TABLE 4-12 KEY COSTING ELEMENTS

FUNCTION	DETAILS	BUDGET
Building Costs		2,316,908
Chiller Plant Costs	Cooling plant upgrades	5,683,791
Co-gen Plant Costs	6 New Engines	14,400,000
Heating Plant Costs	Boilers and accessories	2,891,412
Distribution Costs	Piping, valving	2,987,841
Electrical Costs	Generators, fire alarm, new supply line	2,500,151
Telecom Costs	In-line optical backbone	561,760
Civil Infrastructure Costs		2,817,475
Existing Heating, Cooling & Domestic Hot Water Systems Upgrade	Refurbish existing systems	9,338,490
Subtotal		**45,152,822**
Markups (24%)		10,836,677
Escalation (4%/annum)		9,870,117
Total Costs		**65,859,616**

Note: *All costing in Canadian currency, 2006 cost baseline and including escalation (4% annually).*

TABLE 4-13 CONSTRUCTION TIMING FOR MECHANICAL IMPROVEMENTS

	Scenario A: No Expansion		***Scenario B; FNP Scenario 6.6***						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
HVAC (Mechanical)	1) Modify piping – use storage capacity with generated heat 2) Modulate distribution	3) Split distribution to 2 loops 4) Install back up units 5) Add spare capacities	*Energy Conservation Measures Redistribute piping Connect to CUB2*	*Feed from SUA*	*Stand Alone Heating & Cooling System*	*Feed from SUA*	*Feed from SUA*	*Connect to CUB2*	*Feed from SUA*
Utilities Infrastructure				Decision on SUA in basement B1/B6				Decision on Co-gen Plant & CUB2	
Cogeneration	1) Short falls & future loads requires new engines					2) 9.6 MWe capacity to be added Additional HR – 27,750 MBTUH			
HW Boilers	1) No repair / modification recommended 2) Boiler to remain at its present location		*Energy Conservation Measures 1 x 10000*	2 x 12000 MBH boilers Connect	Stand Alone System	1 x 12000 MBH in SUA	From B3	Connect to CUB2	Co-generation Waste Heat or

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
			MBH boiler Connect to CUB2	to CUB2					3x10,000 MBH CUB2
Electric Boilers	1) Repairs done when required 2) Electric heating costly but good for standby scenario 3) To be kept in place for back up		Maintain for back-up						
Reheat for AHUs	4) Need to repair and put back in service		Maintain for back-up						
Heating Piping System	1) Line size increase / upgrade required at far end with new Co-gen Installation (1-5 yrs) 2) Connect Plaza Unit to loops as B/U (Now)	3) Renew lines (10-20yrs) 4) Split distribution into 2 loops	Connect Plaza Unit to loops as B/U (Now)	Connect to CUB	Stand Alone System	Connect to SUA/CUB	Connect to SUA/ CUB	Connect to CUB	Connect to SUA/ CUB
Domestic Hot Water Supply	1) Use gas fired units where possible	2) Use waste heat from co-gen for DHW heating	Energy Conservation Measures Connect to CUB	New Hot Water Heater Connect to CUB	New Hot Water	New Hot Water Heater Connect to CUB/SUA	New Hot Water Heater Connect to	Heater Connect to CUB	New Hot Water Heater Connect to CUB/SUA

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
							CUB/SUA		
Air-Handling / Ventilation	1) Use smaller units with spare capacities 2) Modulate air & water flows	1) Install pkg. AHU's with gas fired heating where possible Flows 1. Incorporate VAV boxes in air distribution 2. Replace 14th floor Schmon Tower units with pkg. units - Two units (1-2 yrs) 3. Replace Walker complex units- 3 units (3-5 yrs) 4. Replace Welch Hall unit (4-6 yrs) 5. Replace Mckenzie Chown	Max 25-30000 CFM	Sep Systems Labs (Biology/ Chem) BL3, Admin Max 25-30000 CFM	Roof Top DX AHU	Sep Systems Labs, Academic, Admin Max 25-30000 CFM	Sep Systems Labs, Academic, Admin Max 25-30000 CFM	Max 25-30000 CFM	Sep Systems Labs, Academic, Admin Max 25-30000 CFM

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
		Complex unit (4-6 yrs)							
Tunnels	1) Master plan needed (1 yr)			2) To be extended for connections to CUB2 New tunnels for B1/B6 connections		New tunnels for B2 and connections	New tunnels for B3 connections		
Cooling	1) Add new technology-liquid absorption chillers, gas fired chillers, VFD centrifugal chillers 2) Replace idle Trane chiller 3) Use free cooling option 4) Modulate flows	5) Use stand alone packaged units for remote buildings 6) Install back up units Split distribution to 2 loops •	Energy Conservation measures 1 x 600T (absorb-if co-gen OR centrif) Connect to CUB	2 x 800T (centrif)	Stand Alone DX AHU	1 x 800T (centrif)	From B3	Connect to CUB	2 x 700T (absorb-if co-gen OR centrif)

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
Piping System	Line size increase / upgrade required at far end with new Co-gen Installation (1-5 yrs) Renew lines (10-20yrs) Split distribution into 2 loops as B/U (Now) loops with valving • Connect Plaza Unit to		Connect Plaza Unit to loops as B/U (Now)	Connect to CUB	Stand Alone System	Connect to SUA/CUB	Connect to SUA/ CUB	Connect to CUB	Connect to SUA/ CUB

TABLE 4-14 CONSTRUCTION TIMING FOR ELECTRCAIL IMPROVEMENTS

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
Tunnels			*Tunnel to be extended*	*Stand Alone Building*	*Tunnel to be extended*	*Tunnel to be extended*	*Close to existing infrastructure*	*Tunnel to be extended*	
Power Supply	Install new 14kV feeder and new switchgear (Now) in metal clad enclosure Apply IR based PM strategy (Now)	• Replace tunnel feeders (15-20 yrs) • Deploy power conditioners (Now) • 5) Deploy harmonic analysis (Now)		Install new 13.8 kV feeder and new switchgear					
Utilities Infrastructure				Decision on SUA in basement B1/B6	Decision on Co-gen Plant & CUB2				
Main Distribution (13,8 kV)	• Need new Electrical Room • Option 1- basement of new bldg OR Option 2-	1) Replace as needed to support 7 MW. (1-5 yr)		Provide power from Main Electric Room Note: Decision of New/Extended	Provide power from Main Electric Room	Provide power from Main/ Secondary Electric Room	Provide power from Main/ Secondary Electric Room	Provide power from Main Electric Room	Provide power from Main/ Secondary Electric Room

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
	extend existing Electrical Room • Add High-pot testing & infra-red to PM. Replace as needed to support 7 MW. (1-5 yr)			Electrical Room (with new Power Supply Line) could affect if Main or Secondary					
Substation Distribution	• Apply High-pot testing & IR to PM program (Now) • Begin Substation renewal program (5-10 yr)	Replace as needed to support 7 MW. (1-5 yr) • Design substations into each building (1-20 yrs) • 3) 5 New substations with dedicated access (1-20 yrs)	Provide in building as per new requirements fed by adjacent substation	Provide in building as per new requirements with new substation *Estimated load (2,000 KW)*	Provide in building as per new requirements with new substation *Estimated load (808 KW)*	Provide in building as per new requirements with new substation *Estimated load (743 KW)*	Provide in building as per new requirements with new substation *Estimated load (808 KW)*	Provide in building as per new requirements fed by adjacent substation *Estimated load (215 KW)*	Provide in building as per new requirements with new substation *Estimated load (808 KW)*

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
3. Low Voltage (347V, 220V, 110v)	• Continue ongoing lighting systems Upgrade (Now)	1) Centralize alarms / response control (1-5 yrs) 3) Install bldg occupancy controls	Provide in building as per new requirements	Provide in building as per new requirements	Provide in building as per new requirements	Provide in building as per new requirements	Provide in building as per new requirements	Provide in building as per new requirements	Provide in building as per new requirements
Tunnel Distribution	• See Critical Power • Expansion to critical power requires new conduit & fire rating.		Access from adjacent building	Extend to new Building	Do not extend	Extend to new Building	Extend to new Building	Access from adjacent building	Extend to new Building
Existing Cogen Plant	• Provide 800 KW generator for “blackstart” (1 yr) • 2)Telephone “failure” could trip co-gen operation- Provide second power supply from utility .	3)Metering upgrade is “grandfathered” but should be considered (5-10 yr) • 3)Transformer issue -Provide second power supply from utility as above.			Decision on New Co-gen Plant				

	Scenario A: No Expansion		***Scenario B; FNP Scenario 6.6***						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
Critical Power / Emergency Generators	• Install 2 new generators for existing bldgs (250-500 KW & 800KW-blackstart) (1-3 yr) • Distribute this power efficiently in a priority path to critical applications (Now) • *-None- "grandfathered".* • *New installation cannot use the existing cabling*			Provide new 1000 KW generator	Provide new 100 KW generator	Provide new 1000 KW generator			
Electric Heating	• Maintain as back-up heating		Not needed for new constructi on	Not needed for new construction	Not needed for new construction	Not needed for new constructi on	Not needed for new construction	Not needed for new construction	Not needed for new construction
Lighting	• Continue		-T8 &	- T8 &	-T8 &	- T8 &	-T8 &	-T8 &	- T8 &

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
	ongoing replacement to T8 & electronic ballasts (1-10 yr) • Add lighting control • Consider Occupancy sensors for certain areas		Electronic ballast -Lighting controls -Review occupancy sensors	Electronic ballast -Lighting controls -Review occupancy sensors	Electronic ballast -Lighting controls -Review occupancy sensors	Electronic ballast -Lighting controls -Review occupancy sensors	Electronic ballast -Lighting controls -Review occupancy sensors	Electronic ballast -Lighting controls -Review occupancy sensors	Electronic ballast -Lighting controls -Review occupancy sensors
Fire Detection & Alarm	• Consider Central Control Center to supervise alarms (1-3 yr)		Provide new Central Control Center. Connect to CCC	Connect to CCC	Connect to CCC	Connect to CCC	Connect to CCC	Connect to CCC	Connect to CCC
Telecommunications & Data •Voice Equipment & Infrastructure •Data	• New/replacement installations – fibre optic backbone	• Older Telecom rooms – "weakest" link. Consider "new"	Provide new dedicated IT Room with UPS, generator,	Provide new dedicated IT Room with UPS, generator, cooling.	Provide new dedicated IT Room with UPS, generator, cooling.	Provide new dedicated IT Room with UPS, generator,	Provide new dedicated IT Room with UPS, generator, cooling.	Provide new dedicated IT Room with UPS, generator, cooling.	Provide new dedicated IT Room with UPS, generator, cooling.

