II. Existing Conditions

A. General Discussion

1. Existing Central Energy Plan System Configuration

The existing (CEP) steam system consists of one 30,000 PPH gas/oil boiler and three 60,000 PPH coal-fired stoker boilers. Boiler No. 1 (30,000 PPH) is a D-style, watertube boiler manufactured by E. Keeler Co. that fires natural gas and No. 2 fuel oil with a single burner manufactured by Faber and utilizes single-point positioning. Boiler Nos. 2 through 4 (60,000 PPH each) are balanced draft, watertube, spreader stoker boilers capable of firing natural gas and No. 2 fuel oil with two side-mounted burners at a rate of 60,000 PPH on oil or gas. Boiler Nos. 2 through 4 were manufactured by International Boiler Works Co., and the burners were manufactured by Coen Co. All three are equipped with air pre-heaters. None of the existing boilers have economizers used for pre-heating boiler feedwater, and all four boilers were installed in 1980.

A summary of the existing boilers is presented below in Table II-A-1.

TABLE-II-A-1 - SUMMARY OF EXISTING BOILERS

UNIT NO.	BOILER MANUFACTURER	BURNER / STOKER MANUFACTURER	YEAR	TYPE	CAPACITY (PPH)	FUEL	FLUE GAS HEAT RECOVERY	DRAFT
1	E. KEELER CO.	FABER BURNER	1980	D-STYLE, WATERTUBE	30,000	NATURAL GAS / NO. 2 FUEL OIL	NONE	FORCED
2	INTERNATIONAL BOILER WORKS CO.	COEN / DETROIT	1980	SPREADER STOKER, WATERTUBE	60,000	COAL / NATURAL GAS	AIR PREHEATER	BALANCED
3	INTERNATIONAL BOILER WORKS CO.	COEN / DETROIT	1980	SPREADER STOKER, WATERTUBE	60,000	COAL / NATURAL GAS	AIR PREHEATER	BALANCED
4	INTERNATIONAL BOILER WORKS CO.	COEN / DETROIT	1980	SPREADER STOKER, WATERTUBE	60,000	COAL / NATURAL GAS	AIR PREHEATER	BALANCED
TOTAL CAPACITY		---	---	---	210,000	---	---	---
FIRM CAPACITY		---	---	---	150,000	---	---	---

2. Coal Supply

The State of Wyoming presently supplies 40% of the coal used in the United States. The majority of this coal is from the Powder River Basin (PRB) where it is surfaced mined.

The coal required for the University of Wyoming (UW) is stoker grade with specific ranges of various constituents. The quality of the coal utilized by the plant has decreased from the initial operations. The annual coal usage of the UW is approximately 26,000 tons per year (TPY) which is small compared to the quantity of coal exported from the state.

The following information in Table II-A-2 lists the various coal constituents for the existing annual RFP, 2008 coal received, as well as the requirements for proper boiler and stoker operation.

TABLE-II-A-2 - COAL CHARACTERISTICS ANALYSIS UNIVERSITY OF WYOMING				
COAL CHARACTERISTICS	UW BID FORM (2007)	UW COAL ANALYSIS (2008)	IBW ORIGINAL DESIGN (1980)	EXISTING ROTOGRATE STOKERS (FROM DSC)
MOISTURE (% BY WEIGHT)	27.2	10.93	27.2	0 - 10
VOLATILES (% BY WEIGHT)	32.0 - 42.0	N/A	33.9	30 - 40
FIXED CARBON (% BY WEIGHT)	31.0 - 48.0	N/A	31.2	40 - 50
ASH (% BY WEIGHT)	17	9.43	7.7	5 - 15
SULFUR (% BY WEIGHT)	0.7	0.64	0.7	N/A
HHV (BTU/LB)	8,280	10,936	8,280	N/A
FINES (% PASSING 1/4" TO 0" SCREEN)	33	56	N/A	40 MAX

NOTES:
1. ORIGINAL DESIGN BASED UPON POWDER RIVER COAL
2. UW COAL ANALYSIS (2008) - COAL HAS CHARACTERISTICS EQUAL TO CARBON, MT. COAL
3. UNIV. OF WY BID FORM - ASH TYPO (PINK SHADING)

The present specifications for coal purchase indicate that up to 17% moisture content is suitable for the current boilers.

The main deficiency within the CEP operations is the quality of coal being received. The size of the coal in relation to the high percentage of coal fines is the source of the operational difficulties, and stoker grade coal is becoming increasingly difficult to find due to upgraded boiler technologies and types of coal required for each.

The existing Rotograte Stoker feeders are designed to handle stoker grade coal in the size range from 2” to 1/4” with approximately 40% coal fines. A recent CEP analysis indicated that the plant is receiving up to 60% fines mixed with larger coal chunks reaching up to 6” in diameter, and the coal being received has “fines” approximately 70% greater than the plant was designed to use.

In addition, the “fines” have moisture content greater than 50%. Largely due to their moisture content, these “fines” have caused serious problems with the material handling systems in addition to the air pollution control systems. With “wet” coal fines, the hoppers often clog and cause pneumatic conveying systems to operate excessively as they are designed to move a dry product.

An analysis of the carbon content of the fly ash and bottom ash should be performed to determine the amount of unburned carbon and the resultant lack of boiler efficiency. If the plant was provided with economizers in lieu of air preheaters, the moisture content of the “fines” would be more problematic to the very good existing stoker combustion.

The UW has utilized coal from various sources in an attempt to find a product acceptable for the existing plant. A previous coal utilized was adequate, but developed large sodium scaling within the boiler furnace. Because sodium scaling is a problem with some Wyoming coals, there are a number of commercially available agents that can be injected into the furnace to reduce sodium scaling.

Most recent the UW was capable of finding and purchasing coal from a mine Grass Creek Coal that produces a stoker grade coal. The stoker grade coal has reduced numerous issues at the plant however should not be considered as a permanent fix to the coal quality operational issues experienced in the last few years due to unstable coal markets and unstable coal production.

3. Ash Disposal

Presently, the fly ash and bottom ash are centrally collected and transported back to the coal supplier for disposal. It is suspected that the mine will soon discontinue taking the ash due to local area complaints. Previously, the ash was transported to a landfill for disposal. Because of limited landfill capacity and dust issues, the landfill no longer accepts the coal ash.

The Laramie Power Generation Station has a dedicated ash landfill. The power station was contacted about the possibility of disposing the UW’s coal ash at the Laramie facility. At this time, the power station cannot accept ash from other sources. The amount of the UW’s ash is extremely small compared to the electric generation station, and it is recommended that this option be further investigated.

There are a number of facilities in Colorado that accept coal ash. If the coal supplier cannot dispose of the ash, various other methods of disposal should be investigated. The separation of fly ash and bottom ash should also be evaluated.

Physically separating the ash may be an enhancement, but not a permanent solution. Fly ash can generally be disposed of at no expense and can sometimes be sold. Fly ash can be used to make other products such as asphalt and wall-board, but bottom ash must still be disposed of accordingly. The existing CEP bottom ash contains arsenic, cadmium, magnesium, lead, nickel, mercury, and chloride.

B. Heating System

1. Central Energy Plant

a) General Overview

Ross Infrastructure (RI) conducted a condition and operation assessment of the existing coal handling and ash handling equipment on March 31st through April 1st, 2009, at the CEP at the UW located in Laramie, WY.

The purpose of the assessment was to investigate the existing coal and ash handling equipment and identify any areas where operations could be improved and maintenance could be reduced.

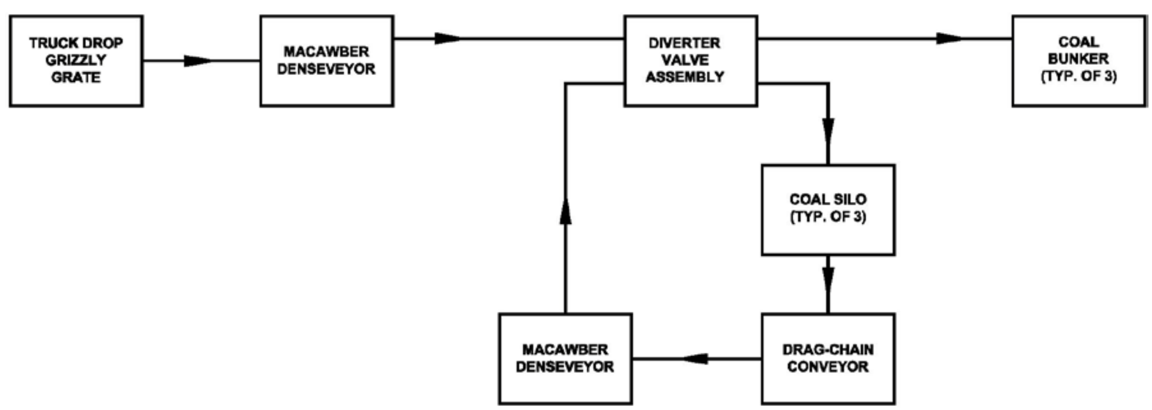
b) Existing Central Energy Plant Condition Assessment

It is evident that the CEP steam system equipment has been well maintained for nearly 30 years and is considered to be in very good condition. The CEP is one of the cleaner coal-fired facilities that RI has ever worked with.

The existing coal transfer system is typical and is designed to handle ***dry*** coal ranging from 2" to 1/256". The existing pneumatic conveying systems experience poor material flow and feed when trying to convey wet coal.

The existing system consists of a truck unloading area where coal is dropped onto a grizzly grate and down to the main Macawber Denseveyor. From here, the coal is pneumatically conveyed to a diverter valve assembly that conveys the coal to either the coal storage silos or to the coal bunkers to the individual boiler stokers. From the coal silos, coal is conveyed via a drag-chain conveyor down to a second transfer Macawber Denseveyor back through the diverter valve assembly to the coal bunkers. The existing coal transfer system is illustrated below in Figure II-B-1.

Figure II-B-1 – Coal Transfer



The existing ash transfer system is designed to handle approximately 3,000 TPY according to the CEP flow process Operation Permit No. 32-156-1. According to existing CEP ash haulage data dating back to 1990, the actual average ash removal is approximately 1,700 TPY ranging from as little as 1,300 TPY to as much as 2,500 TPY.

The existing ash system collects fly ash from seven baghouse hoppers, three breeching drop-out hoppers, nine ash re-injection hoppers, and six second-pass drop-out hoppers. The existing ash system also collects bottom ash from three windbox bottom ash hoppers and six siftings hoppers.

The fly ash combines with the bottom ash before going to the ash silo where it passes through primary and secondary separators and then a bag filter where it drops down to the main ash silo hopper for truck removal. A single steam exhauster pulls the vacuum on the entire system prior to passing through an air washer to atmosphere. The existing ash transfer system is illustrated below in Figure II- B-2 and II-B-3.

