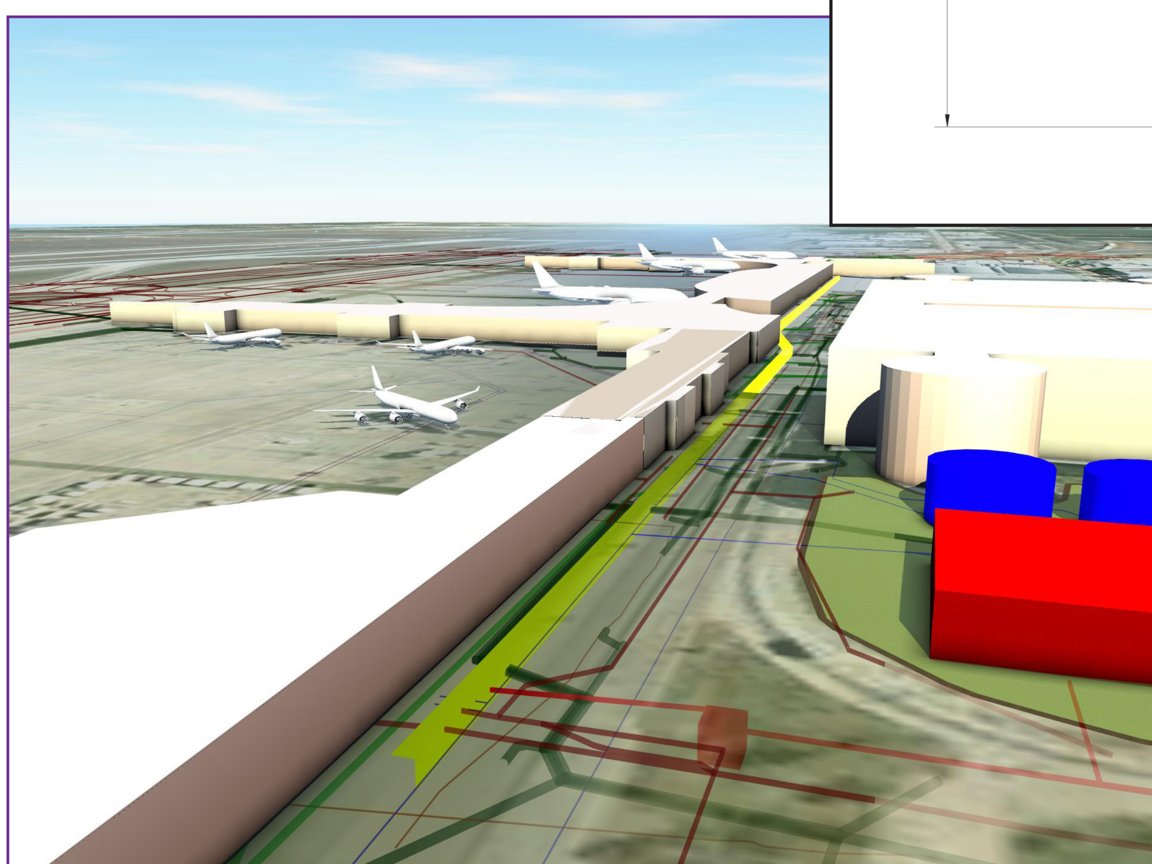
Natural Gas serves Concessions and Emergency Engine Generators in Terminal Buildings. Heating is provided by means of heating water from the Central Utility Plant.

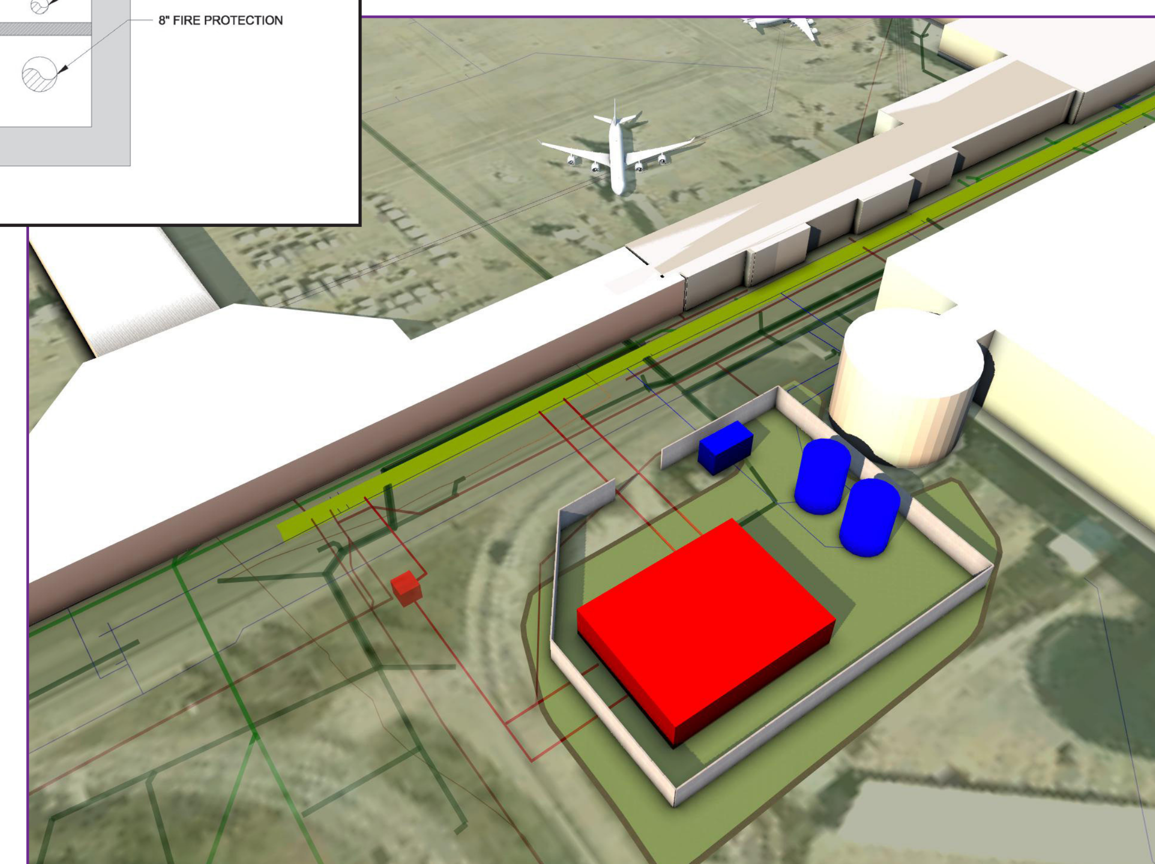
ASSUMPTIONS:

1. Each Terminal and Processor Building has Concessions at 7,500 CFH at 2 psi

ENABLING PROJECTS 3D IMAGES



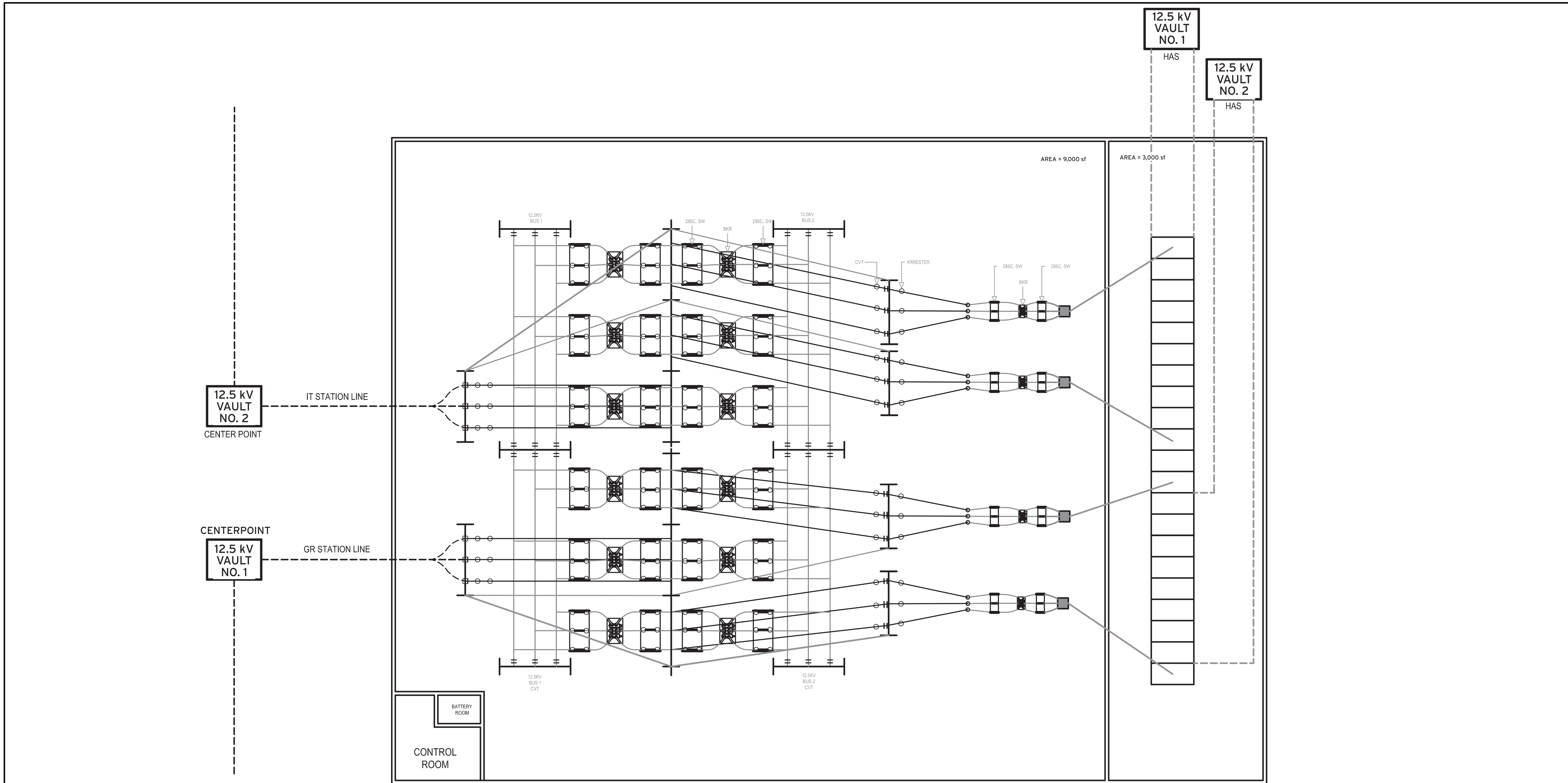




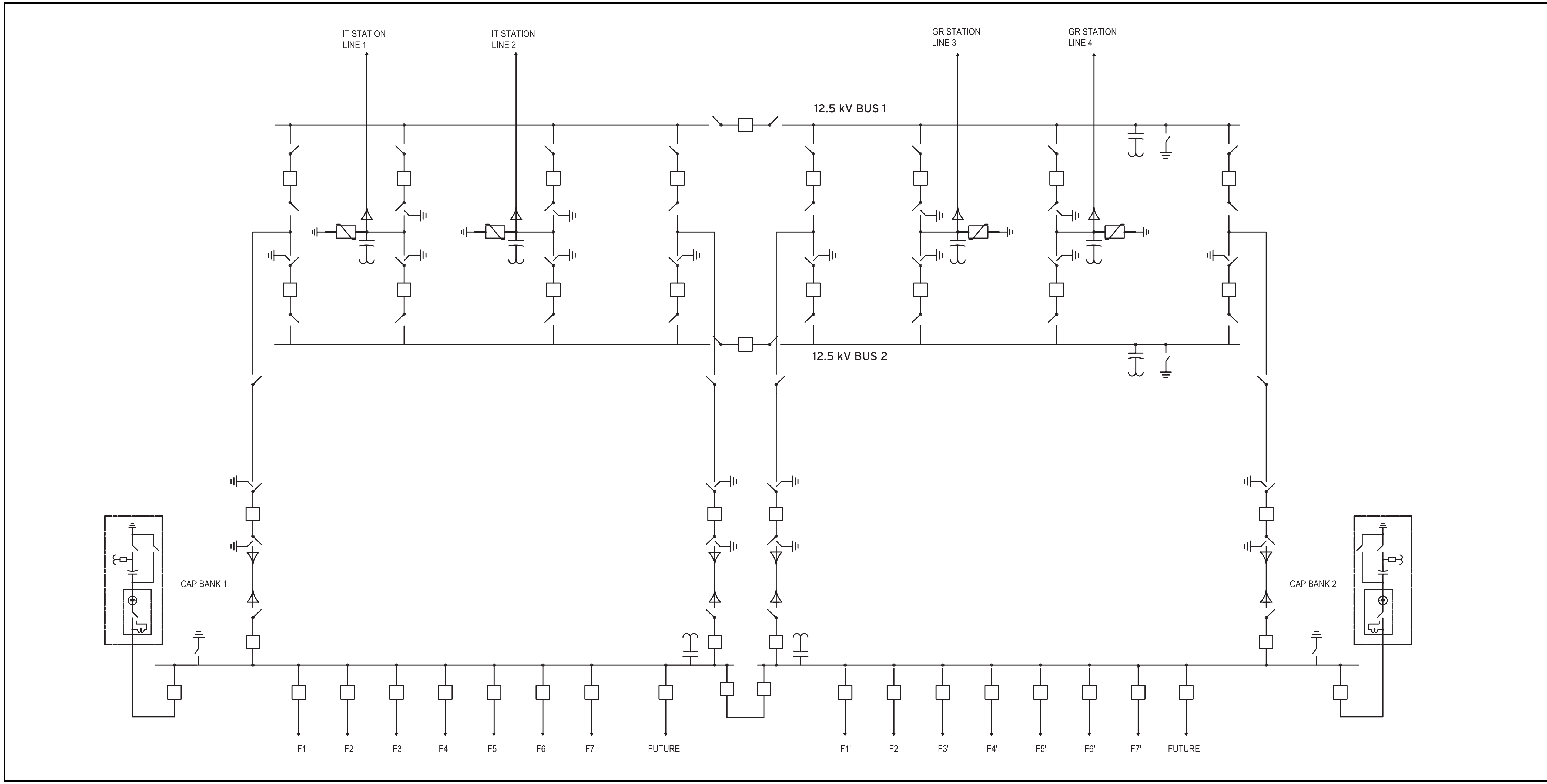
Appendix B

Site Utility Figures

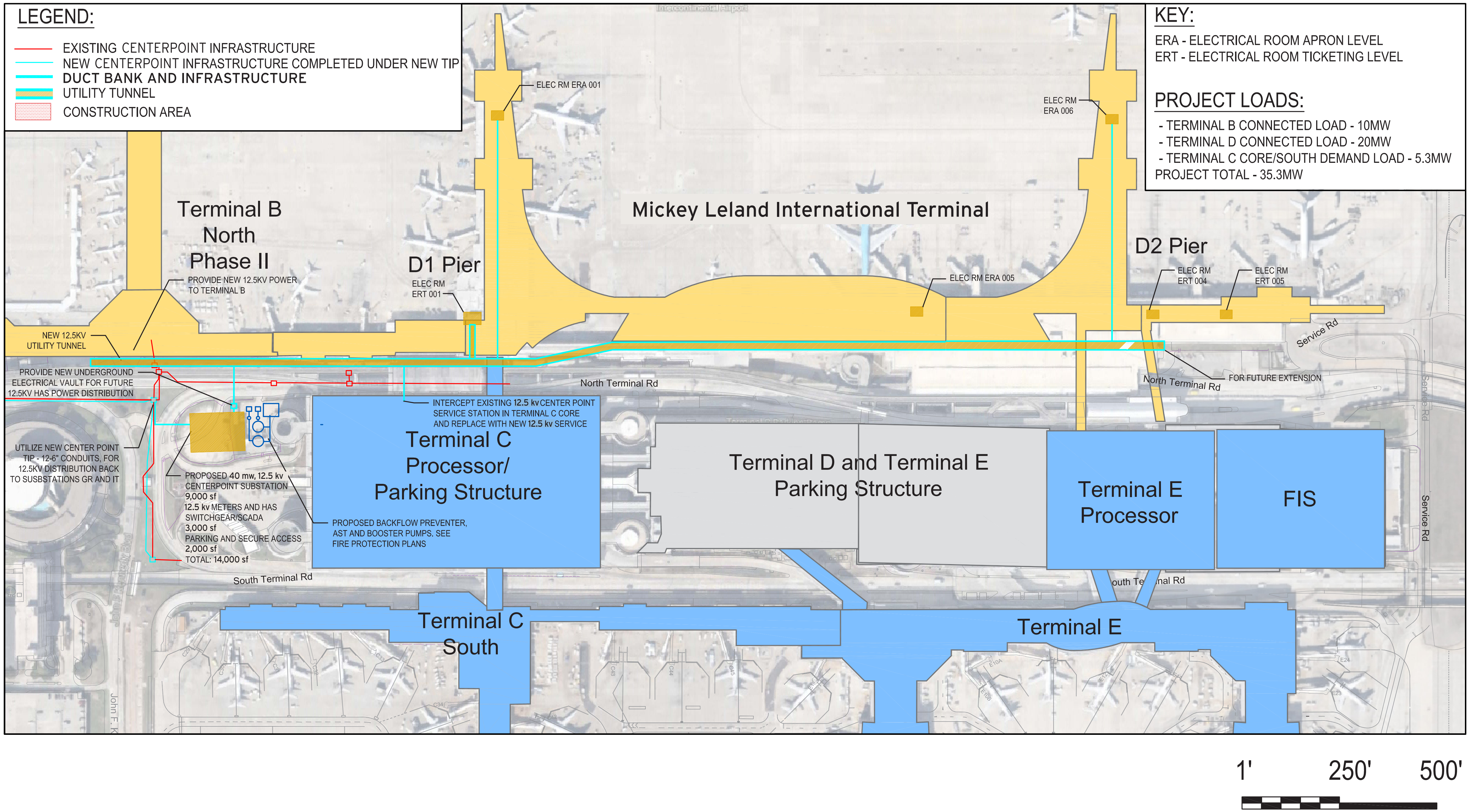
ELECTRICAL


12.5 kV VAULT NO. 1
HAS
12.5 kV VAULT NO. 2
HAS
AREA = 9,000 sf
AREA = 3,000 sf
DISC. SW
BKR
CVT
ARRESTER
12.5 kV VAULT NO. 2
CENTER POINT
IT STATION LINE
CENTERPOINT
12.5 kV VAULT NO. 1
GR STATION LINE
BATTERY ROOM
CONTROL ROOM

EXISTING 1 - LINE



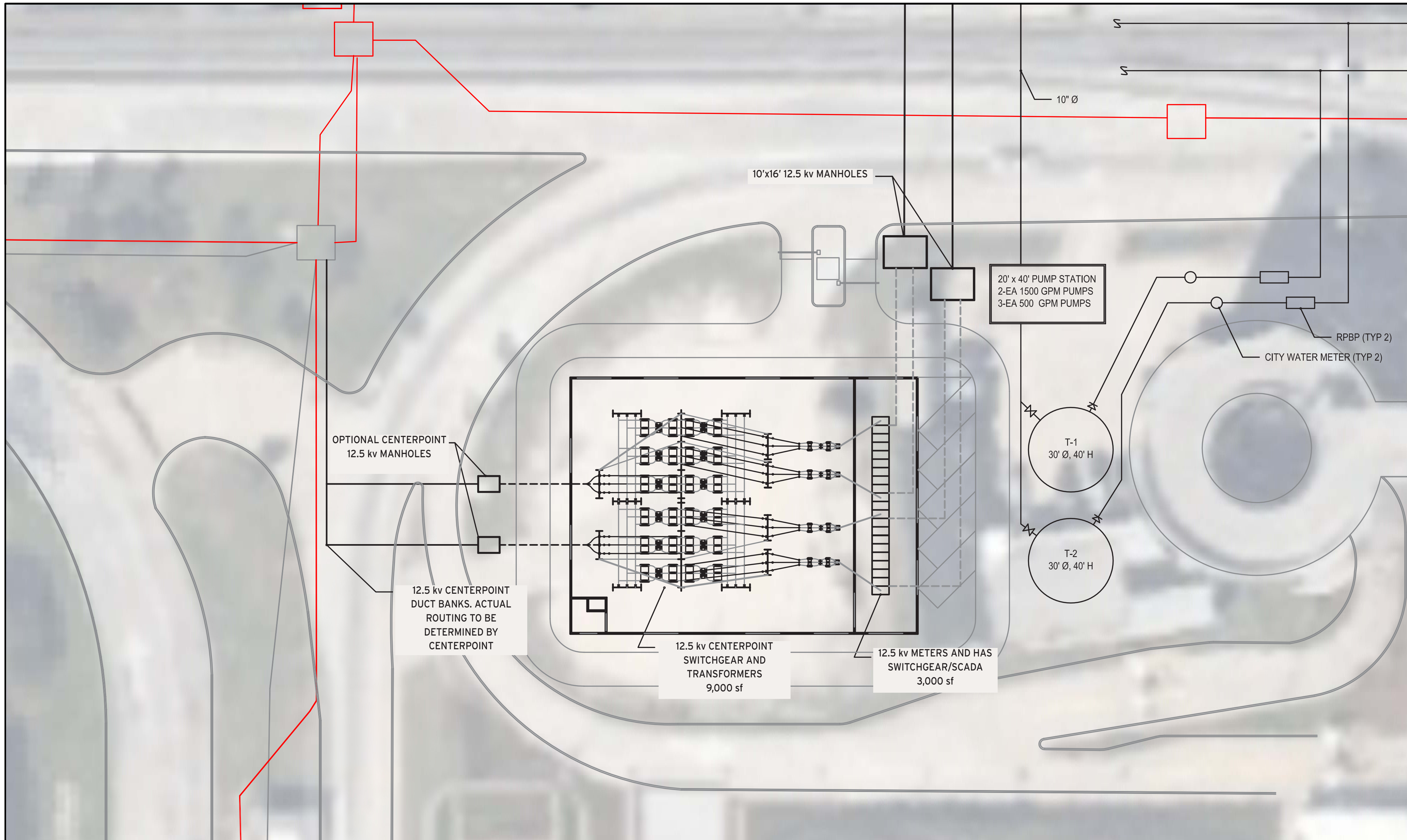
ELECTRICAL - PROPOSED SITE PLAN



SCALE = 1"=250'

B. 1 b

SITE PLAN: FIRE PROTECTION AND 12.5 kV SUBSTATION



Loads Powered by New 12.5kV Substation	Demand Loads
TERMINAL D - MLIT	8,906,481
TERMINAL B (North & Core)	13,781,271
C-CORE & TERM C SOUTH	5,839,000
TERMINAL A	5,903,000
FIS	2,365,000
SUBSTATION TOTAL	36,794,752

NOTES:

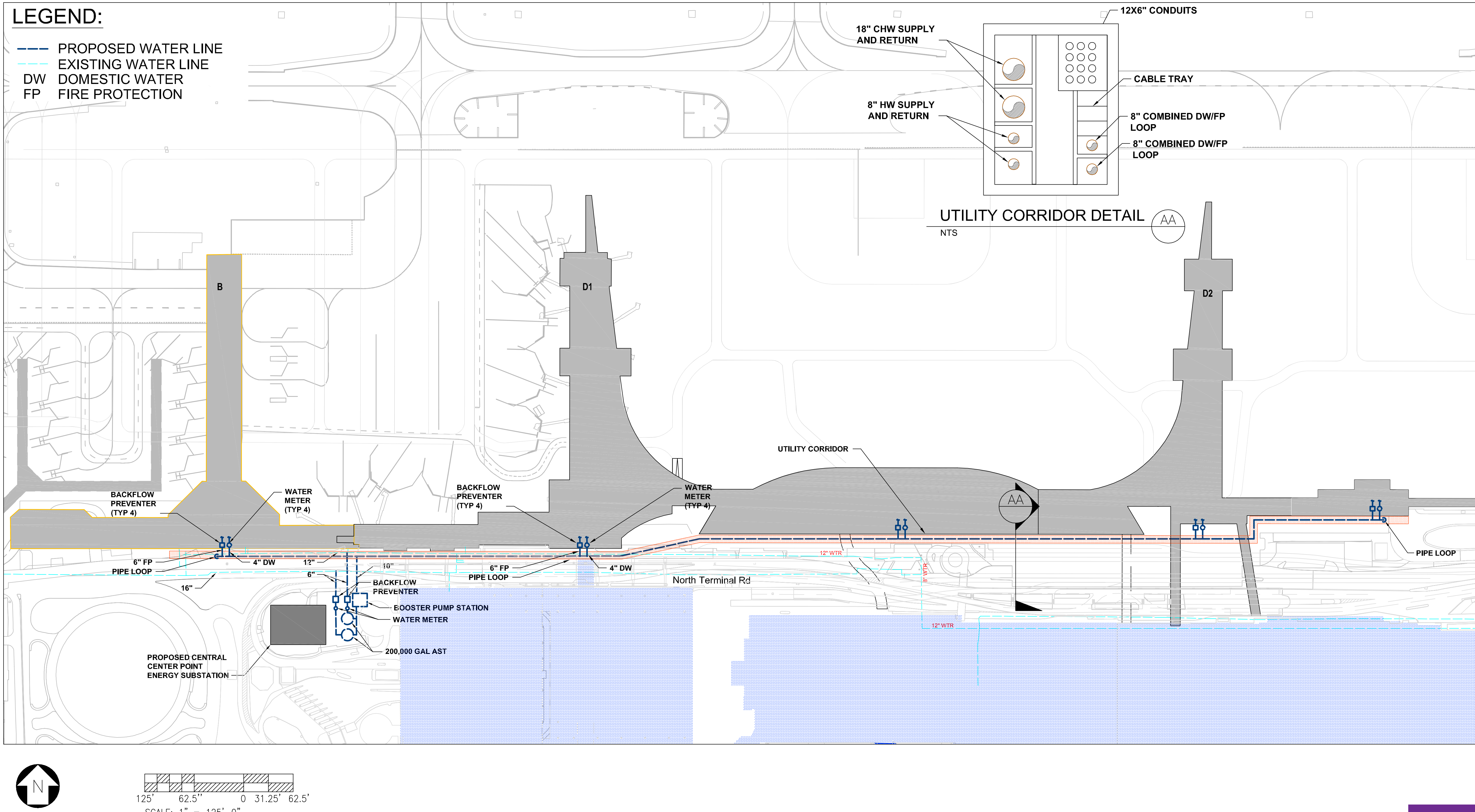
- CONNECT NEW SUBSTATION TO EXISTING 12.5KV CENTERPOINT INFRASTRUCTURE WITH (12) 6" CONDUITS, FOR EACH SET OF FEEDERS BACK TO SUBSTATIONS IT AND GR.
- THE SUBSTATION SHALL RECEIVE (4) DEDICATED CIRCUITS FROM THE CENTERPOINT SUBSTATIONS.
- SUBSTATION SHALL BE A MINIMUM OF 40MW IN ORDER TO HANDLE THE PROPOSED LOADS AS INDICATED ABOVE.
- POWER SHALL BE PROVIDED TO THE NORTH TERMINALS VIA A UTILITY TUNNEL WITH (12) 6" CONDUITS EACH.
- THE SUBSTATION SHALL BE CONSTRUCTED PRIOR TO THE COMPLETION OF TERMINAL B1.

1' 40' 80'

SCALE = 1"=40'

B. 1 c

PROPOSED DOMESTIC WATER / FIRE PROTECTION: SITE PLAN



SITE PLAN: FIRE PROTECTION AND 12.5 kV SUBSTATION

LEGEND:

- EXISTING CENTERPOINT INFRASTRUCTURE
- NEW CENTERPOINT INFRASTRUCTURE COMPLETED UNDER NEW TIP
- DUCT BANK AND INFRASTRUCTURE COMPLETED IN CURRENT PHASE
- DUCT BANK AND INFRASTRUCTURE COMPLETED IN PREVIOUS PHASE
- UTILITY TUNNEL COMPLETED IN CURRENT PHASE
- UTILITY COMPLETED IN PREVIOUS PHASE
- CONSTRUCTION AREA

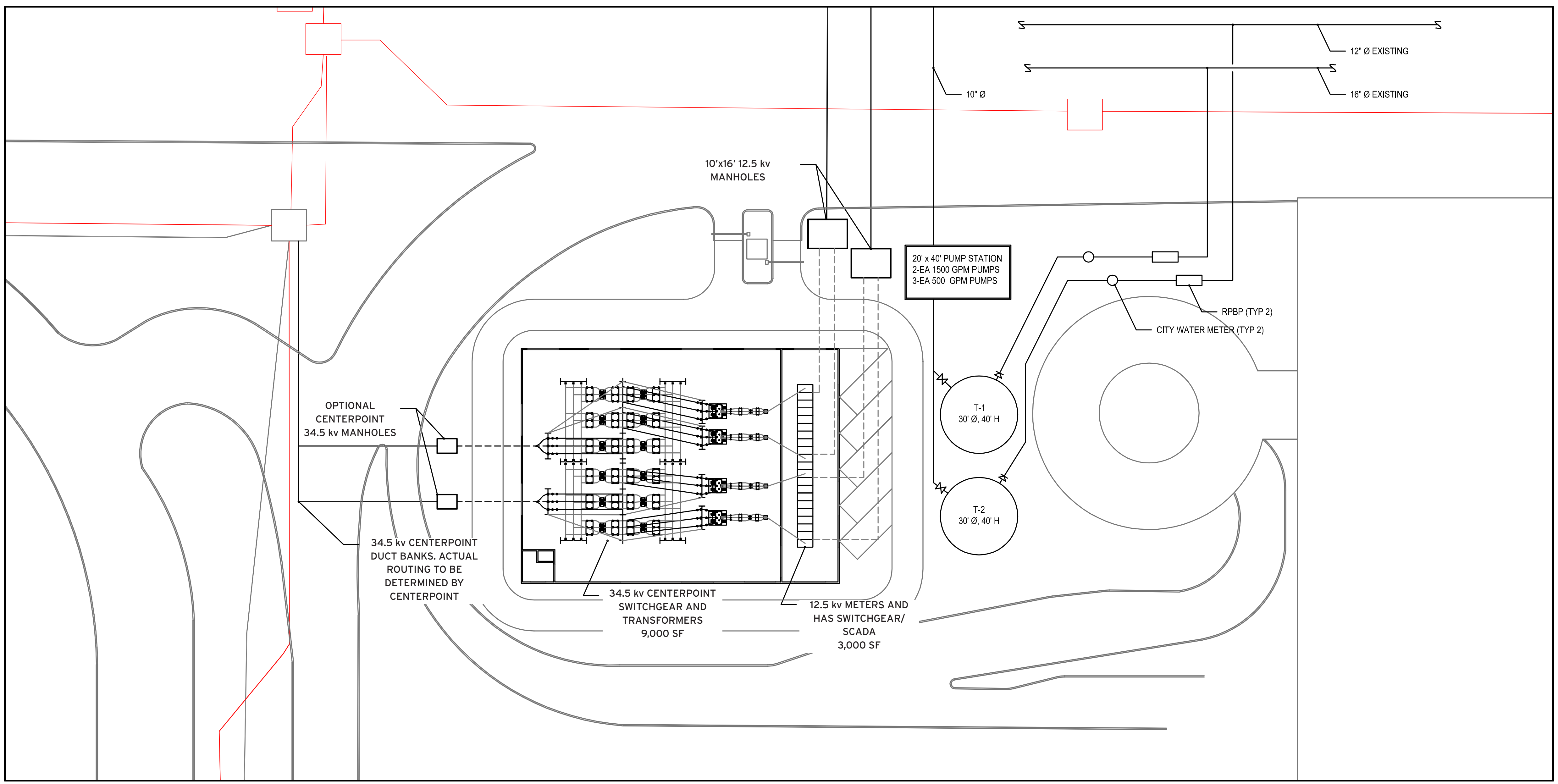
PHASE ONE LOADS:

- TERMINAL B - 10 mw CONNECTED LOAD
- TERMINAL D1 - 10 mw CONNECTED LOAD

PHASE 1 TOTAL - 20 mw

KEY:

ERA - ELECTRICAL ROOM ARRIVALS LEVEL
ERT - ELECTRICAL ROOM TICKETING LEVEL

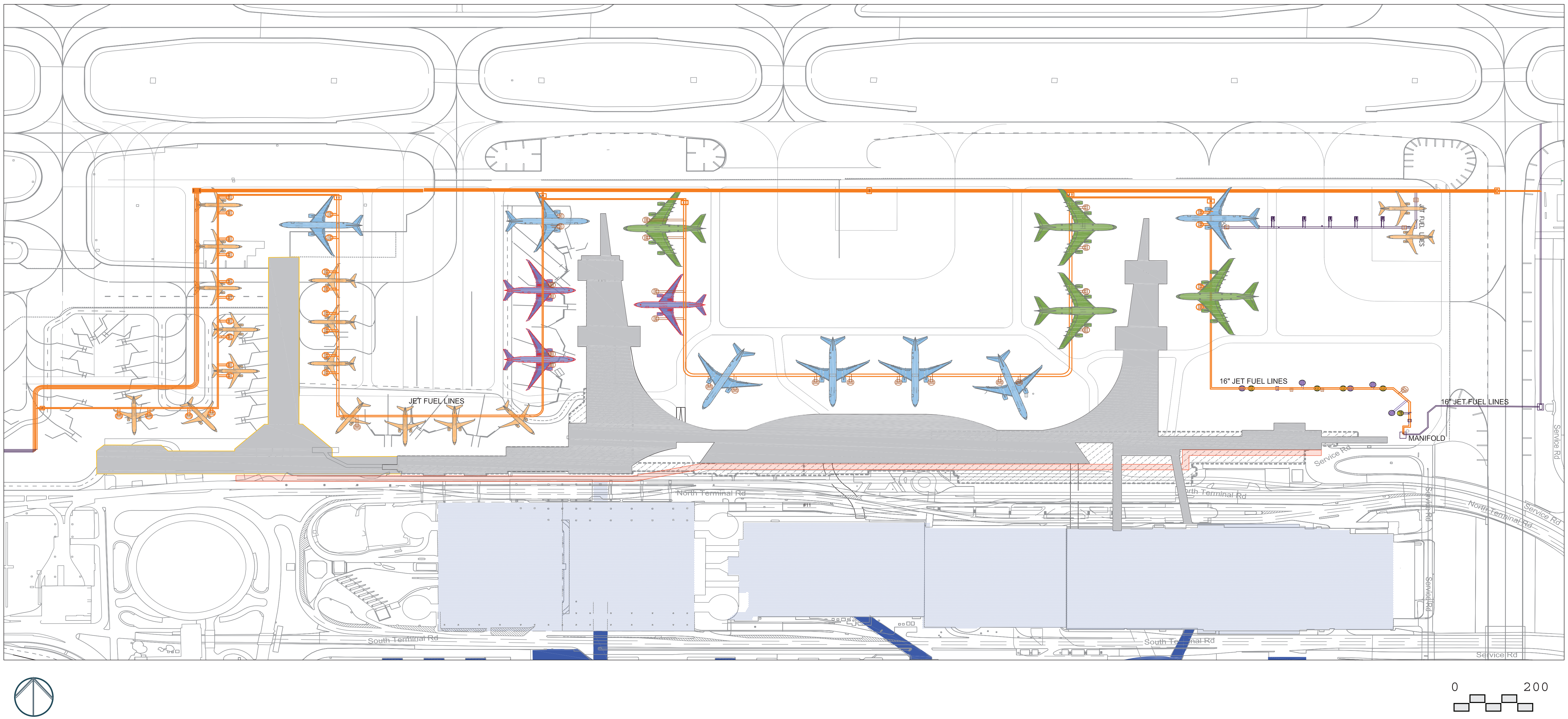


1' 40' 80'

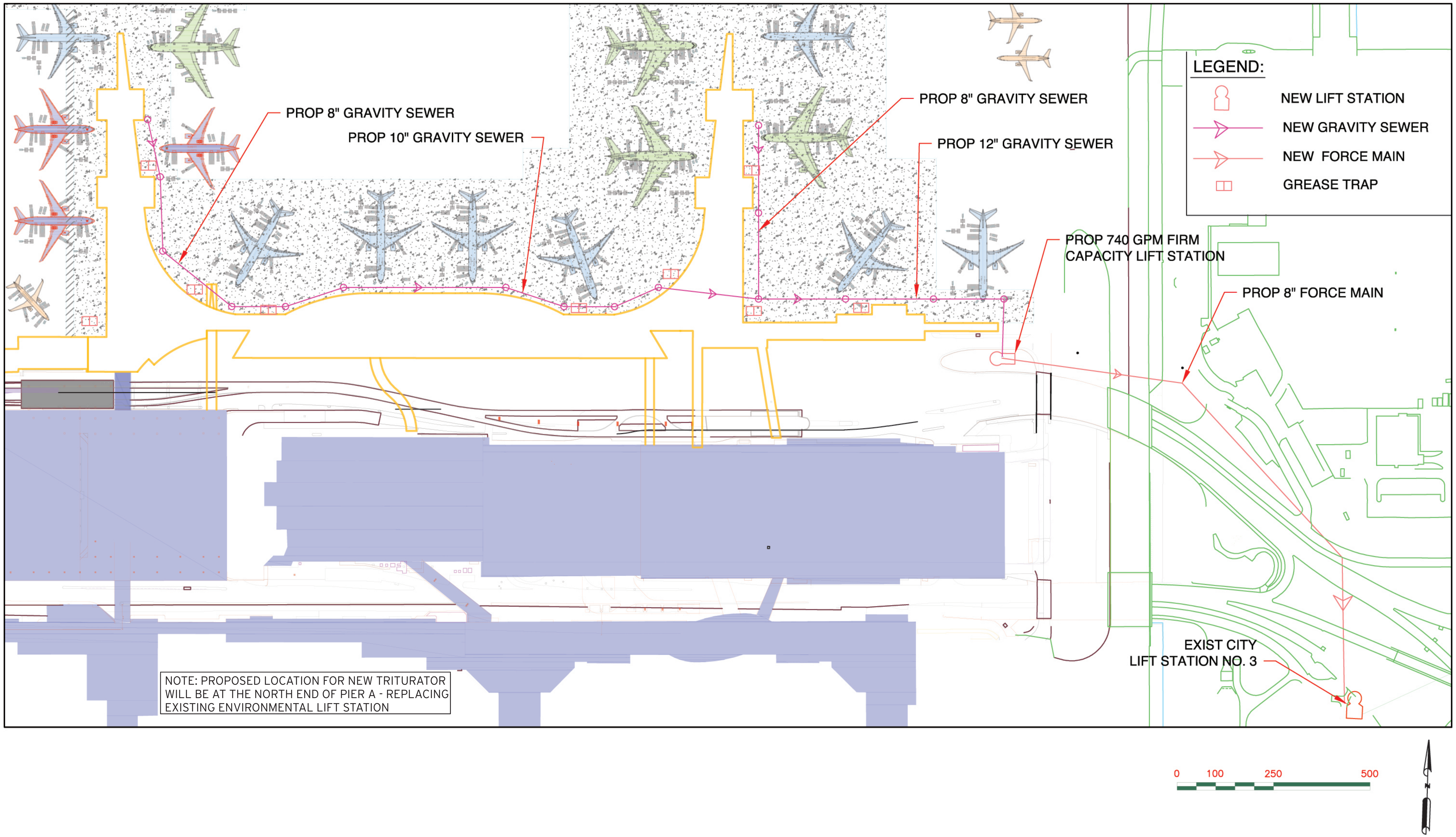
SCALE = 1"=40'

B. 2 a

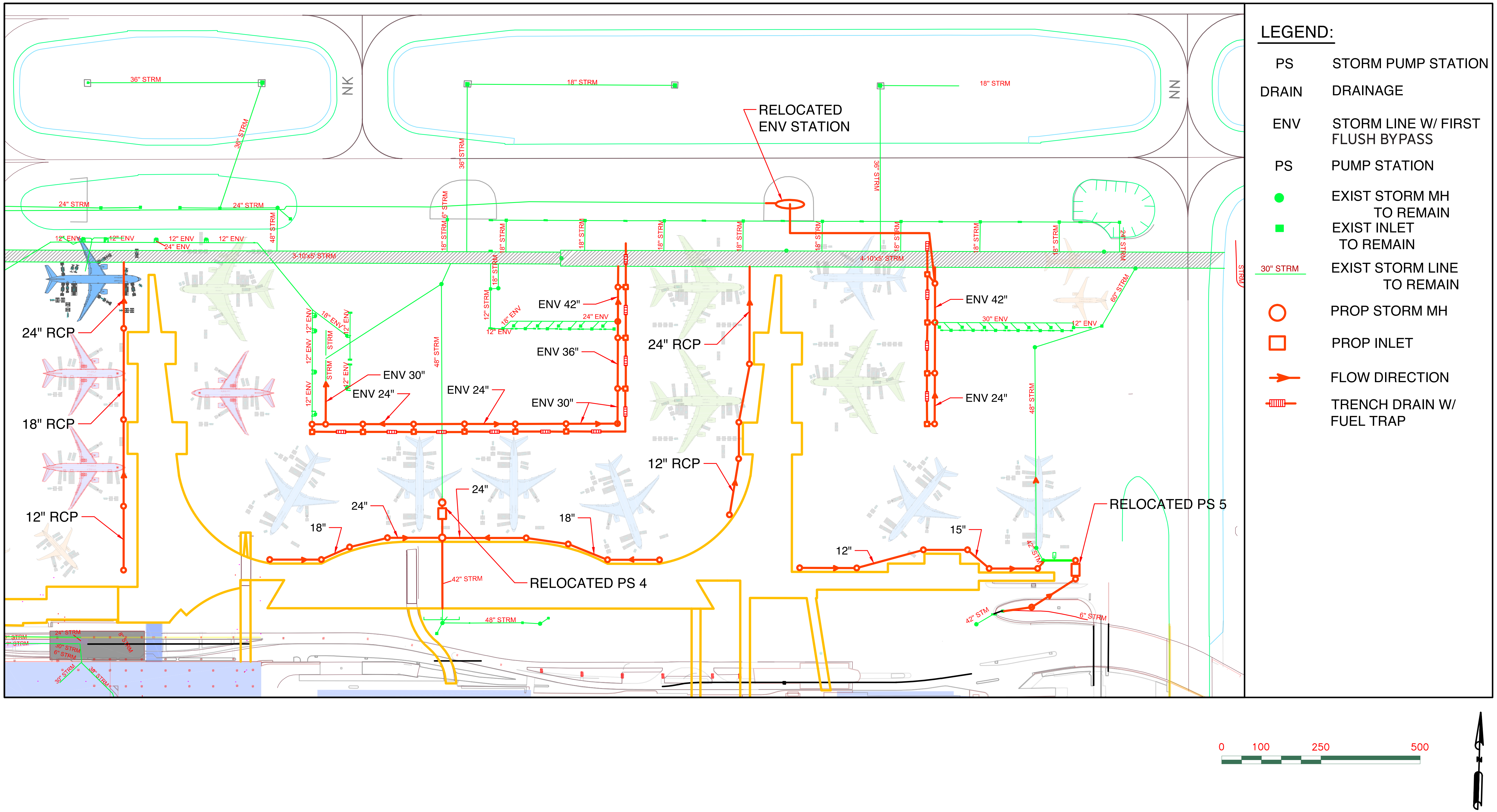
JET FUEL


JET FUEL LINES
16" JET FUEL LINES
16" JET FUEL LINES
MANIFOLD
North Terminal Rd
South Terminal Rd
Service Rd
0
200

