6 INFRASTRUCTURE AND UTILITIES

6 INFRASTRUCTURE AND UTILITIES

Campus life is supported by a physical network of buildings and infrastructure systems that manage the energy and water flows on campus. It is critical that these systems reliably support existing campus operations and allow for future expansion. The UC system's Sustainable Practices Policy places strict requirements on campus energy and water systems, including carbon neutrality from operations by 2025, a 20% per-capita water use reduction by 2020, followed by an additional 36% reduction of the same by 2025.

This Master Plan Study provides guidance for the planning of campus buildings and infrastructure systems such that future growth can be reliably supported and environmental goals met. This involves balancing the cost and resource savings advantages of combining existing systems with the efficiency gains that can be made by implementing new systems.

Glossary of Terms

Energy Efficiency Measure (EEM) - A modification made to a building's systems or operation that is intended to reduce annual energy consumption

Energy Use Intensity (EUI) - A building's annual energy use, as consumed on-site, measured in kBtu/ft2/year

Solar Heat Gain Coefficient (SHGC) - The fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward

Solar fraction - The ratio of solar energy input to total energy input (normally including natural gas) in a solar powered system

Thermal Mass - High thermal capacity building constructions, such as brick or concrete, that can reduce internal temperature fluctuations by usefully absorbing and releasing heat over time

STRATEGIC PRIORITIES

- Reduce building carbon emissions, increase energy efficiency in current building stock and design highly efficient new buildings, such that specified Energy Use Intensity (EUI) targets are met
- Increase redundancy in the campus power network, employ a combination of building energy efficiency upgrades, local photovoltaic (PV) generation, and demand side management, to reduce load on existing feeders and sub-stations
- Connect new Core Campus buildings to the existing chilled water network and consider replacement of existing chillers with high-efficiency magnetic bearing models
- Study the costs and benefits of decommissioning the steam network and transitioning to supplying the majority of campus heating needs through localized electric heat pumps for significant carbon savings
- Develop an integrated approach to stormwater management and quality by adopting a campus-wide approach and identifying opportunities for multiple benefits

Figure 6.1 CAMPUS ENERGY USE AND CARBON EMISSIONS (MtCO2e) [1]