	Scenario A: No Expansion		*Scenario B; FNP Scenario 6.6*						
Building Phase	***Present Day***	***Ongoing Improvements***	***Building B5 (Addition to Welch Hall)***	***Building B1/B6 (Sciences Bldg)***	***Building B7 (Glenridge)***	***Building B3***	***Building B2***	***Schmon Tower Expansion***	***Building B4***
Infrastructure Communications •Pathways Infra. •Communications Spaces Infra •-Support Systems (UPS & EPS)	• Support – provide UPS, generator, cooling & fire protection for key rooms		cooling. Use fibre optic cabling	Use fibre optic cabling	Use fibre optic cabling	cooling. Use fibre optic cabling	Use fibre optic cabling	Use fibre optic cabling	Use fibre optic cabling

TABLE 4-15 CONSTRUCTION TIMING FOR MUNICIPAL/CIVIL IMPROVEMENTS

	Scenario A: No Expansion		*Scenario B: Expansion Outlined in FNP (Proposed Building Sequence)*							
Building Phase	**Present Day**	**Ongoing Improvements**	**Building B5 (Addition to Welch Hall)**	**Building B1 (Sciences Bldg)**	**Building B6**	**Building B3**	**Building B2**	**Building B4**	**Schmon Tower Expansion**	**Building B7**
Water Supply	Construction of approximately 190 m of 150 mm diam. looping the Village watermain system to the existing watermain on University Rd.	Condition assessment and replacement of old watermain pipe.	Connection to existing 250 mm diameter watermain on University Road West.	Construction of Phase 1 of Ring Watermain, including new watermain along University Rd. from Isaac Brock Blvd. E. to Glenridge Ave., and (1) new revenue meter.		Construction of Phase 2 of ring watermain through campus to Glenridge Ave. and twinning of existing 250 mm diam. Watermain on Glenridge Ave.			Connection to existing 250 mm diameter watermain.	Connection to existing 200 mm diameter watermain.
Sanitary Sewer	In-situ repair of broken sewer pipe. Complete CCTV inspection of sewer network. Upgrade existing 100 mm diam.	Continue annual maintenance of pumps in the pumping station.	Reconstruction of pumping station and new 200 mm diameter sewer along University Road (Note: alternate servicing plan for buildings B5, B1, B6) *ALTERNATE:* Connection to existing sewer outlet from Welch Hall (subject to detailed building assessment).	*ALTERNATE:* Connection to existing 150 mm diameter sanitary sewer in the Mackenzie Chown Complex (assuming	*ALTERNATE:* Connection to existing 250 mm diameter sewer south of the Mackenzie Chown Complex (assuming				Connection to existing sanitary sewer.	Connection to existing 200 mm diameter sanitary sewer on Norman Road.

	Scenario A: No Expansion		*Scenario B: Expansion Outlined in FNP (Proposed Building Sequence)*							
Building Phase	**Present Day**	**Ongoing Improvements**	**Building B5 (Addition to Welch Hall)**	**Building B1 (Sciences Bldg)**	**Building B6**	**Building B3**	**Building B2**	**Building B4**	**Schmon Tower Expansion**	**Building B7**
	forcemain section to 150 mm diam. Fill and draw test at pumping station and possible inspection of pumps by manufacture r.			finished floor elevation of 172.7 m).	finished floor elevation of 172.5 m).					
Storm Drainage	Monitor storm sewer for flooding. Monitor Lake Moody water levels. CCTV inspection of Storm sewer system.	Implementation of stormwater management quality controls (i.e. wet ponds, bioinfiltration filters, etc.) on a project by project basis. Implementation plan (retrofit) for Stormceptor Manholes		Reroute approximatel y 140 m of storm sewer around buildings.	Reroute approximatel y 435 m of storm sewer around buildings.	Reroute storm sewer around buildings.	Reroute storm sewer around buildings .			

	Scenario A: No Expansion		*Scenario B: Expansion Outlined in FNP (Proposed Building Sequence)*							
Building Phase	**Present Day**	**Ongoing Improvements**	**Building B5 (Addition to Welch Hall)**	**Building B1 (Sciences Bldg)**	**Building B6**	**Building B3**	**Building B2**	**Building B4**	**Schmon Tower Expansion**	**Building B7**
Estimated Costs	$200,000	$2M (over 20 years)	$4,000 (connection to existing only)	$750,000 (includes phase 1 watermain, reconstruction of pumping station and new sewer)		$580,000 (includes phase 2 watermai n)	$270,000	$4,500	$4,000	$6,000

5.0 RECOMMENDATIONS

5.1 MECHANICAL RECOMMENDATIONS

5.1.1 Infrastructure Design and Planning

1. For all new building consider LEED/ Canadian Green Building Council Standards and possibly certification at the Design stage.
2. Support the proposed new Sciences Building (B1) with utilities (Heating, cooling, emergency power for the required 24/7 HVAC system in the Animal Areas and BL3 Lab)
3. In a dedicated area interconnected to the campus system.
4. Modify the existing cooling and heating distribution network into a double loop system with provision for interconnection. The two loops should be served by the two central utilities plants independently, with each loop servicing about half the campus. This will ensure more load is handled by the existing distribution piping and would avoid major replacement of the existing system.
5. To support expansions away from the main campus areas and tunnel infrastructure, install dedicated stand alone (heating and cooling) systems for building blocks that are considered uneconomical to be fed from the central systems, however power supply to the stand alone units will be from the grid / co-generation plant that will add load and strain on the co-gen plant
6. Build utility system redundancies to optimize system robustness and reliability of services.
7. Revisit system design to optimize air and water flow rates to reduce energy consumption.
8. Eliminate the use of CFC's and HCFC's from the air-conditioning equipment.

5.2 HVAC System

5.2.1 Cooling System

The existing cooling load for the site is approximately 2,900 tons, including the load for Plaza 2006 and Mackenzie Chown Block "D" addition. Additional anticipated future load, considering the Scenario 6.6 mentioned in the "Facility Needs and Priorities Study", is approximately 3,300 tons. This together with a recommended built-in "spare capacity" of 600-800 tons requires a total installed refrigeration capacity of 6,800 – 7,000 tons. To generate this load economically and without interruption, a number of actions are recommended as follows:

- Modification of the existing refrigeration system
- Modifying air and water distribution systems to modulate based on load variations
- Conserving energy and heat recoveries
- Addressing redundancies
- Installation of new high efficiency refrigeration plants

All these recommendations are elaborated herewith:

5.2.2 Modification of the Existing System

1. Existing chilled water distribution system shall be modified to operate at a temperature differential of 14^0 F to increase the overall cooling load transfer capacity. This will also increase the thermal storage capacity from the existing 39,984 MBTU to 46,648 MBTU. Manufacturers of the existing centrifugal and liquid absorption chillers shall be consulted to review the option of changing the existing machines to operate at 14^0 F ΔT
2. The existing Trane liquid absorption chiller is not operating at its maximum capacity due to limitations on the hot water inlet temperature to the chiller. This chiller is generating 850 - 900 tons of cooling against the design capacity of 1,100 tons. In order to boost its capacity it is recommended to increase the inlet water temperature by electric or gas heating thereby enabling the chiller to operate at its design capacity
3. The McQuay centrifugal chiller of 1,500 tons design capacity, presently operating at 1,100 tons shall be reviewed and overhauled to operate close to its design value
4. The existing chilled water and condenser water distribution piping should be reviewed for the possibility of using condenser water, during winter, for free cooling options using suitable size water-to-water heat exchangers
5. The existing sitting Trane CentraVac 1,000 tons chiller (idle), originally designed to operate on R-11 (CFC) refrigerant, shall be replaced by a new centrifugal or liquid absorption chiller. However, this chiller cannot be installed in the existing central utilities building (CUB) due to non-availability of roof space for the installation of its associated cooling tower. This replacement chiller shall be installed in the newly proposed central utilities building (CUB2) details of which are elaborated herewith
6. Consideration shall be given to split the existing chilled water distribution loop into two independent loops with central utility buildings CUB and CUB2 feeding one loop respectively. The two loops should be interconnected through normally closed valves to provide back up under emergency. This will further enhance the load handling capacity of the distribution system apart from providing system redundancy

5.2.3 Modifying Air and Water Distribution Systems

1. The existing chilled water distribution system shall be modified to operate on primary – secondary distribution system with variable frequency drive motors, and two-way control valves thereby modulating the flow as per the load requirements
2. The secondary distribution pumps head pressure shall be revised to handle flow through the tunnel only and not through risers of individual buildings to reduce the overall head pressure by 100 – 120 feet and chilled water pumps power rating by 100 HP. Chilled water distribution to individual buildings shall be through dedicated variable frequency drive pumps sized to handle specific pressure drops and flows. Also, reduction in the secondary pumps pressure will significantly minimize leakage / breakdown chances in the existing old piping and cooling coils

3. Review the possibility of installing economizers on the air handling units and use of 100% outside air when the outdoor air enthalpy is below the design room enthalpy
4. The air distribution system shall have variable air volume (VAV) boxes
5. Review the possibility of installing variable frequency drive fan motors thereby modulating the airflow apart from modulating the heating and cooling water flow to the air-handlers
6. Piping from the storage tank shall be modified so that the thermal stored capacity could supplement cooling load during peak demands
7. The existing 16"Φ / 10"Φ chilled water distribution lines when operating at the present design capacity of 4,800 GPM will have 8.43 FPS velocity and 1.218 Ft / 100 Ft head loss. The increase in the chilled water temperature differential to 14 ^{0}F will reduce the flow velocity and head loss in the existing piping to 7.83 FPS and 1.058 Ft / 100 FT with flexibility to increase flow in future, if required

5.2.4 Conserving Energy and Heat Recovery

1. Install air-to-air and air-to-water heat recovery systems to extract maximum heat from the exhaust air
2. Heat should be recovered from all exhaust air from the laboratories through closed circuit glycol loops
3. Review the options of using blow through air-handlers instead of draw through units to conserve energy
4. Air-handling units serving the Schmon Tower at 14th floor building are in poor condition and shall be replaced by packaged units with refrigerant (DX) cooling and indirect gas fired heating. Each air-handler shall be replaced by units with sufficient spare capacity to provide necessary redundancy. These units shall also have built-in economizer and fully modulating fresh air and return air dampers to operate the units in free cooling mode when the ambient enthalpy drops below the room enthalpy. Supply and return fans for the units shall have variable frequency drives. This action will conserve energy to the maximum and will reduce chilled water flow requirement through the main piping by 230 GPM approximately thereby reducing load on existing chillers by 135 tons. Also, chilled water would not have to be pumped to the 14th floor level thereby reducing the required head pressure. Electrical operating cost will also be reduced due to reduction of pumps HP rating. However, location of these units has to be critically reviewed, since they cannot be installed on the roof due to microwaves issues. Possibility of using custom built units with forced ventilation for the condensing sections shall be considered. This arrangement would also require natural gas supply to the unit
5. Similar consideration shall be given for other air-handlers that need replacement, where possible. This will further reduce chilled water requirement and refrigeration load tons on the central plant
6. Review the possibility of installing variable frequency drives on the supply and return fans of the existing air-handling units and modifying the controls to reduce the airflow and temperatures in unoccupied / partially occupied areas. Estimated reduction in overall cooling load, based on 80% area utilization and 80% time utilization factor, will be

approximately 15 – 20%. This will further reduce the maximum demand for chilled water flow through the main piping and refrigeration load

7. Ducting layouts shall be reviewed in detail and consideration shall be given to the use of VAV boxes, where possible, to conserve energy
8. Fresh air intake for all air-handlers shall be reviewed critically and minimum fresh air required as per ASHRAE or other relevant codes shall be provided thereby reducing the overall cooling load

5.2.5 Redundancies

1. The primary circulation system for the existing two chillers shall be combined through a common manifold, if possible, and a 3rd pump should be provided as standby thereby ensuring continuous operation of the chillers during pumps breakdown / maintenance. Similar arrangement should be done for the condenser water pumps. This arrangement will ensure uninterrupted chilled water distribution
2. A 3rd pump should be added to the two already existing secondary distribution pumps thereby giving the flexibility of operating two pumps at a time with the 3rd pump as standby. All the three pumps shall be provided with variable frequency drives so as to operate as per the load demand thereby conserving energy
3. A standby chiller should be provided in each of the central utilities building to handle campus loads during breakdowns and peak demands
4. Larger buildings/areas should be served by more then one air-handling unit so that in the event of a breakdown the entire building is not without cooling, heating and ventilation
5. Each new air-handling unit should be sized for 15% - 20% additional capacity for future load addition.