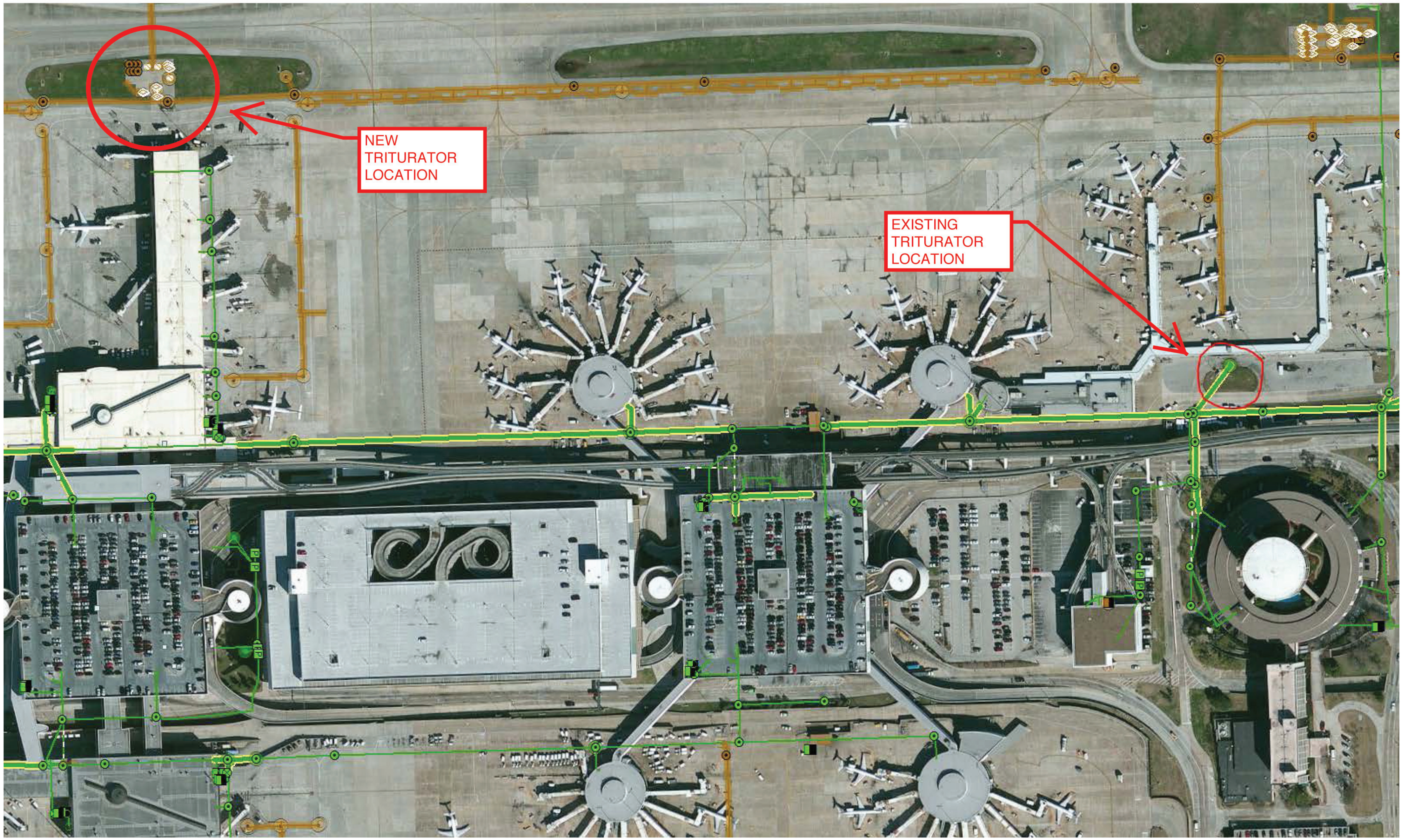
SANITARY DEMO/PROPOSED SITE PLAN



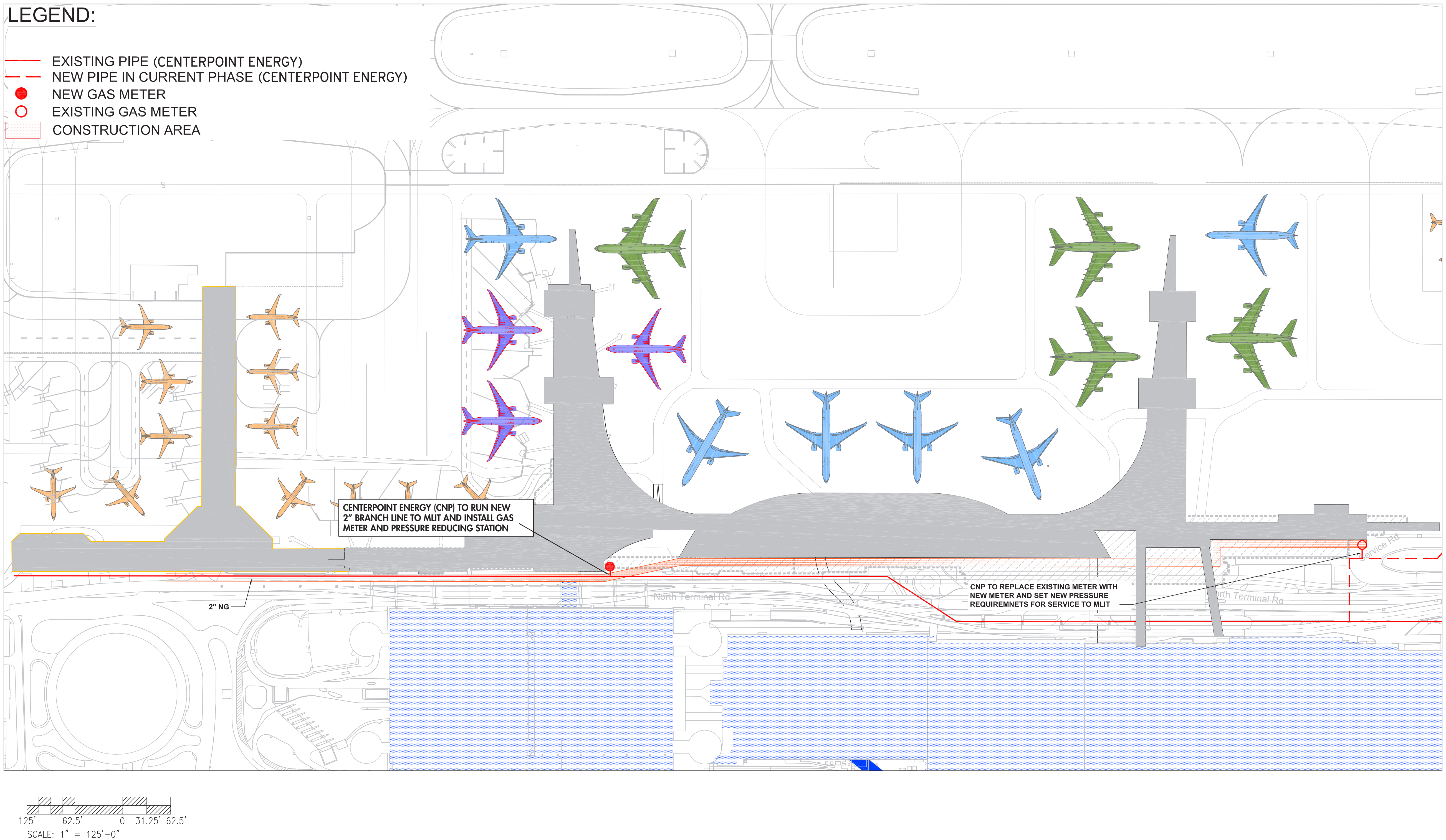
STORM DEMO/PROPOSED SITE PLAN



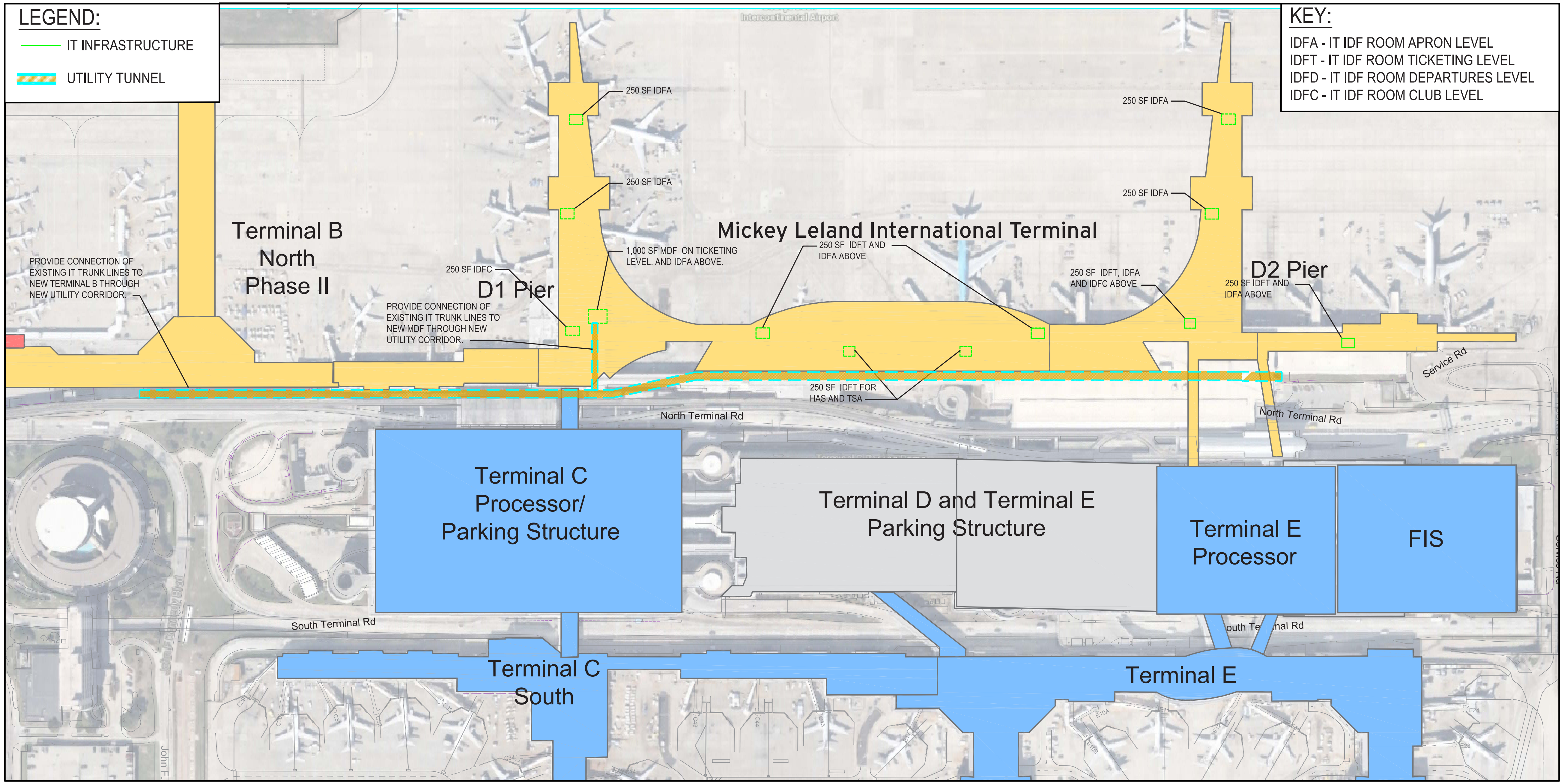
TRITURATOR



PROPOSED NATURAL GAS SITE PLAN



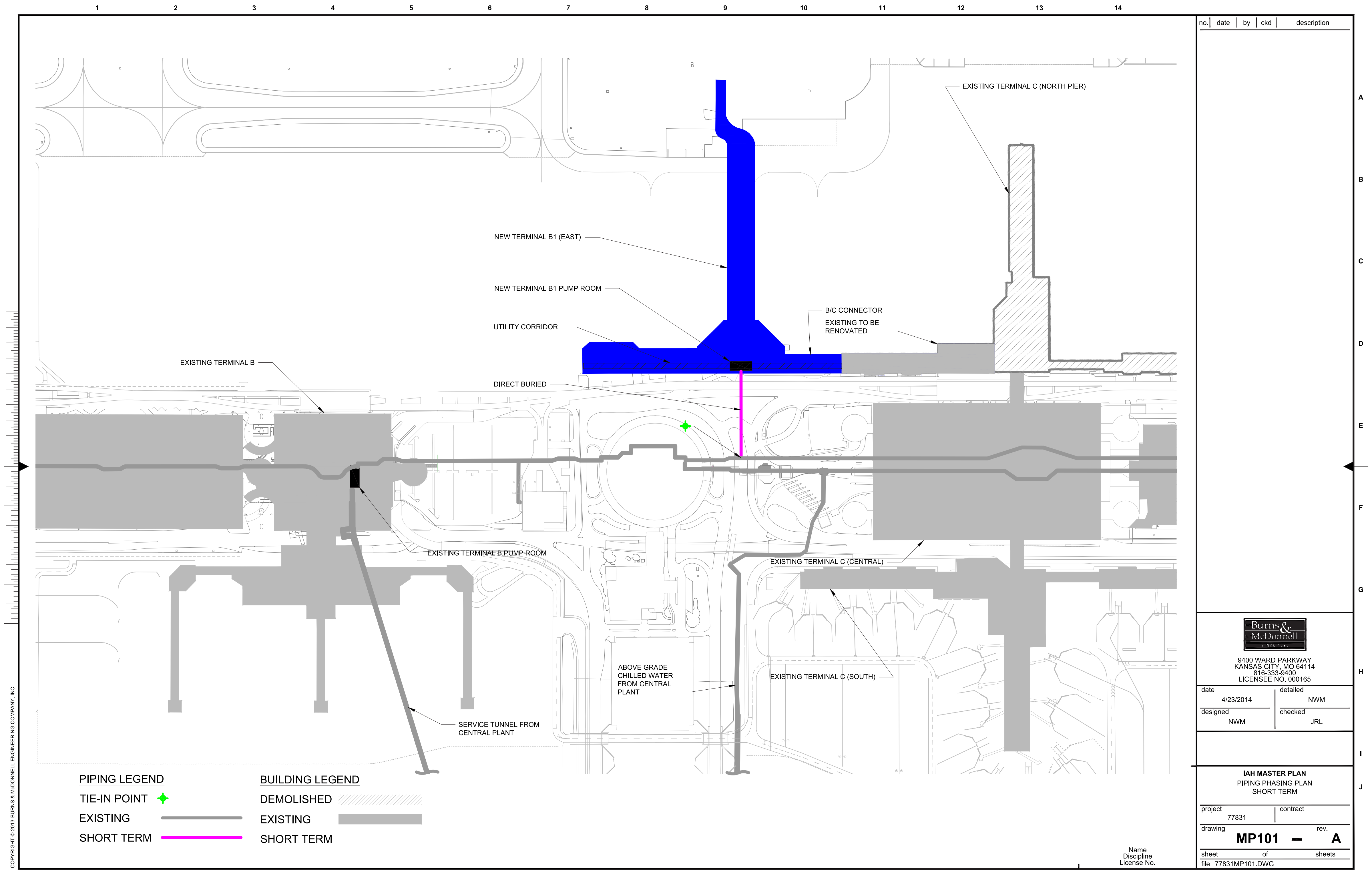
PROPOSED ALTERNATIVE IT DISTRIBUTION



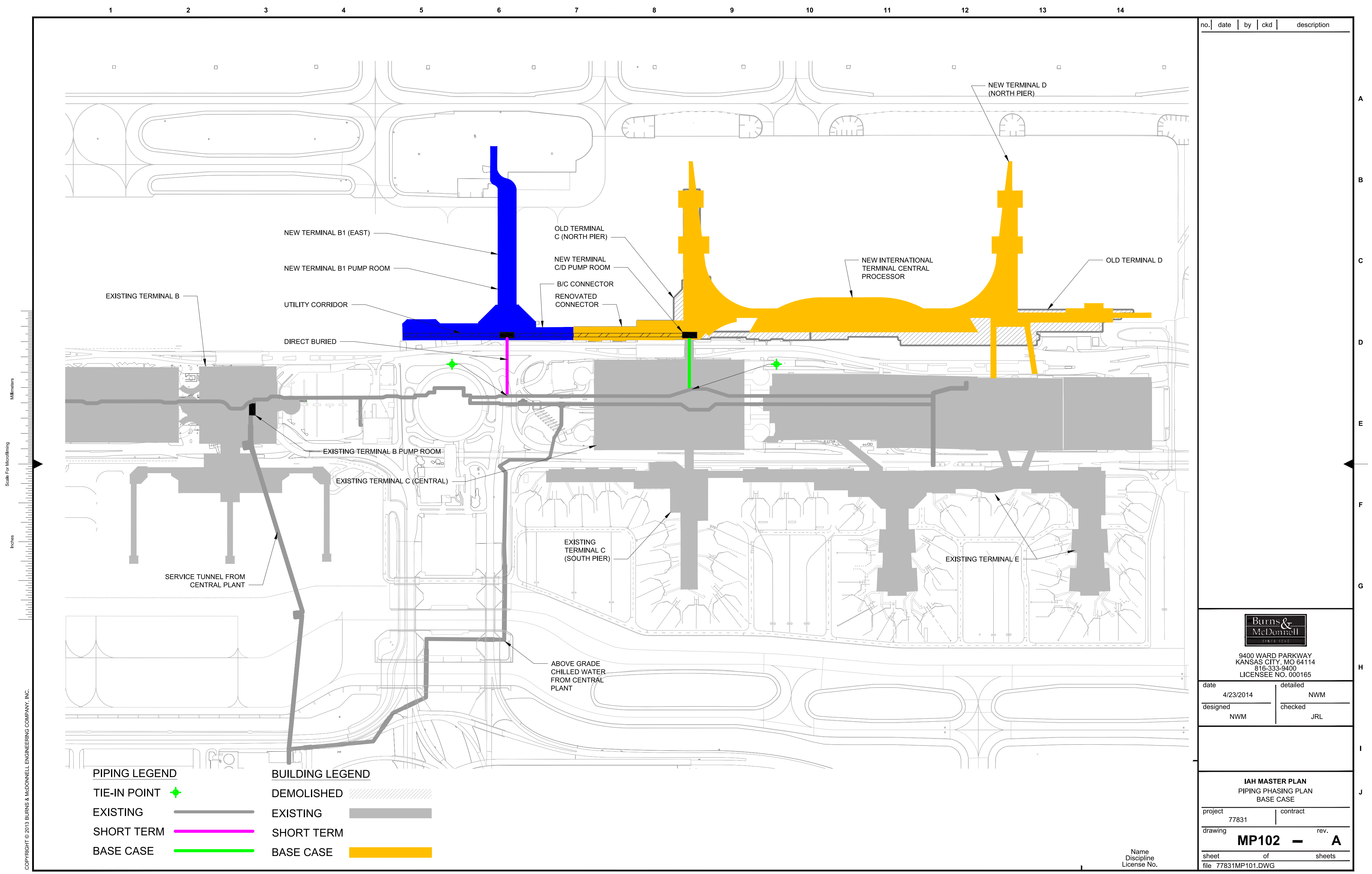
1'   250'   500'

SCALE = 1"=250'

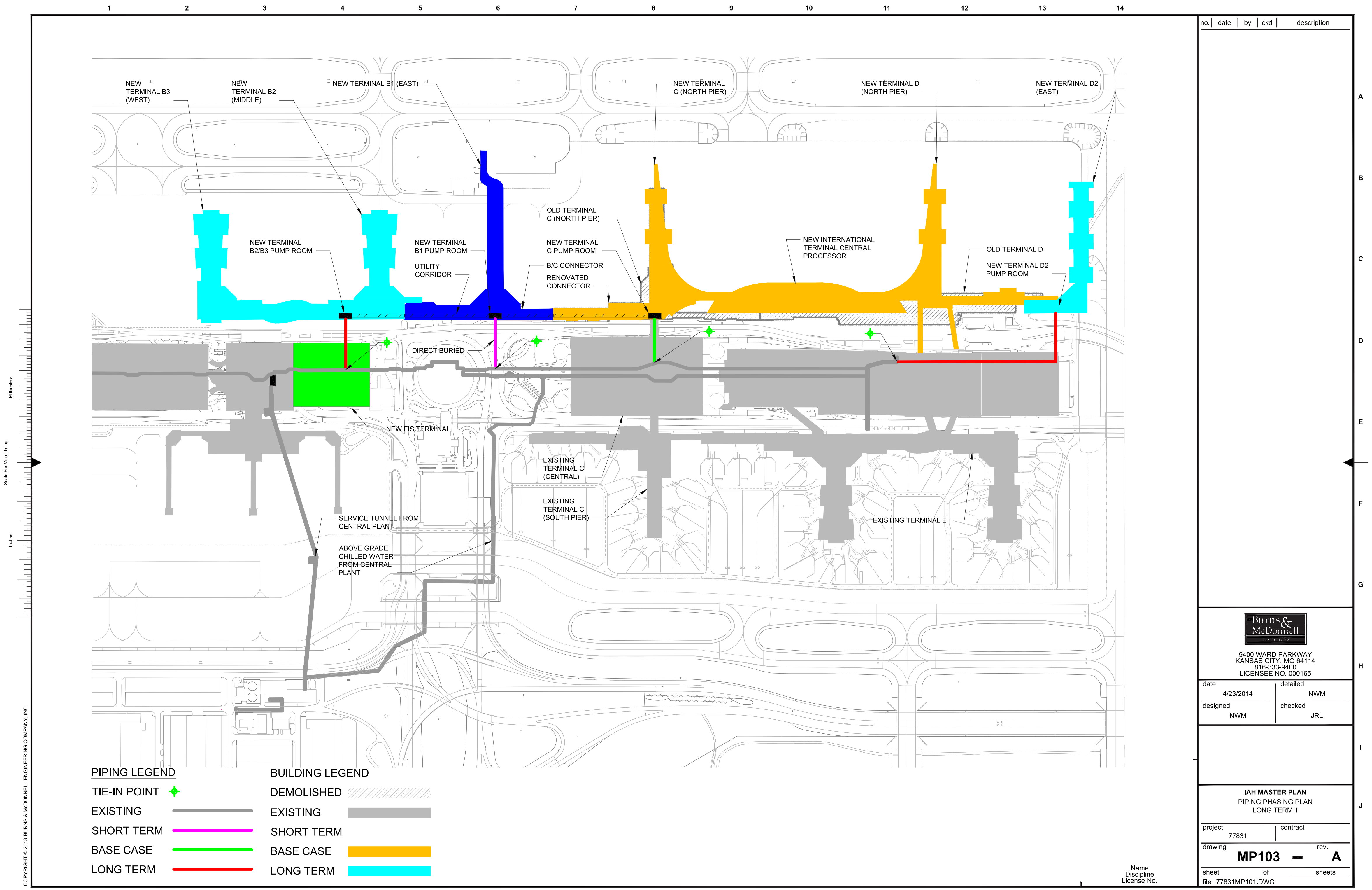
CHILLED & HEATING WATER: PHASE I



CHILLED & HEATING WATER: PHASE II

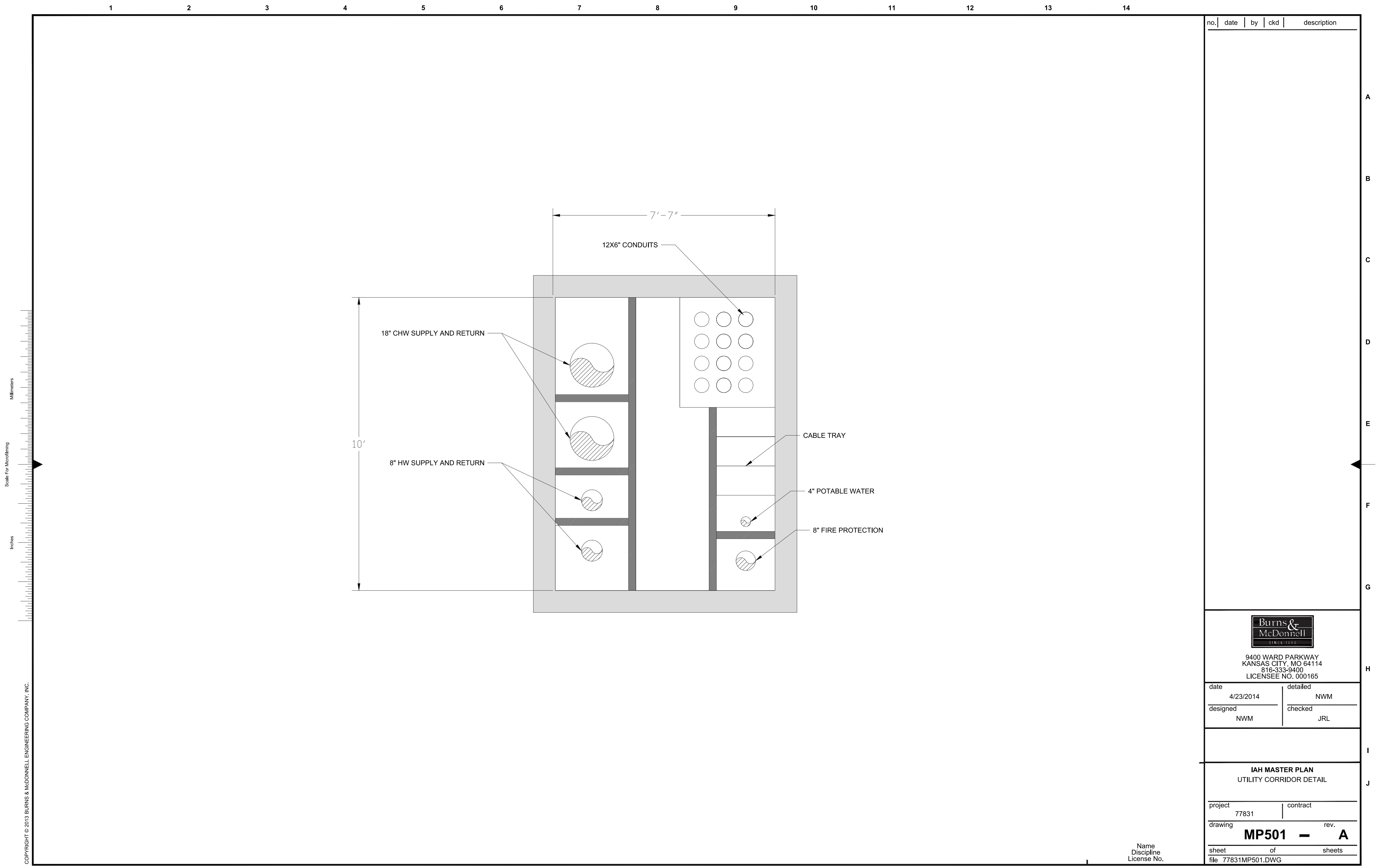


CHILLED & HEATING WATER: PHASE III



B. 9 b

CHILLED & HEATING WATER: UTILIDOR SECTION



Appendix C

Range of Magnitude (ROM) Construction Costs

TERMINAL B1 / MLIT / FUTURE UTILITIES ENABLING ROM COSTS

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas
8-17-2014 Update

UTILITIES MASTER PLAN PROJECTS - ROM COST SUMMARY

COMPONENT DESCRIPTION			
UTILITIES MASTERPLAN PROJECTS PROGRAM COSTS			*UTILIDOR Alternative*
a. *PROJECTED PROGRAM TERMINAL B1 - UTILITY ENABLING PROJECTS*	*Total Cost*	$	91,810,150
b. *PROJECTED MLIT PROGRAM UTILITY ENABLING PROJECTS*	*Total Cost*	$	71,234,360
c. *PROJECTED PROGRAM FUTURE UTILITY PROJECTS*	*TOTAL COST*	$	157,469,620
PROJECTED PROGRAM UTILITIES MASTER PLAN PROJECTS COSTS	*TOTAL*	$	320,514,130

C.

TERMINAL B - UTILITY ENABLING PROJECTS - SUMMARY

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas
8-17-2014 Update

TERMINAL B1 - UTILITY ENABLING PROJECTS - SUMMARY

SYSTEM DESCRIPTION

			UTILIDOR ALTERNATIVE
UTILITY ENABLING PROJECT 1; ELECTRICAL (with EMERGENCY GENERATOR PACKAGE)		$	28,970,800
UTILITY ENABLING PROJECT 2; FIRE PROTECTION		$	2,654,690
UTILITY ENABLING PROJECT 3; CHILLED WATER/HEATING WATER		$	612,430
UTILITY ENABLING PROJECT 4; AVIATION FUEL		$	14,728,350
UTILITY ENABLING PROJECT 6; TRITURATOR		$	500,000
UTILITY ENABLING PROJECT; ADD ALTERNATE 1; EXTEND UTILIDOR TUNNEL TO TERM A		$	8,315,700
SUBTOTAL - UTILITIES COST OF WORK		**$**	**55,781,970**
Escalation to January 2016	5.0%	$	2,789,099
SUBTOTAL - COST OF WORK		**$**	**58,571,069**
Architecture/Engineering Fees	8.0%	$	4,685,685
Program Management Fees	4.0%	$	2,342,843
CMAR Fees	3.0%	$	1,757,132
CMAR General Requirements / CMAR Overhead	10.0%	$	5,857,107
Testing	1.0%	$	585,711
Inspection	1.5%	$	878,566
QA/QC Services	1.0%	$	585,711
Insurance	2.0%	$	1,171,421
Bonds	2.0%	$	1,171,421
Administrative Fees	1.0%	$	585,711
Commissioning	1.5%	$	878,566
Public Art	1.75%	$	1,024,994
SUBTOTAL - OWNER'S SOFT COSTS	36.75%	**$**	**21,524,868**
Program Contingency (Planning Phase)	20.0%	$	11,714,214
PROJECTED PROGRAM TERMINAL B1 - UTILITY ENABLING PROJECTS COST TOTAL		***$***	***91,810,150***

C. a 1

TERMINAL B - UTILITY ENABLING PROJECT 1: ELECTRICAL

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas

FAITHFUL GOULD

TERMINAL B1 - UTILITY ENABLING PROJECT 1; ELECTRICAL

8-17-2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	40		*SITE ELECTRICAL UTILITES - TERMINAL C (formerly B)*						
G	40	4010	**ELECTRICAL DISTRIBUTION**						
			Alternative: Centerpoint Energy (CNP) to install a 12.5kV Central Receiving Station at C-Carage. Direct buried duct bank, 12 each 6" PVC conduits, from a Central Receiving Station, at C-Garage, across the North Terminal Road. Intercept the new Utility Corridor and run 12 6" PVC conduits to the west to Terminal B.						
			40 MW, 12.5kV Central Receiving Station at C-Carage.	1	LS	20,000,000	20,000,000		
			HAS Switchgear (10 MW)	1	LS	1,000,000	1,000,000		
			12.5kV / 480V sub/transformer	3	EA	700,000	2,100,000		
			Underground Concrete Encased Electrical Ductbank, assume 12 - 6" PVC conduit, w/ conductor	278	LF	1,650	458,700		
			Utility Corridor Electrical Ductbank, assume 12 - 6" exposed Schedule 80 conduits	5,064	LF	50.00	253,200		
			I.T. and EM Conduit in RACK System for Terminals B2, B3 & A, assume 12 - 6" exposed Schedule 80 conduit	5,064	LF	50	253,200		
			Emergency Generator package with 2 MW / 12.5 kV with 5,000 gal diesel fuel tank and feeders to serve Term B & MLIT	1	LS	1,600,000	1,600,000		
			ELECTRICAL DISTRIBUTION SUBTOTAL					25,665,100	
G	40		**SITE SECURITY**						
			Critical Facility, with HAS Switchgear room, a 4,000 SF vault below and 2,000 SF of Parking access	12,000	SF	200	2,400,000		
			CCTV at Critical Facility	1	LS	10,000	10,000		
			Security lighting at Critical Facility	1	LS	30,000	30,000		
			CMU security wall with access-controlled gate around Central Receiving Station	1	LS	25,000	25,000		
			SITE SECURITY SUBTOTAL					2,465,000	
			CONCRETE BOX CULVERT						
			Concrete box culvert, 8'x10' with excavation, 3' overburden, lighting, drainage, pipe racks, Etc.	422	LF	1,850	780,700		
			Assume relocation of (16) 8" lines at 30' each	480	LF	125.00	60,000		
			CONCRETE BOX CULVERT SUBTOTAL					840,700	
G	40		***TOTAL - SITE ELECTRICAL UTILITIES - TERMINAL B1***						***$ 28,970,800***

C. a 2

TERMINAL B - UTILITIES ENABLING PROJECT 2: FP / DW

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas

FAITHFUL GOULD

TERMINAL B1 - UTILITIES ENABLING PROJECT 2; FP/DW

8-17-2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	30		SITE MECHANICAL UTILITIES - TERMINAL C (formerly B)						
			Alternative: 16" Direct buried ductile iron pipe, across North Terminal Road. Intercept Utility Corridor, convert to 16" Schedule 40 Carbon Steel and install 16" Tee. Reduce to 12" welded Schedule 40 Carbon Steel and install 16" Tee. Reduce to 12" welded Schedule 40 Carbon Steel and run west to Terminal B. Cap off Tee to east.						
			Alternative: New Central Water Storage System with 2 ea 500,000 Gallon tanks near Terminal B complex with 1 ea 1500 gpm pump, 1 ea future space for 1500 pump, 2 ea 500 gpm pumps, 2 ea 500 gpm tank fill pump, 2 ea future spaces for 500 gpm pumps, Pump House, Electrical, Earthwork, and Controls						
G	30	3010	WATER SUPPLY						
			FP/DW: 500,000 gallon AST Concrete	2	EA	900,000	1,800,000		
			FP/DW: 1,500 GPM pumps	1	EA	75,000	75,000		
			FP/DW: 1,500 GPM pumps (infrastructure for future pump)	1	EA	7,500	7,500		
			FP/DW: 500 GPM pumps	2	EA	30,000	60,000		
			FP/DW: 500 GPM tank fill pumps	2	EA	30,000	60,000		
			FP/DW: 500 GPM pumps (infrastructure for future pump)	2	EA	5,000	10,000		
			FP/DW: Water main piping tie, 16" direct buried ductile including excavation, compaction and backfill	603	LF	150	90,450		
			FP/DW: Water main piping Tee, 16" carbon steel in new Utility Corridor	1	EA	9,100	9,100		
			FP/DW: Water main piping tie, 12" Schedule 40 carbon steel	422	LF	220	92,840		
			Tap and tee existing 12" water line for new 10" water line	1	EA	4,200	4,200		
			Tap and tee existing 16" water line for new 10" water line	1	EA	9,100	9,100		
			Backflow preventor, 10"	3	EA	18,000	54,000		
			Water Meter, 10"	3	EA	10,000	30,000		
			Miscellaneous valves and connections	1	LS	15,000	15,000		
			Pump house enclosure with electrical, controls, and earthwork	1	LS	300,000	300,000		
			Assume relocation of (10) 8" lines at 30' each	300	LF	125.00	37,500		
			WATER SUPPLY SUBTOTAL					2,654,690	
G	30		TOTAL - SITE MECHANICAL UTILITIES - TERMINAL B1						$ 2,654,690

C. a 3

TERMINAL B - UTILITIES ENABLING PROJECT 3: CHILLED WATER / HEATING WATER

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas

TERMINAL B1 - UTILITIES ENABLING PROJECT 3; CHILLED WATER/HEATING WATER

8-17-2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	30		*SITE MECHANICAL UTILITIES - TERMINAL C (formerly B)*						
G	30	3040	**HEATING DISTRIBUTION**						
			Heating distribution lines, tie to existing system:						
			Heating hot water supply and return lines, 8" dia. direct burry Pre-Insulated Pipe System	250	LF	128	32,000		
			Heating hot water supply and return lines, 8" Insulated in PIPE RACK Pipe System	422	LF	355	149,810		
			Tie-in to existing heating hot water piping	2	EA	2,900	5,800		
			HEATING DISTRIBUTION SUBTOTAL					187,610	
G	30	3050	**COOLING DISTRIBUTION**						
			Cooling distribution lines, tie to existing system:						
			Chilled water supply and return lines, 18" dia. direct burry Pre-Insulated Pipe System	250	LF	268	67,000		
			Chilled water supply and return lines, 18" dia. Insulated in PIPE RACK Pipe System	422	LF	810	341,820		
			Tie-in to existing chilled water piping	2	EA	8,000	16,000		
			COOLING DISTRIBUTION SUBTOTAL					424,820	
G	30		*TOTAL - SITE MECHANICAL UTILITIES - TERMINAL B1*						*$ 612,430*

TERMINAL B - UTILITIES ENABLING PROJECT 4: AVIATION FUEL

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas

FAITHFUL GOULD

TERMINAL B1 - UTILITIES ENABLING PROJECT 4; AVIATION FUEL

8-17-2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES - TERM. B						
G 30 3060 **FUEL DISTRIBUTION**						
Remove existing fuel mains and manifolds, above ground	4,280	LF	25.00	107,000		
Slurry fill existing fuel branch lines and remain overnight hydrant lines	2,140	LF	16.00	34,240		
Remove existing isolation valve vault	0	EA	28,000			
Remove existing fuel hydrant pit	3	EA	21,000	63,000		
Fuel Mains: 16" dia. Steel pipe, epoxy lining, exterior coated, welded and x-rayed	8,000	LF	486	3,888,000		
Main line cathodic protection	1	LS	40,000	40,000		
Main line low point drain pit, 1 per 400 LF	20	EA	30,200	604,000		
Main line high point vent pit, 1 per 400 LF	20	EA	30,200	604,000		
Main line isolation valve vault	4	EA	321,000	1,284,000		
Main line isolation valves, 16" twin seal double block and bleed valve with electric motorized operator	8	EA	28,500	228,000		
Fuel Branch Lines: 12" dia. Steel pipe, epoxy lining, exterior coated, welded and x-rayed	4,790	LF	420	2,011,800		
Branch line cathodic protection	1	LS	40,000	40,000		
Branch line low point drain pit, 1 per 400 LF	12	EA	30,200	361,645		
Branch line high point vent pit, 1 per 400 LF	12	EA	30,200	361,645		
Branch line isolation valve vault	4	EA	321,000	1,284,000		
Branch line isolation valves, 12" twin seal double block and bleed valve with electric motorized operator	18	EA	21,500	387,000		
Fuel hydrant pit (DABICO), 2 each under each wing at each gate (4 total per gate)	36	EA	69,375	2,497,500		
Electrical power, 480 V, to the valve vaults with MOV DBBs.	4,040	LF	30.00	121,200		
Emergency Fuel Shutoff Button to isolate the DBB Valves closed by signaling the MOV's to close the valves to the branch lines that serve the respective hydrant pit (1 per gate plus 1 for each RON gate	9	EA	15,000	135,000		
Communications duct bank to the valve vaults for fuel detection, fuel/water level and valve position indication, to feed back to the Terminal building and connect to the EFSO system and Fuel Farm controls system	4,240	LF	18.00	76,320		
Testing, flushing and commissioning fuel system in 4 separate phases	1	LS	600,000	600,000		
Initial fuel load, (costs assumed to be by Airlines operating and maintenance budgets)	1	LS	0	0		
FUEL DISTRIBUTION SUBTOTAL					14,728,350	
G 30 *TOTAL - SITE MECHANICAL UTILITIES - TERMINAL B1*						$ 14,728,350

C. a 5

TERMINAL B - UTILITIES ENABLING PROJECT 6: TRITURATOR

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas

TERMINAL B1 - UTILITIES ENABLING PROJECT 6; TRITURATOR

8-17-2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	30		*SITE MECHANICAL UTILITIES - TERMINAL C (formerly B)*						
G	30	3020	**SANITARY SEWER**						
			Remove Environmental Lift Station at North Terminal A	1	LS	200,000	200,000		
			Triturator: Replace existing Environmental Lift Station, located at North A with a new Triturator	1	LS	300,000	300,000		
			SANITARY SEWER SUBTOTAL					500,000	
G	30		*TOTAL - SITE MECHANICAL UTILITIES - TERMINAL B1*						$ 500,000

TERMINAL B - UTILITIES ENABLING PROJECT: ALTERNATE 1: EXTENDED TUNNEL TO TERMINAL A

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Utilities Master Plan Range of Magnitude Costs
Houston, Texas

TERMINAL B1 - UTILITIES ENABLING PROJECT- ADD ALTERNATE 1 ; EXTEND UTILIDOR TUNNEL TO TERM A

8-17-2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 40 SITE ELECTRICAL UTILITES						
G 40 4010 ELECTRICAL DISTRIBUTION						
New Terminals B2, B3 & Renovation of Terminal A, B-Core, C-Core, and FIS						
CONCRETE BOX CULVERT						
Concrete box culvert, 8'x10' with excavation, 3' overburden, lighting, drainage, pipe racks, Etc.	4,222	LF	1,850	7,810,700		
Assume relocation of (100) 8" lines at 30' each	3,000	LF	125.00	375,000		
Crossing of North Terminal Road for UTILIDOR including: permits, traffic barriers, traffic control, flagmen, temporary signage, demolition, excavation, backfill, paving, and stripping at A-Core and B-Core	2	EA	65,000	130,000		
CONCRETE BOX CULVERT SUBTOTAL					8,315,700	
G 40 TOTAL - ADD ALTERNATE 1						*$ 8,315,700*

MLIT - UTILITY ENABLING PROJECTS - SUMMARY

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas
8-17-2014 Update

MLIT PROGRAM UTILITY ENABLING PROJECTS - COST MODEL SUMMARY

COMPONENT DESCRIPTION		UTILIDOR Alternative
UTILITY ENABLING PROJECTS COSTS		
Utility Enabling Project 1; ELECTRICAL		$ 12,667,400
Utility Enabling Project 2; FIRE PROTECTION/DOMESTIC WATER		$ 1,480,700
Utility Enabling Project 3; CHILLED WATER/HEATING WATER		$ 2,752,220
Utility Enabling Project 4; AVIATION FUEL		$ 25,231,766
Utility Enabling Project 5; ENVIRONMENTAL LIFT STATIONS		$ 200,000
Utility Enabling Project 7; SANITARY		$ 948,455
SUBTOTAL - UTILITY ENABLING PROJECTS COST OF WORK		**$ 43,280,541**
Escalation to January 2016	5.0%	$ 2,164,027
SUBTOTAL - UTILITY ENABLING PROJECTS COST OF WORK		**$ 45,444,568**
Architecture/Engineering Fees	8.0%	$ 3,635,565
Program Management Fees	4.0%	$ 1,817,783
CMAR Fees	3.0%	$ 1,363,337
CMAR General Requirements / CMAR Overhead	10.0%	$ 4,544,457
Testing	1.0%	$ 454,446
Inspection	1.5%	$ 681,669
QA/QC Services	1.0%	$ 454,446
Insurance	2.0%	$ 908,891
Bonds	2.0%	$ 908,891
Administrative Fees	1.0%	$ 454,446
Commissioning	1.5%	$ 681,669
Public Art	1.75%	$ 795,280
SUBTOTAL - OWNER'S SOFT COSTS	36.75%	**$ 16,700,879**
Program Contingency (Planning Phase)	20.0%	$ 9,088,914
PROJECTED MLIT PROGRAM UTILITY ENABLING PROJECTS	***Total Cost***	***$ 71,234,360***

MLIT - UTILITIES ENABLING PROJECT 1: ELECTRICAL

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Houston, Texas

UTILITIES ENABLING PROJECT 1; ELECTRICAL - MLIT

8-17-2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	40		*SITE ELECTRICAL UTILITES - MLIT*						
G	40	4010	**ELECTRICAL DISTRIBUTION**						
			Alternative: New dedicated CNP circuits to existing 12.5 kV Central Receiving Station at C-Garage. Part direct buried duct bank with 12 6" PVC conduits from Central Receiving Station at C-Garage across the North Terminal Road. Intercept the new Utility Corridor and run 12 6" PVC conduits to the east to MLIT Substation						
			40 MW, 12.5kV Central Receiving Station at C-Carage. (Constructed in previous project)						
			HAS Switchgear (20 MW)	1	LS	2,000,000	2,000,000		
			12.5kV / 480V sub/transformer	6	EA	700,000	4,200,000		
			Underground Concrete Encased Electrical Ductbank, assume 12 - 6" PVC conduit, w/ conductor	200	LF	1,650	330,000		
			Utility Corridor Electrical Ductbank, assume 12 - 6" exposed Schedule 80 conduits	28,980	LF	50.00	1,449,000		
			ELECTRICAL DISTRIBUTION SUBTOTAL					7,979,000	
G	40		**SITE SECURITY**						
			Critical Facility, with HAS Switchgear room, a 4,000 SF vault below and 2,000 SF of Parking access. (Constructed in previous project)						
			CCTV at Receiving Station (Constructed in previous project)						
			Security lighting at Receiving Station (Constructed in previous project)						
			CMU security wall with access-controlled gate around Receiving Station. (Constructed in previous project)						
			SITE SECURITY SUBTOTAL					-	
			CONCRETE BOX CULVERT						
			Concrete box culvert, 8'x10' with excavation, 3' overburden, lighting, drainage, pipe racks, Etc.	2,364	LF	1,850	4,373,400		
			Assume relocation of (84) 8" lines at 30' each	2,520	LF	125	315,000		
			CONCRETE BOX CULVERT SUBTOTAL					4,688,400	
G	40		***TOTAL - SITE ELECTRICAL UTILITIES - MLIT***						***$ 12,667,400***

C. b 2

MLIT - UTILITIES ENABLING PROJECT 2: FP / DW

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Houston, Texas

UTILITIES ENABLING PROJECT PROJECT 2; FP/DW - MLIT

8-17-2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	30		SITE MECHANICAL UTILITIES - MLIT						
			Alternative: Connect to existing 16" Tee in new Utility Corridor, reduce to 12" welded Schedule 40 Carbon Steel and run east to serve MLIT						
			Alternative: Existing Central Water Storage Sysyem Upgrades. Central FP/DW Water storage and pump house already constructed to new Utility Corridor. Install new pumps.						
G	30	3010	**WATER SUPPLY**						
			FP/DW: 1,500 GPM pumps	1	EA	75,000	75,000		
			FP/DW: 1,500 GPM pumps (infrastructure for future pump)						
			FP/DW: 500 GPM pumps	2	EA	30,000	60,000		
			FP/DW: Water main piping tie, 16" welded Schedule 40 carbon steel in New Utility Corridor	2,970	LF	320	950,400		
			Tap and tee existing 12" water line for new10" water line	1	EA	4,200	4,200		
			Tap and tee existing 16" water line for new 10" water line	1	EA	9,100	9,100		
			Backflow preventor, 10"	4	EA	18,000	72,000		
			Water Meter, 10"	4	EA	10,000	40,000		
			Miscellaneous valves and connections	1	LS	20,000	20,000		
			New pump electrical and controls. (Pump House constructed previously.)	1	LS	100,000	100,000		
			Assume relocation of (40) 8" lines at 30' each	1,200	LF	125	150,000		
			WATER SUPPLY SUBTOTAL					1,480,700	
G	30		TOTAL - SITE MECHANICAL UTILITIES - MLIT						$ 1,480,700

MLIT - UTILITIES ENABLING PROJECT 3: CHILLED WATER / HEATING WATER

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Houston, Texas

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UTILITIES ENABLING PROJECT 3; CHILLED WATER/HEATING WATER - MLIT

8-17-2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES - MLIT						
G 30 3040 HEATING DISTRIBUTION						
Heating distribution lines, tie to existing system:						
MILT Alternative: Intercept Terminal B 8" supply and return lines in Utility Corridor and run east to tie into the lines serving Terminal C to form a loop.						
Heating hot water supply and return lines, 8" Insulated in PIPE RACK Pipe System	2,364	LF	355	839,220		
Tie-in to existing heating hot water piping	2	EA	2,900	5,800		
HEATING DISTRIBUTION SUBTOTAL					845,020	
G 30 3050 COOLING DISTRIBUTION						
Cooling distribution lines, tie to existing system:						
Chilled water supply and return lines, 18" Insulated in PIPE RACK Pipe System	2,364	LF	800	1,891,200		
Tie-in to existing chilled water piping	2	EA	8,000	16,000		
COOLING DISTRIBUTION SUBTOTAL					1,907,200	
G 30 TOTAL - SITE MECHANICAL UTILITIES - MLIT						***$ 2,752,220***

MLIT - UTILITIES ENABLING PROJECT 4: AVIATION FUEL

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Houston, Texas

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UTILITIES ENABLING PROJECT 4; AVIATION FUEL - MLIT

8-17-2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	30		*SITE MECHANICAL UTILITIES - MLIT*						
G	30	3060	**FUEL DISTRIBUTION**						
			Remove existing fuel mains and manifolds, above ground	22,808	LF	25.00	570,200		
			Slurry fill existing fuel branch lines and remain overnight hydrant lines	11,404	LF	16.00	182,464		
			Remove existing isolation valve vault	2	EA	28,000	56,000		
			Remove existing fuel hydrant pit	15	EA	21,000	315,000		
			Fuel Mains: 16" dia. Steel pipe, epoxy lining, exterior coated, welded and x-rayed	12,392	LF	486	6,022,512		
			Main line cathodic protection	1	LS	40,000	40,000		
			Main line low point drain pit, 1 per 400 LF	31	EA	30,200	935,596		
			Main line high point vent pit, 1 per 400 LF	31	EA	30,200	935,596		
			Main line isolation valve vault	2	EA	321,000	642,000		
			Main line isolation valves, 16" twin seal double block and bleed valve with electric motorized operator	4	EA	28,500	114,000		
			Fuel Branch Lines: 12" dia. Steel pipe, epoxy lining, exterior coated, welded and x-rayed	7,298	LF	420	3,065,160		
			Branch line cathodic protection	1	LS	40,000	40,000		
			Branch line low point drain pit, 1 per 400 LF	18	EA	30,200	550,999		
			Branch line high point vent pit, 1 per 400 LF	18	EA	30,200	550,999		
			Branch line isolation valve vault	8	EA	321,000	2,568,000		
			Branch line isolation valves, 12" twin seal double block and bleed valve with electric motorized operator	18	EA	21,500	387,000		
			Fuel hydrant pit (DABICO), 2 each under each wing at each gate (4 total per gate)	100	EA	69,375	6,937,500		
			Electrical power, 480 V, to the valve vaults with MOV DBBs.	7,030	LF	30.00	210,900		
			Emergency Fuel Shutoff Button to isolate the DBB Valves closed by signaling the MOV's to close the valves to the branch lines that serve the respective hydrant pit (1 per gate plus 1 for each RON gate	25	EA	15,000	375,000		
			Communications duct bank to the valve vaults for fuel detection, fuel/water level and valve position indication, to feed back to the Terminal building and connect to the EFSO system and Fuel Farm controls system	7,380	LF	18.00	132,840		
			Testing, flushing and commissioning fuel system in 4 separate phases	1	LS	600,000	600,000		
			Initial fuel load, (costs assumed to be by Airlines operating and maintenance budgets)						
			FUEL DISTRIBUTION SUBTOTAL					25,231,766	
G	30		*TOTAL - SITE MECHANICAL UTILITIES - MLIT*						*$ 25,231,766*

C. b 5

MLIT - UTILITIES ENABLING PROJECT 5: ENVIRONMENTAL LIFT STATION

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Utilities Master Plan Range of Magnitude Costs
Houston, Texas

UTILITIES ENABLING PROJECT 5; ENVIRONMENTAL LIFT STATION at MLIT

8-17-2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES - MLIT						
G 30 3020 ENVIRONMENTAL LIFT STATION						
Demo of existing Environmental Lift Stations	1	LS	50,000	50,000		
New Environmental Lift Stations	1	LS	150,000	150,000		
SANITARY SEWER SUBTOTAL					200,000	
G 30 TOTAL - SITE MECHANICAL UTILITIES - MLIT						$ 200,000

MLIT - UTILITIES ENABLING PROJECT 7: SANITARY SEWER

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Houston, Texas

UTILITIES ENABLING PROJECT 7; SANITARY SEWER at MLIT

8-17-2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES - MLIT						
G 30 3020 **SANITARY SEWER**						
New lift station at end of Terminal D, 400 GPM, with 10,000 Gal. wet well	1	LS	35,000	35,000		
Forced main sewer line, 8"	1,385	LF	35.00	48,475		
Gravity sewer line, 10"	3,540	LF	27.00	95,580		
Sanitary sewer manhole (aircraft rated)	19	EA	9,100	172,900		
Connect to existing FIS lift station	1	LS	25,000	25,000		
Grease interceptors, (2) @ 4,500 gallons each, (9,000 gallons per location) concrete vaults	9	LOC	60,000	540,000		
Stainless steel pipe from Kitchens to interceptor (Included in Building Project)						
Ductile iron pipe from discharge to sanitary	1	LS	31,500	31,500		
SANITARY SEWER SUBTOTAL					948,455	
G 30 TOTAL - SITE MECHANICAL UTILITIES - MLIT						$ 948,455

FUTURE UTILITY PROJECTS - SUMMARY

AH - Bush International Airport
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Houston, Texas
3/17/2014 Update

FAITHFUL GOULD

FUTURE UTILITY PROJECTS - SUMMARY

YSTEM DESCRIPTION

				UTILIDOR ALTERNATIVE
G40	ELECTRICAL DISTRIBUTION		$	22,225,100
G30	FIRE PROTECTION WATER SUPPLY		$	1,654,600
G30	HEATING DISTRIBUTION, COOLING DISTRIBUTION		$	1,679,120
G30	FUEL DISTRIBUTION		$	55,000,000
G30	CENTRAL UTILITY PLANT		$	4,576,000
	SUBTOTAL - UTILITIES COST OF WORK		**$**	**85,134,820**
	Escalation (assume to June 2023)	18.0%	$	15,324,268
	SUBTOTAL - COST OF WORK		**$**	**100,459,088**
	Architecture/Engineering Fees	8.0%	$	8,036,727
	Program Management Fees	4.0%	$	4,018,364
	CMAR Fees	3.0%	$	3,013,773
	CMAR General Requirements / CMAR Overhead	10.0%	$	10,045,909
	Testing	1.0%	$	1,004,591
	Inspection	1.5%	$	1,506,886
	QA/QC Services	1.0%	$	1,004,591
	Insurance	2.0%	$	2,009,182
	Bonds	2.0%	$	2,009,182
	Administrative Fees	1.0%	$	1,004,591
	Commissioning	1.5%	$	1,506,886
	Public Art	1.75%	$	1,758,034
	SUBTOTAL - OWNER'S SOFT COSTS	36.75%	**$**	**36,918,715**
	Program Contingency (Planning Phase)	20.0%	$	20,091,818
PROJECTED PROGRAM FUTURE UTILITY PROJECTS		***COST TOTAL***	***$***	***157,469,620***

C. c 1

FUTURE UTILITY PROJECT 1: ELECTRICAL

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Houston, Texas

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FUTURE UTILITY PROJECT 1; ELECTRICAL

