DIVISION NO. 3 - SYSTEM ANALYSIS

3.1 FUTURE LOAD PROJECTIONS

3.1.1 Future Campus Plan

The projected increase in the peak campus cooling and heating loads is based upon the George Mason University Master Plan (2009), which identifies the construction of several new facilities as well as additions to existing buildings. The most notable difference between the campus planning in 2006 and the current (2009) plan is the shift of development to the Southwest Sector of campus. Previously, this portion of campus encompassed approximately 15% of the future development of the campus. In the 2009 Campus Plan, approximately 36% of the future development is planned within the Southwest Sector. The locations of the proposed future projects on the GMU campus are indicated in Figure No. 3-1.

3.1.2 Heating System

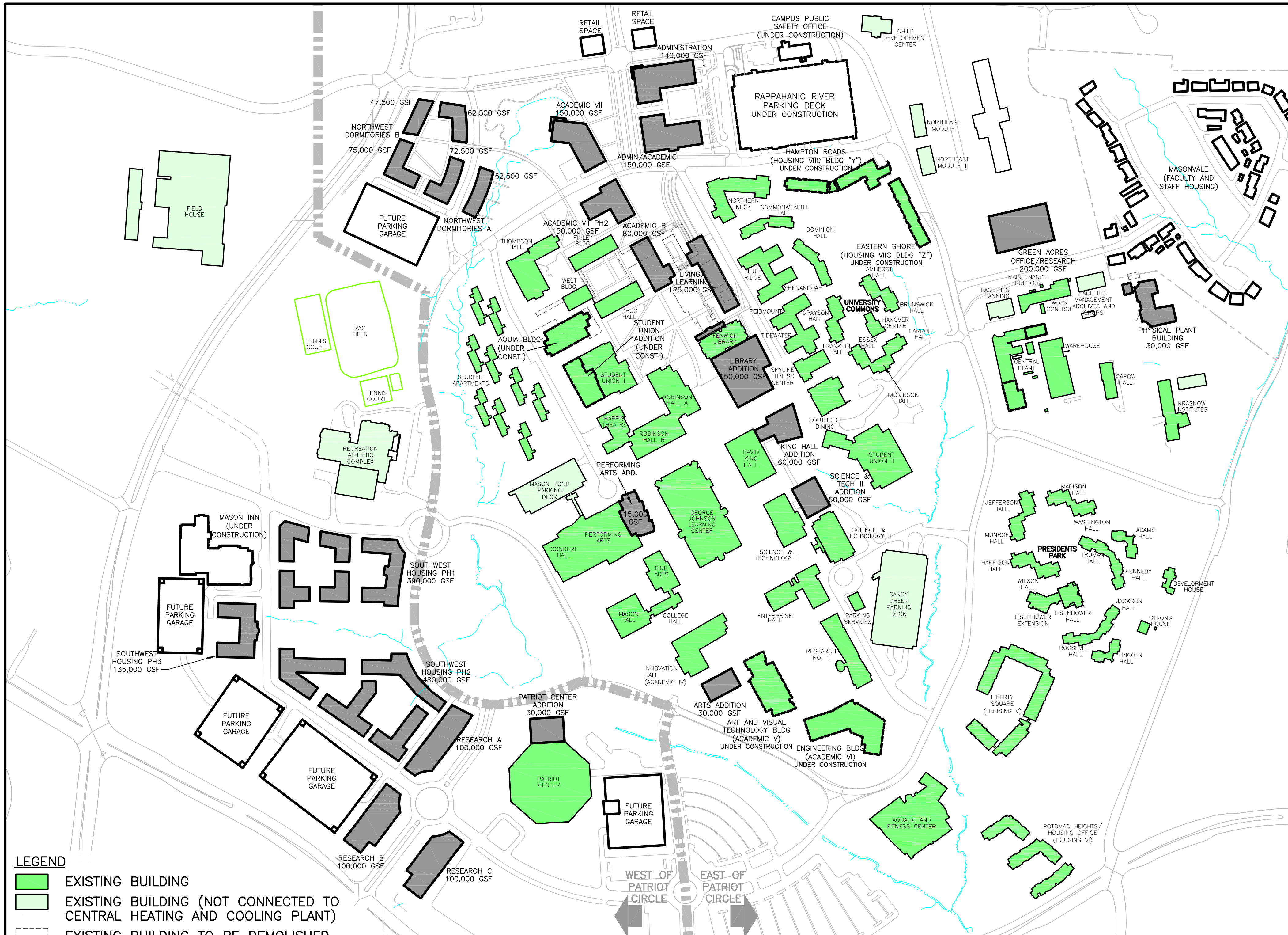
The future building area and space utilization provided by GMU were utilized to estimate the connected heating loads for each future facility. The projected loads are based upon the unitary load factors associated with the space utilization of the existing campus buildings. The existing diversity factor was applied to the future load estimates to develop an approximate peak load. A summary of the development of the estimated future heating loads is presented in Table No. 3-1. The current peak cooling load of 56 million Btu's per hour (MMBH) will increase to approximately 130 MMBH when all the planned facilities are constructed.

3.1.3 Cooling System

The estimated future building areas and space utilization provided by GMU were utilized to develop connected cooling loads for each facility based upon the unitary load factors associated with the existing buildings. The current campus diversity factor (54%) was applied to the design load estimates of the future buildings to estimate the peak system load. A summary of the development of the estimated future cooling loads is presented in Table No. 3-2. The current peak cooling load of 5,900 tons will increase to approximately 12,500 tons when all the planned facilities are constructed.

3.2 HIGH TEMPERATURE HOT WATER GENERATION

The high temperature hot water (HTHW) installed capacity of the GMU Central Plant is 85 MMBH, with a firm capacity of 60 MMBH. The firm capacity will be increased to 65 MMBH in 2010 when Boiler No. 2 is replaced with a 25 MMBH unit. The 2007 Central Plant expansion (currently in progress) was intended to include an additional 25 MMBH hot water boiler; however, the boiler addition was deferred due to cost limitations.



LEGEND

- EXISTING BUILDING
- EXISTING BUILDING (NOT CONNECTED TO CENTRAL HEATING AND COOLING PLANT)
- EXISTING BUILDING TO BE DEMOLISHED
- BUILDING CURRENTLY UNDER CONSTRUCTION
- FUTURE BUILDING
- FUTURE BUILDING TO BE CONNECTED TO CENTRAL HEATING AND COOLING PLANT

SOURCE: FUTURE SITE PLAN BASED UPON THE CAMPUS PLAN AS OF APRIL 30, 2009 AND THE FOLLOWING:
1. "NORTH SECTOR MASTER PLAN" BY EHRENKRANTZ ECKSTUT & KUHN ARCHITECTS (MARCH 2009)
2. "SOUTHWEST SECTOR MASTER PLAN" BY EHRENKRANTZ ECKSTUT & KUHN ARCHITECTS (AUGUST 2007)
3. "GEORGE MASON UNIVERSITY FACULTY & STAFF HOUSING" BY MASON HOUSING, INC (MARCH 2008)
4. "PERFORMING ARTS BUILDING ADDITION" BY HUGHES GROUP ARCHITECTS (JUNE 2008)
5. "SURGE SPACE/IT BUILDING" CLARK NEXSEN ARCHITECTURE & ENGINEERING (NOVEMBER 2007)

FUTURE BUILDING SUMMARY
GEORGE MASON UNIVERSITY

PHASE	YEAR ONLINE	PROJECT	ESTIMATED GROSS AREA (GSF)
UNDER CONSTRUCTION	JUN '09	ART & VISUAL TECH BLDG (ACADEMIC V)	90,000
	JUN '09	ENGINEERING BUILDING (ACADEMIC VI)	180,000
	SEP '09	HAMPTON ROADS (HOUSING VIIC BLDG "Y")	97,400
	DEC '09	AQUIA BUILDING	60,000
	JUN '10	EASTERN SHORE (HOUSING VIIC BLDG "Z")	97,400
	SEP '10	STUDENT UNION ADDITION	60,000
FUTURE (2010-2014)	SEP '10	PERFORMING ARTS ADDITION	15,000
	2011	ADMINISTRATION	140,000
	2011	SCIENCE & TECH II ADDITION	50,000
	2012	LIBRARY ADDITION	150,000
	2012	NORTHWEST DORMITORIES A	135,000
	2012	PATRIOT CENTER ADDITION	30,000
	2012	PHYSICAL PLANT BUILDING	30,000
	2013	ACADEMIC VII	150,000
	2013	LIVING/LEARNING	125,000
(>2014)	2015	RESEARCH A	100,000
	2015	SOUTHWEST HOUSING PH1	390,000
	2015	KING HALL ADDITION	60,000
	2017	RESEARCH B	100,000
	2017	ACADEMIC VII PH2	150,000
	2017	SOUTHWEST HOUSING PH2	480,000
	2019	RESEARCH C	100,000
	2019	ADMIN/ACADEMIC	150,000
	2019	SOUTHWEST HOUSING PH3	135,000
	2019	ARTS ADDITION	30,000
	2020	ACADEMIC B	80,000
	2020	NORTHWEST DORMITORIES B	185,000
	2020	GREEN ACRES RESEARCH/OFFICE	200,000

BUILDIINGS WEST OF PATRIOT CIRCLE

N

250 0 250 500

SCALE: 1" = 500' – 0"

GEORGE MASON UNIVERSITY
FUTURE SITE PLAN – THROUGH 2020

SCALE: 1" = 500'

GMU UPDATE TO UTILITY MASTER PLAN

RMF ENGINEERING, INC. BALTIMORE, MD

GEORGE MASON UNIV. FAIRFAX, VA

28 JULY 2009

FIGURE NO. 3–1

TABLE NO. 3-1: FUTURE HEATING LOAD SUMMARY

GEORGE MASON UNIVERSITY

PHASE	YEAR ONLINE	PROJECT	ESTIMATED GROSS AREA (GSF)	HEATING LOAD: UNITARY LOAD (BTU/HR/GSF)	HEATING LOAD: CONNECTED HEATING LOAD (10^3 BTU/HR)	HEATING LOAD: CAMPUS CONNECTED LOAD (10^3 BTU/HR)	HEATING LOAD: CAMPUS PEAK LOAD (10^3 BTU/HR)
WINTER 2009			2,601,605	60	156,600	156,600	55,900
UNDER CONST.	JUN '09	ART & VISUAL TECH BLDG	90,000	65	5,900	162,500	58,000
	JUN '09	ENGINEERING BUILDING	180,000	65	11,700	174,200	62,200
	SEP '09	HAMPTON ROADS	97,400	45	4,400	178,600	63,800
	DEC '09	AQUIA BUILDING	60,000	CONNECTED TO LOW TEMP SYSTEM IN THOMPSON			
	JUN '10	EASTERN SHORE	97,400	45	4,400	183,000	65,400
	SEP '10	STUDENT UNION ADDITION	60,000	60	3,600	186,600	66,700
FUTURE	SEP '10	PERFORMING ARTS ADDITION	15,000	65	1,000	187,600	67,100
	2011	ADMINISTRATION	140,000	60	8,400	196,000	70,100
	2011	SCIENCE & TECH II ADDITION	50,000	65	3,300	199,300	71,300
	2012	LIBRARY ADDITION	150,000	50	7,500	206,800	74,000
	2012	NORTHWEST DORMITORIES A	135,000	45	6,100	212,900	76,200
	2012	PATRIOT CENTER ADDITION	30,000	60	1,800	214,700	76,800
	2012	PHYSICAL PLANT BUILDING	30,000	40	1,200	215,900	77,200
	2013	ACADEMIC VII	150,000	65	9,800	225,700	80,700
	2013	LIVING/LEARNING	125,000	65	8,100	233,800	83,600
	2014	THOMPSON HALL CONNECTION	80,000	65	5,200	239,000	85,500
	2014	FINLEY, EAST, WEST, & KRUG	84,000	65	5,500	244,500	87,500
	2014	DATA CENTER	60,000	60	3,600	248,100	88,800
	2015	RESEARCH A	100,000	65	6,500	254,600	91,100
	2015	SOUTHWEST HOUSING PH1	390,000	45	17,600	272,200	97,400
	2015	KING HALL ADDITION	60,000	65	3,900	276,100	98,800
	2017	RESEARCH B	100,000	65	6,500	282,600	101,100
	2017	ACADEMIC VII PH2	150,000	65	9,800	292,400	104,600
	2017	SOUTHWEST HOUSING PH2	480,000	45	21,600	314,000	112,300
	2019	RESEARCH C	100,000	65	6,500	320,500	114,600
	2019	ADMIN/ACADEMIC	150,000	65	9,800	330,300	118,100
	2019	SOUTHWEST HOUSING PH3	135,000	45	6,100	336,400	120,300
	2019	ARTS ADDITION	30,000	65	2,000	338,400	121,000
	2020	ACADEMIC B	80,000	65	5,200	343,600	122,900
	2020	NORTHWEST DORMITORIES B	185,000	45	8,300	351,900	125,900
	2020	GREEN ACRES RESEARCH/OFFICE	200,000	65	13,000	364,900	130,500
TOTAL			6,395,405	---	364,900	---	---

NOTES:

1. CAMPUS PEAK LOAD IS BASED UPON A DIVERSITY FACTOR OF 0.36
2. ☐ REPRESENTS BUILDING PROJECTS WEST OF PATRIOT CIRCLE.

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RMF 6 AUG 2009

TABLE NO. 3-2: FUTURE COOLING LOAD SUMMARY

GEORGE MASON UNIVERSITY

PHASE	YEAR ONLINE	PROJECT	ESTIMATED GROSS AREA (GSF)	COOLING LOAD			
				UNITARY LOAD (GSF/TON)	CONNECTED COOLING LOAD (TONS)	CAMPUS CONNECTED LOAD (TONS)	CAMPUS PEAK LOAD (TONS)
SUMMER 2008			3,249,600	295	11,000	11,000	6,000
UNDER CONST.	JUN '09	ART & VISUAL TECH BLDG	90,000	250	360	11,360	6,200
	JUN '09	ENGINEERING BUILDING	180,000	250	720	12,080	6,590
	SEP '09	HAMPTON ROADS	97,400	450	215	12,300	6,710
	DEC '09	AQUIA BUILDING	60,000	200	300	12,600	6,870
	JUN '10	EASTERN SHORE	97,400	450	215	12,820	6,990
	SEP '10	STUDENT UNION ADDITION	60,000	200	300	13,120	7,150
FUTURE	SEP '10	PERFORMING ARTS ADDITION	15,000	250	60	13,180	7,180
	2011	ADMINISTRATION	140,000	200	700	13,880	7,560
	2011	SCIENCE & TECH II ADDITION	50,000	250	200	14,080	7,670
	2012	LIBRARY ADDITION	150,000	300	500	14,580	7,940
	2012	NORTHWEST DORMITORIES A	135,000	450	300	14,880	8,100
	2012	PATRIOT CENTER ADDITION	30,000	200	150	15,030	8,180
	2012	PHYSICAL PLANT BUILDING	30,000	280	105	15,140	8,240
	2013	ACADEMIC VII	150,000	250	600	15,740	8,570
	2013	LIVING/LEARNING	125,000	250	500	16,240	8,840
	2014	THOMPSON HALL CONNECTION	80,000	250	320	16,560	9,010
	2015	RESEARCH A	100,000	250	400	16,960	9,230
	2015	SOUTHWEST HOUSING PH1	390,000	450	865	17,830	9,700
	2015	KING HALL ADDITION	60,000	250	240	18,070	9,830
	2017	RESEARCH B	100,000	250	400	18,470	10,050
	2017	ACADEMIC VII PH2	150,000	250	600	19,070	10,380
	2017	SOUTHWEST HOUSING PH2	480,000	450	1,065	20,140	10,960
	2019	RESEARCH C	100,000	250	400	20,540	11,180
	2019	ADMIN/ACADEMIC	150,000	250	600	21,140	11,510
	2019	SOUTHWEST HOUSING PH3	135,000	450	300	21,440	11,670
	2019	ARTS ADDITION	30,000	250	120	21,560	11,740
	2020	ACADEMIC B	80,000	250	320	21,880	11,910
	2020	NORTHWEST DORMITORIES B	185,000	450	410	22,290	12,130
	2020	GREEN ACRES RESEARCH/OFFICE	200,000	250	800	23,090	12,570
TOTAL			6,899,400	---	23,065	---	---

NOTES:

1. CAMPUS PEAK LOAD IS BASED UPON A DIVERSITY FACTOR OF 0.55
2. REPRESENTS BUILDING PROJECTS WEST OF PATRIOT CIRCLE.

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A graph representing the existing central plant heating capacity versus the future heating load requirements is presented in Figure No. 3-2. The future projected load will exceed the firm capacity of the plant (with the Boiler No. 2 replacement) once the current projects under construction are complete. Therefore, there is an immediate need for additional boiler capacity.

To establish funding and implement a project to expand the Central Heating Plant will require several years during which the existing plant would operate without standby capacity. As an alternative, the Satellite Plant programmed for the Southwest Sector could be utilized to provide the needed standby capacity for the Central Heating system. The Satellite Plant was originally proposed in the 2002 Utility Master Plan to serve the facilities west of Patriot Circle. As the planning for future development has shifted to the southwest, the Satellite Plant has developed a more prominent role in the future utility planning. While initially planned as a low temperature hot water (LTHW) plant, modifying the utility plan to develop a high temperature hot water plant that is connected to the central distribution system will provide the campus with the additional capacity needed. The University will have the flexibility to add capacity to either the Central Plant or the Satellite Plant to support the future load beyond 2014.

In order to distribute LTHW to the Southwest Sector of campus, heat exchangers would be installed at the Satellite Plant to convert the HTHW to LTHW.

With funding allocated for the Satellite Plant in the Southwest Sector of campus, one (1) 25 MMBH boiler should be installed in the near term. At later stages of development, two (2) additional 25 MMBH boilers should be added to either the Satellite Plant or the Central Plant to meet the necessary capacity requirements of the full buildout (2020). This would increase the total capacity of the campus to 165 MMBH with a firm capacity of 140 MMBH. A graph representing high temperature hot water capacity vs. future load requirements is presented in Figure No. 3-3.

The net increase in capital cost over the current 10-year planning horizon to install the HTHW boilers instead of LTHW boilers at the Satellite Plant is approximately $1.3 million. The details for construction costs for these two systems are presented in Division No. 4 – Appendix.

3.3 CHILLED WATER GENERATION

The current (2009) firm capacity for the Chiller Plant is 6,850 tons. Chiller No. 9 is currently under construction and is scheduled to be online by 2010. With the addition of this chiller, the plant firm capacity will be is 8,320 tons. Considering the future peak load of 12,470 tons, approximately 4,200 tons of additional plant cooling output is ultimately required.

A graph representing the existing central plant cooling capacity versus the future cooling load requirements is presented in Figure No. 3-4. The future projected load will exceed the firm capacity of the plant, which includes the capacity of Chiller No. 9, within the next five years.