5.2.6 Installation of New High Efficiency Refrigeration Plant

1. Install a new direct gas fired liquid absorption chiller to replace the old Trane chiller, designed to operate on R-11 refrigerant (sitting idle at present). The new chiller shall be installed in the existing central utilities building CUB to serve as a standby chiller for the existing two refrigeration units. This will require either modification to the existing condenser water piping, due to limitations on the installation of a 3rd cooling tower on the roof, or reviewing the possibility of locating a new space for the cooling tower. The capacity of this chiller shall be 1,100 tons operating at a differential temperature of 14^0 F
2. If it is decided to proceed with the installation of new co-generation units in CUB2 area then new liquid absorption chillers shall be installed in CUB2 area to handle the new loads for Welch Hall expansion (B5), Schmon Tower expansion, Building B4 and existing load shortages. If new co-generation engines are not to be installed then options for the installation of new direct gas fired liquid absorption chillers or variable frequency drive centrifugal chillers should be reviewed
3. New direct gas fired liquid absorption chillers or variable frequency drive centrifugal chillers should also be installed in the satellite utility building SUA to handle loads for building

B1/B6, B2 and B3. Capacity of each chiller shall be worked out as per the overall load requirement

4. All the new chillers shall have closed circuit cooling towers and the condenser water piping shall be designed to use condenser water for free cooling. Condenser water flow rate will be sufficient enough to handle the entire campus load during free cooling mode. This will also avoid the use of existing 100 tons split unit during winter/off peak season apart from conserving reasonable energy and giving time for chiller maintenance
5. The new chillers shall be provided with dedicated new constant volume primary pumps along with a standby pump and three variable volume secondary distribution pumps with two pumps in operation and the third one as stand-by
6. Review the possibility of connecting the chillers installed in SUA area to the existing 16"Φ main piping for back up service
7. New buildings, built away from the existing main tunnel (Glenridge area) shall have dedicated stand-alone rooftop packaged units with refrigerant cooling, indirect gas fired heating, and free cooling option. This will eliminate dependency of the new blocks on the centralized cooling system and, with each unit having its own dedicated controls, the overall capital as well as revenue cost will be less as compared to a centralized system. Building blocks close to the existing tunnels shall be connected to the existing cooling system as mentioned earlier. Estimated loads to be handled by the stand alone refrigerant (DX) cooling system would be approximately 500 tons and the balance load will be handled by the new units.

5.2.7 General Actions for Chilling Plant Improvements

1. Increasing the chilled water temperature differential to 14°F would require stress analysis to be redone for the chilled water piping.

2. Chilled water main distribution piping is almost 40 years old and needs to be tested so as to ensure that it is still in good condition and will not breakdown in the near future. A phased replacement plan will need to be developed.

3. Air-handling units to be selected in future shall not be sized for more then 25,000 – 30,000 CFM to reduce maintenance related problems and dependency of a large number of areas on one unit.

4. P & I diagrams shall be developed for each air-handling unit as these drawings help in developing optimum flows and future changes effectively and economically.

5.3 Heating Recommendations

5.3.1 Modification to the Existing System

The existing site heat load, including domestic hot water load as mentioned in previous studies, is 59,970 MBTUH. The additional anticipated future load, considering scenario 6.6 mentioned in the "Facility Needs and Priorities Study", will be approximately 34,000 MBTUH. This together with a spare capacity margin of 9,000 MBTUH requires total installed heat generation capacity of 103,000 MBTUH. To generate this load economically and without interruptions the following actions are recommended:

- Modification of the existing system
- Conserve energy
- Redundancies
- Installation of new hot water boilers / co-generation engines

1. The existing hot water central heating system operates at a temperature differential of 20°F. This limits the heat transfer capacity through the existing pumps and piping system to 20,000 MBTUH. Modifying the system to operate at a temperature differential of 30°F will not only increase the system capacity to 30,000 MBTUH but will also increase thermal storage tank capacity to 99,960 MBTU
2. Heat exchanger HX-02, transferring heat energy from the engines to the campus hot water heating, has heat transfer limitations of 17,500 MBTUH on the hot water heating side (1,000 GPM at 167°F / 203°F). Changing P-29 and P-30 pumps capacity to 1,500 GPM will enhance this capacity to 22,500 MBTUH which is the maximum available from the co-generation engines
3. The gas fired hot water boiler has been installed in a way that it cannot supplement the heating load beyond the capacity of the co-generation engines. This boiler transfers heat to the hot water loop through heat exchanger HX-4. With 7 – 8 co-generation engines in operation, water temperature on the heat transferred side (hot water loop) will be in the range of 190 - 200°F, and consequently this boiler cannot contribute any energy during this period. It is only when a few engines are in operation that this boiler can share the heat load. Also, as per the present installation, this boiler frequently develops leakage and other related maintenance problems. It is recommended to remove this boiler or consideration can be given of retaining this boiler in its present position with some modifications to the piping system
4. The piping layout for the thermal storage system shall be reviewed to ensure that this energy reserve can be used to supplement the peak demand when required
5. Since the existing main piping cannot handle flows beyond 2,000 GPM, it is recommended to split this loop into two independent distribution loops. This will enhance the flow handling capacity of the central distribution system with one loop serving buildings from central utilities block up to Mackenzie Chown Complex (or wherever it is practical) and the other loop serving installations from Student Centre building Branch

6. The two loops, mentioned above, shall be able to handle all existing and proposed new loads mentioned above with flexibility of further additions when required. Proposed modifications will enhance the central piping distribution capacity up to 82,000 MBTUH
7. Where possible replace the existing electrically operated domestic hot water heaters with direct gas fired units thereby extracting maximum heat transfer and reducing electrical and hot water loads
8. The Plaza 2006 heating systems shall operate independently and shall be connected to loop #2 for back up service

Modifications to the above-mentioned distribution system will have the following advantages:

- With minimum capital expenditure the hot water flow capacity through tunnel piping will increase to over 4,000 GPM.
- Two pipe loops will reduce dependency on one main piping system and in the event of breakdown in one area other areas would not be affected.
- Each loop will have the flexibility to add load in future.
- Both the loops shall be connected to each other through normally closed valves thereby giving the flexibility of feeding both the loops either through engine heating water circuit or hot water boilers. However, necessary isolation valves shall be provided to prevent any short circuit in the event of having to open the interconnecting tunnel valves.
- Almost all the campus heating and some of the domestic hot water heating load will be through engine heat energy or hot water generation using natural gas as the heating media. At present the cost of natural gas is less than the cost of electricity including self-generated electricity.
- Partial shifting of domestic hot water heating load to gas fired heating will give maximum heat transfer efficiency and optimum energy consumption.
- With most of the domestic hot water heating load shifted to the campus hot water heating system there will be reasonable hot water demand even in the summer and it will be possible to operate seven engines during the summer without rejecting and wasting their heat energy through cooling towers.
- With change in the design differential temperature the thermal storage tank will be able to supplement additional heat energy during peak demands whenever required

5.3.2 Conserve Energy

1. Pumps P-29 and P-30 mentioned above shall be provided with variable frequency drives so that flow can be adjusted based on the number of engines in operation thereby maintaining a constant hot water inlet / outlet temperature
2. The existing hot water distribution pumps P-1 and P-2 shall be provided with variable frequency drive motors and supply to the individual heating coils should be through two-way valves thereby modulating the hot water flow as per the load requirements
3. New hot water boilers should be provided with primary and secondary distribution pumps with variable frequency drives

4. Replacing the Schmon Tower air-handlers with rooftop units, at the 14th floor as mentioned earlier in addressing the chilled water system, having indirect gas fired heating. This will reduce the heat load on the main system by 2,520 MBTUH and will also eliminate the need to pump hot water to the 14th floor
5. Other air-handling units that need replacement and could be replaced by packaged units should also be provided with indirect gas fired heating to further reduce the hot water load and improve the heat transfer efficiency
6. With variable frequency drives provided on the secondary distribution pumps, flow through each piping loop will be based on actual demand thereby optimizing flow through the piping, reducing required HP, and conserving energy
7. The connected load for the existing 12 electric boilers installed in various buildings is 5.592 MW which when operated even in the nights consumes a lot of electricity thereby increasing the electrical load and utility bills considerably. Reduction of this load will reduce the maximum demand for electricity

5.3.3 Redundancy

1. The primary and secondary distribution pumps should be provided with standby units to ensure uninterrupted supply during pumps breakdown / maintenance
2. Spare hot water boilers shall be installed in the proposed new CUB2 and SUA areas
3. Where possible electric heating should be replaced by hot water heating or indirect gas fired heating. However, all existing electrical boilers shall be kept where installed to provide back-up heating
4. Hot water distribution through the main piping in the tunnel shall be a set of three secondary distribution pumps with one or two pumps in operation, depending on the load, and the 3rd pump as stand-by. Hot water distribution to individual buildings shall be through dedicated branch distribution pumps with one pump operating and one stand-by

5.3.4 Installation of New Hot Water Boilers / Co-generation Engines

1. In the proposed new central utilities building CUB2, install new co-generation engines, if financially feasible, and use the available waste heat for building heating through loop #2 mentioned above. This will also require installation of a hot water boiler for back up purposes
2. If the installation of the new co-generation engines is not pursued, then new hot water boilers suitable to handle the load of loop #2 along with the new loads for Welch Hall expansion, Schmon Tower expansion and Building B4 together with reasonable spare capacity should be installed.
3. Loop # 1 mentioned above shall be fed from hot water generated through the existing co-generation engines and thermal storage back up system. Anticipated flow through this loop, including load for domestic hot water and some pre-heating loads, will be well below the maximum flow capacity of 2,000 GPM. Existing pumps P-1 and P-2 shall be able to

handle this load. Moreover, there will be some flexibility for future additions of load if required

4. Install new hot water boilers in the proposed new satellite utilities area. These hot water boilers shall be able to handle loads for buildings B1/ B6, B2 and B3 with reasonable spare capacity. This loop could also be connected to the central loop for emergency back up
5. Installation of hot water boilers would not require an "Operating Engineer" to be hired as per the "OPERATING ENGINEERS ACT 2000"
6. Buildings constructed away from the existing tunnel system should be provided with stand alone heating system using indirect gas fired heating

5.3.5 General Action for Heating System

1. With changes in the operating differential temperature stress analysis shall be carried out for the entire hot water piping and supports shall be provided accordingly
2. Existing piping shall be reviewed to check its present working condition. Corrosion and pitting within the hot water pipes has been observed at various locations. A phased replacement plan for hot water piping shall be reviewed
3. Expansion loops shall be reviewed and re-designed

5.3.6 Ventilation System

Some of the air-handlers are drawing a high volume of fresh air which is high for current design standards. Supply, return, and exhaust air requirements for individual areas and buildings shall be reviewed to reduce fresh air intake as per the codes, thereby reducing the overall cooling load.