Figure II-B-2 – Ash Transfer

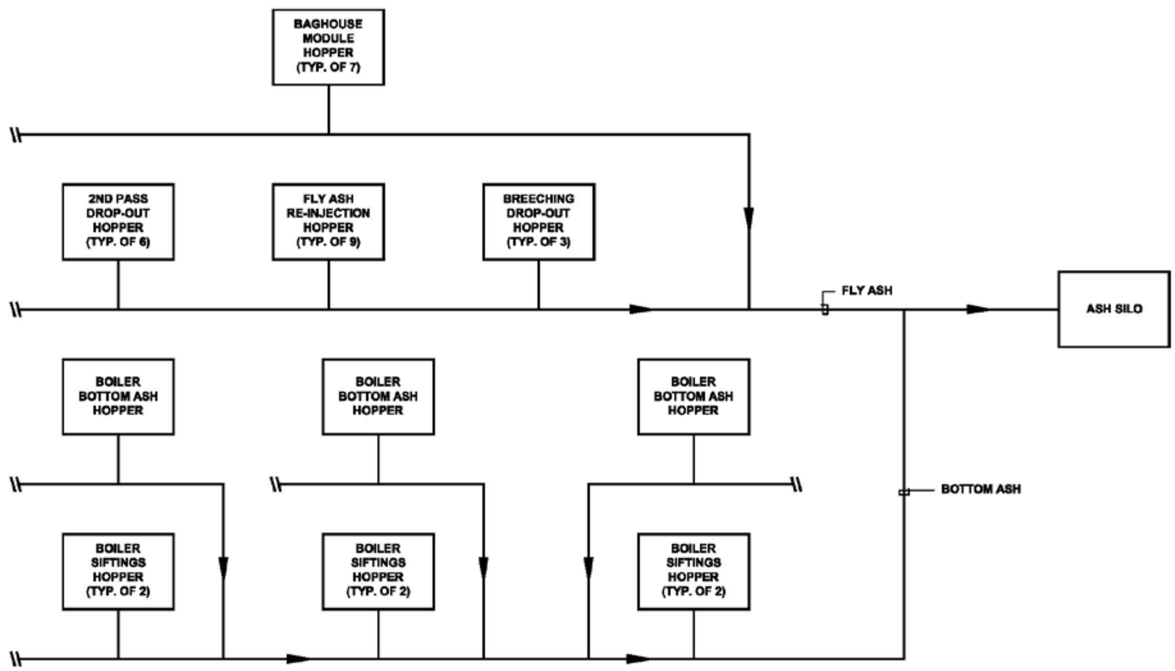
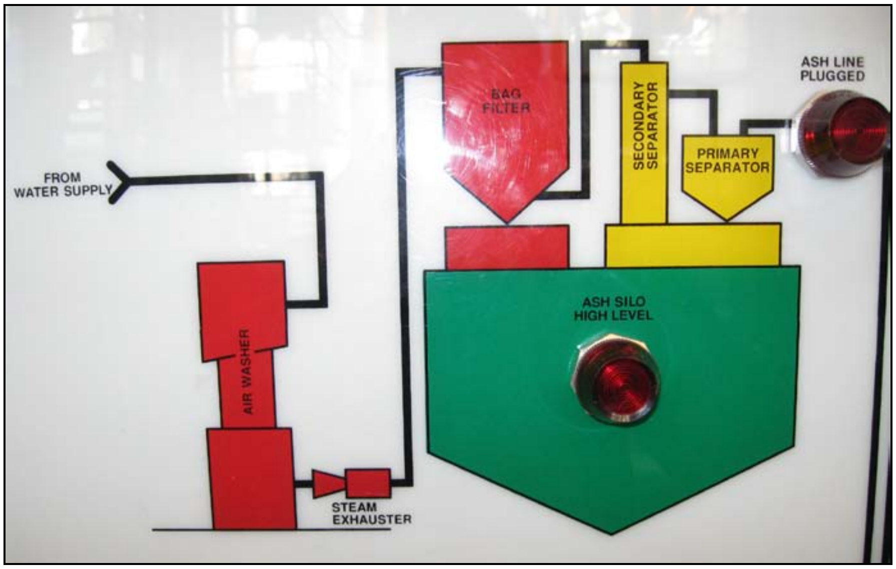


Figure II-B-3 – Ash Silo



c) Coal and Ash Assessment

As previously stated in this study, the primary issue with the operation of the CEP is the large percentage of coal fines that is received from the existing coal mine in relation to the design requirement of the boiler spreader stokers and ash handling system. The ***wet*** condition of the coal exacerbates the problem causing the pneumatic coal conveying system to operate excessively and inefficiently. The following photographs illustrate the inconsistency of the coal which is not optimum in size for spreader stoker boilers (2" – 1/4" recommended) and that some of the coal arrives snow-covered.

Figure II-B-4

Figure II-B-5

A typical pneumatic Macawber Denseveyor type system is designed to handle raw coal fuel moving it from a drop delivery reception system to a coal bunker. The coal can range from 2"

(50mm) size to pulverized particles of less than 1/256" (0.1mm). The robust Denseveyor system is in an explosion-proof configuration to achieve a clean transfer of coal to the bunker with machine reliability and minimal maintenance. Typical material characteristics are as follows:

- Raw Coal Material
- Bulk Density Aerated 56 lb/ft^3 (900 kg/m^3)
- Size Lump up to 2" (50 mm)
- Temperature 75-175°F (25-80°C)
- Moisture 5%
- High moisture conditions causes poor material flow and fee; explosive environment.

During the time of the site survey, it was noted that the Denseveyors and associated air compressors ran excessively during coal deliveries. Over two days, it was noted that the coal arrived to the site extremely wet. The high moisture content is not recommended for the Denseveyors shown below.

Figure II-B-6

Figure II-B-7

Once the wet coal is sluggishly conveyed to the coal storage silos, moisture in the coal can drain to the bottom of the silo hoppers and mix with the excessive coal fines forming a "mud-like" consistency that will clog the hoppers. As can be seen from the photo below in figure II-B-8, the silo hoppers and knife-gate valves are clogged and often require “hammering” on the exterior of the equipment in an attempt to loosen the coal.

Figure II-B-8

Boiler Nos. 2 through 4 each have three existing Rotograte underthrow spreader stoker feeders as can be seen from the photograph below.

Figure II-B-9

The recommended stoker grade coal size for these feeders is 2” to 1/4” with a maximum of 40% fines, dry. The actual coal size delivered is anywhere from 6" in diameter to pulverized dust that is primarily wet. Underthrow spreader stoker feeders of this vintage are not designed to "throw" pulverized coal, and the current distribution air (overfire air) is not designed to "blow" pulverized coal. Coal chunks that are too large can bind and break the feeders, and coal fines can collect inside the distributor box itself and combust causing stoker fires, hopper fires, etc.

The existing ash system, baghouse, and ash silo are all experiencing higher loading and adverse operating conditions due to carryover of coal fines into the ash system. According to plant personnel, a typical year for bag replacement for the existing baghouse is around 12 bags per year. Recently, the CEP replaced 600 bags as well as several others for the ash silo bag filter. Plant personnel believe this is due to coal fines carryover.

The overall condition of the ash system, ash silo, hoppers, baghouse, and stacks appeared to be in good condition given the age of the equipment as can be seen in the photographs below. However, a thorough internal inspection of the equipment was not conducted at the time of the assessment.

Figure II-B-10

Figure II-B-11

An item of concern is the existing steam exhauster for the ash conveying system. Currently, the exhauster is the single point of failure for the entire system. If the steam exhauster is down for maintenance or repair, the CEP cannot pull ash and subsequently, cannot burn coal. The steam exhauster is nearing the end of its remaining useful life and is shown below in Figure II-B-12.

Figure II-B-12

2. Steam Distribution

a) General Overview

The steam distribution system on the UW campus consists of steam and condensate piping installed as direct buried piping and located in underground utility tunnels. The steam originates solely at the (CEP) located at the northeast corner of the campus and travels south and west to serve the majority of the buildings on the campus. Currently, the CEP provides 125 psig high pressure steam to the distribution system and some of the buildings on the northeast corner of campus. Generally high pressure is primarily used for transport to the pressure reducing stations (PRVs) centrally located on the main campus. The pressure reducing stations provide 70 psig and 12 psig pressures to the building entrances. The buildings with high and medium pressure service are provided with a PRV to provide low pressure to the heating equipment. A layout of the existing steam distribution piping indicating installation, a steam pressure and general size is shown in **Drawing II-B-2-a** of Appendix II along with supplemental drawings 1-6 that correspond.

The steam generally follows the path through campus described below:

- From the CEP, 125 psig steam routes south along 19th St. with takeoff branches serving Regulated Materials Management Center, Wyoming Technology Business Center, Animal Science/Microbiology, Centennial Complex and the Arena/Auditorium. Each of these buildings has a PRV to provide low pressure steam to the heating equipment. From the Arena/Auditorium mechanical room, 90 psig steam is provided to a PRV located in Field house north, reducing steam pressure to 75 psig. Steam at 75 psig is supplied from the PRV to Rochele Athletic Center and the Indoor Football Practice Facility. In the tunnel west of the Law Building some of the steam flow is diverted through a tee fitting into a direct buried 125 psig steam line traveling west towards 15th St. The remainder of the steam flow is reduced to 70 psig by a PRV at this location. The 70 psig steam service leaving the PRV mainly serves Law, War Memorial Field house, Corbett Physical Education, the Fine Arts Center, the Dormitories, and few of the Sororities.

- The 125 psig steam line traveling west, along Willet Drive, north of the Fraternities, towards 15th St. is reduced to 70 psig at a PRV north of Sigma Nu fraternity. This 70 psig steam service leaving the PRV mainly distributes steam to buildings west of 15th St. and to a PRV, located by the Pi Kappa Alpha sorority at the intersection of 15th St. and Sorority Row, reducing pressure to 12 psig. The 12 psig steam service leaving the PRV serves the Fraternities, Campus Greenhouse, and most of the Sororities. West of 15th St., the 70 psig steam service distributes steam directly to about half the buildings and to a PRV at McWhinnie Hall, reducing pressure to 12 psig. The remainder of the buildings west of 15th St. is served by the 12 psig steam service.

The following locations also include back feeds from the 70 psig service to the 12 psig through PRVs:

- Knight Hall
- Biological Sciences
- Physical Sciences
- Classroom
- The tunnel outside the Old Power Plant
- Aven Nelson
- McWhinnie

b) Existing Steam and Condensate Distribution System Configuration and Condition Assessment

The steam and condensate piping is primarily routed in walkable utility tunnels, with some limited direct buried piping that was installed to create a loop where pressure or flow problems were encountered. The current utility tunnel system starts as a radial feed from the (CEP) and connects into the originally installed campus loop around Prexy's Pasture shown in Drawing II-B-2-a within Appendix II-B. The top ceiling of the utility tunnel is used as surface sidewalks in multiple areas of the campus while other areas of the utility tunnel system are routed under existing buildings. The original utility tunnel loop was installed when the campus was originally developed. The radial feed from the current CEP connects to the original loop and is approximately 28 years old.

Investigation of the existing steam tunnel distribution system included a walkthrough of the utility tunnels in November 2008 with UW personnel to observe the existing conditions and assess the distribution system. The UW personnel indicated that there are annual maintenance walks of the tunnels and deficiencies located are addressed as soon as possible.

The deficiencies were categorized by high or low priority, based on the urgency of the upgrade. Life safety and structural upgrades are rated as highest priority. Utility interferences, utility crossings, pipe support degradation, and wiring installed in the tunnel are lower priority deficiencies to be addressed. Photos were taken throughout the utility tunnel system and are included and described below. A CD containing additional photos and a Tunnel Condition Assessment Matrix II-B-2-b is included as part of the Appendix.

High priority items within the tunnel include the following:

- Inadequate Access/Egress hatches.
- Limited Ventilation within confined spaces.
- Egress pathway.
- Structural degradations that may lead to potential failures.

Currently access ways are limited in number, location, and separation to access/egress the tunnel. Most of the current locations access ways are padlocked and open directly upward into a pedestrian sidewalk or into existing building mechanical rooms that restricts personnel exit paths from the tunnels under emergency conditions. Additionally, the current surface access/egress doors are not waterproof and allow infiltration of debris and natural elements which cause corrosion to the internal utilities. Photos of existing access/egress surface hatches are shown on the following page.

Access Egress Shaft Photos

Mechanical ventilation is only used in a few locations in the utility tunnel system for local temperature control. The current fans are undersized and do not maintain acceptable temperature and humidity conditions for large portions of the tunnel.

Another item which affects access/egress within the tunnels is the routing of civil utilities, electrical and telecom wiring. In some locations, these utilities are routed perpendicular through the tunnel at knee to shoulder level causing personnel to crawl over or pass under. Examples of perpendicular utilities through the tunnel that limit egress are represented in the photos below.

Horizontal Utility Crossing Photos

Some areas of the utility tunnel are very congested and narrow and do not allow personnel to negotiate the tunnel system swiftly without crouching or turning sideways for extended lengths of tunnel. Photos of this restriction are defined in the paralleling utility photos indicated below.

Paralleling Utility Photos

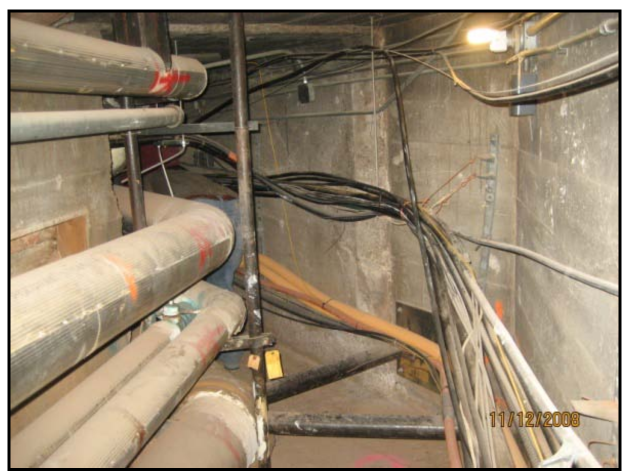
There are multiple high priority structural deficiencies throughout the tunnel identified below through descriptions and the following photos.