FIGURE NO. 3-2: EXISTING HOT WATER CAPACITY VS. FUTURE LOAD

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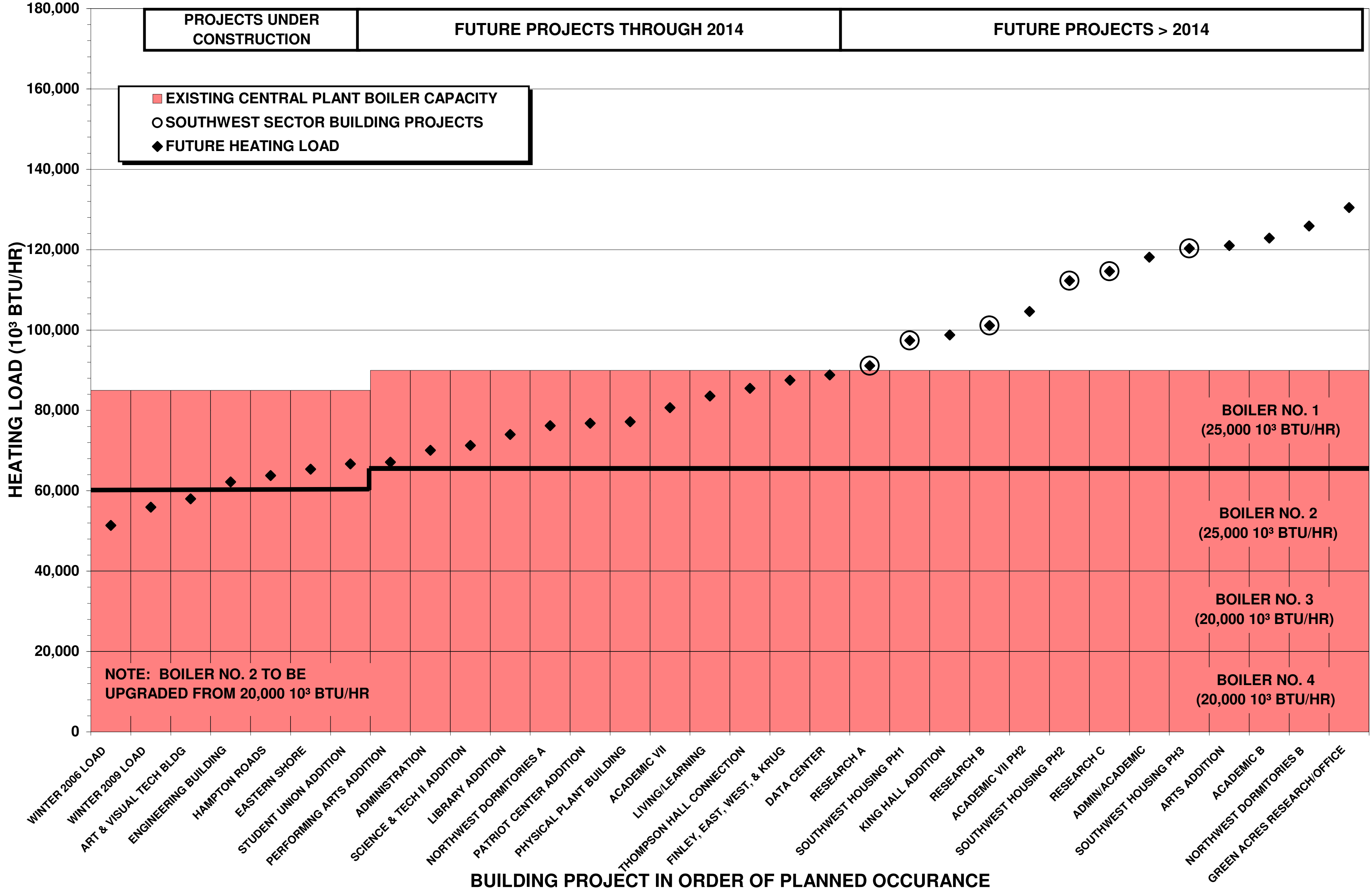

FUTURE NO. 3-3: FUTURE CAMPUS HOT WATER CAPACITY VS. FUTURE LOAD

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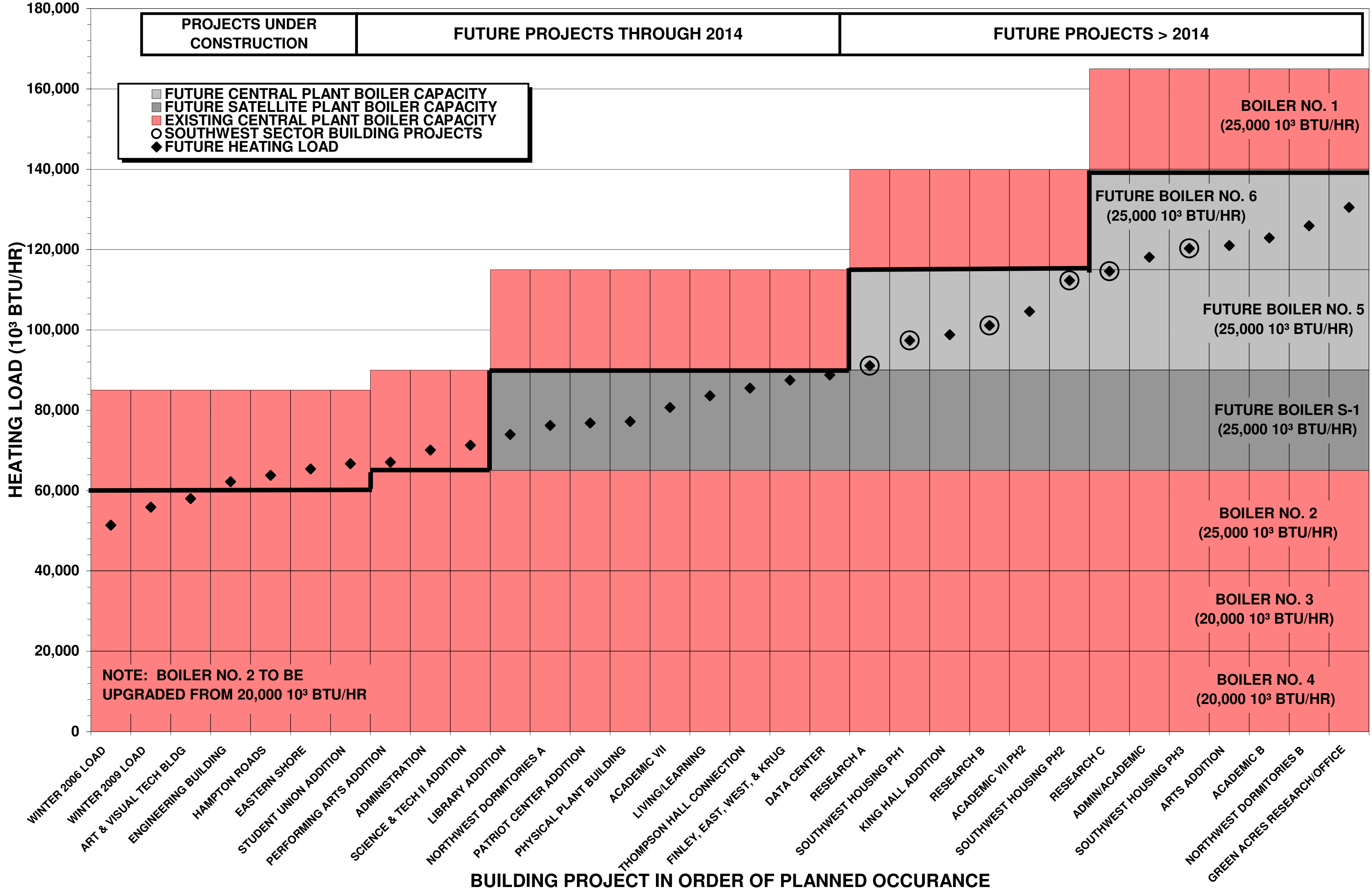

FIGURE NO. 3-4: EXISTING CHILLED WATER CAPACITY VS. FUTURE LOAD

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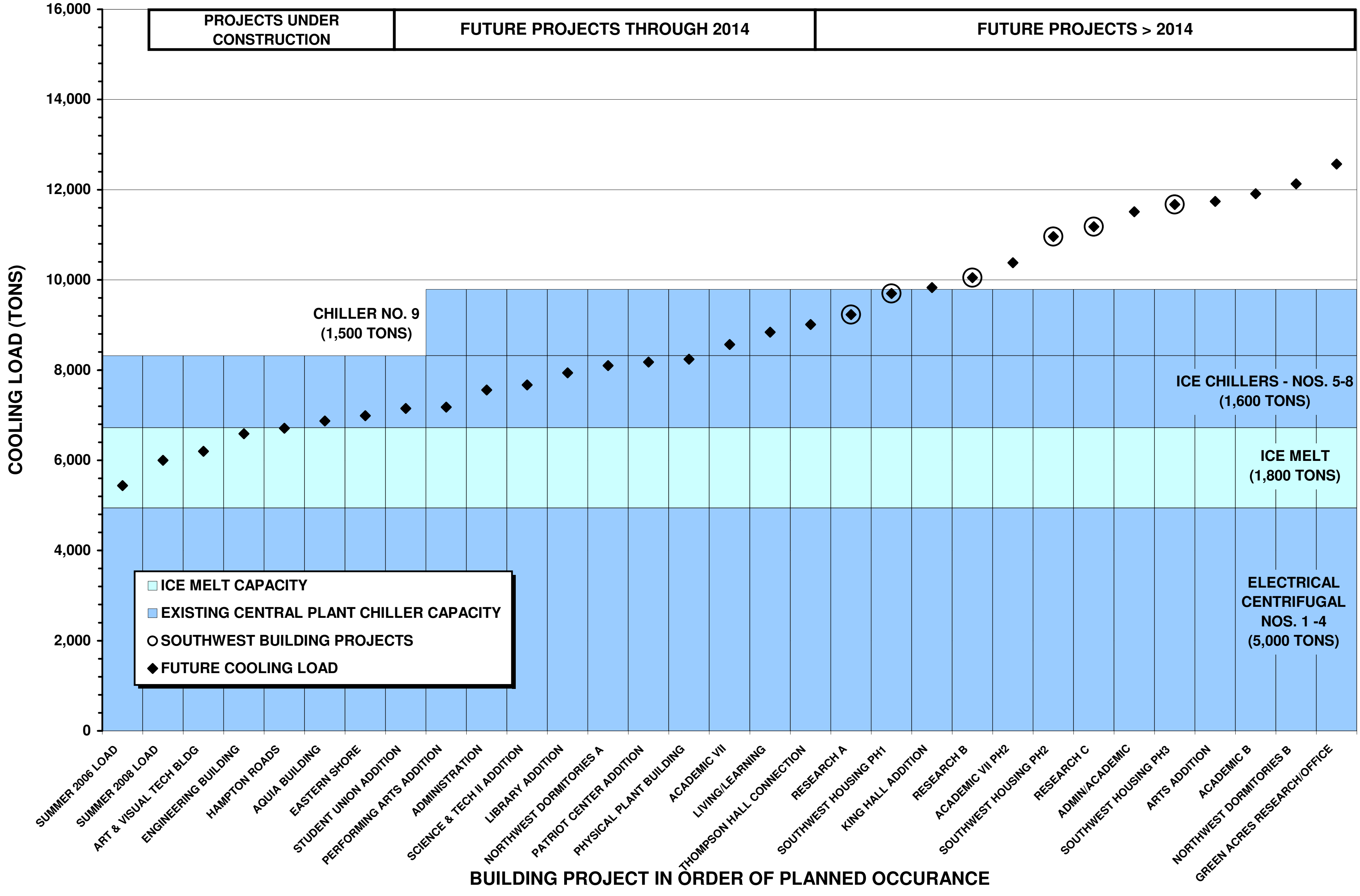

Similarly to the heating system, the University will have the flexibility to add chiller capacity to either the Central Plant of the Satellite Plant to support the futur7e load beyond 2014.

The Satellite Plant in the southwest sector of campus is proposed to include two (2) 1,100 ton chillers in the near term. At later stages of development, two (2) 1,500 ton chillers should be installed at the central plant to meet the necessary capacity requirements of the full buildout (2020). This would increase the total capacity of the campus to 14,930 tons with a firm capacity of 13,460 tons. A graph representing chilled water capacity vs. future load requirements is presented in Figure No. 3-5.

3.4 FUTURE UTILITY DISTRIBUTION

A “loop” of the chilled water and HTHW distribution piping in the northern portion of the campus was proposed in the 2002 Utility Master Plan to provide additional capacity and reliability. The University had initiated the loop concept with the eastern leg of the loop that was constructed with the Housing VII facilities. The northern leg is planned with the addition of Academic VII and the Northwest Dormitories. The current loop approach is intact with the exception of the western leg, which is not associated with a “sponsor” project. This 700 linear feet (LF) extension is currently identified as a standalone infrastructure project. A site plan that indicates the North Loop distribution piping is presented in Figure No. 3-6.

3.4.1 HTHW Distribution

To assess the existing HTHW distribution system’s ability to distribute the near term requirements of the campus from the Central Plant only, the computerized hydraulic model was utilized to simulate the future peak HTHW flow conditions for 2014. The results of the model are presented in Figure No. 3-7. The maximum distribution loss of 28 feet occurs at the Student Union Building, which is within the operating conditions of the existing distribution pumps. There are no pipe segments within the distribution system that exceeds the recommended velocity limitations of 12 FPS.

If the western leg of the North Loop were to be connected under this scenario, the maximum distribution loss is reduced down to 26 feet. A schematic of the near term flow requirements with the North Loop completed is presented in Division No. 4 – Appendix.

The capability of the existing HTHW distribution system to distribute the full buildout (2020) heating requirements from the Central Plant only was also assessed. This scenario was modeled to simulate the outage of the proposed 25 MMBH boiler in the Satellite Plant. The results of the model are presented in Figure No. 3-8. The maximum distribution loss of 75 feet occurs at the Southwest Sector connection at the Satellite Plant, which is within the operating conditions of the existing distribution pumps. The Southwest Sector will be served LTHW via a heat exchanger system located at the Satellite Plant. There are no pipe segments within the distribution system that exceeds the recommended velocity limitations of 12 FPS.

FIGURE NO. 3-5: CAMPUS CHILLED WATER CAPACITY VS. FUTURE LOAD

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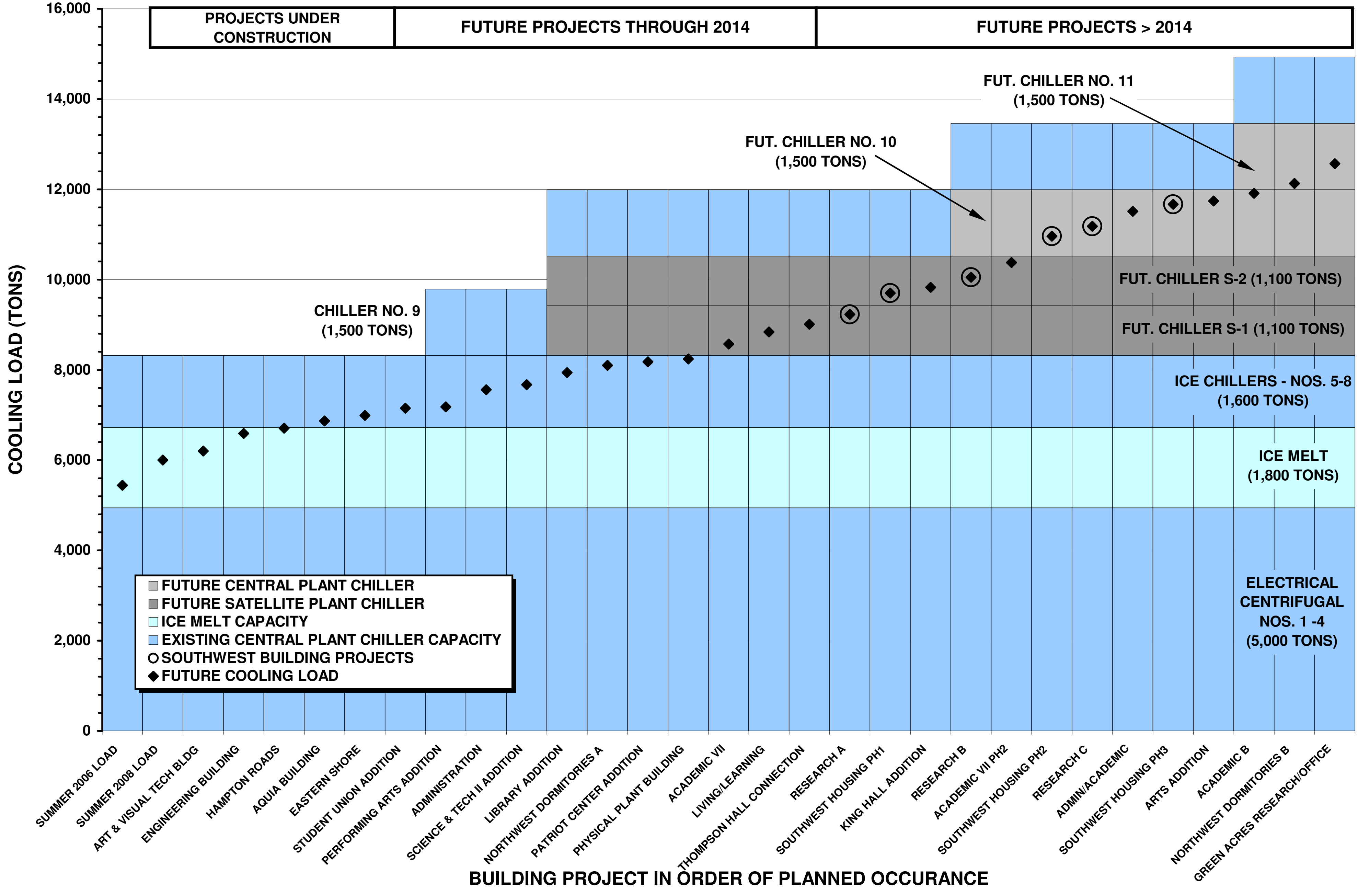

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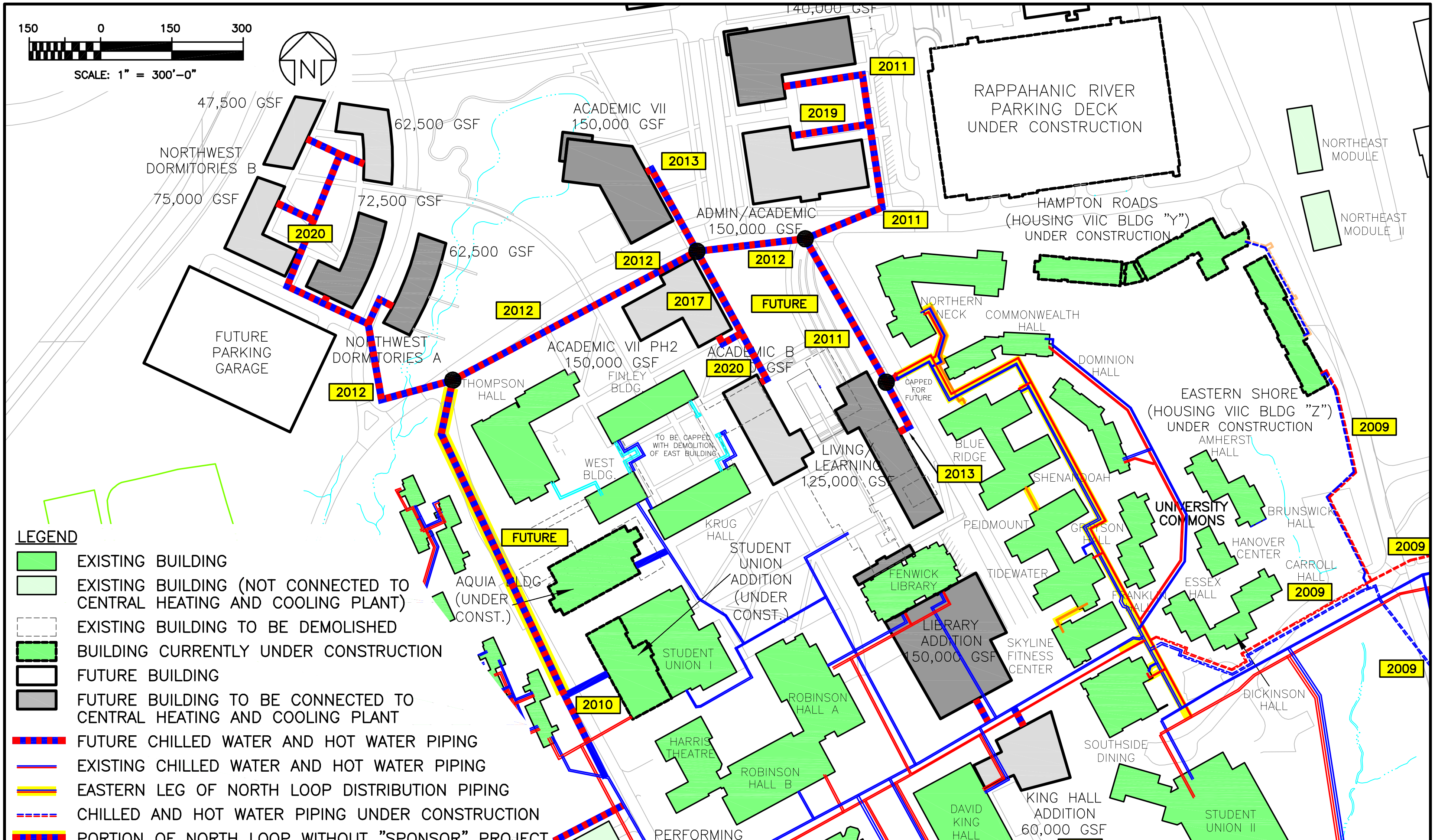

FUTURE SITE PLAN — NORTH LOOP PIPING

SCALE: 1" = 300'

