UMCP UTILITIES MASTER PLAN

FINAL SUBMISSION

University of Maryland College Park

JUNE 2012

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DIVISION NO. 1 - EXECUTIVE SUMMARY

1.1 OBJECTIVE

The University of Maryland College Park (UMCP) has recently completed a facility planning effort that has established a long term vision for the campus. Consequently, this Utility Master Plan was developed to support the long term vision of the campus as well as provide guidance in achieving the additional goals of maintaining a reliable, cost effective and sustainable utility infrastructure.

1.2 BACKGROUND

The UMCP Campus includes approximately 13.5 million gross square feet of building facilities to support the mission of the University. The operation of these buildings is reliant upon the utility infrastructure to maintain operations. The primary systems that comprise the campus utility infrastructure include:

- Steam
- Chilled Water
- Electric
- Domestic Water
- Sanitary Sewer
- Storm water collection

These utility systems were divided into two categories. The “energy systems” which include steam, chilled water and electric require the purchase of fuel or electric to operate and therefore maximizing the associated efficiency has direct impact on energy costs and environment emissions. The second category of “water systems” provides a critical service of supplying domestic water to buildings while ensuring the sanitary and storm water flows are effectively carried off of the campus.

The current campus planning has identified future campus development totaling approximately 6.4 million square feet which represents a 50% increase compared to the existing campus. This growth was divided into two phases. The first phase represents new construction and renovation projects anticipated to occur within the next 10 years. The second phase of identified growth was targeted for the years 11 through 20. A site plan indicating the current UMCP planning is presented in Figure No.1-1.

The existing utility conditions were compared to the projected growth to identify utility requirements needed to facilitate the multiple phases of new facilities. Utility projects were established for each phase to upgrade existing utility systems and expand capacities consistent with future load projections.

1.2.1 Central Steam System

The Energy Plant provides steam to approximately 11.3 million square of building facilities on the UMCP campus. The Energy Plant has been operated by the Suez Energy (formerly Trigen) for the past eight years and this arrangement is contracted to continue through 2017. Suez Energy is responsible for maintaining the Energy Plant, steam distribution and the Satellite Central Utility Building No. 4.

The primary source of the steam generated as the Energy Plant is from the cogeneration system that is comprised of two 10.5 megawatt combustion turbines with Heat Recovery Steam Generators (HRSG) that total 280,000 pph of steam generation capacity. The plant also maintains two 45-year old standby boilers with a combined capacity of 213,000 pph. While these boilers are currently maintained in a reliable condition, they are beyond the average life for an industrial boiler. A replacement cost allocation for the standby boilers has been included towards the end of Phase No. 1. The combustion turbines are eight years old and are anticipated to require overhauls or replacement within the first phase as well and an associated cost has been budgeted.

The combustion turbines were installed in 1998, and in 2002 the Central Heating Plant upgraded the existing auxiliaries to the existing boiler plant. The work included the instrumentation and controls for Boiler Nos. 2 and 4, including new burners, installing two new deaerators, new feed water pumps, new condensate pumps, and new condensate polishers.

The plant also has a back-pressure turbine that is capable of generating 4,900 kW. At design air conditions the plant can generate a total of 25.9 MW, but during a typical summer condition the plant can only generate 17 MW.

The current peak boiler load for the site is approximately 245,000 pph. The firm capacity of the plant is considered the steam generation without the availability of the largest single unit. Maintaining a firm capacity greater than the peak load is a standard level of reliability. For the UMCP Energy Plant the firm capacity of 353,000 pph is significantly higher than the 245,000 pph peak load.

The future campus development is anticipated to increase the peak steam load to 330,000 pph over the next 20 years (Phase Nos. 1 and 2). The current capacity configuration is adequate to support this load growth; however, because of the age of the existing equipment, replacement costs should be budgeted. The major replacement interval anticipated within the next 10 years presents an opportunity to evaluate alternative steam generation concepts and establish a long term plan for system flexibility.