1. Replacing the Schmon Tower air-handlers with rooftop units, at the 14th floor as mentioned earlier in addressing the chilled water system, having indirect gas fired heating. This will reduce the heat load on the main system by 2,520 MBTUH and will also eliminate the need to pump hot water to the 14th floor
2. Other air-handling units that need replacement and could be replaced by packaged units should also be provided with indirect gas fired heating to further reduce the hot water load and improve the heat transfer efficiency.

5.4 CONTROLS

1. Buildings with EMNET building controls system needs to be upgraded to Johnson Controls Metasys system for effective systems control. The following existing buildings have EMNET controls.

Blocks A, B, C, D, E, F, G, H and J
Decew Residence / Vallee Residence
Arthur Schmon Tower
Thistle Complex (minimal systems on Johnson Controls)

Robert S. K. Welch Hall (minimal systems on Johnson Controls)
Physical Education (Walker) Complex (minimal systems on Johnson Controls)
Controls upgrade needs to be addressed soon.

5.5 ELECTRICAL RECOMMENDATIONS

1. Current feeder supply and cogen capacity is rated for 7.0 MW and current power consumption is at 7.4 MW. Therefore the university is in a energy supply deficit and cannot meet its demand on an islanding power strategy and meet all current power demand.
2. With the projected expansion and population growth, the situation denoted above will only become more stringent on the Utilities.
3. Operations personnel are aware they are operating on the supply cusp and currently have a 'power shedding' procedure in place for electricity supply failures.
4. Without upgrades in supply and/or capacity, power shedding strategies must favour priority 'essential power' needs i.e. fire alarm, elevators, key pumps, telecommunications.

5.5.1 Key Recommendation:

1. Self generation capacity should have adequate sizing to handle all proposed expansion.
2. New feeder lines should be sized and installed to handle full expansion needs for the planned 20 year UMP planning window."

5.5.2 Power Supply

- Provision of a second utility feeder line from local utility (13.8 kV) to the campus.
- Installation of new 13.8 kV switchgear to distribute power to the proposed new buildings.
- Performance/Reliability testing of existing 13.8 kV feeder lines with replacement/upgrades as required to ensure system robustness and reliability.
- Addition of two new feeders fed from the 13.8 kV switchgear to supply anticipated new campus buildings.

5.5.3 Medium Voltage Distribution

- Installation of 2nd utility feeder (13.8 kV) from local utility to the campus to meet campus power demands in the event that the co-generation plant is not running.
- Installation of new 13.8 kV switchgear fed from the 2nd utility feeder to meet future power and reliability requirements.
- Performance/reliability testing (infra-red) of the existing 13.8 kV feeders with the feeder replacement following any poor test results.
- Addition of two new feeders from the new 13.8 kV switchgear will be required to continue providing redundancy or power supply.

- Performance/reliability testing (infra-red) of the existing substations and building distribution/panels on about 5 year intervals.

5.5.4 Essential Power and Distribution

- Installation of a new generator on the West side of the campus (at Thistle Complex, Walker Complex, Welch Hall or Taro Hall). The additional power would be used for telecommunications, essential mechanical systems and other critical equipment or systems.
- To ensure reliable restart in the event of utility shut-down, provide a new generator for "black-start" of the co-gen engines.
- Installation of a new generator in B1/B6 for the science building, Plaza 2006 and the Student Centre.
- Provide a new generator in B1/B6 for the installation of supply essential power to B1/B6 and the future B2, B3 and B4. Alternatively provide a unit for B1/B6 and space for future addition of another generator for the other buildings.
- Installation of a new generator for B7.

NOTE: *Global demand for emergency generation over the past years has resulted in a typical delay for receipt of a new generator to be 12-18 months. Supply of larger equipment can be 15-24 months.*

5.5.5 Fire Alarm System

- Implementation of a central alarm and control facility (CACF) for the campus. A central CACF would allow for monitoring of the fire alarm systems by the university and allow for 2 stage alarm systems.

5.5.6 Lighting

- Upgrading or replacement of all T12 fixtures to for T8 lamps for existing buildings and for new buildings.
- Provide lighting controls to automatically turn off or down the lighting during non core hours.

5.5.7 Power Quality

- Install capacitor banks at each of the 600 V substations to improve the power factor and reduce transmission losses.
- Have a harmonic analysis completed for the distribution system. If the total harmonic distortion is above acceptable levels, the harmonic source should be mitigated or removed to improve the distribution systems efficiency.

5.5.8 Energy Efficiency

- Implement strategies to reduce the power consumption of the lighting system.
- Optimize power factor connection to realize cost savings.
- Install harmonic analysis/trending capability to monitor power quality and assist in system troubleshooting and optimization.
- Select energy efficient equipment and provide variable speed drives on all major equipment.
- Consider LEED/CO GBC Standards for new building design.

5.6 TELECOMMUNICATIONS AND DATA

The key issue in planning for future growth and expansion is ensuring sufficient pathways and spaces to support the necessary infrastructure. Currently, this issue manifests itself in the management of cabletrays in the existing tunnel systems and the allocation of space and services for wiring rooms. In order to prepare for the eventual deployment of Voice over IP (VoIP) services requiring highly dependable supply, the wiring rooms will require uninterruptible power supply (UPS) and generator back-up.

We are recommending an expansion of the existing fibre optic infrastructure as part of any new construction. The deployment of "wireless" will actually require significant amounts of copper and fibre cabling and as such does not change the recommendations for pathways and spaces. For new buildings, we have assumed either the expansion of the existing tunnel system or installation of new ductbanks to accommodate new cabling to link the building. Where "rights of way" do not exist (i.e. across major roads not owned by the University) wireless can be deployed.

5.6.1 Existing Installations

1. Implement a fully segregated pathways system for cabling in tunnels.
2. Continue move towards standardization of structured cabling plant wiring rooms.
3. Prepare existing and new wiring rooms to accommodate critical operations equipment (i.e. space, HVAC and critical power).
4. Expand fibre backbone to accommodate projected areas of growth (i.e. new fibre node at south end of campus).
5. Reserve spaces and pathways to support expansion of wireless services.
6. Consider support in building wireless services by external third party providers for "Student/Residence" spaces (i.e. outsource to Bell, Telus or Rogers).
7. Provide UPS and generator back-up for the Telecom Rooms on the Campus.

5.6.2 New Installations

As part of the recommendations, when the existing wiring rooms or new ones are constructed the following minimum standards should be implemented:

1. Emergency power connected to a backup generator source. Budget approximately 12kW per room. This assumes approximately 5 kW of equipment load and 7 kW of HVAC load.
2. Emergency lighting within each wiring room.
3. Minimum of 2 tons of supplemental cooling in each room; connected to emergency power noted in item 1 above.
4. Grounding system within the wiring room; bonded to power source for the room.

5.7 MUNICIPAL INFRASTRUCTURE

The facility Water Supply and Sanitary Sewer system is reviewed in Section 9.4 (Phase I report). The recommendations are presented:

- Based on current estimates of sewage flow, the existing outfall to Lockhart Drive is sufficient for the existing campus, and has available capacity for future university expansion.
- Flow estimates based on the MOE and OBC criteria are considered conservative and account for the varied use of facilities. Therefore, consideration should be made for flow monitoring to confirm existing flows and confirm available capacity for future campus expansions.
- Video inspections are recommended over the next 5 years to confirm supply water pipe conditions based on the requirements for future campus expansions/or expansion?
- In order to determine the condition of the existing campus sewage collection system, a video inspection program of the existing sewers should be implemented.
- Existing capacity/flows on Lockhart Drive are to be reviewed further with the City of St. Catharines for existing and future flow requirements.
- The internal campus sanitary sewage system also appears to have sufficient capacity to handle future university expansion. In order to adequately confirm the ability of the existing sewage collection system to convey additional flows, flow monitoring may be required.

5.7.1 Water Supply

Based on the analyses and investigations described in Appendix 1 of this report, the following conclusions and recommendations can be made regarding water supply issues within the Brock University campus:

1. The fire flow capacity of the existing water distribution system is marginal for institutional fire protection.

2. The existing distribution system does not extend adequately to service all of the future buildings.

3. Hydraulic model simulation shows that the addition of a new ring main in support of the future development increases the fire protection substantially.

4. The recommended watermain installation will be approximately 1,250m and include a metering chamber complete with emergence bypass and several new fire hydrants.

5. Many watermains were constructed originally when the campus was first established and would appear to be in moderate to poor condition. A replacement program over the next 20 years should begin.

6. A condition assessment of the existing water distribution system should be carried out at the earliest possible opportunity to assess what watermains can provide for the long term servicing need of the campus.

7. It is anticipated that due to the nature of the tunnel utility system some watermain replacement and the construction on the proposed new watermains may be difficult. Therefore, the accessibility of existing watermains must also be investigated.

8. A detailed design assessment will be required to address constructability issues and consideration of the benefits of a trenchless construction.

5.7.2 Sanitary Servicing

The existing sanitary infrastructure has sufficient capacity to accommodate current estimated sewage flows within the main campus. Based on current estimates of sewage flow, the outfall to Lockhart Drive is sufficient for the existing campus. Only 19% of the outfall rated capacity is currently utilized. Following are the conclusions and recommendations for the sanitary sewer requirements for both the existing infrastructure and that proposed to accommodate the future campus expansion:

Existing Sanitary System

1. A condition assessment, specifically a CCTV inspection of the main sanitary sewer branches identified considerable sediment and debris within the pipes.

2. The CCTV inspection revealed a significant beak in the PVC sewer just north of MH105 of the west branch and a circumferential crack in the concrete sewer located a distance of

10.4m north of MH4. These sections of sewer should be repaired/replaced as soon as possible.

Future Sanitary System

1. Sanitary sewage flows on the main campus are projected to increase by 30% as a result of the proposed development as identified in the FNP Study.

2. The existing sanitary infrastructure has sufficient capacity to accommodate the projected flows.

3. The recommended sanitary servicing scheme to accommodate future buildings B1, B2, B3, B4 and B5 requires the construction of a new 200mm diam. sewer along University Road conveying flows to the pump station.

4. The existing pump station has sufficient additional capacity to accept the flows projected for future buildings B1, B2, B3, B4 and B5.

5. Future buildings B6 and B1 have alternative schemes that allow them to be serviced independently of the recommended sewer along University Road, as do the building expansions for Welch Hall and Schmon Tower.