SOURCE: FUTURE SITE PLAN BASED UPON THE CAMPUS PLAN AS OF APRIL 30, 2009

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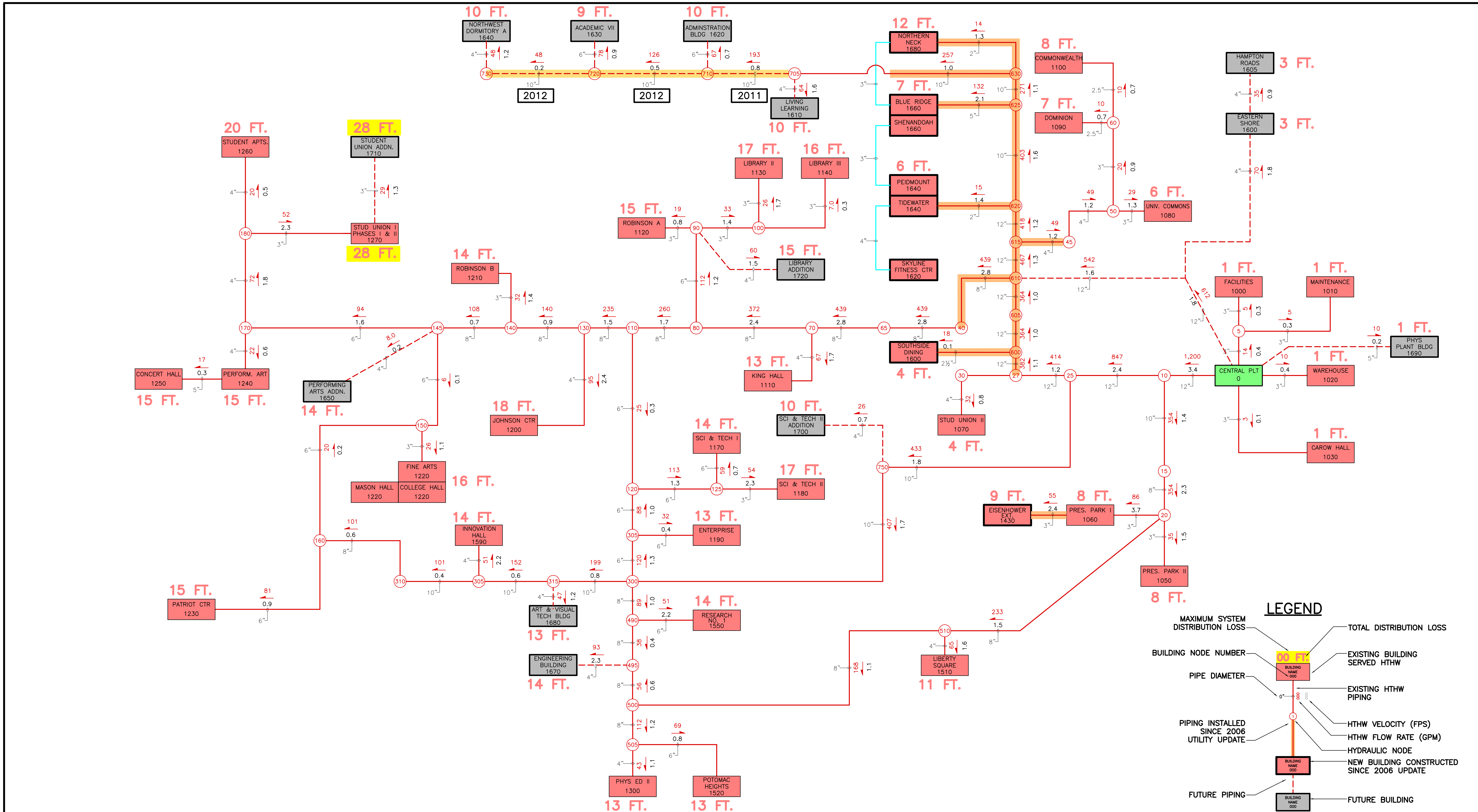
FIGURE NO. 3-6



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2014 HIGH TEMPERATURE HOT WATER SYSTEM SCHEMATIC – NORTH LOOP INCOMPLETE

SCALE: NONE

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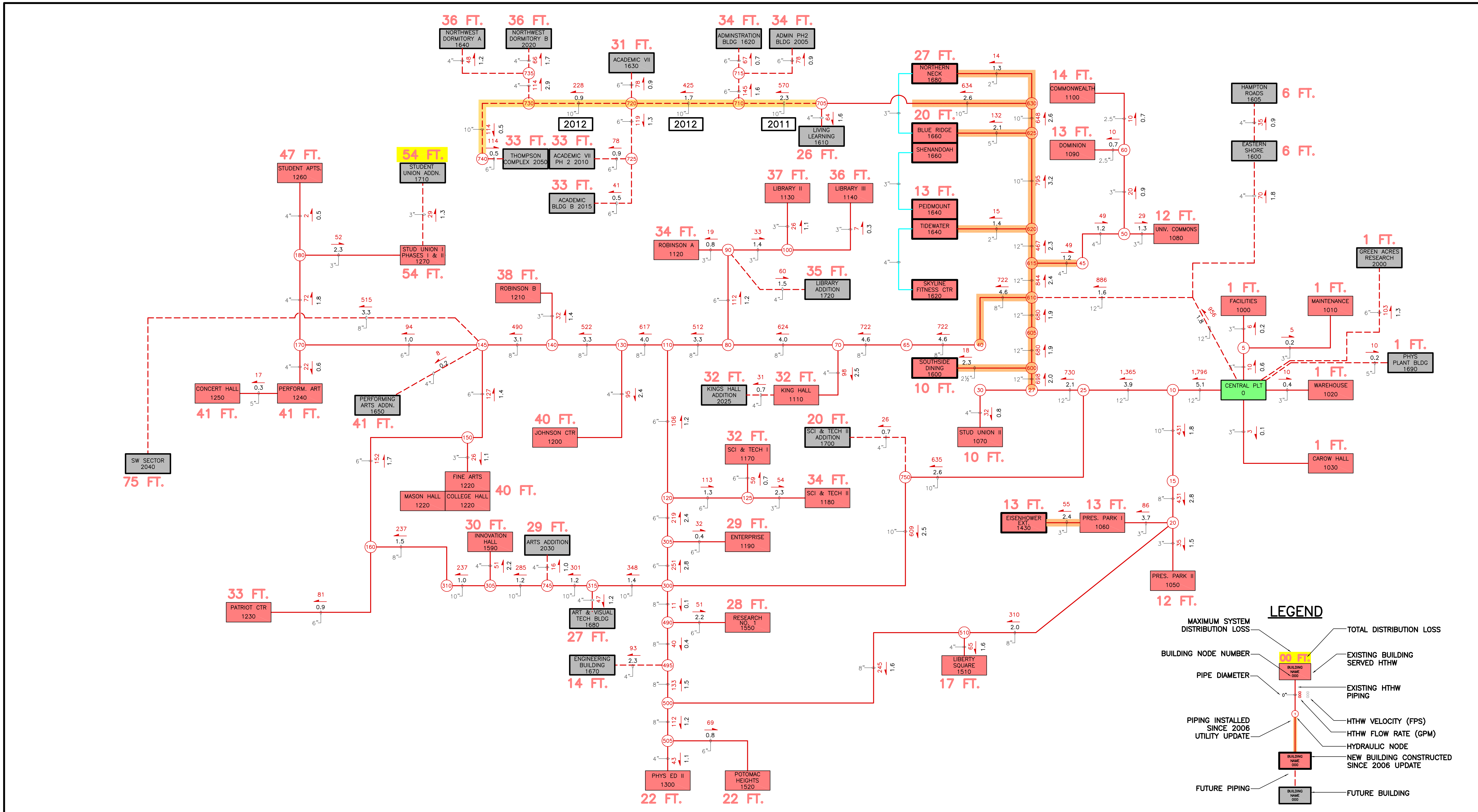
FIGURE NO. 3-7



2020 HIGH TEMPERATURE HOT WATER SYSTEM SCHEMATIC – NORTH LOOP INCOMPLETE

SCALE: NONE

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FIGURE NO. 3-8

Therefore, future boiler upgrades could be added to the Central Plant without distribution limitations.

3.4.2 Chilled Water Distribution

3.4.2.1 Near Term (2014)

The computerized hydraulic model was also utilized to assess the existing chilled water distribution system's ability to export the near term cooling requirements from the Central Plant. The results of the model are presented in Figure No. 3-9. The maximum distribution loss of 76 feet occurs at the future Adminstration building. The highest velocity is 10.8 FPS in the transite main pipe from the Central Plant to the Library III. This velocity is below the maximum allowable velocity for a transite pipe. However, there are two sections of chilled water pipe that are above the recommended maximum allowable velocity for PVC pipe. These segments were noted in Division No. 2 (2009 Updated System Conditions) and include the radial feed to the Patriot Center and the 12-inch line to President's Park. Continually exceeding the velocity can increase the risk of pipe failure resulting from water hammer, caused by sudden changes in system flow or velocity. These pipe segments are recommended for replacement in the future with schedule 40 welded steel piping that would allow for higher velocities.

Similarly to the HTHW hydraulics, if the western leg of the North Loop were to be connected under this scenario, the maximum distribution loss is reduced down to 71 feet. A schematic of the near term flow requirements with the North Loop completed is presented in Division No. 4 – Appendix.

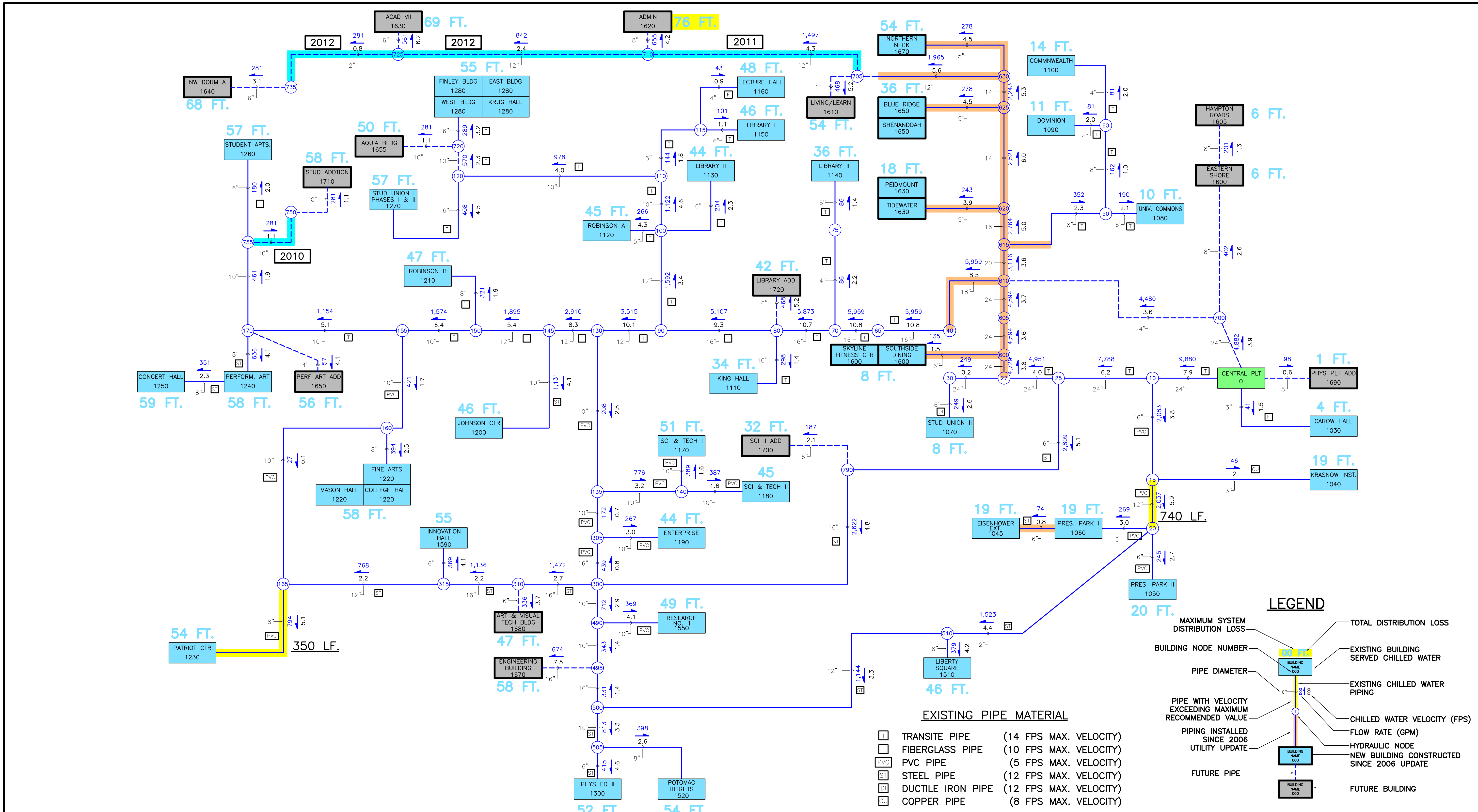
An outage scenario was developed to determine the maximum distribution loss within the chilled water system if the 12-inch PVC piping between Krasnow Institutes and the President's Park were to suffer an outage. The results of this outage scenario are presented in Figure No. 3-10. Although there are no high velocities within the chilled water mains, the maximum distribution loss of 208 feet occurs at Liberty Square (Housing V). This is above the design capabilities of the existing chilled water distribution pumps at the Central Plant and therefore a system flow limitation would result the flow to the following facilities be limited to approximately 85% of their peak load:

- Aquatic Center & Expansion
- Potomac Heights (Housing VI)
- Liberty Square (Housing V)
- Presidents Park

This would be required if the wet-bulb temperature was above 70°F and would require manual adjustment at each building.

3.4.2.2 Full Buildout (2020)

The capability of the existing chilled water distribution system to distribute the full buildout (2020) cooling requirements with the Satellite Plant operational was assessed. The Satellite



2014 CHILLED WATER SYSTEM SCHEMATIC – NORTH LOOP INCOMPLETE

SCALE: NONE

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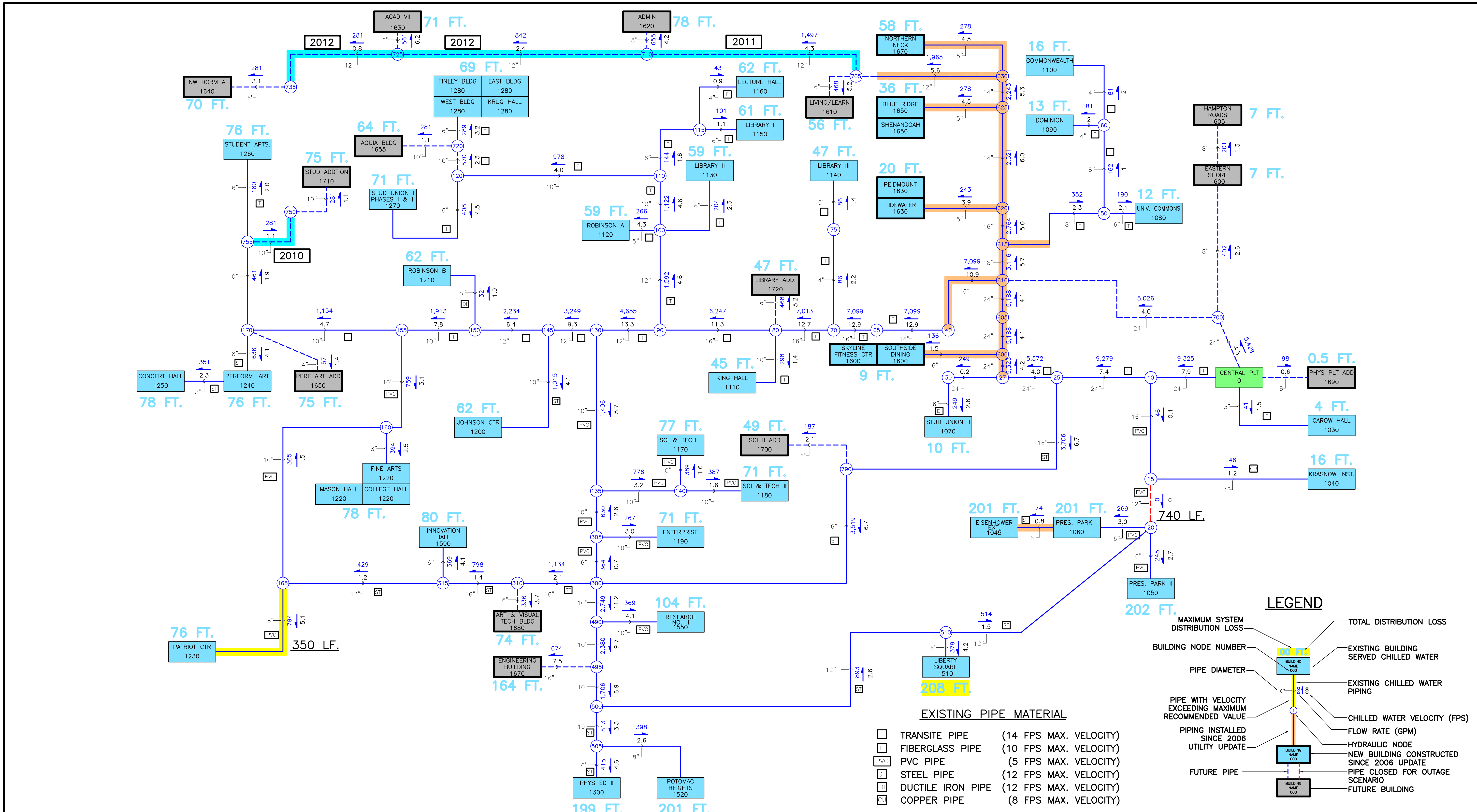
FIGURE NO. 3-9



2014 CHILLED WATER SYSTEM SCHEMATIC – PVC OUTAGE

SCALE: NONE

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FIGURE NO. 3–10

Plant was modeled with two of three 1,100 ton chillers operating (one standby) to supplement the output of the Central Plant. This would be considered the normal operation at full buildout. This model also incorporated completion of the western leg of the North Loop. A schematic of this scenario is presented in Figure No. 3-11. With the exception of the two segments of PVC piping that were noted previously, there are no pipe segments that are above the recommended velocity limitations of the corresponding pipe material. The maximum distribution loss associated with the Central Plant is 121 feet (Administration Building). The corresponding distribution loss associated with the Satellite Plant is 76 feet (Research C). Adding the distribution loss of each building to the associated building pressure differential requirement, the total pumping need for each facility was established. A graph summarizing these pumping requirements is presented in Figure No. 3-12.

If the Satellite Plant was isolated from the Main Campus, the maximum distribution loss associated with the Central Plant would increase to 131 feet. This distribution loss, in addition to the building loss, is still within the operating capabilities of the existing distribution pumps at the Central Plant.

As stated previously, the PVC radial pipe segment to the Patriot Center is recommended for replacement with schedule 40 welded steel that would allow for higher velocities within the pipe. With this replacement, there is a potential to utilize this segment of piping in conjunction with the distribution piping within the Southwest Sector to create another chilled water loop.