8/17/2014 Update

UTILIDOR ALTERNATIVE

			DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
			SITEWORK						
G	40		*SITE ELECTRICAL UTILITES*						
G	40	4010	**ELECTRICAL DISTRIBUTION**						
			New Terminals B2, B3 & Renovation of Terminal A, B-Core, C-Core, and FIS						
			Assume that 40 MW, 12.5kV Central Receiving Station is already constructed	1	LS	0	0		
			HAS Switchgear (10 MW)	1	LS	2,000,000	2,000,000		
			Term B2, 12.5kV / 480V sub/transformer	3	EA	700,000	2,100,000		
			Term B3, 12.5kV / 480V sub/transformer	3	EA	700,000	2,100,000		
			Term A, 12.5kV / 480V sub/transformer (HAS project 634 replaces the switchgear in A-Core)	N/A		0	0		
			B-Core, 12.5kV / 480V sub/transformer	6	EA	700,000	4,200,000		
			C-Core, 12.5kV / 480V sub/transformer	6	EA	700,000	4,200,000		
			FIS, 12.5kV / 480V sub/transformer	3	EA	700,000	2,100,000		
			Underground Concrete Encased Electrical Ductbank for Terminals B2, B3 & A, assume 12 - 6" PVC conduit, w/ conductor	278	LF	1,650	458,700		
			Conduit in RACK System for Terminals B2, B3 & A, assume 12 - 6" exposed Schedule 80 conduit	50,664	LF	50	2,533,200		
			I.T. and EM Conduit in RACK System for Terminals B2, B3 & A, assume 12 - 6" exposed Schedule 80 conduit	50,664	LF	50	2,533,200		
			ELECTRICAL DISTRIBUTION SUBTOTAL					22,225,100	
G	40		**SITE SECURITY**						
			Assume Crtical Facility is already constructed	1	LS	0	0		
			Assume CMU security wall with access-controlled gate around Receiving Station is already constructed	1	LS	0	0		
			SITE SECURITY SUBTOTAL					-	
			CONCRETE BOX CULVERT						
			(included with Utilities Enabling Add Alternate)						
			~~Concrete box culvert, 8'x10' with excavation, 3' overburden, lighting, drainage, pipe racks, Etc.~~						
			~~Assume relocation of (100) 8" lines at 30' each~~						
			CONCRETE BOX CULVERT SUBTOTAL					-	
G	40		***TOTAL - SITE ELECTRICAL UTILITIES***						***$ 22,225,100***

C. c 2

FUTURE UTILITY PROJECT 2: FP / DW

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Houston, Texas

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FUTURE UTILITY PROJECT 2; FP/DW

8/17/2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES						
Alternative: Tie into Central Water Storage system and extend carbon steel force main in Utility Corridor from Terminal B1 to Terminals B2, B3 & A						
G 30 3010 WATER SUPPLY						
FP/DW: 1,500 GPM pumps	1	EA	75,000	75,000		
FP/DW: 500 GPM pumps	2	EA	30,000	60,000		
FP/DW: Water main piping tie, 16" carbon steelin new Utility Corridor	3,800	LF	320.00	1,216,000		
Tap and tee existing 16" water line for new 16" water line	1	EA	9,100	9,100		
Backflow preventor, 10"	4	EA	18,000	72,000		
Water Meter, 10"	4	EA	10,000	40,000		
Miscellaneous valves and connections	1	LS	45,000	45,000		
New pump electrical and controls. Pump house is already constructed	1	LS	100,000	100,000		
Assume relocation of (10) 8" lines at 30' each	300	LF	125.00	37,500		
WATER SUPPLY SUBTOTAL					1,654,600	
G 30 TOTAL - SITE MECHANICAL UTILITIES						$ 1,654,600

C. c 3

FUTURE UTILITY PROJECT 3: CHILLED WATER / HEATING WATER

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Utilities Master Plan Range of Magnitude Costs
Houston, Texas

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FUTURE UTILITY PROJECT 3; CHILLED WATER/HEATING WATER

8/17/2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES						
G 30 3040 **HEATING DISTRIBUTION**						
Heating distribution lines, tie to existing system:						
Base Case: Direct buried supply & return piping to & from existing Utility Tunnel, across North Terminal Road, to & from Terminal B2						
Heating hot water supply and return lines, 8" dia. direct burry Pre-Insulated Pipe System	250	LF	830	207,500		
Heating hot water supply and return lines, 8" dia. Insulated in PIPE RACK Pipe System, with loop tie-back to Term B1	844	LF	355	299,620		
Tie-in to existing heating hot water piping	2	EA	2,900	5,800		
HEATING DISTRIBUTION SUBTOTAL					512,920	
G 30 3050 **COOLING DISTRIBUTION**						
Cooling distribution lines, tie to existing system:						
Base Case: Direct buried supply & return piping to & from existing Utility Tunnel, across North Terminal Road, to & from Terminal B2						
Chilled water supply and return lines, 18" dia. direct burry Pre-Insulated Pipe System	250	LF	1,900	475,000		
Chilled water supply and return lines, 18" dia. Insulated in PIPE RACK Pipe System with loop tie-back to Term B1	844	LF	800	675,200		
Tie-in to existing chilled water piping	2	EA	8,000	16,000		
COOLING DISTRIBUTION SUBTOTAL					1,166,200	
G 30 TOTAL - SITE MECHANICAL UTILITIES						$ 1,679,120

FUTURE UTILITY PROJECT 4: AVIATION FUEL

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Houston, Texas

FUTURE UTILITY PROJECT 4; AVIATION FUEL

8/17/2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES - TERM. B2, B3, & A						
G 30 3060 FUEL DISTRIBUTION						
Allowance for fuel distribution for Terminals B2, B3, and A	1	LS	55,000,000	55,000,000		
Initial fuel load, (costs assumed to be by Airlines operating and maintenance budgets)	1	LS	0	0		
FUEL DISTRIBUTION SUBTOTAL					55,000,000	
G 30 TOTAL - SITE MECHANICAL UTILITIES						*$ 55,000,000*

FUTURE UTILITY PROJECT 5: CENTRAL UTILITY PLANT

IAH - Bush International Airport
Utilities Master Plan Range of Magnitude Costs
Houston, Texas

FUTURE UTILITY PROJECT 5; CENTRAL UTILITY PLANT

8/17/2014 Update

UTILIDOR ALTERNATIVE

DESCRIPTION	QTY	UNIT	UNIT COST	EST'D COST	SUB TOTAL	TOTAL COST
SITEWORK						
G 30 SITE MECHANICAL UTILITIES -CENTRAL UTILITIES PLANT						
G 30 3090 CENTRAL UTILITIES PLANT						
HAS to replace existing boilers 4 and 5, with new 16,000 MBH heating water generators. (Boilers 4 & 5 to be demolished in 2023, 7 years before the end of their expected service lives).	2	EA	390,000	780,000		
HAS to replace the 3 steam driven chillers (2 ea 3300 Ton units, CH-6 & 8 and 1 ea 1000 Ton unit, CH-1) with new electric drive chillers as follows: 1 ea 3000 Ton, CH-10, 1 ea 1000 Ton, CH-11, and 1 ea 2500 Ton, CH-12. (Steam driven chillers to be demolished in 2023, 2 years before their expected end of service life).						
3000 Ton Trane Duplex CenTraVac - dual compressor machine with Remote Mounted 4,160V Adaptive Frequency Drives	1	EA	1,627,000	1,627,000		
2500 Ton Trane Duplex CenTraVac - dual compressor machine with Remote Mounted 4,160V Adaptive Frequency Drives	1	EA	1,446,000	1,446,000		
1,000 Trane Simplex CenTraVac - Single Compressor machine with Remote Mounted 4160V Adaptive Frequency Drive	1	EA	723,000	723,000		
CENTRAL UTILITIES PLANT SUBTOTAL					4,576,000	
G 30 TOTAL - SITE MECHANICAL UTILITIES						$ 4,576,000

Volume II
Appendix D

Bush Intercontinental Airport (IAH) Report

prepared for HNTB Utility Master Plan
Houston Airport System (HAS) • Houston, TX

September 2014 • Project No. 77831

prepared by Burns & McDonnell Engineering Company, Inc. • Raleigh, NC

TABLE OF CONTENTS

Page No.

LIST OF TABLES

Page No.

LIST OF FIGURES

Page No.

CHAPTER 1 - EXISTING SITE AND EQUIPMENT

CENTRAL PLANT INFRASTRUCTURE

The Central Utility Plant (CUP) was initially constructed in 1965 to serve the Airport facilities. Multiple additions and expansions have occurred since, to represent the current layout, with over 20,000 square feet of space. The CUP building houses chilled water and hot water assets with cooling towers located to the southwest exterior of the building. Chilled water assets consist of both electrically-driven and steam-driven centrifugal chillers. Hot water production assets consist of both hot water boilers and steam boilers coupled with steam to hot water heat exchangers. Hot water boilers currently serve the entirety of the Airport's heating load whereas the steam boilers are used to supply steam driven chillers or, in the case of emergency, hot water converters.

Chilled Water Equipment

The central plant supplies 39°F chilled water to the Airport Terminals. The chilled water system utilizes a variable primary pumping configuration with the chilled water pumps supplying to a common header allowing for operational flexibility. The chilled water equipment is summarized in the tables below.

Table 1-1: Existing Central Plant Chillers

TAG	MANUF.	DRIVE	NOM. CAP. [TONS]	REFRIG.	INST. YEAR	EXPECTED RETIREMENT YEAR	SUPPLY/ RETURN
CH-1	YORK	STEAM	1,000	134A	2001	2026	39°F/54°F
CH-3	TRANE	ELECTRIC	3,000	134A	2012	2037	39°F/54°F
CH-4	TRANE	ELECTRIC	3,000	134A	2012	2037	39°F/54°F
CH-5	TRANE	ELECTRIC	2,500	134A	2012	2037	39°F/54°F
CH-6	YORK	STEAM	3,300	134A	2000	2025	39°F/54°F
CH-7	YORK	ELECTRIC	3,340	134A	2000	2025	39°F/54°F
CH-8	YORK	STEAM	3,300	134A	2000	2025	39°F/54°F
CH-9	YORK	ELECTRIC	3,340	134A	2000	2025	39°F/54°F

*Service life expectancy of 25 years based on ASHRAE 2011 HVAC Applications Table 37.4
** Efficiency not provided

Table 1-2: Existing Central Plant Chilled Water Pumps

TAG	MANUF.	TYPE	HEAD [FT]	FLOW [GPM]	POWER [HP]	INST. YEAR	EXPECTED RETIREMENT YEAR
CHP-1	WORTHINGTON	HORIZONTAL/ SPLIT CASE	250	1,600	200	2012	2032
CHP-2	WORTHINGTON	HORIZONTAL/ SPLIT CASE	250	1,600	200	2012	2032
CHP-3	WORTHINGTON	HORIZONTAL/ SPLIT CASE	250	1,600	200	2012	2032
CHP-5	TACO	VERT/INLINE	250	4,800	450	2013	2033
CHP-6	TACO	VERT/INLINE	250	4,800	450	2013	2033
CHP-8	AURORA	HORIZONTAL/ SPLIT CASE		2,500	200	2012	2032
CHP-9	AURORA	HORIZONTAL/ SPLIT CASE		2,500	200	2012	2032
CHP-10	AURORA	HORIZONTAL/ SPLIT CASE		5,344	350	2012	2032
CHP-11	AURORA	HORIZONTAL/ SPLIT CASE		5,344	350	2012	2032
CHP-12	AURORA	HORIZONTAL/ SPLIT CASE		5,344	350	2012	2032
CHP-13	AURORA	HORIZONTAL/ SPLIT CASE		5,344	350	2012	2032
CHP-14	AURORA	HORIZONTAL/ SPLIT CASE		5,344	350	2012	2032

*Service life expectancy of 20 years based on ASHRAE 2011 HVAC Applications Table 37.4
** Head not provided

Hot Water Equipment

The central plant supplies 185°F -200°F high temperature hot water (HTHW) to the Airport Terminals. Previously, Boilers 4 and 5 were responsible for providing steam to Hot Water Converters (HWCs) which subsequently served the hot water load. These HWCs were designed for higher hot water supply temperature of 300°F. HWCs 1 through 4 were removed in May of 2013 according to O&M reports while HWCs 5 through 7 provided the heating load demanded by the Terminals. Additional O&M reports show that in December of 2013 these remaining HWCs were taken offline until Boilers 4 and 5 could be retrofitted with new burners. Boilers 6 through 10, which are designed for 240°F hot water, were brought online during this time to provide the entirety of the heating load which they currently serve. Though Boilers 4 and 5 are back online and capable of producing hot water through HWCs 5 through 7; Boilers 4 and 5 are primarily used to serve steam-driven Chillers 1, 6, and 8 and are used only for emergency backup to serve the Terminal heating load. This being said, the report does not include the thermal capacity of Boilers 4 and 5 and the HWCs for capacity planning of boilers and hot water pumps. The hot water equipment is summarized by the tables below.

Table 1-3: Existing Central Plant Boilers

TAG	MANUF.	TYPE	OUTPUT	FUEL	CAPACITY (MMBTU/HR)	INST. YEAR	EXPECTED RETIREMENT YEAR
BLR-4	NEBRASKA	STEAM	230 PSIG @ 600F	NAT. GAS	56	2000	2030
BLR-5	NEBRASKA	STEAM	230 PSIG @ 600F	NAT. GAS	56	2000	2030
BLR-6	UNILUX	HOT WATER	330 PSIG @ 240F	NAT. GAS	14	2012	2034
BLR-7	UNILUX	HOT WATER	330 PSIG @ 240F	NAT. GAS	14	2012	2034
BLR-8	UNILUX	HOT WATER	330 PSIG @ 240F	NAT. GAS	14	2012	2034
BLR-9	UNILUX	HOT WATER	330 PSIG @ 240F	NAT. GAS	14	2012	2034
BLR-10	UNILUX	HOT WATER	330 PSIG @ 240F	NAT. GAS	14	2012	2034

*Boiler 4 and Boiler 5 burners replaced in 2014

*Service life expectancy of 22 years based on ASHRAE 2011 HVAC Applications Table 37.4

Table 1-4: Existing Central Plant Hot Water Pumps

TAG	MANUF.	TYPE	HEAD [FT]	FLOW [GPM]	POWER [HP]	INST. YEAR	EXPECTED RETIREMENT YEAR
HWP-1	WORTHINGTON	HORIZONTAL/SPLIT CASE	300	700	100	2012	2032
HWP-2	WORTHINGTON	HORIZONTAL/SPLIT CASE	300	700	100	2012	2032
HWP-3	WORTHINGTON	HORIZONTAL/SPLIT CASE	300	700	100	2012	2032
HWP-4	WORTHINGTON	HORIZONTAL/SPLIT CASE	300	700	100	2012	2032
HWP-5	WORTHINGTON	HORIZONTAL/SPLIT CASE	300	700	100	2012	2032
HWP-6	WORTHINGTON	HORIZONTAL/SPLIT CASE	300	700	100	2012	2032
HWP-7	WORTHINGTON	HORIZONTAL/SPLIT CASE	300	700	100	2012	2032

*Service life expectancy of 20 years based on ASHRAE 2011 HVAC Applications Table 37.4

DISTRIBUTION SYSTEM

Hot Water and Chilled Water is distributed from the Central Utility Plant (CUP) to the Airport Terminals to Terminal booster pumps for the chilled water system and to heat exchangers providing secondary Terminal-side hot water loops for the hot water system. The individual systems are discussed below.

Chilled Water System

Chilled water enters the Airport interior utility corridor at the Terminal B mechanical room via a 14" and 20" line in the southeast corner of the Terminal B Core Building as well as at Valve Box 190, located to the west of Terminal C, via a 36" aboveground line. From the Terminal B mechanical room, an 18" line routes to the west to serve Terminal A; while, a 20" line extends to the east to serve Terminals C-E within the ITT tunnel. Secondary booster pumps, located in the Terminal pump rooms, provide the additional pressure to supply the individual Terminals with chilled water.

Hot Water System

Hot water enters the Airport at the Terminal B mechanical room in the southeast corner of the Terminal B Core Building. This piping extends from the CUP to the mechanical room in an underground tunnel, entering as two 12" mains. From this mechanical room one 8" main routes to the west to serve Terminal

A; while one 14” line routes to the east to serve Terminals C-E within the ITT tunnel. Hot water mains supply heat exchangers; in the Terminals, decoupling the primary hot water loop from the Terminal side hot water distribution system.

CHAPTER 2 - LOAD ANALYSIS

Utilizing information provided by the Airport and future space allocation discussed above, the following sections provide details on existing loads and future load projections. Loads are designated by the following groupings:

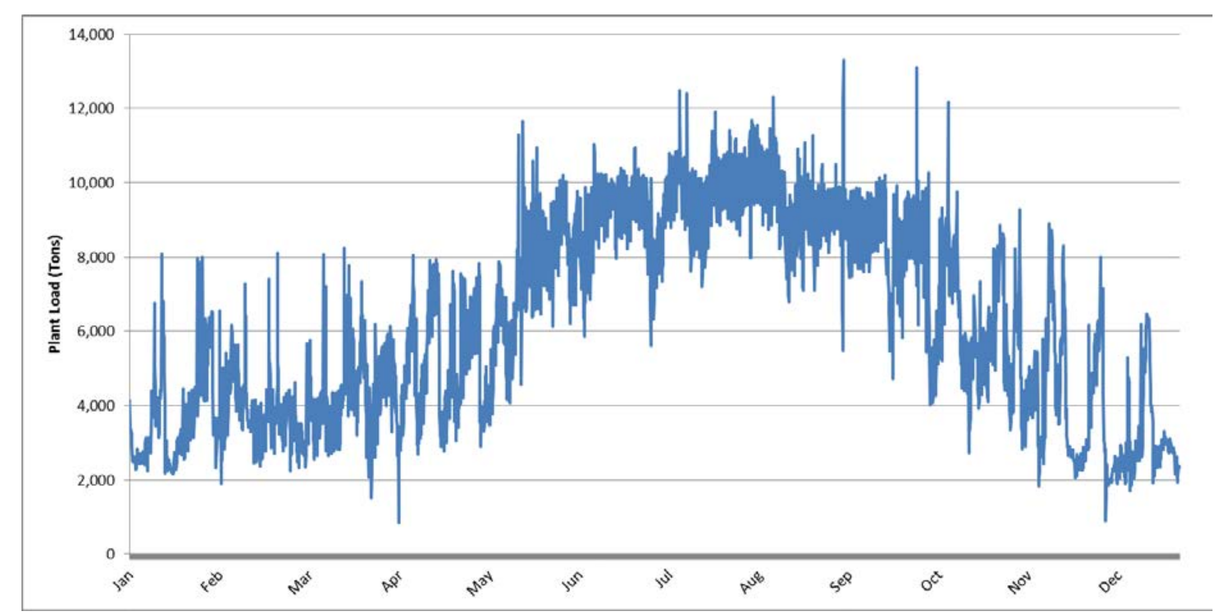
- Existing – Loads based on current operations data
- Short Term – Terminal B1 estimated construction in 2015
- Base Case – Terminal D1 and Terminal D2 estimated construction in 2020
- Long Term – Terminal B2, Terminal B3, New FIS Building, Terminal D3 estimated construction between 2023 and 2030

CHILLED WATER

Existing

The Central Utility Plant existing chilled water profile was used to construct existing and future individual Terminal load profiles. It was assembled from Airport-supplied O&M reports and is shown below:

Figure 2-1: Central Plant Chilled Water Load Profile



Existing Terminal square footages were obtained from the Leigh Fisher Assessment of Existing Conditions report. Utilizing the Central Utility Plant chilled water profile; the existing Terminal loads were developed based on square footage to estimate Terminal-side peak loads.

Future

Based on information from USA SHELCO, a Terminal-side assumption of 230 square feet/ton was applied to future construction areas estimated by HNTB. All loads below assume a rebuild option is chosen. The difference in loads between the rebuild and renovate options are minor and the rebuild option is the most conservative. These future chilled water peak loads are assembled with the existing chilled water loads in the table below:

Table 2-1: Cooling Loads

	Cooling (Tons)				
	Terminal Side		Plant Side		
	Existing	Future	Existing	Future	Phase
A PIER (NORTH)	833		708		EXISTING
A PIER (SOUTH)	726		617		EXISTING
A PIER (CENTRAL)	1,267		1,077		EXISTING
B PIER (WEST)		1,522		1,293	LONG TERM
B PIER (MIDDLE)		1,522		1,293	LONG TERM
B PIER (EAST)		1,522		1,293	SHORT TERM
B PIER (NORTH)	352		299		EXISTING
B PIER (CENTRAL)	1,053		895		EXISTING
EXPANSION		333		283	LONG TERM
CENTRAL PROC		1,266		1,076	BASE CASE
D PIER #1	792	767	673	652	BASE CASE
C PIER (SOUTH)	1,155		981		EXISTING
C PIER (CENTRAL)	1,897		1,613		EXISTING
B/C CONNECTOR		290		246	BASE CASE
D PIER #2 & #3 CONNECTOR		150		128	LONG TERM
D PIER #2	1,823	1,169	1,550	993	BASE CASE
D PIER #3		1,169		993	LONG TERM
E	2,603		2,212		EXISTING
FIS (EXISTING)	3,137	130	2,666	111	EXISTING
FIS		1,361		1,157	LONG TERM

*Assumed 85% diversity factor applied to Plant peak loads to yield individual Terminal peak loads

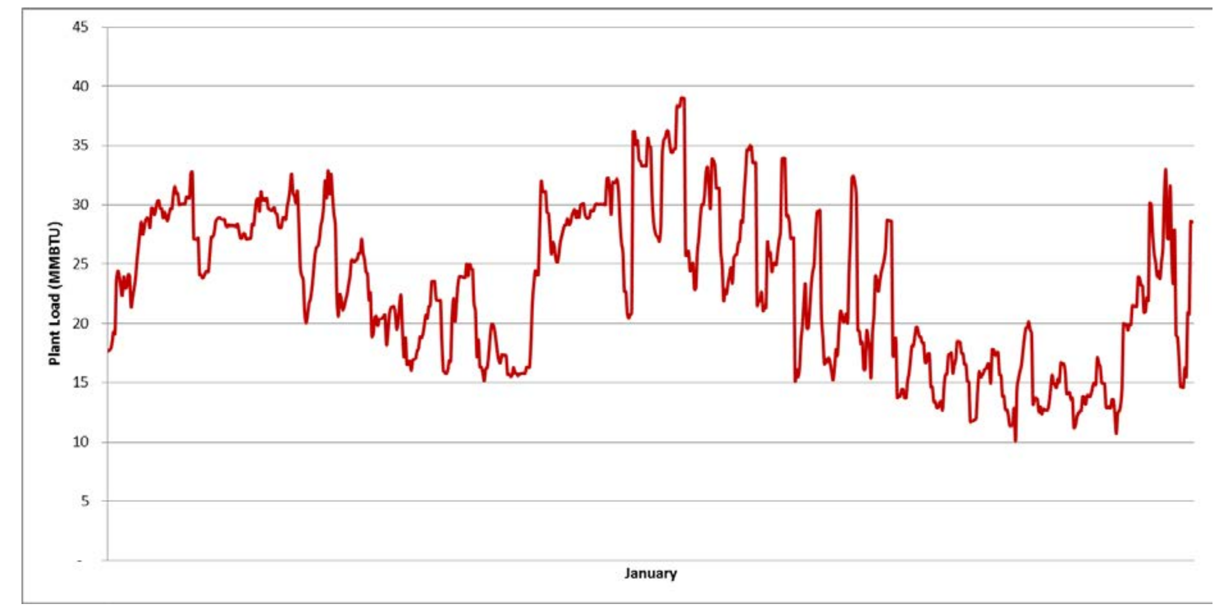
The existing Central Utility Plant chilled water profile was normalized about its maximum and the Terminal peaks were applied to this normalized profile to produce individual Terminal load profiles.

HOT WATER

Existing

Comfort Systems USA provided hourly boiler logs for January 2013 as well as a single day's hourly data recorded for each remaining month. The January profile is shown below:

Figure 2-2 Central Plant Hot Water Load - January



From these boiler logs it was assumed that Central Plant hot water loads peaks in January. This load data and the existing Terminal square footages from the Leigh Fisher Assessment of Existing Conditions report were correlated to yield a BTU/square foot metric for existing Terminals in a fashion similar to the chilled water load analysis.

Future

Based on information from USA SHELCO, a Terminal-side assumption of 25 BTU/square foot was applied to future construction areas estimated by HNTB. All loads below assume a rebuild option is chosen. The difference in loads between the rebuild and renovate options are minor and the rebuild option is the most conservative. These future hot water peak loads are assembled with the existing hot water loads in the table below:

Table 2-2: Heating Loads

	Heating (MMBTU)				
	Terminal Side		Plant Side		
	Existing	Future	Existing	Future	Phase
A PIER (NORTH)	2.445		2.078		EXISTING
A PIER (SOUTH)	2.132		1.812		EXISTING
A PIER (CENTRAL)	3.719		3.161		EXISTING
B PIER (WEST)		8.750		7.438	LONG TERM
B PIER (MIDDLE)		8.750		7.438	LONG TERM
B PIER (EAST)		8.750		7.438	SHORT TERM
B PIER (NORTH)	1.032		0.877		EXISTING
B PIER (CENTRAL)	3.091		2.627		EXISTING
EXPANSION		1.913		1.626	LONG TERM
CENTRAL PROC		7.281		6.189	BASE CASE
D PIER #1	2.325	4.412	1.976	3.750	BASE CASE
C PIER (SOUTH)	3.389		2.881		EXISTING
C PIER (CENTRAL)	5.569		4.734		EXISTING
B/C CONNECTOR		1.666		1.416	BASE CASE
D PIER #2 & #3 CONNECTOR		0.863		0.733	LONG TERM
D PIER #2	5.352	6.720	4.550	5.712	BASE CASE
D PIER #3		6.720		5.712	LONG TERM
E	7.641		6.494		EXISTING
FIS (EXISTING)	9.208	0.750	7.827	0.638	EXISTING
FIS		7.825		6.651	LONG TERM

*Assumed 85% diversity factor applied to Plant peak loads to yield individual Terminal peak loads

CONSTRUCTION PHASING PLANS

Heating and Cooling Loads tables above represent the rebuild case. HNTB, however, provided rebuild and renovate option square footage estimates for the Base Case phase. The table below summarizes both Rebuild and Renovate loads by construction phase:

1) Existing, 2014
2) Short Term, 2016 (Terminal B1 - East)
3) Base Case, 2020 (Terminal D1, Central Processor and Terminal D2)
4) Long Term 1, 2023 (Terminal B2)
5) Long Term 2, 2025 (Terminal B3)
6) Long Term 3, 2030 (Terminal D3)

7) Long Term 3 with Satellite Plant, 2030

Table 2-3: Central Plant Load Breakdown by Construction Phase

		Rebuild		Renovate	
Phase	Year	MMBTU	Tons	MMBTU	Tons
Existing	2014	39.018	13,292	39.018	13,292
Short Term	2016	45.578	14,287	45.578	14,287
Base Case	2020	56.757	15,143	56.306	15,064
Long Term	2023	72.471	17,875	72.021	17,797
Long	2025	79.909	19,169	79.458	19,091
Long	2030	86.354	20,290	85.903	20,211

The Base Case phase introduces the load differential observed between rebuild and renovate options and, therefore, this load differential carries through the remaining Long Term phases. The rebuild option loads are greater than those in the renovate option. Accordingly, these loads were considered in the capacity planning analysis. Construction of the B/C Connector is assumed to take place in the Base phase instead of the Short Term phase so as to not extend toward an unbuilt Terminal C without functionality.

CHAPTER 3 - SYSTEM ANALYSIS

As the Airport expands, the CUP capacity will need to increase to match the future heating and cooling loads. In analyzing this future growth and development of IAH, the following three options were considered.

- **Base Case -** Remove the existing steam boilers, Boiler 4 and Boiler 5 in 2023 in advance of the end of their service life, in the boiler room at the existing CUP to utilize the space for future hot water boilers.

- **Alternate 1** – Plant Expansion – Provide additional space at the existing CUP to accommodate future plant growth.

- **Alternate 2** - Satellite Plant – Provide additional space at a remote location relative to the existing CUP.

Only results for the Base Case are shown for the capacity analysis. The hydraulic model is primarily focused on the Base Case. However, a full build out satellite plant option has been provided to demonstrate the hydraulic benefits over the Base Case and Alternate 1. The Base Case and Alternate 1 are considered to be hydraulically identical. Annual cost estimates are included for all cases.

CENTRAL PLANT CAPACITY ANALYSIS

Currently, assets of the Central Utilities Plant provide enough firm capacity to be able to maintain N+1 redundancy for both chilled and hot water in support of Terminal B Pier B1, and MLIT D1 and D2 facilities. In order to maintain this level of redundancy, the total installed capacity must be great enough to meet the peak load demands if the largest piece of production equipment is out of service (N+1 redundancy). The plant will not have adequate firm capacity throughout the entire 30 year analysis, requiring additional capacity to be installed for any load expansion beyond new facilities B1, D1 and D2. The capacity planning provided herein assumes that no additional plant space is required outside of the existing Central Plant. In this case, Boilers 4 and 5 are demolished in 2023, 7 years before the end of their expected service lives. As discussed below, operating the steam boilers solely to produce chilled water is inefficient compared to electrical driven units and utilizing existing plant space provides the lowest capital cost option. Without steam capacity, all steam driven chillers are likewise demolished in 2023, two years before their expected end of service life. Due to the size of the steam driven chillers and their surface condensers, it is assumed that electric chillers of equal or less capacity as well as one 2,500T

electric chiller can be installed in their place. Additionally, this case assumes that two 16,000 MBH hot water boilers are installed in place of the steam boilers to serve future loads.

Chilled Water

As seen in Figure 3-1, in order for the Airport to maintain N+1 redundancy for chilled water production at the Long Term phase, an additional 2,500T chiller must be installed. The analysis assumes a maximum size chiller of 3000 tons for replacement. Utilizing this strategy, the replacement chillers will match the recently installed Trane chillers in Project 621 and will provide greater efficiency than the existing York OM chillers.

Figure 3-1: Chiller Capacity Roadmap, Graphical

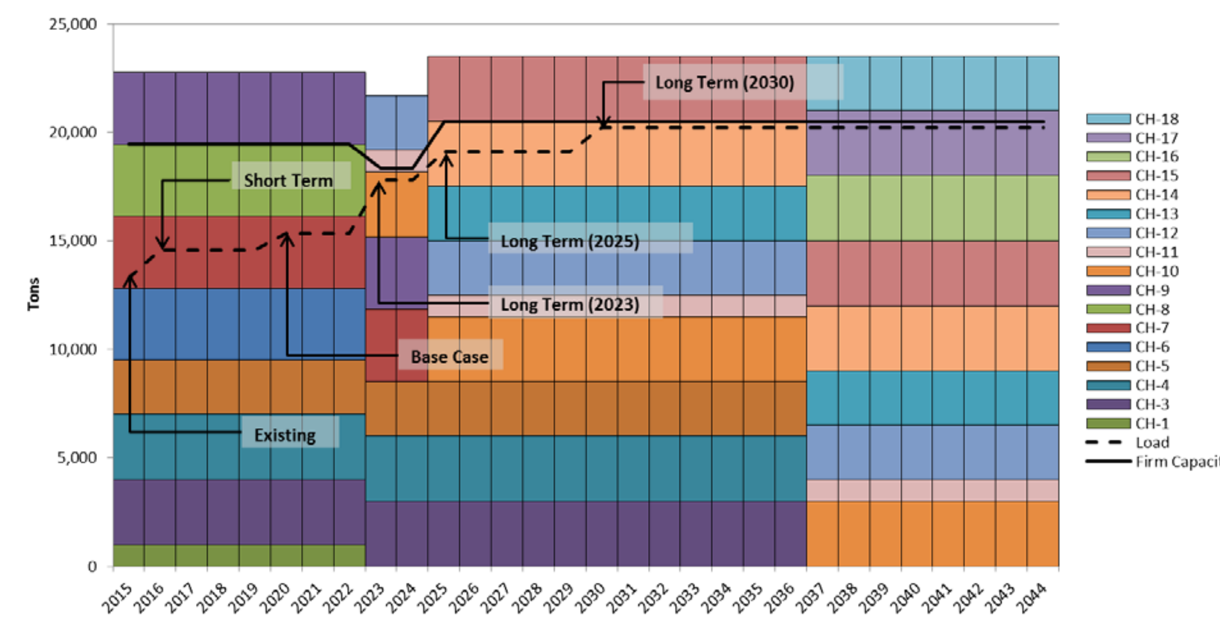


Table 3-1: Chiller Capacity Roadmap, Tabulated

	Capacity (Tons)	Install Date	Life Expectancy	Retire Date
Chiller #1 (Steam)	1,000	2001	25	2023
Chiller #3 (Elec)	3,000	2012	25	2037
Chiller #4 (Elec)	3,000	2012	25	2037
Chiller #5 (Elec)	2,500	2012	25	2037
Chiller #6 (Steam)	3,300	2000	25	2023
Chiller #7 (Elec)	3,340	2000	25	2035
Chiller #8 (Steam)	3,300	2000	25	2023
Chiller #9 (Elec)	3,340	2000	25	2014
Chiller #10	3000	2023	25	2045
Chiller #11	1000	2023	25	2045
Chiller #12	2500	2023	25	2045
Chiller #13	2500	2025	25	2048
Chiller #14	3000	2025	25	2055
Chiller #15	3000	2025	25	2060
Chiller #16	3000	2037	25	2062
Chiller #17	3000	2037	25	2062
Chiller #18	2500	2037	25	2062

Currently, the Central Utility Plant is designed for supplying the Airport with 39°F chilled to be returned at 54°F. Therefore, analysis presented in this report assumes a 15°F temperature differential but a pump capacity review utilizing a 10°F differential is also provided. Year 2013 O&M summertime chilled water logs show operating supply/return temperature differentials between these two values. In the assumed 15°F temperature differential case, it can be seen from the figure below that the Central Utility Plant currently has enough capacity to provide for increased loads through the progression of the project phases. However, as shown in the figure below, a lessened supply/return temperature differential strongly affects the redundancy of the chilled water pumping capacity, and therefore any systemic changes made to affect this differential should be done so with regard to the pumping capacity.

Figure 3-2: Chilled Water Pump Capacity Roadmap, Graphical

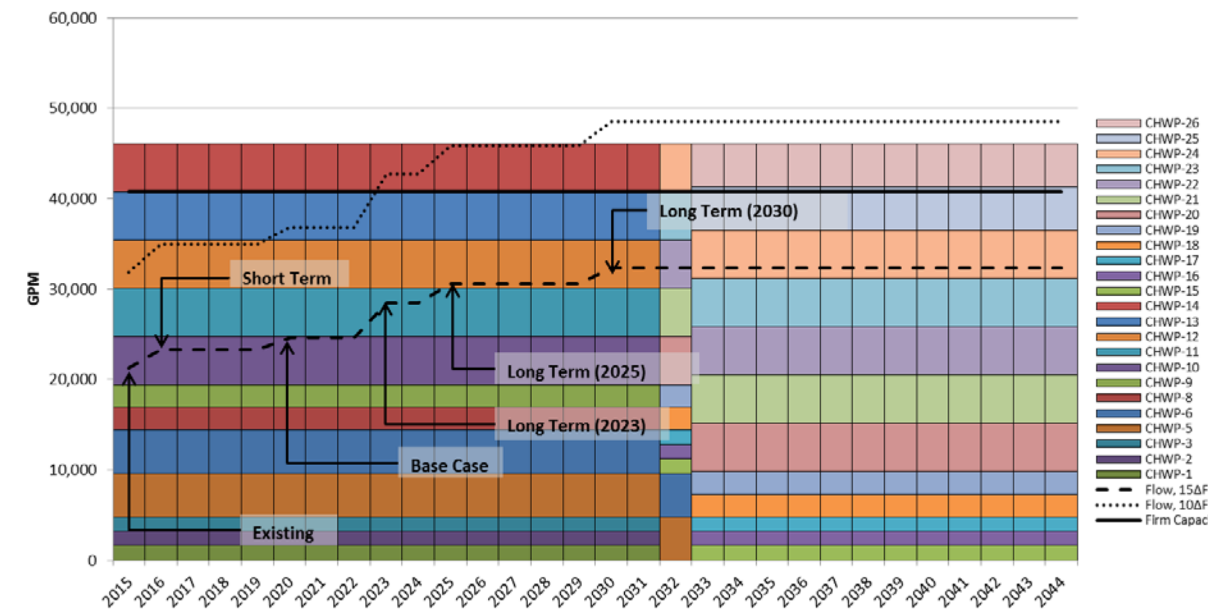


Table 3-2 Chilled Water Pump Capacity Roadmap, Tabulated

	Capacity (GPM)	Install Date	Life Expectancy	Retire Date
Chilled Water Pump #1	1,600	2012	20	2032
Chilled Water Pump #2	1,600	2012	20	2032
Chilled Water Pump #3	1,600	2012	20	2032
Chilled Water Pump #5	4,800	2013	20	2033
Chilled Water Pump #6	4,800	2013	20	2033
Chilled Water Pump #8	2,500	2012	20	2032
Chilled Water Pump #9	2,500	2012	20	2032
Chilled Water Pump #10	5,344	2012	20	2032
Chilled Water Pump #11	5,344	2012	20	2032
Chilled Water Pump #12	5,344	2012	20	2032
Chilled Water Pump #13	5,344	2012	20	2032
Chilled Water Pump #14	5,344	2012	20	2032
Chilled Water Pump #15	1,600	2032	20	2052
Chilled Water Pump #16	1,600	2032	20	2052
Chilled Water Pump #17	1,600	2032	20	2052
Chilled Water Pump #18	2,500	2032	20	2052
Chilled Water Pump #19	2,500	2032	20	2052
Chilled Water Pump #20	5,344	2032	20	2052
Chilled Water Pump #21	5,344	2032	20	2052
Chilled Water Pump #22	5,344	2032	20	2052
Chilled Water Pump #23	5,344	2032	20	2052
Chilled Water Pump #24	5,344	2032	20	2052
Chilled Water Pump #25	4,800	2033	20	2053
Chilled Water Pump #26	4,800	2033	20	2053

Based on ASHRAE service life expectancy of 22 years, Cooling Towers 1, 3 and 4 are recommended for replacement in 2022. As captured by in the figure below, no additional cooling tower capacity, beyond replacement of equal size towers, is required in the Base Case option. Firm capacity stated below is per cooling tower cell.

Figure 3-3: Cooling Tower Capacity Roadmap, Graphical

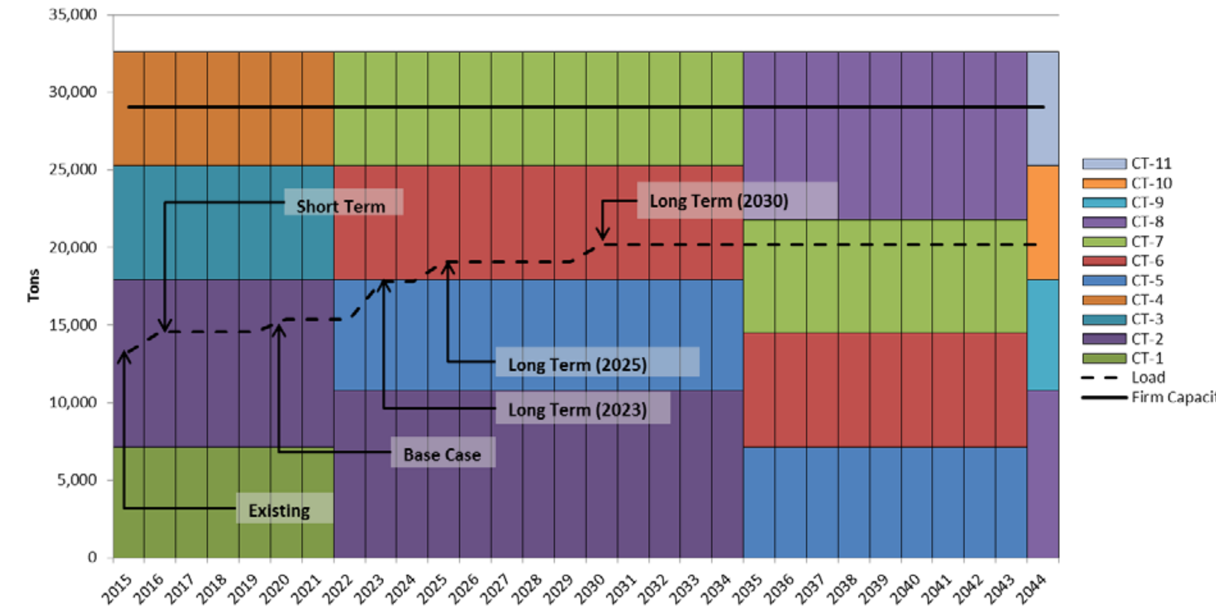


Table 3-3: Cooling Tower Capacity Roadmap, Tabulated

	Capacity (Tons)	Install Date	Life Expectancy	Retire Date
Cooling Tower #1	7,109	2000	22	2022
Cooling Tower #2	10,800	2013	22	2035
Cooling Tower #3	7,347	2000	22	2022
Cooling Tower #4	7,347	2000	22	2022
Cooling Tower #5	7,109	2022	22	2044
Cooling Tower #6	7,347	2022	22	2044
Cooling Tower #7	7,347	2022	22	2044
Cooling Tower #8	10,800	2035	22	2057
Cooling Tower #9	7,109	2044	22	2066
Cooling Tower #10	7,347	2044	22	2066
Cooling Tower #11	7,347	2044	22	2066

Hot Water

As seen in the figure and table below, in order for the Airport to maintain N+1 redundancy for hot water production at the Long Term (2023) phase, additional boiler capacity must be installed.

Figure 3-4: Boiler Capacity Roadmap, Graphical

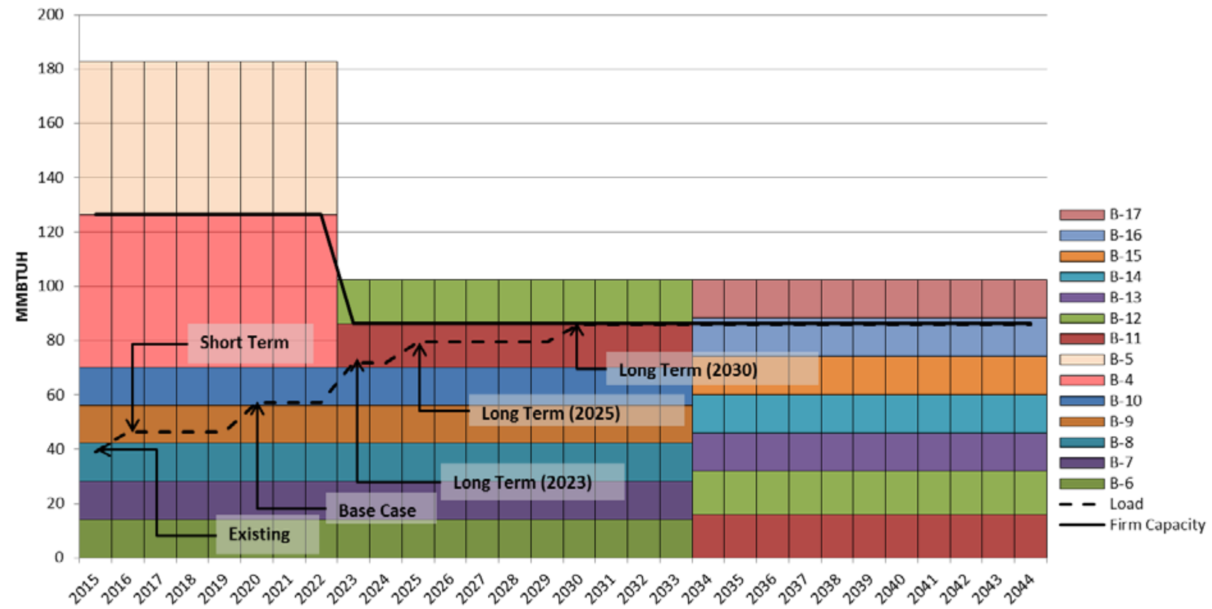


Table 3-4: Boiler Capacity Roadmap, Tabulated

	Capacity (BTU)	Install Date	Life Expectancy	Retire Date
Boiler #4	56,191,000	2000	30	2023*
Boiler #5	56,191,000	2000	30	2023*
Boiler #6	14,050,000	2012	22	2034
Boiler #7	14,050,000	2012	22	2034
Boiler #8	14,050,000	2012	22	2034
Boiler #9	14,050,000	2012	22	2034
Boiler #10	14,050,000	2012	22	2034
Boiler #11	16,000,000	2022	22	2044
Boiler #12	16,000,000	2022	22	2044
Boiler #13	14,050,000	2034	22	2056
Boiler #14	14,050,000	2034	22	2056
Boiler #15	14,050,000	2034	22	2056
Boiler #16	14,050,000	2034	22	2056
Boiler #17	14,050,000	2034	22	2056

*Retired early based on Base Case scenario.

Hot Water Pumps 5-7 are currently utilized with the HWCs and can be reused once the steam boilers are removed. The Central Plant has adequate pumping capacity throughout the life of this analysis with replacement of pumps only being required due to age. The graph below provides both flow demands based on a 45°F and 60°F temperature differential. The boilers are design at the higher differential temperature. The plant currently operates at 45°F differential temperature. Although capacity is not an

issue throughout the life of this analysis, fewer pumps would need to be replaced if the plant utilized the higher differential during peak loads. However, this would also require the plant to generate water hotter than is currently generated and is not in line with the goals of the Airport to distribute a lower temperature hot water.

Figure 3-5: Hot Water Pump Capacity Roadmap, Graphical

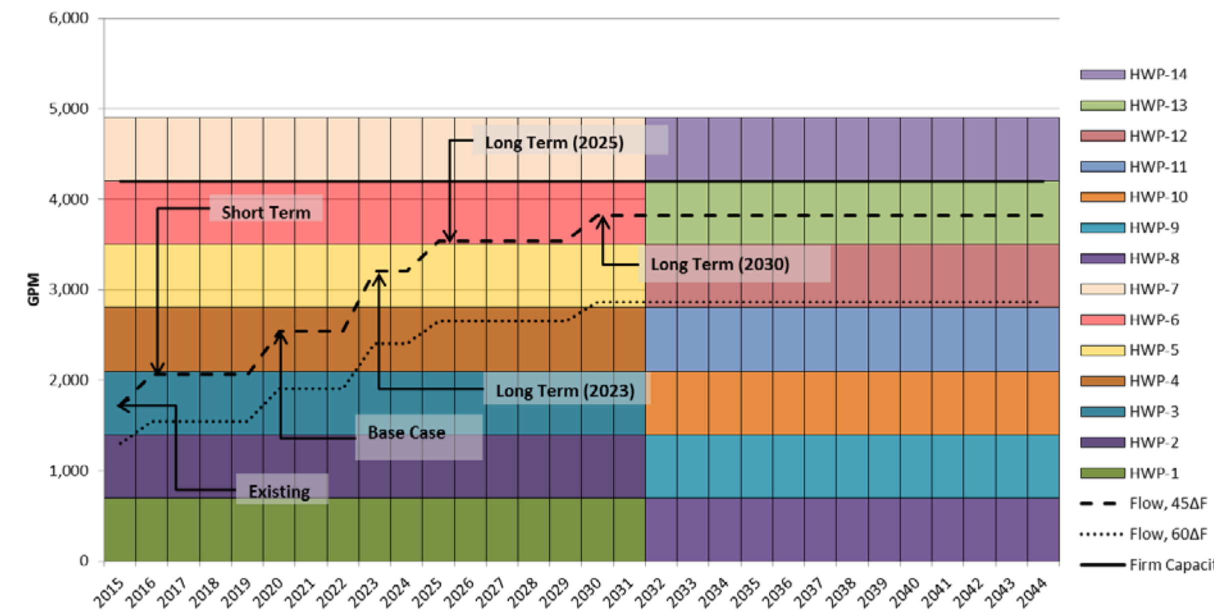


Figure 3-6: Hot Water Pump Capacity Roadmap, Tabulated

	Capacity (GPM)	Install Date	Life Expectancy	Retire Date
Hot Water Pump #1	700	2012	20	2032
Hot Water Pump #2	700	2012	20	2032
Hot Water Pump #3	700	2012	20	2032
Hot Water Pump #4	700	2012	20	2032
Hot Water Pump #5	700	2012	20	2032
Hot Water Pump #6	700	2012	20	2032
Hot Water Pump #7	700	2012	20	2032
Hot Water Pump #8	700	2032	20	2052
Hot Water Pump #9	700	2032	20	2052
Hot Water Pump #10	700	2032	20	2052
Hot Water Pump #11	700	2032	20	2052
Hot Water Pump #12	700	2032	20	2052
Hot Water Pump #13	700	2032	20	2052
Hot Water Pump #14	700	2032	20	2052

DISTRIBUTION SYSTEM ANALYSIS

The existing distribution system at IAH was originally installed in 1965 with several modifications and expansions occurring as recently as 2013. The system ranges in age from approximately 1- 50 years old. Visual inspections of the system revealed several instances of removed or deteriorating insulation and some external corrosion on pipe (Refer to Condition Assessment Section for additional details). However, the overall condition of the piping system and the remaining service life of the piping system is dependent on use, system maintenance and water treatment. The best way to effectively evaluate this without major disruptions to the system is through non-destructive examination (NDE). The figure below provides details on the anticipated service life remaining of the piping system based on an assumed 50 year service life. This assumption is only used as a benchmark for comparison and a non-destructive test should be completed to more accurately assess the remaining service life of the piping systems.