6. Future building B7 will be serviced by the existing sanitary sewer on Norman Road, east of Glenridge Avenue.

7. As a means of reducing future sediment debris deposition within the sanitary (or storm) sewer system, it is recommended that siltation controls be implemented prior to the start of any construction work on the campus. In addition, a provision for the flushing and CCTV inspection of sewers should be included in all projects involving sewer works directly or construction projects that have the potential to impact sewers on-site.

8. It is recommended that an annual maintenance program be developed to flush and inspect the existing sewers and to perform repairs as necessary.

9. It is recommended that the operating pump in the SPS be sent to the manufacturer for a complete inspection. If the rated capacity can not be met by the existing pump, it should be replaced.

5.7.3 Storm Water Drainage

The existing storm sewer system servicing the main campus drains in two directions. The smaller northern portion discharges northward over the escarpment at one large outfall to the west and several smaller outlets at several locations farther to the east The larger southern portion drains

southward via an extensive storm sewer system which outlets to Lake Moody near the southwest corner of the campus.

A. Main Campus

Theoretical design calculations indicate that substantial portions of the existing storm sewer system are overloaded by the two and five year design storms under both existing and proposed conditions. However, university maintenance staff indicates that no significant flooding problems have been observed for many years. It has therefore been concluded that the theoretical analysis may be conservative and no significant sewer upgrades are recommended at this time. The situation should be observed on an ongoing basis to confirm whether further investigation is warranted. No existing stormwater management control is provided within the main campus area.

B. South Campus

The south campus is serviced by its own storm sewer system and stormwater management facility which ultimately discharge to Lake Moody to the west of the south campus lands. Detailed design sheets for the storm sewer system were available for review for this study. Therefore, additional hydraulic analysis of this system was not required for purposes of this report. The design calculations and drainage area plan clearly indicate that the system is design to convey the five year peak flow from only Parking Lots T, U, and V southwest of the intersection of Glenridge Avenue and St. David's Road. Minimal spare capacity exists in the storm sewer system.

Though detailed design calculations regarding the existing SWM facility were not available it appears that the facility is designed as an engineered wetland primarily to accommodate the 25 millimetre rainfall event for water quality control purposes only (i.e. no evidence of quantity control). Two existing outlets from the south campus storm sewer network discharge flows to the northeast corner of the SWM facility. A third inlet to the pond not shown on the design drawings was identified during a site visit by TSH staff. This third inlet appears to accommodate flows from an existing open ditch conveying overland flow from south and west of Parking Lot V.

Based on the findings of the analyses and investigations described in this report, the following conclusions and recommendations can be made regarding storm drainage issues within the Brock University campus.

Existing Storm System

A. Main Campus

1. The main downstream outlet from the main campus is partially submerged by current Lake Moody water levels. University staff members have indicated that current water levels are significantly higher that what was previously considered typical. These high water levels are believed to diminish the effective capacity of the box culvert outlet to Moody Lake while

causing water to "pond" within downstream reaches of the storm sewer system. It is recommended that downstream control of Moody Lake water levels should be investigated further to assess potential ongoing or future impacts on the effective capacity of the downstream portions of the storm sewer system (i.e. backwater effects).

B. South Campus

2. It is somewhat unclear to date what the intended design capacity of the SWM facility is, particularly in light of the fact that the third inlet to the wetland at its southeast corner does not appear to have been part of the original design. Based on the observations of University maintenance staff that minimal ponding has been observed within the SWM facility, it is possible but still unconfirmed that the facility's capacity is underutilized under existing conditions. Further investigation into this issue will be necessary.

C. Future

3. Theoretical design calculations indicate that substantial portions of the existing storm sewer system are overloaded by the two and five year design storms under both existing and proposed conditions. However, university maintenance staff indicates that no significant flooding problems have been observed for many years. It has therefore been concluded that the theoretical analysis may be conservative and no significant sewer upgrades are recommended at this time. The situation should be observed on an ongoing basis to confirm whether further investigation is warranted.

4. Based on the currently proposed locations of future buildings, up to approximately 575 metres of storm sewer will need to be relocated to avoid conflicts with the future building footprints.

5. Quantity control is not expected to be required within the existing system provided adequate storm sewer capacity is available downstream of any proposed future development that will increase the peak runoff rates from the development site.

6. Stormwater management quality controls are expected to be a requirement of the Conservation Authority and local municipalities for future expansion within the campus as this is now standard practice for new development. Various potentially feasible SWM alternatives are described in Section 9.5.3.3 of this report. Up to two wet ponds may be implemented along with a number of oil/grit separators at key locations as shown on Drawing 4 in Appendix 1.

Other potentially beneficial SWM measures may include bioinfiltration filters and/or vegetated swales. However, due to a lack of specific information regarding future modifications to the internal road pattern and parking lot locations/configurations detailed recommendations and cost estimates regarding their implementation cannot be made at this time.

Storm Water Drainage

Based upon Section 9.5.7 (Phase I report), the key recommendations for storm water drainage are presented.

A. Main Campus

1. Review further the drainage area characteristics and storm sewer system configuration to verify if installed design capacities can handle future expansions.
2. Consideration should be given to implementing storm water quantity control with the university expansion.
3. Storm water quality controls will be requirements for future facility development and will be expected by the municipality and conservation authority. Implement ponds, wetlands, ditching, oil/grit separators as part of future development design.
4. Downstream control of Lake Moodie water levels needs to be assessed for its impact on drainage of the downstream portions of the storm sewer system.

B. South Campus

1. Future development will require the construction of additional storm sewers or extension of the existing system depending on the proposed layouts.
2. Further investigation into the capacity of the existing SWM facility will be needed to confirm to what extent the existing wetlands can service future development.

5.7.4 Building Expansions as per Scenario 6.6

Decision Charts have been prepared to assist Brock with the many factors that must be considered for the various options to extend the heating/Cooling systems on the Campus. Please refer to Figures 5- 4 for further information.

A B1/B6 Building Design

1. To handle future additional loads and supplement the existing systems shortfall, the following is recommended:

   a. Plan the proposed new utility area (SUA), in the basement of Building B1/B6, connected to the existing campus utilities infrastructure in a way that allows future additions of cooling/heating equipment along with accessories. Modify the existing

single loop distribution system to a double loop system as mentioned earlier in the report.

b. Develop a new central utility building (CUB2) at the tunnel end (north-west side) with new chillers and boilers, capable of handling new loads, and adopt the double loop distribution system.

c. The existing piping distribution system is aging (25+) years and will need to be changed out over the next decade. As part of the replacement, the pipe sizes at the tunnel ends (6"Ø and 10"Ø pipe) should be increased as per the new requirements. The new equipment can be installed as needed to support the Campus expansions.

B Expansions Beyond B1/B6

1. Provide new CUB2 to house heating and cooling systems.

2. If Brock University decides to go ahead with the cogeneration option based on available funding, a portion of the new central utility building (CUB2) should also be earmarked for the installation of new cogeneration engines. The CUB2 Building should be architecturally developed and placed so as to be acceptable to all concerned (including the donors). The new cogeneration area should be planned with the possibility of adding engines in phases. Brock's attention and review should include a visit to Hamilton Community Energy, a recently constructed very successful co-generation plant located in a heavily populated area of downtown Hamiton that provides heating and hot water to several municipal buildings, a regional high school and community housing located adjacent to the HCE.

3. We understand that subsequent to the B1/B6 Building, the likely scenario is for Mixed Use Academic Buildings B2 and B3 to proceed. Anticipated loads for these two buildings are specified here-in this report.

C Stand-Alone Systems

1. Expansion beyond tunnel infrastructure requires (Glenridge, Downtown) Stand Alone Systems

5.8 Tunnel Underground Utility Infrastructure

1. Extend the tunnel to service the proposed Building B1/B6 Sciences Building.

2. Extend the tunnels to service proposed Building B2 from B1/B6

3. Extend the tunnel to service proposed Building B5 and then to B4.

5.9 Alternative Energy Solutions/Utility Management Practices

Brock will have to decide if they wish to pursue alternate energy sources to supplement the current utility infrastructure. Without subsidies or a desire to implement as a learning project, the case for wind and other alternate technologies on a strictly cost scenario does not meet most payback calculations.

6.0 COST ESTIMATE

6.1 Summary

The Brock University Utilities Master Plan Estimate was developed as a 'Class D' cost estimate. The rates here within are order-of-magnitude (within 15% of later estimates based on detailed design information) for the purpose of program sizing and prioritization only. Costs within the body of this report refer to the Brock Utilities Master Plan Version 06 cost estimate by Vermeulens Cost Consultants, dated April 4, 2007.

In order to capture accurate pricing and scope, a variety of comparable projects were referenced from our extensive database. Vermeulens methodology is to analyze detailed construction bid and GMP results and adjust for current project and market conditions. The unit rates here within are in-line with locally adjusted rates seen in projects at Durham University, St. Michael's Hospital and the University of Toronto. The scope of work included in this cost estimate is in-line with similar central utility and campus infrastructure projects throughout North America.

The overall utility capacity and scope of work included in this estimate was developed to serve Scenario 6.6 from the "Facilities Needs and Priorities Study", conducted by Urban Strategies Inc.

To aid in allocating costs to different phases of this project, the estimate has been separated into nine components and then further subdivided into construction phases. Escalation for the phasing of this project has been carried at four percent per annum to the middle of the potential construction phase (e.g. Phase 1: 2007 – 2012: 5yr/2 = 2.5yr * 4%/yr = 10%). Based on recommendations found within the body of this report the following costs have been estimated.

TOTAL COST SUMMARY	**$,000's**
New Cooling Plant	9,536
New Heating Plant	5,138
New Cogeneration Plant	22,872
New Tunnels and Utility Distribution	4,675
New Electrical Switchgear and Emergency Generators	3,955
Telecommunication Upgrades	762
New Civil Infrastructure	4,040
Modifications to Existing Control Systems	2,321
Upgrades to Existing Utilities	12,561
TOTAL UTILITY AND INFRASTRUCTURE ESTIMATED COSTS	**65,860**

Costs are net present value of all future construction. See Table 6-s 6-1 to 6-9 in Section 6.12 of this report.

PHASED COST SUMMARY	$,000's
Phase 1: 2007 – 2012 : No Expansion, B1/B6, B5 & Existing Upgrades	26,014
Phase 2: 2010 – 2015 : No Expansion, Schmon Tower, CUB2 and B7	16,965
Phase 3: 2013 – 2018: No Expansion, B2	17,290
Phase 3: 2013 – 2018: No Expansion, B2	5,590
TOTAL PHASED ESTIMATED COSTS	**65,860**

Costs are net present value of all future construction. See Table 6-s 6-10 to 6-13 in Section 6.13 of this report

The cost breakouts for 'Upgrades to Existing Utilities' include all the recommended measures to upgrade the current systems to proper operating capabilities. See Table 6-9 in Section 6.12 of this report.

The above costs include all direct construction costs, general contractor's overhead and profit, design and construction contingencies. As seen throughout the body of this report; markups on direct costs total to 24% of direct costs.