3.4.2.3 Alternate System Scenarios for Full Buildout (2020)

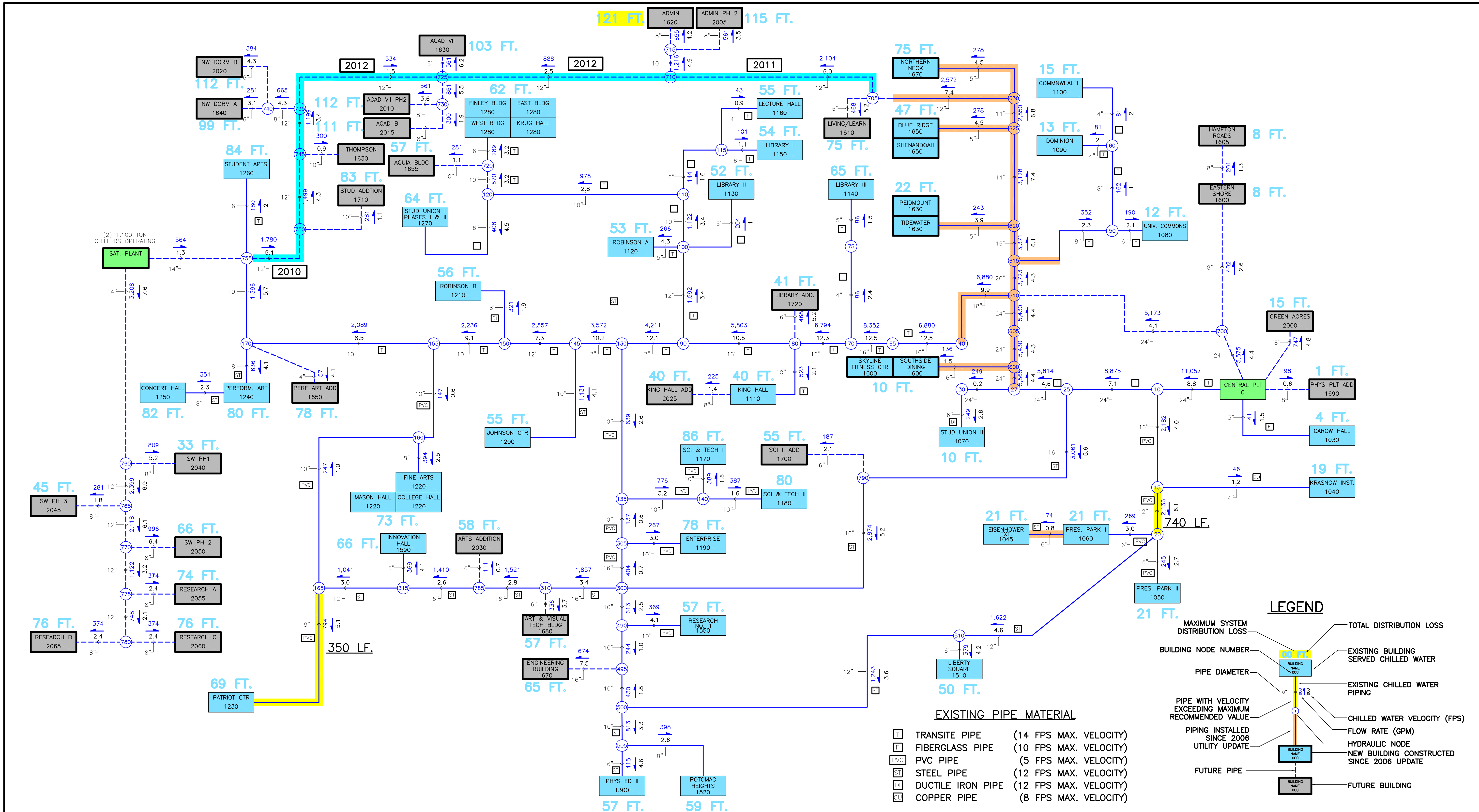
- **Single Chiller Operation at Satellite Plant with Western Leg**

The capability of the existing chilled water distribution system to distribute the full buildout (2020) cooling requirements with a single 1,100 ton chiller at the Satellite Plant was assessed. A schematic of this scenario is presented in Division No. 4 – Appendix. There are several pipe segments within the main distribution that are above the recommended velocity limitation of the corresponding pipe material. The maximum distribution loss associated with the Central Plant is 161 feet (Administration Building). This distribution loss, in addition to the building loss, is still within the operating capabilities of the existing distribution pumps at the Central Plant.

- **Normal Operation without Western Leg (2020)**

If the Western Leg of the North Loop were not to be constructed before the full buildout (2020), there will not be enough pumping capacity at the Central Plant to distribute the required cooling load. The maximum distribution loss under this scenario at the full buildout load is 239 feet.

To determine when the pumping requirements under normal operation exceed the pumping capacity of the Central Plant, the maximum distribution loss was determined for each future building that is connected to the chilled water system beyond 2015. A summary of the pumping requirements for each of these connections is presented in Figure No. 3-13. In order to ensure that the pumping requirements are below the pump head of the Central Plant distribution pumps



GMU UPDATE TO UTILITY MASTER PLAN

2020 CHILLED WATER SYSTEM SCHEMATIC – NORMAL OPERATION

SCALE: NONE

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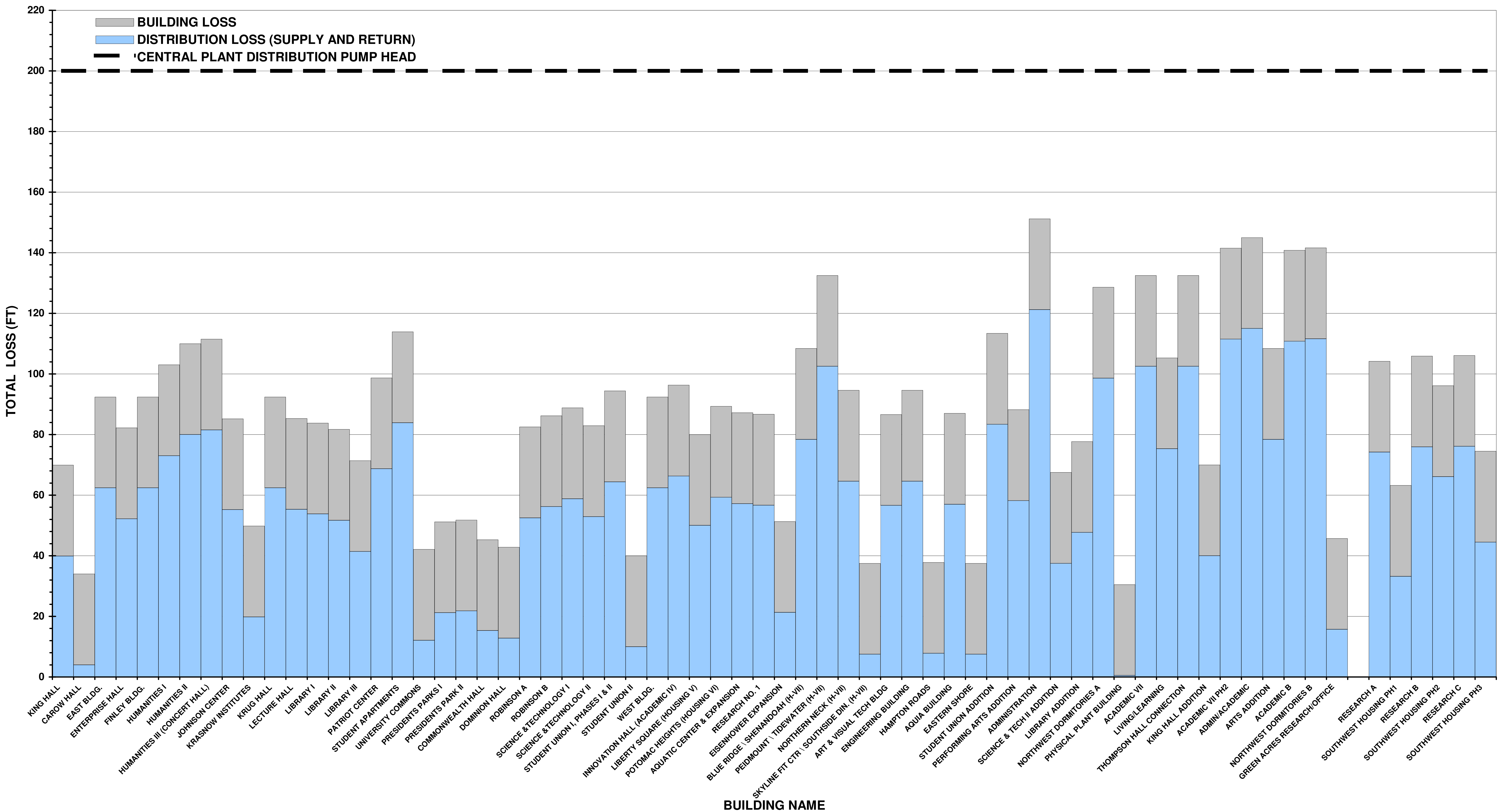
FAIRFAX, VA

28 JULY 2009

FIGURE NO. 3–11

FIGURE NO. 3-12: FUTURE CHILLED WATER BUILDING PRESSURE SUMMARY(2020) - NORMAL OPERATION

GEORGE MASON UNIVERSITY



during normal operation, the western leg of the North Loop should be installed before the total peak cooling load reaches approximately 11,000 tons. Currently, this is programmed to occur in 2019 with the connection of the Admin/Academic Building.

- **Central Plant Only Without Western Leg (2020)**

The capability of the existing chilled water distribution system to distribute the full buildout (2020) cooling requirements from the Central Plant alone was also assessed. Again, this scenario would occur if the Satellite Plant was not able to supply cooling load to the campus. The results of the model are presented in Figure No. 3-14. It is assumed under this scenario that the Southwest sector of buildings would be fed through secondary pumps within the Satellite Plant. The maximum distribution loss of 276 feet occurs at the Satellite Plant, which is beyond the operating capabilities of the existing distribution pumps at the Central Plant. Also, there are multiple pipe segments within the distribution mains that exceed the recommended velocity limitations of the corresponding pipe material.

- **Central Plant Only With Western Leg (2020)**

If the western leg of the North Loop were to be connected under this scenario, the maximum distribution loss in the system would be 291 feet at the Satellite Plant. A schematic of the full buildout (2020) chilled water model with the North Loop complete is presented in Figure No. 3-15. The installation of the western leg balances flow in the North Loop; however, the pressure loss to the Satellite Plant is increased as a result in the shift of system flow.

The existing distribution and pumping systems can support only 72% of the full buildout load when the Central Plant is providing the entire cooling load.

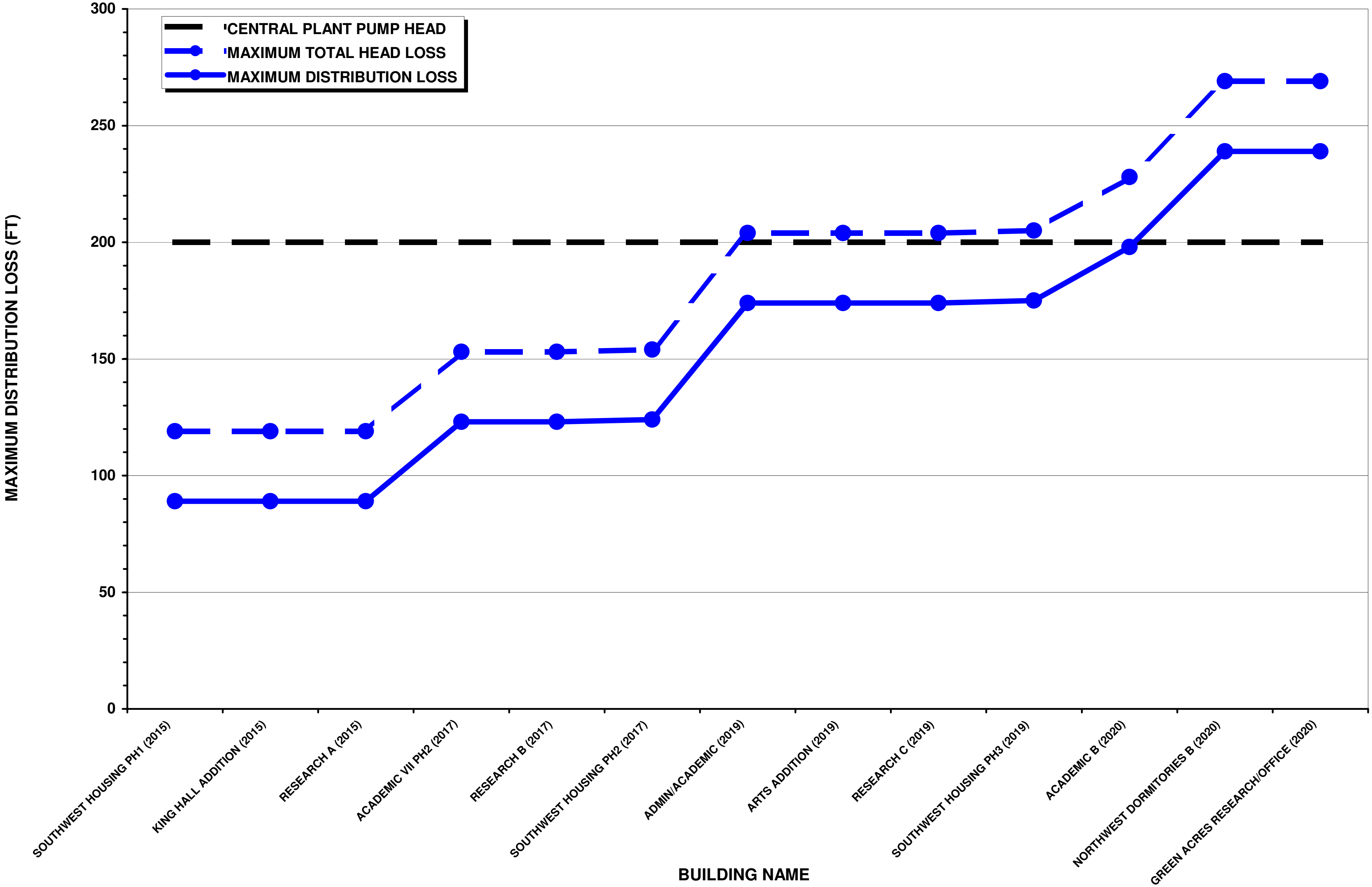
- **Central Plant Only with Western Leg and Interstitial Line (2020)**

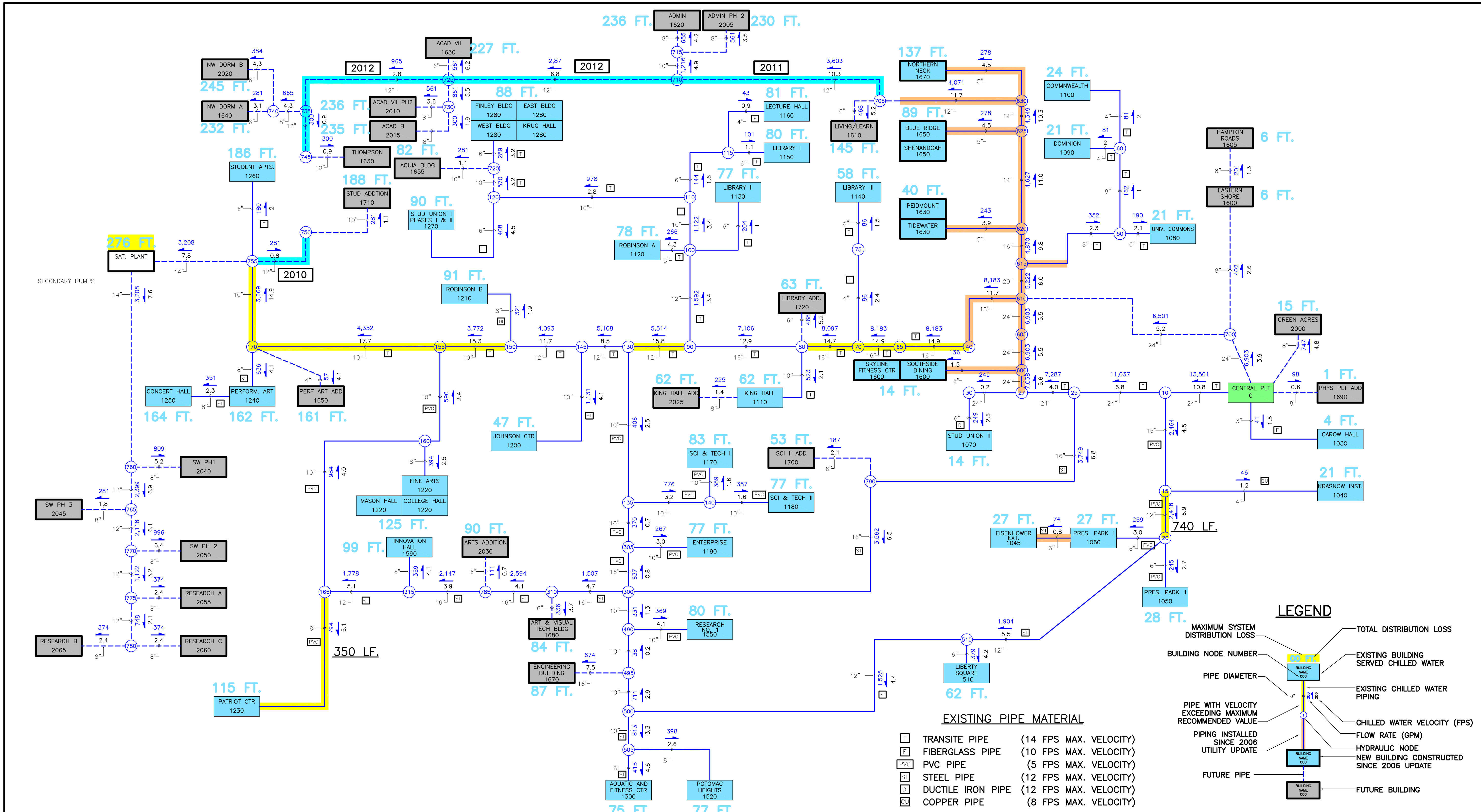
One opportunity to reduce maximum distribution loss within the system would be to add an interstitial pipe segment that could occur with the construction of Academic VII Phase II, Academic B, and Living/Learning Center. A site plan indicating the location of this pipe segment is presented in Figure No. 3-16.

A hydraulic schematic for this scenario is presented in Figure No. 3-17. The maximum distribution loss in the system is reduced to 250 feet (at the Satellite Plant). As before, there are multiple pipe segments within the distribution mains that exceed the recommended velocity limitations. The existing distribution and Central Plant pumping systems can support only 77% of the full buildout load without the Satellite Plant.

Since the addition of this interstitial piping is not beneficial for mode of operation, it will not be included in the final recommendations.