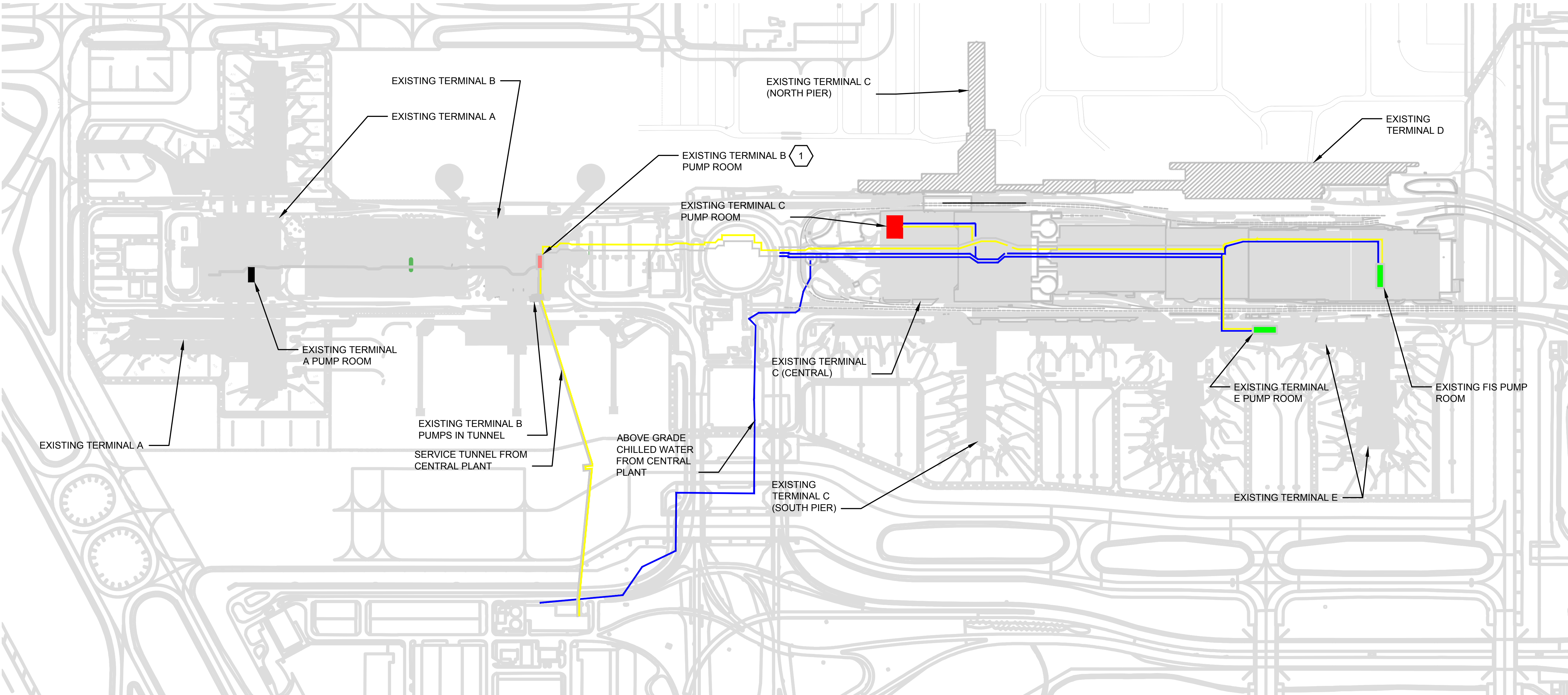
NOTES:

1. TOTAL EXPECTED SERVICE LIFE OF DISTRIBUTION PIPING IS ESTIMATED TO BE 50 YEARS FROM INSTALL DATE. ACTUAL CONDITION OF PIPING WILL BE BASED ON RESULTS OF NON-DESTRUCTIVE TESTING.

2. PIPING SHOWN IS A GENERAL REPRESENTATION OF MAJOR PIPES AND HEADERS AND DOES NOT INDICATE MINOR PIPING REPLACEMENTS AND RENOVATIONS.

KEYED NOTES:

(1) REMAINING AGE OF CHILLED WATER EQUIPMENT SHOWN. SEE PROJECT 621 FOR HOT WATER HEAT EXCHANGER AND PUMP REPLACEMENTS.



CHW: REMAINING PIPING AGE	HW: REMAINING PIPING AGE	MECH ROOMS: REMAINING AGE
>15 YEARS	>15 YEARS	>15 YEARS
10-15 YEARS	10-15 YEARS	10-15 YEARS
UNKNOWN	UNKNOWN	5-9 YEARS
		<5 YEARS

N

DISTRIBUTION PIPING
SERVICE LIFE

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Non-Destructive Evaluation (NDE) Scope of Work

The following section provides guidance for establishing a non-destructive evaluation for existing distribution piping. The NDE should serve as an asset replacement plan to be used in parallel with all future capacity planning.

Systems that operate above 200°F and below 400°F and that contain liquid or two-phase fluids, should be inspected for indications of flow accelerated corrosion (FAC) on a regular basis. This basis is defined by initial baseline thickness readings and follow-up inspections no greater than four (4) years apart. More frequent inspections should be performed as wall thickness readings provide an estimate on loss rate in mils/year.

Thickness readings should be taken utilizing ultrasonic thickness (UT) inspection techniques. To perform this inspection, the insulation on the component should be removed and all paint, rust, scale, and debris removed down to bare metal. A grid is applied to the component following either the contractor supplied and Owner approved inspection grid or the Electric Power Research Institute (EPRI) inspection guidelines. A good rule of thumb is that any piping under 4” NPS should be inspected on a 1” grid minimum. Piping 4” to 10” NPS should have a minimum 2” grid and anything over 10” NPS have 3” minimum grid spacing. Readings are taken at the intersection points of these grids. Grids should be labelled with letters (A, B, C, etc) around the circumference (columns) and along the flow path (rows) numbered (1, 2, 3, etc). Each component in a system should get a letter, number, or combination designation. Photographs of the grid prior to inspection should be taken from multiple angles for documentation purposes, and to recreate the grid should it be worn away.

Areas of inspection should be centered first on those components subjected to two-phase flow. These are typically drains off of heaters, vessels, drip legs, or extraction steam lines. Primary focus should be at geometry changes (elbows), restrictions (reducers, orifices, etc), or valve stations. At a minimum the component and two (2) to three (3) pipe diameters should be inspected downstream from the end of the component. Single phase areas should be focused on the highest velocity areas, then followed by temperature, and then reviewing geometry changes, restrictions, and valve stations.

The inspection agency should be calibrating their equipment frequently and as-built piping specifications should be provided prior to the start of inspection to develop test plans. Test readings should be accurate within 0.001”. Readings should be compared against as-built nominal wall thickness. Areas that are found within mill tolerances, 112.5% to 87.5%, are presumed to have no damage but should be planned for future inspection. Areas that have between 87.5% and 70% of nominal wall thickness should be planned

for inspection within one (1) calendar year to develop baseline wall loss rates. Areas that are less than 70% nominal wall thickness should be reviewed by for replacement. ASME minimum wall thickness calculations should be performed for all components inspected to determine remaining wall thickness to failure.

ASME B31.1, B31.3, and B31G provide guidance on establishing an Owner developed inspection program. Note that piping alone is not the only concern. Pressure vessels should be inspected on a regular basis. For boiler systems, even hot water boilers, the two-phase interface where steam and water interact are prone to two-phase FAC attack and should be considered for inspection every two (2) years. This can be extended if regular inspection proves that damage is not present, or not progressing. As the steam system is decommissioned, the most vulnerable aspects of the system are being removed which should help to extend the system’s effective life. Testing scope of work should include both new and old piping. Results of both sections should be compared to evaluate the existing value in the water treatment program.

HYDRUALIC DISTRIBUTION ANALYSIS

The IAH hot water and chilled water systems were modeled and analyzed using Pipe Flow Expert software. The chilled water and hot water systems were each modeled in several scenarios to capture the increasing load and capacity of the Airport from a representation of the existing system to a full future build out over 16 years. The following load scenarios were developed for both hot water and chilled water flow models:

8) Existing, 2014– Model Baseline
9) Short Term, 2016 (Terminal B1 - East)
10) Base Case, 2020 (Terminal D1, Central Processor and Terminal D2)
11) Long Term 1, 2023 (Terminal B2)
12) Long Term 2, 2025 (Terminal B3)
13) Long Term 3, 2030 (Terminal D3)
14) Long Term 3 with Satellite Plant, 2030

Assumptions

Several assumptions were needed in order to model the existing and future hydronic systems serving the Airport. The chilled water system was modeled from the CUP chillers and chilled water pumps to the Terminal booster pumps. Various air handling units (AHUs) are direct fed from the main chilled water distribution system and have also been accounted for. The hot water system was modeled from the CUP boilers and hot water pumps to the Terminal heat exchangers. The individual Terminal loads are diversified to account for the actual anticipated loads realized in the distribution mains. The following assumptions were utilized in creating and analyzing the flow models.

- General
  - Utilized previously developed Shelco Flow Model
  - No terminal side modeling has been completed
  - Distribution Pipe Lengths based on Site Utility Plans
  - Future Load Scenarios are in line with current phasing plans developed by UMP team
  - Future Pipe Sizes Based on Peak Velocities
    - 10 ft/s (Mains)
    - 8 ft/s (Branches)
  - Trended load data or system pressure data was not available for model calibration. System pressures at the plant and at Terminal pump rooms were captured during a site visit in March 2014. These values would not represent actual peak load scenarios for hot water and chilled water but were utilized as a rough order of magnitude comparison to confirm the results of the baseline (existing) model.

- Chilled Water
  - Existing Loads based on trended peak central plant loads for 2013
    - Individual Terminal Loads are a ratio of overall SF
  - Future Loads are based on a combination of projected Terminal sizes (SF) and 230 SF/Ton assumption developed by the UMP team.
    - A diversity factor of 85% is included to the future loads to account for a diversified load realized in the distribution mains.
  - Terminal Chilled Water Pump NPSHR – 20 ft
  - Terminal AHU Pressure Loss (directly fed without utilizing Terminal pumps) – 10 psi
  - Elbows and Isolation Valves on each Branch
  - CUP Chiller Pressure Loss – 20 ft
  - Return Pressure to Plant – 50 psi
- Hot Water
  - Existing Loads based on trended central plant loads for January 2013
    - Individual Terminal Loads are a ratio of overall SF
  - Future Loads are based on a combination of projected Terminal sizes (SF) and 25 Btu/SF assumption developed by the UMP team.
    - A diversity factor of 85% is included to the future loads to account for a diversified load realized in the distribution mains.
  - Terminal Heat Exchanger Pressure Loss – 10 psi
  - Elbows and Isolation Valves on each Branch
  - Central Utility Plant (CUP) Boiler Pressure Loss – 3 psi
  - Return Pressure to Plant – 70 psi

Results

A summary of the chilled water and hot water results from the Pipe Flow Expert modeling software are provided below. Several headers or potential problem areas were chosen to show velocities in the below summary tables. Refer to the following figures for locations. Velocity flow maps are provided in the Appendix for a visual representation of the flow model results.

Figure 3-7 Chilled Water Piping Summary Locations (1-3)

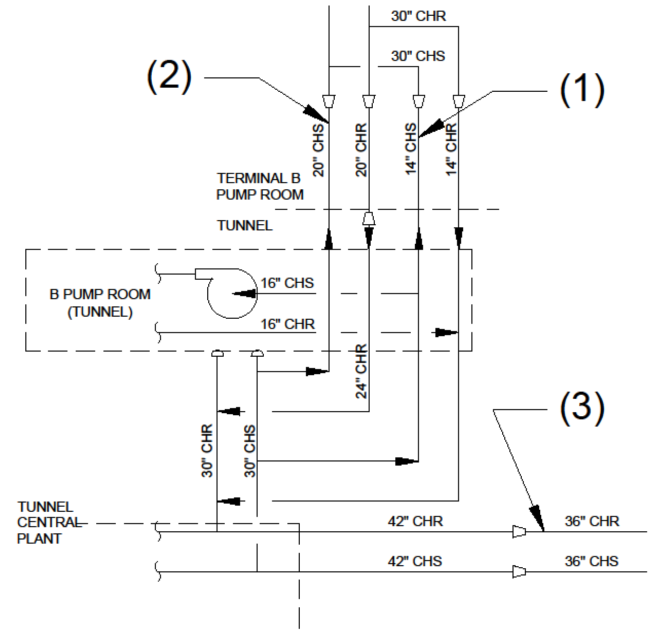


Figure 3-8 Chilled Water Piping Summary Locations (4)

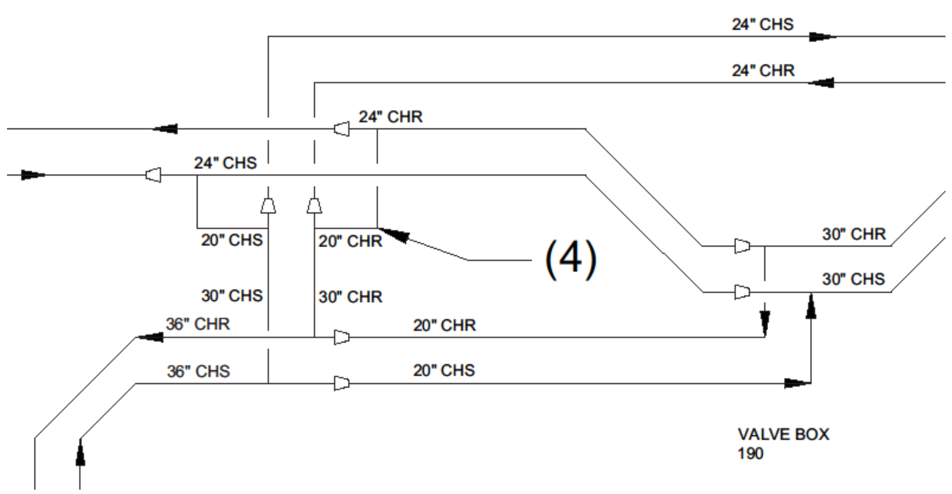


Table 3-5 Chilled Water Hydraulic Model Results Summary Table

Phase	Year	Load (Tons)	Capacity (Tons)	Header Velocities (ft/s)			
				14" (1)	20" (2)	36" (3)	20" Tie At Tree (4)
Existing	2014	13,294	19,440	7.06	4.24	4.88	4.78
Short Term	2016	14,588	19,440	7.61	4.58	5.39	6.33
Base Case	2020	15,444	19,440	7.96	4.80	5.74	7.36
Long Term 1	2023	17,894	22,740	9.60	5.82	6.52	9.86
Long Term 2	2025	19,188	22,740	10.60	6.44	6.89	10.53
Long Term 3	2030	20,308	23,740	11.01	6.70	7.35	11.53
Long Term 3 - Satellite Plant Option	2030	20,308	25,140	8.71	5.27	4.89	8.93

Figure 3-9 Hot Water Piping Summary Locations (1-3)

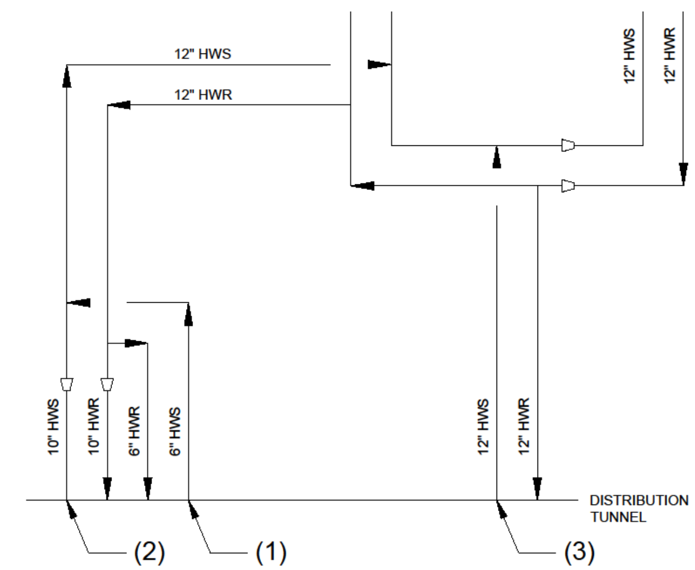


Table 3-6 Hot Water Hydraulic Model Results Summary Table

Phase	Year	Load (MMBH)	Capacity (MMBH)	Header Velocities (ft/s)		
				6" (1)	10" (2)	12" (3)
Existing	2014	42.14	70.25	1.96	2.68	2.98
Short Term	2016	49.59	70.25	2.31	3.15	3.50
Base Case	2020	60.30	102.25	2.81	3.83	4.26
Long Term 1	2023	75.04	102.25	3.52	4.78	5.29
Long Term 2	2025	82.46	102.25	3.87	5.25	5.81
Long Term 3	2030	88.90	102.25	4.17	5.66	6.26
Long Term 3 - Satellite Plant Option	2030	88.90	102.25	2.84	3.86	4.29

Chilled Water Results

In the Existing, Short Term, and Base Case flow model scenarios, no pressure or velocity issues have been identified. In the long term scenarios, high velocity issues greater than 10 ft/s occur in two locations. The first section is the 20" tie-in piping, location (4), near the "Christmas Tree" connection. Chilled water is supplied from the CUP through a 36" line and connects at the two redundant headers at three locations. The flow through the 20" line is over 10 ft/s as early as 2025 and increases to over 11.5 ft/s by 2030. The second section where high velocities occur is located in the utility tunnel south of Pump Room B, location (1). Project 621 added two 2,070 gpm chilled water pumps within the tunnel to supply Terminal B south. The velocity in the 14" piping between the suction of these pumps and the CUP is approximately over 10 ft/s by 2025 and increases to over 11 ft/s by 2030.

While the velocity in these lines increases over a recommended maximum velocity of 10 ft/s, the instances are minimal due to load variances in the system. Table 7, F22.3 (2009 ASHRAE Handbook), states that water piping systems can minimize erosion while operating up to 12 ft/s if the normal operation is below this point for a minimum of 4,000 hours per year. However, these should be testing locations for non-destructive testing as discussed above. Although it is not recommended for replacement unless warranted by testing results, a potential solution would be to upsize the 20" line at the Christmas Tree (approximately 20 ft of piping) to a 24" line and to upsize the 14" line (approximately 2,000 ft of piping) in the utility tunnel to a 16" line. This would reduce the velocities to about 8 ft/s. Another potential solution is incorporating a satellite plant supplying chilled water at the east portion of the distribution network. No issues related to pressure have been identified from the flow model.

Hot Water Results

In the Existing, Short Term and Base Case flow model, no pressure or velocity issues have been identified in the distribution system. However, in the Base Case and Long Term models the header within the central plant is undersized to utilize all five existing hot water boilers. The velocities within the 10" main header exceed the 10 ft/s baseline and reach approximately 10.9 ft/s.

Similar to the chilled water discussion above, the high velocities within the plant header are only experienced for a few hours though out the year and do not appear to be a major issue worth replacing. However, these locations should be verified with non-destructive testing. Following removal of the steam boilers in 2023, and installation of additional capacity, these flow issues will be resolved within the plant header. Installing additional capacity in a Satellite Plant would also relieve the main headers of velocity issues. No issues related to pressure have been identified from the flow model.

CAPACITY COST ESTIMATES

The following section provides rough order of magnitude (ROM) cost estimates for each option analyzed. The cost estimates include capacity additions and capacity replacements to maintain firm capacity throughout the 30 year analysis. The estimates do not include capital required for distribution piping replacement as a result of age. This is considered equal in all cases and replacement would be dependent of the results of an NDE. Cost estimates utilize the following assumptions for indirect costs:

- Equipment Contingency – 15%
- Balance of Plant Contingency – 30%
- Construction Contingency - 20%
- Misc. Indirect Costs – 9%
- Design and Construction Administration Costs – 8%

Base Case

The first option for utility growth is removing the existing steam boilers, Boiler 4 and Boiler 5, and installing new equipment in this space. The capacity and hydraulic analyses have been completed with only considering this capacity as back-up capacity primarily because the boilers are currently only utilized for operation of the steam driven chillers which is not economically beneficial over the electric drive chillers. In addition, the high reliability of the IAH electrical system does not justify the use of the steam driven chillers as a backup in the event of a power outage. Therefore, it is recommended that the steam boiler room be utilized for future expansion of the CUP beginning in 2023 with the installation of two new 16,000 MBH hot water boilers. Ideally all boilers, including the existing boilers, could be moved in the existing steam boiler room to achieve code compliance by separating combustion assets from refrigeration assets. ASHRAE 15 and NFPA 85 state that special consideration and safety measures concerning refrigerant monitoring and combustion control is required to co-locate boilers and chillers within a common space. However, additional design would be required to confirm that the existing five hot water boilers and the future boilers could fit within the existing steam boiler space. Relocating the existing five boilers would have operational benefits, but these benefits are not considered to be great enough to warrant the capital cost required to relocate the existing assets and the cost is not carried forward in this analysis. All future boiler capacity is evaluated to be located within the steam boiler room.

With the removal of the steam boilers, the three steam driven chillers will have to be replaced with electrical driven chillers to serve the chilled water load to maintain firm capacity. The removal of these steam driven chillers in 2023 would be two years earlier than the end of their expected service life. The table below shows the thirty year capital investments for this scenario. All costs provide are in 2014 dollars and do not account for inflation.

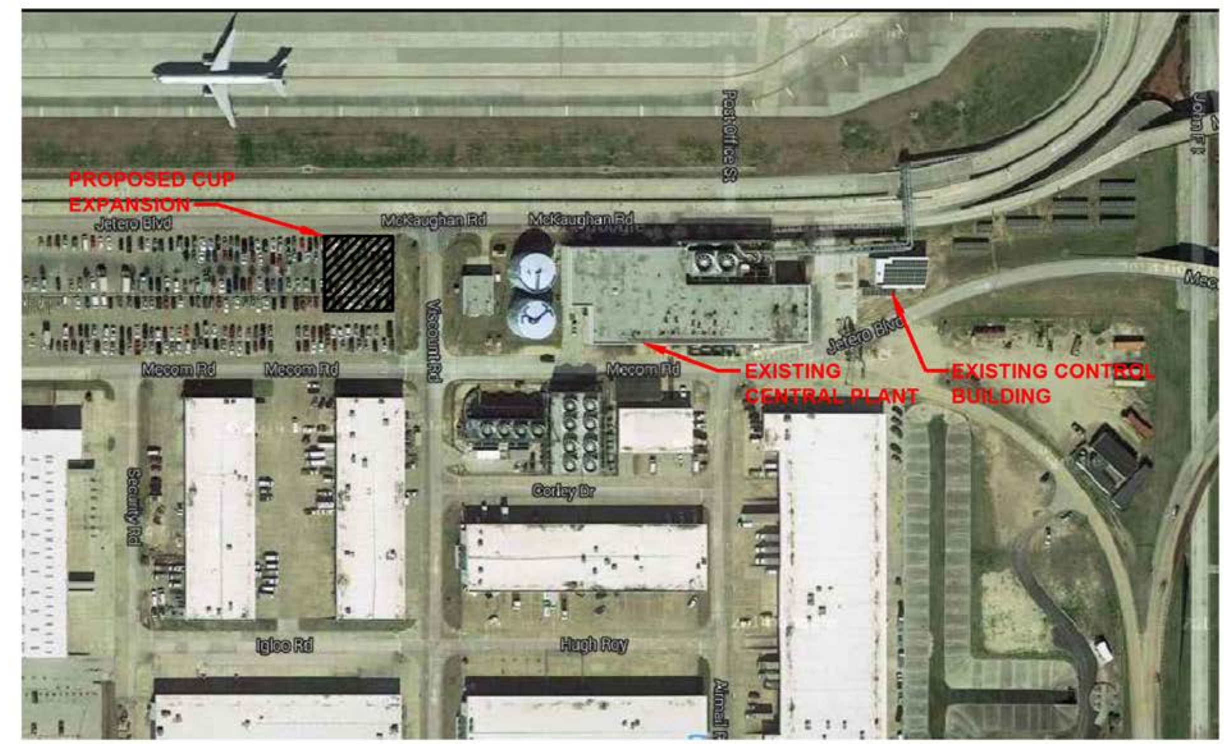
Table 3-7 Base Case ROM - Capital Cost Roadmap

	2014 $					
Year	Equipment Costs	Plant/Building Costs	Demolition Costs	Miscellaneous	Sub Total	Total Costs
2022	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
2023	$3,666,800	$-	$383,964	$480,000	$4,530,764	$7,416,460
2025	$4,642,500	$-	$171,200	$450,000	$5,263,700	$8,593,540
2032	$795,000	$-	$39,750	$-	$834,750	$1,347,787
2033	$180,000	$-	$9,000	$-	$189,000	$305,159
2034	$1,055,000	$-	$52,750	$-	$1,107,750	$1,788,573
2035	$1,296,000	$-	$64,800	$-	$1,360,800	$2,197,148
2037	$4,122,500	$-	$206,125	$-	$4,328,625	$6,988,998
2038	$180,000	$-	$9,000	$-	$189,000	$305,159
2044	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
Total	**$21,170,520**	**$-**	**$1,198,225**	**$930,000**	**$23,298,745**	**$37,814,012**

Alternative #1 - Central Plant Expansion

The second option considered is to expand the central plant. Construction is limited to the west due to the water facility and control building and limited to the east due to the new control building constructed in Project 621. Therefore, the proposed location for expansion is to the east at the current parking lot location between Jetero Boulevard and Mecom Road shown in the figure below. This will require the construction of a new building which will be in close proximity to the chilled water, hot water and electrical distribution network.

Figure 3-10 Central Plant Expansion



It is recommended that the CUP expansion be completed by 2023 with one new 16,000 MBH hot water boiler installed and an additional installed in 2025 to increase the hot water capacity. The existing CUP would have enough installed capacity with the steam boilers to operate through 2030. However, based on load increases in 2023 the steam boilers would no longer be utilized solely as emergency back-up assets and would be required to carry a percentage of the hot water load. Additionally, based on hot water demands the second hot water boiler is not needed until 2030 following removal of the steam boilers; conversely removal of the steam driven chillers in 2025 due to age, reduces the feasibility to maintain the steam boilers to only be used as back-up capacity. Maintaining the steam boilers would not be cost effective based on high operations and maintenance costs and would need to be utilized on a regular basis to maintain availability during an emergency. The time of construction of the expansion is driven by the required space for extra hot water capacity.

In this option, the replacement of the steam driven chillers can be completed as capacity is required, assuming the steam boilers are still operational. Based on capacity planning, the three steam driven chillers will need to be replaced with electric chillers in 2025.

The table below shows the thirty year capital investments for this scenario. All costs provide are in 2014 dollars and do not account for inflation.

Table 3-8 Alternate 1 ROM - Capital Cost Roadmap

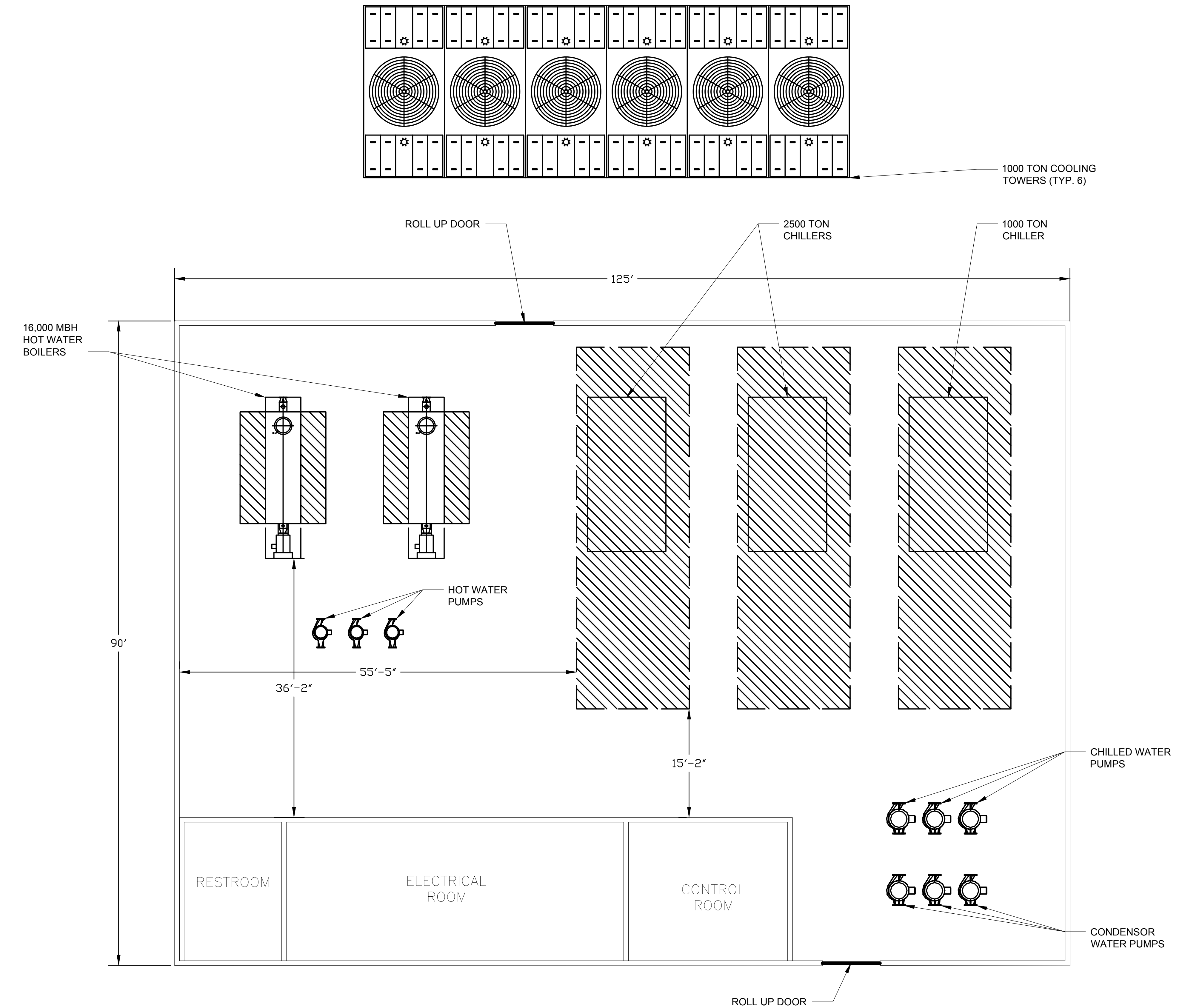
	2014 $					
Year	Equipment Costs	Plant/Building Costs	Demolition Costs	Miscellaneous	Sub Total	Total Costs
2022	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
2023	$241,400	$4,631,923	$-	$240,000	$5,113,323	$9,281,999
2025	$8,067,900	$-	$555,164	$690,000	$9,313,064	$15,182,187
2032	$795,000	$-	$39,750	$-	$834,750	$1,347,787
2033	$180,000	$-	$9,000	$-	$189,000	$305,159
2034	$1,055,000	$-	$52,750	$-	$1,107,750	$1,788,573
2035	$1,296,000	$-	$64,800	$-	$1,360,800	$2,197,148
2037	$4,122,500	$-	$206,125	$-	$4,328,625	$6,988,998
2038	$180,000	$-	$9,000	$-	$189,000	$305,159
2044	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
Total	**$21,170,520**	**$4,631,923**	**$1,198,225**	**$930,000**	**$27,930,668**	**$46,268,198**

Alternative #2 – Satellite Plant

The final option considered is to build a new satellite plant at another location from the existing CUP. This will provide the additional chilled water and hot water capacity required while also improving redundancy and reliability. As shown in the figure below, the proposed satellite plant location is east of Terminals E and FIS, along the road connecting S Terminal Road and Will Clayton Parkway.

Figure 3-11 Satellite Plant

It is recommended that the satellite plant is completed by 2023 with one new 16,000 MBH hot water boiler. By 2025, an additional hot water boiler, two new 2500 ton chillers and a 1000 ton chiller will be installed in the satellite plant to accommodate the increased chilled water load as well as alleviate high velocity issues in the chilled water system. The chillers are sized to provide the needed capacity, while still relieving the velocity issues in the event one chiller is down at the satellite plant. Cooling towers would also be installed at the satellite plant as required with the new chiller capacity. The figure below shows a proposed layout of the satellite plant with the full build out of major equipment by 2025.



SATELLITE PLANT LAYOUT

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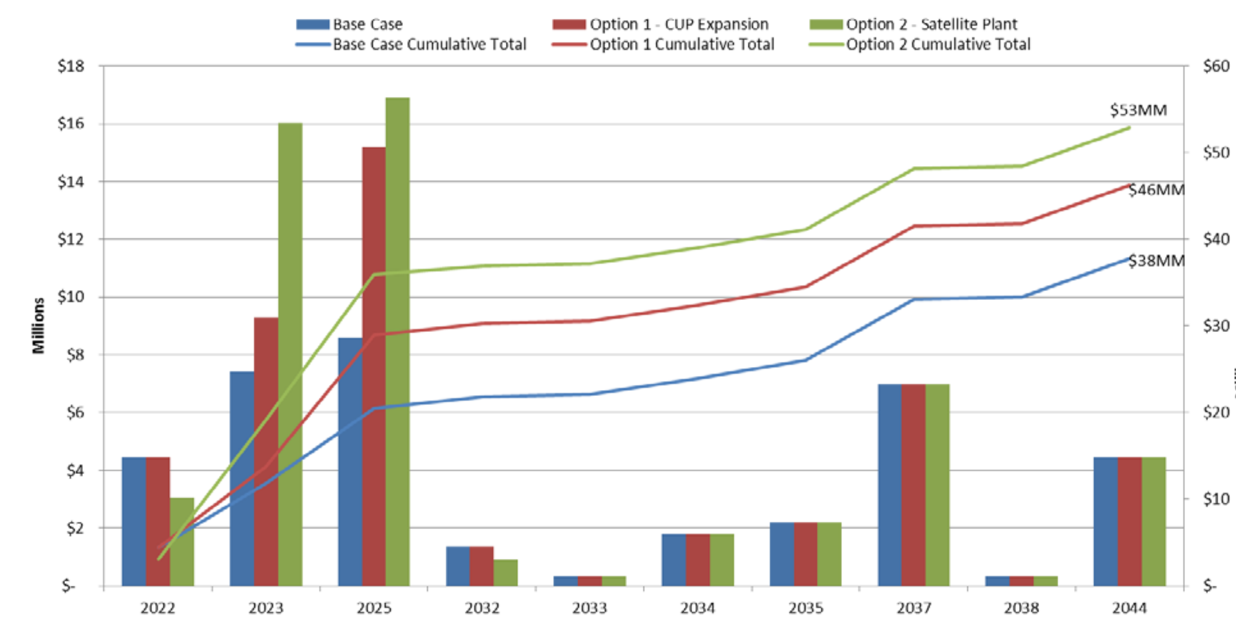
With a remote plant feeding the distribution system from a second point and preventing high velocities as the load increases, modifications to the existing network described earlier will not be required. It will however, require new hot water and chilled water distribution to tie in to the network near the Terminal D, Terminal E and FIS connections which is a significant cost in this option. The table below shows the thirty year capital investments for this scenario. All costs provide are in 2014 dollars and do not account for inflation.

Table 3-10 Alternate 2 ROM - Capital Cost Roadmap

	2014 $					
Year	Equipment Costs	Plant/Building Costs	Demolition Costs	Miscellaneous	Sub Total	Total Costs
2022	$1,763,280	$-	$130,818	$-	$1,894,098	$3,058,211
2023	$311,400	$8,267,788	$-	$240,000	$8,819,188	$16,031,201
2025	$9,130,980	$-	$555,164	$690,000	$10,376,144	$16,898,636
2032	$515,000	$-	$39,750	$-	$554,750	$895,699
2033	$180,000	$-	$9,000	$-	$189,000	$305,159
2034	$1,055,000	$-	$52,750	$-	$1,107,750	$1,788,573
2035	$1,296,000	$-	$64,800	$-	$1,360,800	$2,197,148
2037	$4,122,500	$-	$206,125	$-	$4,328,625	$6,988,998
2038	$180,000	$-	$9,000	$-	$189,000	$305,159
2044	$2,616,360	$-	$130,818	$-	$2,747,178	$4,435,594
Total	**$21,170,520**	**$8,267,788**	**$1,198,225**	**$930,000**	**$31,566,533**	**$52,904,378**

The figure below compares the relative costs associated with each option and their total over the 30 year analysis. As shown, the satellite option requires the most capital up front and long term, but provides the most operational flexibility. The option of utilizing the existing CUP building requires the least capital up front and the least cost over the life of the analysis.

Figure 3-12 Capital Costs Estimates



The tables below provide the 2044 (final year of analysis) equipment list for boilers and chillers. Auxiliary equipment (pumps, cooling towers, etc.) are not shown for clarity. As shown in the table below, equal capacity is installed in all options in 2044.

Table 3-11 2044 Installed CHW and HW Equipment List – Base Case

2044 Installed Equipment			Size	Units
Existing CUP	CHW	Chiller #10	3,000	Tons
		Chiller #11	1,000	Tons
		Chiller #12	2,500	Tons
		Chiller #13	2,500	Tons
		Chiller #14	3,000	Tons
		Chiller #15	3,000	Tons
		Chiller #16	3,000	Tons
		Chiller #17	3,000	Tons
		Chiller #18	2,500	Tons
		Total	**23,500**	**Tons**
	HW	Boiler #11	16	MMBTU
		Boiler #12	16	MMBTU
		Boiler #13	14.05	MMBTU
		Boiler #14	14.05	MMBTU
		Boiler #15	14.05	MMBTU
		Boiler #16	14.05	MMBTU
		Boiler #17	14.05	MMBTU
		Total	**102.25**	**MMBTU**

Table 3-12 2044 Installed CHW and HW Equipment List – Alternate 1

2044 Installed Equipment			Size	Units
Existing CUP	CHW	Chiller #10	3,000	Tons
		Chiller #11	1,000	Tons
		Chiller #12	2,500	Tons
		Chiller #14	3,000	Tons
		Chiller #15	3,000	Tons
		Chiller #16	3,000	Tons
		Chiller #17	3,000	Tons
		Chiller #18	2,500	Tons
		Total	**21,000**	**Tons**
	HW	Boiler #13	14.05	MMBTU
		Boiler #14	14.05	MMBTU
		Boiler #15	14.05	MMBTU
		Boiler #16	14.05	MMBTU
		Boiler #17	14.05	MMBTU
		Total	**70.25**	**MMBTU**
Cup Expansion	CHW	Chiller #13	2,500	Tons
		Total	2,500	**Tons**
	HW	Boiler #11	16	MMBTU
		Boiler #12	16	MMBTU
		Total	**32**	**MMBTU**
		Total CHW Installed	**23,500**	**Tons**
		Total HW Installed	**102.25**	**MMBTU**

Table 3-13 2044 Installed CHW and HW Equipment List – Alternate 2

2044 Installed Equipment			Size	Units
Existing CUP	CHW	Chiller #10	3,000	Tons
		Chiller #14	3,000	Tons
		Chiller #15	3,000	Tons
		Chiller #16	3,000	Tons
		Chiller #17	3,000	Tons
		Chiller #18	2,500	Tons
		Total	**17,500**	**Tons**
	HW	Boiler #13	14.05	MMBTU
		Boiler #14	14.05	MMBTU
		Boiler #15	14.05	MMBTU
		Boiler #16	14.05	MMBTU
		Boiler #17	14.05	MMBTU
		Total	**70.25**	**MMBTU**
Satellite Plant	CHW	Chiller #11	1,000	Tons
		Chiller #12	2,500	Tons
		Chiller #13	2,500	Tons
		Total	**6,000**	**Tons**
	HW	Boiler #11	16	MMBTU
		Boiler #12	16	MMBTU
		Total	**32**	**MMBTU**
		Total CHW Installed	**23,500**	**Tons**
		Total HW Installed	**102.25**	**MMBTU**

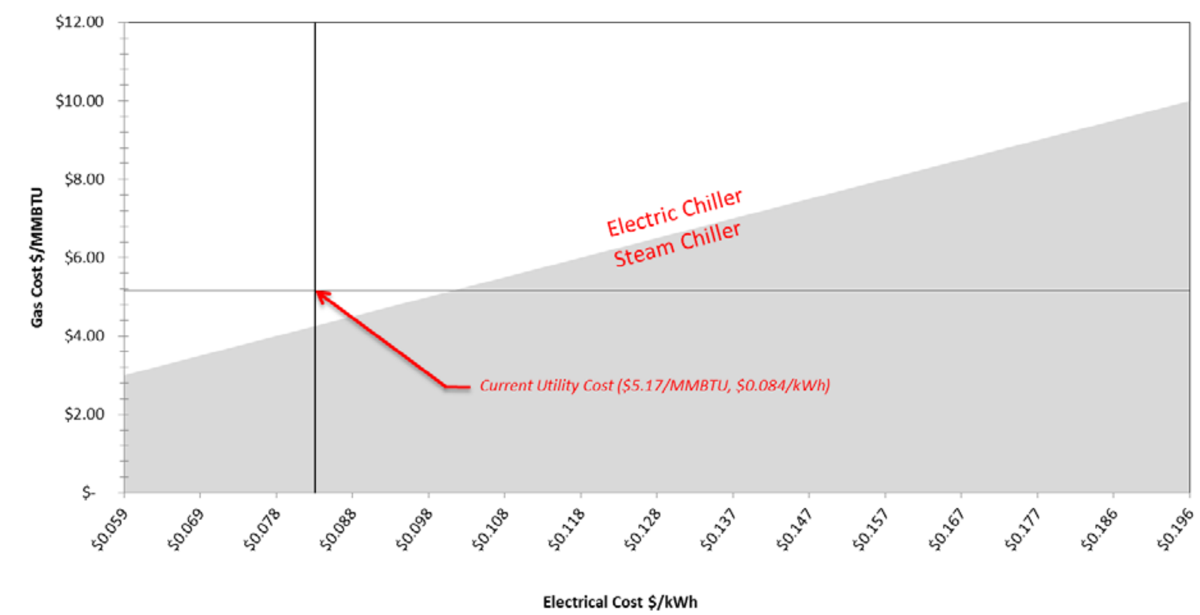
STEAM VERSUS ELECTRIC CHILLER ANALYSIS

IAH has a combination of steam and electric chillers at the CUP. The following analysis has been completed in support of the base case plant expansion option (removal of steam Boiler 4 and Boiler 5), showing the economical disadvantages of operating the steam driven chillers over the electrical chillers. This analysis is only reflective of the natural gas and electrical utility costs. Additional O&M costs occur by having to operate and maintain the steam turbine drives and boilers that are predominately used for chilled water production.

Depending on utility rates at any given time, it may be more economical to operate one versus the other assuming the Airport load does not require the operation of all chillers at the plant. The charts below show the breakeven line for running the Trane electric chillers versus the steam driven chillers and the

York electric chillers versus the steam driven chillers given various electricity and natural gas costs. At the current average utility costs, it is more economically viable to operate the either the York or the Trane electric chillers over the steam driven chillers. At a current natural gas rate of $5.17/MMBtu, the electricity costs would need to increase to at least $0.10 kWh for steam driven chillers to be more cost effective than the Trane electric chillers and increase to at least $ .089/kWh for steam driven chillers to be more cost effective than the York electric chillers. At the current electricity rate or $0.084/kWh, the natural gas costs would need to decrease to $4.27/MMBtu for steam driven chillers to be more cost effective than the Trane electric chillers and $4.81/MMBtu for the York electric chillers.

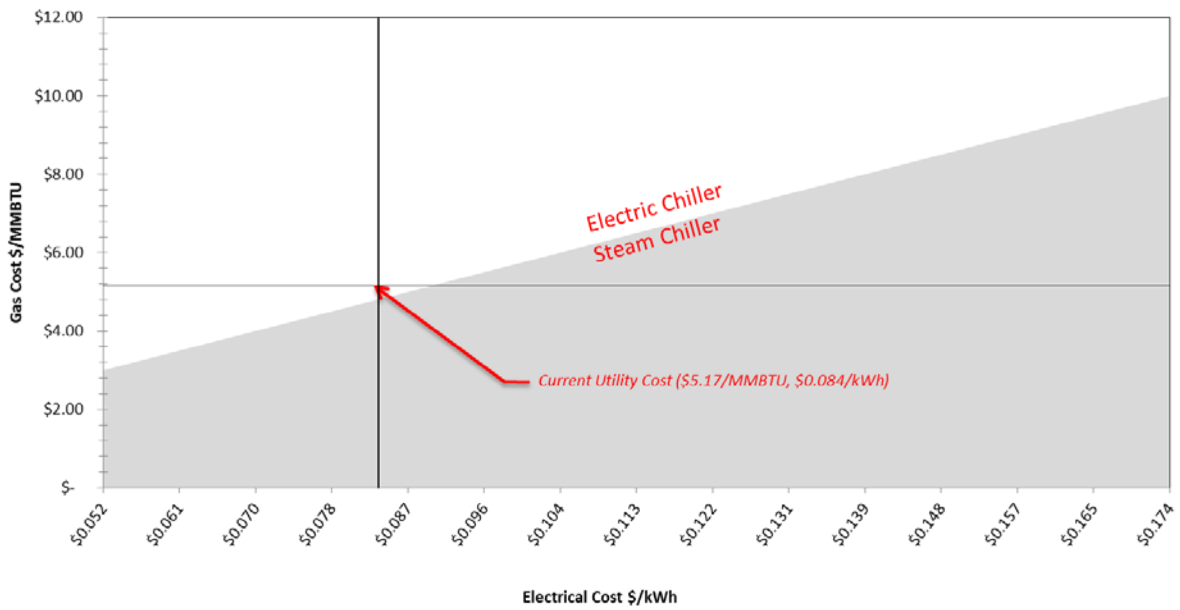
Table 3-14 York Steam Driven Chiller vs. Trane Electric Chiller



**Assumed Trane chiller efficiency of .558 kW/Ton as published in the PN621 Equipment Schedule*

***Assumed Steam Driven Chiller steam consumption of 8.16 lb/Ton*

Table 3-15 York Steam Driven Chiller vs. York Electric Chiller



**Assumed Trane chiller efficiency of .629 kW/Ton as published in the PN621 Equipment Schedule*

***Assumed Steam Driven Chiller steam consumption of 8.16 lb/Ton*

These results show significant margin reflecting the benefits of the electric chillers in lieu of the steam driven chillers. Further, when considering the added O&M cost burden of steam driven equipment, the margin widens.

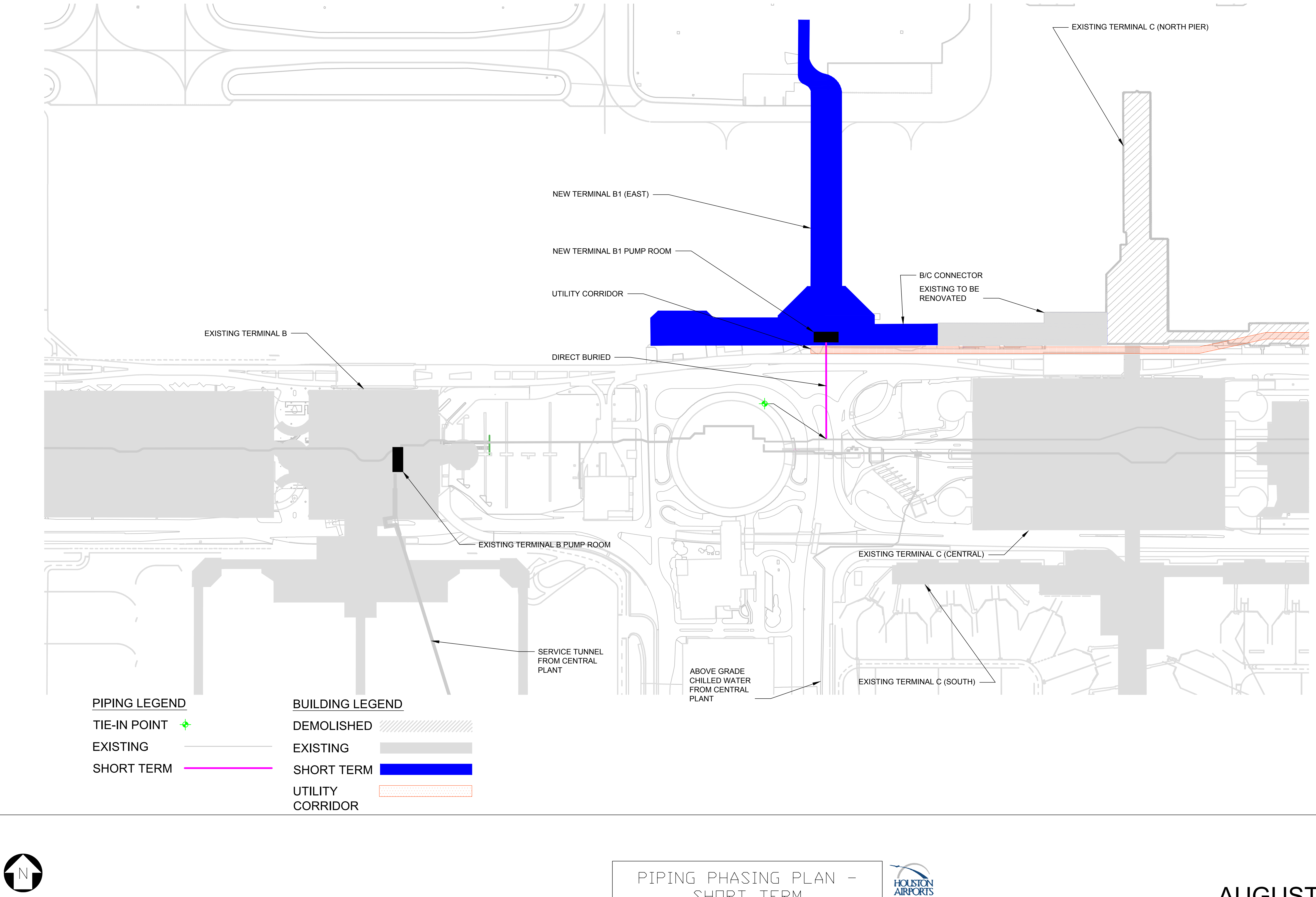
CHAPTER 4 - TERMINAL CONNECTIONS AND CONSTRUCTION PHASING PLAN

TERMINAL CONSTRUCTION PHASING PLANS

As the Airport grows, new Terminals will be connected to the distribution network. The capacity planning has been completed assuming new Terminal connections are phased. The construction and renovation of future Terminals over the next 16 years is broken down into the three phases; Short Term, Base Case, and Long Term. Terminal connections to the distribution system will be made independently; however, ties between Terminal pump rooms will be provided through a utility corridor running East-West. This will provide redundancy running from Terminal B2/3 pump room to Terminal B1 pump room and finally Terminal D1 pump room. Pumps and heat exchangers will be designed and size to serve a specified zone within the facility with the ability to back feed other zones in the event of an emergency.