6.2 Estimate Format

The Brock University Utilities Master Plan cost estimate was first completed in "Elemental" cost format with the following component breakdowns as seen in Section 6.14 of this report;

- Chiller Plant
- Heating Plant
- Cogeneration Plant
- Distribution
- Electrical
- Telecom
- Civil Infrastructure
- Existing Upgrades

The "Elemental" cost estimate is in current dollars only. Costs by discipline, were then subdivided into the following phases as seen in Section 6.12 of this report;

- Phase 1: 2007 – 2012 : No Expansion, B1/B6, B5 and Existing Upgrades
- Phase 2: 2010 – 2015 : No Expansion, Schmon Tower, CUB2 and B7
- Phase 3: 2013 – 2018: No Expansion, B2
- Phase 4: 2016 – 2024: No Expansion, B3 and B4

Lastly, the above phases were subdivided by each building in the phased expansion including costs for implementing strategies including no expansion. See Section 6.13 of this report.

6.3 Markup and Contingency

General requirements of eight percent have been applied to all direct construction costs to cover items such as: supervision and labour, temporary facilities, accommodations, temporary fences, winter conditions, permits, insurance bonds and other expenses (see Section A-6) of the detailed estimate in Section 6.14 for a further breakdown). Contractors' profit fee and risk have been included at three percent of direct construction costs.

A design contingency of ten percent and a construction contingency of three percent have been applied to all direct construction costs. Design contingency is intended to cover documentation error, estimating error, unforeseen site conditions, scope changes etc. Construction contingency is intended to cover changes during construction.

The "mark-ups" of 24% referred to in the cost summary tables of this report is the total of the General Requirements (8%), Profit/Fee (3%), Design Contingency (10%) and Construction Contingency (3%).

Escalation contingency of four percent per annum has been applied to estimated construction costs. Although escalation for the local construction market has been higher for 2005 and 2006, it is our opinion that escalation will tend to the historical long term average of four percent per annum. Escalation has been calculated to the middle of the potential expansion time frames.

Excluded from the estimate are: hazardous waste removal, loose furnishings and equipment, project contingency, architect's and engineer's fees, moving, administrative and financing costs and the GST.

Bidding conditions are expected to be one construction manager, open bidding for sub-contractors, open specifications for materials and manufacturers.

The rates here within are order-of-magnitude (within 15% of later estimates based on detailed design information) for the purpose of program sizing and prioritization only.

6.4 Regulatory Environment and Market Conditions

The cost estimates here-within have no cost allocation or contingency for unforeseen changes in governing municipal regulations or specific changes in market conditions. Local shortages in labour, steel, concrete and copper can have substantial impacts on the construction costs here-within. In order to hedge against such risk the project management team should allocate a project contingency. This contingency should be in addition to other budget allocations such as professional fees, design fees, etc.

In addition to a project contingency the project team must ensure that cost estimates are continuously updated and reviewed to ensure that all current regulations and market conditions have been accounted for.

6.5 Mechanical

6.5.1 Cooling Plant

Building Construction

The cooling plant will be housed in a 280 m^2 basement mechanical space, located in the proposed new B1/B6 building. Estimated costs for this construction are $802,178 and can be found in Table 6-2.

Chilled Water Capacity

The estimated cost of the mechanical systems for the newly installed 4500ton of chiller capacity is **$8,733,587 or $1,941/ton**. This cost is the net present value of all four potential construction phases. Only plant piping is included in the HVAC piping cost. Distribution within the new buildings should be carried with the cost of the new buildings. Chilled water supply and return to the new buildings is carried in the distribution section of this estimate.

6.5.2 Heating Plant

Building Construction

The heating plant will be housed in a 280 m^2 basement mechanical space, located in the proposed new B1/B6 building. Estimated costs for this construction are $849,098 and can be found in Table 6-3.

Heating Water Capacity

The estimated cost of the mechanical systems for the new 58,000mbh heating plant is **$4,288,695 or $74/mbh**. This cost is the net present value of all four potential construction phases. Only plant piping is included in the HVAC piping cost. Distribution within the new buildings should be carried with the cost of the new buildings. Hot water/steam supply and return to the new buildings is carried in the distribution section of this estimate.

6.6 Cogeneration

6.6.1 New Cogeneration Plant

The cogeneration plant will be housed in a 300 m^2 standalone building (CUB2). Building costs allow for a simple one, story steel structure, with brick cladding and minimal interior work. The estimated building cost total **$984,285**. Cost summaries can be found in Table 6-4.

6.4.2 Cogeneration Equipment

The proposed cogeneration plant will have 9.6MWe capacity via six Caterpillar natural gas engine generators. Budgetary cogeneration equipment costs were supplied by Toromont and were estimated to be $**20,428,800 or $2,128/kWe** (see Table 6-4).

Pricing includes: all associated air units, ductwork, pumps, pipe, heat exchangers, circulation pumps, piping, electrical service and distribution.

6.4.3 Cogeneration Controls

The Cogeneration Plant will be completely controlled by a Johnson DDC system. Estimated costs for the construction of this system are $152/kWe or $1,459,200 (see Table 6-4).

6.4.4 Existing Systems Upgrade

The HVAC systems upgrade include replacement of 7-8 air-handling units, replacement of one of the existing centrifugal chiller, phased replacement of chilled water and hot water distribution piping, installation of standby pumps, replacement of 3-way valves with 2-way valves, new VFD's on pumps and air-handlers, etc as per the details mentioned in Table 6-9.

Existing Controls Upgrade

Existing building blocks, constructed before 2001 and operating on EMNET control system using OPTO 22 hardware in the field, are to be converted to have Johnson Controls Metasys system. This involves an upgrade for approximately 1,700 control points. Estimated costs for controls upgrade is $ 1,700,000 (see Table 6-9).

6.7 Distribution

6.7.1 Utility Tunnels

The Utilities Master Plan calls for utility tunnels to link the new central utility building, with the future construction proposed in scenario 6.6 of the FNP study. In total, the length of this tunnel system has been estimated to be 232 m. The tunnel will be 10' wide by 8' high and it is assumed that it will be three feet below grade.

Cost estimates assumed a cast in place concrete structure with a 6" slab on grade, 12" concrete walls and a concrete roof. Allowances have been made for rock removal, lighting and fire alarm systems to the tunnel. The total cost for the utility tunnels is estimated to be **$3,123,150** (see Table 6-5).

6.7.2 Utility Distribution

Within the new tunnels allowances have been made for HVAC piping and electrical feeders. All lengths will be extended to the takeoff point of the future buildings. The total cost of these items is estimated to be **$1,551,667** (see Table 6-5).

6.8 Electrical

6.8.1 13.8kv Power Supply

The Utilities Master Plan calls for a new 13.8kv feeder and switchgear to be installed in the basement of the new satellite utility building. The switchgear will be housed along with new emergency generators. The total area required for the electrical equipment is estimated to be 200 m^2 with a total cost of **$549,996** for building construction (see Table 6-6).

Horizon Utility has proposed to engineer and install a new 13.8kv feeder that will be brought to the campus property line. The estimate then brings the line overhead to the playing field, underground to the tunnel system and finally through the tunnels to the new switch room. The estimate includes all feeder and associated panels with the exception of feeder within the new buildings and secondary distribution. The feeder for the new buildings has been included with the "Distribution" component of this estimate. The secondary switching and distribution has not been included in this estimate as it should be part of the new building construction costs. The total cost for the new switchgear and incoming power is estimated to be **$2,020,933** (see Table 6-6).

6.8.2 Essential Power

This Utilities Master Plan calls for the installation of two 1000kw emergency generators. The essential power estimate includes a paralleling switchgear, all associated feeder and distribution. The feeder for the new buildings has been included with the "Distribution" component of this estimate. The secondary switching and distribution has not been included in this estimate as it should be part of the new building construction costs. Total costs for essential power have been estimated to be **$1,384,290** (see Table 6-6).

6.9 Telecommunications

The telecommunications estimate is composed of; a new fiber optic node, clean-up of existing cable and new cable and trays for new buildings. Additional allowances have been made for modifications to existing tel/data rooms. The total estimated costs for upgrading the tel/data system and providing the infrastructure for the new buildings have been estimated to be **$762,273** (see Table 6-7).

6.10 Civil Infrastructure

The utilities master plan requires the addition of new water, sewer and sanitary systems. Only minor repairs and the installation of a 150mm PVC main are would be required prior to any expansion. Costs for the aforementioned costs can be found in the following section of this report.

Piping unit rates allow for approximately one meter of rock removal for sanitary excavation work. With all proposed expansions, it's estimated that the campus will require 1,285 m of water main, 580 m sewer line and 550 m of storm sewers. In addition to piping costs, allowances for water metering, manholes, catch basins, pump station replacement and run-off ponds have been included. The total estimated costs are **$4,039,709** (see Table 6-8).

6.11 Existing Upgrades

Air Handling Systems

As noted in the Utilities Master Plan, there are several air handling units that have reached the end of there useful life. The estimate has allowed for the replacement of seven air handling units in total, with a total capacity of 182,190 cfm. The air handlers to be replaced are located at; Schmon Tower (2), Welch Hall (1), Walker Complex (3), Mackenzie Chown Block (1). These units will be custom built with direct gas fired heating, DX cooling, economizers and direct digital controls. Allowances have been made to reconfigure the ductwork headers, install new dampers, new fire alarm devices and miscellaneous terminal units (see Table 6-9).

Mechanical Equipment

The heating and cooling plants will be modified to operate at new temperature differentials. This will require the modification of controls, changing impellers, adding VFD's and conducting a variety of tests. Additionally, upgrades will be preformed on the existing McQuay chiller and the idle 1000ton chiller in the CUB will be replaced. (See Table 6-9)

Upgrade Existing Control Systems

The current EMNET control system will be converted to a Johnson DDC control system. The cost estimate allows for the replacement of 1700 control points in total.

HVAC Distribution Piping

The main chilled water and hot water distribution loops will be increased in size to 16" and 10" diameters respectively. The overall estimated quantity of pipe for replacement is 7,600 m.

Electrical Equipment

The Utilities Master Plan calls for the addition of two new emergency generators to be installed in existing facilities; one at 500 kW and the other at 800 kW. Allowances have been made for the complete installation and integration of these new units (see Table 6-9).

Electrical Distribution

As indicated in the Utilities Master Plan the existing 13.8 kV overhead feeder is quite old. The estimate has allowed for hi-pot testing and the replacement of overhead feeder (see Table 6-9).

Power Factor Correction

The estimate assumes that the 17 existing substations will have new capacitor banks installed (150 KVAR average). Additionally, a $20,000 allowance has been included for 'Harmonics Analysis' that is required to size the capacitor banks properly (see Table 6-9).

Present Day Civil Upgrades

The current civil systems require the construction of a new 150mm water main and the repair and inspection of existing sanitary systems. Other system upgrades are required for expansion scenarios only.

Costs

The total costs for the various "Existing Upgrades" has been estimated to be **$14,881,756** (see Table 6-9).