FIGURE NO. 3-13: CENTRAL PLANT PUMPING REQUIREMENT SUMMARY
NORMAL OPERATION (WESTERN LEG INCOMPLETE)
GEORGE MASON UNIVERSITY





2020 CHILLED WATER SYSTEM SCHEMATIC – NORTH LOOP INCOMPLETE

SCALE: NONE

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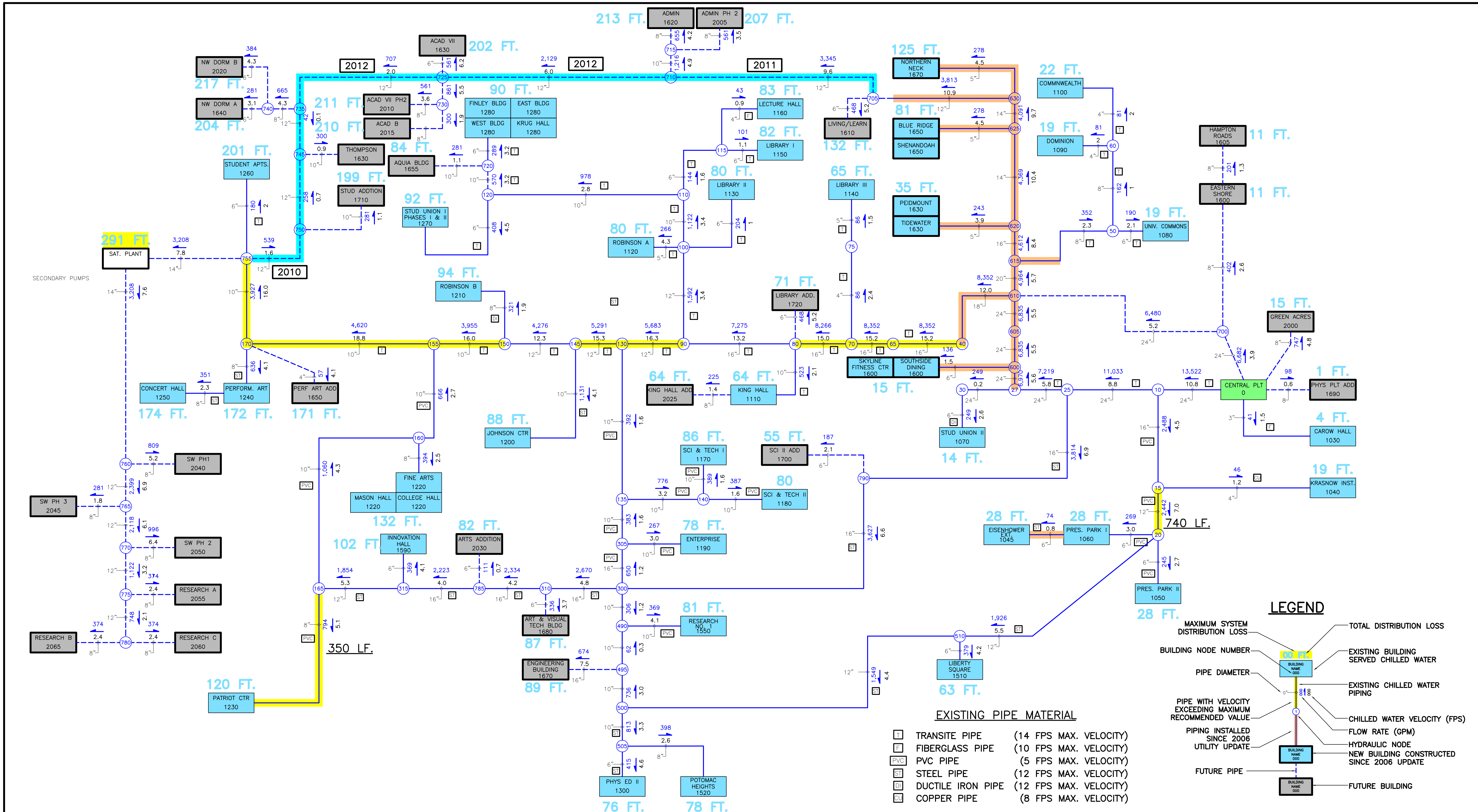
FIGURE NO. 3–14



2020 CHILLED WATER SYSTEM SCHEMATIC – NORTH LOOP COMPLETED

SCALE: NONE

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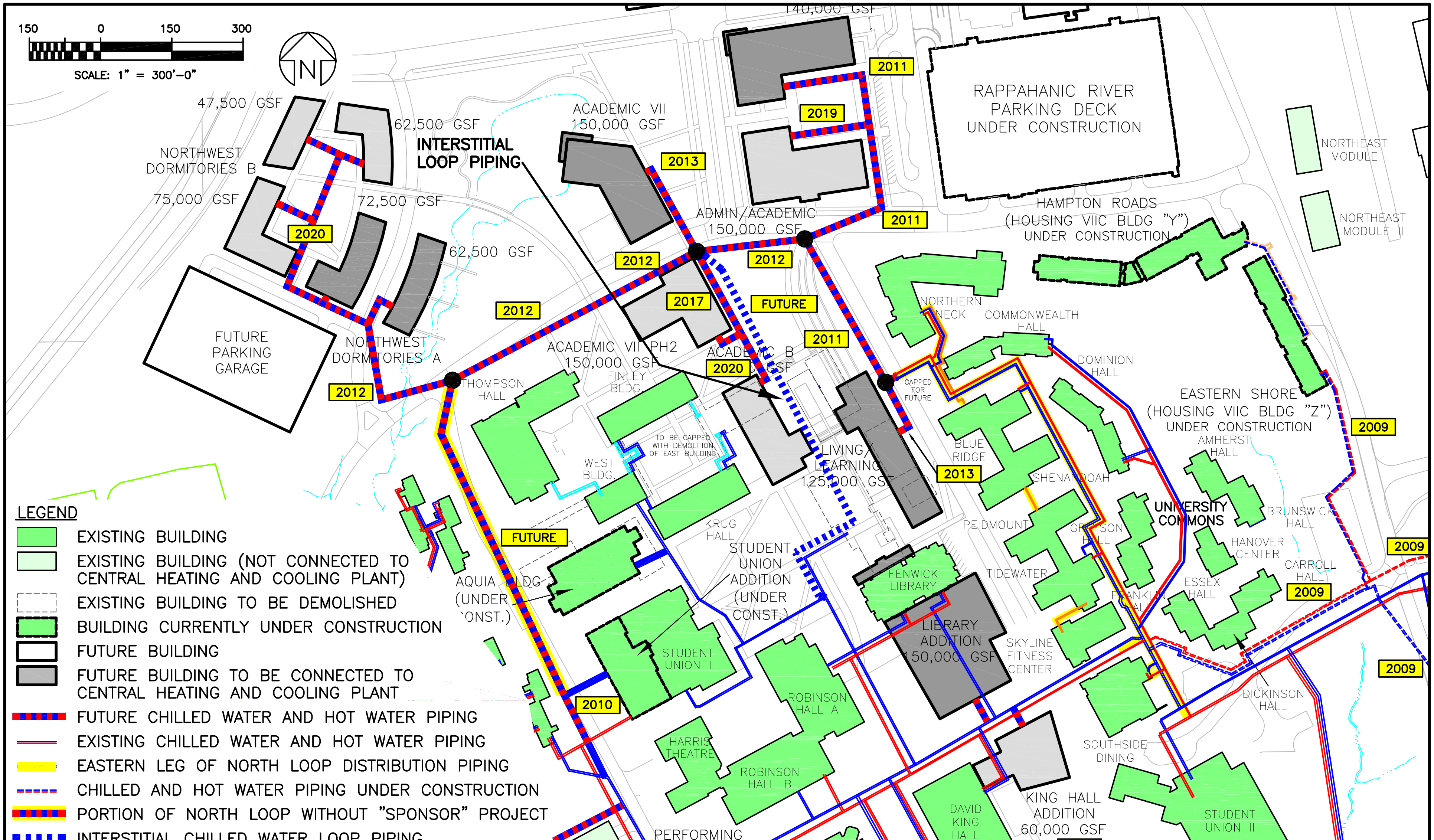
28 JULY 2009

FIGURE NO. 3–15

FILE: H:\Proj\109083A0\MP\DWGS\9083A-ft-CHW-HTHW.dwg



FUTURE SITE PLAN
INTERSTITIAL NORTH LOOP PIPING

SCALE: 1" = 300'

SOURCE: FUTURE SITE PLAN BASED UPON THE CAMPUS PLAN AS OF APRIL 30, 2009

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RMF ENGINEERING, INC.
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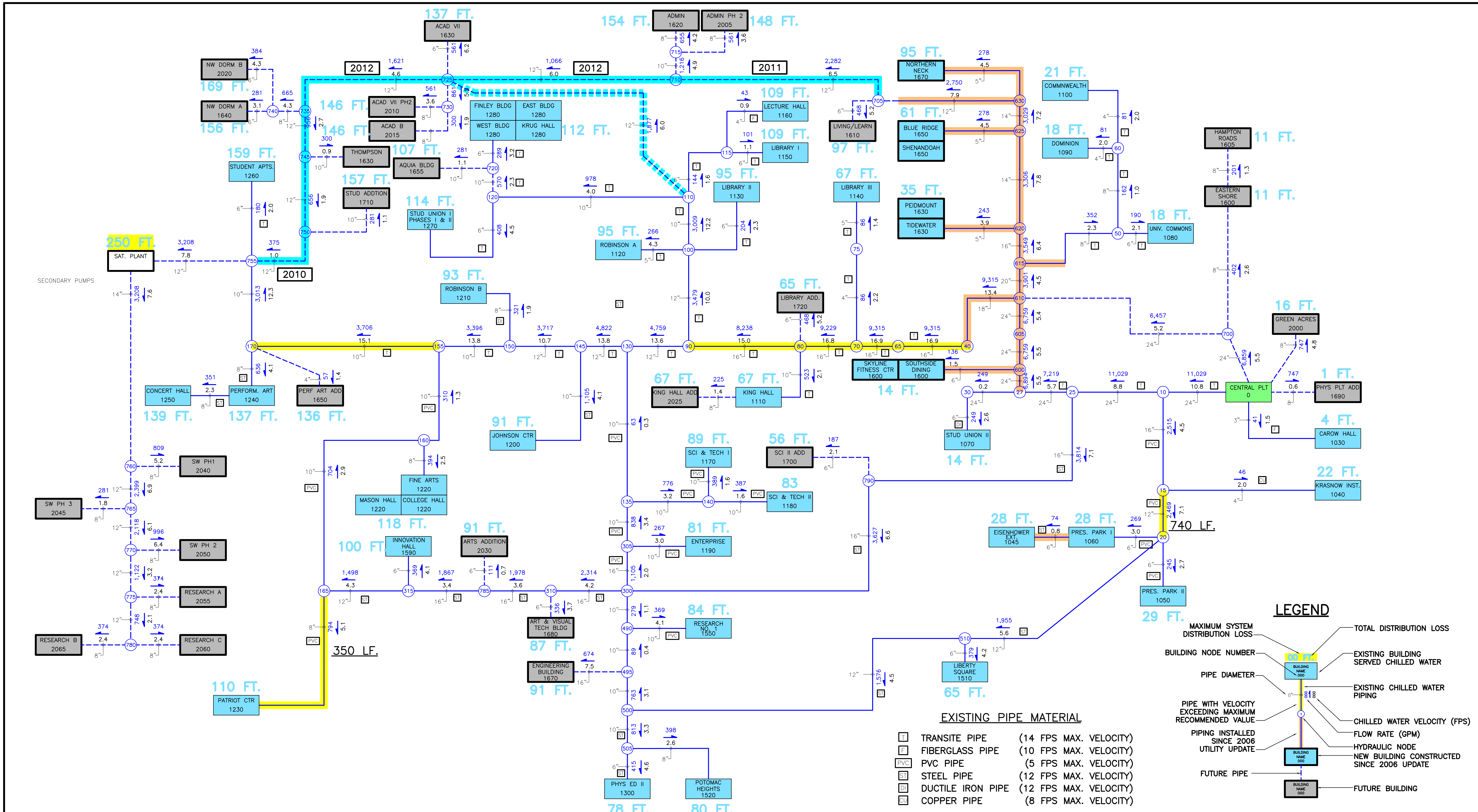
28 JULY 2009

FIGURE NO. 3-16



2020 CHILLED WATER SYSTEM SCHEMATIC – INTERSTITIAL LOOP PIPING (NORTH LOOP COMPLETE)

SCALE: NONE

GMU UPDATE TO UTILITY MASTER PLAN

RMF ENGINEERING, INC.
BALTIMORE, MD

GEORGE MASON UNIV.
FAIRFAX, VA

28 JULY 2009

FIGURE NO. 3–17

3.4.2.4 Summary of Chilled Water Distribution

The Central Plant cannot serve the entire campus buildout without support of the Satellite Plant. A minimum of two operating chillers within the Satellite Plant is needed and a third standby unit is recommended. With the Satellite and Central Plants operating together, the western leg of North Loop is need by 2019.

3.5 FUTURE SANITARY SEWER COLLECTION

The capacity threshold of the 10-inch mains for the East and West Connections is 1,120 gallons per minute (GPM) each, based upon an assumed constant grade of 1%. A summary of the future sanitary sewer collection requirements is presented in Table No. 3-3.

For this analysis, it was initially assumed that the future building projects will be connected to the nearest sanitary collection main. This results in an imbalance in system flow and causes the "west" sanitary main to exceed the capacity threshold. As new buildings are added to the campus, sewer flows to the two main pipe segments need to be balanced to ensure neither main is overloaded. Multiple combinations of building connections to the two sewer mains are possible. The most logical configuration based upon campus planning and current assumptions is presented in Figure No. 3-18. A summary of the balanced future sanitary sewer collection requirements is presented in Table No. 3-4. Under this configuration, the projected flow in each main is less than the estimated maximum of 1,120 gpm. The total system flow of the "east" and "west" mains combined is approximately 2,120 gpm, which is within 1% of the total capacity of the two mains. Considering the analysis is a "global" evaluation with an assumed constant grade of 1% and no metering data to confirm load assumptions, a full sanitary hydraulic analysis for the campus is recommended well before the time when the load is within 5% of the total system capacity. This study should be commissioned and completed by 2014.

3.6 SUMMARY OF RECOMMENDATIONS AND SCHEDULE

In general, the campus is continuing to grow consistently as projected in the initial 2002 Utility Master Plan. The shift in the expansion of the various regions of campus can be supported by implementing the utility projects initially proposed in 2002. The timing and costs of these projects have been updated to reflect current needs and recent conditions. The revised costs and the schedule are presented in Table No. 3-5. The proposed site plan and plant layout is presented in Figure No. 3-19. The budgetary capital costs are based upon the following current unitary cost factors:

1. Heating Equipment - $100 / thousand Btu's per hour (MBH)
2. Cooling Equipment - $2,000 / ton
3. Building Costs - $200 / gsf
4. HTHW and Chilled Water Mains - $3,500 / linear foot
5. LTHW and Chilled Water Mains - $2,000 / linear foot
6. HTHW and Chilled Water Radial Feeds - $1,600 / linear foot

TABLE NO. 3-3: FUTURE SEWER COLLECTION SUMMARY
GEORGE MASON UNIVERSITY

PHASE	YEAR ONLINE	PROJEJCT	AREA (GSF)	SPACE UTILIZATION	UNITARY LOAD (GPM/GSF)	PEAK BUILDING DEMAND WEST CONNECT. (GPM)	EAST CONNECT. (GPM)	ROBERTS ROAD CONNECT. (GPM)	BUILDING CONSUM. (GPD)
2009 TOTAL			3,606,415	---	0.0003	368	795	11	489,650
UNDER CONSTRUCTION	JUN '09	ART & VISUAL TECH BLDG	90,000	CLASSROOM	0.0003	23	---	---	11,040
	JUN '09	ENGINEERING BUILDING	180,000	CLASSROOM	0.0003	45	---	---	21,600
	SEP '09	HAMPTON ROADS	97,400	DORMITORY	0.0003	---	29	---	11,140
	DEC '09	AQUIA BUILDING	60,000	OFFICE / COMP.	0.0003	15	---	---	7,200
	JUN '10	EASTERN SHORE	97,400	DORMITORY	0.0003	---	29	---	11,140
	SEP '10	STUDENT UNION ADDITION	60,000	ASSEMBLY	0.0003	15	---	---	5,760
	SUBTOTAL		584,800	---	0.0003	98	58	---	67,880
FUTURE	SEP '10	PERFORMING ARTS ADDITION	15,000	CLASSROOM	0.0003	4	---	---	1,920
	2011	ADMINISTRATION	140,000	OFFICE	0.0003	---	35	---	16,800
	2011	SCIENCE & TECH II ADDITION	50,000	LABORATORY	0.0006	---	30	---	14,400
	2012	LIBRARY ADDITION	150,000	LIBRARIES	0.0003	38	---	---	18,240
	2012	NORTHWEST DORMITORIES A	135,000	DORMITORY	0.0003	41	---	---	15,740
	2012	PATRIOT CENTER ADDITION	30,000	ASSEMBLY	0.0003	8	---	---	3,070
	2012	PHYSICAL PLANT BUILDING	30,000	MAINTENANCE	0.0001	---	---	3	1,150
	2013	ACADEMIC VII	150,000	CLASSROOM	0.0003	38	---	---	18,240
	2013	LIVING/LEARNING	125,000	CLASSROOM	0.0003	31	---	---	14,880
	2015	SOUTHWEST HOUSING PH1	390,000	DORMITORY	0.0003	117	---	---	44,930
	2015	KING HALL ADDITION	60,000	CLASS / LAB	0.0005	---	27	---	12,960
	2015	RESEARCH A	100,000	LABORATORY	0.0006	60	---	---	28,800
	2017	ACADEMIC VII PH2	150,000	CLASSROOM	0.0003	38	---	---	18,240
	2017	RESEARCH B	100,000	LABORATORY	0.0006	60	---	---	28,800
	2017	SOUTHWEST HOUSING PH2	480,000	DORMITORY	0.0003	144	---	---	55,300
	2019	ADMIN/ACADEMIC	150,000	OFFICE	0.0003	---	38	---	18,240
	2019	ARTS ADDITION	30,000	CLASSROOM	0.0003	8	---	---	3,840
	2019	RESEARCH C	100,000	LABORATORY	0.0006	60	---	---	28,800
	2019	SOUTHWEST HOUSING PH3	135,000	DORMITORY	0.0003	41	---	---	15,740
	2020	ACADEMIC B	80,000	CLASSROOM	0.0003	20	---	---	9,600
	2020	NORTHWEST DORMITORIES B	185,000	DORMITORY	0.0003	56	---	---	21,500
	2020	GREEN ACRES RESEARCH/OFFICE	200,000	LABORATORY	0.0006	---	---	120	57,600
	SUBTOTAL		2,985,000	---	0.0003	764	130	123	448,790
FUTURE TOTAL			6,591,415	---	0.0004	1,230	983	134	1,006,320

NOTES: 1. EACH OF THE EXISTING 10-INCH MAINS HAS A CAPACITY THRESHOLD OF 1,120 GPM, BASED UPON AN ASSUMED CONSTANT GRADE OF 1%.

2. WEST AND EAST CONNECTIONS CARRYING 99% OF THE ESTIMATED COMBINED CAPACITY

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LEGEND

- EXISTING BUILDING
- EXISTING BUILDING TO BE DEMOLISHED
- BUILDING CURRENTLY UNDER CONSTRUCTION
- FUTURE BUILDING
- BUILDING WITH WESTERN SANITARY SEWER CONNECTION
- BUILDING WITH EASTERN SANITARY SEWER CONNECTION
- BUILDING WITH ROBERTS ROAD SANITARY SEWER CONNECTION
- EXISTING SANITARY SEWER PIPING
- FUTURE SANITARY SEWER PIPE ROUTING
- FUTURE BUILDINGS SHIFTED FROM WESTERN CONNECTION TO EASTERN CONNECTION TO BALANCE FLOW

NOTE: FACULTY AND STAFF HOUSING TO BE CONNECTED DIRECTLY TO FAIRFAX COUNTY SANITARY SEWER SYSTEM.

SOURCE: FUTURE SITE PLAN BASED UPON THE CAMPUS PLAN AS OF APRIL 30, 2009 AND THE FOLLOWING:

1. "NORTH SECTOR MASTER PLAN" BY EHRENKRANTZ ECKSTUT & KUHN ARCHITECTS (MARCH 2009)
2. "SOUTHWEST SECTOR MASTER PLAN" BY EHRENKRANTZ ECKSTUT & KUHN ARCHITECTS (AUGUST 2007)
3. "GEORGE MASON UNIVERSITY FACULTY & STAFF HOUSING" BY MASON HOUSING, INC (MARCH 2008)
4. "PERFORMING ARTS BUILDING ADDITION" BY HUGHES GROUP ARCHITECTS (JUNE 2008)
5. "SURGE SPACE/IT BUILDING" CLARK NEXSEN ARCHITECTURE & ENGINEERING (NOVEMBER 2007)

N

250 0 250 500

SCALE: 1" = 500' – 0"

FUTURE GEORGE MASON UNIVERSITY SITE PLAN WITH SANITARY SEWER PIPE ROUTING

SCALE: 1" = 500'

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FAIRFAX, VA

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FIGURE NO. 3–18

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TABLE NO. 3-4: FUTURE SEWER COLLECTION SUMMARY (BALANCED)

GEORGE MASON UNIVERSITY

PHASE	YEAR ONLINE	PROJEJCT	AREA (GSF)	SPACE UTILIZATION	UNITARY LOAD (GPM/GSF)	PEAK BUILDING DEMAND WEST CONNECT. (GPM)	PEAK BUILDING DEMAND EAST CONNECT. (GPM)	PEAK BUILDING DEMAND ROBERTS ROAD CONNECT. (GPM)	BUILDING CONSUM. (GPD)
2009 TOTAL			3,606,415	---	0.0003	368	795	11	489,650
UNDER CONSTRUCTION	JUN '09	ART & VISUAL TECH BLDG	90,000	CLASSROOM	0.0003	23	---	---	11,040
	JUN '09	ENGINEERING BUILDING	180,000	CLASSROOM	0.0003	45	---	---	21,600
	SEP '09	HAMPTON ROADS	97,400	DORMITORY	0.0003	---	29	---	11,140
	DEC '09	AQUIA BUILDING	60,000	OFFICE / COMP.	0.0003	15	---	---	7,200
	JUN '10	EASTERN SHORE	97,400	DORMITORY	0.0003	---	29	---	11,140
	SEP '10	STUDENT UNION ADDITION	60,000	ASSEMBLY	0.0003	15	---	---	5,760
	SUBTOTAL		584,800	---	0.0003	98	58	---	67,880
FUTURE	SEP '10	PERFORMING ARTS ADDITION	15,000	CLASSROOM	0.0003	4	---	---	1,920
	2011	ADMINISTRATION	140,000	OFFICE	0.0003	---	35	---	16,800
	2011	SCIENCE & TECH II ADDITION	50,000	LABORATORY	0.0006	---	30	---	14,400
	2012	LIBRARY ADDITION	150,000	LIBRARIES	0.0003	38	---	---	18,240
	2012	NORTHWEST DORMITORIES A	135,000	DORMITORY	0.0003	41	---	---	15,740
	2012	PATRIOT CENTER ADDITION	30,000	ASSEMBLY	0.0003	8	---	---	3,070
	2012	PHYSICAL PLANT BUILDING	30,000	MAINTENANCE	0.0001	---	---	3	1,150
	2013	ACADEMIC VII	150,000	CLASSROOM	0.0003	---	38	---	18,240
	2013	LIVING/LEARNING	125,000	CLASSROOM	0.0003	---	31	---	14,880
	2015	SOUTHWEST HOUSING PH1	390,000	DORMITORY	0.0003	117	---	---	44,930
	2015	KING HALL ADDITION	60,000	CLASS / LAB	0.0005	---	27	---	12,960
	2015	RESEARCH A	100,000	LABORATORY	0.0006	60	---	---	28,800
	2017	ACADEMIC VII PH2	150,000	CLASSROOM	0.0003	---	38	---	18,240
	2017	RESEARCH B	100,000	LABORATORY	0.0006	60	---	---	28,800
	2017	SOUTHWEST HOUSING PH2	480,000	DORMITORY	0.0003	144	---	---	55,300
	2019	ADMIN/ACADEMIC	150,000	OFFICE	0.0003	---	38	---	18,240
	2019	ARTS ADDITION	30,000	CLASSROOM	0.0003	8	---	---	3,840
	2019	RESEARCH C	100,000	LABORATORY	0.0006	60	---	---	28,800
	2019	SOUTHWEST HOUSING PH3	135,000	DORMITORY	0.0003	41	---	---	15,740
	2020	ACADEMIC B	80,000	CLASSROOM	0.0003	---	20	---	9,600
	2020	NORTHWEST DORMITORIES B	185,000	DORMITORY	0.0003	56	---	---	21,500
	2020	GREEN ACRES RESEARCH/OFFICE	200,000	LABORATORY	0.0006	---	---	120	57,600
	SUBTOTAL		2,985,000	---	0.0003	637	257	123	448,790
FUTURE TOTAL			6,591,415	---	0.0004	1,103	1,110	134	1,006,320