Short Term

Terminal B1 (East) is the first Terminal to be constructed and connected to the main distribution system which is scheduled to be completed in 2016. Unique to other future Terminals, the Terminal B1 distribution connection will be direct buried to keep the current traffic pattern intact along North Terminal Road. The connection is sized based on the peak load at a maximum velocity of 8 ft/s. To allow for redundancy, the Terminal will be connected to the existing parallel distribution main with a full size line. The hot water headers in this section of the distribution system are 10” and the chilled water headers are 24”. A Terminal connection to both headers provides redundancy and increased reliability. This method is expected to be utilized on all future Terminal connections where redundant headers are installed in the distribution system.



PIPING PHASING PLAN – SHORT TERM

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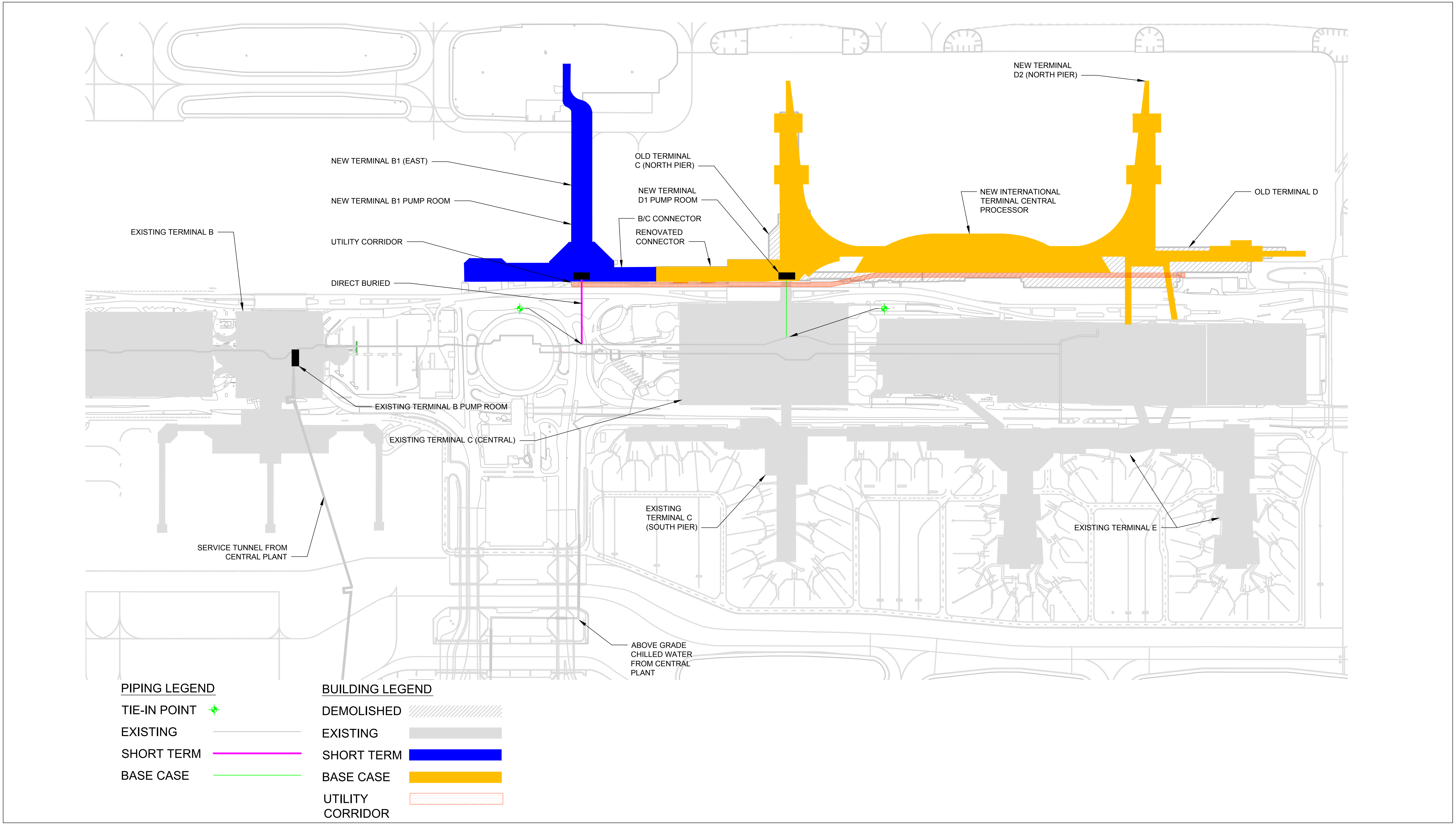
Base Case

The Base Case consists of the new Terminal D1, Central Processor, new Terminal D2 and B/D Connector which will all served by a common pump room located in the new D1 North Pier. These are planned to be added to the distribution system in 2020. The connections to the chilled water and hot water distribution systems are designed based on the methods described in the Short Term. Rather than being direct buried, the connection to the new Terminal D1 pump room will be routed through existing tunnels. In this phase, a connection can be made from the Terminal B1 pump room to the new Terminal D1 pump room to increase redundancy and allow for the backfeeding between the two Terminals.

Long Term

The Long Term phase consists of the addition of Terminal B2 (Middle) in 2023, the new FIS Terminal in 2023 and Terminal B3 (West) in 2025. These will be added to the distribution system utilizing the same methods from the Short Term and the Base Case with connections routed through utility tunnels. The United Terminals B2 and B3 will be served from a common pump room located in Terminal B2. A utility corridor will also allow for a final interconnection between this pump room and the United Terminal B1 pump room for redundancy. The new FIS Terminal will connect to the chilled water and hot water headers just east of the existing Terminal B and be served by its own pump room. The chilled water headers at this connection are 20”, and the hot water headers are 14”.

A final Terminal D3 will be added to the system in 2030. While this Terminal will be served utilizing a single pump room not connected to other Terminals, it can be tied into both existing main distribution headers to allow for redundancy.



PIPING PHASING PLAN – BASE CASE

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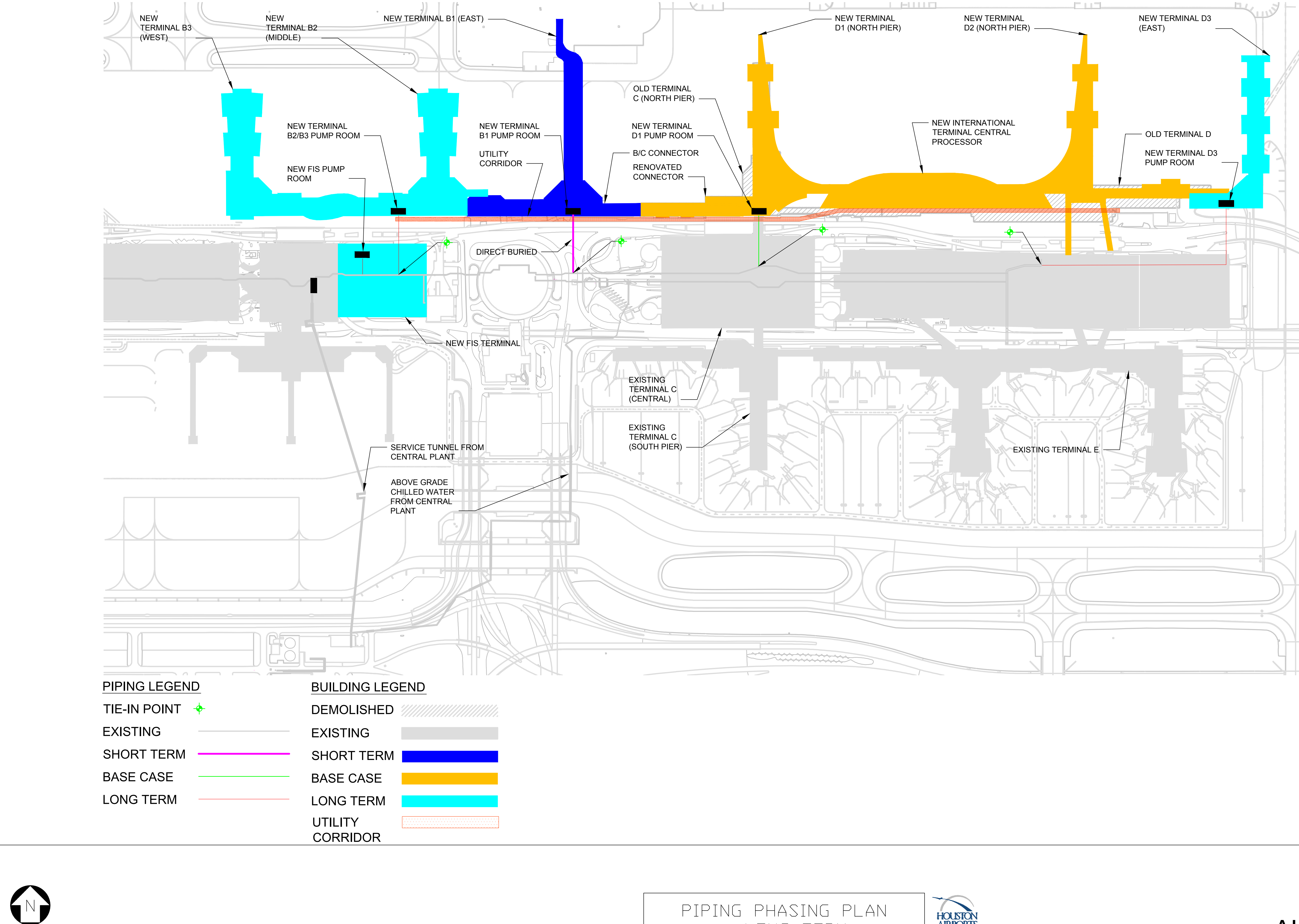

PIPING PHASING PLAN – LONG TERM

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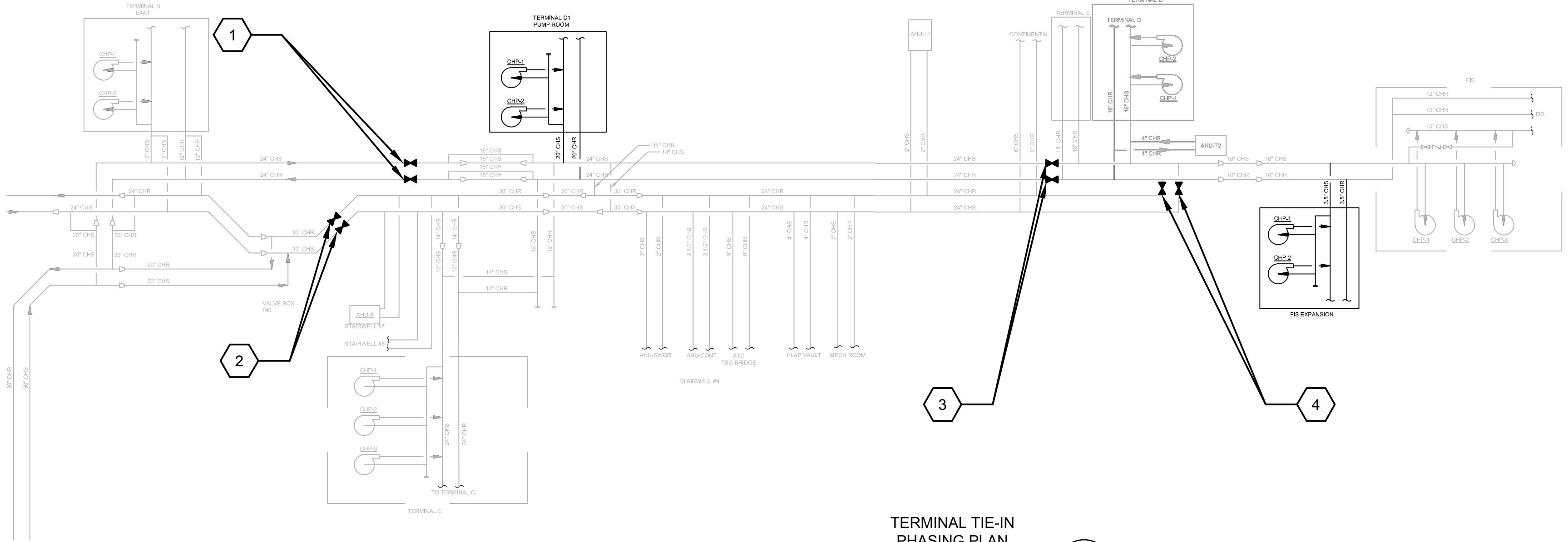
Typical Building Connection

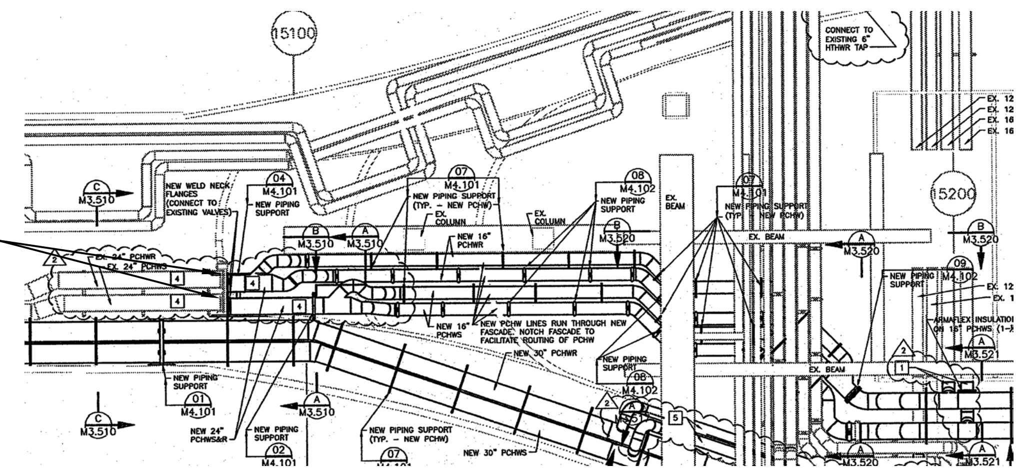
Another benefit of connecting Terminals to redundant headers is the ability to tie-in to the existing system without taking any other Terminals offline. The figures below show the existing chilled water and hot water isolation valves and their locations for the tie-in of the new pump room located in Terminal D1. This method allows for the tie-in to each distribution main to be phased. A similar phasing plan would be used for the tie-in for new Terminals B1 (East) and D3.



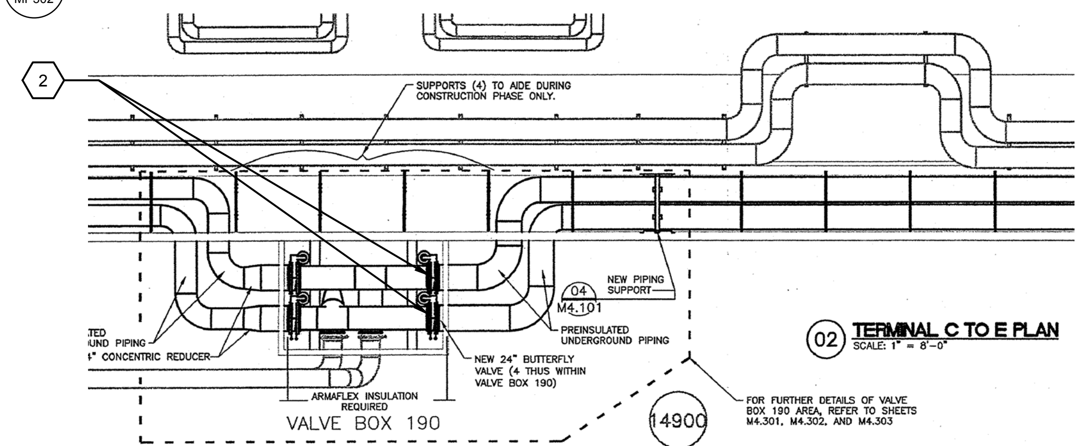
TERMINAL TIE-IN PHASING PLAN
NOT TO SCALE
1 MP502

KEYED NOTES:

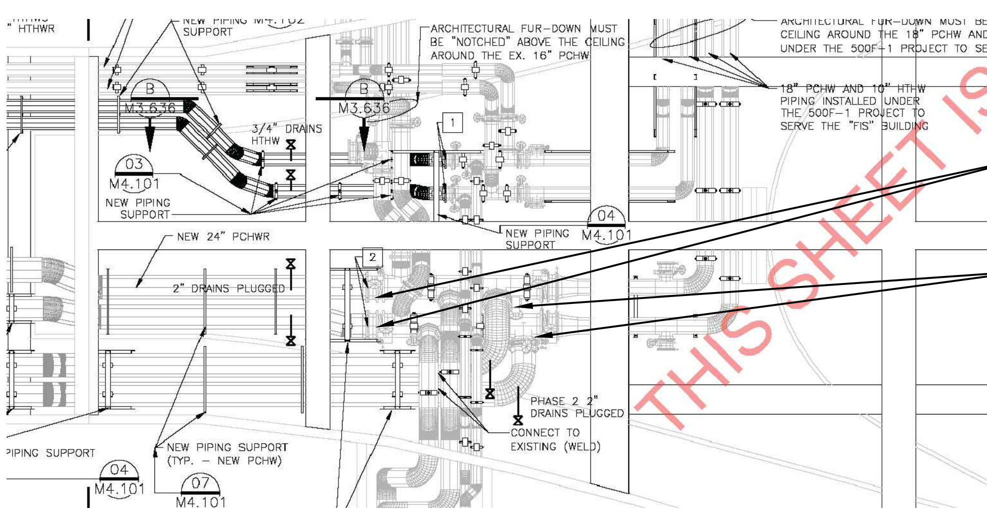
1. SEE DETAIL MP502/A FOR ISOLATION VALVE LOCATION.
2. SEE DETAIL MP502/B FOR ISOLATION VALVE LOCATION.
3. SEE DETAIL MP502/C FOR ISOLATION VALVE LOCATION.
4. SEE DETAIL MP502/C FOR ISOLATION VALVE LOCATION.



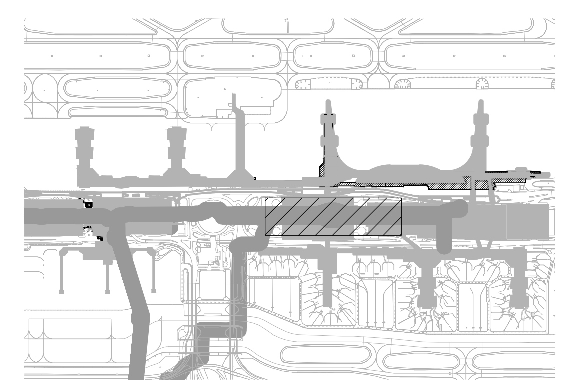
ISOLATION VALVE DETAIL
NOT TO SCALE
A MP502



ISOLATION VALVE DETAIL
NOT TO SCALE
B MP502



ISOLATION VALVE DETAIL
NOT TO SCALE
C MP502



SITE KEY

NEW TERMINAL CHW TIE-IN PHASING

HOUSTON AIRPORTS
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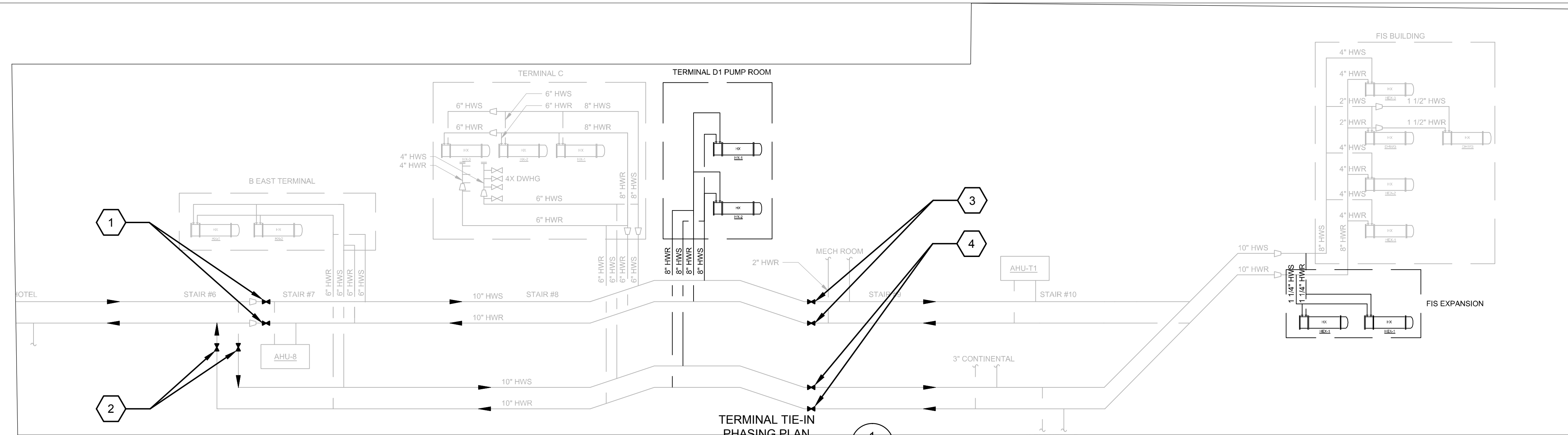
KEYED NOTES:

1 SEE DETAIL MP503A FOR ISOLATION VALVE LOCATION.

2 SEE DETAIL MP503/A FOR ISOLATION VALVE LOCATION.

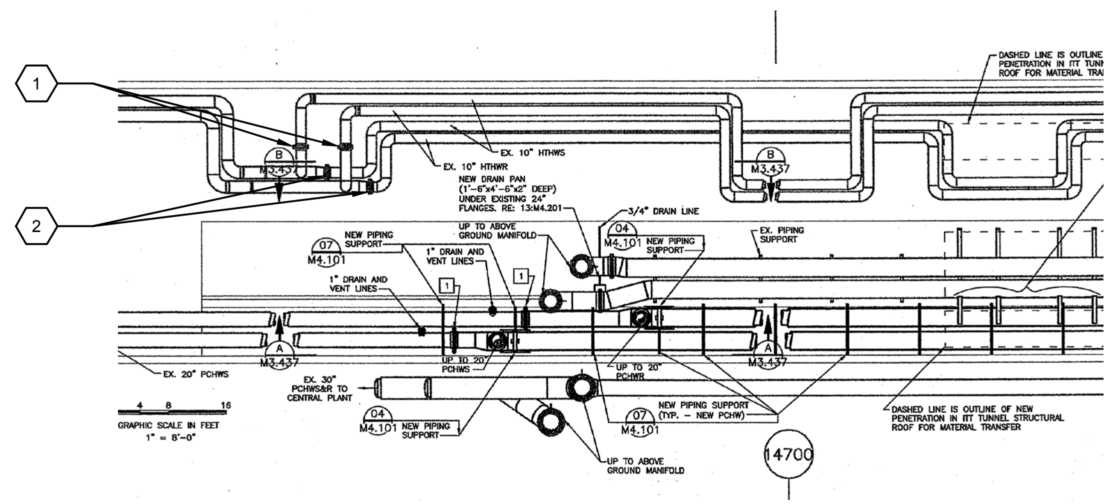
3 SEE DETAIL MP503/B FOR ISOLATION VALVE LOCATION.

4 SEE DETAIL MP503/C FOR ISOLATION VALVE LOCATION.



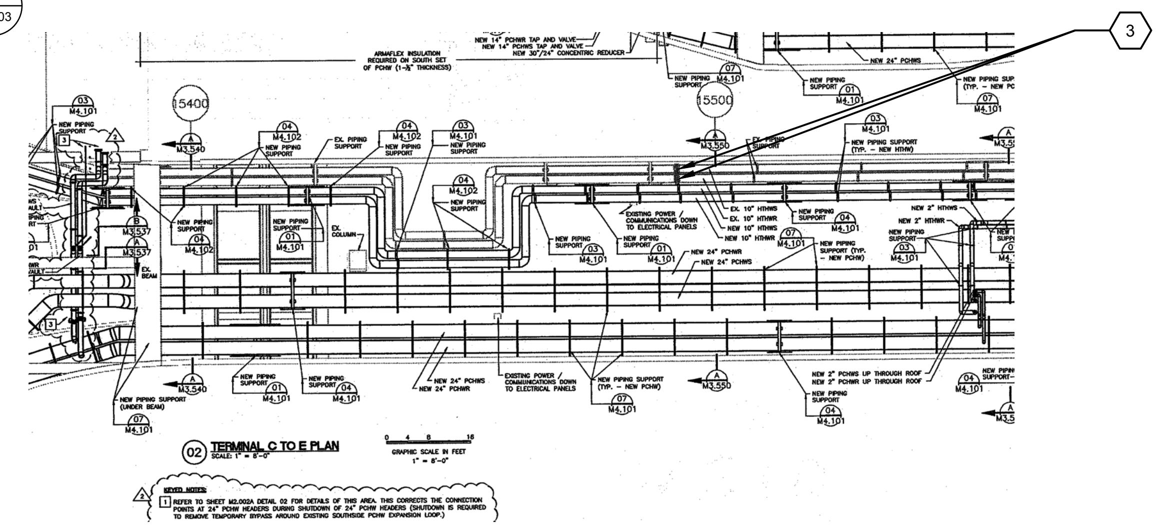
TERMINAL TIE-IN PHASING PLAN 1 MP503

NOT TO SCALE



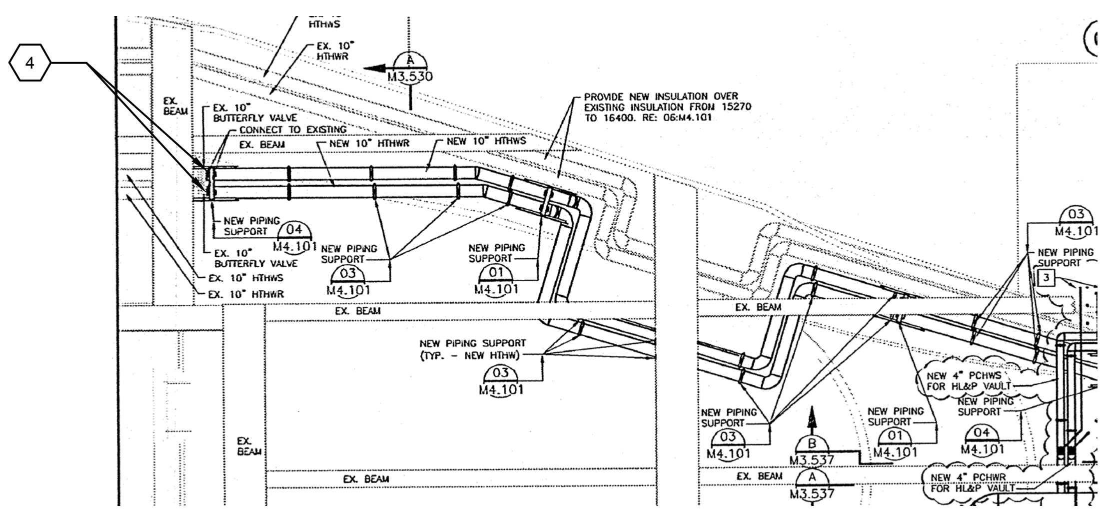
ISOLATION VALVE DETAIL A MP503

NOT TO SCALE



ISOLATION VALVE DETAIL B MP503

NOT TO SCALE



ISOLATION VALVE DETAIL C MP503

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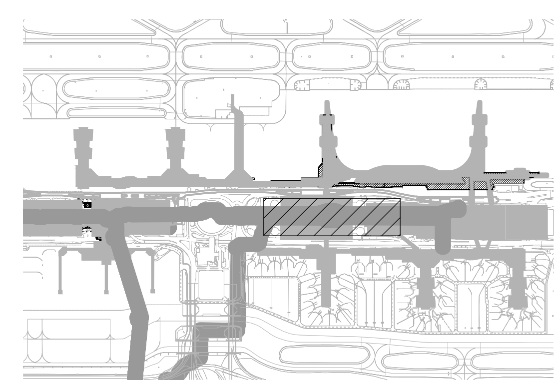


SITE KEY

NEW TERMINAL HW TIE-IN PHASING

HOUSTON AIRPORTS HNTB

AUGUST 2014

CHAPTER 5 - LOW TEMPERATURE HOT WATER ANALYSIS

The current peak hot water distribution temperature from the CUP is approximately 200 °F. The 200 °F distribution hot water is decoupled from the Terminals with a shell and tube heat exchanger. The Terminal side loop provides a maximum of 180 °F hot water to air handling units (AHUs). The following analysis is based on the potential to lower the supply temperature from the central plant and additionally lowering the supply temperature on the Terminal side loops.

AIR HANDLING UNITS

The potential for supplying AHUs with lower temperature hot water was investigated. Maintaining a designed heat output from existing AHUs while lowering the supply temperature would also require lowing the leaving water temperature to maintain the overall temperature differential. However, the AHU would experience a minor derate in overall airside capacity due to a lower temperature hot water supplied. Most of the AHUs are designed for 180°F supply hot water. Additionally, lowering the Terminal side supply temperatures would reduce the performance of the heat exchanger. The heat exchangers would need to be replaced to maintain the Terminal side loads and the CUP return temperature of 155°F.

HEAT PUMP CHILLERS

Heat pump or "heat recovery" chillers allow waste heat generated during the production of chilled water, which is normally rejected through a cooling tower, to be recovered and used to produce "free" heating hot water. This can result in substantial natural gas savings for the Airport, resulting from reduced boiler run hours. These chillers are capable of producing heating water temperatures from 110°F to 170°F, with a typical supply temperature of approximately 140°F to 155°F. Heat pump chillers are available in a various sizes ranging from small 30 ton packaged units to large 6200 ton field erected machines. There are many benefits to heat pump chillers aside from the natural gas savings, including:

- Reduced required makeup water due to cooling tower evaporation
- Reduced boiler carbon footprint
- Reduced usage of water treatment chemicals

Figure 5-1 Heat Pump Chiller

Equipment first cost is a major consideration when evaluation the feasibility of any heat pump chiller project. While most commercial electric centrifugal chillers can be purchased for approximately $300/ton, it is not uncommon for a heat pump chiller's first cost to exceed $1000/ton. Some of this additional first cost can be offset when cooling tower costs are considered. If the chiller is to be operated with a coincident heating and cooling load only, the chiller can operate with no cooling tower as all heat will be rejected to the heating hot water loop. However, a cooling tower, heat exchanger, or other means of heat rejections will be required if load or operational conditions require the chiller be operated to produce chilled water only.

The efficiency of a heat pump chiller is heavily dependent on the temperature of the hot water produced. As the required temperature of the hot water is increased, the chiller's efficiency will generally decrease. The typical efficiency of a heat recovery chiller, supplying 140°F water, is approximately 1.4 to 1.6 kW/ton. This efficiency is much lower than typical electric chillers, which typically operate at or below 0.6 kW/ton. The cost of the additional electricity consumed is typically more than offset by the gas costs avoided through the production of "free" hot water.

It is recommended that the Airport investigate designing future Terminals to be heated with lower temperature hot water. In this case, a heat pump chiller may be installed in the Terminals to provide energy savings.

Without Terminal load profiles, it was assumed that individual Terminal load profiles could be scaled from the CUP chilled water profile, in a fashion similar to the discussion provided within the Load Analysis Section. Initial heat pump chiller size was calculated assuming the heat pump chiller is sized for base loading on the evaporator side for 90% of its yearly operation. These initial estimates were then optimized to provide the maximum savings over the life of the analysis with respect to yearly fluctuation in fuel and electricity costs. These costs are summarized below in Table 5-1.

Table 5-1: Heat Pump Chiller Projected NPV Savings

	Loads							
	Cooling (Tons)	Heating (MBH)	Install Date	Yearly Fuel Savings (MMBTU)	Fuel Savings ($2014)	Addt'l Power Cons. (kWh/Yr)	Addt'l Power Cost ($2014)	Savings ($2014)
B PIER #1	275	4,677	2016	33,965	$175,597	1,817,891	$152,703	$22,894
B PIER #2	275	4,677	2023	33,965	$175,597	1,817,891	$152,703	$22,894
B PIER #3	275	4,677	2025	33,965	$175,597	1,817,891	$152,703	$22,894
D PIER #1	175	2,976	2020	22,691	$117,313	1,185,186	$99,556	$17,757
D PIER #2	200	3,401	2020	25,483	$131,746	1,342,661	$112,784	$18,962
D PIER #3	200	3,401	2030	25,483	$131,746	1,342,661	$112,784	$18,962
NEW FIS	275	4,677	2025	31,483	$162,768	1,752,596	$147,218	$15,550

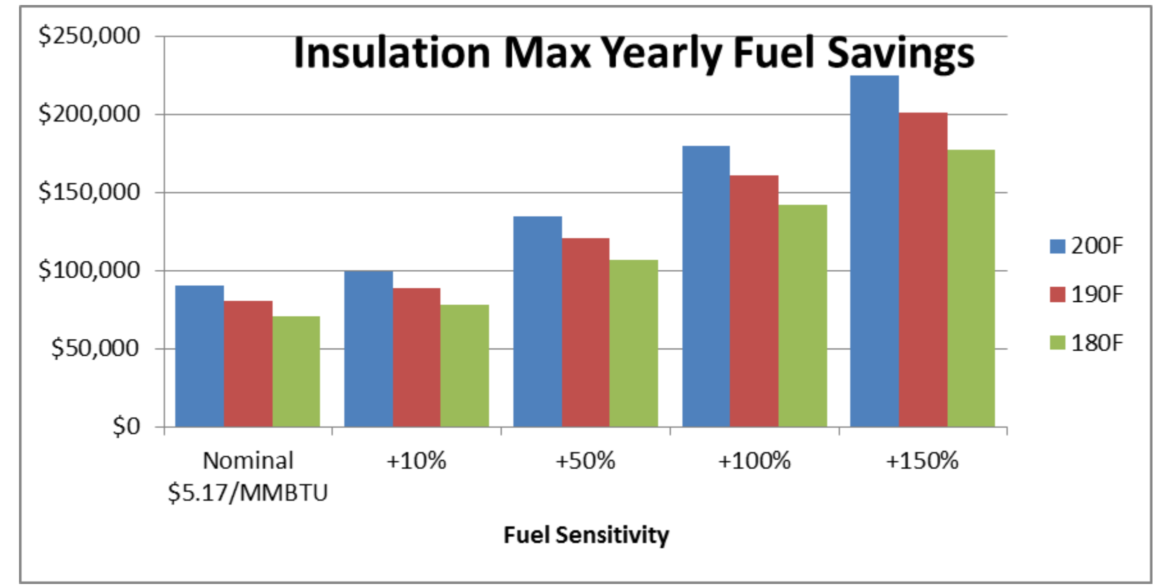
*Fuel savings considered through life of analysis, 2044
*6% Discount Rate
*Assuming existing CUP at 0.8 kW/Ton average
*Assuming boiler efficiency of 83% HHV

The feasibility of installation of the heat pump chiller within the Terminal space would still be dependent on service from the central plant. The heat pump chiller efficiency is based on the need to simultaneously heat and cool the space. This limits the size of the chiller to being significantly smaller than the overall requirement to meet peak loads. The chiller would have to be installed to operate in parallel with the central hot water and chilled water system to provide the required capacity. Although this is not a fully decentralized configuration, additional building O&M costs would occur, and more space would be required to be constructed at the Terminals. The intent of this analysis is to provide potential energy savings at a low level of resolution.

INSULATION

In addition to potential savings from heat pump chillers, there are additional savings available due to minimizing heat transfer losses in the underground tunnel. A heat transfer model was developed to calculate losses from the individual 6", 10", and 12" hot water supply lines as a function of insulation quality (present vs. degraded/absent) as shown in the figure below:

Figure 5-2: Fuel Savings from Insulation



The data represented in the figure corresponds to the maximum fuel savings available, i.e. if a total transition were made from uninsulated piping to insulated piping. Therefore, true savings can be understood by multiplying these values by the percentage of hot water supply piping with poor or no insulation. Based on a visual condition assessment it was estimated that about 2% of the distribution piping either experienced removed insulation or severe deterioration. Based on this estimation, approximately $1,800 is lost annually based on current fuel prices. In the same manner, the effect on cost savings with respect to lower hot water supply temperature can be understood and it can be seen that lowering the supply temperature reduces the cost savings of insulating pipe. Approximately 1% reduction in annual savings is realized per degree reduction of supply temperature.

LIMITATIONS

Lowering the hot water supply temperature while serving the same heat load creates a degree of concern with the distribution hot water return temperature. Lower return temperatures promote better heat transfer and thus better efficiencies but too much heat transfer from the flue gas can cause condensation of harmful sulfuric acid onto the boiler tubes. Being that the calculated hot water supply temperature drop (or loss) from the CUP to the Airport is within a few degrees (<2°F)Fahrenheit, the maximum temperature drop of the return lines to the CUP is similar (or less) a few degrees Fahrenheit. This results in requiring that the hot water return temperature at the Terminal B pump room be a few Fahrenheit degrees above the minimum boiler return temperature of 155°F.

If the Airport decides to lower the hot water supply temperature, the operational temperature differential will also have decrease. Potential exists to lower the supply temperature; however the return temperature is on the bottom edge of acceptable return temperatures to remain from condensing in the boilers and causing internal damage. In the case of maintaining this hot water return temperature limit while lowering the hot water supply temperature, it can be understood that at best, an X% change in supply-return temperature difference results in a 1/X% change in pumping capacity. Increasing pumping capacity results in additional power consumption and a potential for high pipeline velocities. It may also require the installation of additional hot water pumps and may require upsizing the Terminal-side hot water heat exchangers to avoid unacceptable pressure losses.

CHAPTER 6 - CHP SYSTEM ANALYSIS

CHP INTRODUCTION

Combined Heat and Power (CHP) is a system utilizing a prime mover such as a combustion turbine generator or a reciprocating engine to produce electricity. The waste heat from that prime mover is then used to produce hot water or steam to be utilized in the central heating supply. CHP can greatly increase the overall efficiency of the system, reduce the amount of purchased utilities, and reduce regional emissions. The efficiency and cost effectiveness of the system varies depending on the facility loads and utility costs; therefore a CHP analysis is necessary to determine its feasibility.

PRIME MOVERS

Three prime movers were selected for the CHP analysis; Centaur 50, Mercury 50, and the Jenbacher 624. Each prime mover is coupled with a heat recovery unit (HRU). The selection was based on the ability to maximize operation while utilizing the assumed hot water loads.

Table 6-1: CENTAUR 50 w/ Duct Fired HRU

Maximum Electrical Generating Capacity	5.0	MW
Nominal Turbine Heat Rate (HHV)	13,164	Btu/kWh
Nominal CHP Efficiency	66.3	%
Maximum Unfired Hot Water Production	22.4	MMBtu/hr
Additional Fired Hot Water Production	25.7	MMBtu/hr

Table 6-2: MERCURY 50 w/ Duct Fired HRU

Maximum Electrical Generating Capacity	5.1	MW
Nominal Turbine Heat Rate (HHV)	9,951	Btu/kWh
Nominal CHP Efficiency	65.5	%
Maximum Unfired Hot Water Production	10.5	MMBtu/hr
Additional Fired Hot Water Production	32.6	MMBtu/hr

Table 6-3: JENBACHER 624 w/ HRU

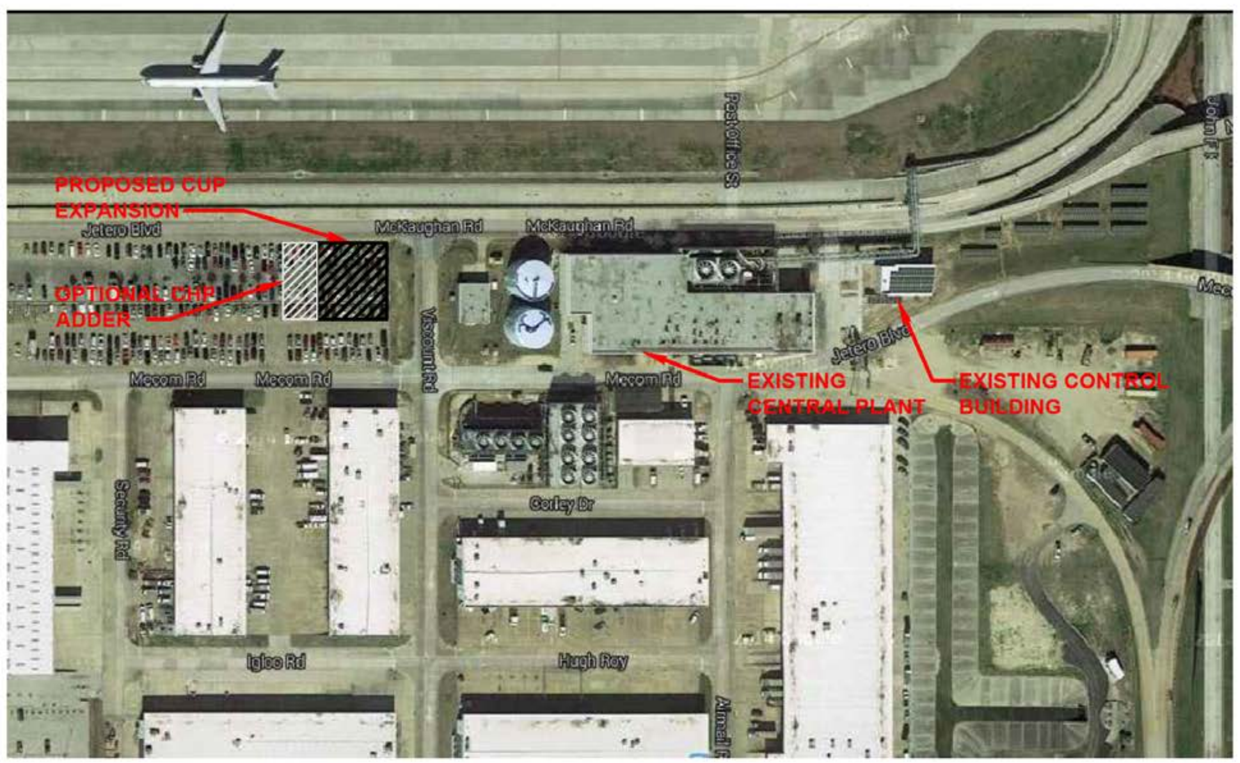
Maximum Electrical Generating Capacity	4.3	MW
Nominal Engine Heat Rate (HHV)	7,401	Btu/kWh
Nominal CHP Efficiency	89.3	%
Maximum Total Hot Water Production	13.9	MMBtu/hr

* Nominal calculations completed at 55 F

Duct-firing is limited to the turbine generator exhausts because the excess air in the reciprocating engine by Jenbacher does not produce the same level of excess oxygen in the exhaust as its turbine counterparts. The electrical and thermal output for each prime mover was estimated across a range of loads (50-100%) and a range of ambient temperatures, corresponding to those experienced in Houston, TX. These outputs were used to calculate an hourly load profile for the prime mover throughout the year, as well as the excess hot water and electrical demand.

A proposed location for the CHP system is shown below. The proposed location is assumed to be additional square footage to the CUP Expansion option discussed in the Central Plant Expansion section above. The additional space would house the prime mover, HRU, electrical equipment and auxiliary mechanical equipment.

Figure 6-1 Combine Heat and Power Plant Expansion



ASSUMPTIONS

The calculations for this analysis were based on the assumptions listed below. Assumption are based on data provided by HAS.

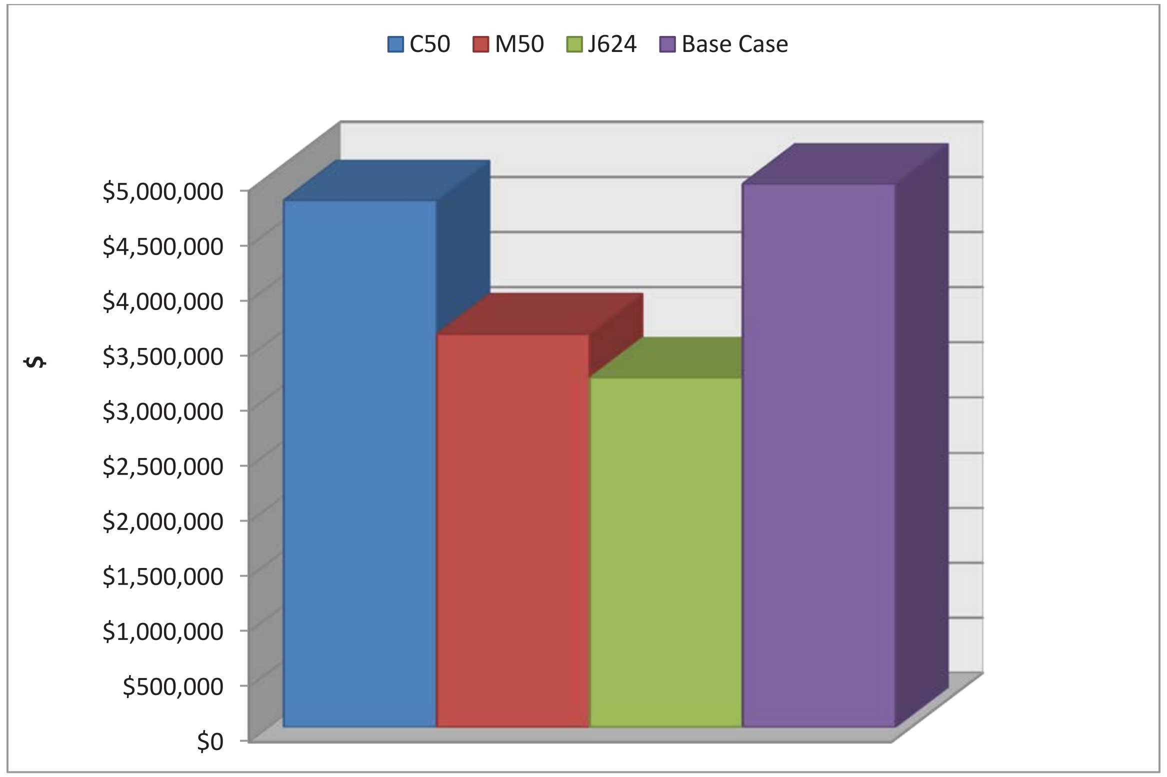
1. Thermal heating loads were developed based on the data provided by IAH

   a. Hourly Loads for the entire month of January, 2013 were provided.
   b. Hourly Loads for a select day were provided for several other months
   c. Hourly Loads for the remaining days in the month were assumed to be constant with the loads provided.
   d. Loads from the surrounding months were averaged for those without provided loads
2. Minimum Airport electrical load: 6MW
3. Natural gas costs: $5.17 per MMBTU
4. Grid electricity rate: $0.084 per kWh
5. Excess hot water load is supplied by an 83% efficient (HHV) boiler
6. Hourly Temperature data follows a Typical Meteorological Year (TMY) in Houston Bush Intercontinental
7. The prime mover is turned off if the hot water load is below the minimum turn down of 50% of the un-fired HRU capacity.
8. Supplemental power is supplied by the grid.

RESULTS

All three options where analyzed based on annual utility cost savings. Annual utility cost savings were compared to the base case cost, in which the entire 6 MW load would be satisfied by grid electricity and the entire hot water demand would be supplied by a boiler. Figure 6-2 compares the total annual utility cost for each prime mover compared to the base case.

Figure 6-2: Total Annual Utility Cost Based on 6 MW Load



The incremental annual cost savings compared to the base case are shown in Figure 6-3. Each prime mover has a lower annual cost than the base case, and the J624 has the largest savings at $1.8 million per year.