6.12 Disciplinary Cost Breakouts

TABLE 6-1: COST SUMMARY BY DISCIPLINE

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Grand Total Costs
Building Costs	(m2)	760	2,162	1,642,740	300	2,247	674,168							2,316,908
Chiller Plant Costs	(ton)	1,000	1,116	1,115,983	700	1,936	1,355,109	1,850	1,185	2,192,400	950	1,074	1,020,295	5,683,787
Cogeneration Plant Costs	(kWe)				4,800	1,500	7,200,000	4,800	1,500	7,200,000				14,400,000
Heating Plant Costs	(mbh)	24,000	54	1,289,660	10,000	49	485,146	12,000	52	627,720	12,000	41	488,886	2,891,412
Distribution Costs				611,897			838,072			418,684			1,119,188	2,987,840
Electrical Costs				2,041,651			458,500							2,500,151
Telecom Costs				528,280			11,700			5,760			16,020	561,760
Civil Infrastructure Costs				1,633,540			258,320			423,690			456,925	2,772,475
Existing Upgrade Costs				10,549,490			339,000			75,000			75,000	11,038,490
Subtotal Total Costs				**19,413,240**			**11,620,015**			**10,943,254**			**3,176,314**	**45,152,822**
Markups (24%)				4,659,178			2,788,804			2,626,381			762,315	10,836,677
Escalation (4%/annum)			10.0%	1,941,324		22.0%	2,556,403		34.0%	3,720,706		52.0%	1,651,683	9,870,117
Total Costs				**26,013,742**			**16,965,222**			**17,290,341**			**5,590,312**	**65,859,616**

TABLE 6-2: CHILLER PLANT

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
Building Costs (m2)														
A1 Substructure		280	312	87,245										87,245
A2 Structure		280	89	24,920										24,920
A3 Enclosure		280	595	166,471										166,471
B1,2,3 Interiors		280	119	33,253										33,253
C1 Mechanical		280	569	159,451										159,451
C2 Electrical		280	455	127,300										127,300
D Sitework		280		0										0
Subtotal Building Costs		**280**	**2,138**	**598,640**										**598,640**
Equipment Cost (ton)														
SUA														
Centrifugal Chillers		1,000	450	450,000				800	450	360,000	600	450	270,000	1,080,000
Cooling Towers		1,000	150	150,000				800	150	120,000	600	150	90,000	360,000
Pumps, and other equipment		1,000	270	269,733				800	257	205,511	600	257	154,133	629,378
CUB2														
Steam absorption chillers					700	1,000	700,000	700	1,000	700,000				1,400,000
Centrifugal Chillers							0	350	450	157,500	350	450	157,500	315,000
Cooling Towers					700	150	105,000	1,050	150	157,500	350	150	52,500	315,000
Pumps, and other equipment					700	257	179,822	1,000	257	256,889	350	257	89,911	526,622
Subtotal Equipment Costs		**1,000**	**870**	**869,733**	**700**	**1,407**	**984,822**	**1,850**	**1,058**	**1,957,400**	**950**	**857**	**814,045**	**4,626,000**
Other Costs														
HVAC Piping	(m)	175	650	113,750	250	650	162,500	200	650	130,000	175	650	113,750	520,000
Gas Piping	(m)				106	507	53,787			0			0	53,787
Connect to existing	(no)	4	10,000	40,000	2	10,000	20,000			0			0	60,000
Equipment Start-up	(ls)	20,000	1	20,000	35,000	1	35,000	25,000	1	25,000	20,000	1	20,000	100,000
Controls	(pts)	35	1,000	35,000	45	1,000	45,000	35	1,000	35,000	35	1,000	35,000	150,000
Motor Wiring	(ls)	37,500	1	37,500	54,000	1	54,000	45,000	1	45,000	37,500	1	37,500	174,000

TABLE 6-2: CHILLER PLANT

	Construction Phase												
	Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
Subtotal Other Costs			**246,250**			**370,287**			**235,000**			**206,250**	**1,057,787**
Subtotal Chiller Plant Costs			**1,714,623**			**1,355,109**			**2,192,400**			**1,020,295**	**6,282,427**
Markups (24%)			411,510			325,226			526,176			244,871	1,507,782
Escalation (4%/annum)		10.0%	171,462		22.0%	298,124		34.0%	745,416		52.0%	530,553	1,745,555
Total Chiller Plant Costs			**2,297,595**			**1,978,459**			**3,463,992**			**1,795,718**	**9,535,765**

TABLE 6-3: HEATING PLANT

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
Building Costs (m2)														
A1 Substructure		280	312	87,245										87,245
A2 Structure		280	89	24,920										24,920
A3 Enclosure		280	595	166,471										166,471
B1,2,3 Interiors		280	119	33,253										33,253
C1 Mechanical		280	695	194,466										194,466
C2 Electrical		280	455	127,300										127,300
D Sitework		280		0										0
Subtotal Building Costs		**280**	**2,263**	**633,655**										**633,655**
Equipment Cost (MBH)														
SUA														
Hot water boilers		24,000	15	360,000				12,000	15	180,000	12,000	15	180,000	720,000
Steam boilers		5,022	18	90,396										90,396
Pumps, and other equipment		24,000	14	339,000				12,000	14	169,500	12,000	14	169,500	678,000
CUB2														
Hot water boilers					10,000	15	150,000							150,000
Pumps, and other equipment					10,000	19	185,000							185,000
Subtotal Equipment Costs		**24,000**	**33**	**789,396**	**10,000**	**34**	**335,000**	**12,000**	**29**	**349,500**	**12,000**	**29**	**349,500**	**1,823,396**
Other Costs														
HVAC Piping	(m)	400	650	260,000	100	650	65,000	200	650	130,000	100	650	65,000	520,000
Gas Piping	(m)	36	507	18,264	20	507	10,146	30	507	15,220	20	507	10,146	53,776
Steam Piping	(m)	200	120	24,000				150	120	18,000	77	120	9,240	51,240
Connect to existing	(no)	4	10,000	40,000	2	10,000	20,000							60,000
Equipment Start-up	(ls)	40,000	1	40,000	15,000	1	15,000	30,000	1	30,000	15,000	1	15,000	100,000
Controls	(pts)	65	1,000	65,000	20	1,000	20,000	45	1,000	45,000	20	1,000	20,000	150,000
Motor Wiring	(ls)	53,000	1	53,000	20,000	1	20,000	40,000	1	40,000	20,000	1	20,000	133,000

TABLE 6-3: HEATING PLANT

	Construction Phase												
	Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
Subtotal Other Costs			**500,264**			**150,146**			**278,220**			**139,386**	**1,068,016**
Subtotal Heating Plant Costs			**1,923,315**			**485,146**			**627,720**			**488,886**	**3,525,067**
Markups (24%)			461,596			116,435			150,653			117,333	846,016
Escalation (4%/annum)		10.0%	192,331		22.0%	106,732		34.0%	213,425		52.0%	254,221	766,709
Total Heating Plant Costs			**2,577,242**			**708,314**			**991,797**			**860,440**	**5,137,793**

TABLE 6-4: COGENERATION PLANT

	Construction Phase												
	Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
Building Costs (m2)													
A1 Substructure				300	307	92,091							92,091
A2 Structure				300	264	79,200							79,200
A3 Enclosure				300	1,037	311,049							311,049
B1,2,3 Interiors				300	87	25,950							25,950
C1 Mechanical				300	435	130,378							130,378
C2 Electrical				300	108	32,500							32,500
D Sitework				300	10	3,000							3,000
Subtotal Building Costs				**300**	**2,247**	**674,168**							**674,168**
Equipment Cost (kWe)													
SUA													
Gas turbine engines				4,800	1,050	5,040,000	4,800	1,050	5,040,000				10,080,000
Heat recovery equipment				4,800	250	1,200,000	4,800	250	1,200,000				2,400,000
Subtotal Equipment Costs				**4,800**	**1,300**	**6,240,000**	**4,800**	**1,300**	**6,240,000**				**12,480,000**
Other Costs													
DDC Control System				4,800	100	480,000	4,800	100	480,000				960,000
Engineering & Commissioning				4,800	100	480,000	4,800	100	480,000				960,000
Subtotal Other Costs						**960,000**			**960,000**				**1,920,000**
Subtotal Cogeneration Plant Costs						**7,874,168**			**7,200,000**				**15,074,168**
Markups (24%)						1,889,800			1,728,000				3,617,800
Escalation (4%/annum)					22.0%	1,732,317		34.0%	2,448,000				4,180,317
Total Cogeneration Plant Costs						**11,496,285**			**11,376,000**				**22,872,285**

TABLE 6-5: DISTRIBUTION

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
Chilled water piping	(m)	80	500	40,000	30	500	15,000	75	500	37,500	185	500	92,500	185,000
Hot water piping	(m)	80	500	40,000	30	500	15,000	75	500	37,500	185	500	92,500	185,000
Electrical feeder	(m)	149	525	78,225	272	525	142,800	75	525	39,375	185	525	97,125	357,525
Emergency feeder	(m)	149	394	58,706	272	394	107,168	75	394	29,550	185	394	72,890	268,314
Tunnels	(m)	46	8,500	391,000	65	8,500	552,500	32	8,500	272,000	89	8,500	756,500	1,972,000
Tunnel fi-out	(m)	46	86	3,966	65	86	5,604	32	86	2,759	89	86	7,673	20,001
Subtotal Distribution Costs				**611,897**			**838,072**			**418,684**			**1,119,188**	**2,987,840**
Markups (24%)				146,855			201,137			100,484			268,605	717,082
Escalation (4%/annum)			10.0%	61,190		22.0%	184,376		34.0%	142,352		52.0%	581,978	969,895
Total Distribution Costs				**819,942**			**1,223,585**			**661,520**			**1,969,770**	**4,674,817**

TABLE 6-6: ELECTRICAL

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			Grand Total Costs
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	
Building Costs (m2)														
A1 Substructure		200	304	60,800										`
A2 Structure		200	89	17,800										17,800
A3 Enclosure		200	609	121,800										121,800
B1,2,3 Interiors		200	92	18,480										18,480
C1 Mechanical		200	818	159,355										159,355
C2 Electrical		200	161	32,210										32,210
D Sitework		200		0										0
Subtotal Building Costs		**200**	**2,052**	**410,445**										**410,445**
Normal Service & Distribution														
New 13.8kv switchgear	(ls)	300,000	1	300,000										300,000
Incoming feeder	(m)	1,310	571	747,525										747,525
Feeder to existing switch	(m)	640	262	167,680										167,680
Connect to existing switch	(ls)	25,000	1	25,000										25,000
Emergency Service & Distribution														
New Emergency Generators	(kw)	1,000	400	400,000	1,000	400	400,000							800,000
Transfer Switches	(no)	1	58,500	58,500	1	58,500	58,500							117,000
Emergency Switchboard	(ls)	100,000	1	100,000										100,000
Subtotal Distribution Costs				**1,798,705**			**458,500**							**2,257,205**
Incoming Service														
New power line to campus	(ls)	185,000	1	185,000										185,000
Overhead power line	(m)	366	131	47,946										47,946
Connect to new service	(no)	1	10,000	10,000										10,000
Subtotal Incoming Service Costs				**242,946**			**0**							**242,946**
Subtotal Electrical Costs				**2,452,096**			**458,500**							**2,910,596**
Markups (24%)				588,503			110,040							698,543
Escalation (4%/annum)			10.0%	245,210		22.0%	100,870							346,080
Total Electrical Costs				**3,285,809**			**669,410**							**3,955,219**