NOTE: [shaded box] REPRESENTS BUILDING PROJECT WHOSE LOAD WAS SHIFTED FROM WEST TO EAST CONNECTION IN ORDER TO BALANCE FLOW

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TABLE NO. 3-5: SUMMARY OF INFRASTRUCTURE UPGRADES - 2009 COSTS (PRELIMINARY)
GEORGE MASON UNIVERSITY - FAIRFAX CAMPUS

PHASE NO.	ONLINE TIME FRAME	PROJECT	INFRASTRUCTURE UPGRADES						
			HEATING AND COOLING		DISTRIBUTION LOOP		RADIAL DISTRIBUTION		TOTAL COST ($)
			DESCRIPTION	CONSTRUCT. COST ($)	DESCRIPTION	CONSTRUCT. COST ($)	DESCRIPTION	CONSTRUCT. COST ($)	
UNDER CONST.	JUN '09	ART & VISUAL TECH BLDG (ACADEMIC V)	CURRENTLY UNDER DESIGN OR IN CONSTRUCTION						
	JUN '09	ENGINEERING BUILDING (ACADEMIC VI)							
	SEP '09	HAMPTON ROADS (HOUSING VIIC BLDG "Y")							
	DEC '09	AQUIA BUILDING							
	JUN '10	EASTERN SHORE (HOUSING VIIC BLDG "Z")							
	SEP '10	STUDENT UNION ADDITION							
FUTURE	SEP '10	PERFORMING ARTS ADDITION	---	---	---	---	100 LF CHW & HTHW	160,000	160,000
	2011	ADMINISTRATION	---	---	---	---	480 LF CHW & HTHW	768,000	770,000
	2011	SCIENCE & TECH II ADDITION	---	---	---	---	130 LF CHW & HTHW	208,000	210,000
	2012	LIBRARY ADDITION	SAT. PLANT (2) 1,100 TONS CHW	6,000,000	SAT. PLANT BACKFEED (1,300 LF)	4,600,000	100 LF CHW & HTHW	160,000	14,200,000
			SAT. PLANT (1) 25 MMBH HTHW	3,400,000					
	2012	NORTHWEST DORMITORIES A	---	---	NORTH LOOP PHASE II (810 LF)	2,800,000	200 LF CHW & HTHW	320,000	3,120,000
	2012	PATRIOT CENTER ADDITION	---	---	---	---	100 LF CHW & HTHW	160,000	160,000
	2012	PHYSICAL PLANT BUILDING	---	---	---	---	600 LF CHW & HTHW	960,000	960,000
	2013	ACADEMIC VII	---	---	---	---	100 LF CHW & HTHW	160,000	160,000
	2013	LIVING/LEARNING	---	---	---	---	100 LF CHW & HTHW	160,000	160,000
	2014	THOMPSON HALL CONNECTION							
	2014	FINLEY, EAST, WEST, & KRUG	---	---	SANITARY SYSTEM HYDRAULIC ANALYSIS	40,000	100 LF CHW & HTHW	160,000	200,000
	2014	DATA CENTER							
	2015	SOUTHWEST HOUSING PH1	---	---	SOUTHWEST CHW & LTHW (460 LF)	920,000	470 LF CHW & LTHW	752,000	1,670,000
	2015	KING HALL ADDITION	---	---	---	---	100 LF CHW & HTHW	160,000	160,000
	2015	RESEARCH A	ADD BOILER NO. 5 (25 MMBH)	2,500,000	SOUTHWEST CHW & LTHW (1,200 LF)	2,400,000	100 LF CHW & LTHW	160,000	5,060,000
	2017	ACADEMIC VII PH2	---	---	---	---	100 LF CHW & HTHW	160,000	160,000
	2017	RESEARCH B	ADD CHILLER NO. 10 (1,500 TONS)	3,000,000	SOUTHWEST CHW & LTHW (200 LF)	400,000	100 LF CHW & LTHW	160,000	3,560,000
	2017	SOUTHWEST HOUSING PH2	---	---	---	---	300 LF CHW & LTHW	480,000	480,000
	---	COMPLETION OF NORTH LOOP	---	---	NORTH LOOP COMPLETION (700 LF)	2,500,000	---	---	2,500,000
	2019	ADMIN/ACADEMIC	---	---	---	---	100 LF CHW & HTHW	160,000	160,000
	2019	ARTS ADDITION	---	---		---	100 LF CHW & HTHW	160,000	160,000
	2019	RESEARCH C	ADD BOILER NO. 6 (25 MMBH)	2,500,000	---	---	100 LF CHW & LTHW	160,000	2,660,000
	2019	SOUTHWEST HOUSING PH3	---	---	---	---	100 LF CHW & LTHW	160,000	160,000
	2020	ACADEMIC B	ADD CHILLER NO. 11 (1,500 TONS)	3,000,000	---	---	100 LF CHW & HTHW	160,000	3,160,000
	2020	NORTHWEST DORMITORIES B	---	---	---	---	250 LF CHW & HTHW	400,000	400,000
	2020	GREEN ACRES RESEARCH/OFFICE	---	---	---	---	300 LF CHW & HTHW	480,000	480,000
TOTAL			---	20,400,000	---	13,660,000	---	6,768,000	40,900,000

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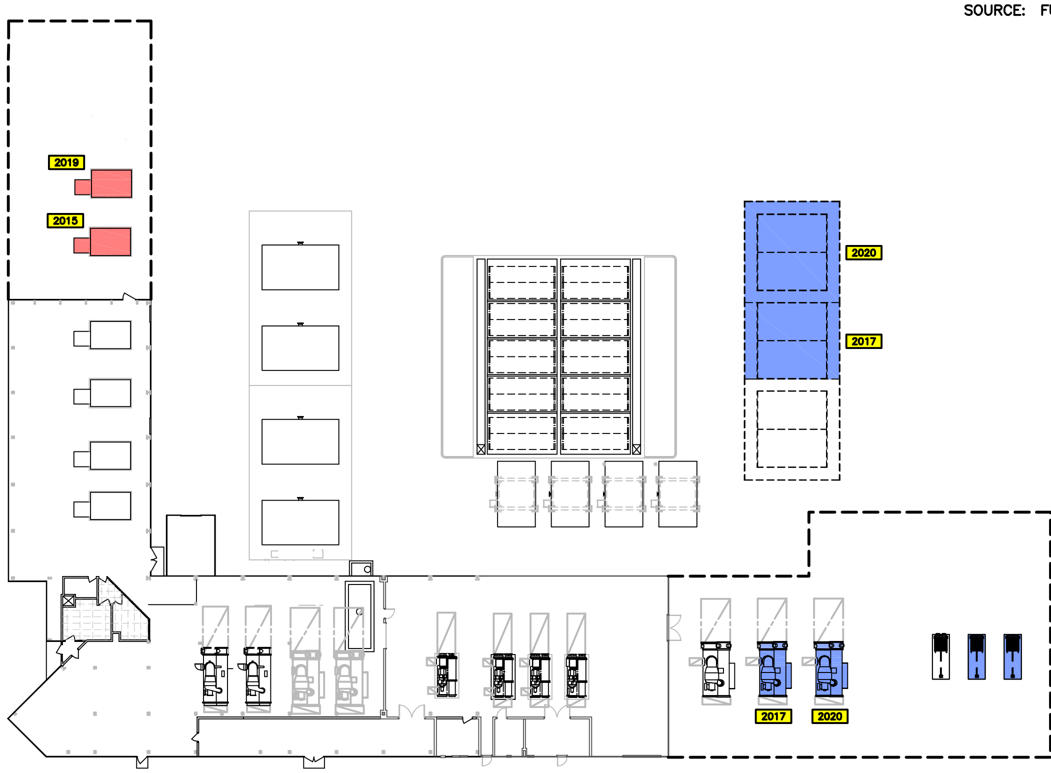
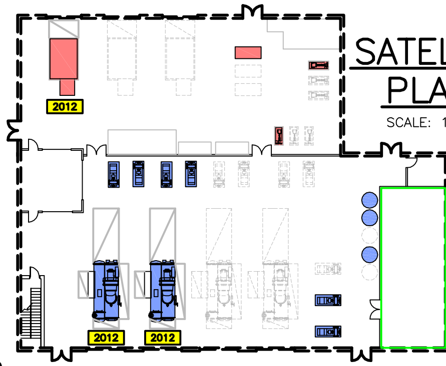
SOURCE: FUTURE SITE PLAN BASED UPON THE CAMPUS PLAN AS OF APRIL 30, 2009 AND THE FOLLOWING:
1. "NORTH SECTOR MASTER PLAN" BY EHRENKRANTZ ECKSTUT & KUHN ARCHITECTS (MARCH 2009)
2. "SOUTHWEST SECTOR MASTER PLAN" BY EHRENKRANTZ ECKSTUT & KUHN ARCHITECTS (AUGUST 2007)
3. "GEORGE MASON UNIVERSITY FACULTY & STAFF HOUSING" BY MASON HOUSING, INC (MARCH 2008)
4. "PERFORMING ARTS BUILDING ADDITION" BY HUGHES GROUP ARCHITECTS (JUNE 2008)
5. "SURGE SPACE/IT BUILDING" CLARK NEXSEN ARCHITECTURE & ENGINEERING (NOVEMBER 2007)



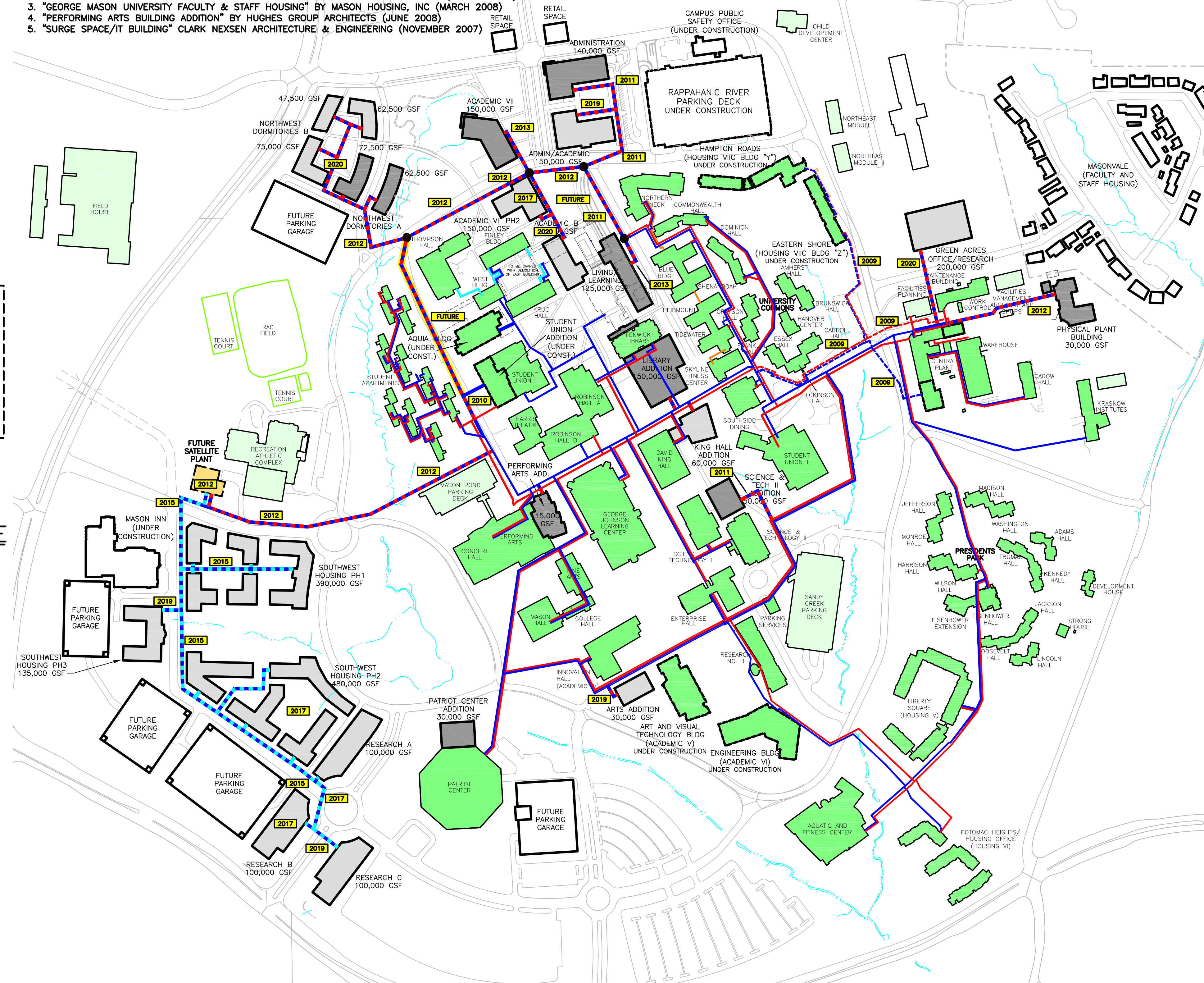
CENTRAL PLANT

SCALE: 1"=60'



SATELLITE PLANT

SCALE: 1"=60'



LEGEND

- EXISTING BUILDING
- EXISTING BUILDING (NOT CONNECTED TO CENTRAL HEATING AND COOLING PLANT)
- EXISTING BUILDING TO BE DEMOLISHED
- BUILDING CURRENTLY UNDER CONSTRUCTION
- FUTURE BUILDING
- FUTURE BUILDING – PHASE I (2010 – 2015)
- FUTURE BUILDING – PHASE II (2016 – 2020)
- FUTURE COOLING EQUIPMENT
- FUTURE HEATING EQUIPMENT
- EXISTING CHILLED WATER AND HOT WATER PIPING
- CHILLED AND HOT WATER PIPING UNDER CONSTRUCTION
- FUTURE CHILLED WATER AND HIGH TEMPERATURE HOT WATER PIPING
- FUTURE CHILLED WATER AND LOW TEMPERATURE HOT WATER PIPING

125 0 125 250

SCALE: 1" = 250' – 0"

FUTURE GEORGE MASON UNIVERSITY SITE PLAN AND PLANT FLOOR PLANS – FULL BUILDOUT

SCALE: 1" = 500'

GMU UPDATE TO UTILITY MASTER PLAN

RMF ENGINEERING, INC.
BALTIMORE, MD

GEORGE MASON UNIV.
FAIRFAX, VA

28 JULY 2009

FIGURE NO. 3–19

Note: These costs are 2009 **construction costs only** and do not include escalation or project costs (i.e. project design fees, project contingencies, etc.)

The following is a summary of the requirements for each of the utilities that would need to be implemented:

High Temperature Hot Water Boiler Capacity

- The future projected heating load will exceed the firm capacity of the Central Plant (with the Boiler No. 2 replacement) once the current projects under construction are complete. Because of this, there is an immediate need for additional boiler capacity. To establish funding and implement a project to expand the Central Plant will require several years. The Satellite Plant programmed for the Southwest Sector will be utilized to provide the needed standby capacity for the Central Heating System.
- The Satellite Plant will generate High Temperature Hot Water (HTHW) to allow distribution to the main Campus. Heat exchangers will also be installed at the Satellite Plant to allow for Low Temperature Hot Water (LTHW) to be distributed to the building of the Southwest Sector.

Chilled Water Chiller Capacity

- The Central Plant cannot serve the entire campus buildout without support of the Satellite Plant. A minimum of two operating chillers within the Satellite Plant is needed and a third standby unit is recommended.

Chilled Water Distribution

- The western leg of the North Loop is required during normal operation when the total peak cooling load is approximately 11,000 tons. Currently, this is programmed to occur in 2019 with the connection of the Admin/Academic Building.
- Currently, two sections of piping (8-inch segment leading to the Patriot Center and the 12-inch segment between Krasnow Institutes and the President's Park) are above recommended maximum allowable velocity for PVC pipe. They should be replaced with welded schedule 40 steel.

Sanitary Sewer

- A full sanitary hydraulic analysis for the campus is recommended well before the time when the load is within 5% of the total system capacity. This study should be commissioned and completed by 2014.

3.7 SUMMARY OF ASSUMPTIONS FOR THE 2009 UTILITY MASTER PLAN

The following is a summary of the various assumptions utilized in this analysis:

High Temperature Hot Water Boiler Capacity

- Design capacity of Boiler No. 1 at Central Plant can be achieved (25,000 10^3 btu/hr)
- Design capacity of Boiler Nos. 3 and 4 at Central Plant can be achieved (20,000 10^3 Btu/h each)
- Boiler No. 2 is planned to replaced in the near term and the replacement will be able to achieve the design capacity (25,000 10^3 btu/hr)

High Temperature Hot Water Distribution

- Building pressure differential requirement is assumed to be 30 feet.
- Site temperature differential is at 90°F for peak load conditions.
- HTHW piping from the Satellite Plant to the Main Campus would be installed to allow for the Satellite Plant to supplement flow to the Main Campus.
- LTHW piping will be installed in the Southwest Sector.

Chilled Water Chiller Capacity

- Design capacities of the existing chillers at Central Plant can be achieved (6,540 tons total)
- Chilled water can be exported from ice melt at the Central Plant (1,780 tons total)
- Design capacity of Chiller No. 9 (currently in design) at Central Plant can be achieved (1,470 tons)

Chilled Water Distribution

- Chilled water piping from the Satellite Plant to the Main Campus would be installed to allow for the Satellite Plant to supplement flow to the Main Campus.
- Building pressure differential requirement is assumed to be 30 feet.
- Site temperature differential is at 14°F for peak load conditions.
- Satellite Plant distribution pumps will circulate flow in the Southwest Sector

Sanitary Sewer

- Peak building sanitary demand based upon building area and space utilization.
- No metering data was used to confirm load assumptions.
- Capacity threshold for the sanitary mains based upon an assumed constant grade of 1%.