Several options were developed as potential capacity replacements to occur within the next 10 years. A preliminary evaluation was performed to assess whether there would be a significant economic advantage to immediately implementing the alternative energy options as well as establishing the future direction of the campus steam system. Five primary options were considered and are listed below:

- Option No. 1 : 20 MW of combustion turbines with natural gas-fired boilers in the existing Energy Plant
- Option No. 2 : All natural gas-fired boilers in the existing Energy Plant with no cogeneration in the existing Energy plant
- Option No. 3 : 20 MW of combustion turbines in the existing Energy Plant and a new plant with a 10 MW combustion turbine
- Option No. 4 : All natural gas-fired boilers in the Energy Plant and a new plant with a 150,000 pph biomass boiler system
- Option No. 5 : 20 MW of combustion turbines in the Energy Plant and a new plant with a 150,000 pph biomass boiler system

Option Nos. 1 and 2 are based upon relying on the existing Energy Plant site to support the future steam needs of the entire campus. As a result of the proposed East Campus Development there are limitations being imposed upon the existing site that would prohibit a major expansion of the existing building. For technologies that require a significant increase in area a new plant site was established on the north half of campus. Option Nos. 3, 4 and 5 include the development of this new plant location, but also include maintaining the existing Energy Plant site for at least the next 20 years included in the future planning cycle.

Option Nos. 4 and 5 include developing a biomass energy plant consistent with the University's climate action plan. The plant capacity was limited for this analysis to 150,000 pph based upon the distribution infrastructure between the proposed plant site and the campus load centers. Ultimately under future scenarios (beyond 20 years) additional piping can be added to expand the export and generation capacity of the new plant, possibly allowing the retirement of the existing Energy Plant.

The primary challenges with the implementing a biomass plant or the concept of additional cogeneration (Option No. 3) include equipment staging and the operations of multiple heating plants. Currently the steam load and existing cogeneration system are well balanced. There is adequate steam load to base load the cogeneration system, but the peak thermal load does not exceed the capacity of the HRSG. Even under future load scenarios supplement steam capacity would be needed for only about 3,000 hours per year. Therefore, a biomass system would be competing for operation versus and existing cogeneration system. The second challenge of operating multiple steam plants is the additional labor costs and complications in equipment staging and condensate return. While these issues represent formidable challenges, the application of biomass plant is feasible and was evaluated on a life cycle cost basis. The following are the results of the life cycle cost comparison of the five options:

Option No.	Total Capital Cost	Annual Savings	25-year Present Value of Life Cycle Costs	Carbon Reduction
1	$20 million	$4.7 million/yr	$917 million	17,400 TPY
2	$38 million	- - -	$1,022 million	---
3	$89 million	$5.4 million/yr	$973 million	19,100 TPY
4	$107 million	$1.5 million/yr	$1,063 million	73,300 TPY
5	$89 million	$6.7 million/yr	$949 million	69.600 TPY

Option No. 1 which can be considered a status quo approach has the lowest life cycle cost; however, the life cycle cost of Option No. 5 is within 4% and if future parameters change, this option could become the most cost effective approach. The key parameter for the biomass option is the potential fuel cost and long term availability. While there are currently no biomass fuels which could be secured for a long term supply (10 years or more) at a cost comparable to natural gas; future opportunities may arise that facilitate a cost effective fuel supply. In summary there is not an economic justification for the immediate implementation of a biomass plant; however, it is feasible that future market conditions could result in a cost effective alternative energy facility. Therefore, the University should maintain flexibility and allocate area for a potential plant location on the north half of campus.

The existing steam distribution has adequate capacity to support the current and future loads. A discrepancy was noted in the amount of steam exported from the plant and the total steam metered at the buildings. The building steam was 22% less than the export steam which could be the result of metering inaccuracies; however, to confirm this, a leak survey of the steam distribution is recommended.

Steam and condensate losses are inherent in all central steam systems and vary depending upon the age and condition of the piping as well as the steam use and condensate return within the buildings. A general evaluation of implementing hot water districts (fed from the central steam system) was performed to assess the economic viability of a partial hot water distribution system. The evaluation resulted in favorable economics for a district hot water system provided the connected buildings did not directly utilize steam for heating or process loads.

Based upon these results, new building projects should evaluate utilizing a district hot water system that originates in a Satellite Central Utility Building and is distributed directly to the building systems.

1.2.2 Chilled Water System

The majority of the campus buildings are connected to one of eight existing Satellite Central Utilities Buildings (SCUBs) located throughout campus to generate and distribute chilled water. The SCUB concept has the advantages of a district energy system in that each plant serves a diversified cooling load utilizing efficient, water-cooled chiller technology. The system has grown to eight SCUBs with two more currently in development. There are currently 30 chillers installed in the existing SCUBs. Within the next five years 16 of the chillers will be beyond an average life of 25 years. While exceeding the average equipment life does not necessitate replacement; the older units typically are less efficient, less reliable and tend to be more maintenance intensive. The replacement of each unit should be evaluated on a chiller-by-chiller basis; however, for this analysis allocation of costs for equipment replacement after 25 years of operation was established.