- The concrete floor, walls and ceiling are spalling and large cracks and mineral deposits are visible.
- Aggregate and rebar are visible in failing sections.
- There are high moisture levels from infiltration of surface and ground water through cracks in the roof and the walls. Open surface grating and utility penetrations are also a source.
- Investigation of tunnel age indicates portions of the tunnels have extended past the useful acceptable life of the concrete materials.
- Portions of the tunnel have steel and wood bracing installed to support the failing tunnel structure of which is also currently failing.

Structural Deficiency Photos

The portions of utility tunnels identified as needing immediate structural work are the segments between Biological Sciences to Knight Hall and the tunnel segment under Engineering, Agricultural and Education buildings. The replacement of these tunnel segments are critical to maintain a safe tunnel environment for personnel and to ensure the distribution piping, primary power and telecom systems are not compromised by a structural failure as can be seen in the following photos.

Structural Deficiency Photos



Structural Deficiency Photos

Lower Priority Deficiencies include the following:

- Congested Areas from fiber optic and some primary power wiring.
- Improper hanger installations.
- Corroding supports and hangers.
- Inadequate quantity of sump pumps.
- Heat loss from inadequate insulation or non-insulated piping.
- Improper lighting and/or damaged lighting fixtures.

Most of the steam tunnel segments are utilized for fiber optic, computer network wire routing and in some areas, primary power cabling. These utilities add a significant quantity of poorly placed pull, splice, and junction boxes, and have reduced the free area for rapid egress travel in an emergency situation. Cabling is routed on top of steam and condensate piping and routed along the floor that place personnel are in contact with energized primary electrical and telecom cabling while walking on a floor with standing water. Some branch takeoffs are difficult to access from the main tunnel due to the fiber optic cabling mounted along the wall and across the branch opening. The cables pass by the branch takeoffs without transferring routing to the ceiling and leaving an opening to enter the branch tunnel.

Egress Deficiency Photos

A majority of the existing pipe support systems use bolted unistrut design with some engineered welded structural steel. Most of the existing supports are painted steel and are corroding due to high humidity, pipe leaks, or water infiltration from tunnel structural deficiencies. Some portions of the utility tunnel have stanchions corroded to the point they no longer support the pipe and need immediate attention. Select support locations have the lower 6" – 12" of the unistrut cut off and replaced with galvanized steel. Some areas in the tunnel have had the entire unistrut steel support replaced with a galvanized unistrut. The replacement steel has started to corrode since the new galvanized steel has been bolted directly to the floor. Examples of structural support deficiencies are included in the following photos.

Structural Support Deficiency Photos

Sump pumps used for pumping water from the utility tunnel are located far apart. Some of these sump pumps are not functioning and are in need of maintenance.

Non-insulated or under-insulated pipe and fittings, leaking pipe fittings, leaking and inoperable trap stations and non-insulated pressure reducing valves are causing most of the temperature, and humidity issues directly related to the ventilation and temperature control issues noted above.

The majority of the utility tunnel lighting has compact fluorescent light bulbs installed. The spacing of the fixtures in the majority of the tunnel system is rated as fair as compared to a good/excellent. Approximately 10% of the bulbs throughout the tunnel are burned out and the fixture or wiring is damaged or corroded.

c) Steam and Condensate Distribution Summary and Recommendations

The deficiencies noted above are recommended to be corrected, upgraded or replaced as necessary for appropriate personnel safety and systems integrity through operations. Descriptions of recommendations include the following:

- *Add access points at 250-300 ft intervals along side of the existing tunnel system.*

  It is recommended to add access points throughout the tunnel system that would have a hinged locked hatch with a panic bar at the top. The structure would also contain louvers and ducting to allow natural ventilation to occur. Examples of access hatches are shown in the photos below. Cost for a vertical access point connected to the side of the existing utility tunnel structure is estimated at $12,000 each. If piping is located on each side of the tunnel the cost will be in the range of $40,000 (+/-) due to required piping modifications.

Photos of Recommended Access Hatch Types

- *Upgrades or replacement to existing tunnel segments to avoid tunnel structural failure.*

Areas of replacement are indicated on Drawing II-B-2-c-1 within Appendix II-B and described below. Estimated cost of each segment is included on the following page in Table II-B-2-c-2.

Approximately 760 ft of the segment from Biological Sciences to Knight Hall is recommended to be replaced in the same location of the existing tunnel. At the same time it is recommended to place a set of ductbanks along side of the new tunnel structure to remove the primary power and telecom wiring from this tunnel section.

It is recommended to replace and relocate the tunnel segment out from under the Engineering, Agricultural and Education buildings to prevent structural failure from cutting service to a portion of the campus. The existing piping can serve as a back feed to serve Engineering, Agricultural and Education buildings. The cost to reconstruct the existing tunnel under the buildings would be cost prohibitive compared to relocating the tunnel and services to Lewis St. Analysis, estimates of, and recommendations of upgrades to the existing tunnel structure will be required to be performed by a licensed structural engineer.

It is recommended to replace the 10" direct buried pipe along Willet Drive which is limited in capacity. The pipe would be replaced a new 12" line located in a new walk able utility tunnel. The utility tunnel will route along the same respective area in Willet Drive from the PRV vault near Honor's House east to the Arena tunnel area. This new tunnel will also replace the existing congested east/west tunnel segment along Fraternity Row.

The final segment of utility tunnel replacement is recommended along Sorority Row and including the north/south segment east of 15th St. This tunnel has a low ceiling height, limited width and primary power and telecom inside.

It is recommended to remove the steel pan material and check the structure within the utility tunnel segment to the Washakie Worst case scenario is the roof will need to be removed and replaced.

- *Replace or fix inoperable sump pumps and Add sump pump locations.*

Addition of sump pump locations is recommended in areas of high ground water content, tunnel water infiltration, tunnel low points, and at each new utility tunnel access/egress locations. Each sump is estimated to have a cost of $3000 per location including the pump, electrical and associated piping.

- *Upgrade deteriorating or failing supports.*

  Any pipe support stanchions with corroded feet should be replaced to maintain adequate support for piping. The lower 12" should be replaced and reinstalled with galvanized steel unistrut mounted on a 2" grouted concrete base. The estimated cost for each replacement is $400 per location.

- *Replace inadequate insulation and ACM when piping upgrades made.*

  A minimum of 3" of insulation with protection shields should be utilized on piping. The insulation on the steam pipe section from Agricultural Building past Education Building should be modified to bring local tunnel temperatures down below 100 degrees F.

- *Replace incandescent bulbs and fixtures with fluorescent bulbs and fixtures rated for high temperature and humidity conditions.*

  The new light fixture can be placed either in the ceiling or high on the wall as space allows, on 12'-0" centers. All wiring should be removed and replaced as the areas are upgraded. New illuminated switches should be installed in 100-150 ft intervals to turn on/off lights as personnel navigate the tunnel system.

Table II-B-2-c-2

Table II-B-2-c-2 Steam Distribution System Replacement Estimate				
Description of Items	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
System Sizes and Configuration				
Construction Period 2010-2015				
Replace existing Utility Tunnel with New Waterproof Walkable Tunnel w/ 10" HPS Sch. 80 Piping, 6" HPC Sch. 80 Piping, 2" CA, Pipe Insulation, Pipe Supports & Anchors, Lighting & Sumps (From Biological Sciences to Knight Hall)	760	lf	$5,000	$3,800,000
System Allowances & Costs				
1% Connect to Existing System Allowance	1	ls	$38,000	$38,000
7% Fitting Allowance	1	ls	$266,000	$266,000
3% Valve Allowance	1	ls	$114,000	$114,000
2.5% System Testing	1	ls	$105,500	$105,500
2.5% Traffic/Road Barriers	1	ls	$105,450	$105,450
2.5% Distribution Interference	1	ls	$105,450	$105,450
2.5% Site Construction Requirements	1	ls	$105,450	$105,450
25% Estimating Contingency	1	ls	$1,159,963	$1,159,963
8% A/E Design Fees	1	ls	$463,985	$463,985
Total 2010-2015				**$6,263,798**
System Sizes and Configuration				
Construction Period 2015-2020				
Replace Direct Buried Piping with New Waterproof Walkable Tunnel w/ 12" HPS Sch. 80 Piping, 6" HPC Sch. 80 Piping, 2" CA, Pipe Insulation, Pipe Supports & Anchors, Lighting & Sumps (From Willet Pit to the Arena)	1340	lf	$4,000	$5,360,000
System Allowances & Costs				
1% Connect to Existing System Allowance	1	ls	$53,600	$53,600
7% Fitting Allowance	1	ls	$375,200	$375,200
3% Valve Allowance	1	ls	$160,800	$160,800
2.5% System Testing	1	ls	$148,700	$148,700

[redacted]

:/Road Barriers	1	ls	$148,740	$148,740	2.5% Traffic
ɔution Interference	1	ls	$148,740	$148,740	2.5% Distrib
:onstruction Requirements	1	ls	$148,740	$148,740	2.5% Site C
ıting Contingency	1	ls	$1,636,130	$1,636,130	25% Estima
;ign Fees	1	ls	$654,452	$654,452	8% A/E Des
2020				**$8,835,102**	**Total 2015-**
:es and Configuration					***System Siz***
Construction Period 2020-2030					
sting Utility Tunnel with New Waterproof Walkable Tunnel w/ 8" 0 Piping, 4" HPC Sch. 80 Piping, 2" CA, Pipe Insulation, Pipe Anchors, Lighting & Sumps (Sorority Row and South from Willet Sorority Row)	1600	lf	$5,000	$8,000,000	Replace ex HPS Sch. 8 Supports & Pit down to
owances & Costs					***System All***
t to Existing System Allowance	1	ls	$80,000	$80,000	1% Connec
.llowance	1	ls	$560,000	$560,000	7% Fitting A

d) Steam Flow Analysis

The UW requested that a computer software flow model be developed as a part of the campus master plan to analyze the current steam distribution system. The computer software program chosen to do the flow analysis was AFT Arrow Version 4.0, a fluid modeling software developed by Applied Flow Technology for analyzing compressible fluid systems. The program utilizes a Gaussian Elimination matrix method to perform iterations that balance fluid flow to provide an output including pipe flows and pressures.

The model was developed by applying the known parameters of the existing campus system such as pipe type and size, pressures and flow rates to existing buildings into the model. Pipe data including material, lengths, diameters, and fittings were provided by the UW. Diversified building loads estimated by AEI were input into the program and are further described in section III Building Load Analysis.

Each building load was input as pounds per hour (lb/hr) to represent building steam usage. The main pressure reducing valves (PRVs) in the utility tunnel were modeled and set to 12-70 psig pressures identified from an existing schematic flow diagram provided by the UW. A select few of the building PRVs were modeled and included those that were known to use 70 psig steam that was reduced and then feed back into the 12 psig distribution system.

The buildings where this is known to occur are:

- Physical Sciences
- Biological Sciences
- Knight Hall
- Aven Nelson
- Mcwhinnie Hall

The (CEP) was modeled as a closed tank system and was modeled with 125 psig steam set point as directed by the UW to match the existing system. Steam pressure readings taken from pressure indicators within the system were also provided by the UW to potentially serve as a method to calibrate the model. After further review it was determined that they only represent local timed pressures and do not indicate what is occurring within individual buildings around the general area of the pressure indicator. Therefore the estimated load/flow values defined above were assumed to be adequate per historical data and used to perform the flow analysis of the existing system. Information pertaining to the evaluation of the existing steam system model is described below.

A campus steam distribution map, developed in AFT, with pipe number designations is shown in Drawing II-B-2-d-1a and a complete output report including pipe flow and pressure data is included in Figure II-B-2-d-1b of Appendix II-B. Evaluation of the model and results are included below.