DIVISION NO. 4 - APPENDIX

4.1 ASHRAE DESIGN CONDITIONS

4.2 FUTURE CONSTRUCTION COSTS – PRELIMINARY

4.3 FUTURE HTHW HYDRAULICS

4.4 FUTURE CHILLED WATER HYDRAULICS

4.5 REVIEW COMMENTS AND ACTION TAKEN BY RMF ENGINEERING

4.1 ASHRAE DESIGN CONDITIONS

WASHINGTON DC DULLES INT'L AR, VA, USA

WMO#: **724030**

Lat: **38.94N** Long: **77.45W** Elev: **325** StdP: **14.52** Time Zone: **-5.00 (NAE)** Period: **82-06** WBAN: **93738**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	**10.7**	**15.7**	**-3.1**	**4.7**	**15.8**	**1.9**	**6.1**	**20.3**	**25.1**	**33.4**	**23.0**	**33.2**	**6.1**	**310**

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	**20.5**	**93.5**	**75.1**	**90.8**	**74.3**	**88.2**	**73.0**	**77.7**	**88.8**	**76.5**	**86.6**	**75.3**	**84.3**	**9.0**	**290**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 55/69
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
74.5	**130.5**	**82.0**	**73.5**	**126.0**	**80.8**	**72.5**	**121.9**	**79.8**	**41.2**	**89.0**	**40.0**	**87.2**	**38.9**	**84.5**	**712**

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
20.5	**18.3**	**16.4**	**84.0**	**1.1**	**97.1**	**8.2**	**3.5**	**-4.8**	**99.6**	**-9.6**	**101.6**	**-14.2**	**103.5**	**-20.2**	**106.0**

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		55.1	33.3	36.4	43.9	54.0	62.9	71.7	76.4	75.0	67.3	55.7	46.3	36.8
	Sd			10.42	8.95	9.65	8.51	7.49	6.16	4.97	5.37	7.24	8.02	9.01	9.76
	HDD50		1848	528	389	241	51	2	0	0	0	1	33	177	426
	HDD65		4735	984	800	656	344	132	15	1	3	58	306	562	874
	CDD50		3704	9	9	53	171	402	652	819	776	521	209	66	17
	CDD65		1119	0	0	4	14	67	217	355	314	128	18	2	0
	CDH74		10773	0	1	51	229	767	2056	3482	2915	1091	165	15	1
	CDH80		4139	0	0	12	61	241	756	1512	1179	353	24	1	0
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		66.7	69.0	81.1	86.8	89.7	93.8	97.0	96.4	93.5	83.2	76.1	69.8
		MCWB		59.3	55.8	62.8	66.6	71.2	74.3	76.1	76.2	73.7	68.4	63.0	61.4
	2%	DB		60.9	61.5	72.1	80.5	86.1	90.3	93.8	92.8	87.7	78.7	70.2	62.6
		MCWB		55.2	52.9	57.5	63.3	69.9	73.9	75.7	74.9	71.8	66.4	60.0	56.1
	5%	DB		53.9	56.2	66.2	75.3	82.5	87.5	91.0	89.7	83.9	74.6	66.0	56.7
		MCWB		47.2	48.0	54.9	60.9	68.3	72.7	75.3	73.6	69.9	63.9	58.9	51.4
	10%	DB		47.8	51.0	60.8	70.4	78.1	84.6	88.2	86.6	80.5	70.4	61.9	51.8
		MCWB		42.2	44.4	51.2	58.0	65.6	71.5	74.0	72.5	68.5	61.7	55.0	46.1
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		61.9	59.7	64.4	69.0	75.4	78.0	79.9	78.9	76.2	71.5	66.2	62.9
		MCDB		64.5	64.2	77.2	81.3	86.1	88.8	91.2	90.5	86.5	78.2	71.3	67.3
	2%	WB		55.5	54.3	60.4	65.9	72.4	76.2	78.1	77.2	74.4	69.2	63.3	57.7
		MCDB		60.0	59.6	69.2	76.3	82.3	86.4	89.3	88.3	82.9	75.5	68.0	61.6
	5%	WB		48.1	49.5	56.5	62.7	70.0	74.9	77.0	75.9	72.8	66.4	59.9	52.6
		MCDB		52.5	55.0	63.9	72.1	78.8	84.0	87.3	85.5	79.9	72.4	64.8	55.8
	10%	WB		42.8	45.3	52.3	59.9	67.6	73.3	75.7	74.6	71.0	63.5	56.1	46.4
		MCDB		47.0	50.5	60.1	69.0	75.9	81.4	84.5	83.2	77.1	68.8	60.8	50.6
Mean Daily Temperature Range		MDBR		17.2	18.7	20.8	22.9	22.1	21.2	20.5	20.5	21.2	22.8	20.7	17.6
	5% DB	MCDBR		24.7	27.2	30.0	31.1	27.9	24.4	24.3	24.0	24.8	27.1	25.7	24.0
		MCWBR		18.2	18.9	18.0	16.2	13.5	10.5	9.3	9.2	11.1	15.6	17.3	18.2
	5% WB	MCDBR		21.6	22.6	25.6	25.7	23.2	21.0	20.6	20.6	20.1	21.8	20.6	20.5
		MCWBR		17.9	17.6	17.3	14.7	12.5	10.0	9.0	9.1	10.3	13.9	16.3	17.7
Clear Sky Solar Irradiance	taub			0.313	0.344	0.394	0.404	0.462	0.523	0.544	0.576	0.418	0.365	0.333	0.311
	taud			2.422	2.228	2.065	2.085	1.932	1.808	1.787	1.687	2.160	2.303	2.401	2.477
	Ebn,noon			273	276	272	277	262	245	239	226	262	266	263	266
	Edh,noon			29	39	49	50	60	67	68	73	44	35	29	26

CDD*n* Cooling degree-days base n°F, °F-day
CDH*n* Cooling degree-hours base n°F, °F-hour
DB Dry bulb temperature, °F
DP Dew point temperature, °F
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, Btu/h/ft2
Elev Elevation, ft
Enth Enthalpy, Btu/lb
HDD*n* Heating degree-days base n°F, °F-day
Hours 8/4 & 55/69 Number of hours between 8 a.m. and 4 p.m with DB between 55 and 69 °F
HR Humidity ratio, grains of moisture per lb of dry air
Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °F
MCDBR Mean coincident dry bulb temp. range, °F
MCDP Mean coincident dew point temperature, °F
MCWB Mean coincident wet bulb temperature, °F
MCWBR Mean coincident wet bulb temp. range, °F
MCWS Mean coincident wind speed, mph
MDBR Mean dry bulb temp. range, °F
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East
Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °F
StdP Standard pressure at station elevation, psi
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °F
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °F
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, mph

4.2 FUTURE CONSTRUCTION COSTS – PRELIMINARY

FUTURE CONSTRUCTION COSTS - WITH HTHW SATELLITE PLANT (PRELIMINARY)

GEORGE MASON UNIVERSITY

		SATELLITE PLANT (HTHW)							CENTRAL PLANT (HTHW)						
PHASE	UTILITY	EQUIPMENT CAPACITY	BUILDING AREA (GSF)	EQUIPMENT COSTS ($)	BUILDING COSTS ($)	SAT. PLANT TO LOOP DIST. COSTS ($)	SOUTHWEST DIST. PIPING COSTS ($)	TOTAL CONST. COSTS ($)	EQUIPMENT CAPACITY	BUILDING AREA (GSF)	EQUIPMENT COSTS ($)	BUILDING COSTS ($)	NORTH LOOP DIST. PIPING COSTS ($)	TOTAL CONST. COSTS ($)	TOTAL CAMPUS CONST. COSTS ($)
PHASE I (2009 - 2014)	COOLING	2,200 TONS	8,100	4,400,000	1,620,000	4,550,000	---	13,970,000	---	---	---	---	2,840,000	2,840,000	16,800,000
	HEATING	25,000 MBH	4,500	2,500,000	900,000				---	---	---	---			
	SUBTOTAL	---	12,600	6,900,000	2,520,000	4,550,000	---	13,970,000	---	---	---	---	2,840,000	2,840,000	16,800,000
BUILDOUT (>2014)	COOLING	---	---	---	---	---	3,320,000	3,440,000	3,000 TONS	---	6,000,000	---	---	11,000,000	14,400,000
	HEATING	---	---	120,000[2]	---				50,000 MBH	---	5,000,000	---			
TOTAL		---	12,600	7,020,000	2,520,000	4,550,000	3,320,000	17,410,000	---	---	11,000,000	---	2,840,000	13,840,000	31,300,000

NOTES:

1. COOLING EQUIPMENT COSTS BASED UPON $2,000/TON AND HEATING EQUIPMENT COSTS BASED UPON $100/MBH.
2. HEATING EQUIPMENT COSTS INCLUDE COST OF HOT WATER HEAT EXCHANGERS BASED UPON $10/MBH.
3. BUILDING COSTS BASED UPON $200/GSF.
4. DISTRIBUTION CHILLED WATER AND HIGH TEMPERATURE HOT WATER PIPING COSTS BASED UPON A COST OF $3,500/LF.
5. DISTRIBUTION CHILLED WATER AND LOW TEMPERATURE HOT WATER PIPING COSTS BASED UPON A COST OF $2,000/LF.
6. CONSTRUCTION COSTS DO NOT INCLUDE PROJECT COSTS (PROJECT DESIGN FEES, PROJECT CONTINGENCIES, ETC.)

FILE: H:\PROJ\109083A0\MP\CALC\9083A-PLANT$.XLS

RMF 12 JUNE 2009

FUTURE CONSTRUCTION COSTS - WITH LTHW SATELLITE PLANT (PRELIMINARY)

GEORGE MASON UNIVERSITY

PHASE	UTILITY	SATELLITE PLANT (LTHW)							CENTRAL PLANT (HTHW)						TOTAL CAMPUS CONST. COSTS ($)
		EQUIPMENT CAPACITY	BUILDING AREA (GSF)	EQUIPMENT COSTS ($)	BUILDING COSTS ($)	SAT. PLANT TO LOOP DIST. COSTS ($)	SOUTHWEST DIST. PIPING COSTS ($)	TOTAL CONST. COSTS ($)	EQUIPMENT CAPACITY	BUILDING AREA (GSF)	EQUIPMENT COSTS ($)	BUILDING COSTS ($)	NORTH LOOP DIST. PIPING COSTS ($)	TOTAL CONST. COSTS ($)	
PHASE I (2009 - 2014)	COOLING	2,200 TONS	8,100	4,400,000	1,620,000	4,550,000	---	12,720,000	---	---	---	---	2,840,000	2,840,000	15,600,000
	HEATING	25,000 MBH	4,500	1,250,000	900,000				---	---	---	---			
	SUBTOTAL	---	12,600	5,650,000	2,520,000	4,550,000	---	12,720,000	---	---	---	---	2,840,000	2,840,000	15,600,000
BUILDOUT (>2014)	COOLING	---	---	---	---	---	3,320,000	3,440,000	3,000 TONS	---	6,000,000	---	---	11,000,000	14,400,000
	HEATING	---	---	120,000[2]	---				50,000 MBH	---	5,000,000	---			
TOTAL		---	12,600	5,770,000	2,520,000	4,550,000	3,320,000	16,160,000	---	---	11,000,000	---	2,840,000	13,840,000	30,000,000

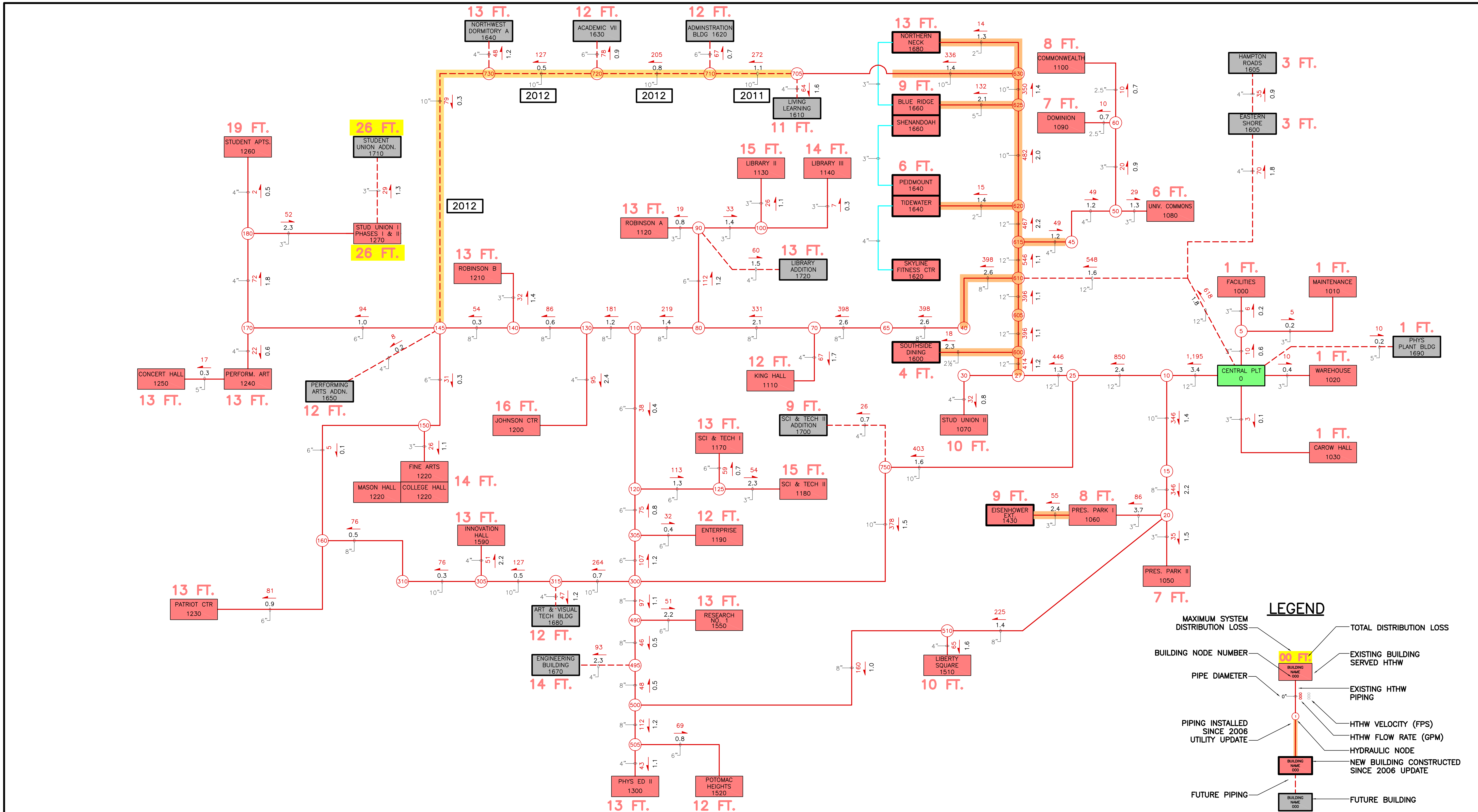
<u>NOTES:</u>

1. COOLING EQUIPMENT COSTS BASED UPON $2,000/TON AND HEATING EQUIPMENT COSTS BASED UPON $50/MBH.
2. HEATING EQUIPMENT COSTS INCLUDE COST OF HOT WATER HEAT EXCHANGERS BASED UPON $10/MBH.
3. BUILDING COSTS BASED UPON $200/GSF.
4. DISTRIBUTION CHILLED WATER AND HIGH TEMPERATURE HOT WATER PIPING COSTS BASED UPON A COST OF $3,500/LF.
5. DISTRIBUTION CHILLED WATER AND LOW TEMPERATURE HOT WATER PIPING COSTS BASED UPON A COST OF $2,000/LF.
6. CONSTRUCTION COSTS DO NOT INCLUDE PROJECT COSTS (PROJECT DESIGN FEES, PROJECT CONTINGENCIES, ETC.)

FILE: H:\PROJ\109083A0\MP\CALC\9083A-PLANT$.XLS

RMF 12 JUNE 2009

4.3 FUTURE HTHW HYDRAULICS



2014 HIGH TEMPERATURE HOT WATER SYSTEM SCHEMATIC – NORTH LOOP COMPLETE

SCALE: NONE

GMU UPDATE TO UTILITY MASTER PLAN

RMF ENGINEERING, INC.
BALTIMORE, MD

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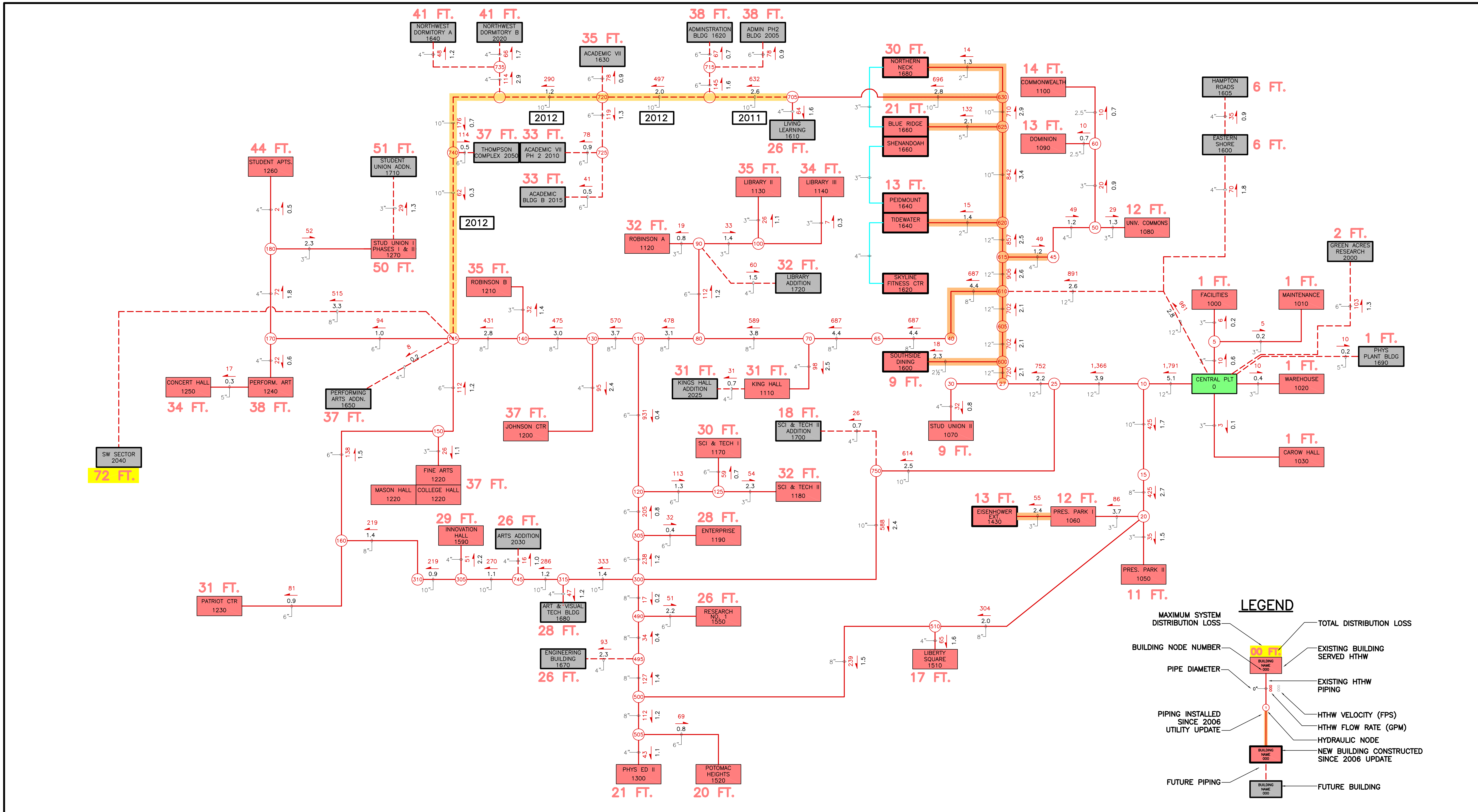
28 JULY 2009