Figure 6-3: Total Annual Savings

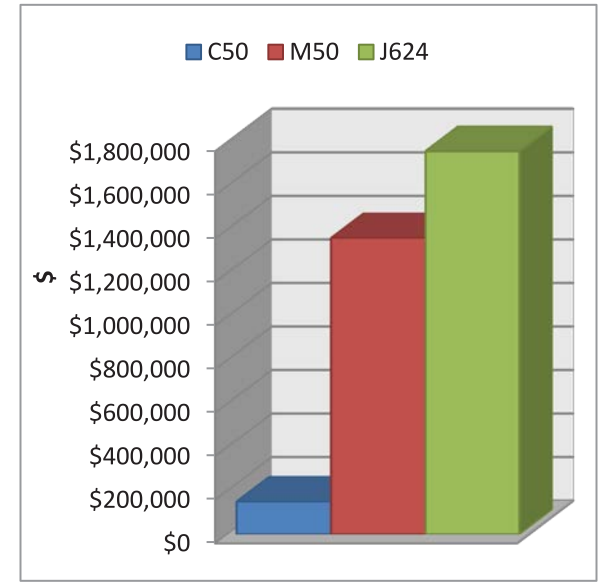


Figure 6-4: Total Annual MWh Produced

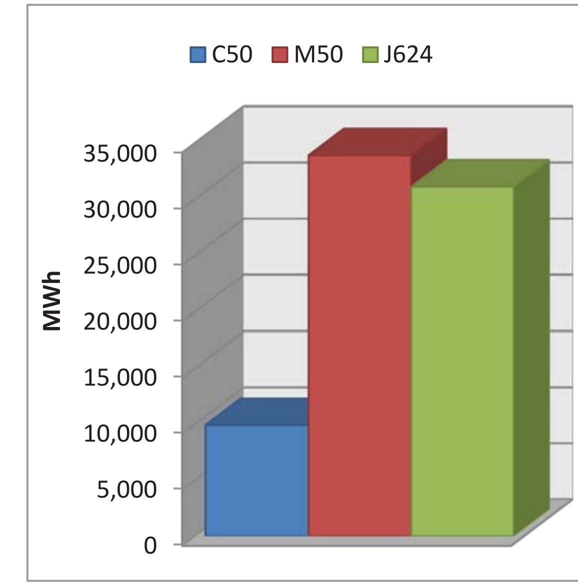
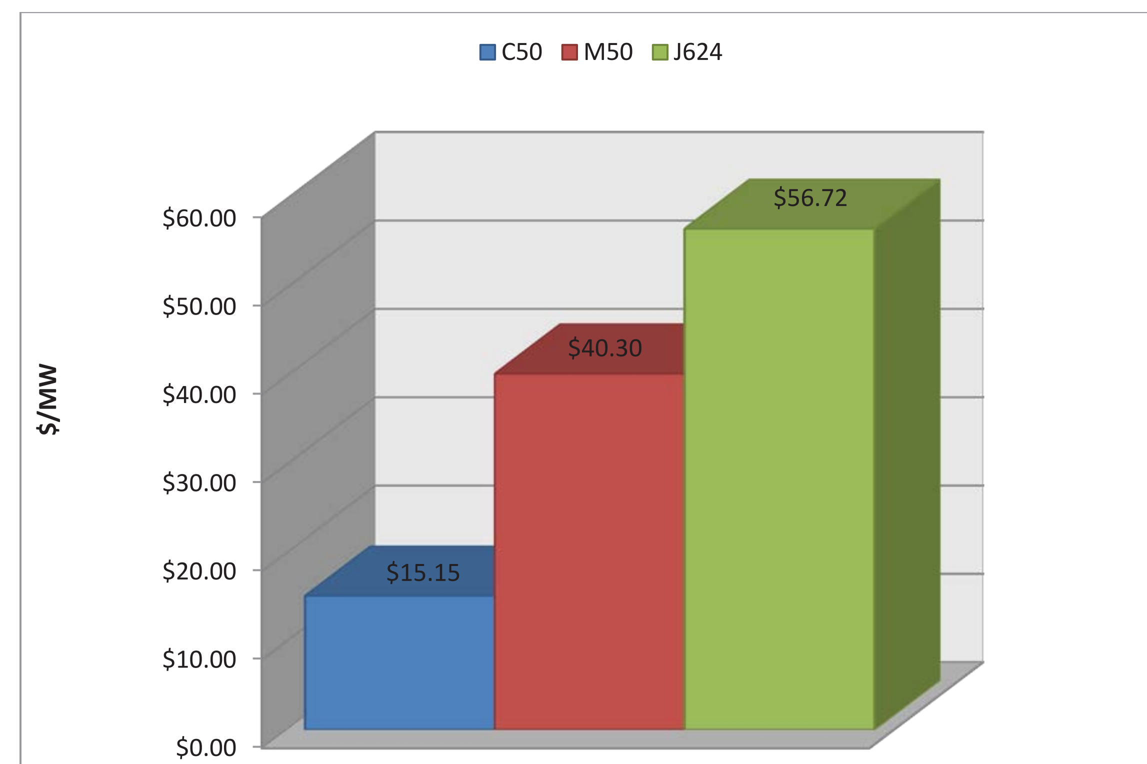


Figure 6-5: CHP Annual Utility Savings per MW Generated



	Additional Annual Fuel Costs	Annual Electrical Savings	Total Utility Savings	Savings/MW	Annual O&M Costs **	ROM Costs $MM	Simple Payback, Yrs
C50	$640,583	$829,005	$188,422	$19.03	$324,000	$15.5	N/A
M50	$1,447,975	$2,837,181	$1,389,206	$40.99	$468,000	$17.7	19
J624	$818,236	$2,604,678	$1,786,442	$57.41	$386,000	$11.5	8

**All cost/savings are incremental to the Base Case*
***Annual O&M costs are based on Long Term Service Agreements (LTSA) to cover the maintenance of the prime mover.*

The results show that the J624 and the M50 were significantly better options then the C50. This is attributed to their higher ratios of thermal to electricity outputs for equivalent fuel consumptions.

Although the C50 can produce the largest amount of electricity and heat, its annual production is the least amount of the three options, seen in figure 4-3, resulting in the lowest amount of savings per MW. The hot water demand was below the C50's minimum load 71 percent of the year, resulting in non-utilization during that time.

The M50 load was also limited by the hot water demand 32 percent of the year, but was not turned off for any significant period of time resulting in the highest capacity factor of the three.

Despite the J624 having a lower overall hot water capacity than the M50, it was limited more by the hot water demand because of its minimum hot water load. Despite its decreased run time, it has the largest amount of savings per year and savings per MW.

For each option the Airport electricity demand is reduced while the natural gas demand is increased but each prime mover analyzed showed net annual utility costs savings. These results show that CHP could be a viable option and is recommended for a detailed analysis. A detailed analysis would include developing a capital cost estimate for each option and evaluating the life cycle costs.

In addition to providing cost savings for power and hot water production, two of the three CHP options are estimated to also provide CO_2 reductions according to the table below. The Centaur 50 option does not provide a carbon offset due to its poor heat rate unlike the Mercury 50 and Jenbacher 624. Options offsetting local grid CO_2 production may be eligible for receiving carbon credits. However, without full knowledge of the Airport's air permits, conclusion of the effect of CHP carbon dioxide emissions cannot be made.

Table 6-4: Calculated CO_2 Emissions

		Base Case	Centaur 50	Mercury 50	Jenbacher 624
Typical Emissions Rates					
*Utility Equivalent Generation	lb/MWh	1,223	1,223	1,223	1,223
CHP Production	lb/MMBtu		117	117	117
Operating Profiles					
**Utility Generation Required	MWh	54,137	45,561	20,852	23,713
CHP Fuel Consumption	MMBtu	0	136,580	345,572	233,341
Annual Emissions Totals					
Annual Equivalent CO_2 Emissions	Tons	30,032	32,523	29,908	25,539
Equivalent CO_2 Reduction (Regional)	**Tons**		**-2,491**	**125**	**4,494**
Automobile Reduction	**cars**		**-453**	**23**	**816**

*Based on eGRID 2010 ERCOT subregion
**Includes 3% distribution loss

CHAPTER 7 - ELECTRICAL INFRASTRUCTURE

In 2013, Jacobs Engineering completed an assessment of the electrical infrastructure at George Bush Intercontinental Airport (IAH). The assessment was completed under Houston Airport Systems (HAS) 715B-LOA-008. The condition assessment evaluated the entire electrical infrastructure from the Center Point Energy service point at the Terminal transformers to the 480V distribution panels. Based on findings in the condition assessment, the Jacobs study provided rough order of magnitude (ROM) equipment costs for deficient items. The following discussion utilizes the findings from the Jacobs's condition assessment to develop an overall project phasing plan to effectively correct the deficiencies while minimizing downtime and providing an overall ROM project costs. All equipment costs utilize those provided in the Jacobs study. The project phasing cost estimates utilize the following assumptions:

- Miscellaneous Costs – 25%
- Contingency – 40%
- Indirect – 9%
- Engineering - 8%

All recommended projects are grouped and title as provided in the Jacobs study. Additional details, beyond those provided below, to each recommendation can be found in the Jacobs study.

TERMINAL A

Terminal A was originally constructed and opened in 1969. After opening there have been several renovations to reconstruct the north and south concourses. The Terminal was built for the operations of several airlines such as; Air Canada, United, Alaska, American, Delta, Frontier, Spirit, and US Airways. Inside the Terminal building there are various upscale retail and restaurant shops in each concourse.

The main source of power supplied to the Terminal A Core Building is originated at CenterPoint's Basement Level Vault with two 12.47kV-480/277V transformers serving a switchgear lineup with a Main-Tie-Tie-Main configuration. From CenterPoint, auto transfer switches (ATO) are used to feed each transformer and used to allow the service to transfer between the two different 12.47kV distribution lines.

From the assessment report, the Terminal A electrical equipment and distribution system was installed in 1969 and has exceeded its anticipated operation life. Although the equipment is currently operational and

in fair condition, it is recommended to replace all outdated equipment. The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs. Additional details for each Project Phase are provided below.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Terminal A North Concourse Automatic Transformer Load Study and Upgrade if Required	2A
	2	Terminal A Core Building Switchgear Replacement	1A
	3	Code Issues and Other Deficiencies for Repairs	All
Near Term	4	Terminal A Core Building Electrical Distribution Panel Refurbishment	1A
	5	Terminal A Core Building Manual Transfer Switches	1A
Long Term	6	Terminal A North Concourse Switchgear Replacement	2A
	7	Terminal A South Concourse Switchgear Replacement	3A

** Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs*

Project 1A

- **Terminal A Core Building Switchgear Replacement (Priority)**
  - **Electrical Distribution Panel Refurbishment (Near Term)**
  - **Manual Transfer Switches (Near Term)**

Overview

Most of the electrical equipment in the Core building has served beyond its life expectancy and is recommended for replacement. The replacement of electrical distribution equipment includes switchgear, distribution panels, feeders, and branch panels with the exception of the ones that were upgraded in the1999 renovation. In Terminal A core building there are two main switchgears; AC-MSGA1 and AC-MSGA2.

In an event of an electrical failure on one side of the switchgear, there are critical loads within the building that cannot lose power for a long period of time. Ideally the system would utilize manual transfer switches and be able to select and transfer critical loads to another reliable source.

Phasing Plan

Replacing the Terminal A Core Building switchgear is considered a Priority recommendation due to overall age (44 years) and limitations of spare and available parts for maintenance and repairs. Replacing the two main switchgears would require downtime for those loads downstream of the switchgear. This downtime should also be utilized to replace or refurbish the electrical distribution and distribution panels on this circuit. To minimize the downtime, the two switchgears and associated distribution should be replaced in an alternating phase. There are many branch circuits used to serve the public areas, but replacement of these circuits would have to be prolonged until tenant retrofits occur. As long as the circuits are not supplying critical loads and it is not essential to have continuous power, the branch circuits serving those non-critical loads can be upgraded along with the replacement of Terminal A core building electrical distribution panel refurbishment. A short circuit analysis was performed on Terminal A at the 480V level and from the results of the analysis, not all of the equipment has sufficient short circuit rating compared with the calculated fault current. The items that are listed as having insufficient short circuit rating should be replaced by new ones with adequate short circuit ratings. When replacing insufficient short circuit panels and outdated panels, the replacements should also be grouped by common service entrance point.

Additionally installation of the new switchgear should be in parallel with manual transfer switches. Manual transfer switches provide a quick and fast transfer of critical loads within two sides of switchgear. Before a manual transfer switch can be implemented in the system, HAS must determine all the critical loads within Terminal A. Upon completion of the critical load list, it is important to check if all the critical loads are balanced between the two sides of the switchgear. During an event of power outage in one side of switchgear, the manual transfer switches can be used to distribute all the critical loads to the second side of the switchgear. The execution of the transfer switches for the critical loads can be worked together with the upgrade of electrical distribution panel refurbishment. The importance of the implementation would be balancing of selected critical equipment between the two sides of the switchgear to maintain critical services in the event of electrical failure on one side.

Additional items can be considered as minor issues such as; repair missing dead fronts, repair previous damage, label breakers, label panel schedules, repair corrosions. These are all include in the overall phasing estimate.

Cost Estimation

For Project 1A, the total renovation cost is approximately $2,560,580. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the repairs and

replacements required due to deficiencies as indicated in the tables and additional construction and programing costs associated with replacing the switchgear and associated distribution components. The total costs shown are not inclusive of any redesign or rearrangement of electrical equipment or non-electrical equipment that is a result of code compliance.

Table 7-1 Terminal A - Project 1A ROM Costs

Item	ROM Costs
Distribution Panels and Panels	$144,309
Switchgear	$1,098,630
Subtotal	$1,242,939
Misc	$310,735
Subtotal	$1,553,674
Contingency	$621,470
Subtotal	$2,175,144
Indirect	$195,763
Subtotal	$2,370,907
Engineering	$189,673
Total	$2,560,580

Project 2A

- **Terminal A North Concourse Automatic Transformer Load Study and Upgrade if Required (Priority)**
    - **Terminal A North Concourse Switchgear Replacement (Long Term)**

Overview

In order for redundancy to work within the system, one side of the equipment must be able to handle the full load of the whole system in case a failure occurs in the other side of the system. A 14-month peak load report obtained from the electrical utility transformer indicated a peak load of 678KVA of the first transformer rating and a peak load of 740KVA on the second transformer. The total peak loads of two transformers are 1418KVA which equals to 95 percent of one transformer rating. With these loads the transformer redundancies may be compromised with less than five percent of additional load growth.

Additionally, the current switchgear lineup configuration in Terminal A North Concourse is a Main-Tie-Main. The downfall of the configuration is not permitting for operation of one half of the switchgear lineup during repair of the other half of the switchgear lineup. When there is a future upgrade in the switchgear lineup, it is best to have a main-tie-tie-main configuration. The proposed configuration allows for full isolation between the two switchgear lineups and isolation and de-energization of any one lineup through the times of repair and maintenance.

Phasing Plan

It is important for CenterPoint to evaluate the load history on the utility transformers providing supplemental 480V power to the Terminal A North Concourse. Once the load history has been verified, if the transformers are reaching peak capacity, CenterPoint must upgrade the utility transformers. The new utility transformers should be sized to sustain redundancy for feeder loads and still have room for future growth.

The upgrading of utility transformers can be combined with the replacement of switchgear configuration. The new switchgear will be a Main-Tie-Tie-Main with barriers, and arc flash protection to facilitate isolation of switchgear sections for service. Also, a set of dual transformers will be used for redundant utility service to the switchgear. Dependent on the available open space for new transformers and switchgear, these can potentially be installed prior to the full removal of existing transformers and switchgear, minimizing downtime. However, if the transformers require replacement in place, the switchgear and all replacements on the common service point should be replaced in parallel.

From the results of the analysis not all equipment installed has sufficient short circuit ratings compared with the calculated fault current. The items that are listed as insufficient short circuit ratings in the Jacobs study will be replaced by new ones with adequate short circuit ratings. When replacing insufficient short circuit panels, the panels can be grouped with the same service entrance point. In Terminal A North Concourse, there are three switchgears that are in need of attention; AN-SWGR1A, AN-SWGR1B, and AN-SWGR2A. The defective feeder panels are recommended to be categorized by the service entrance switchgear and split into different work groups.

Some of the items identified in the Jacobs study can be considered as minor issues such as; repair missing dead fronts, repair previous damage, label breakers, label panel schedules, repair corrosions. The tables below show the grouping of the panels according to their service entrance point along with panels that have minor deficiencies.

Cost Estimation

The total renovation cost for Project 2A is approximately $2,338,520. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the repairs and replacements required due to deficiencies as indicated in the tables and additional construction and programing costs associated with replacing the switchgear and associated distribution components. The

total costs shown are not inclusive of any redesign or rearrangement of electrical equipment or non-electrical equipment that is a result of code compliance.

Table 7-2 Terminal A - Project 2A ROM Costs

Item	ROM Costs
Distribution Panels and Panels	$36,519
Switchgear	$1,098,630
Subtotal	$1,135,149
Misc	$283,787
Subtotal	$1,418,936
Contingency	$567,574
Subtotal	$1,986,511
Indirect	$178,786
Subtotal	$2,165,296
Engineering	$173,224
Total	$2,338,520

Project 3A

- **Terminal A South Concourse Switchgear Replacement (Long Term)**

Overview

The switchgear lineup configuration in Terminal A South Concourse is Main-Tie-Main. This configuration permits manual ties during the times of transformer failure or transfer switch failure and allows for continued service of the loads on redundant transformers. The negative side of the configuration is not permitting for operation of one half of the switchgear lineup during repair of the other half of the switchgear lineup. For future replacement in the switchgear lineups, it is best to have a Main-Tie-Tie-Main scheme. The proposed configuration allows for full isolation between the two switchgear lineups and isolation and de-energization of any one lineup through the times of repair and maintenance.

Phasing Plan

For a scheduled repair or maintenance on switchgear, the safest way to handle the situation would be de-energization of both halves of the switchgear lineup or provide electrical and physical isolations from the risk of arc flash while the a busway is energized during operation. The new switchgear will be a Main-Tie-Tie-Main with barriers, and arc flash protection to facilitate isolation of switchgear sections for service. Also, a set of dual transformers will be used for redundant utility service to the switchgear. The replacement of the switchgear should be done in phases; De-energization of the switchgear needs to be done in sections.

A short circuit analysis was performed on Terminal A at the 480V level. From the results of the analysis not all equipment installed has sufficient short circuit ratings compared with the calculated fault current. The items that are listed as insufficient short circuit ratings will be replaced by new ones with adequate short circuit ratings. When replacing insufficient short circuit panels, the panels can be grouped with same service entrance point. In Terminal A South Concourse, there are two switchgears that are in needs of attention; AS-SWGR1A and AS-SWGR2A. The defected feeder panels will be categorized by the service entrance switchgear and split into different work groups.

Some of the items from the Jacobs study can be considered as minor issues such as; repair missing dead fronts, repair previous damage, label breakers, label panel schedules, repair corrosions.

Cost Estimation

Current deficiency cost for Project 3A is approximately $1,161,030. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the repairs and

replacements required due to deficiencies as indicated in the tables and additional construction and programing costs associated with replacing the switchgear and associated distribution components. The total costs shown are not inclusive of any redesign or rearrangement of electrical equipment or non-electrical equipment that is a result of code compliance.

Table 7-3 Terminal A - Project 3A ROM Costs

Item	ROM Costs
Distribution Panels and Panels	$14,264
Switchgear	$549,315
Subtotal	$563,579
Misc	$140,895
Subtotal	$704,474
Contingency	$281,789
Subtotal	$986,263
Indirect	$88,764
Subtotal	$1,075,027
Engineering	$86,002
Total	$1,161,030

TERMINAL B

According to the electrical infrastructure assessments, Terminal B was one of the initially constructed Terminals at IAH, but only minor renovations have occurred in the late 1990s and early 2000s. Many of the electrical systems and equipment have reached its maximum life and are in needs of being upgraded.

The main source of power supplied to the Terminal B Core Building is originated at CenterPoint's Basement Level Vault with six 500KVA 277V transformers. Three single-phase 277V transformers are arranged in a wye configuration for a 1500 KVA, three-phase, four-wire wye 277V/480V electrical service transformer. The two 1500 KVA transformers are configured in parallel for redundancy. As the load on the building has increased the building load has exceeded the capacity of one transformer bank and both transformer banks are required to support the current load. The 14-month peak load history from the electrical utility indicated a peak load in August 2012 of 2199 KVA. The peak load corresponds to a 73 percent of the transformer rating with both transformers in service in the normal configuration but corresponds to 147 percent of the transformer rating with only one transformer in service confirming that the transformers are not currently redundant.

From the assessment report, Terminal B electrical distribution system and equipment were installed in 1990 and are approaching 25 years of operation. Even though the equipment is currently operational and mostly in fair condition; it is recommended that they should be replaced in the near future for safe practice.

Planning for the Terminal B renovation would occur in phases while keeping downtime as minimum as possible. Some electrical items that are needed to be address for immediate attention and there are others can be done in the near future.

From the assessment report, the Terminal A electrical equipment and distribution system was installed in 1969 and has exceeded its anticipated operation life. Although the equipment is currently operational and in good condition, it is recommended to replace all outdated equipment. The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs. Additional details for each Project Phase are provided below.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Flight Station 6 Transformer Load Study and Upgrade	2B
	2	Terminal B Core Building Vault and Switchgear Replacement	1B
	3	Code Issues and Other Deficiencies for Repairs	1B
Near Term	4	Critical Equipment Manual Transfer Switches	1B
	5	Replacement of Terminal B Core Building Aging Electrical Infrastructure	1B
Long Term	6	Replacement of Flight Station Aging Electrical Infastructure	3B
	7	Replacement of Flight Station Switchgear	3B

** Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs*

Project 1B

- **Terminal B Core Building Vault and Switchgear Replacement (Priority)**
    - **Replacement of Terminal B Core Building Aging Electrical Infrastructure (Near Term)**
    - **Critical Equipment Manual Transfer Switches (Near Term)**

Overview

In Terminal B, a majority of the electrical equipment has reached or served beyond its anticipated service life and is in need of replacement; such as switchgear and electrical distribution, distribution panels, busways, feeders, and branch panels.

Currently, the electrical service to the Terminal B core building is a single bus with a main switchgear line up. The main switchgear is a single lineup located in the tunnel level of the main electrical room and does not include a dual main or tie breakers. In order to provide redundancy to the system, there needs to have dual transformers and dual selector switches and upgrade the building switchgear to Main-Tie-Tie-Main configuration. New proposed utility automatic transfer switches (ATO) will be servicing the new transformers as the main source. In a case of electrical failure with the primary source, the ATOs would be switched to a secondary service and be powered from an alternative source. The new 480V switchgear breakers shall include (a) dual settings for relays during normal operating and maintenance settings for reduced arc flash energy when maintenance control switches are activated, (b) Draw out breakers for closed door operation of equipment draw-out and remote operation of breaker operation and breaker draw-out, (c) arc flash resistant switchgear with pressure venting provisions, and (d) infrared inspection ports.

In an event of electrical failures on one side of the switchgear, there are critical loads within the building that cannot lose power for a long period of time; a manual transfer switch can be used to switch loads between sides. It would be ideal if the system can provide manual transfer switches and be able to select and transfer critical loads to another reliable source.

Phasing Plan

In order for Terminal B core building electrical distribute system to have redundancy; there shall be dual transformers along with dual sector switches and replace existing switchgear with Main-Tie-Tie-Main configuration. The transformers would be supplied from a utility automatic transfer switch with two sources coming from separate substations for redundancy. The new transformers would have a rating that can handle maximum peak load and still have room for future expansion. The main switchgear in the switchgear room is in conflict with current electrical code requirements, and with the new switchgear configuration the current room space will not have adequate room space. A new location or expansion of switchgear room is needed. Once the new switchgear has been built in its new location, electrical loads from the old switchgear can be transferred one at a time without causing massive power outage in Terminal B.

During the process of upgrading the switchgear configuration, other upgrades can be incorporated. There are many branch circuits used to serve the public areas but these circuits would have to be prolonged until tenant retrofits occur. For non-public areas, as long as the circuits are not supplying critical loads and it is not essential to have a continuous power, the branch circuits can be upgraded along with the electrical panels.

The purpose of a fault analysis is to determine the magnitudes of the currents present during the fault and finding the maximum current to ensure devices can survive the fault. A short circuit analysis was performed on Terminal B core building at the 480V level. From the result of the analysis not all equipment installed has sufficient short circuit ratings compared with the calculated fault current. For all the items that are listed as insufficient short circuit will be replaced by new ones with adequate short circuit rating. When replacing insufficient short circuit panels, the panels can be grouped with same service entrance point. In Terminal B core building, switchgear MSGR is the main switchgear supplying the feeder loads. All the defective feeder panels under MSGR can be replaced along with the upgrade of main switchgear.

For a quick and fast transfer of critical loads within two sides of switchgear, a manual transfer switch is preferred. Before a manual transfer switch can be implemented in the system, HAS must determine all the

critical loads within Terminal B. Upon completion of critical load list, it is important to check if all the critical loads are balanced between two sides of switchgear. During an event of power outage in one side of switchgear, one can use the manual transfer switch to distribute all the critical loads to the second side of the switchgear. The execution of the transfer switches for the critical loads can be worked together with the upgrade of Main-Tie-Tie-Main switchgear. The importance of the implementation would be balancing of selected critical equipment between the two sides of the switchgear to maintain critical services in the event of electrical failure in one side.

There are some deficiencies in the Jacobs study that were noted with minor issues such as; repair corrosion, repair missing dead fronts, breakers locked or tagged out, repair previous damage, label breakers, label panel schedules, repair corrosions. These miscellaneous deficiencies are recommended to be fixed along with panel replacements.

Cost Estimation

For Project 1B, the total renovation cost is approximately $1,047,135. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the repairs and replacements required due to deficiencies as indicated in the tables and additional construction and programing costs associated with replacing the switchgear and associated distribution components. In this project renovation, there are many items have failed the short circuit rating which are in need of panel replacement and other adjustments needed for miscellaneous items. The total costs shown are not inclusive of any redesign or rearrangement of electrical equipment or non-electrical equipment that is a result of code compliance.

Table 7-4 Terminal B - Project 1B ROM Costs

Item	ROM Costs
Distribution Panels and Panels	$216,808
Switchgear	$291,484
Subtotal	$508,292
Misc	$127,073
Subtotal	$635,365
Contingency	$254,146
Subtotal	$889,512
Indirect	$80,056
Subtotal	$969,568
Engineering	$77,565
Total	$1,047,135

Project 2B

- **Flight Station 6 Transformer Load Study and Upgrade (Priority)**
  - **Flight Station 6 Switchboard DP Not in Compliance with NEC Code (Priority)**

Overview

In Flight Station 6, there is a need for the CenterPoint to review electrical load history on the utility transformer feeding the supplemental 480V power to Terminal B Flight Station 6. The supplemental electrical service is a pad-mounted 750KVA, three-phase, four wire wye 277V/480V electrical service transformer. A 14-month peak load report obtained from the electrical utility transformer indicated a peak load in July 2012 of 785KVA. The excess load exceeds the transformation and corresponds to a 105 percent of the transformer rating. Each of the two switchboards can handle up to 1600 amps, and 785KVA equivalents to 944 amps. The utility pad mounted transformer is feeding two secondary feeders to two main distribution switchboards. According to NEC 230.71 (a), there shall be not more than six sets of disconnect per service grouped in any one location. Currently, the main distribution switchboard DP does not have a main breaker and there are seven distribution breakers installed which exceeded the maximum allowable service disconnecting means.

Phasing Plan

It is important for CenterPoint to evaluate the load history on the utility transformer providing supplemental 480V power to the Terminal B Flight Station 6. Once the load history has been verified, if the transformer is reaching peak capacity, CenterPoint must upgrade the utility transformer. The new utility transformers shall be designed that will be able to provide redundancy for feeder loads and still have room for future growth.

In order to be compliance with NEC, the main distribution switchboard DP needs to have a main circuit breaker installed. Since there is no main circuit breaker in the switchboard, a disconnecting mean will need to be installed before the switchboard. A planning phase has to be developed in order to have minimum down time as possible. The best recommended time for installation of the main disconnect would be when the utility is upgrading the existing 750KVA transformer, a time coordination has to be make between HAS and CenterPoint. In order to have equipment in an electrically safe work situation, it involves a number of steps, includes isolating the electrical supply from the loads, locking it off, and taking measurements to verify that the system is de-energized. A location for the new disconnect has to be verified first, and the location has to be compliance with NEC code. Once the utility powered down the power to the transformer, all power supplying switchboards DP and DPN-A, and panel HB will be turned off. Dependent on the importance of the powered down loads, an alternative power source might be needed to supply those loads. A temporary power generator can be used to supply the DP-1600A feeder

loads. In Flight Station 5, there is equipment in need of attention and the work can be combined with Flight Station 6.

There are some deficiencies that were noted with minor issues such as; repair corrosion, repair missing dead fronts, breakers locked or tagged out, repair previous damage, label breakers, label panel schedules, and repair corrosions. These miscellaneous deficiencies are recommended to be fixed along with panel replacements.

Cost Estimation

Current deficiency cost for Project 2B is approximately $29,875. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the repairs and replacements required due to deficiencies as indicated in the tables. For distribution panel DP-1600A to be in compliance with NEC code, there is a need for an installation of main disconnect. The cost of main disconnect is not associated within the deficiency table provided in the Jacobs study, since a further detailed investigation is required. The total cost does not include the cost for transformer replacement and should be covered by Centerpoint. The total costs shown are not inclusive of any redesign or rearrangement of electrical equipment or non-electrical equipment that is a result of code compliance.

Table 7-5 Terminal B - Project 2B ROM Costs

Item	ROM Costs
Distribution Panels and Panels	$14,501
Switchgear	$-
Subtotal	$14,501
Misc	$3,625
Subtotal	$18,126
Contingency	$7,250
Subtotal	$25,377
Indirect	$2,284
Subtotal	$27,661
Engineering	$2,213
Total	$29,875

Project 3B

- **Replacement of Flight Station Switchgear (Long Term)**
  - **Replacement of Flight Station Aging Electrical Infrastructure (Long Term)**

Overview

The current 480V main switchgear in the flight stations does not provide redundancy within the system. For the electrical system to be serviced as redundant; the switchgear has to be upgraded to a Main-Tie-Tie-Main configuration, with dual transformers and auto transfer switches. The proposed configuration allows full isolation between the two switchgear lineups and isolation and de-energization of any one lineup through the times of repair and maintenance.

For flight stations within Terminal B, for the time being most of the major electrical equipment are in good standing of expectancy service life but it is vital to have a replacement plan when the time comes. Electrical distribution replacement includes electrical distribution panels, busway, feeders, and branch panels. It is recommended to coordinate replacement with future construction. Terminal expansion to the north of the B Core building is expected in the Long Term phases discussed in the UMP. The expansion will require removal of the Terminal B Flight Station.

Phasing Plan

For Terminal B switchgear upgrade, it is important for HAS to determine all the critical loads within the Terminal and distributed between the switchgear lineups. When there is an event of failure in one side of the switchgear, the transfer of the loads can be done between the two sides of the switchgear to maintain critical services. During the process of upgrading the switchgear, other work can be incorporated along with it such as replacement of aged electrical distribution. There are many branch circuits used to serve the public areas but these circuits would have to prolong it until tenant retrofit occurs. For non-public areas, as long as the circuits are not supplying critical loads and it is not essential to have a continuous power. The branch circuits serving those non-critical loads can be upgraded along with the electrical panels.

Reliability is an important factor for achieving a sustainable power source especially in a case of Airport Terminal operations. During the process of the flight station switchgear is being upgraded, one must consider all the critical loads involves within the flight stations. The critical services to consider are; e.g. lighting, critical cooling air handling units, sum pumps, sewage ejectors, chilled water pumps, and other infrastructure required for continued operation. In the case of where continuous power is essential to the load, a backup generator can be used to deliver power directly to the electrical system. Also, with the new switchgear configuration, the switchgear room must have enough available space to fit the equipment and meet NEC code with working space clearance.

Cost Estimation

To provide a cost estimation of the project, a farther detailed investigation would be needed. In the electrical assessment report, not all relevant information was provided and there were no cost involved with the switchgear replacement. Also, with the installation of new switchgear configuration, space availability might be an issue so redesign of the facility may be required at additional cost.

TERMINAL E

Terminal E was originally constructed by Continental and has had multiple expansions and additions. In 2002, building renovations started on Terminal E and Federal Inspection Services (FIS). After the renovation, the building expanded to almost 800,000 square feet and United Airlines was added to the addition.

CenterPoint supplies dual transformers at Terminal E with 12.47KV-480/277V rating serving a switchgear lineup with a main-tie-main configuration. Each of the transformers is fed from different substations for redundancy purpose. The two transformers are served with manual transfer switches permitting the transfer of service between two different 12.47kV distribution lines.

The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs. Additional details for each Project Phase are provided below.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Egress Door Panic Hardware	1E
	2	Other Deficiencies for Repairs	2E
Long Term	3	Main-tie-Tie Main Switchgear	3E
	4	Arc Flash Resistant Switchgear	3E
	5	Manual Transfer Switches	3E

** Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs*

Project 1E

- **Egress Door Panic Hardware (Priority)**

Overview

At each of the switchgear rooms within Terminal E, there are violations of the NEC code. Most of the violations involve not meeting minimum space requirements and egress door panic hardware not installed. For all personnel doors intended for entrance to and egress from shall have panic hardware installed along with it. The doors in the switchgear rooms did not meet that requirement.

Phasing Plan

The current switchgear rooms' personnel doors do not comply with the NEC code. According to NEC Article 110.26 (C) (3); where equipment is rated 800A or more that contains overcurrent devices, switching devices, or control devices and there is a personnel door(s) intended for entrance to and egress from the working space less than 25 feet from the nearest edge of the working space, the door(s) shall open in the direction of egress and be equipped with panic hardware. On the personnel doors there shall be panic hardware installed to be in compliance with the code.

Cost Estimation

The total renovation cost for Project 1E is approximately $1,550. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the installation of egress panic hardware as indicated in the tables.

Project 2E

- **Deficiencies for Repairs (Priority)**

Overview

Several deficiencies have been highlighted that need to be addressed that are a result of a failed short circuit analysis.

Phasing Plan

The purpose of a fault analysis is to determine the magnitudes of the currents present during the fault and finding the maximum current to ensure devices can survive the fault. A short circuit analysis was performed on Terminal E at the 480V level. The outcome of the analysis is that not all equipment is able to withstand the maximum fault current within the system when comparing the ratings and calculated ratings. All the items that are listed as insufficient short circuit will be replaced by new ones with adequate short circuit rating. When replacing insufficient short circuit panels, the panels can be grouped via same service entrance point. In Terminal E, there are total of four main switchgears and each with two

sides; MSB1A, MSB1B, MSB2A, MSB2B, MSB3A, MSB3B, MSB4A, and MSB4B. The defected feeder panels are recommended to be categorized by the service entrance switchgear and split into different work groups.

There are some deficiencies in the Jacobs study that were noted with minor issues such as; repair corrosion, repair missing dead fronts, breakers locked or tagged out, repair previous damage, label breakers, label panel schedules and repair corrosions. These miscellaneous deficiencies are recommend to be fixed along with panel replacements.

Cost Estimation

The total renovation cost for Project 2E is approximately $208,735. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the repairs and replacements required due to deficiencies as indicated in the tables. In Project 1E, there are many items have violated the NEC code requirements, and most of the violations involved with lack of equipment clearance and not enough working space for electrical equipment. The total costs shown are not inclusive of any redesign or rearrangement of electrical equipment or non-electrical equipment that is a result of code compliance.

Table 7-6 Terminal E - Project 2E ROM Costs

Item	ROM Costs
Distribution Panels and Panels	$101,323
Switchgear	$-
Subtotal	$101,323
Misc	$25,331
Subtotal	$126,654
Contingency	$50,662
Subtotal	$177,315
Indirect	$15,958
Subtotal	$193,274
Engineering	$15,462
Total	$208,735

Project 3E

- **Main-Tie-Tie-Main Switchgear (Long Term)**
- **Arc Flash Resistant Switchgear (Long Term)**
- **Manual Transfer Switches (Long Term)**

Overview

In Terminal E, most of the electrical distribution equipment is in fairly good condition and there are no equipment identified as beyond its service life since the Terminal was constructed in the early 2000s.The current switchgear lineup configurations in Terminal E are Main-Tie-Main. In a Main-Tie-Main, the configuration permits manual ties during the times of transformer failure or automatic transfer switch failure and allow s for continued service of the loads on redundant transformers. The down fall of the configuration is not permitting for operation of one half of the switchgear lineup during repair of the other half of the switchgear lineup. When there is a future upgrade in the switchgear lineup, it is best to have a Main-Tie-Tie-Main configuration. The recommended configuration allows for full isolation between the two switchgear lineups and isolation and de-energization of any one lineup through the times of repair and maintenance. Arc flash resistant switchgear is recommended for future upgrade. All new switchgear is recommended to have breakers including (a) dual settings for relays for normal operating settings and maintenance settings for reduced arc flash energy when maintenance control switches are activated, (b) Draw out breakers for closed door operation of equipment draw-out and remote operation of breaker operation and breaker draw-out, (c) arc flash resistant switchgear with pressure venting provisions, and (d) infrared inspection ports.

In an event of an electrical failure on one side of the switchgear, there are critical loads within the building that cannot lose power for a long period of time; a manual transfer switch can be used to switch loads between sides. It would be ideal if the system can provide manual transfer switches and be able to select and transfer critical loads to another reliable source.

Phasing Plan

The replacement of Main-Tie-Tie-Main switchgear configuration is a recommendation for future upgrades and is not considered a priority since the current switchgear is in healthy condition and has good remaining service life. Whenever there is a scheduled repair or maintenance on switchgear, the safest way to handle the situation would be de-energization of both halves of the switchgear lineup or provide electrical and physical isolations from the risk of arc flash while with busway is energized during operation. The new switchgear will be a Main-Tie-Tie-Main with barriers, and arc flash protection to facilitate isolation of switchgear sections for service. Also, a set of dual transformers will be used for redundant utility service to the switchgear. The replacement of the switchgear should be prepared in

phases; De-energization of the switchgear needs to be done in sections. Since the current configuration is a Main-Tie-Main, which means one can shut off one side of the source and transfer the loads to the second side without exceeding the maximum transformer capacity. The second phase of the plan can be initiated after the completion of the first side of the switchgear lineup. For the second phase, the critical loads on the second side of the switchgear can be temporary transferred to the newly constructed switchgear. After the completion of Main-Tie-Tie-Main configuration, the loads in each lineup will have balanced loads between two sides of the switchgear.

For a quick and fast transfer of critical loads within two sides of switchgear, a manual transfer switch is preferred. Before a manual transfer switch can be implemented in the system, HAS must determine all the critical loads within Terminal E. Upon completion of critical load list, it is important to check if all the critical loads are balanced between two sides of switchgear. During an event of power outage in one side of switchgear, the manual transfer switch can be used to distribute all the critical loads to the second side of the switchgear. The execution of the transfer switches for the critical loads can be worked together with the upgrade of Main-Tie-Tie-Main switchgear. An important factor of the implementation would be balancing of selected critical equipment between the two sides of the switchgear to maintain critical services in the event of failure of one side.

Cost Estimation

To provide a cost estimation of the project, a farther detailed investigation would be needed. In the electrical assessment report, not all relevant information was provided and there were no cost involved with the switchgear replacement. Also, with the installation of new switchgear configuration, space availability might be an issue so redesign of the facility may be required at additional cost.

FIS BUILDING

The current Federal Inspection Services (FIS) building was renovated along with the Terminal E/Federal Inspection Services building upgrade. In 2002, HAS started the renovation phases and expanded to about 800,000 square feet. FIS building is used for international travelers' process through customs and immigration with the Customs and Border Protection. Also, the building serves as administrative offices, the connection points between Terminals D and E, and baggage handling equipment.

CenterPoint is the electrical service provider for the FIS Building. In the FIS Building, there are a total of four 2MVA 12.47kV-480/277V transformers feeding the electrical distribution. Each set of two transformers are serving a switchgear lineup with a Main-Tie-Main configuration. The incoming power sources are supplied from different substations to provide redundancy to the system. During the times of system failure from the incoming power source, transfer switches can be used to transfer between the two different 12.47kV distribution lines.

The following table summarizes the recommendations based on identified deficiencies from the Jacobs 2013 Condition Assessment. Each recommendation provided from the condition assessment is grouped into a recommended project phasing category. The recommended project phasing refers to a suggested project grouping to minimize downtime and overall project costs. Additional details for each Project Phase are provided below.

Recommendations		Description	Recommended Project Phasing*
Priority	1	Preventative Maintenance	1FIS
	2	Code Issues and Other Deficiencies for Repairs	1FIS
Long Term	3	Replace FIS Building switchgear of MTTM Configuration	2FIS

** Recommended Project Phasing refers to suggested project groupings to minimize downtime and overall project costs*

Project 1FIS

- **Preventative Maintenance (Priority)**
- **Code Issues and Other Deficiencies for Repairs (Priority)**

Overview

At the beginning of the maintenance program, all FIS Building equipment maintenance was completed by others, but all the testing were restricted with only construction testing. Thereafter, a preventive maintenance plan was developed by HAS but mostly limited to breaker testing.

At each of the switchgear rooms within FIS building, there are violations of the NEC code. Most of the violations involves with not meeting minimum space requirement and egress door panic hardware not installed. For all personnel doors intended for entrance to and egress from shall have panic hardware installed along with it. The doors in the switchgear rooms did not meet that requirement. Also, there are other issues need to be addressed such as repair or replacement of panels.

Phasing Plan

It is inevitable for electrical equipment to degrade over time. In order to maintain the value of the asset, an ongoing preventative maintenance of the electrical system should be constructed. Before equipment

has served 75% of the rated life, a replacement plan should have been implemented to replace components to prevent any major failures in the distribution system. A detailed preventive maintenance plan will evaluate the condition of the equipment and determine the most cost-effective and practicable solution to guarantee its overall performance, reliability and safety. Some typical equipment to be inspected includes but not limited to switchgear, circuit breakers, transformers, switches, etc.

The current switchgear rooms' personnel doors are not in compliance with the NEC code. According to NEC Article 110.26 (C) (3); where equipment is rated 800A or more that contains overcurrent devices, switching devices, or control devices are installed and there is a personnel door(s) intended for entrance to and egress from the working space less than 25 feet from the nearest edge of the working space, the door(s) shall open in the direction of egress and be equipped with listed panic hardware. On the personnel doors there shall be panic hardware installed to be in satisfy with the code.

The purpose of a fault analysis is to determine the magnitudes of the currents present during the fault and finding the maximum current to ensure devices can survive the fault. A short circuit analysis was performed on Terminal E at the 480V level. The outcome of the analysis is that not all equipment is able to withstand the maximum fault current within the system when comparing the rated and calculated ratings. For all the items that are listed as insufficient short circuit will be replaced by new ones with adequate short circuit rating. When replacing insufficient short circuit panels, the panels can be grouped with same service entrance point. In FSI Building, there are total of four main switchgears; MSA, MSB, MSC and MSD. Each of the switchgears is supplying a motor control center.

There are some deficiencies that were noted in the Jacobs study with minor issues such as; repair corrosion, repair missing dead fronts, breakers locked or tagged out, repair previous damage, label breakers, label panel schedules and repair corrosions. These miscellaneous deficiencies are recommended to be fixed along with panel replacements.

Cost Estimation

The total renovation cost for Project 1FIS is approximately $230,310. The equipment deficiency cost values were obtained from the electrical assessment report. The cost value includes the repairs and replacements required due to deficiencies as indicated in the tables. In Project 1FIS, there are many items have violated the NEC code requirements, and most of the violations involved with egress door panic hardware, lack of equipment clearance and not enough working space for electrical equipment. The total costs shown are not inclusive of any redesign or rearrangement of electrical equipment or non-electrical equipment that is a result of code compliance.

Table 7-7 Terminal FIS - Project 1FIS ROM Costs

Item	ROM Costs
Distribution Panels and Panels	$111,795.95
Switchgear	$-
Subtotal	$111,795.95
Misc	$27,948.99
Subtotal	$139,744.94
Contingency	$55,897.98
Subtotal	$195,642.91
Indirect	$17,607.86
Subtotal	$213,250.77
Engineering	$17,060.06
Total	$230,310

Project 2FIS

- **Replace FIS Building Switchgear for Main-Tie-Tie-Main Configuration (Long Term)**
  - **Arc Flash Resistant Switchgear (Long Term)**
  - **Manual Transfer Switches (Long Term)**

Overview

Within FIS Building, most of the electrical distribution equipment is in fairly good condition and there are no equipment identified as beyond its service life since the building was constructed in the early 2002.The current switchgear lineup configurations in FIS Building are Main-Tie-Main. In a Main-Tie-Main, the configuration permits manual ties during the times of transformer failure or automatic transfer switch failure and allow for continued of the loads on redundant transformers. The negative side of the configuration is not permitting for operation of one half of the switchgear lineup during repair of the other half of the switchgear lineup. For Project 2FIS, the switchgear replacement is not an urgent repair, but when there is a future renovation in the switchgear lineup, it is best to have a Main-Tie-Tie-Main configuration. The recommended configuration allows for full isolation between the two switchgear lineups and isolation and de-energization of any one lineup through the times of repair and maintenance. Arc flash resistant switchgear is recommended for future upgrade. All new switchgear is recommended to have breakers including (a) dual settings for relays for normal operating settings and maintenance settings for reduced arc flash energy when maintenance control switches are activated, (b) Draw out breakers for closed door operation of equipment draw-out and remote operation of breaker operation and breaker draw-out, (c) arc flash resistant switchgear with pressure venting provisions, and (d) infrared inspection ports.

In an event of electrical failures on one side of the switchgear, there are critical loads within the building that cannot lose power for a long period of time; a manual transfer switch can be used to switch loads between sides. It would be ideal if the system can provide manual transfer switches and be able to select and transfer critical loads to another reliable source.

Phasing Plan

For normal switchgear, it has been designed to withstand and deal with the issue of bolted faults, where the current peaks to an abnormal high level but is safely interrupted by the protective device contained in the equipment. However, most protective devices cannot detect and interrupt dangerous internal arcing faults, which have a low current level, but can generate a far more dangerous scenario for operating personnel. The arc-resistant switchgear protects operating and maintenance personnel from dangerous arcing faults by redirecting or channeling the arc energy out of the t of the switchgear, regardless of the origination location of the arc. The replacement of Main-Tie-Tie-Main switchgear configuration is a recommendation for future upgrades since the current switchgear is in healthy condition and has good remaining service life. Whenever there is a scheduled repair or maintenance on switchgear, the safest way to handle the situation would be de-energization of both halves of the switchgear lineup or provide electrical and physical isolations from the risk of arc flash while with busway energized during operation. The new switchgear will be a Main-Tie-Tie-Main with barriers, and arc flash protection to facilitate isolation of switchgear sections for service. Also, a set of dual transformers will be used for redundant utility service to the switchgear. The replacement of the switchgear should be prepared in phases; De-energization of the switchgear needs to be done in sections. Since the current configuration is a Main-Tie-Main, which means one can shut off one side of the source and transfer the loads to the second side without exceeding the maximum transformer capacity. The second phase of the plan can be initiated after the completion of the first side of the switchgear lineup. For the second phase, the critical loads on the second side of the switchgear can be temporary transferred to the newly constructed switchgear. After the completion of Main-Tie-Tie-Main configuration, the loads in each lineup will have balanced loads between two sides of the switchgear.

For a quick and fast transfer of critical loads within two sides of switchgear, a manual transfer switch is preferred. Before a manual transfer switch can be implemented in the system, HAS must determine all the critical loads within FIS Building. Upon completion of critical load list, it is important to check if all the critical loads are balanced between two sides of switchgear. During an event of power outage in one side of switchgear, one can use the manual transfer switch to distribute all the critical loads to the second side of the switchgear. The execution of the transfer switches for the critical loads can be worked together with the upgrade of Main-Tie-Tie-Main switchgear. The importance of the implementation would be balancing of selected critical equipment between the two sides of the switchgear to maintain critical services in the event of electrical failure in one side.

Cost Estimation

To provide a cost estimation of the project, a future detailed investigation would be needed. In the electrical assessment report, not all relevant information was provided and there were no cost involved with the switchgear replacement. Also, with the installation of new switchgear configuration, space availability might be an issue so redesign of the facility may be required at additional cost.

CHAPTER 8 - CONDITION ASSESMENT

EXISTING SYSTEM

IAH is served primarily by hot water and chilled water from the Central Utility Plant (CUP) located south of the Terminals along Jetero Blvd. The CUP consists of hot water and steam boilers, electric and steam driven chillers, and all ancillary equipment such as pumps and heat exchangers. Hot water and chilled water distribution headers serve the Terminals through an underground utility tunnel between the CUP and the Terminal B pump room. An additional above ground chilled water header serves the Terminals through a connection just west of Terminal C.

ASSESSMENT OF CHILLED WATER AND HOT WATER SYSTEM

The conducted assessment was based on observations regarding physical condition, operational reliability, and maintainability. Condition assessments are provided for the CUP major equipment and primary distribution headers between the CUP and the Terminals. This condition assessment is not an exhaustive list and only a summary of observations made on site visits and discussions with Comfort USA and IAH plant staff. Equipment and remaining service life information is presented in the previous sections.

Central Plant Chilled Water

The following equipment was noted as potential problems within the Central Plant chilled water system.

- CHP-5, CHP-6 – Out of Service (Site Visit 3/14)
    - CHP-5 and 6 are vertical turbine pumps installed in 2013. From discussions with Comfort USA, these motors have been sent out for repair three separate times since their isntallation. Although the pumps and motors are under warranty, this frequency of repair is abnormal and is causing IAH’s CUP more down time than expected.

Figure 8-1 CHP-5 Out of Service

- CHP-10 – Out of Service, cracked insulation (Site Visit 3/14)
  - As of March 2014, CHP-10 was taken out of service due to cracked insulation. Due to safety concerns, the insulation should be replaced or repaired prior to putting the pump back in service.

Figure 8-2 Cracked Insulation on CHP-10

- CT-3, CT-4 installed with wrong fill
  - From discussions with IAH and Comfort USA staff, the wrong fill was originally installed in CT-3 and CT-4 resulting in a decrease in performance. To achieve optimal performance the fill should be replaced according to the manufacturer's specifications or the cooling towers themselves replaced.