The proposed future projects identified in Phase Nos. 1 and 2 of the future campus planning will increase the total campus cooling load by 42%. Considering the upcoming chiller replacements and need for new capacity, various options were developed for comparison to the current approach of developing SCUBs to serve the campus chilled water needs. These options built upon the advantages of district cooling and considered consolidation of the existing SCUBs into larger districts or a single central chilled water system. The following are options evaluated:

- Chilled Water SCUBs (district cooling approach)
- 3 Regional Chiller Plants (Northwest, Northeast and South Campuses)
- 2 Regional Chiller Plants (North and South Campus)
- A Central Chilled Water Plant

The option comparison was based upon life cycle costs that include annual energy and maintenance costs as well as capital costs for new chilled water plants and interconnecting distribution piping. The two significant challenges associated with consolidating the existing SCUBs into large districts are the cost and feasibility of install large diameter interconnecting chilled water piping in congested utility corridors and identifying locations for significant size district plants. Prior to addressing these challenges in detail and life cycle cost analysis was developed to determine if the consolidated options warrant further investigation. The present value of the life cycle costs for each option is summarized below:

Option	Chiller & Plant Capital Costs ($million)	Piping Capital Costs ($million)	Present Value of Capital Costs ($million)	Present Value of Annual Costs ($million)	Total Present Value ($million)
SCUBs	59.9	10.9	41.7	86.9	128.5
3 Regions	67.8	26.3	58.3	81.9	140.1
2 Regions	66.6	30.1	65.6	81.6	147.2
Central	59.1	50.7	75.0	79.4	154.4

The preferred approach is the continued development of chilled water SCUBs for future campus growth.

1.2.3 Electrical System

The UMCP campus is provided electric power from the Potomac Electric Power Company (PEPCO) through the University owned Mowatt Substation. The PEPCO power supply includes six 13.8 kV feeders into the Mowatt Substation which serve nine pairs of UMCP distribution feeders. The majority of buildings are connected to a primary feeder and secondary backup feeder for reliability.

The peak electric load of the campus is approximately 45.7 MW which is approximately 20% lower than the firm capacity of the substation (58.0 MW).

The existing combined heat and power plant (CHP) includes two 10.5 MW natural gas combustion turbines and a single 4,900 kW steam turbine. The capacities are based upon ISO conditions (nameplate). Ideally the two combustion turbines would provide power to the campus in the event of a PEPCO power outage. The total output of the CHP during summer conditions is approximately 21 MW (nameplate capacity) which is approximately 45% of the peak load of the campus, therefore during a PEPCO outage the CHP could support a significant portion of the campus electric load. Currently the distribution feeders that connect the CHP to the electric infrastructure include multiple building connections as well. In order to direct the CHP power to the strategic campus loads, non-essential building loads would need to be manually switched off of the electrical distribution system in its present configuration.

System flexibility could be enhanced by a hardwire redistribution of the loads and the addition of two (2) feeders, as described later in this Master Plan document, and listed below:

A) Reconfigure the loads on feeders 1 through 4 that deliver power from the CHP to the Mowatt substation, so that there are no loads connected to Feeder 3. This would provide a direct 6.4 MW of generated capacity to be delivered to the Mowatt substation for distribution throughout the campus as dictated by conditions. This could also be completed by installing automatic controls.

B) Develop a new critical power feeder emanating from the Mowatt substation. This feeder would be dedicated to serving strategically selected loads deemed as critical to operation of the system in times of island-mode power operation, where the Utility is out of service. The University should plan to reconfigure building connections to establish a "Critical Feeder".

In the event of a PEPCO power outage, the on-site electrical generation could be selectively distributed throughout the campus with the installation of a Power Monitoring and Control system creating a "Smart Grid" network. This system would monitor power throughout the campus on a real-time basis, and could respond to a PEPCO power outage by automatically de-energizing non-critical loads and directing the generated power to selected areas. In theory, the Smart Grid could allow selected portions of the campus to remain energized throughout a PEPCO outage, but final determination of this capability will depend on the CHP response characteristics. The system would also be flexible enough to allow for selective switching of individual transformer loads of 1,000 kVA and larger, thereby enabling selective load shedding where necessary.