The steam mains on the east side of campus can accommodate additional capacity due to the large pipe diameters and 125 psig high pressure steam. The steam distribution system on the west side of campus however is near or at full capacity due to smaller pipe diameters and lower steam pressures. The velocity in pipes at numerous locations is approaching 12,000 ft per minute (fpm), which is the maximum recommended velocity to minimize noise and pipe erosion. The following locations were found to be nearing 12,000 fpm:

- The 10” diameter, high pressure steam main in the tunnel outside the Law Building is almost at full capacity. The pipe is labeled P37 and is located south of the two converging 10” steam mains and north of the PRV as shown on Drawing II-B-2-d-1a of Appendix II-B.
- The 70 psig steam mains from the 125 psig to 70 psig PRV located near the Willet Pit to the west. The steam main going northwest towards McWhinnie Hall and the main going southwest towards the College of Engineering Library are almost at full capacity. The piping to the west of these two buildings is adequate for the estimated capacities.
- The 12 psig steam main after the PRV in the tunnel outside of the Old Power Plant, designated as P384, is above 12,000 fpm indicating the current capacity is limited or at full capacity.

There are back feeds at numerous locations where the 70 psig steam service is intended to increase the capacity of the 12 psig steam service on the west side of campus. Initially, the software was not able to converge on a solution after running numerous iterations. This is due to the number of loops in the system and lack of given pressure data that could be input into the model correlating to a specific load instance. In order for the program to converge on a realistic solution, the number of flow paths was reduced. These removed paths were chosen through assumptions towards loops that provide the least advantage in terms of capacity, initially determined by pipe diameter and distance from the steam mains. Some of the back feeds at the buildings were shut off to evaluate the affect on the system, which resulted in no effect on the steam main capacities. The closed back feeds and input pipes with no flow are represented by dotted lines on the AFT model in Figure II-B-2-d-1a of Appendix II-B.

The evaluation of the current steam distribution system has indicated that a few locations are at or near recommended capacities based on velocity and pressure drop. The remainder of the steam distribution system appears to be adequate to support the estimated existing capacities and there is no immediate need to increasing the size of the piping in the system for the purpose of increasing capacity. The effect of the future loads on the existing steam distribution system is evaluated in Section III of this report.

e) Condensate Flow Analysis

The UW requested that a computer software flow model be developed as a part of the campus master plan to analyze the current limitations of the existing piping and possible options for increasing the capacity of the condensate system for future heating loads. The computer software program chosen to do the flow analysis was AFT Fathom Version 7.0, a fluid modeling software developed by Applied Flow Technology for incompressible fluids. The program utilizes a Gaussian Elimination matrix method to perform iterations to balance fluid flow to provide an output including flows and pressures.

The model was developed by applying the known parameters of the existing campus system such as pipe type and size, pressures and flow rates to existing buildings into the model. Pipe data including material, lengths, diameters, and fittings were provided by the UW. Diversified building loads estimated by AEI were input into the program and are further described in section III Building Load Analysis.

It was recognized that pump operation times and gravity loads with respect to one another were unknown. Since this information was not available a diversity factor of 100% was assumed to provide a worst case loading scenario to the piping system back to the condensate receivers that pump directly to the CEP. Each building load was correlated to the steam usage above and assumed to have no system losses. Each condensate pump was set to rated flows provided by the UW. The model was used to calculate the pump pressure required to satisfy the existing estimated campus loads. This data was then compared to actual pump pressures to determine if the system is adequate. Information pertaining to the evaluation of the existing condensate system model is described below.

A campus condensate distribution map, developed in AFT, with pipe number designations is shown in Drawing II-B-2-e-1a along with a complete output report including pipe flow, pressure and pump pressure data is represented in Figure II-B-2-e-1b within the Appendix II-B. Evaluation of the model and results are included below.

The condensate piping is adequate for the existing loads on the campus and can accommodate additional capacity. The model results indicated the pumps at each building and pumping stations have adequate head to transport condensate back to the condensate receivers through the existing piping configuration.

One location is noted to be above recommended velocity or pressure loss. The pipes are listed as P131, P132, P383, and P384 which is the 3" diameter piping north of the fraternities that tie in after all of the branch load connections terminate at the condensate receiver at Willet Pit. This piping has a flow of about 265 gallons per minute (gpm), resulting in a velocity of about 11.5 ft per second (fps). Typically, hydronic piping is sized for a max flow of 10 fps to avoid excessive pipe erosion and pressure drop.

f) Steam and Condensate Flow Summary

The existing campus steam fluid model indicates that the main 75 psig and 12 psig existing steam services on the west side of campus are at capacity. The high pressure service on the east side of campus is adequate for the campus loads and can handle additional capacity.

The existing campus condensate piping appears to be adequate for the current loads and can handle additional capacity with exception to a 3" pipe into the receiver pit at Willet. This conclusion is based on having 100% flow from all of the condensate pumps and gravity lines simultaneously, which is not really representative of the flow that is likely at one point in time for the campus. A diversified flow of 50%-75% is a realistic approach to pumping operations which in turn increases the available capacity of the condensate distribution system further and results in no deficiencies of the existing system.

C. Cooling System

There are multiple systems on the UW Campus that provide cooling to the current campus buildings during occupied state. These systems include chilled water production at a CEP, Evaporative Cooling, Direct Expansion Refrigerant and operable windows (no cooling) sufficing for the building yearly cooling loads. A building cooling source campus map is shown in Drawing II-C-1-a of Appendix II-C which identifies the type of cooling provided at each building. Descriptions of each type of system are identified below.

1. Central Energy Plant

a) General Overview

The majority of the buildings on campus are cooled by a central chilled water system located in the (CEP). The chilled water produced at the CEP is distributed to campus buildings and back to the CEP within direct buried distribution piping throughout the campus.

b) Existing Central Energy Plant Chilled Water System Configuration and Condition Assessment

The chilled water system at the CEP consists of two electric centrifugal chillers of 800 and 1,200-ton nominal capacity, and two plate and frame heat exchangers. Chilled water is distributed by three pumps, each rated for 1,500 gallons per minute (gpm) capacity at 160 ft of head. The pumps are piped in parallel and through a common header to each chiller and then to the campus as a variable primary system. A flow diagram of the chilled water system is shown in Drawing II-C-1-b-1 in Appendix II-C. The distribution pumps are controlled through pressure differential sensors located on campus that modulate the pumps VFD's to control speed of the pump and satisfy system pressure throughout seasonal loading on campus.

The condenser system consists of two cooling towers, and three distribution pumps that are piped to a common header which supplies water flow to each chiller condenser and plate and frame heat exchanger. Cooling tower number 1 (CT-1) consists of three packaged cross flow-type cells with factory fabricated basins built into each tower. Cooling tower number 2 (CT-2) consists of two field erected counterflow-type cells over a field poured concrete basin. A flow diagram of the condenser system is shown in Drawing II-C-1-b-2 of Appendix II-C. Water flow to the chillers and plate and frame heat exchangers occur during seasonal shifts to satisfy campus chilled water loads through chiller mechanical production or free cooling through the plate and frame heat exchangers. The condenser water pumps are sized for equal capacity. Two pumps are piped in parallel on cooling tower #2 for redundancy and one pump is piped to Cooling Tower #1 without redundancy.

Recent chilled water system projects during 2008 and 2009 replaced an existing portion of the chilled water system with a new 1,200-ton chiller, all distribution pumps, VFD's, piping and specialties to convert the chilled water system to a variable primary system. A second project also took place in 2009 to rebuild the two existing cooling towers internals to increase thermal capacity to 1200 tons each and upgrade the overall structural integrity of the towers to like new conditions. New condenser water pumps, piping, valves and specialties were installed at the same time.

To determine the condition of the remainder of the (CEP) cooling system, a visual assessment and evaluation discussion was held with the UW Physical Plant and CEP staff. The visual assessment resulted in no notable concerns and the equipment appeared to be well maintained by the CEP staff. The evaluation discussion presented similar results and a summary of equipment conditions can be found in Table II-C-1-1.

Table II-C-1-1 Chilled Water Condition Assessment

Condition Evaluation Assessment, Based on Estimated Life Expectancy					
Equipment	Poor Yrs < 5	Fair 5-10 Yrs	Good 10-20 Yrs.	Excellent 20+ Years	Comments
Chiller 1			X	X	
Chiller 2				X	New in 2009
Chilled Water Pump 1				X	New in 2008
Chilled Water Pump 1 VFD				X	
Chilled Water Pump 2				X	New in 2008
Chillled Water Pump 2 VFD				X	
Chillled Water Pump 3				X	New in 2008
Chilled Water Pump 3 VFD				X	
CEP Chilled Water System Valves			X	X	New Portions in 2008
CEP Chilled Water Piping			X	X	New Portions in 2008
CEP Chilled Water System Sensors and Devices				X	New Portions in 2008
Chilled Water Insulation			X	X	New Portions in 2008
Cooling Tower 1 (Three Cell BAC)				X	Rebuilt in 2009
Cooling Tower 1 VFD's				X	
Cooling Tower 2 (Two Cell Field Erected)				X	Rebuilt in 2009
Cooling Tower 2 VFD's				X	
Condenser Pump 1				X	New in 2008
Condenser Pump 1 VFD				X	
Condenser Pump 2				X	New in 2008
Condenser Pump 2 VFD				X	
Condenser Pump 3				X	New in 2008
Condenser Pump 3 VFD				X	
Condenser Water System Valves			X	X	New Portions in 2008
Exterior Below Grade Condenser Water Piping			X	X	
Exterior Above Grade Condenser Water Piping			X	X	
Interior Condenser Water Piping			X	X	New Portions in 2008
CEP Chilled Water System Sensors and Devices				X	New Portions in 2008
Plate and Frame Heat Exchanger 1			X		
Plate and Frame Heat Exchanger 2			X		
Chilled and Condenser Water Chemical Treatment Sytems			X	X	
Chilled and Condenser Water System Controls				X	Recently Upgraded

c) Summary

Generally, all of the existing CEP cooling system equipment and auxiliaries are in good condition with at least 20 years of expected useful life remaining. Beyond annual maintenance or unknown repair cost, there is no existing equipment that requires a set year capital expenditure to be placed for upgrade or renovations to existing equipment with exception to adding equipment as required to upgrade the system to firm or N+1 Redundancy noted below:

- Plant firm capacity and equipment redundancy is currently not satisfactory to maintain continuous operations under full load conditions if a component of the 1200 ton chiller were to be shut down for maintenance or fails during normal operations.
- The only equipment that is currently maintaining current firm and N+1 capacity are the cooling towers, condenser water pumps, Plate and Frame Heat Exchangers, and chilled water distribution pumps.
- From the condenser water flow diagram analysis it appears that there is no bypass from the pump outlet to the pump inlet for water temperature control to maintain an acceptable level of icing at the towers.

Further capacity analysis and projected equipment requirements are evaluated in Section III Building Load Analysis under part C-3. Options for the current deficiencies and future projected loads are presented in Part D of Section IV Options Analysis.

2. Local Building Cooling

a) General Overview

A small number of the buildings on the UW Campus are cooled by means of local evaporative cooling systems, DX systems or through operable windows.

DX systems are primarily utilized for a backup source of cooling or where there is no means to cool an existing building from the campus chilled water loop. DX cooling also requires less floor to floor height due to a larger delta T and lesser duct sizes.

Evaporative cooling is utilized at the UW due to the relatively low wet bulb temperature during the spring, summer and fall cooling seasons, which is usually effective when the wet bulb temperature is below 60 deg. Evaporative cooling is typically utilized in newer buildings or in buildings where floor to floor heights can accommodate the increased duct sizes due to the low delta T gained from an evaporative cooling system.

Current evaporative cooling systems utilized on campus involve delivering a ventilation supply airstream through a stream of water within air handling units to cool the air from the cooling effect of evaporating water. The cooling affect occurs from pulling latent heat from the surrounding spaces to evaporate the water which in turn cools the air. Evaporative cooling systems are either direct air to water contact or indirect with a heat exchanger between the water and air source. Figure-II-C-2-a within Appendix II-C is a typical AHU configuration utilized by the UW that includes direct evaporative cooling. Direct evaporatively cooled systems typically have greater efficiencies and can sustain larger loads than indirect systems which lead to larger use in building cooling systems where applicable.

b) Summary

DX systems are typically not used on campus with exception to a few areas on campus including the Data center where cooling is provided via both chilled water and DX as a backup source.

Evaporative cooling systems are currently located in 8 buildings on campus which are successfully operated with proper control and maintenance to maintain the duct clear from biological residue that may exist in poorly maintained systems. The control has also been tweaked to prevent moisture issues from subsiding within the building and building equipment proper.