Figure 8-3 Wrong Fill in Cooling Towers

- Central Plant Controls System
  - The Central Plant operations staff has been experiencing internet problems which limits control of the internet based control system.

Central Plant Hot Water

The following equipment was noted as potential problems within the Central Utility Plant hot water system.

- Boilers 6-10 condensing issues
  - Through discussions with IAH and Comfort USA staff, Boilers 6-10 are experiencing major condensing issues. The condensing will cause severe corrosion within the boilers and ultimately shortening the useful life and efficiencies. The boilers are currently receiving a minimum return temperature of 155F, which is above the recommended 150F minimum to avoid condensing. Therefore, the issue is likely internal to the boilers. The boilers are currently under warranty and should be serviced to achieve optimal performance and increase their service life.

Figure 8-4 Condensing Issues in the Boilers

Distribution

The following items were noted as potential problems within the chilled water and hot water distribution systems.

- Sections of uninsulated chilled water and hot water pipe in utility tunnel between CUP and Terminal B Pump Room (most commonly at supports).
  - Uninsulated hot water segments lose excessive heat through the distribution system, thus serving as a source of inefficiency and increased boiler fuel consumption. In a low flow hot water scenario such as those seen in the summer, it was calculated that uninsulated piping may cause pipeline temperature drops of up to 0.2-.3 F°/100 ft. These pipeline losses due to lack of insulation are calculated to cost between $45.00 and $112.00/foot /year depending on the price of natural gas as shown in the table below:

Table 8-1 Fuel Savings Resulting from Insulating Distribution Network

	Fuel Costs	Insulation
	$/MMBTU	$/ft
	$5.17	$45.00
Percent Increase	+10%	$49.00
	+50%	$67.00
	+100%	$90.00
	+150%	$112.00

Figure 8-5 Missing Insulation in Tunnel Piping

- Water leaking into tunnel
  - This leakage is resulting in large sections of standing water as well as damage to piping insulation.

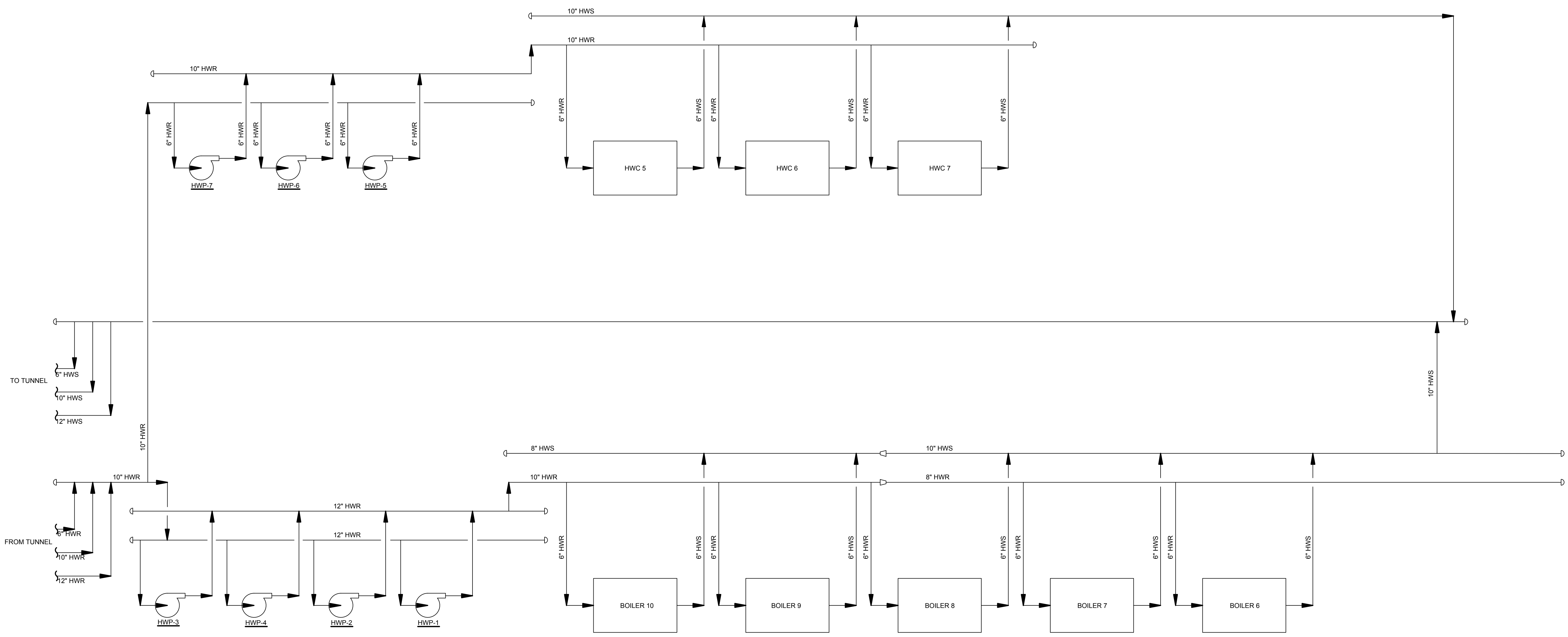
Figure 8-6 Deteriorating Insulation in Tunnel

Volume II
Appendix D

Bush Intercontinental Airport (IAH) Report

Appendix A

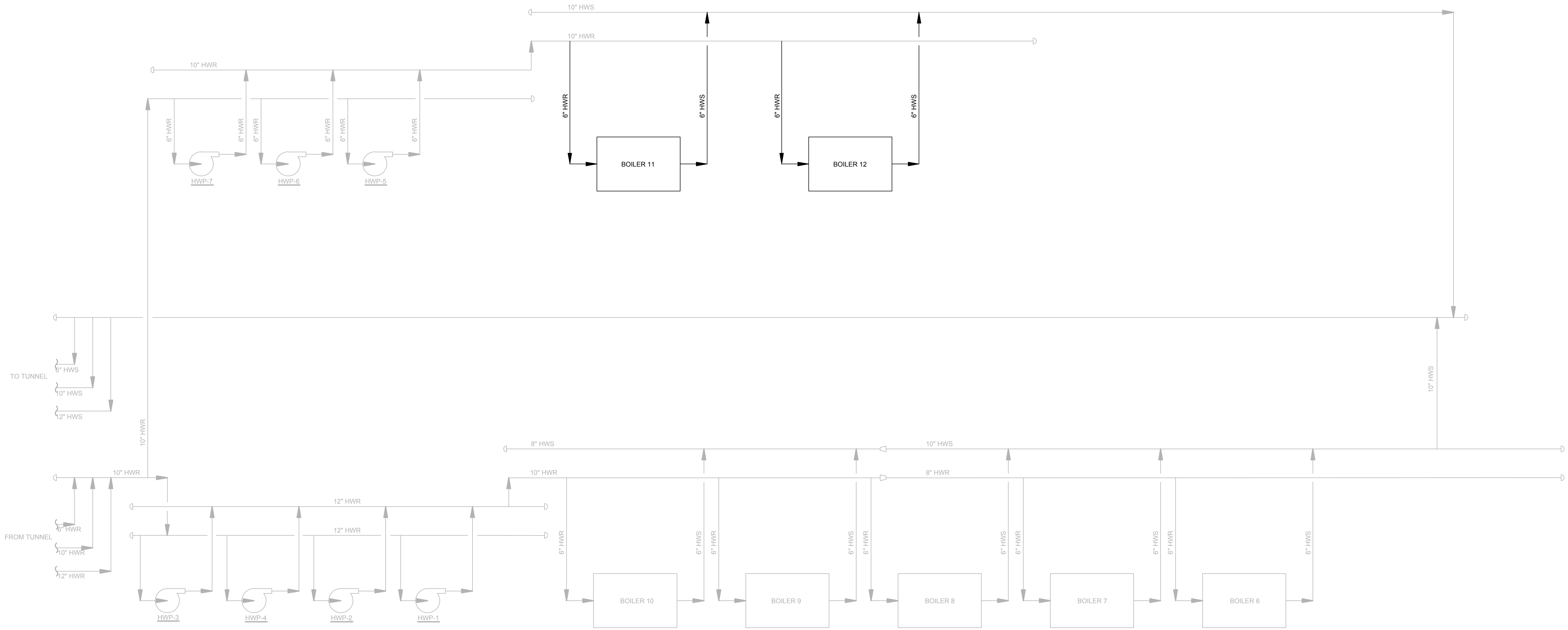
Hot Water Process Flow Diagrams



CENTRAL PLANT - HW EXISTING

HOUSTON AIRPORTS
HNTB

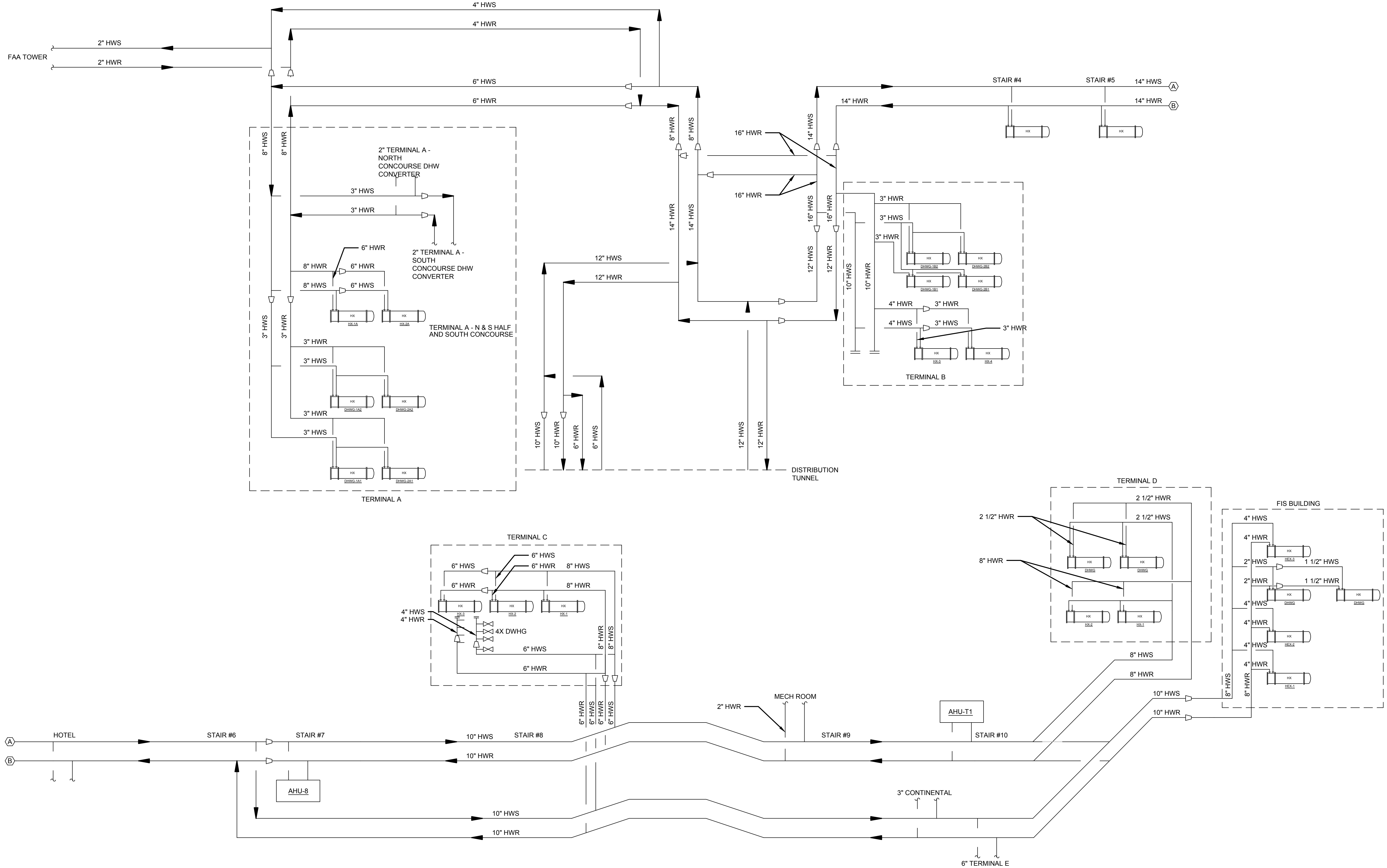
AUGUST 2014



CENTRAL PLANT - HW LONG TERM

HOUSTON AIRPORTS
HNTB

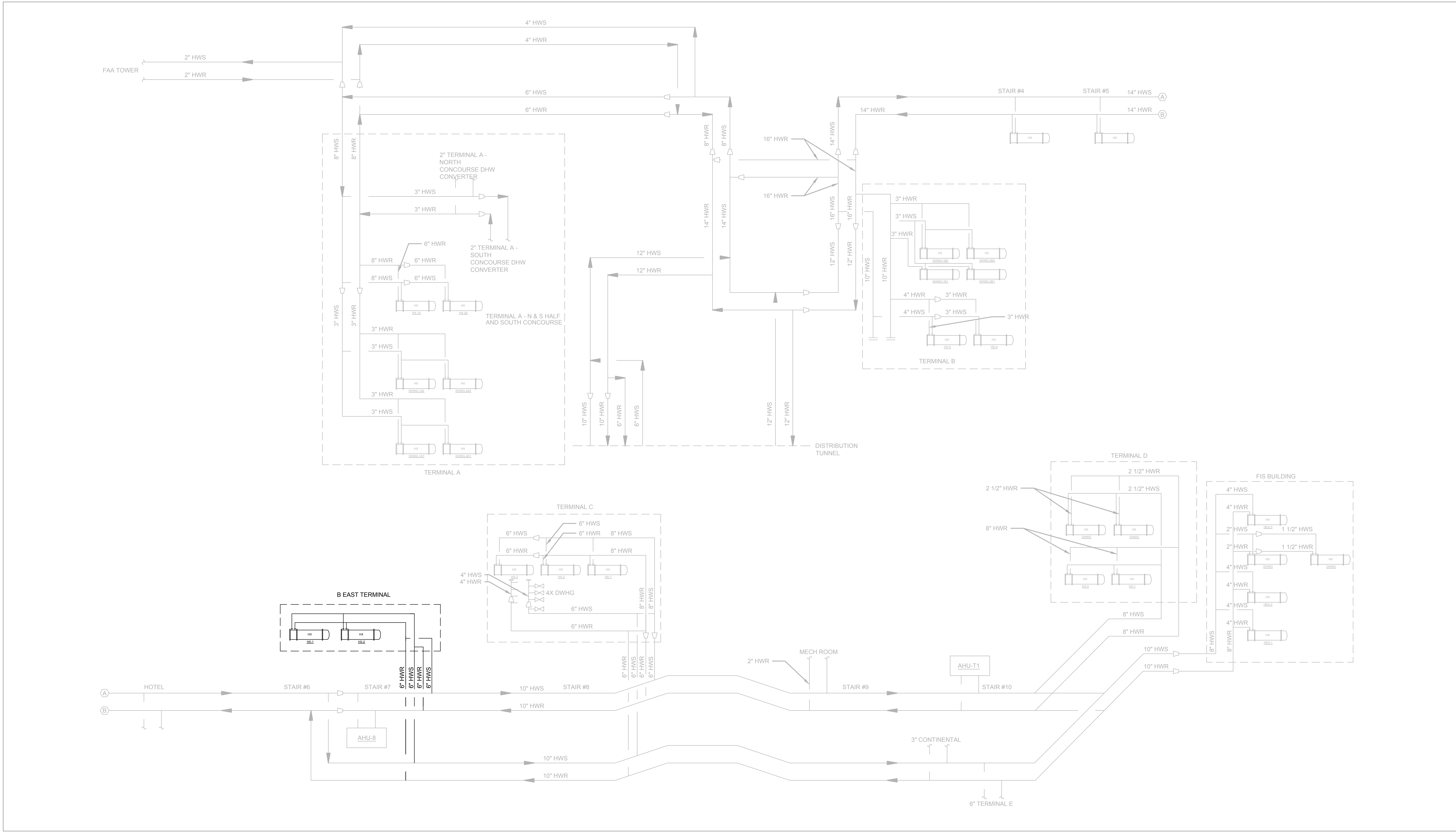
AUGUST 2014



DISTRIBUTION - HW EXISTING

HOUSTON AIRPORTS
HNTB

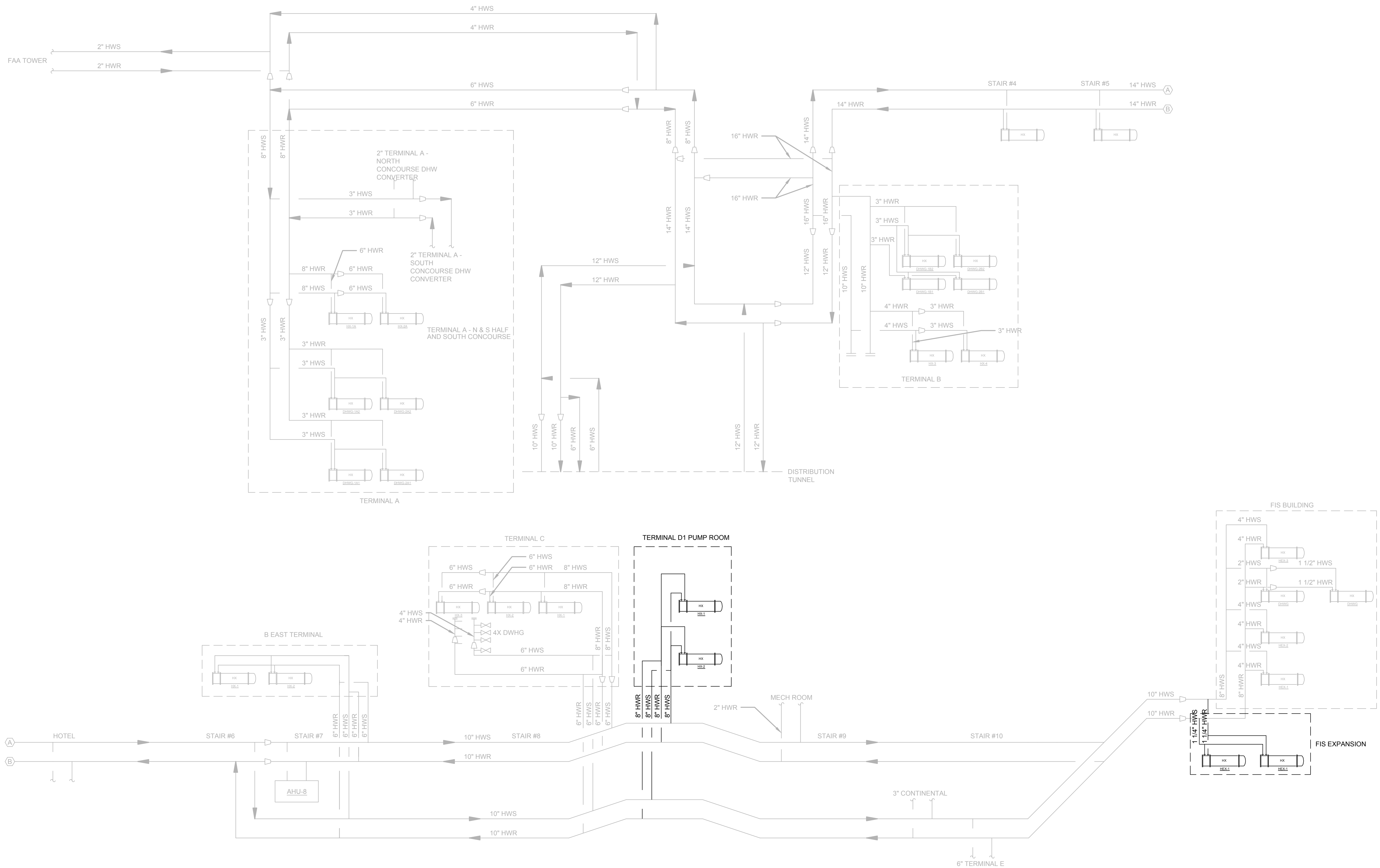
AUGUST 2014



DISTRIBUTION - HW SHORT TERM

HOUSTON AIRPORTS
HNTB

AUGUST 2014



DISTRIBUTION - HW BASE CASE

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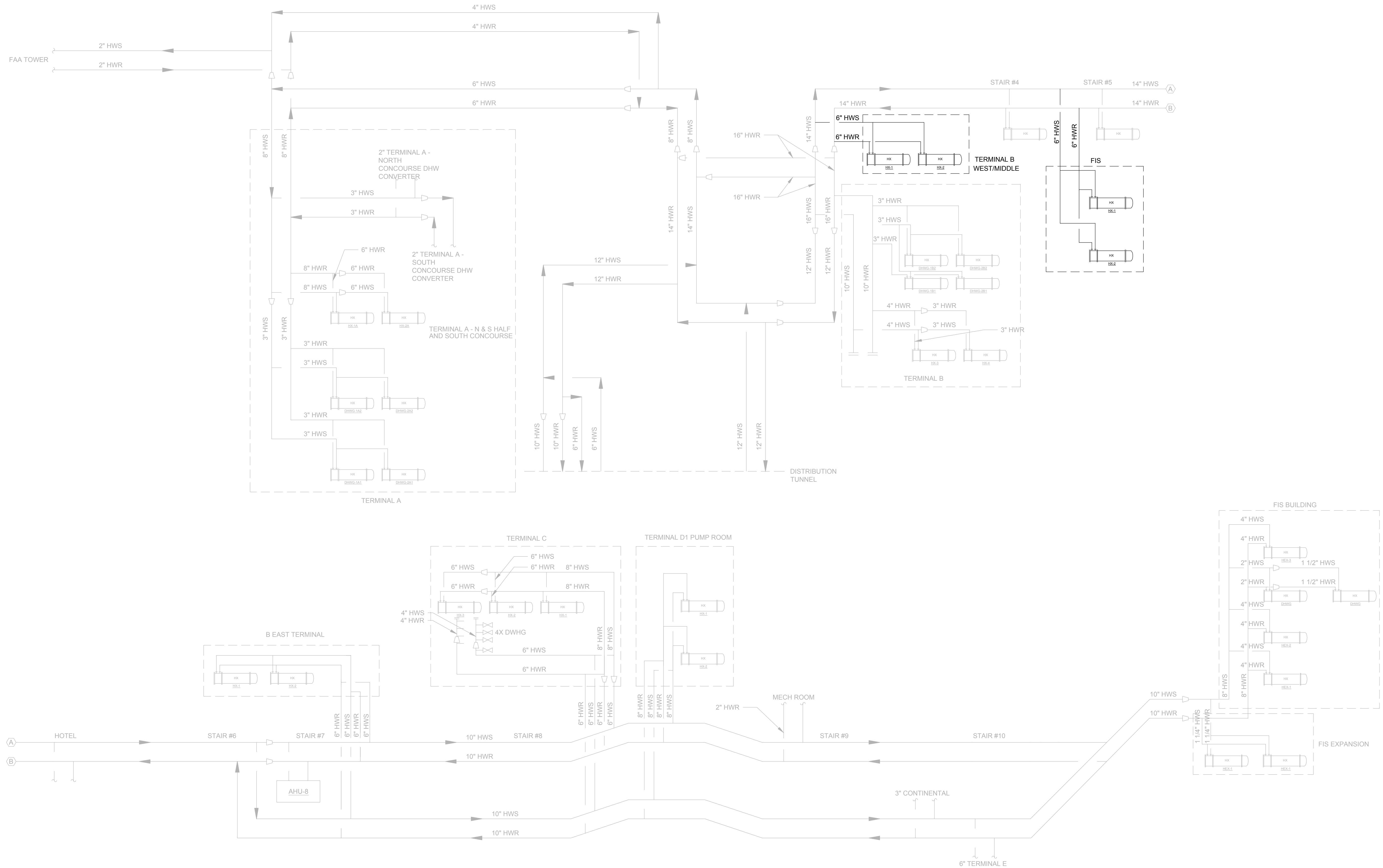

DISTRIBUTION - HW LONG TERM

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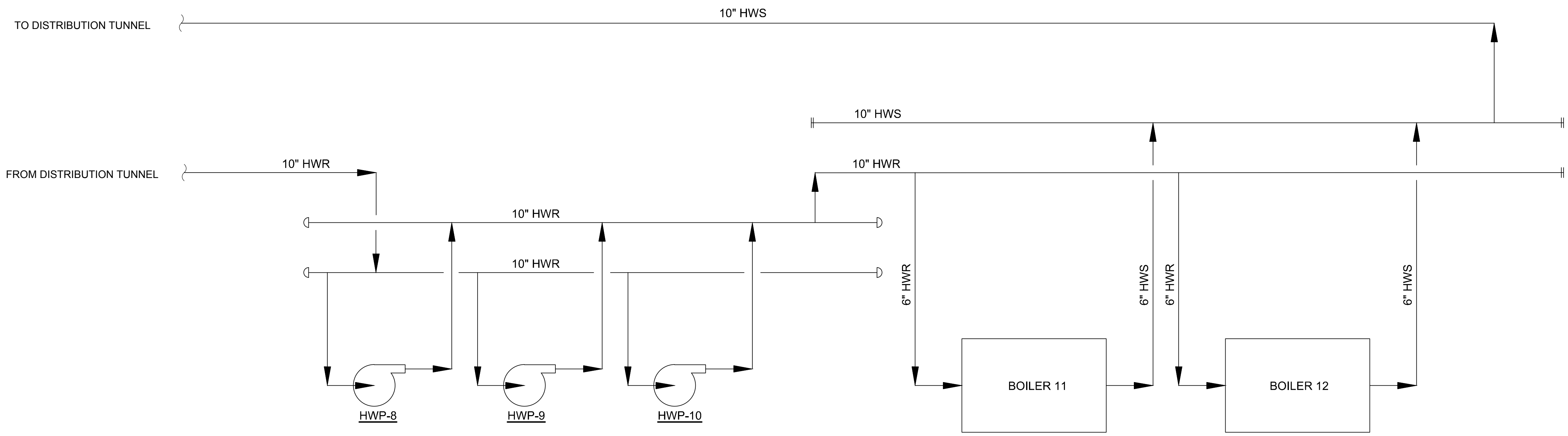
AUGUST 2014



SATELLITE PLANT- HW

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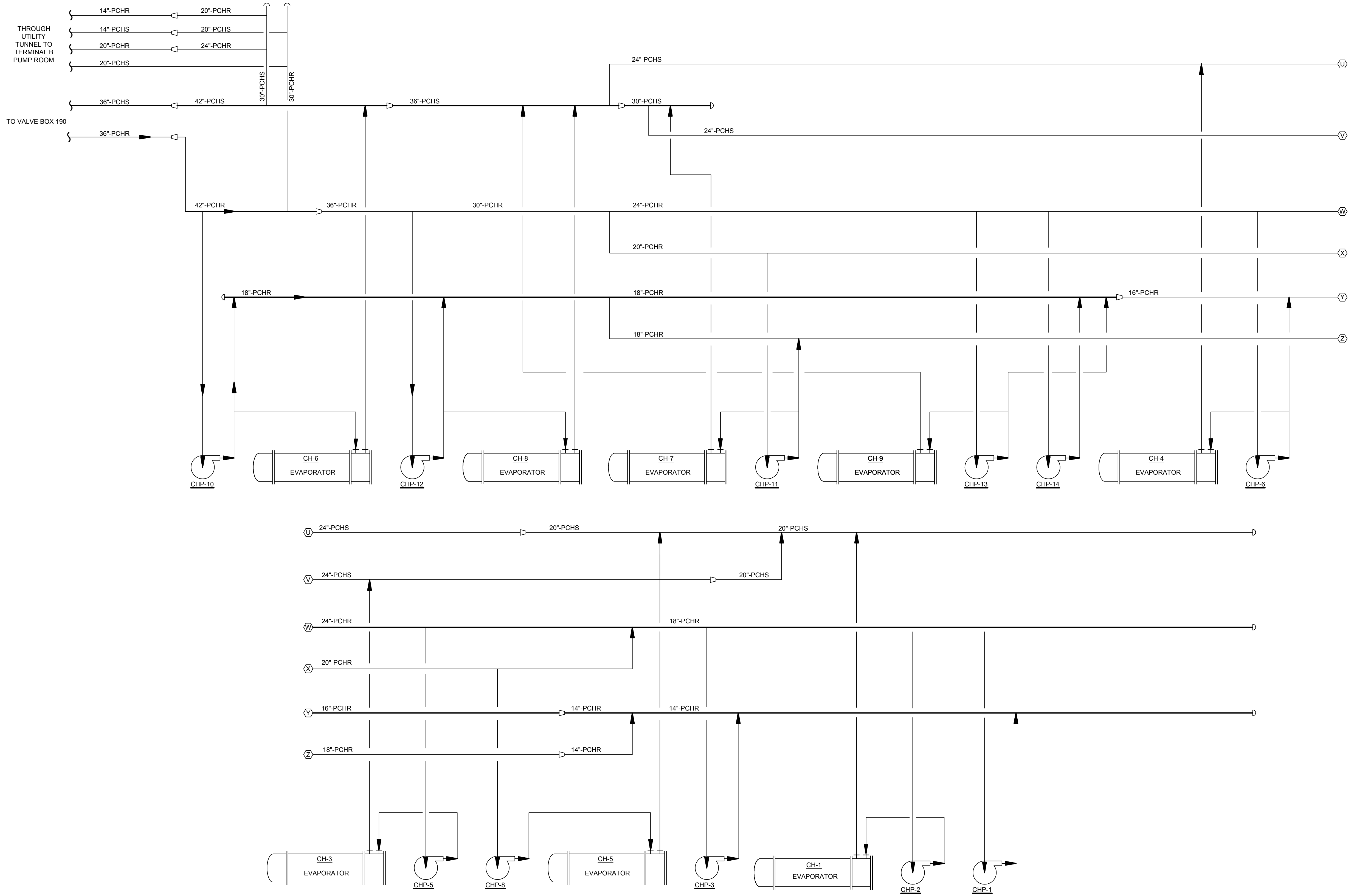
Volume II
Appendix D

Bush Intercontinental Airport (IAH) Report

Appendix B

CHW Process Flow Diagrams



CENTRAL PLANT - CHW EXISTING

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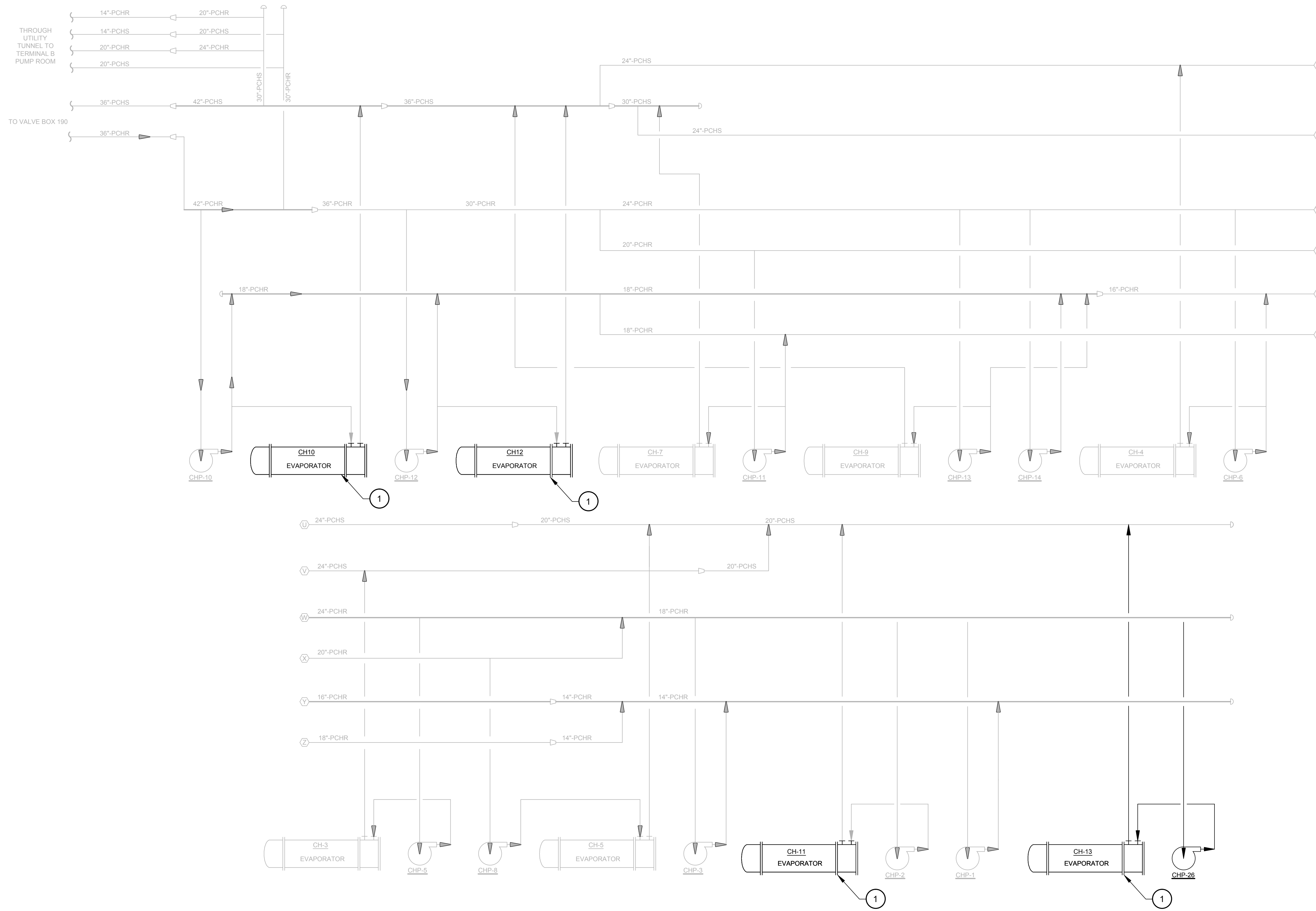
NOTE:
1. ONLY CHILLERS INSTALLED AS NEW CAPACITY OR REPLACEMENT OF STEAM DRIVEN CHILLERS WITH ELECTRICAL CHILLERS ARE SHOWN BOLD FOR CLARITY.



CENTRAL PLANT - CHW LONG TERM

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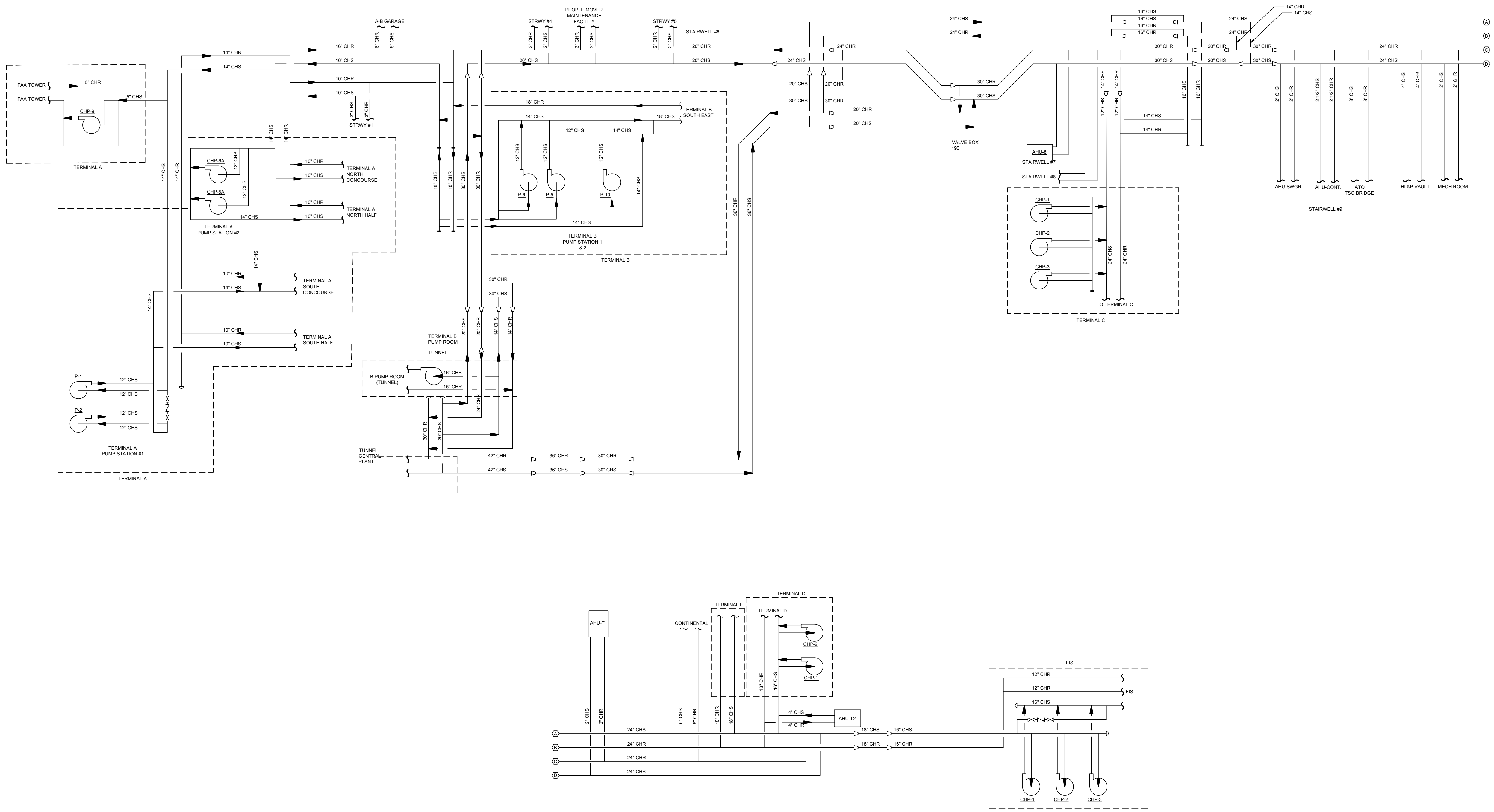

DISTRIBUTION - CHW EXISTING

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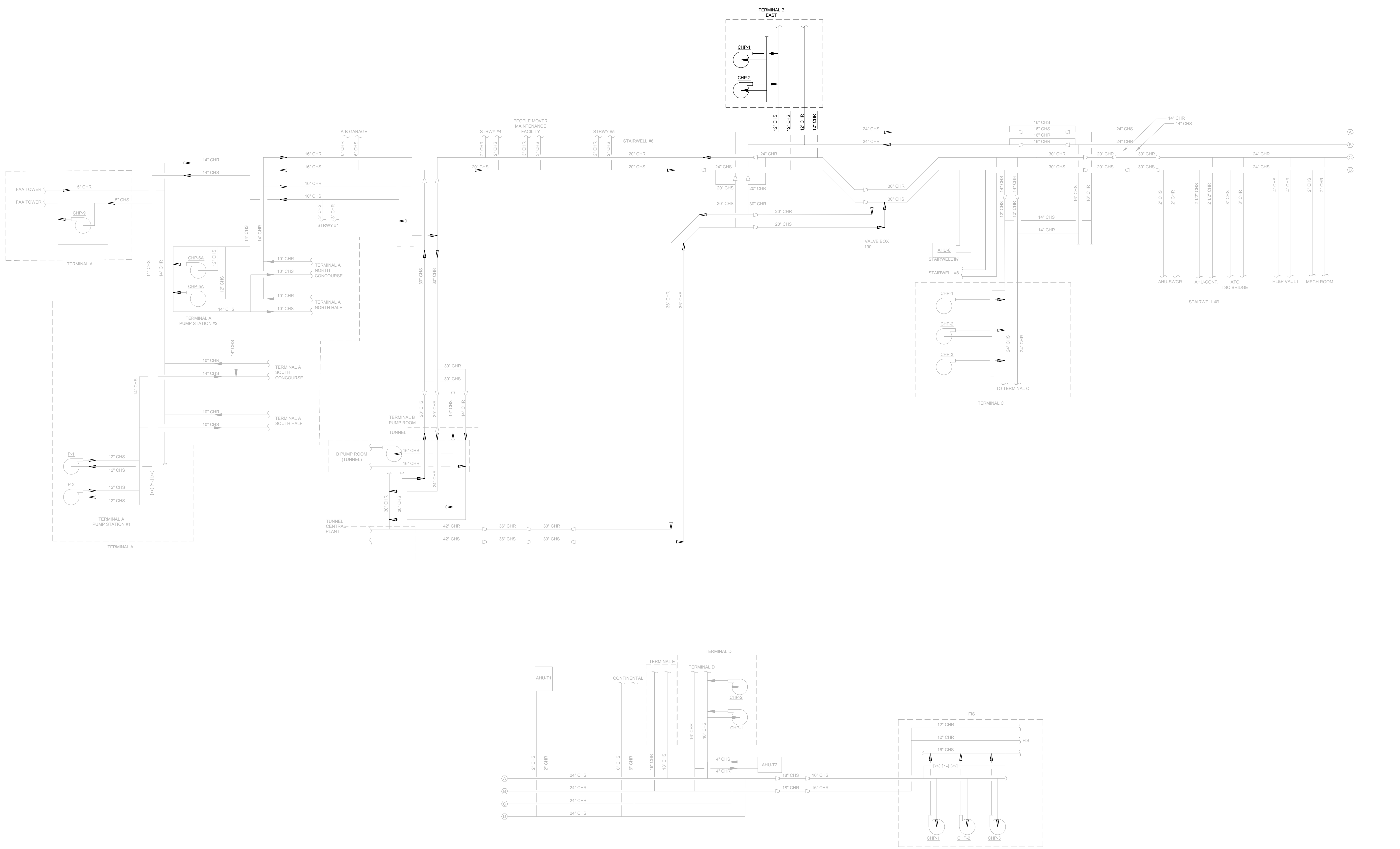
AUGUST 2014



DISTRIBUTION - CHW SHORT TERM

HOUSTON AIRPORTS
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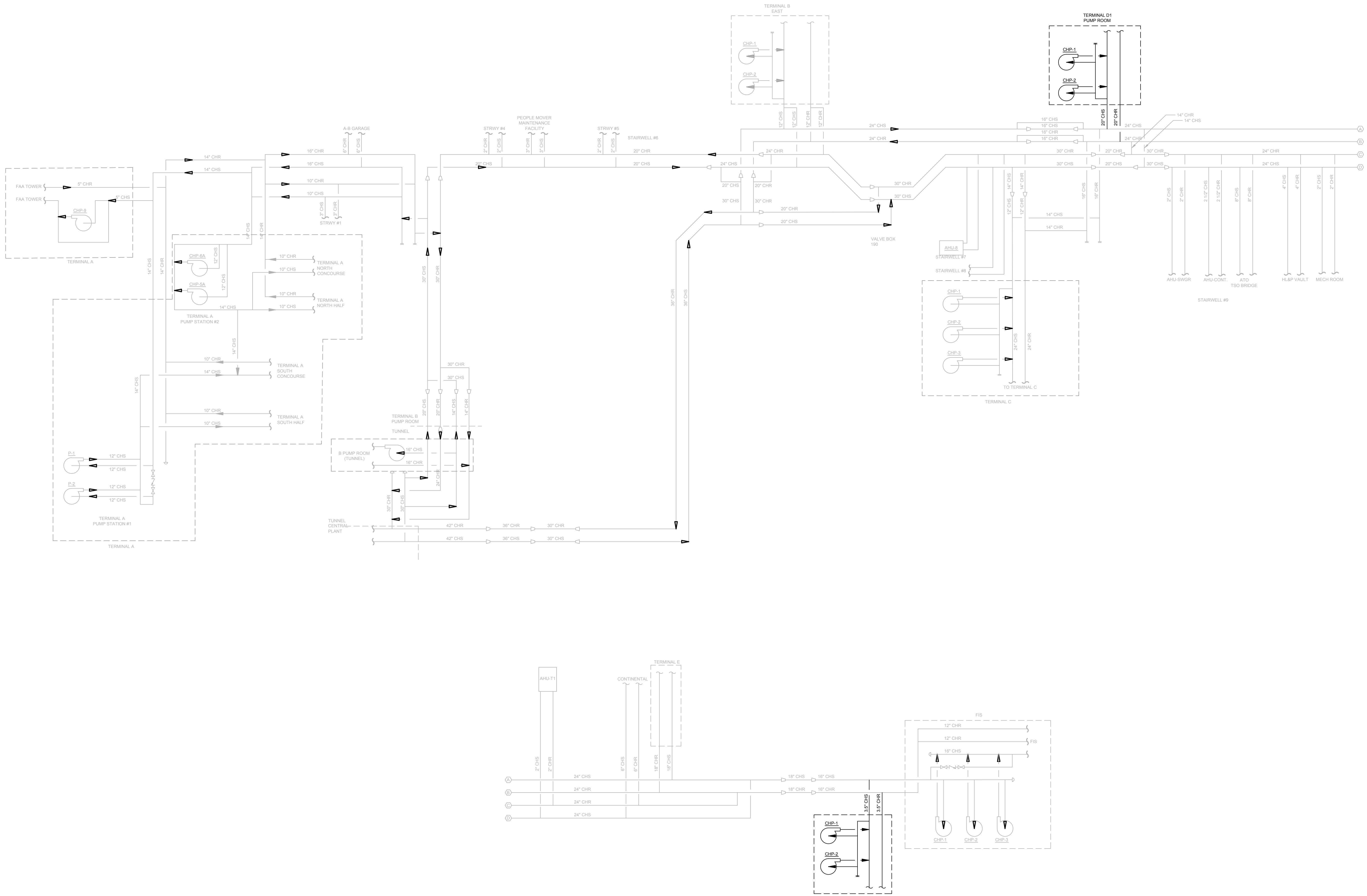

DISTRIBUTION - CHW BASE CASE

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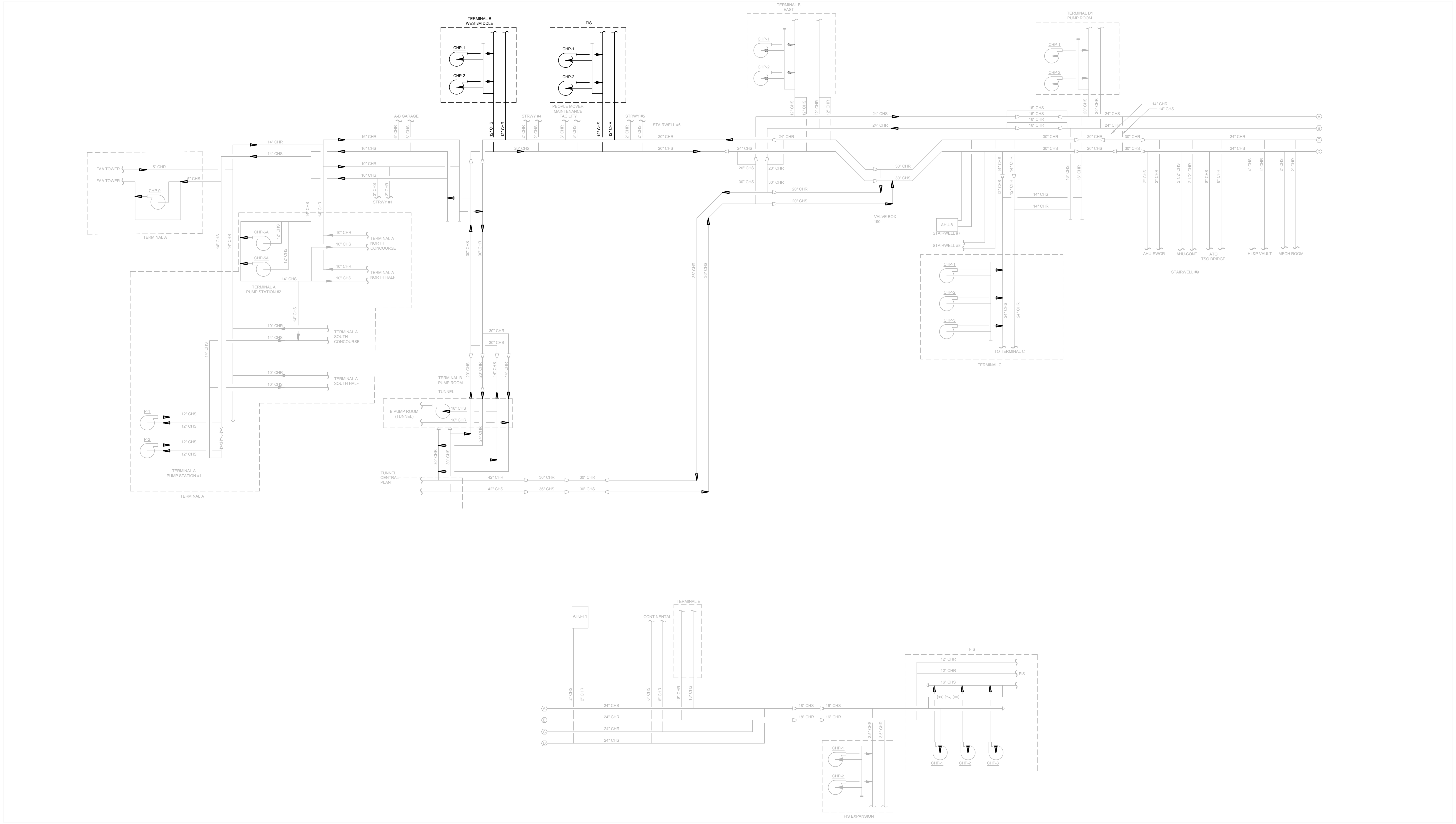
AUGUST 2014