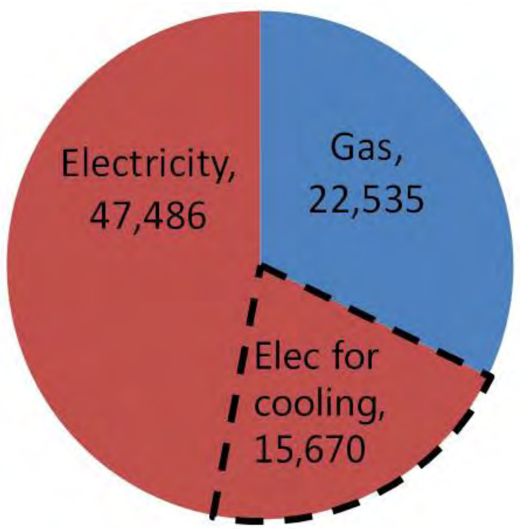
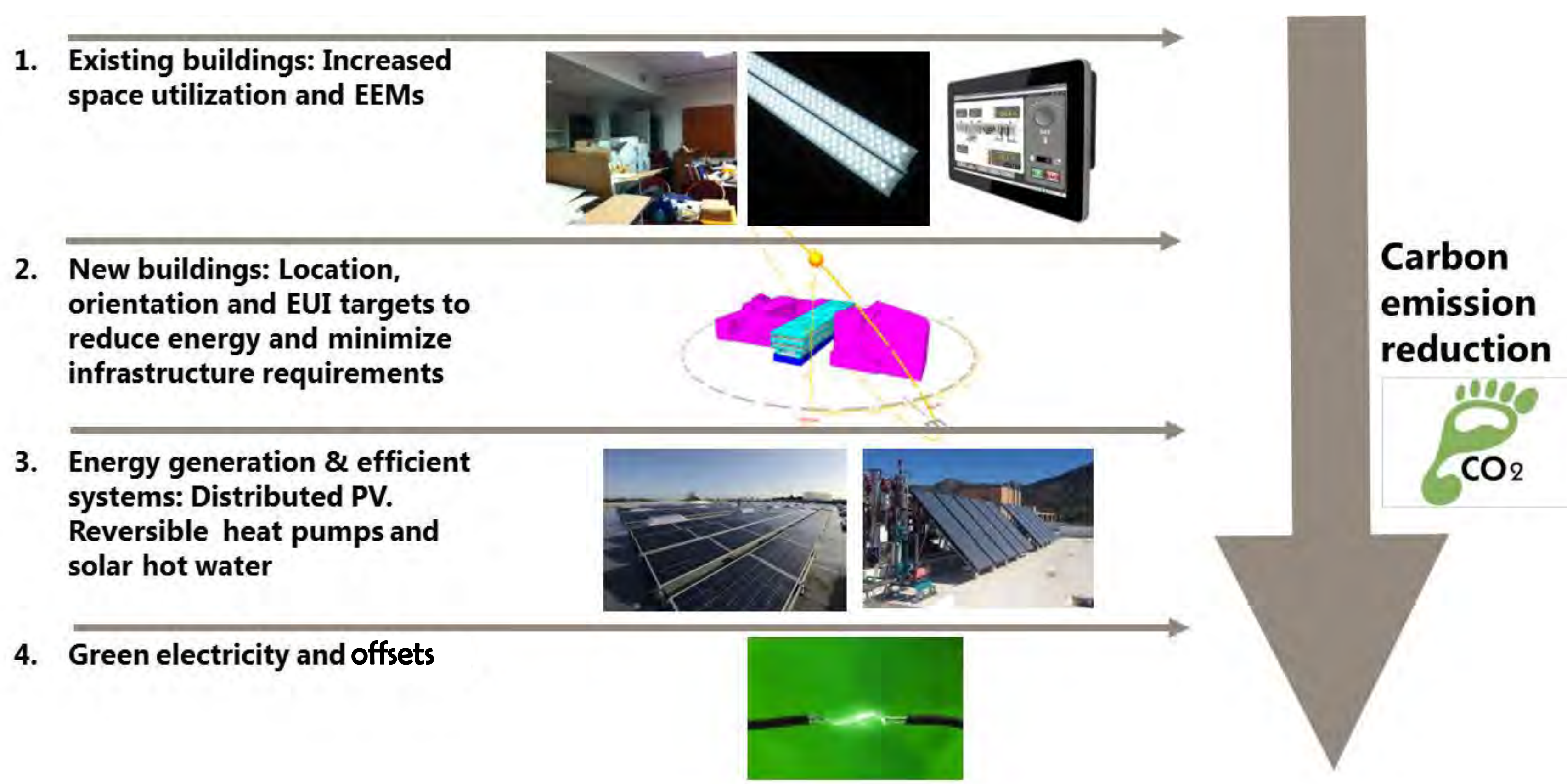


Figure 6.2 ACHIEVING CARBON EMISSION REDUCTIONS THROUGH SUCCESSIVE ENERGY EFFICIENCY MEASURES



[1]"Electricity for cooling" is a calculated value based on campus building energy models only, as no annual campus cooling data was available. "Electricity" and "Gas" are numbers quoted from campus utility bills. "Electricity" includes all electricity, including that devoted to cooling. Campus fleet emissions are not included but these are small in comparison to built environment emissions, 1764 MtCO2e.

6.1 Vision

In the fiscal year 2014/2015, the university consumed 123,900 MWh of electricity. Of this, 3,900 MWh was generated by the West Campus PV farm; the rest was supplied by Riverside Public Utilities. During the same period the campus consumed 3,900,000 therms of natural gas. This energy use is responsible for the release of around 67,000 MtCO2e (assuming 824 lb CO2/MWh electricity and 117 lb CO2/MMBtu natural gas.) Fig. 6.1 shows the amount of carbon emissions produced by electricity used for cooling.