3. Chilled Water Distribution System

a) General Overview

The chilled water distribution system on the UW campus consists of direct buried supply and return chilled water piping. The chilled water originates at the CEP at the northeast corner of campus. The pumping flow and head for the system is provided solely by the primary pumps located at the CEP. A layout of the existing chilled water distribution piping indicating location and pipe diameters is shown in Drawing II-C-3-a in Appendix II-C. From the CEP, a single main distribution pipe routes south along 19th St. with branch connections to the Wyoming Technology Business Center, Animal Science/Molecular Biology, and Centennial Complex. South of the Wainwright and Willett Bungalows, the piping routes to the west and branches into two mains serving the campus.

b) Existing Chilled Water Distribution System Configuration and Condition Assessment

The existing chilled water distribution consists of direct buried piping extending from the northeast corner of campus at the CEP to the far west side of the campus. The majority of the piping is ductile iron from the CEP to Geology; however transite and schedule 20 steel piping are also installed on the west side of the campus. Some of the branch piping to the buildings is high density polyethylene (HDPE) and C900 polyvinyl chloride (PVC). The majority of the piping was installed in 1982 when the construction of the CEP was completed. Some of the branch piping to buildings and the extension of pipe main from the Business Building east to the Information Technology Building and then north to the pipe main north of the fraternities was installed between 2007 and 2008. The chilled water piping on the far west side of campus near Physical Sciences, Biological Sciences, Classroom, and Earth Sciences was installed in 1968. A map of the age of the distribution piping is shown in Drawing II-C-3-b in Appendix II-C. The piping installed in 1968 is probably nearing its expected useful life and is based on a 50 year useful life expectancy. The piping installed in 1982 should be in good condition for another 20 years and the remainder of the piping is less than five years old.

c) Hydraulic Analysis

The UW requested that a computer software flow model be developed as a part of the campus master plan to analyze the current limitations of the existing piping and possible options for increasing the capacity of the system for future cooling loads. The computer software program chosen to do the flow analysis was AFT Fathom Version 7.0, a fluid modeling software developed by Applied Flow Technology for incompressible fluids. The program utilizes a Gaussian Elimination matrix method to perform iterations that balance fluid flow to provide an output including flows and pressures.

The model was developed by applying the known parameters of the existing campus system such as pipe type and size, pressures and flow rates to existing buildings into the model. Pipe data including material, lengths, diameters, and fittings were provided by the UW. Diversified building loads were estimated by AEI and are further described in Section III, Building Load Analysis. The estimate loads were developed as tons of cooling and converted to a flow rate GPM that correspond to a 14° water temperature differential. Each of these building flow rates were represented in the model as a flow control valve. Pressure reducing valves were also included at each building and set at 50 ft pressure drop to represent an estimated pressure drop that occur from building piping and cooling equipment The chilled water pumps were set to the rated flows provided by the UW.

The model was executed to calculate the required pump pressure for the flows and piping configuration noted above. This pressure was then compared to the actual CEP pump to determine if the rated pump pressure was adequate. The distribution piping was evaluated to determine if any excessive velocities and/or pressure drops occur from the estimated flows. Recommended velocities and pressure drops should be maintained below 10 feet per second (FPS) and 5 Ft/100 Ft of pipe respectively. Information pertaining to the evaluation of the existing condensate system model is described in the following paragraph.

A campus chilled water distribution map developed in AFT, including pipe number designations, is shown in Drawing II-C-3-c-1a and an output report of pipe flow and pressure data is included in Figure II-C-3-c-1b of Appendix II-C. Evaluation of the model and results are included below.

The existing chilled water distribution does not appear to have any limitations for the estimated building cooling loads. Excessive velocities are not present and the current pumps are capable of satisfying the required system capacity and head.

d) Summary

In summary, the existing chilled water distribution system does not have any limitations with the current loads. The diameter of the pipe and the pressure provided by the pumps at the CEP is adequate to serve the current building loads.

D. Compressed Air

1. Compressed Air Distribution System

a) General Overview

The compressed air system at the UW Campus consists of three equally sized air compressors that serve compressed air to the campus through distribution piping within the existing steam tunnels. The system generally serves air to pneumatic controls as well as process equipment loads on campus.

b) Existing Compressed Air Distribution System Configuration and Condition Assessment

Two of the compressors are located at the Engineering Building and the other at the CEP. The compressors were manufactured by Ingersoll Rand, are rated at 75 hp, and have a capacity of 320 SCFM at 125 psig supply pressure. Each compressor is provided with an air dryer and inlet and outlet filters. One 650 gallon compressed air tank is provided for both compressors to charge.

The compressors header to a distribution network of piping that distributes to the majority of the buildings on campus. The piping is carbon steel and copper piping, and is routed through the underground tunnels with the steam and condensate piping. A map of the compressed air piping through the underground tunnels is provided in Drawing II-D-1-b of Appendix II-D.

The compressors, dryers, filters, and tanks are noted by the UW to be in good condition. Operating logs are maintained to keep a record of run-time hours and maintenance activities. The distribution system was investigated by a walk-through of the tunnels and was observed by AEI to be in fair to excellent condition.

c) Hydraulic Analysis

The UW requested that a computer software flow model be developed as a part of the campus master plan to analyze the current limitations of the existing compressed air piping. The computer software program chosen to do the flow analysis was AFT Arrow Version 4.0, a fluid modeling software developed by Applied Flow Technology for compressible fluids. The program utilizes a Gaussian Elimination matrix method to perform iterations to balance fluid flow to provide an output including flows and pressures.

The model was developed by applying the known parameters of the existing campus system such as pipe type and size, pressures and flow rates to existing buildings into the model. Pipe data including material, lengths, diameters, and fittings were provided by the UW. Diversified building loads were estimated by AEI and are further described in section III Building Load Analysis The estimate loads were developed as SCFM that are applied to each building.

A campus compressed air map developed in AFT, including pipe number designations is shown in Drawing II-D-1-c-1a, and an output report of pipe flow and pressure data is included in Figure II-D-1-c-1b in Appendix II-D.

Overall, the current compressed air piping is more than adequate for the loads that were developed for the buildings on campus. There were not any excessive pressure drops noted for the majority of the piping with exception to a branch line serving the dormitories. The information provided by the UW indicates a ½" line serves White Hall, Downey Hall, Wasakie Center, McIntyre Hall, and Orr Hall. The total load results in excess of 50 scfm, which corresponds to a velocity of 2,600 feet per minute (fpm) and a pressure drop of 30 psi. The remaining pressure is almost 90 psig after it leaves this pipe.

d) Summary

There are no notable concerns for the existing compressed air system and distribution system with the exception of the line serving the dormitories. If additional loads are suggested to be added to this pipe it is recommended to physically review the existing pipe pressure drop for the actual system operation. The review should conclude if the pipe is adequate or if replacement with a larger pipe is required. A second option is to parallel the existing pipe with a new pipe to serve the additional loads.

E. Electrical System

1. General Overview

The main campus electrical power is delivered to the site from Rocky Mountain Power (RMP) at 7,620/13,200 volts, 3-phase, grounded wye. The majority of the loads are fed from two primary metered main switchgear assemblies that serve the primary distribution systems for the west and east sections of the campus. Campus is divided into the east and west services with 15th St. as the general line of separation. The majority of the existing academic and administrative loads are served by the west service point. Refer to the attached system One-Line Diagrams that have been updated to current status, with the exception that the main primary system recloser for the east campus system has been removed during the summer months of 2009.

Each of the two main switchgear units is equipped with a main overcurrent protective device having a trip setting at 480 amperes and five (5) feeder switch assemblies with trip settings for most devices at 240 amperes serving underground feeders. There are two interconnection ties between the east and west feeders with normally-open switches that allow for emergency operation only and not for normal use. There is a third service point fed from a 13,200 volt overhead source that is primary metered serving housing and related loads to the southeast corner of the campus and roughly defined as the area east of 22nd St. and south of Willett Drive. Several of the single story apartment units in this area are fed from RMP distribution overhead lines not on the campus systems. The third service does not have interconnection capability with any of the other campus systems.

Transformation to building service voltages is achieved by application of vault and/or pad mounted oil-filled distribution transformer equipment. Building service voltages are generally 277/480 volt, or 120/208 volt, 3-phase. The transformers are grounded wye primary and grounded wye secondary. All oil-filled transformers and equipment have been tested and oil with Polychlorinated Biphenyls (PCB's) have been removed and replaced with non-PCB oil or the equipment has been replaced.

2. Existing Electrical System Configuration and Condition Assessment

The Main Campus primary distribution system is configured in a general radial feed arrangement with loop interconnection provision to facilitate emergency operations. For the most part, the radial and loop feed conductors are sized at #4/0 AWG (ICEA Ampacity = 278) with #2 AWG (ICEA Ampacity = 148) feeders to individual building services. Primary switch cabinets are utilized throughout the main campus areas to serve individual loads and establish loop interconnection configurations. The loops are established using normally-open feeder switch units in distribution cabinets to allow emergency operation only for load connection and isolation of potentially damaged feeder sections or equipment.

The overall condition of the primary distribution and service equipment is acceptable, but replacement of selected equipment items should be considered. Some equipment and installations can be immediately identified as candidates for replacement, such as the switchgear at Coe Library. A review of the equipment documentation and site observations indicate that approximately 70-75% of the equipment is, at minimum, “serviceable” and ``can be continued to be safely left in operation for 10 years or more. All of the overhead lines remaining on the system should be programmed to be replaced by underground distribution in the immediate future. Existing unit substation equipment utilizing indoor primary dry type transformers (such as used in Physical Science) should be candidates for replacement. Use of pad mounted, oil-filled transformers are easier to replace and will not impact use of the building for months while waiting for replacement equipment.

Testing of components for the primary distribution system should continue. Transformer oil sampling and testing should be continued on an annual basis. Existing EPR and Cross-Linked Polyethylene (XLPE) cable sections have been tested using Partial Discharge methods. This approach should continue with increased emphasis on XLPE cable sections. This type of program could be developed by complete system survey or utilized as an “action list” that might be established and maintained by the facilities electrical group at the UW on an ongoing basis.

All existing duct banks utilize 4” conduits encased in concrete. The utility tunnels are generally not utilized for routing of feeder conduits through the campus areas. There are numerous alcoves in the tunnel system where cable splicing has occurred in the past. A priority assignment process might include removal of these splices from the tunnel system and replaced with splicing in underground vaults or pad mounted termination cabinets. Any reference to future or new duct bank assemblies will assume similar products organized and assembled into duct bank configurations that will be routed apart from the utility tunnels nor constricted to the tunnel configurations.

There have been some recent incidents where service to the main campus primary system has been caused by the main primary devices tripping under transient and surge conditions. The pole-mounted recloser on the East Campus Primary feeder has been removed from service during the summer months of 2009 to help reduce the nuisance tripping operations. Protective analysis and characteristic curve adjustment on these devices can be performed to reduce the occurrence of such tripping. Coordination with RMP staff and application of analytical methods will be needed to solve these problems.

One configuration issue should be given top priority in the first phases of work under this study. In the Central Energy Plant (CEP), an existing 1,500 KVA (13.2KV to 2.4 KV) transformer and 960 KW generator is utilized to provide power for the original plant and 2,400 volt chiller. A separate 1500 KVA, 13.2 volt to 480 volt transformer is in place to supply power for the new chiller equipment. It is recommended that the two existing transformers, standby generator, and associated feeders and switchgear be removed with a new 13.2KV to 480 volt 1,500 KVA transformer and 2.0 MW standby generator to serve the CEP and Chiller and automatic transfer switch assembly be provided to simplify and renovate this part of the CEP service.

3. Summary

The existing primary service and distribution is, with a few exceptions, serving the University of Wyoming requirements and is capable of load expansion in the immediate future. The main protective devices for the east and west distribution systems are each configured with a trip setting at 480 amperes. The demand loads provided by the UW are 200 amperes for the west campus distribution system and 167 amperes for the east campus distribution system.

Utilization of existing equipment can be expected with selective replacement of degraded or improper components. System expansion and extension of new service points will be utilized to serve future loads that will bring the existing service points into an overloaded condition. Interconnection of those new service points will serve to improve reliability and load characteristics for the existing systems.