FIGURE NO. 4.3.1



2020 HIGH TEMPERATURE HOT WATER SYSTEM SCHEMATIC – NORTH LOOP COMPLETE

SCALE: NONE

GMU UPDATE TO UTILITY MASTER PLAN

RMF ENGINEERING, INC.
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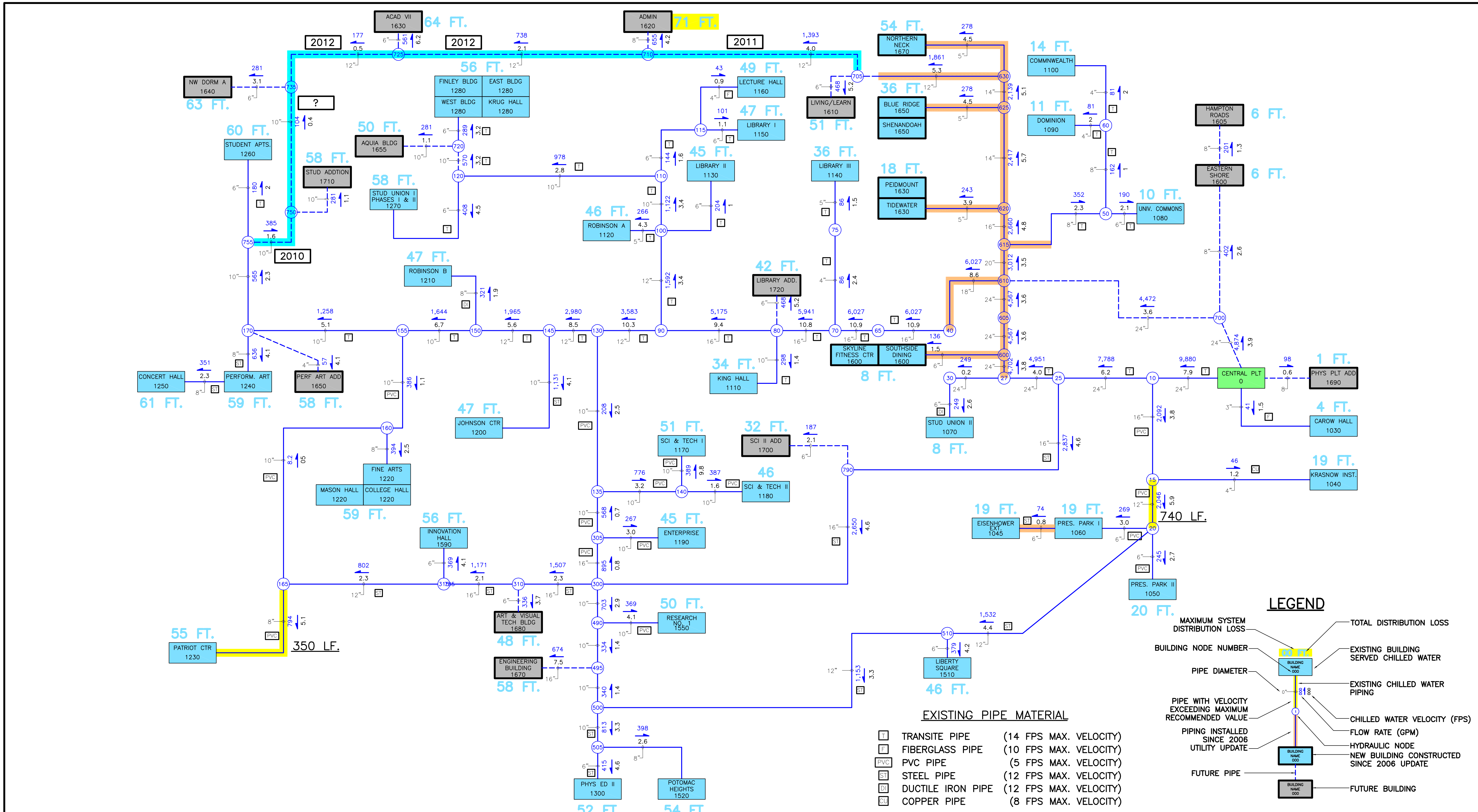
28 JULY 2009

FIGURE NO. 4.3.2

4.4 FUTURE CHILLED WATER HYDRAULICS



2014 CHILLED WATER SYSTEM SCHEMATIC – NORTH LOOP COMPLETED

SCALE: NONE

GMU UPDATE TO UTILITY MASTER PLAN

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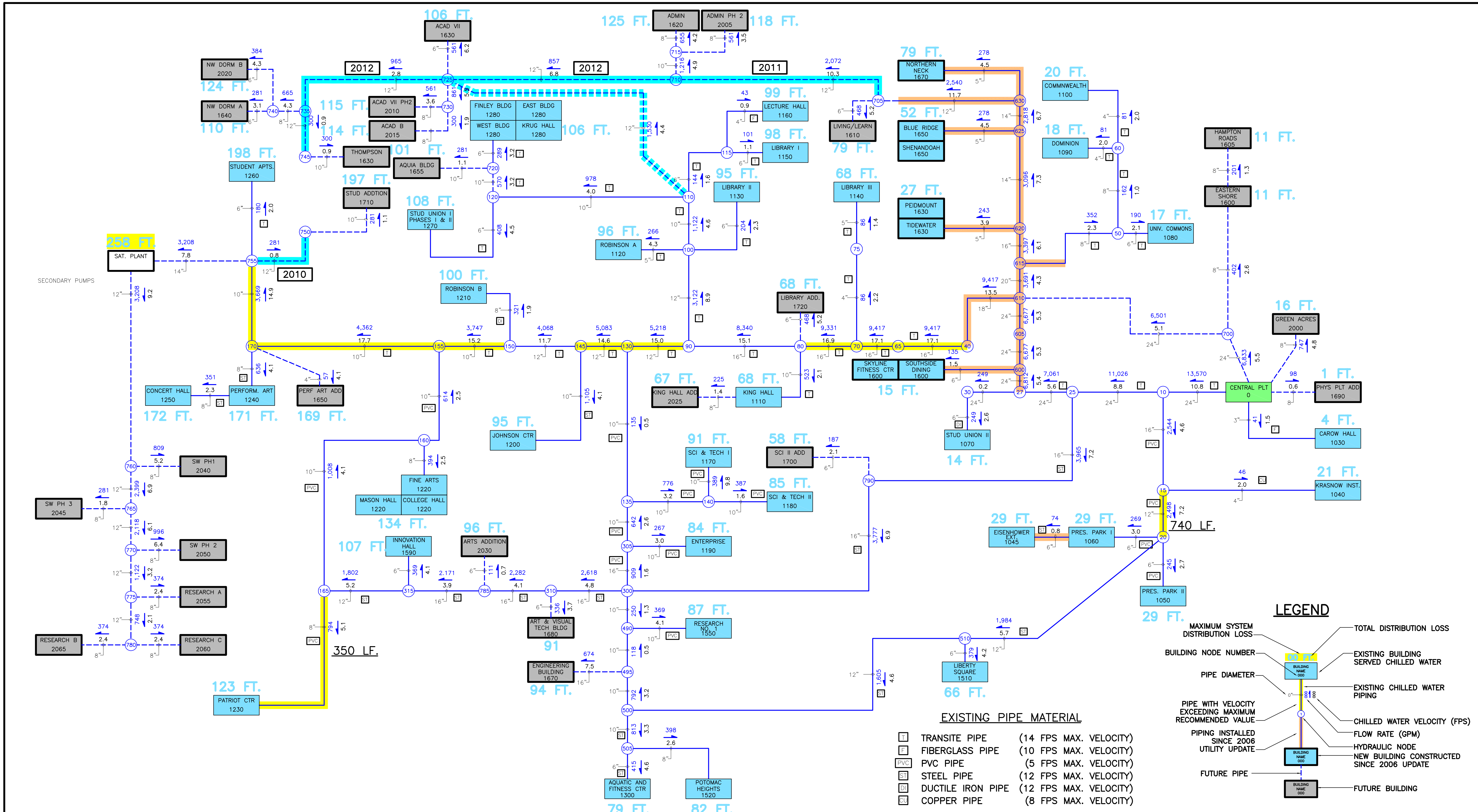
28 JULY 2009

FIGURE NO. 4.4.1



GMU UPDATE TO UTILITY MASTER PLAN

2020 CHILLED WATER SYSTEM SCHEMATIC – INTERSTITIAL LOOP PIPING (NORTH LOOP INCOMPLETE)

SCALE: NONE

RMF ENGINEERING, INC.
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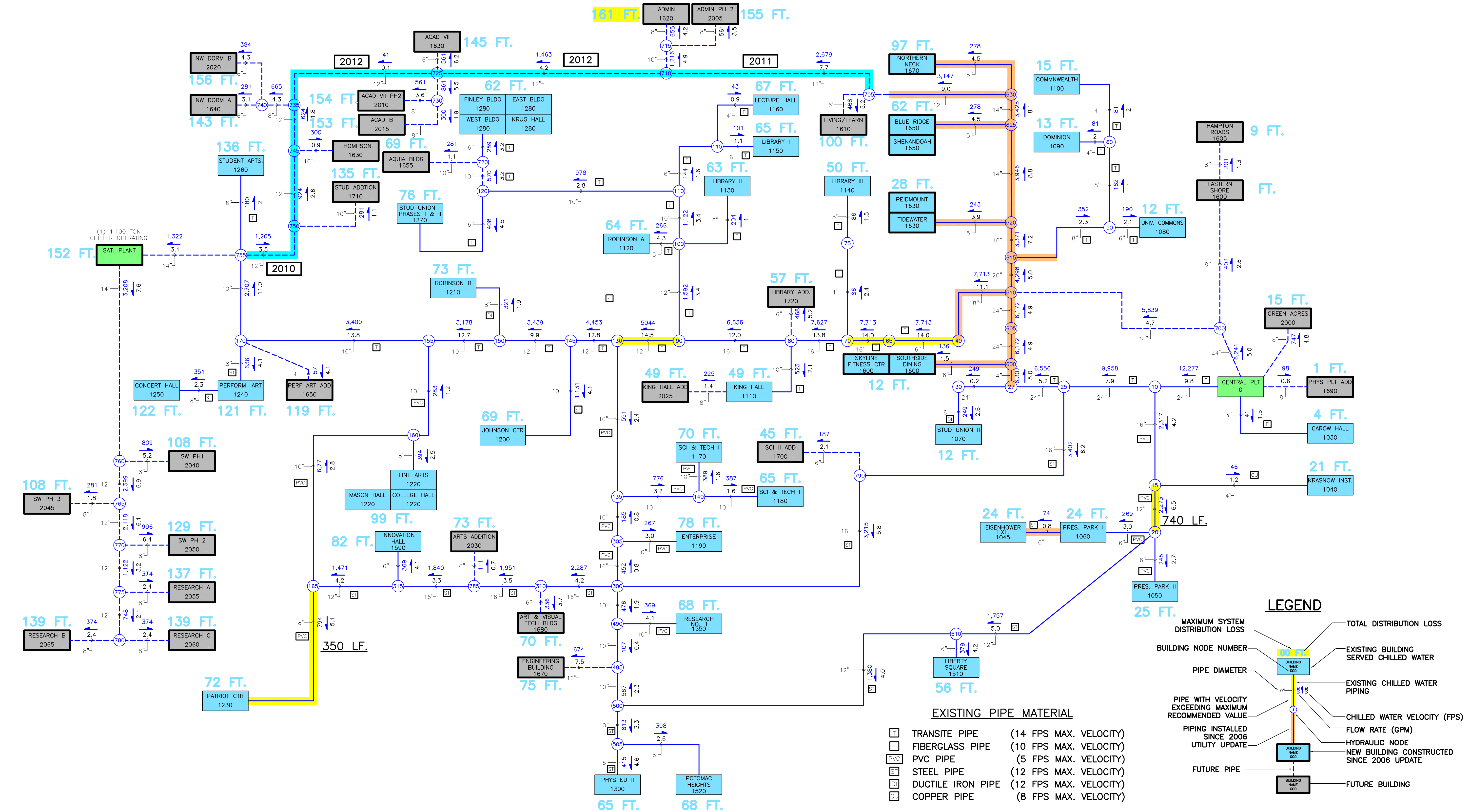
28 JULY 2009

FIGURE NO. 4.4.2



GMU UPDATE TO UTILITY MASTER PLAN

2020 CHILLED WATER SYSTEM SCHEMATIC — NORMAL OPERATION

SCALE: NONE

RMF ENGINEERING, INC.
BALTIMORE, MD

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FAIRFAX, VA

28 JULY 2009

FIGURE NO. 4.4.3

4.5 REVIEW COMMENTS AND ACTION TAKEN BY RMF ENGINEERING

REVIEW COMMENTS: 2009 Utility Master Plan Update - Draft Submission

2009 Utility Master Plan Update - Comments - RMF Engineering					
Reviewer(s): various				Date: July 2009	
		Action Legend: C = Concur D = Do not agree E = Exception (see comment) X = Delete Comment			
No.	Reviewer	Comment	Code	Action	Resp Pty
1	R James Kaminski	Typical of all Figures: A. Acad 5 is now known as 'School of Art'. B. Acad 6 is now known as 'The Engineering Building'. C. Hotel/Conference Center is now known as 'Mason Inn'. D. Parking Deck 3 is now known as 'Rappahanick River Parking Deck'. E. Police/Safety Building is now known as 'Police and Safety Headquarters'. F. Housing 7C, Building Y is now known as 'Hampton Roads'. G. Housing 7C, Building Z is now known as 'Eastern Shore'. H. Faculty/Staff Housing is now known as 'Masonvale'. I. PE Addition is now known as 'The Rac — Recreation and Athletic Complex'. J. Robinson Field is now known as 'RAC Field'. K. Data Center / Surge Space is now known as 'Aquia Building'. L. Carpentry Shop / Maintenance Building Addition is now known as 'Facilities Management Archives and Shops'. M. Learning Center is now known as the 'Johnson Center'.	C	Updated figures and tables.	C. Gray
2	R James Kaminski	Figures 2-2, 2-3, 2-4, 2-5, and 2-6: Acad 5 and Acad 6 are not shown, or shown not connected. Both of these buildings are currently on line.		The high temperature hot water drawings (Fig 2-2 and 2-3) reflects the buildings that were connected to the central heating system when the peak heating load occurred (February 2009). Similarly, the chilled water drawings (Fig 2-4 and 2-5) reflects the buildings that were connected to the central cooling system when the peak cooling load occurred (September 2008). Acad 5 and Acad 6 were not scheduled to come online until June 2009.	C. Gray
3	R James Kaminski	Figure 2-3: Maximum distribution loss of 15 feet shown, is not in accordance with the narrative, page 2.8, indicating 13 feet.	C	Updated text to be 15 feet to match the figure.	C. Gray
4	R James Kaminski	Figure 1-4: LTHW piping shown in SW quad is not in accordance with the narrative, page 1-3, indicating HTHW.	C	Piping in Southwest Sector is intended to be LTHW. Within the Satellite Plant, heat exchangers will convert the HTHW (whether generated from the Central Plant or the Satellite Plant) to LTHW. Text has been added within Division No. 1 and Division No. 3 to convey this.	C. Gray
5	R James Kaminski	Figure 2-6: Sanitary main shown as cross connected between Roberts Road and the 'East' Main. Verify!	C	Drawings provided by GMU indicate that majority of buildings currently shown that drain to Roberts Road Connection actually draínto the East Connection. Figure updated to indicate correct building connections. Table No. 2-9 (2009 Sanitary Sewer Collection Summary) was also updated.	C. Gray
6	R James Kaminski	Figure 2-6: Lateral for Parking Services not shown.	C	Incorporated sanitary piping for Parking Services	C. Gray
7	R James Kaminski	Figure 3-11: Northern Neck, Blueridge/Shenandoah, Piedmont/Tidewater, Skyline Fitness Center, and Southside Dining are not shown. All of these buildings are currently on line.	C	This figure did not print correctly in the hard copies of the draft report. Will correct.	C. Gray

REVIEW COMMENTS: 2009 Utility Master Plan Update - Draft Submission

No.	Reviewer	Comment	Code	Action	Resp Pty
8	R James Kaminski	Figures 2-5, 3-9, 3-10, 3-11, 4-16, and 4-17: Type, or size of pipes, not shown, or incorrectly shown in various locations A. Between 'Pres. Park 1' and 'Eisenhower Ext.' Steel pipe runs thru Eisenhower to feed the Eisenhower Addition. Verify. B. Between nodes 500 and node 510 (steel), 20 and 510 (steel), 500 and 505 (steel), 505 and Potomac Heights (unknown), 505 and 'Phys Ed II' [Aquatics and Fitness Center] (steel). Verify C. Feed to Johnson Center is steel, not Transite, as shown. Verify. D. Feed to Krasnow is 4" copper, not 3" steel, as shown. Verify. E. 18" pipe size shown between nodes 610 and 615. I thought that this line was 20". Verify.	C	Updated pipe sizes and material of hydraulics	C. Gray
9	R James Kaminski	Division 4: Figures 4-14 (?), 4-15(?), 4-16(?), and 4-17(?) are not labeled.	C	Will label figures in Division 4 for easy reference.	C. Gray
10	R James Kaminski	Figure 3-12: Sanitary sewer shown between Johnson Center and King Hall is draining what? Verify.		Piping was removed when Johnson Center was constructed in 1986. Removed piping from drawing.	C. Gray
11	R James Kaminski	Figures 3-7, 3-8, 3-9, 3-10, 3-11, 4-14, 4-15, 4-16, and 4-17 are missing various node numbers	C	Numbered future nodes in each of these drawings.	C. Gray
12	R James Kaminski	Figure 4-17: Velocities shown between nodes 150 and 155, 155 and 170, 170 and the take off to the Satellite Plant exceed the maximum recommended velocities, but are not highlighted as such	C	Highlighted pipe segments that exceed recommended velocities	C. Gray
13	R James Kaminski	Closing the North Loop is modeled in the four figures located in Division 4, but it was not shown in Figure 3-13 Full Buildout. (...Add a plannimetric view to Division 4, showing the North Loop closed.) Curiously, closing this loop doesn't help much reducing the CW high head loss at the Admin Building (269 vs. 247 feet). Does this mean that perhaps we should install a 12" main (instead of 10" as shown) from Blue Ridge to the NW dorms? Increasing the size of the North Loop main to 12" would reduce the velocity (and the pipe losses) by 40%+ .		10" piping in model were actually 12" and the heads are correct for those models. The heads will change when the pipe size from comment number 8E is changes. Increasing the North Loop from 12" to 14" will reduce the pipe losses to building like the Admin building by 12-15%. The maximum distribution loss of the system with the complete 12" North Loop is 260 feet. If the North Loop was upsized to 14", the distribution loss would be reduced down to 250 feet.	C. Gray
14	Robert Endebrock	I am surprised to see that we have abandoned the idea of a future loop from the NW sector down Aquia Lane to tie in behind SUB I. Are we all in agreement that we do not want this in the out years plan?	D	Completion of Northern Loop has not been abandoned. The western leg of this loop is not associated with a "sponsor" project. The 700 linear feet extension is currently identified as a stand alone infrastructure project.	C. Gray
15	R James Kaminski	Another loop opportunity would occur with the construction of Acad 7 Phase 2, Acad B, and the Living/Learning Center. It would make sense then to loop the CW line back into the 10" line at Library 2 (node 110). This loop would offer some redundancy to the Housing 7 complex, and may reduce the high head loss at the Admin Building.		With the additional loop piping, the maximum distribution loss is reduced from 261 feet to 220 feet. This model is presented in Fig No. 3-14. Again, this is if all of the campus cooling load is served from the Central Plant only.	C. Gray
16	R James Kaminski	I recommend that both these scenarios be modeled. We need to reduce the high head losses in the North Loop to avoid using secondary pumps at these buildings, if possible.	C	See comment numbers 13 and 15. Additional model was developed to simulate "Normal Operation", Satellite Plant operating with (2) 1,100 ton units and remainder of cooling load distributed by Central Plant.	C. Gray

REVIEW COMMENTS: 2009 Utility Master Plan Update - Draft Submission

No.	Reviewer	Comment	Code	Action	Resp Pty
17	R James Kaminski	We are still seeing rather high head losses in the North Loop, and the SW Quad with the SHCP operational (two of three chillers operating). For example, the model is showing 121 foot loss at the Admin Building. If the A/E uses rooftop units on this five story building, we're facing a total head loss of 181' (121' + 60' to the roof), which would exceed the capacity of the CHCP pumps, right? The plant currently pumps between 60 & 65 psi CW; it could perhaps be boosted to 75 psi, but I'm unsure that we would (or could) want to increase it any higher. Recall that one of the goals here is to not have secondary pumps, if possible. You mentioned earlier that increasing the pipe size in the North Loop would not help much. Could we add a pump on the North Loop? How would that be controlled? We're looking to RMF to recommend a solution here. Got any other ideas?	D	The loss of 121 feet would be considered typical for a chilled water distribution of this size and there should be no need for concern. The existing distribution system is adequate to support the full buildout (2020) chilled water load. In the Normal Operation hydraulic model, the average distribution loss is around 1.1 ft /100 ft. Typical design for chilled water piping is between 2 -3 ft per 100 ft. Also for this scenario, there are no main distribution lines that exceeds recommended maximum allowable velocity. The chilled water distribution pumps at the Central Plant are designed for 200 feet of head, which must overcome distribution and building losses. In a chilled water closed loop system, the building loss is determined by friction loss within the pipe and not the static head from the height of the building. Typical building losses are between 25-35 feet. In my analysis, I have been using 30 feet for the building loss. Therefore, the total loss (121 feet + 30 feet = 151 feet) is within the design of the chilled water distribution pumps at the Central Plant. See attached graph. A reduction in pump head for the chilled water system would result in energy savings at • Replace the main distribution chilled water piping with larger piping. This would be cos • Increase the existing and future building temperature differential. Currently within the r • Install building pumps strategically within the building(s) that are the most hydraulically	C. Gray