In order to reduce campus carbon emissions to zero by 2025 an integrated approach is needed to improve campus efficiency while supporting campus growth. This Master Plan Study outlines a menu of options that can bring the campus's power, cooling, and heating carbon emissions to carbon neutrality, while increasing system redundancy where necessary. This begins with addressing energy efficiency in existing buildings and moves through proposed new buildings, campus level heating and cooling efficiency, on-site renewables and the purchasing of Renewable Energy Certificates (RECs) and offsets. Fig. 6.2 shows this process.

The other major component of campus infrastructure planning is water. A campus-wide approach to the water system and sanitary sewer system infrastructure analysis allows the University to comprehensively review the systems to determine areas for recommended improvements, upgrades and conservation opportunities.

University stormwater management analyses and recommendations are provided to ensure future development helps the University comply with its permit requirements and that best management practices are properly implemented.

6.2 Methodology: Carbon Model Review

The carbon modeling process consisted of creating energy models of each building typology for annual heating, cooling, and power demands (described in more detail in the Energy Modeling section below.) These demands were multiplied across existing and future campus program areas in order to predict campus demands in 2025. The Planning Team then constructed a campus carbon model by assuming the following:

- No major existing building renovations
- New buildings built to Title 24 California Energy Code minimum standards
- All existing and new core buildings to be connected to the chilled water network with no changes made to chilled water central plant
- All existing core buildings to remain connected to the steam network with no changes made to the steam plant
- All new buildings to be heated by local gas-fired condensing boilers

The model yielded a predicted, business-as-usual carbon emission figure. Those measures, when individually applied and compared to the baseline, are characterized by a total campus carbon emission reduction as a percentage of the baseline total. This provides a clear metric with which to compare reduction measures. The heating and cooling sections below analyze system options through their carbon reduction potential as well as their ability to reliably support campus expansion.

By combining building level measures with suggested campus heating and cooling strategies, a potential whole-campus carbon reduction strategy can be implemented. Fig. 6.4 outlines a series of step-wise reductions.