The existing distribution system has been modeled and analyzed using software applications from EDSA Micro Corporation. The modeling activity was completed in 2004 and included short circuit analysis and coordination study. Model modifications have been made to reflect changes since the 2004 study was completed. The model changes and measured demand values to the East Campus electrical model is represented in Figure II-E-3-1 and changes with demand loads to the West Campus electrical model is represented in Figure II-E-3-2 within Appendix II-E.

F. Domestic Water System

1. General Overview

The existing UW campus lies within the boundary of City of Laramie potable water distribution system Pressure Zone 2. As a result, potable water on campus is provided by gravity from the Zone 2 above-ground water tanks located on a ridge immediately east of campus. A boundary between city Pressure Zone 1 and Pressure Zone 2 is located along a portion of the current west and north campus boundary. Future campus development may therefore take place in areas that are currently within City Pressure Zone 1. A map showing City of Laramie potable water distribution system pressure zones is included in Appendix II-F-3.

2. Existing Domestic Water System Configuration and Condition Assessment

The Pressure Zone 2 water storage tanks supply two City 16” water mains that serve as the sole domestic water supply pipelines for the campus. The first of these 16” mains runs westward under Grand Avenue from 30th St. to 9th St., and the second main runs northward along 30th St. and then west across campus along Willett Drive and Lewis St. A map of the campus water distribution system and nearby City water mains is included in Appendix II-F-1.

A field survey of the existing domestic campus water system configuration was conducted by Electrical System Consultants Inc. (ESC). This survey included locating facilities in the field and researching existing drawings of various components of the campus potable water distribution system. Collected field data included determining pipe diameters, pipe materials, and locations of pipes, fire hydrant, pipe junctions, and valves. These data were made available in the form of an ArcGIS® geodatabase. The ArcGIS® data were imported into an AutoCAD® drawing file in order to allow manipulation of pipe reaches to establish a pre-determined quantity of pipes and nodes (pipe intersection points) for modeling purposes. The AutoCAD® drawing of the existing campus potable water distribution system is available in Appendix II-F-1**.**

The university currently meters campus water demand by a combination of master meters, which measure combined demand for several buildings in each of a number of areas of the campus, and individual building water meters. The use of master meters simplifies the City meter reading and billing process and reduces the number of meters that the University must maintain. Reliance on master meters limits the ability of university staff to determine water demand at some individual buildings on campus. As a result, determining the specific locations of high water demand and developing measures to reduce demand in master metered areas is difficult.

Based on discussions with UW staff, the general condition of the campus domestic water distribution system is considered to be reasonably good in that system maintenance requirements are not excessive. Existing campus cast iron water lines have presumably deteriorated to varying degrees as has been the case with cast iron City water lines. An assessment of campus water line leakage has not been completed.

3. Hydraulic Analysis

Using WaterCAD® V8i modeling software, an existing base model of the campus domestic water system was developed. This model contained 250 individual pipe segments and 218 nodes (pipe intersections or dead ends). Supporting information; including pipe diameters, pipe materials, pipe lengths, Hazen-Williams pipe friction coefficients, fire flow demand criteria, and node elevations; were included in the model. Data concerning water levels in the City Pressure Zone 2 tanks were provided by Mr. Mike Lytle of the City of Laramie and were included as the source of supply for the model. City water tank data is included in Appendix II-F-3.

Hazen-Williams pipe coefficients were derived from *Water Distribution Modeling, First Edition (*Haestad Press, 2001, Table 2.3). Values were referenced directly when possible; otherwise, linear interpolation was used for campus pipe diameters that were not listed in this reference. A copy of Table 2.3 from the Haestad reference is included in Appendix II-F-3. Since average and peak daily water demand are typically insignificant in comparison to fire flow demand, fire flow demand criteria were obtained and evaluated for inclusion in the model. Fire flow demand was applied to model nodes that were located at or near existing fire hydrants. Model fire flow demand was established as minimum 2,000 gpm flow with an upper limit of 3,500 gpm. Table B105.1 from the 2006 International Fire-Code, from which these criteria were obtained, can be seen in Appendix II-F-3. The American Water Works Association (AWWA) defines required fire flow as requiring a minimum residual pressure of 20 psig. This additional criterion was therefore included in the WaterCAD® models.

In order to assess the existing domestic water distribution system hydraulics, three existing condition scenarios were developed and modeled using WaterCAD®. Output from each existing condition modeling scenario included a tabular WaterCAD®-generated modeling scenario summary, a color-coded modeling map, and a tabulated fire flow report. On WaterCAD® maps, pipes are color coded by diameter. Fire flow was assessed sequentially at each of a number of selected nodes in the existing campus water distribution system. Green nodes on maps indicate locations at which the model shows that the existing distribution system is capable of delivering adequate fire flow. Red nodes indicate locations where the model shows that the existing distribution system is not capable of delivering adequate fire flow. One of each of these WaterCAD® output documents for the existing condition modeling scenarios is included in Appendix II-F-4.

The three existing condition WaterCAD® modeling scenarios included:

- *Scenario DE-1* – This model run assessed average daily campus demand of 500 gpm, the quantity of which was developed through discussions with UW staff, plus fire flow at each campus fire hydrant that was modeled one hydrant at a time sequentially across the system.

- *Scenario DE-2* – This scenario considered average daily campus demand was scaled upward by a factor of 2.72 to represent peak day demand. This scalar was obtained from Chapter 12 of the Wyoming Department of Environmental Quality, Water Quality Division (WDEQ/WQD) Rules and Regulations. Peak daily demand was then modeled in conjunction with the same fire flow demand that was assessed under Scenario DE-1.

- *Scenario DE-3* – This scenario included peak daily demand plus estimated 1,000 gpm irrigation water demand plus fire flow demand at each campus fire hydrant.

Calibration of early model runs consisted of comparing campus fire hydrant test data that were obtained from UW and pertinent available City hydrant test data with model output. Campus and City hydrant data included measured static water pressures at hydrants and calculated fire flows at 20 psig residual pressures based on measured hydrant flow and pressure data. Comparison of hydrant test data and early model output indicated an acceptably close correlation between the two sets of data. A summary comparison of these data and copies of campus and City hydrant test sheets are included in Appendix II-F-3.

Scenario DE-1 modeling output indicated that about one-third of existing campus fire hydrants (24 hydrants out of a total of 74 hydrants) are incapable of providing required fire flows and minimum residual pressure during fire flow demand. Similar results were produced from Scenario DE-2 and DE-3, in which 25 and 27 hydrants, respectively, were shown to be incapable of meeting fire flow requirements.

Assessment of these modeling results indicated that the primary cause of inability to meet fire flow criteria was the existence of a significant number of 6" diameter and other undersized water mains in the campus water distribution system. In every instance where a modeled hydrant failed to deliver adequate fire flow discharge or pressure, that hydrant received flow via a six 6" or smaller water main. Fire flows in these small pipe diameters produced high flow velocities, which resulted in large friction head losses and resultant decreases in pipe flow rates and pressures at the hydrants. Fire hydrants that failed to meet fire flow demand criteria are identified by color on scenario maps and in tabular format in the fire flow report for each existing condition modeling scenario that is included in Appendix II-F-4.

4. Summary

The UW campus potable water distribution system is part of the larger City of Laramie public water supply system. The campus distribution system lies within City Pressure Zone 2, which receives water from two above-ground water storage tanks that are located a short distance east of the campus. The condition of individual pipelines within the campus system is unknown, but, based on the experience of the City of Laramie, older cast iron campus water mains have probably deteriorated to varying and potentially significant extents. WaterCAD® modeling of the campus water distribution system under existing conditions and based on fire flow demand criteria indicated that the significant number of 6" and smaller diameter water mains on campus contributes to the inability of numerous campus fire hydrants to meet theoretical fire flow demand criteria.

G. Irrigation Water System

1. General Overview

The core campus irrigation water distribution system consists of approximately 44,450 lineal ft of pipe of varying diameters and materials that receive water primarily from one campus water well. This well produces water having relatively high concentrations of total dissolved solids (TDS), the result of which is that the UW must take care not to apply this water onto the sides of buildings or parked vehicles. Some peripheral components of the irrigation distribution system receive metered flow from the City of Laramie water mains.

The primary irrigation water supply well is located near the northwest corner of the Fine Arts Building and includes a submersible pump and a variable frequency drive (VFD) which maintains a relatively constant discharge pressure of 80 psig. A second and currently inoperative irrigation system water well is located west of the Fine Arts Building well near the southwest corner of the intersection of 15 St. and Willett Drive.

This well has been shut down because well discharge has contained significant quantities of sediment. When in use, this well served as a pressure booster for the irrigation system based on operation of a pressure regulated switch at the well. This switch turned the well pump on if irrigation distribution system pressure fell below 80 psig at the well and shut the well pump off when distribution system pressure at the well exceeded 80 psig.

Both the Fine Arts irrigation water well and the west campus irrigation water well have typically operated from late April to October, with the highest production occurring in the summer months of June and July. The Fine Arts well has an approximate average yield of 400 gpm, and the west campus well, when operating, yields about 200 gpm.

2. Existing Irrigation Water System Configuration and Condition Assessment

The UW irrigation water distribution system irrigates about 94 acres of campus landscaping. A map of irrigation system water mains is included in Appendix II-G-1. The campus irrigation system consists of three components, including the main campus system, the athletic facility system, and the student housing system. The latter two systems cover much of the eastern portion of the campus. Each component is maintained and operated by a separate staff but operates using water from the Fine Arts water well. The overall system is complex, contains a variety of types of components, is operated largely on the basis of past experience, and is not fully documented or understood by UW staff. The UW provided assorted irrigation system documentation and operating data for use during this project.

A field survey and research of existing UW irrigation system documents pertaining to the campus irrigation system were conducted by Electrical System Consultants Inc. (ESC). Collected data included pipe diameters and materials and the locations of pipes, pipe junctions, and valves. These data were made available in the form of an ArcGIS® geodatabase. Similar to the campus domestic water system, the existing irrigation distribution configuration was transferred from the ArcGIS® database into an AutoCAD® drawing file in order to define pipes and nodes for modeling purposes. The irrigation system AutoCAD® base drawing is located in Appendix II-G-1 of this report.

The general condition of the irrigation system is considered by UW staff to be marginally acceptable at this time. During discussions with UW staff it was learned that the irrigation system appears to discharge at adequate pressures but sometimes fails to provide desired quantities of water. UW irrigation criteria include supplying water to provide 2” per week of ground penetration over all irrigated areas. Due to current lack of coordination between the operators of the three components of the campus irrigation system and use by the three distribution system component operators of a single water well source of supply, the desired quantity of irrigation does not always occur in all areas of campus.

3. Hydraulic Analysis

The campus irrigation system was modeled using WaterCAD® V8i. A model shape file was created from the irrigation system base AutoCAD drawing, and this shape file was then imported into WaterCAD® in order to create a base model. The irrigation model of the core campus irrigation system contained 150 pipe segments and 142 nodes (pipe intersections). Two existing condition irrigation system scenarios were modeled. Output from each modeling scenario included a WaterCAD®-generated tabulated scenario summary, a color-coded modeling map, and a tabulated pipe and node summary. On these WaterCAD® maps, red nodes indicated locations at which the model showed that 60 psig minimum water pressure was not available. These supporting documents for each of the existing condition irrigation system modeling scenarios are included in Appendix II-G-3.

The two existing condition WaterCAD® irrigation system modeling scenarios included:

- *Scenario IE-1* – This scenario assessed peak hour core campus irrigation water demand of 504 gpm as determined during discussions with UW staff and utilization of the existing Fine Arts Building water well as the sole source of supply.

- *Scenario IE-2* – This scenario assessed peak hour core campus irrigation water demand plus athletic irrigation water demand of 634 gpm and utilization of the existing Fine Arts Building water well as the sole source of supply.

Calibration of the campus irrigation water distribution system was not feasible since the system is divided into numerous application zones which discharge water at varying rates and pressures and which are not operated at the same time.

Assessment of the existing irrigation water distribution system was based on determining, during simultaneous operation of the entire system, which locations within the system were incapable of discharging water at a pressure equal to or greater than 60 psig. This assessment indicated that a majority of irrigation system discharge nodes provided varying discharge rates at or above 60 psig. Incorporating some or all of the numerous, poorly-defined, small-diameter irrigation zone pipes and varying irrigation application durations into the model were not feasible at this level of analysis.