The priority of the three items identified is as follows:

1.) Install the Power Monitoring and Control System
2.) Install "Critical" power feeder
3.) Install the "Express" Feeder

The express feeder would be a back-up if the Power Monitoring and Control System were installed. The express feeder is still a recommendation, but is not a high priority.

Future campus development will increase the site electric load approximately 12 MW in Phase No. 1 and an additional 5 MW in Phase No. 2. After the initial phase of development the peak electric load will be essentially equal to the firm capacity of the Mowatt Substation. It is anticipated a second substation will be required to support the second phase of future growth. This second substation should be located on the north half of campus to maximize system reliability.

1.2.4 Alternative Energy Considerations

Several alternative energy options were also considered for campus wide implementation on the UMCP site. These options include geothermal, thermal storage and building energy conservation. Geothermal or ground coupled heat pumps systems were evaluated on both a small and large scale application for the UMCP campus. Because the cogeneration system generates steam cost effectively at a relatively low energy rate ($10.20 per Mlb), there is no distinct economic advantage to the implementing a major geothermal system on the campus. However, the steam rate for an individual building increases to approximately $15.00 per mlb. At this rate the smaller building systems results in an economic benefit; especially if the building is located a significant distance from the steam distribution and piping costs can be avoided.

Thermal storage for chilled water systems can be cost effective under the current rate structure because there is a significant difference between on and off peak electric rates. The challenge with implementing either a chilled water or ice storage system is the campus area required for the water or ice tank installation. In addition to fully evaluate the economic benefits, an hourly historic load profile is needed to establish the optimum capacity. Future metering will assist in establishing system load profiles. As existing SCUBs are expanded and new SCUBs built, thermal storage should be evaluated. Since the thermal storage system only shifts the electric load from daytime to nighttime and not reduce electric load, there is no sustainability benefits.

As the University strives to minimize building energy use, future load projections may decrease thereby deferring future capital projects. Evaluation of building energy measures should include the potential impact on the utility infrastructure in the economic analysis.

1.3 WATER SYSTEMS

1.3.1 Potable Water System

The UMCP potable water system is comprised of approximately 16.4 miles of water mains arrayed in an interconnected network around the main campus. The water mains, excluding services to individual buildings, are generally between 4 and 12 inches in diameter, consisting of both cement lined and unlined cast iron and cement lined ductile iron water pipe. The campus is supplied water from the Washington Suburban Sanitary Commission (WSSC) via ten separate meter locations around campus.

In addition to the monthly and daily WSSC consumption records, university building meter readings were summarized for the main campus to develop existing and future campus loads and individual building loads. Existing average water demands per square foot by building type were calculated by taking the existing building metering data and dividing it by the existing square footage of the building, and then by finding the average water demand per square foot of all similar buildings. Similar buildings were categorized as non-academic, auxiliary, academic, administration and library.

Future water demands were calculated based on water demand for projected future building square footage by building type, future Satellite Cooling Utilities Buildings (SCUBs), steam and power plant potable water demands, and existing buildings water demands.

An existing hydraulic model was updated based upon the existing and future water demands, and then utilized to evaluate the adequacy of pressure and fire flows for the entire campus for present and future water demand conditions. The modeling results indicate that under existing fire flow scenarios, the distribution system can meet the fire flow demand throughout the entire system except for the area around Fraternity Row and a few small diameter dead end mains. Similar results were found under future conditions. Existing hydrant flow field tests taken by University staff were compared with these results, which showed similar flow delivery problems in the vicinity of Fraternity Row.   Pressures under peak hour flow conditions were also checked and were satisfactory; pressures of 35 psi or more were found everywhere on campus.

The distribution system was also analyzed for the reliability of supply from the existing mains based on vulnerability review of historical water main breaks on campus. The campus was also broken down into specific zones for isolation during emergency situations and for development of unidirectional flushing and condition assessment programs. It was recommended that critical valves and hydrants be exercised annually and replaced as necessary. In addition to areas prone to water main breaks, areas where new buildings conflict with existing water mains were recommended for new water mains to create loops in the system and to meet the projected demands. Existing water mains with reduced hydraulic capacity, or a pertinent part of previously recommended capital improvement programs were recommended for cleaning and cement mortar lining or new water mains during Phase II improvements. Overall, the recommended program includes approximately 16,800 linear feet (3.2 miles) of water mains to be rehabilitated or replaced based on existing infrastructure needs and to support future development.