Figure 6.3 CARBON MODELING PROCESS

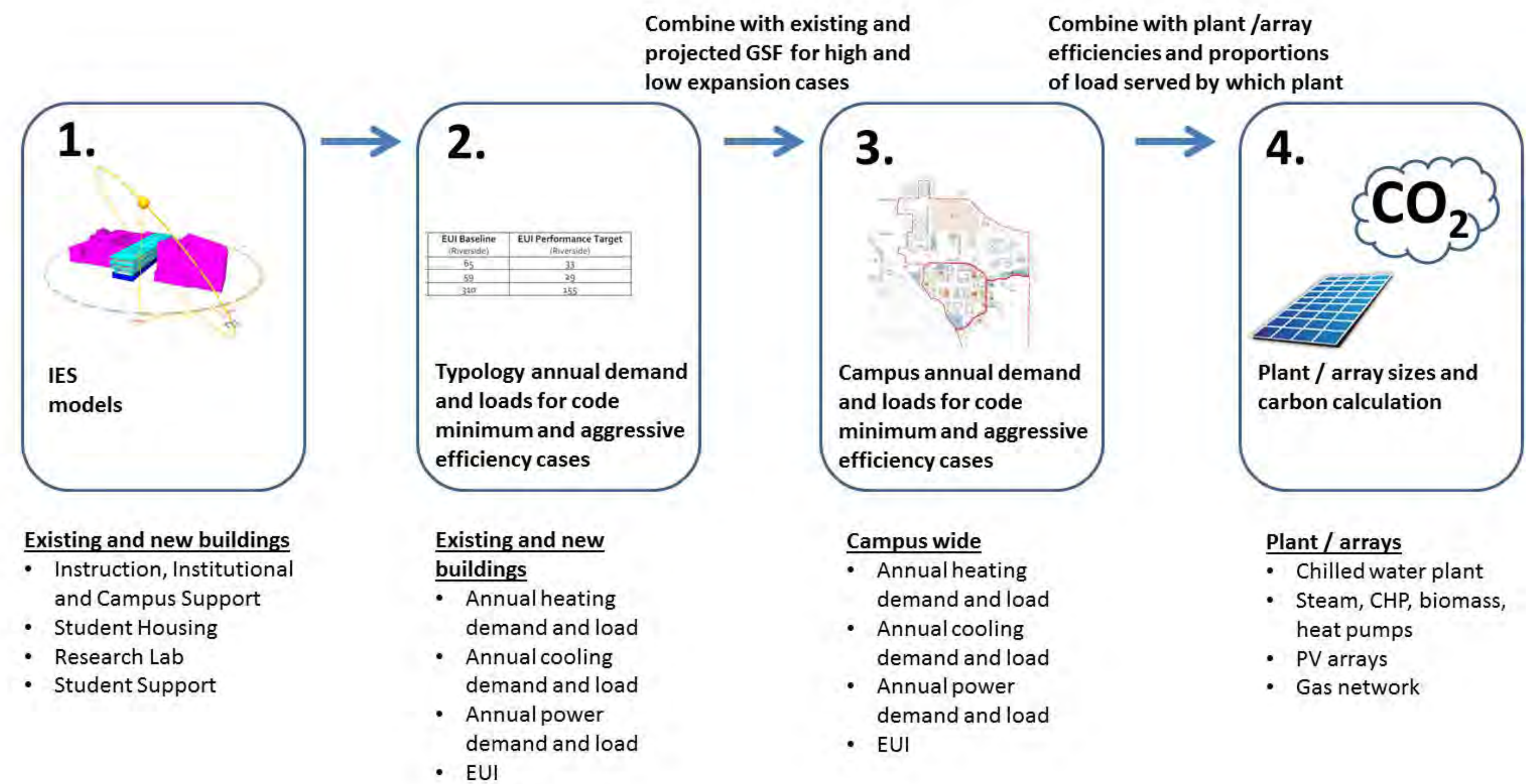


Figure 6.4 STEP-WISE CARBON REDUCTION STRATEGY (Refer to Chapter 7 for further analysis of carbon reduction scenarios.)