4. Summary

The UW campus irrigation system is complex, operated on the basis of changing site conditions and operator experience, and neither its physical makeup nor its operation has been systematically recorded or documented. Most of the system is currently reliant on one water well source of supply, resulting in the potential for potentially significant interruption of campus irrigation efforts if this well fails or becomes inoperable. The irrigation system presumably works reasonably well as indicated by the typically lush appearance of the campus in the cool, dry

Laramie environment. The UW avoids using the City of Laramie potable water supply system as the source of supply for most of the campus system.

H. Sanitary Sewer System

1. General Overview

The existing UW campus sanitary sewer collection system and nearby components of the City of Laramie sanitary sewer collection system consist of approximately 400 manholes with connecting gravity flow pipelines of various diameters. The campus sanitary sewer collection system discharges by gravity into the City collection system, and campus domestic wastewater is conveyed to and treated at the City wastewater treatment plant. The campus is located east and somewhat south of the treatment plant. Sanitary sewer lines in the southern and eastern portions of campus generally discharge southward into the City sanitary sewer lines in Grand Avenue, which flow in a westerly direction. Sanitary sewer lines in the older northwestern portion of campus typically discharge westward or northward into the City sanitary sewer lines in existing residential districts. Long reaches of the City sanitary sewer lines separating campus from the City wastewater treatment plant significantly impact UW options for upgrading the conveyance capacity of the campus sanitary sewer collection system.

2. Existing Sewer System Configuration and Condition Assessment

Campus sanitary sewer manholes were field surveyed during this project based on the current campus survey control system. This field survey was supplemented by extensive review of existing campus site plans. A digital map was then prepared showing the surveyed locations of existing sanitary sewer manholes and connecting pipes, including pipe diameters and flow directions. These structures were shown, along with surveyed campus storm water management facilities, on one base map of the campus and on eight map enlargements showing smaller areas of the campus that are located in Appendix II-H-1.

A spreadsheet containing detailed information regarding each surveyed UW campus sanitary sewer manhole and connecting pipes is included in Appendix II-H-2. Spreadsheet tabs include a base tab containing data pertaining both to campus storm water management system and the campus sanitary sewer system structures; a tab containing storm water management facility data only; a tab containing sanitary sewer facility data only; and several other tabs containing information regarding surveyed water system manholes and related structures. Information pertaining to each surveyed structure that is available in spreadsheet tabs includes the project survey point number; the corresponding City of Laramie manhole number if available; the northing, easting, rim elevation, depth, and invert elevation of each manhole; and the number and orientation of pipes discharging into or conveying flow out of each manhole. This spreadsheet also includes a “Look-Up” tab which allows calculation of half-full pipe and full pipe open channel flow capacity for any pipe reach by typing in the pipe material, the pipe diameter, and the upstream and downstream manhole survey point numbers for the pipe reach under consideration. This spreadsheet serves therefore as both a compilation of data and a simple spreadsheet flow model for both the campus sanitary sewer and storm sewer systems.

Discussions with the UW staff during this project resulted in identification of a number of concerns regarding the existing campus sanitary sewer collection system, including:

- Gravity sanitary sewer collection pipe junctions and bends that are not located within manholes or that do not have adjacent clean-outs are not uncommon on campus; as a result, determining the locations of sanitary sewer pipeline clogs, determining the physical condition of pipelines, and undertaking general sanitary sewer pipeline maintenance are significantly restricted or precluded at these locations;

- Numerous known or potential problems exist within or near King Row and Ivinson Avenue, including:

  - Two existing westward-flowing gravity sanitary sewer lines under King Row, which convey both campus and City wastewater, are old and in poor condition and are probably overloaded;

  - Near the southwest corner of Corbett, a 10" diameter gravity line and a 12" diameter gravity sewer line discharge into a manhole from which a single 10" diameter gravity sewer line conveys wastewater westward;

  - A similar conditions exists southeast of the stadium, where two 10" diameter lines discharge into a manhole from which one 10" diameter line conveys wastewater westward;

  - North of Crane Hall, a westward-flowing 12" diameter gravity sanitary sewer line discharges into an 8" diameter line;

  - North of Washakie, a 12" diameter gravity sanitary sewer line discharges into a 10" diameter line; and

  - Undersized 8" diameter and 10" diameter King Row lines extend westward down Ivinson Avenue, resulting in surcharging during periods of peak wastewater discharge;

- Past repairs to the Physical Sciences sanitary sewer service line were not completed properly, restricting flow in this line;

- A confluence of major gravity sanitary sewer lines from the stadium and the field house does not occur inside a manhole, thereby rendering assessment and maintenance of these lines impossible;

- An existing 6" diameter vitrified clay pipe (VCP) gravity sanitary sewer line that runs westward from the Arts & Sciences building beneath the Biological Sciences building is in poor condition and cannot be maintained properly because of its location beneath the Biological Sciences building;

- A 6" diameter gravity sanitary sewer line that is located on the south side of the old Wainwright Bungalows near Fine Arts and the Law building clogs regularly and is presumably broken or undersized; and

- The existing sanitary sewer service line from Knight Hall to the sanitary sewer main under Ivinson Avenue was constructed at a very flat slope and is apparently partially clogged with tree roots, resulting in low conveyance capacity.

Discussion with Mr. Larry Ketcham, City of Laramie Engineer, indicated that the City currently has no plans to significantly upgrade or modify the City sanitary sewerage collection and treatment system near campus or elsewhere within the City. A long-range study will soon be commissioned to assess, among other options, extending the City sanitary sewage collection system to currently unsewered residential areas that are located east of the City and the campus. This study and its results, if any, should not impact the operation of the campus sanitary sewerage collection system since City wastewater flows from east of the campus are discharged westward through lines that are located in the City, south of the campus.

The physical condition of surveyed manholes was assessed by others during the campus manhole survey, and information from this assessment is summarized within the geodatabase (GIS maps) in Section VI under separate cover.

3. Flow Analysis

Flow analysis of any pipe reach in the campus sanitary sewer system may be accomplished by opening the "Look-Up" tab in the electronic version of the Appendix II-H-2 spreadsheet. Half-pipe and full-pipe flow capacities in units of cubic feet per second (cfs) or gallons per minute (gpm) for any pipe reach in the system may be calculated by inputting the pipe material, pipe diameter, and upstream and downstream manhole survey point numbers for the pipe reach in question. Completion of a UW campus sanitary sewer wastewater collection system model was not included in the scope of work for this project.

4. Summary

The UW campus sanitary sewer collection system is a relatively large component of the City of Laramie sanitary sewer collection system. The UW campus system is a gravity flow system, and is therefore a relatively simple system. The contents of this section and accompanying appendices provide detailed information regarding the existing system that may be used in the future to assess individual components of that system and expansion of the system as required.

I. Storm Sewer System

1. General Overview

The existing UW campus storm water management system consists of approximately 390 manholes and catch basins with connecting pipelines as well as related storm water management structures such as detention and retention ponds. The campus storm water management system is intended to collect and discharge campus storm water runoff into the surrounding City of Laramie storm water collection system.

2. Existing Sanitary System Configuration and Condition Assessment

Campus storm water management structures were surveyed during this project based on the current campus survey control system. A digital map was then prepared showing the surveyed locations of existing storm sewer manholes, inlet basins, storm sewer pipes, and other storm water management structures. These structures are shown, along with surveyed campus sanitary sewer facilities, on one base map of the campus and on eight map enlargements showing smaller areas of the campus that are located in Appendix II-H-1. Surveyed storm water management facilities are also shown on Map SW1 in Appendix II-I-1.

A spreadsheet containing detailed information regarding each surveyed campus storm sewer and sanitary sewer structure and connecting pipes is included in Appendix II-H-2. Spreadsheet tabs include a base tab containing data pertaining both to the campus storm water management system and the campus sanitary sewer system; a tab containing storm water management facility data only; a tab containing sanitary sewer facility data only; and several other tabs containing information regarding surveyed water system manholes and related structures. Information pertaining to each surveyed structure that is available in these spreadsheet tabs includes the survey point number for each structure; the corresponding City of Laramie manhole number if available; the northing, easting, rim elevation, depth, and invert elevation of each structure; and the number and orientation of pipes discharging storm water into or conveying storm water out of each structure.

Recent campus reconnaissance by UW staff during a significant summer storm resulted in compilation of the following list of current storm water management issues:

- Existing landscaping and paving in the vicinity of the east entrance to the Law Building may require modification to ensure that future storm water runoff does not enter the building under the east doors. This improvement may be accomplished by modifying existing pavement and landscaping and/or by re-directing discharge from an existing building roof drainage downspout;

- The small retention pond that is located west of the Centennial Complex was full of water and may therefore be undersized.

- The existing detention pond at the intersection of 22nd St. and Harney St. received little or no storm water runoff due, at least in part, to placement of a log across the concrete pond inlet pad. This structure did not receive or attenuate peak storm water runoff flow as intended.

- Along 9th St., west of the Classroom Building, ponding occurred such that the east 9th St. curb was submerged; existing catch basins and pipes in this area should be checked and cleared of debris as required on a regular basis;

- Flooding occurred at the intersection of 15th St. and Ivinson Avenue, with manhole lids lifted by pressurized pipe flow in surcharged manholes along Ivinson Avenue; this issue is addressed below;

- Flooding occurred at the intersection of 15th St. and Sorority Row; this area is also addressed below; existing catch basins and storm sewer pipes should be checked and cleared of debris as required on a regular basis;

- Flooding occurred at the intersection of 13th St. and Ivinson Avenue, particularly at the northeast corner of this intersection; existing catch basins and storm sewer pipes should be checked and cleared of debris as required on a regular basis;

- The new parking lot that is located west of the Pharmacy Building ponded well, accepting runoff from as far away as the north portion of Prexy's Pasture; it is imperative that catch basins and storm sewer pipes be checked and maintained in this area to maintain current drainage patterns;

- The Frisbee parking lot, which is located east of Crane Hall, performed well in retaining and conveying storm water runoff;

- The existing retention pond that is located south of the football stadium was full and overflowing, with discharge from the pond emergency spillway running down 20th St. to Grand Avenue; this area is addressed below;

- Recently-installed storm sewer facilities in the Union East Parking area performed well and should be maintained and kept clear of debris; and

- The existing detention pond at 22nd St. and Grand Avenue received very little storm water runoff; this structure did not therefore attenuate peak storm water runoff rates; existing catch basins along Grand Avenue should be checked and kept free and clear as required.

In general, this reconnaissance supported the importance of regular maintenance and cleaning of campus storm water catch basins and pipes in order to fully utilize the capabilities of in-place storm water management facilities.

The physical condition of surveyed manholes was assessed by others during the campus manhole survey, and information from this assessment is summarized within the geodatabase (GIS maps) in Section VI under separate cover.

3. Flow Analysis

Flow analysis of the campus storm sewer system following surveying and mapping of the system consisted of two primary components, including surface water hydrologic analysis and storm sewer pipe and detention pond hydraulic analysis. Campus storm water hydrology and hydraulic analyses were completed using hydrology and hydraulic analyses modules in AutoCAD Civil 3D® 2010 (C3D) software. The Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service, SCS) curve number calculation method, which generates a runoff hydrograph from each analysis, was applied during this project. Generation of a runoff hydrograph, which cannot typically be accomplished using the simpler rational method of runoff calculation, is important in that a hydrograph can be routed through detention ponds, culverts, and other structures in order to design or assess existing detention and conveyance structures.

Two storms; the 10 year, 6 hour storm and the 100 year, 6 hour storm; were typically assessed. Precipitation depth during the 10 year, 6 hour storm in Laramie is 1.45”. Precipitation depth during the 100 year, 6 hour storm in Laramie is 2.2” (*Precipitation-Frequency Atlas of the Western United States, Volume II – Wyoming,* National Oceanic and Atmospheric Administration, 1973).

Map SW2 in Appendix II-I-1 shows the locations of NRCS hydrologic soils groups within and near the campus as determined by a search of the NRCS soils web site. Native campus soils are primarily in Hydrologic Soil Group B, soils having a moderate infiltration rate when thoroughly wet; and Hydrologic Soil Group C, soils having a slow infiltration rate when thoroughly wet. Soil infiltration rate and the quantity of storm water runoff over a soil are inversely proportional.