The remaining water mains (approximately 69,800 linear feet, or 13.2 miles) will need to be evaluated and repaired or replaced, as needed over time. The life of water mains is generally 50 to 100 years. Assuming a 100-year replacement cycle, one percent of the system (about 700linear feet) would be replaced each year. Table No. 4-10 estimates the annual project costs needed through Phases I, II and Beyond to renew the water distribution system at this rate, including construction contingencies, cost escalation over time and engineering and implementation costs. As shown in the table, approximately $202,300 would be needed per year through Phase I, $271,900 per year through Phase II, and $365,400 per year through Phase Beyond.

1.3.2 Wastewater System

The UMCP campus contains approximately 20.1 miles of sewer pipe that range from two-inch force mains to 21-inch diameter gravity lines. Almost all wastewater generated in the region is treated at the DC Water Blue Plains Wastewater Treatment Facility (WWTF) operated by the WSSC. Wastewater flow from the campus goes to the WSSC Anacostia 2 Wastewater Pumping station where it is pumped to the WWTF. UMCP has approximately 15 connections to the WSSC mains and discharges an estimated total peak flow of 7.7 mgd. A majority of the sewer interceptors on the campus flow from west to east and discharge into the WSSC main to the east of the campus. The remaining interceptors discharge into the WSSC mains located to the south of the campus.

In some locations, buildings that are proposed within the Master Plan are in direct conflict with existing sewers and either sewer relocation or building reconfiguration is required. In other locations, projected buildings are remote from existing sewer systems and new sewers will be required. Overall, a total of about 11,750 linear feet (2.2 miles) of new sewers may be needed due to conflicts with proposed buildings as currently shown on the campus Master Plan. The total opinion of probable project costs for sanitary sewer improvements is approximately $7.2 million (Table No. 4-12).

An analysis was performed on the capacity of the wastewater system and it was found that there are no capacity issues (existing or proposed) within the system. There are certain areas under both scenarios in which there are low flow velocities, (flow velocities less than the scour velocity of 2 feet per second (fps)). These areas will require more frequent maintenance.

The remaining sewers (approximately 94,295 linear feet, or 17.9 miles, including service connections) will need to be inspected and repaired or replaced as needed over time. A sewer system evaluation survey and television inspections should be conducted to prioritize sewer improvements. The life of sewer pipes is generally 50 to 100 years. Assuming a 100-year replacement cycle, one percent of the system (943 linear feet) would be replaced each year. Table No. 4-13 estimates the annual project costs needed through Phases I, II and Beyond to renew the sanitary sewer system at this rate, including construction contingencies, cost escalation over time and engineering and implementation costs. As shown in the table, approximately $427,000 would be needed per year through Phase I, $573,900 per year through Phase II, and $771,200 per year through Phase Beyond.

1.3.3 Stormwater System

The future development of the UMCP campus is a unique opportunity to improve the stormwater infrastructure of a broad watershed area, while incorporating sustainability measures that will ultimately lead to environmental benefit in the area. Looking at campus stormwater management holistically through this master plan has both cost and permitting advantages over parcel-by-parcel management. Master planning has the permitting benefit of being able to locate water quality treatment measures in one location to compensate for other areas where soils, groundwater, or space will not allow the siting of treatment measures.

Currently, the UMCP campus has 32.8 miles of drainage pipe and 13 permitted stormwater outfalls to Paint Branch. Outside the undeveloped wooded area in the northern end of the campus, the existing campus is moderately developed with dormitories, educational buildings, and athletic facilities.

The percent impervious ranges between 33 percent for the Campus Core to 62 percent for the East District. The total contributing drainage area to the UMCP project area is approximately 688 acres. Most of the campus, approximately 62 percent, is assigned to HSG “D” soils, which are predominantly clay and have a very slow infiltration rate. Approximately 27 percent of the campus is assigned to HSG “C” soils, which have a slow infiltration rate. Approximately 11 percent of the campus is assigned to HSG “B” soils, which provide moderate infiltration. This NRCS rating provides an indication on how well stormwater will infiltrate on the campus. HSG “D” soils are not rated for infiltration. The 2000 Manual prohibits the use of permeable pavement over HSG “D” soils. Thus, stormwater will be slow to infiltrate in many areas of the campus.

The existing capacity of the southeast, central and upper campus drainage systems was assessed and it was found that significant sections of the central and upper campus drainage systems are under capacity. Under future build-out conditions, the undersized pipes should be replaced or supplemented to provide the required capacity if system flow is not reduced.