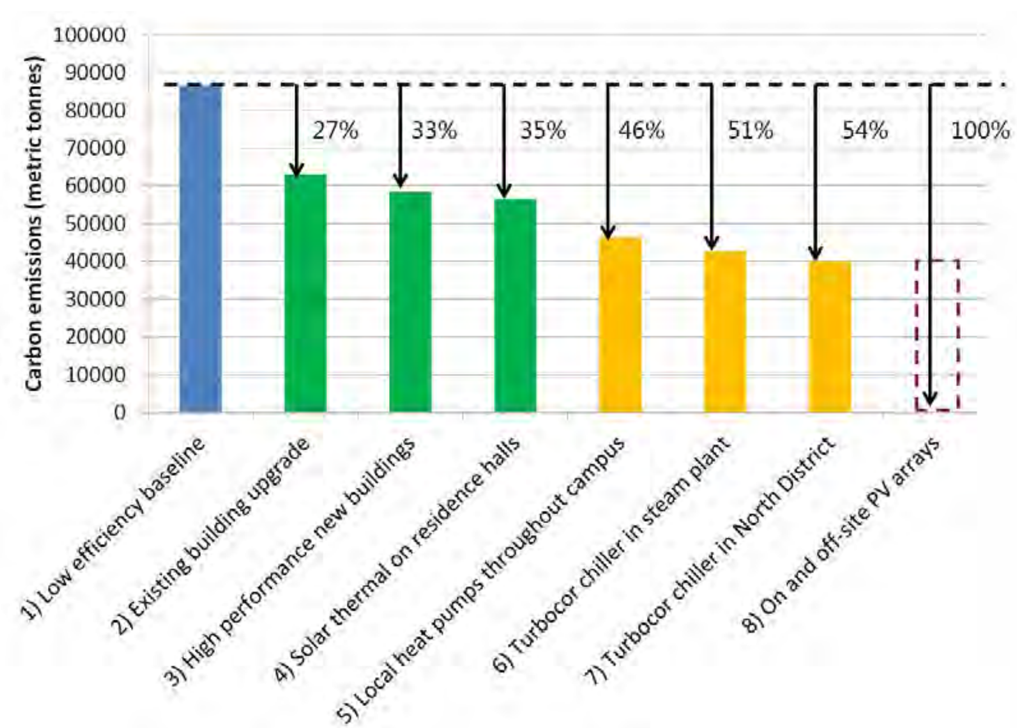
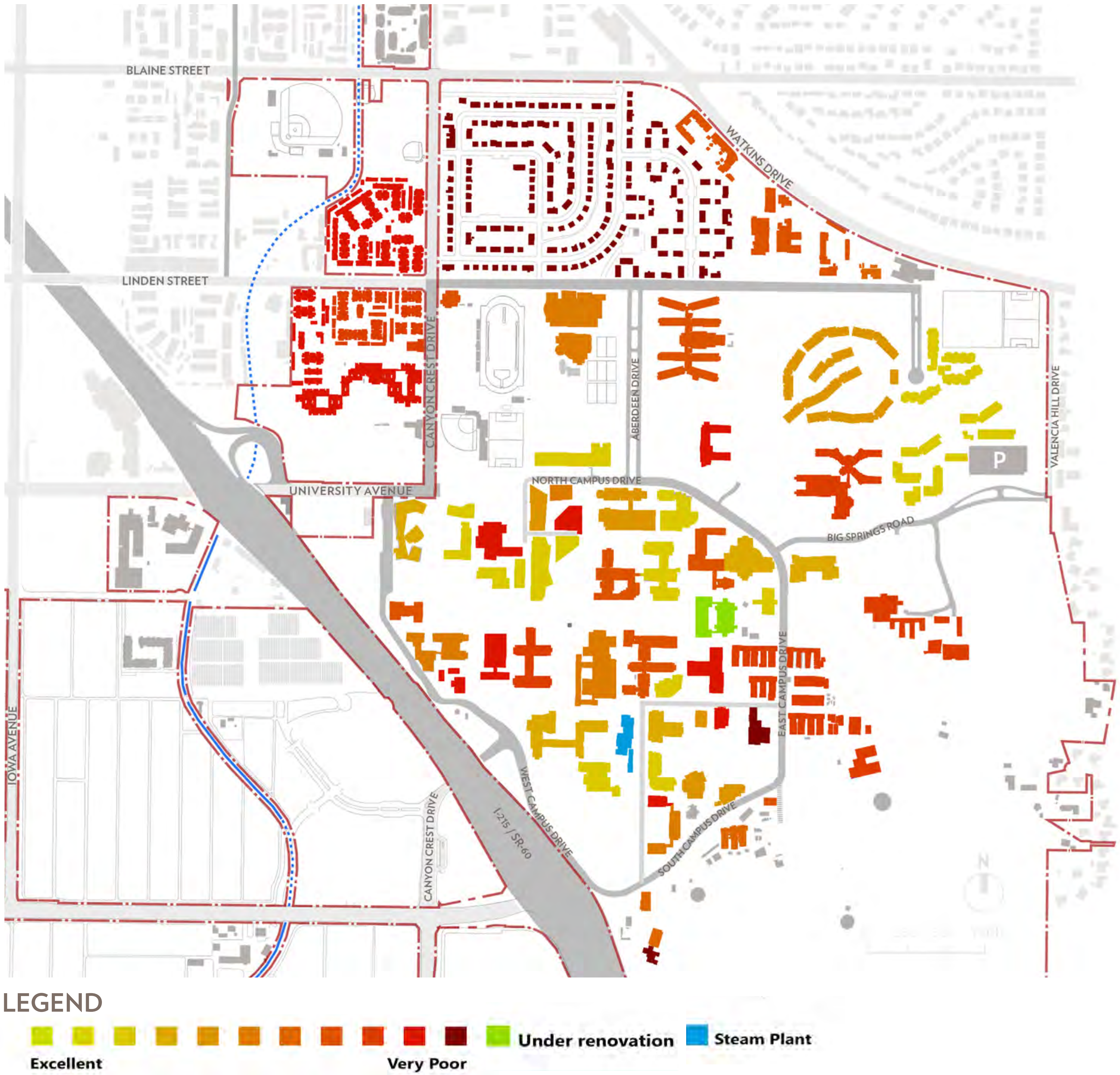


Figure 6.5 "HEAT MAP" OF BUILDING ENVELOPE AND SYSTEMS QUALITY



6.3
Buildings

EXISTING BUILDING FABRIC AND SYSTEMS

Buildings on campus generally range in construction time period from the 1950s to the present day and may be divided into 4 main typologies, listed below with their approximate proportions of total campus floor area indicated.