Map SW3 in Appendix II-I-1 shows drainage basins within and near campus. Each basin was defined on the basis of a storm water runoff outlet point and the boundary of the area from which storm water runoff flows to the basin outlet point. Some campus basins discharge into other campus basins, and some campus basins discharge onto the city streets or into the City of Laramie storm water collection and conveyance system.

Hydrologic and hydraulic analyses during this project included those campus drainage basins within which storm water management problems have been identified recently by campus staff and campus drainage basins within which future campus development is anticipated. Storm water management problems are typically indicated by temporary but significant ponding of storm water runoff during major storm events, entry of storm water runoff into buildings through doors, discharge of storm water runoff out the tops of surcharged manholes, and other types of localized flooding.

The areas on campus that were identified by UW staff as problem areas that should be assessed during this project included:

i. The Willett St./15th St. corridor (Basins B26, B34, and B34A on Map SW4 in Appendix II-I-1);

ii. The area between the Arena Auditorium, the football stadium, Memorial Field House, and the Law Building (Basin B33 on Map SW5 in Appendix II-I-1);

iii. The football stadium and east parking lot (Basins B43 and B44 on Map SW6 in Appendix II-I-1);

iv. The area located north of Arts and Sciences and the Physical Sciences buildings (Basin B3 on Map SW7 in Appendix II-I-1); and

v. The Ivinson Avenue corridor (Basins B6, B7, B13, B14, B15, B16, B17, B18 and B35A on map SW8 in Appendix II-I-1).

A detailed project storm water runoff work spreadsheet is included in Appendix II-I-2, and storm water runoff hydrographs and related documents are included in other appendices as noted below.

i. <u>Willett St./15th St. corridor</u>

As shown on Map SW4 in Appendix II-I-1, a large drainage basin that includes Greenhill Cemetery drains southward to and westward to and along Willett St. This storm water runoff enters a series of catch basins that are located along 15th St. at and south of the Willett St. /15th St. intersection. Assessment of this location included:

- Generating storm water runoff hydrographs for the 10 year, 6 hour storm and the 100 year, 6 hour storm over Basin B26, the Cemetery/Willett St. basin, and Basins 34 and 34A, which discharge westward into the 15th St. catch basins from, respectively, Fraternity Row and Sorority Row; and

- Completing hydraulic analysis of the existing 15th St. storm sewer line that runs southward from Willett St. to the intersection of 15th St. and Ivinson Avenue.

C3D-generated runoff hydrographs for the two design storms over each of the three campus basins under consideration are included in Appendix II-I-3. Calculations are shown in the Appendix II-I-2 work spreadsheet. Hydrologic data and C3D output data are summarized in Table II-I-1 below.

The 15th St. storm sewer line profiles included in Appendix II-I-3 display 15th St. pipeline profiles in three separate reaches. The beginning and end of each reach is located at an existing catch basin or storm sewer manhole. Line 1-1 is the downstream reach, Line 2-2 is the middle reach, and Line 3-3 is the upstream reach as shown on Map SW4 in Appendix II-I-1. The pipe analysis plots in Appendix II-I-3 indicate that the existing 15th St. storm sewer pipes should be capable of conveying runoff from both design storms under open channel flow conditions without manhole surcharging. The 20" diameter upstream 15th St. storm water pipe is shown to surcharge slightly at its downstream end during the 100 year storm event, but this surcharging is eliminated by the increase in the next downstream pipe diameter to 36". While modeling indicates that existing 15th St. storm water pipes are capable of conveying designated storm water runoff flows, inlet capacities of existing catch basins are not known and may not be adequate to collect all storm water from basins B26, B34, and B34A without ponding around the inlets.

ii. Arena Auditorium/Law Building basin

Campus drainage basin B33, the Arena – south and east basin, includes the Arena Auditorium/Law Building area as shown on Map SW5 in Appendix II-I-1. Assessment of this site included generating storm water runoff hydrographs for the 10 year, 6 hour storm and the 100 year, 6 hour storm over Basin B33. At the available level of topographic detail and with a relatively large number of existing storm water catch basins in Basin 33, current C3D modeling results should be considered preliminary in nature. A more detailed site topographic survey and creation and analysis of smaller subbasins within Basin 33 would allow completion of a more detailed and useful storm water and hydraulic analysis model.

C3D-generated runoff hydrographs for the two design storms over this campus basin are included in Appendix II-I-3. Calculations are shown in the Appendix II-I-2 work spreadsheet. Hydrologic data and C3D output data are summarized in Table II-I-1 below.

iii. Football stadium/parking lot

Map SW6 in Appendix II-I-1 shows two drainage basins, Basin B43 and B44, covering the campus football stadium and parking lot area. Storm water runoff from Basin B44 is collected and conveyed by underground storm sewer pipes across Basin B43 to retention Pond B43/44. Based on available topography, the approximate capacity of this pond is about 0.42 ac-ft or about 18,100 cubic feet at a water depth of 1.5 ft. Storm water runoff hydrographs for the Stadium Basins B43 and B44 and a hydrograph for the two basins combined during the 10 year, 6 hour storm and the 100 year, 6 hour storm indicate that the total modeled volume of storm water runoff from these two basins during these storms is about 76,400 cubic ft and about 133,800 cubic ft, respectively. Runoff volume from both modeled storms significantly exceeds the current estimated capacity of retention Pond B43/44.

C3D-generated runoff hydrographs for the two storms over the two basins as well as two hydrographs combining Basin B43 and Basin B44 hydrographs are included in Appendix II-I-3. Calculations, including an estimated area capacity table for Pond B43/44, are shown in the Appendix II-I-2 work spreadsheet. Hydrologic data and C3D output data are summarized in Table II-I-1 below.

iv. Arts & Sciences/Physical Sciences area

Map SW7 in Appendix II-I-1 shows campus Basin B3, which includes the area north of the Arts & Sciences and Physical Sciences Buildings and east of the Pharmacy/Biochemistry Building. As shown on this map, this basin contains a network of storm water catch basins and storm sewer pipes. Like the Arena Auditorium/Law Building basin that is shown on Map SW5 in Appendix II-I-1, modeled storm water runoff for this basin during the 10 year, 6 hour storm and the 100 year, 6 hour storm must be considered an approximation and of limited value. Modeling of this area should include additional field surveying, generation of topographic maps having 0.2 ft contour intervals, and hydrologic and hydraulic analyses based on delineation of several smaller drainage basins within current Basin B3. Current conveyance of runoff from this basin beneath the Pharmacy Building as is currently the case is potentially problematic and should be assessed on the basis of more refined storm water and hydraulic modeling.

C3D-generated runoff hydrographs for the two storms over Basin B3 are included in Appendix II-I-3. Calculations are shown in the Appendix II-I-2 work spreadsheet. Hydrologic data and C3D output data are summarized in Table II-I-1 below.

v. <u>Ivinson Avenue corridor</u>

Storm water runoff within the Ivinson Avenue corridors originates in a number of campus drainage basins as shown on Map SW8 in Appendix II-I-1. Assessment of this area therefore included:

- Generating storm water runoff hydrographs for the 10 year, 6 hour storm and the 100 year, 6 hour storm over each of the ten basins that discharge into the Ivinson Avenue corridor; and

- Completing hydraulic analysis of the existing Ivinson Avenue storm sewer line that runs southward from the intersection of 15th St. and Ivinson Avenue to the intersection of 9th St. and Ivinson Avenue; the ten modeled reaches of existing Ivinson St. storm sewer are labeled on Map SW8.

C3D-generated runoff hydrographs for the two design storms over the ten campus basins that discharge into the Ivinson Avenue Basin are included in Appendix II-I-3. Calculations are shown in the Appendix II-I-2 work spreadsheet. Hydrologic data and C3D output data are summarized in Table II-I-1 below.

Ivinson Avenue storm sewer line profiles in Appendix II-I-3 display 15th St. pipeline in ten separate reaches, which correspond to the ten reaches that are labeled on Map SW8. The beginning and end of each reach occurs at an existing catch basin or storm sewer manhole. Line 1-1 is the downstream reach near the intersection of Ivinson Avenue and 9th St., and Line 10-10 is the upstream reach near the intersection of Ivinson Avenue and 15th St. The pipe analysis plots in Appendix II-I-3 indicate that the existing Ivinson Avenue storm sewer pipes are not capable of conveying modeled runoff from either of the design storms and that manhole surcharging occurs at every manhole location along the avenue during either design storm.

4. Summary

Five existing campus storm water problem areas were identified and analyzed during this project. Project analysis demonstrated the following:

- Analysis of the Willett St./15th St. corridor indicated that existing facilities should be capable of conveying storm water runoff in this area, assuming that adequate catch basin capacity is available to collect storm water runoff and that existing facilities are unclogged and in good operating condition.

- The number of catch basins within Basin B33, the Arena Auditorium/Law Building basin, reduces the value of hydrologic analysis at the level of detail that was available during this study. Future field surveying and developing of a basin topographic map having a 0.2 ft or 0.5 ft contour interval would support dividing basin B33 into sub-basins related to existing catch basin locations and completing a more refined and useful hydrologic and hydraulic analysis.

- The football stadium parking lot basins, B43 and B44, discharge to existing retention Pond B43/44. This retention pond is significantly under-sized to retain 100 year storm runoff from Basins B43 and B44. More detailed storm water analysis and management design should be completed for these basins, and improved storm water management facilities should be installed. These facilities may route some Basin B43/B44 runoff in other directions and/or provide improved attenuation of peak storm water runoff discharge rates.

- The Arts and Sciences/Physical Sciences Building area, like the Arena Auditorium/Law Building basin, contains a number of catch basins. Additional site surveying and preparation of a more detailed area topographic map are required for more refined hydrologic and hydraulic analysis of this area.

- Existing storm water conveyance facilities in Ivinson St. are incapable of conveying modeled peak storm water runoff rates from either the 10 year or the 100 year storm. This significant problem in a core area of the campus may be improved by directing runoff from some contributing basins to other locations, by attenuating peak storm water discharge from some or all of the contributing basins, and/or by installing larger or additional storm sewer pipes under Ivinson Avenue.

The table below contains a summary of storm water runoff information for the campus basins that were assessed under existing conditions. Storm water runoff analyses that were completed during this project included many of the campus runoff basins that are shown on Appendix II-I-1 maps. Appendix II-I-4 contains a tabular summary of information for all delineated campus drainage basins, including basin designations, location descriptions, surface areas in acres, and Natural Resources Conservation Service (NRCS) hydrologic soil group information.

Table II-I-1 Summary – Storm Water Runoff Information – Existing Conditions

Item no.	Basin no. and name	Area (ac)	CN	Time of concentration (min)	Qpk, 10 yr, 6 hr storm	Qpk, 100 yr, 6 hr storm
1	B26 – Willett St	67.49	79.6	168.1	4.2	11.4
2	B34 – Fine Arts N	10.71	82.3	55.2	1.4	4.0
3	B34A – Fine Arts S	10.59	81.5	26.6	1.7	5.3
Total peak discharge at 15th Street and Ivinson Avenue:					7.3	20.7
4	B33 – Arena Aud/Law	8.04	83.1	49.8	1.2	3.4
5	B43 – Stadium	15.65	93.9	8.0	11.1	19.7
6	B44 – Indoor Practice	7.81	95.8	2.9	6.9	11.5
7	B43/B44 combined	23.46	na	na	19.0	32.9
8	B3 – A&S/Phy Sciences	3.29	86.5	33.0	1.0	2.3
9	B6 – 9th/Ivinson (no	1.47	72.8	24.4	0.1	0.3
10	B7 – Merica Hall (no	5.57	78.7	54.1	0.5	1.6
11	B11 – Half Acre	1.67	98.0	1.9	1.7	2.6
12	B13 – Knight north	1.65	89.0	17.5	0.8	1.6
13	B14 – Knight south	0.99	80.5	40.7	0.1	0.4
14	B15 – Coe north/Union	3.60	89.1	4.8	1.8	3.7
15	B16 – Coe south	1.28	90.1	3.0	0.7	1.4
16	B17 – Union parking	5.00	98.0	5.2	5.5	8.6
17	B18 – C&I	3.56	86.6	41.5	0.9	2.2
18	B35A – King Row	4.46	89.3	42.5	1.5	3.3
Total discharge at intersection of Ivinson Avenue and 9th Street:					13.0	23.8