Green infrastructure will be required on the campus to comply with Maryland’s Environmental Site Design (ESD) requirements for stormwater management. An additional benefit to installing green infrastructure is that it will reduce the required size of the under-capacity pipes identified in the pipe capacity analysis.

Because the existing site imperviousness is greater than 40 percent, the project is subject to redevelopment requirements, as described in Section 4.3.2.1. Thus, the project design must either decrease existing imperviousness within the limit of disturbance (LOD) by 50 percent or provide water quality treatment for an equivalent area and provide treatment for any new impervious area. Following is a summary of the drainage assumptions used for the design of the proposed green infrastructure facilities.

- The bioswale, used as a structural BMP, is designed to convey peak rates of runoff during a 25-year 24-hour storm to provide a higher safety factor.

- The HEC-HMS model assumes that 50 percent of the new buildings in the upper and middle watersheds will discharge roof runoff to ESD practices, such as rain gardens, or will have green roofs. It was further assumed that 70 percent of each roof would discharge to an ESD practice or will be green (to account for mechanical equipment on the roofs).

- Fifty percent of sidewalks and 100 percent of parking lots in favorable soils in the middle and upper watersheds were assumed to be constructed with permeable pavement. As stated in Section 4.3.2.3.1.1, the 2000 Manual has the requirement that permeable pavements shall not be installed in HSG "D" soils or on areas of compacted fill. Since most of the campus is located on HSG "D" soils, the ability to use permeable pavements is limited on this campus to areas where there are HSG "B" and "C" soils.

- ESD practices were designed assuming a surface area of 10,000 sf.

- Two underground flood storage areas, one each in the upper and middle watersheds, were designed to provide treatment and reduce peak discharge rates to the downstream stormwater collection system.

Rainwater collected from rooftops may be collected and stored in underground cisterns or chambers for reuse within the building or for irrigation. It is recommended that rainwater from a 1.3-inch or smaller storm, which represents approximately 90 percent of all storms in the College Park area climate, be stored and reused. An analysis was performed on the reuse of rainwater, which assumes that water may be conveyed from the rooftop areas and storage sites to the areas in which it is needed, which appears feasible based on the layout of the Master Plan. It is recommended that the tanks are sized such that they have sufficient capacity to capture the 1.3-inch storm, as during the summer the entire volume may be reused for aiding to meet non-potable demands.

The UMCP Facilities Master Plan includes 17 cisterns on Campus Stormwater Mapping (Appendix 5.5.3). The average new roof area is approximately ½ acre (not including buildings greater than 85,000 square feet). Sizing the tank for capturing a 1.3-inch storm yields an 18,000-gallon tank. If a 20,000-gallon tank were installed, it would provide sufficient water to maintain a 0.2-acre green area during a 4-week drought.

As shown on Tables 4-18 and 4-19, the estimated total project cost of ESD practices is $32.2 million and structural BMPs is $31.6 million.

The future build-out pipe capacities of the southeast, central and upper campus drainage systems were assessed assuming green infrastructure. The size of a replacement pipe needed to convey the 10-year storm future flows was determined. The calculated size of a relief pipe needed, which assumes the existing pipe remains in place, was also estimated.

The capacity analyses for the southeast campus system indicate that the system is adequate for existing and future conditions with green infrastructure. The capacity analyses for the central campus system indicate that the system is undersized east of Baltimore Avenue. The capacity analyses for the upper campus system indicate that most of the drainage system is under capacity and needs to be upsized. As shown on Table No. 4-20, the total estimated project cost for new drains is $10.3 million (sized assuming green infrastructure is constructed). Overall, the UMCP drainage system consists of approximately 173,099 linear feet (32.8 miles) of existing drains. The Utilities Master Plan includes approximately 28,870 linear feet (5.5 miles) of new drains for drain replacements related to campus development in the Campus Master Plan and for new pipes needed to address capacity issues. The remaining drains (approximately 144,229 linear feet, or 27.3 miles) will need to be inspected and repaired or replaced as needed over time. The life of drain pipes is generally 50 to 100 years. Assuming a 100-year replacement cycle, one percent of the system (1,442 linear feet) would be replaced each year. Table No. 4-21 estimates the annual project costs needed through Phases I, II and Beyond to renew the drainage system at this rate, including construction contingencies, cost escalation over time and engineering and implementation costs. As shown in the table, approximately $783,800 would be needed per year through Phase I, $1.1 million per year through Phase II, and $1.4 million per year through Phase Beyond.