- Instruction, Institutional and Campus Support (this includes administrative and faculty buildings with offices, not laboratories)
- Research Lab
- Student Housing
- Student Support (this includes sports facilities and dining)

Some major renovations and minor upgrades have been made over the life of the campus resulting in a broad range of systems and envelope quality. An investigation into the state of current campus buildings was undertaken, which included auditing 14 campus buildings in accordance with ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Level 1 requirements. The buildings varied in terms of age, scale, and typology so as to cover the range on campus. The Planning Team combined the audits with a building-by-building review conducted with the University facilities team. The quality of all building lighting, mechanical systems, and controls were scored from 0 to 5. Scores were then averaged for each building and mapped onto campus buildings, as displayed in Fig. 6.5.

This provides an overview of the state of building systems, highlighting those that are performing inefficiently, those that require some level of upgrade, and those that require little to no improvement.

The list of buildings audited is as follows:

- Psychology Building
- School of Medicine Research Building
- Olmsted Hall
- Hinderaker Hall
- Campus Greenhouses
- Chemical Sciences
- Geology Building
- Orbach Science Library
- Pierce Hall
- Campus Surge
- Highlander Union Building (HUB)
- Materials Science & Engineering Building
- Glen Mor
- Aberdeen-Inverness Residence Hall

The results of the audit and review reveal that there is an opportunity to renovate existing buildings to raise efficiency and reduce the campus carbon footprint, as well as reduce peak power loads, thus relieving pressure on stressed feeders and sub-stations (see Section 6.6 for more details.)

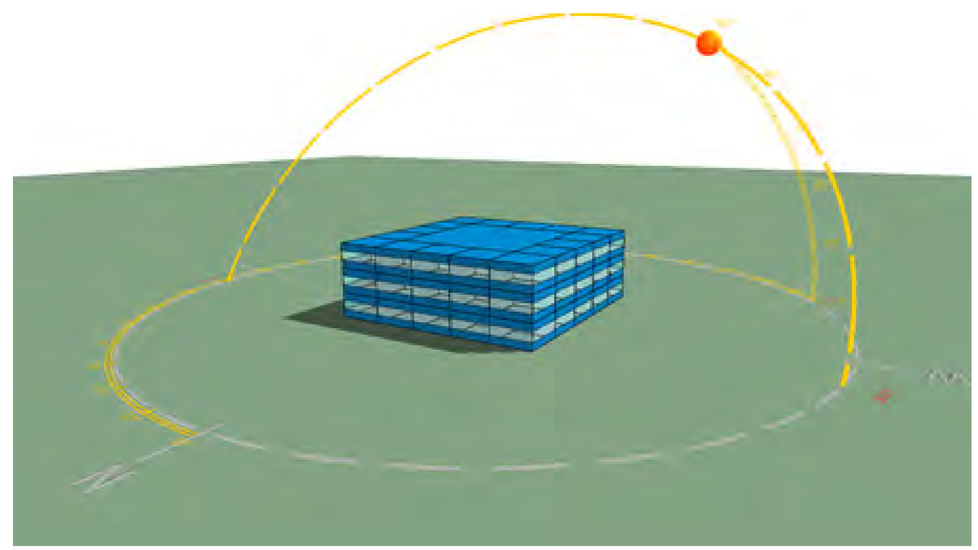
METHODOLOGY AND FINDINGS - ENERGY MODELING

In order to determine the extent to which existing building renovations and efficient design of future buildings can lower annual energy use, the Planning Team used the energy modelling software IES VE to construct six building energy models:

- Existing Instruction, Institutional and Campus Support
- Existing Student Housing
- Existing Student Support
- New Instruction, Institutional and Campus Support
- New Student Housing
- New Student Support

All models were 37,000 st^2 and had the same geometry. Existing models were constructed to represent the average building of that typology on campus in terms of envelope, mechanical systems, and lighting. New models were constructed to meet Title 24 California Energy Code prescriptive requirements for envelope, mechanical systems, and lighting. The Planning Team then used these models to simulate the dynamic energy performance of the buildings over an annual period, using the typical meteorological year weather file for Riverside.