DISTRIBUTION - CHW LONG TERM

HOUSTON AIRPORTS

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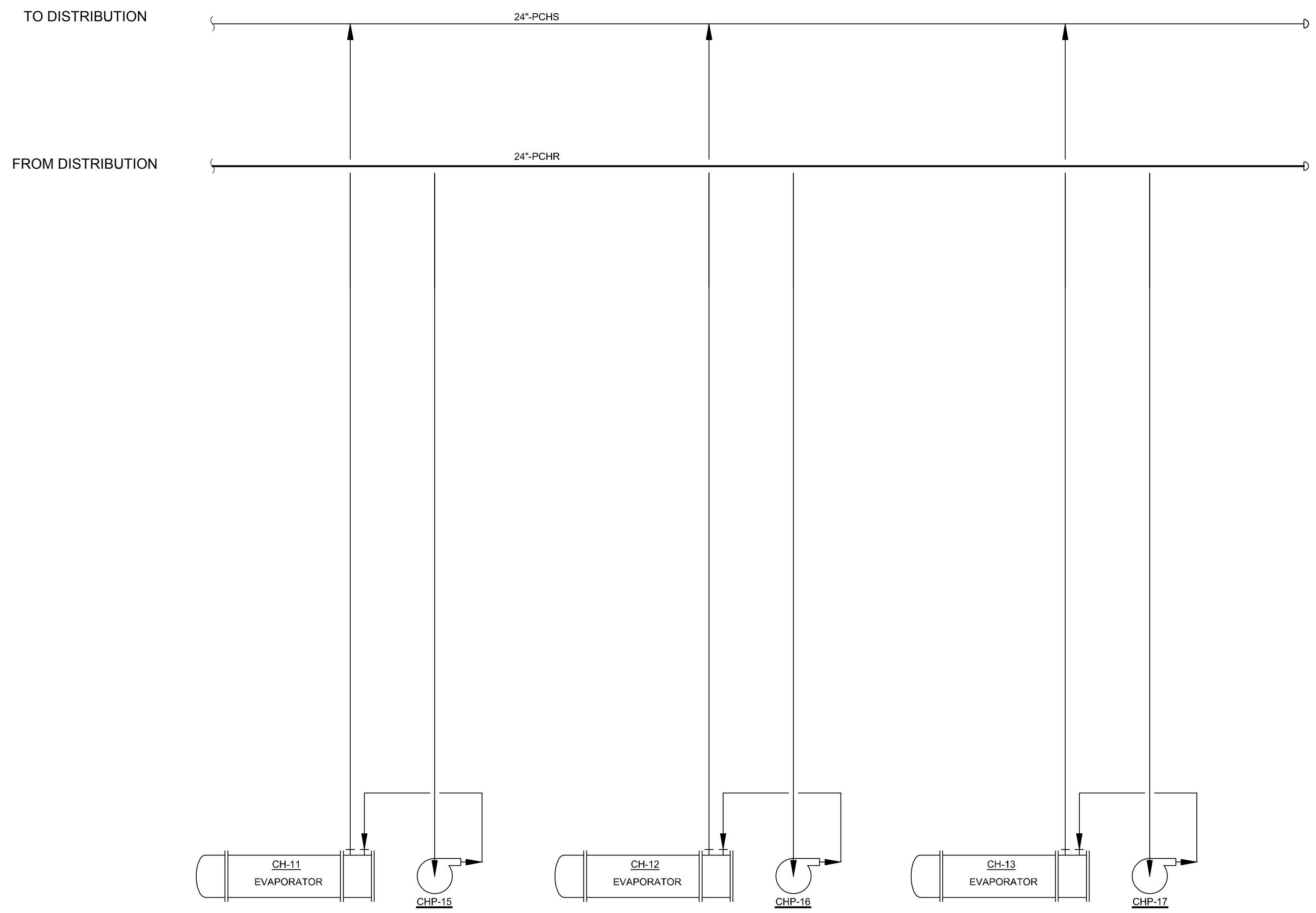
AUGUST 2014



SATELLITE PLANT - CHW

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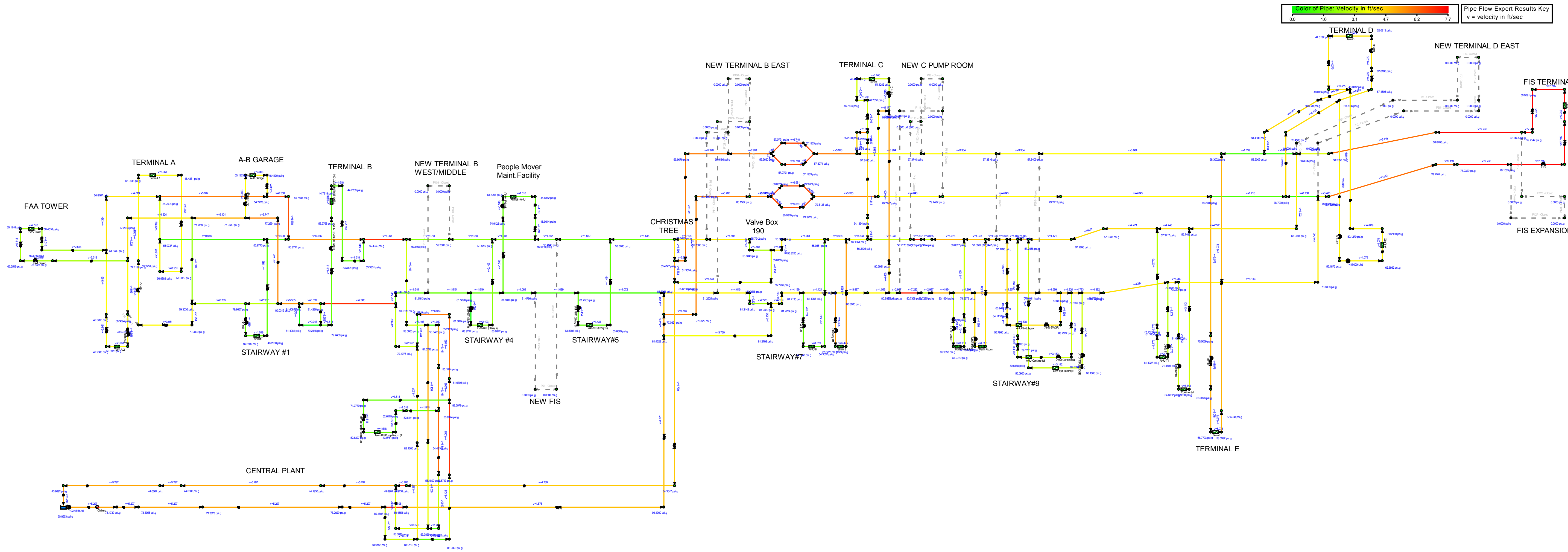
AUGUST 2014

Volume II
Appendix D

Bush Intercontinental Airport (IAH) Report

Appendix C

Flow Model Result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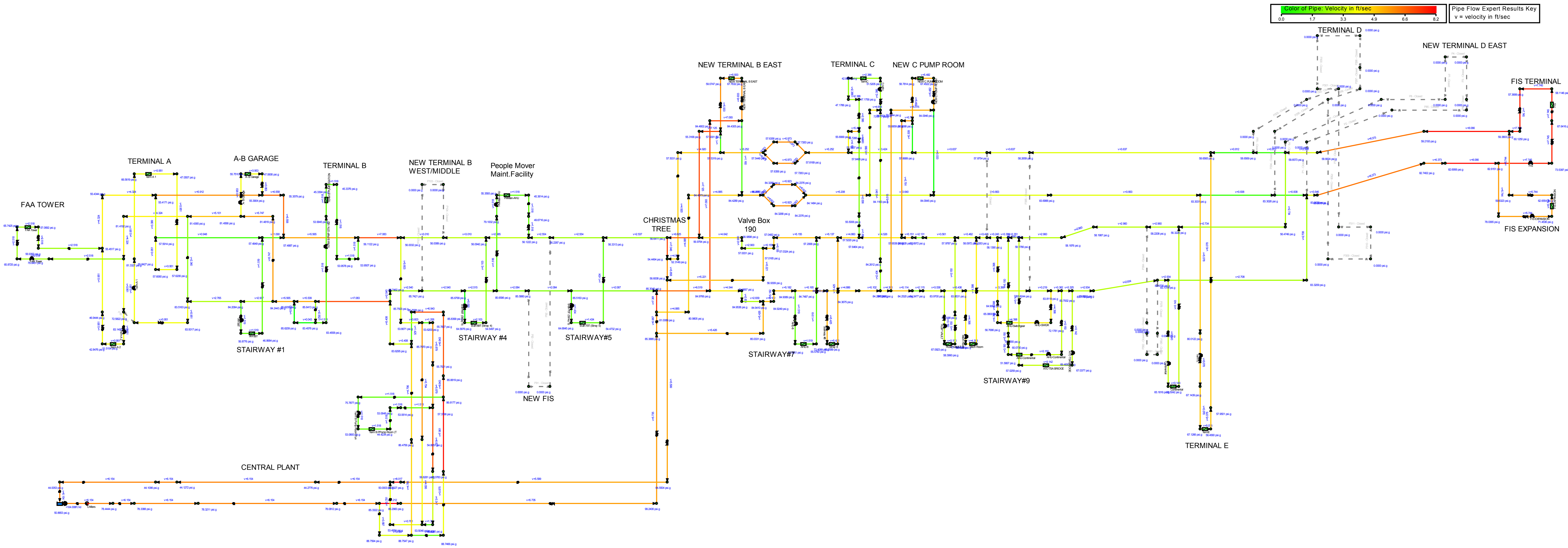
1.6
3.1
4.7
6.2
7.7
Pipe Flow Expert Results Key
v = velocity in ft/sec
TERMINAL D
NEW TERMINAL D EAST
FIS TERMINAL
NEW TERMINAL B EAST
TERMINAL C
NEW C PUMP ROOM
TERMINAL A
A-B GARAGE
TERMINAL B
NEW TERMINAL B WEST/MIDDLE
People Mover Maint.Facility
FAA TOWER
CHRISTMAS TREE
Valve Box 190
FIS EXPANSION
STAIRWAY #1
STAIRWAY #4
STAIRWAY#5
NEW FIS
STAIRWAY#7
STAIRWAY#9
TERMINAL E
CENTRAL PLANT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1.7
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4.9
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8.2
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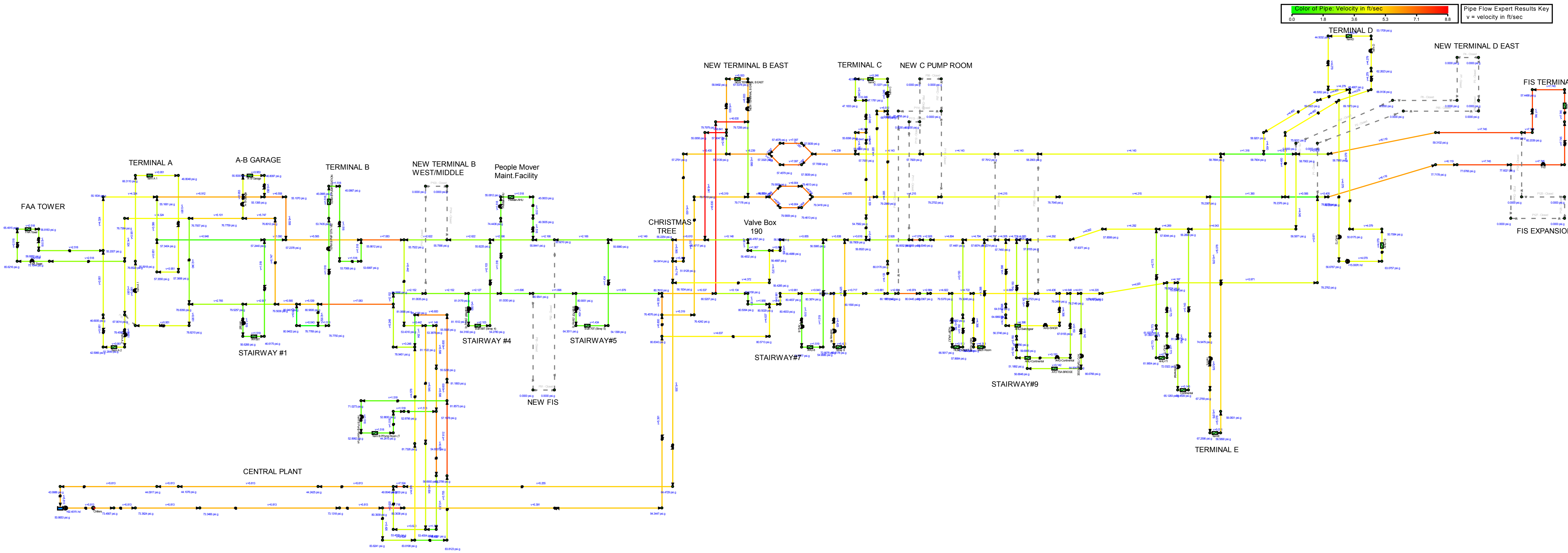
CENTRAL PLANT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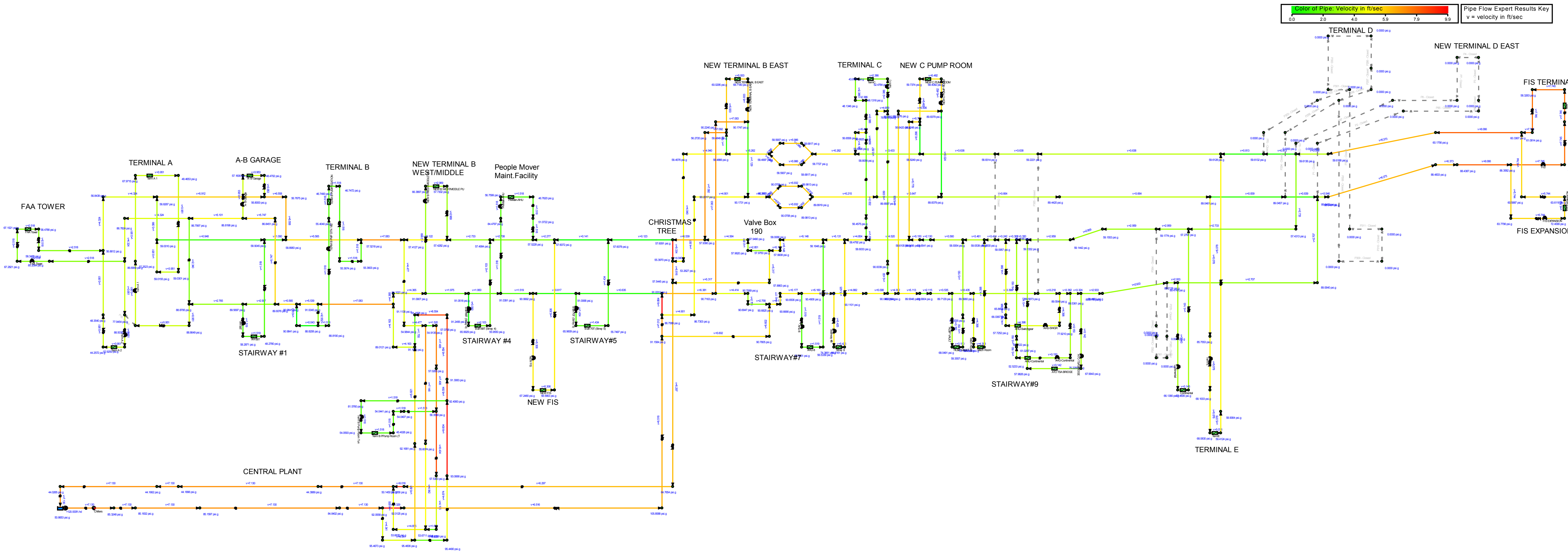
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Pipe Flow Expert Results Key
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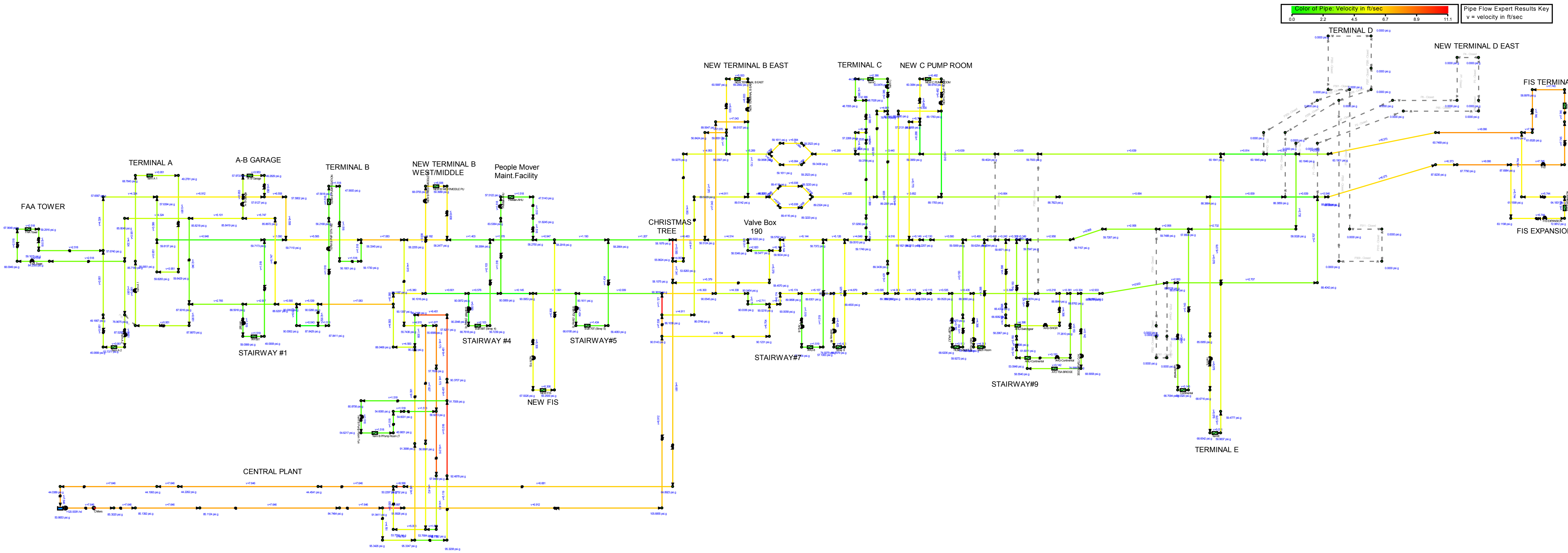
TERMINAL E
CENTRAL PLANT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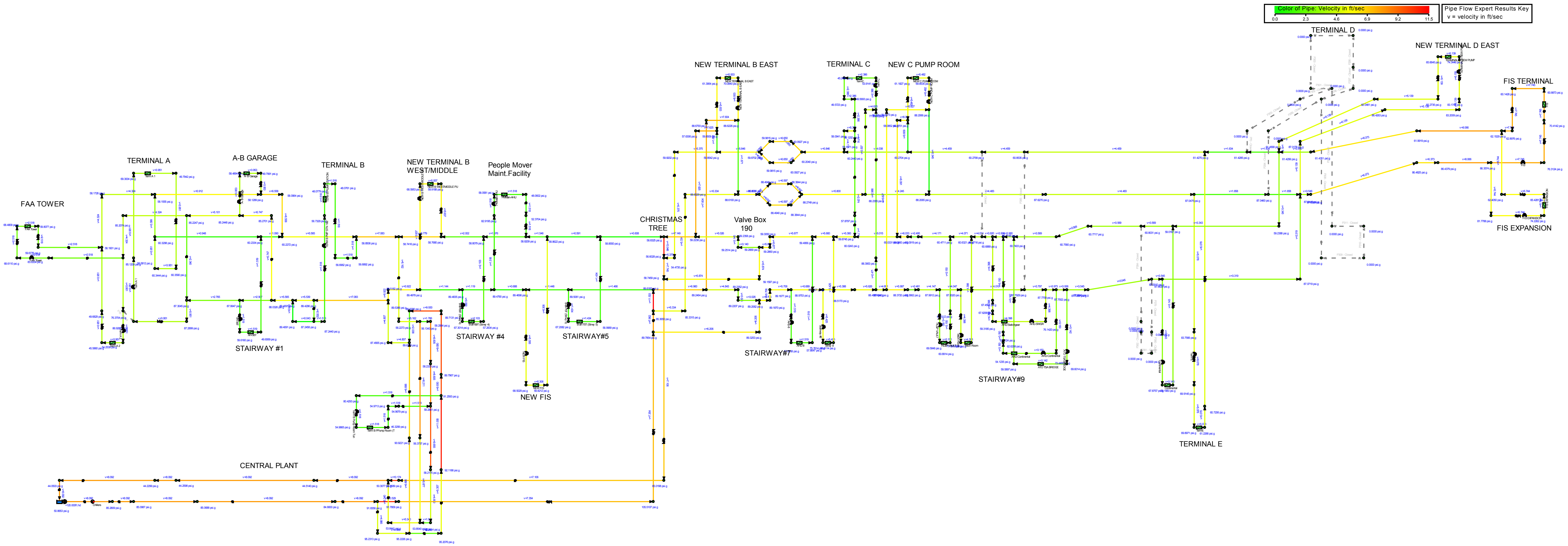
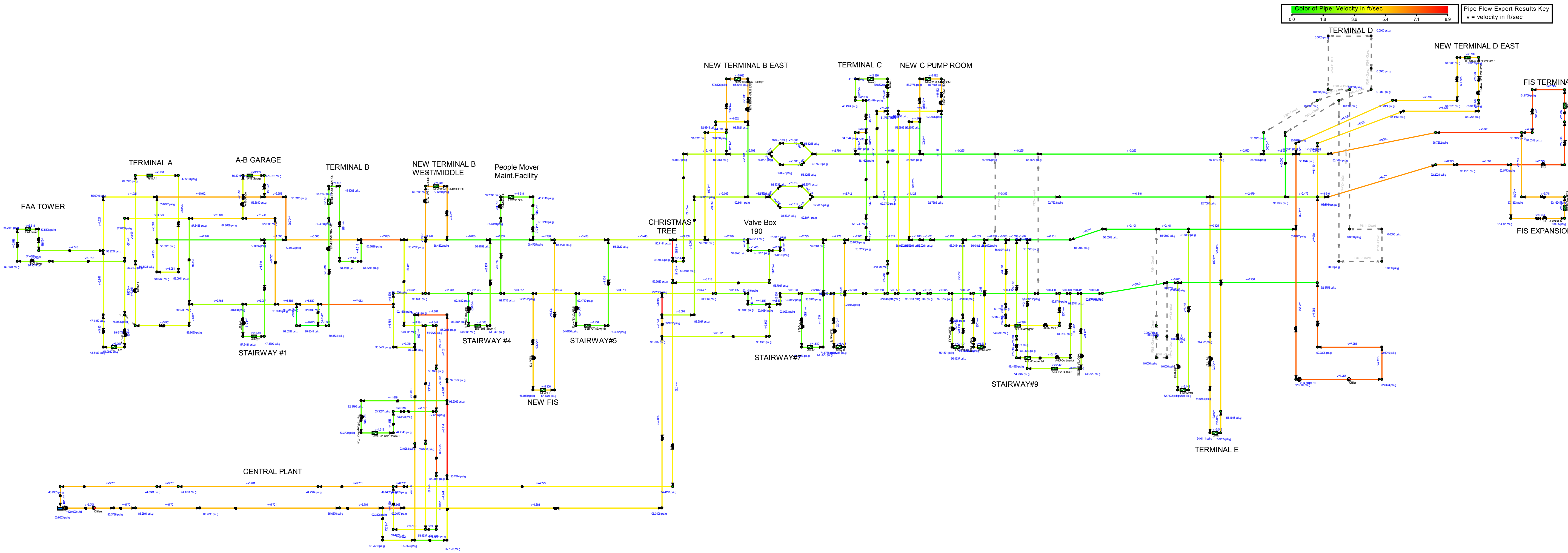
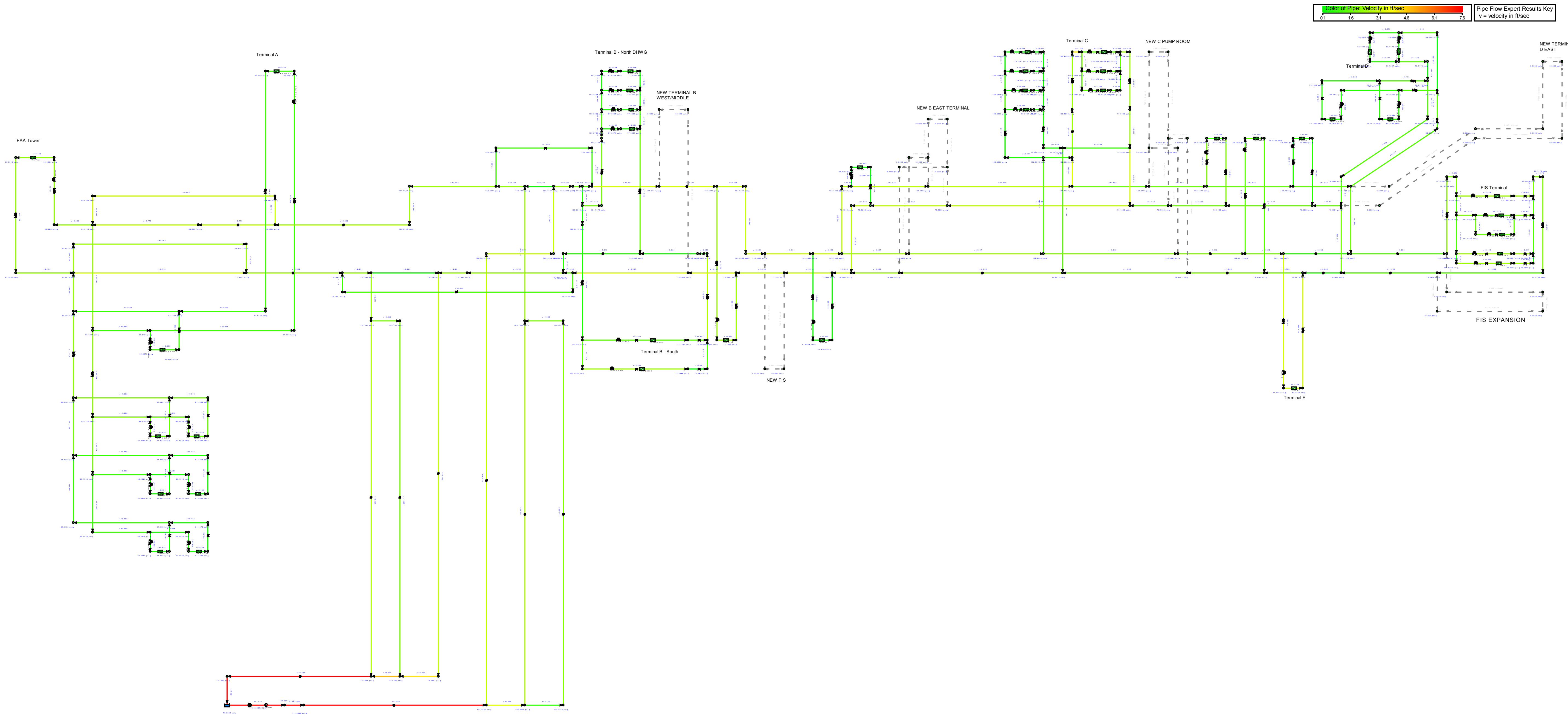
STAIRWAY #4
STAIRWAY#5
NEW FIS
STAIRWAY#7
STAIRWAY#9
TERMINAL E
CENTRAL PLANT

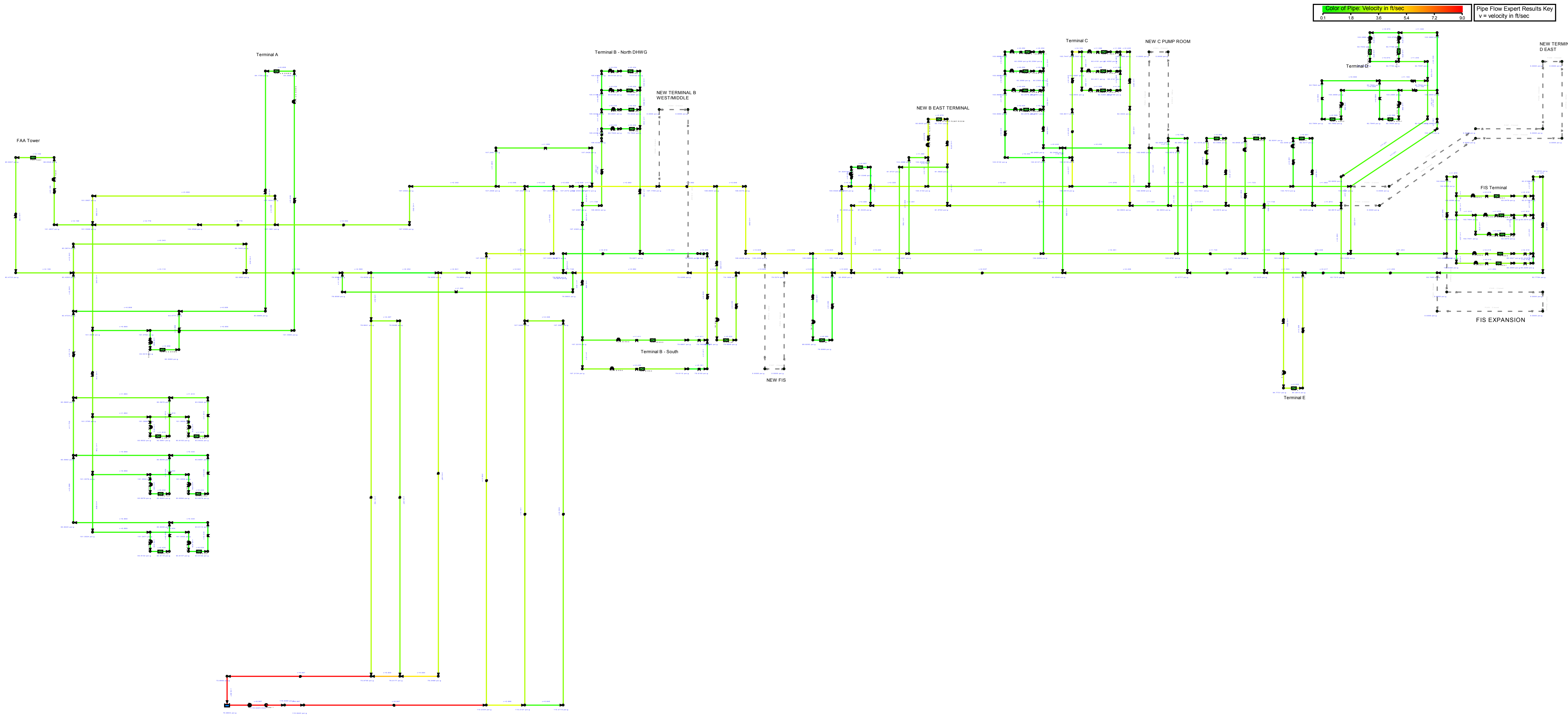

Color of Pipe: Velocity in ft/sec
Pipe Flow Expert Results Key
v = velocity in ft/sec
TERMINAL D
NEW TERMINAL D EAST
FIS TERMINAL
NEW TERMINAL B EAST
TERMINAL C
NEW C PUMP ROOM
TERMINAL A
A-B GARAGE
TERMINAL B
NEW TERMINAL B WEST/MIDDLE
People Mover Maint.Facility
FAA TOWER
CHRISTMAS TREE
Valve Box 190
FIS EXPANSION
STAIRWAY #1
STAIRWAY #4
STAIRWAY#5
STAIRWAY#7
STAIRWAY#9
NEW FIS
TERMINAL E
CENTRAL PLANT

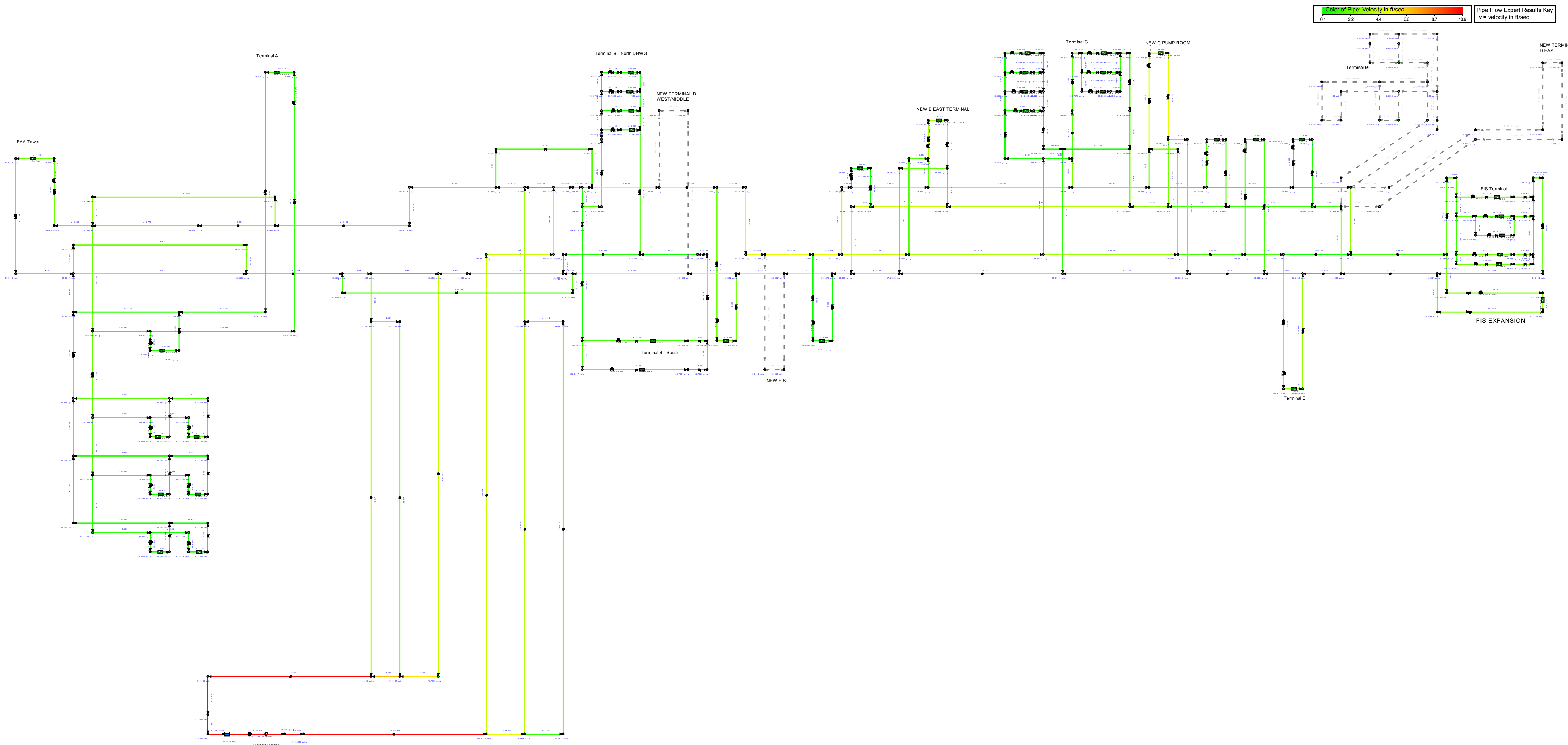
BURNS AND MCDONNELL - IAH UMP - CHW - Long Term 3 - Satellite Plant

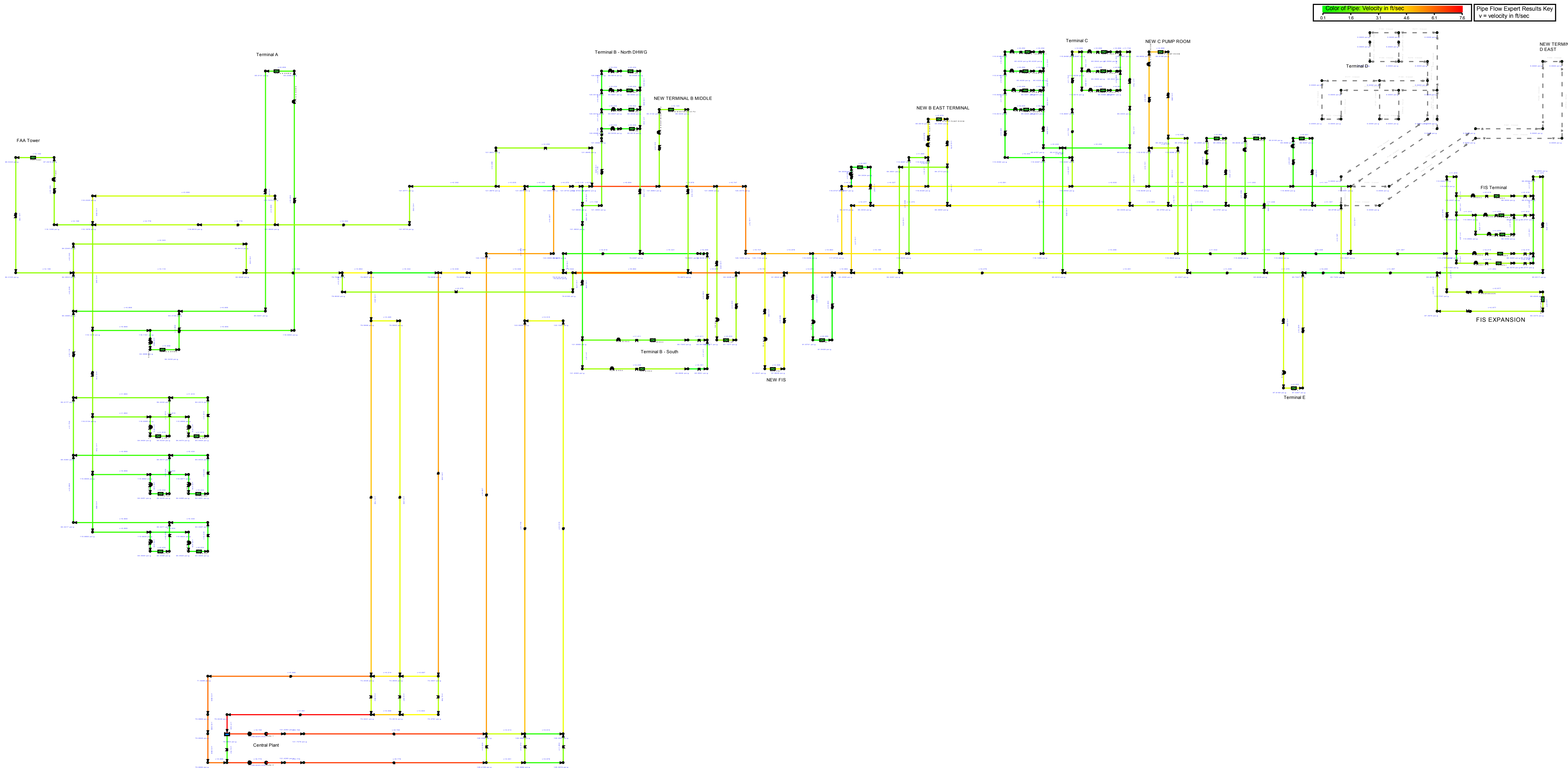
12 May, 2014




Color of Pipe: Velocity in ft/sec
0.1 1.6 3.1 4.6 6.1 7.6
Pipe Flow Expert Results Key
v = velocity in ft/sec
FAA Tower
Terminal A
Terminal B - North DHWG
NEW TERMINAL B
WEST/MIDDLE
NEW B EAST TERMINAL
Terminal C
NEW C PUMP ROOM
Terminal D
NEW TERMINAL
D EAST
FIS Terminal
FIS EXPANSION
Terminal B - South
NEW FIS
Terminal E
Central Plant

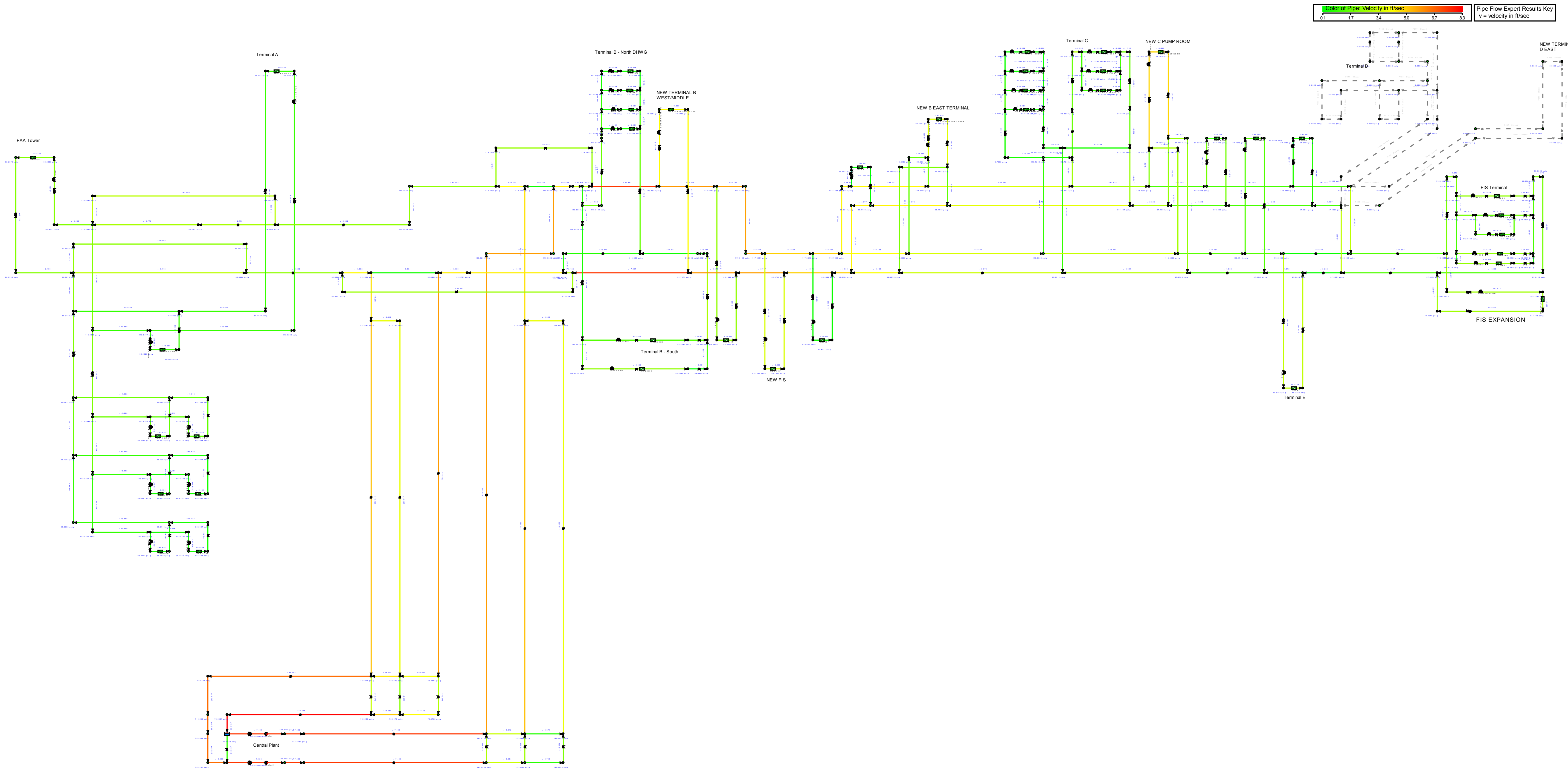

Color of Pipe: Velocity in ft/sec
0.1 1.8 3.6 5.4 7.2 9.0
Pipe Flow Expert Results Key
v = velocity in ft/sec
Terminal A
FAA Tower
Terminal B - North DHWG
NEW TERMINAL B WEST/MIDDLE
NEW B EAST TERMINAL
Terminal C
NEW C PUMP ROOM
Terminal D
NEW TERMINAL D EAST
FIS Terminal
FIS EXPANSION
Terminal B - South
NEW FIS
Terminal E
Central Plant

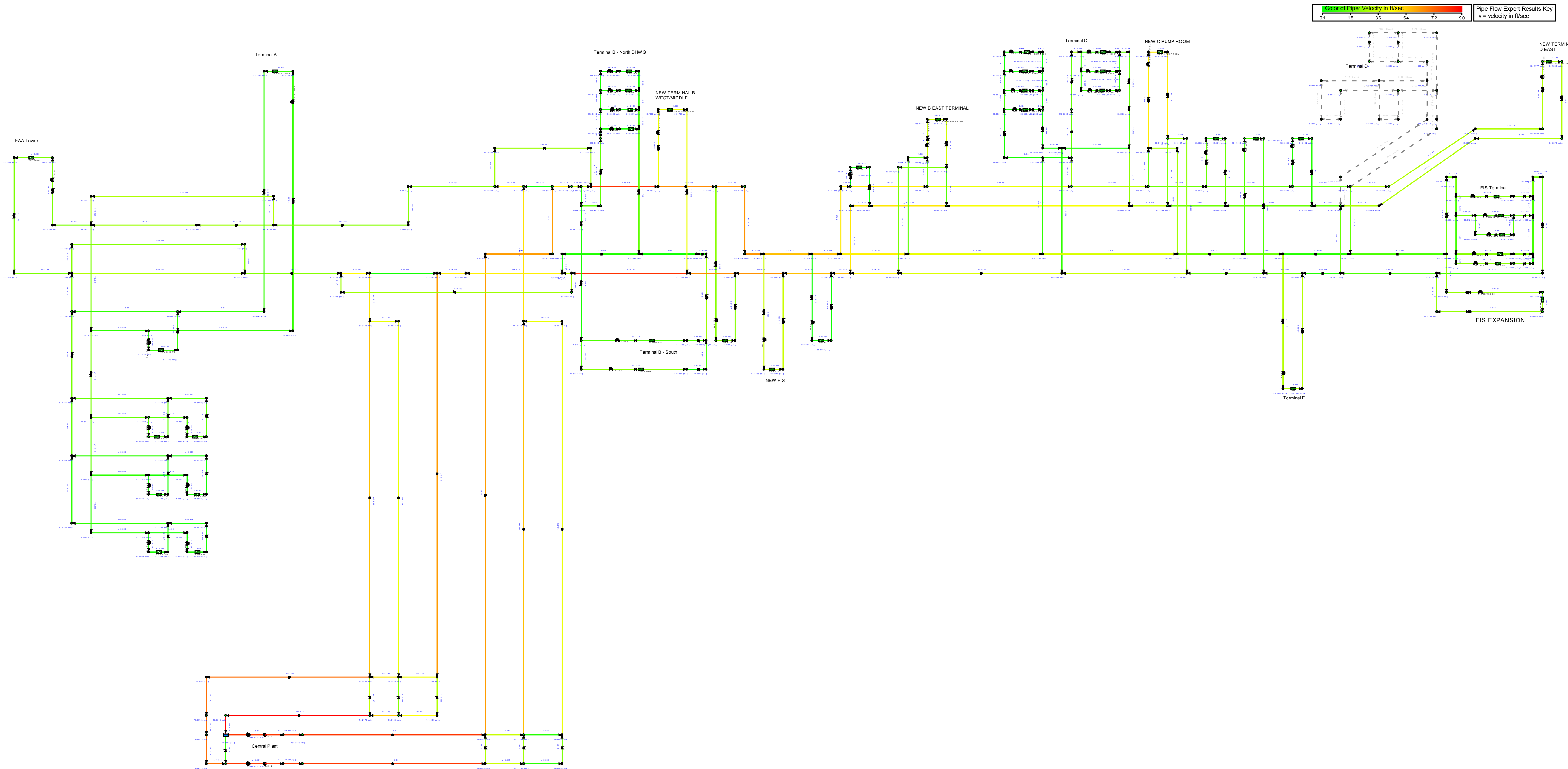

Color of Pipe: Velocity in ft/sec
0.1
2.2
4.4
6.6
8.7
10.9
Pipe Flow Expert Results Key
v = velocity in ft/sec
FAA Tower
Terminal A
Terminal B - North DHWG
NEW TERMINAL B WEST/MIDDLE
NEW B EAST TERMINAL
Terminal C
NEW C PUMP ROOM
Terminal D
NEW TERMINAL D EAST
FIS Terminal
FIS EXPANSION
Terminal B - South
NEW FIS
Terminal E
Central Plant


Color of Pipe: Velocity in ft/sec
0.1
1.6
3.1
4.6
6.1
7.6
Pipe Flow Expert Results Key
v = velocity in ft/sec
Terminal A
FAA Tower
Terminal B - North DHWG
NEW TERMINAL B MIDDLE
NEW B EAST TERMINAL
Terminal C
NEW C PUMP ROOM
Terminal D
NEW TERMINAL D EAST
FIS Terminal
FIS EXPANSION
Terminal E
NEW FIS
Terminal B - South
Central Plant

BURNS AND MCDONNELL - IAH UMP - HW - Long Term 2

05 May, 2014




Color of Pipe: Velocity in ft/sec
0.1 1.8 3.6 5.4 7.2 9.0
Pipe Flow Expert Results Key
v = velocity in ft/sec
Terminal A
Terminal B - North DHWG
NEW TERMINAL B WEST/MIDDLE
NEW B EAST TERMINAL
Terminal C
NEW C PUMP ROOM
Terminal D
NEW TERMINAL D EAST
FAA Tower
FIS Terminal
FIS EXPANSION
Terminal B - South
NEW FIS
Terminal E
Central Plant

BURNS AND MCDONNELL - IAH UMP - HW - Long Term 3 - Satellite Plant

05 May, 2014