TABLE 6-7: TELECOM

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
New tel/data node	(ls)	95,000	1	95,000										95,000
Clean-up existing cable	(m)	100,000	1	100,000										100,000
New cable tray	(m)	46	180	8,280	65	180	11,700	32	180	5,760	89	180	16,020	41,760
New backbone	(ls)	25,000	1	25,000										25,000
Upgrade existing tel/data rooms	(no)	30	10,000	300,000										300,000
Subtotal Telecom Costs				**528,280**			**11,700**			**5,760**			**16,020**	**561,760**
Markups (24%)				126,787			2,808			1,382			3,845	134,822
Escalation (4%/annum)			10.0%	52,828		22.0%	2,574		34.0%	1,958		52.0%	8,330	65,691
Total Telecom Costs				**707,895**			**17,082**			**9,101**			**28,195**	**762,273**

TABLE 6-8 : CIVIL INFRASTRUCTURE

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
New water line	(m)	580	443	256,940	240	443	106,320	330	443	146,190	135	555	74,925	584,375
New sanitary sewer	(m)	535	293	156,755	30	250	7,500	10	250	2,500	20	250	5,000	171,755
New storm sewer	(m)	140	1,000	140,000				170	1,000	170,000	195	1,100	214,500	524,500
Rock excavation	(m3)	1,620	47	76,642	30	50	1,500	10	50	500	20	50	1,000	79,642
Connections to existing	(no)	4	3,750	15,000	7	3,750	22,500	2	3,750	7,500	7	3,214	22,500	67,500
Storm water ponds	(m3)	3,900	50	195,000										195,000
Relocate storm sewer	(m)	575	500	287,500										287,500
New pump station	(ls)	250,000	1	250,000										250,000
Manholes, meters & misc.	(ls)	255,703	1	255,703	120,500	1	120,500	97,000	1	97,000	139,000	1	139,000	612,203
Subtotal Civil Infrastructure Costs				**1,633,540**			**258,320**			**423,690**			**456,925**	**2,772,475**
Markups (24%)				392,050			61,997			101,686			109,662	665,394
Escalation (4%/annum)			10.0%	163,354		22.0%	56,830		34.0%	144,055		52.0%	237,601	601,840
Total Civil Infrastructure Costs				**2,188,944**			**377,147**			**669,430**			**804,188**	**4,039,709**

TABLE 6-9: EXISTING UTILITY UPGRADES

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
Mechanical Upgrades														
Replace existing AHU's	(cfm)	182,190	6	1,061,494										1,061,494
Replace existing ductwork headers @ replaced AHU's	(lbs)	30,000	8	240,000										240,000
Condensing units for AHU's	(no)	7	12,500	87,500										87,500
Miscellaneous Terminal units and pipe to mech rooms	(no)	10	3,490	34,896										34,896
Upgrade McQuay Chillers	(ls)	50,000	1	50,000										50,000
Replace Centrifugal Chiller at CUB	(ton)	1,000	550	550,000										550,000
Increase existing HVAC loop to 16" & 10"	(m)	7,600	660	5,016,000										5,016,000
Piping Stress Analysis	(ls)	25,000	1	25,000										25,000
Modifications to operating temperature	(ls)	10,000	1	10,000										10,000
Reconfigure boiler at CUB	(ls)	25,000	1	25,000										25,000
Modify thermal storage piping	(ls)	10,000	1	10,000										10,000
Change pumps and add VFD's	(ls)	110,000	1	110,000										110,000
Controls Upgrades														
Upgrade existing controls from EMNET to Johnson	(pts)	1,700	1,000	1,700,000										1,700,000
miscellaneous terminal units/plumbing electrical etc.		50	640	32,000										32,000
Electrical Upgrades														
Replace existing generator	(kw)	500	280	140,000										140,000
New generator at CUB	(kw)				800	250	200,000							200,000
Emergency Generator installation	(kw)	500	100	50,000	800	80	64,000							114,000
Reconfigure emergency loading, ATS's, switches etc.	(ls)	280,000	1	280,000										280,000

TABLE 6-9: EXISTING UTILITY UPGRADES

		Construction Phase												
		Phase 1 2007 - 2012			Phase 2 2010 - 2015			Phase 3 2013 - 2018			Phase 4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	**Grand Total Costs**
MI cable to existing buildings	(m)	1,500	394	591,000										591,000
Wiring for replace AHU's	(ls)	46,600	1	46,600										46,600
Upgrade Fire Alarm for replaced AHU's	(ls)	17,500	1	17,500										17,500
Rewire existing Tel/data rooms	(no)	1	75,000	75,000	1	75,000	75,000	1	75,000	75,000	1	75,000	75,000	300,000
Power factor correction	(no)	17	7,500	127,500										127,500
Harmonics Analysis	(ls)	20,000	1	20,000										20,000
Test and replace existing 13.8kv feeder	(ls)	110,000	1	110,000										110,000
Civil Upgrades														
Repair broken lines, repair pumps and inspect system	(ls)	45,000	1	45,000										45,000
Construct new 150mm water line	(m)	190	500	95,000										95,000
Subtotal Existing Upgrades				**10,549,490**			**339,000**			**75,000**			**75,000**	**11,038,490**
Markups (24%)				2,531,878			81,360			18,000			18,000	2,649,238
Escalation (4%/annum)			10.0%	1,054,949		22.0%	74,580		34.0%	25,500		52.0%	39,000	1,194,029
Total Existing Upgrade Costs				**14,136,316**			**494,940**			**118,500**			**132,000**	**14,881,756**

6.13 Phased Cost Breakouts

TABLE - 6-10: PHASE 1 COST SUMMARY

	No Expansion 2007 - 2012			Chiller Plant 2007 - 2012			Heating Plant 2007 - 2012			Electrical Plant 2007 - 2012			B5 - Welsh Addition 2007 - 2012			B1/B6 2007 - 2012			
	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Grand Total Costs
Building Costs (m2)				280	2,138	598,640	280		633,655	200	2,052	410,445							1,642,740
Chiller Plant Costs (ton)				1,000	1,116	1,115,983													1,115,983
Cogeneration Plant Costs (kWe)																			0
Heating Plant Costs (mbh)							24,000	54	1,289,660										1,289,660
Distribution Costs															226,033			385,864	611,897
Electrical Costs												2,041,651							2,041,651
Telecom Costs			520,000												1,800			6,480	528,280
Civil Infrastructure Costs															95,000			1,538,540	1,633,540
Existing Upgrade Costs			10,549,490																10,549,490
Subtotal Phase 1 Costs			**11,069,490**			**1,714,623**			**1,923,315**			**2,452,096**			**322,833**			**1,930,884**	**19,413,241**
Markups (24%)			2,656,678			411,510			461,596			588,503			77,480			463,412	4,659,178
Escalation (4%/annum)		10.0%	1,106,949		10.0%	171,462		10.0%	192,331		10.0%	245,210		10.0%	32,283		10.0%	193,088	1,941,324
Total Phase 1 Costs			**14,833,116**			**2,297,595**			**2,577,242**			**3,285,809**			**432,596**			**2,587,385**	**26,013,743**

TABLE 6-11: PHASE 2 COST SUMMARY

	No Expansion / Common 2010 - 2015			Chiller Plant 2010 - 2015			Heating Plant 2010 - 2015			Electrical Plant 2010 - 2015			Cogenration Plant 2010 - 2015			B7 2010 - 2015			Schmon 2010 - 2015			
	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Grand Total Costs
Building Costs (m2)													300	2,247	674,168							674,168
Chiller Plant Costs (ton)				700	1,936	1,355,109																1,355,109
Cogeneration Plant Costs (kWe)													4,800	1,500	7,200,000							7,200,000
Heating Plant Costs (mbh)							10,000	49	485,146													485,146
Distribution Costs																		245,347			592,725	838,072
Electrical Costs												458,500										458,500
Telecom Costs																		4,500			7,200	11,700
Civil Infrastructure Costs																		175,820			82,500	258,320
Existing Upgrade Costs			339,000																			339,000
Subtotal Phase 2 Costs			**339,000**			**1,355,109**			**485,146**			**458,500**			**7,874,168**			**425,667**			**682,425**	**11,620,015**
Markups (24%)			81,360			325,226			116,435			110,040			1,889,800			102,160			163,782	2,788,804
Escalation (4%/annum)	22.0%		74,580	22.0%		298,124	22.0%		106,732	22.0%		100,870	22.0%		1,732,317	22.0%		93,647	22.0%		150,134	2,556,403
Total Phase 2 Costs			**494,940**			**1,978,459**			**708,314**			**669,410**			**11,496,285**			**621,474**			**996,341**	**16,965,222**

TABLE 6-12: PHASE 3 COST SUMMARY

		No Expansion / Common 2013 - 2018			Chiller Plant 2013 - 2018			Heating Plant 2013 - 2018			Cogenration Plant 2013 - 2018			B2 2013 - 2018			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Grand Total Costs
Building Costs	(m2)																0
Chiller Plant Costs	(ton)				1,850	1,185	2,192,400										2,192,400
Cogeneration Plant Costs	(kWe)										4,800	1,500	7,200,000				7,200,000
Heating Plant Costs	(mbh)									627,720							627,720
Distribution Costs																418,684	418,684
Electrical Costs																	0
Telecom Costs																5,760	5,760
Civil Infrastructure Costs																423,690	423,690
Existing Upgrade Costs				75,000													0
Subtotal Phase 3 Costs				**75,000**			**2,192,400**			**627,720**			**7,200,000**			**848,134**	**10,943,254**
Markups (24%)				18,000			526,176			150,653			1,728,000			203,552	2,626,381
Escalation (4%/annum)			34.0%	25,500		34.0%	745,416		34.0%	213,425		34.0%	2,448,000		34.0%	288,365	3,720,706
Total Phase 3 Costs				**118,500**			**3,463,992**			**991,797**			**11,376,000**			**1,340,051**	**17,290,341**

TABLE 6-13: PHASE 4 COST SUMMARY

		No Expansion / Common 2016 - 2024			Chiller Plant 2016 - 2024			Heating Plant 2016 - 2024			B3 2016 - 2024			B4 2016 - 2024			
		Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Unit	Unit Cost	Total Cost	Grand Total Costs
Building Costs	(m2)																0
Chiller Plant Costs	(ton)				950	1,074	1,020,295										1,020,295
Cogeneration Plant Costs	(kWe)																0
Heating Plant Costs	(mbh)							12,000	41	488,886							488,886
Distribution Costs													756,235			362,953	1,119,188
Electrical Costs																	0
Telecom Costs													10,800			5,220	16,020
Civil Infrastructure Costs													396,425			60,500	456,925
Existing Upgrade Costs				75,000													0
Subtotal Phase 4 Costs				**75,000**			**1,020,295**			**488,886**			**1,163,460**			**428,673**	**3,176,314**
Markups (24%)				18,000			244,871			117,333			279,230			102,882	762,315
Escalation (4%/annum)			52.0%	39,000		52.0%	530,553		52.0%	254,221		52.0%	604,999		52.0%	222,910	1,651,683
Total Phase 4 Costs				**132,000**			**1,795,718**			**860,440**			**2,047,690**			**754,464**	**5,590,313**