Figure 6.6 STANDARDIZED CAMPUS BUILDING MODEL



Because building-level consumption data was not available, the validity of the existing building models was assessed by aggregating across the whole campus. This was done by deriving peak and annual heating, cooling, and power loads from each model, then normalizing with respect to floor area allowed loads and energy to be multiplied across the entire floor area of each typology on campus, to determine annual campus loads, then compared to campus electricity and gas usage. This comparison can be seen in Fig. 6.7. The deviations were within the acceptable range for the method employed.

Figure 6.7 COMPARISON OF CAMPUS POWER AND GAS USE TO MODELED USE

	Annual Energy (MMBtu)	
	Power	Gas
Recorded data	422,756	390,320
Model figures	448,811	359,381
Percentage deviation from modeled to recorded data	6%	9%

After validation, the models' peak and annual heating, cooling, and power were recorded. Energy Use Intensity (EUI) figures were also derived. These EUIs were compared to the UC system's 1999 EUI benchmarks in Fig. 6.8.

The models were then adjusted to represent the application of a package of energy efficiency measures. This allowed prediction of ambitious but achievable EUI targets for each building typology. This was done for both existing building and new building models. The strategies described in the following sections indicate measures that could be applied to reach those target EUIs.

STRATEGIES FOR LOW ENERGY RETROFITS OF EXISTING BUILDINGS

Existing buildings can achieve peak load and annual energy reductions through a range of Energy Efficiency Measures (EEMs). These EEMs can bring the building EUI down to more efficient levels. Fig. 6.8 shows UC system 1999 benchmark EUIs, modeled current building EUIs (taken to apply to the average building in each typology) and modeled target EUIs.

Figure 6.8 EUI BENCHMARKS, EXISTING BUILDING AVERAGE EUI'S AND EXISTING BUILDING TARGET EUI'S

	UC System 1999 EUI benchmarks (kBtu/ft2)	Modeled average existing building EUI (kBtu/ft^2)	Modeled target EUI (kBtu/ft^2)
Instruction, Institutional and Campus Support	65	107	45
Student Housing	59	83	43
Research Lab	310	253	155

In order to make the largest and most cost-effective energy savings, the largest and most inefficient energy users should be targeted first. The largest energy users are the laboratories, because of their high ventilation requirements and, to a certain extent, their process loads. The most inefficient energy users are the older, under-renovated buildings on campus. Therefore, the older laboratories that have not received a major renovation within the last 15 years should be targeted for energy savings first. The EEMs may be divided into 3 categories:

- Lighting
- Mechanical systems
- Envelope

Generally, in older buildings that have not recently been renovated, it will be more cost-effective to implement selected mechanical and lighting upgrades, but any package of measures could include a range of measures from mechanical, lighting and envelope categories. Major envelope upgrades will tend to have a longer payback period and may not be practical. For major single building renovations, the building must be subject to an ASHRAE level 2 or 3 audit, in order to determine the specific EEM package to be applied.

The following order is suggested as a building upgrade program outline, that prioritizes the largest and most cost-effective EEMs so that EUI targets are reached most quickly:

1) Major renovation of the worst performing Research Lab buildings
2) Lighting system upgrades across campus
3) Major renovation of the worst performing Instruction, Institutional and Campus Support buildings
4) Major renovation of the worst performing Student Housing

This order is a general guide. Once buildings are assessed in more detail, a detailed upgrade program may be established. This could prioritize the upgrade of poorly performing student housing buildings if they are found to yield a particularly high savings potential.

The lists below describe building measures that could be applied to achieve target EUIs.

Major renovations:

The following measures have been identified in response to the audits and building review conducted. EEMs are intended to improve currently under-performing systems/components, where they were found. See the Building Audit Report, in the Appendix, for more details on current conditions.

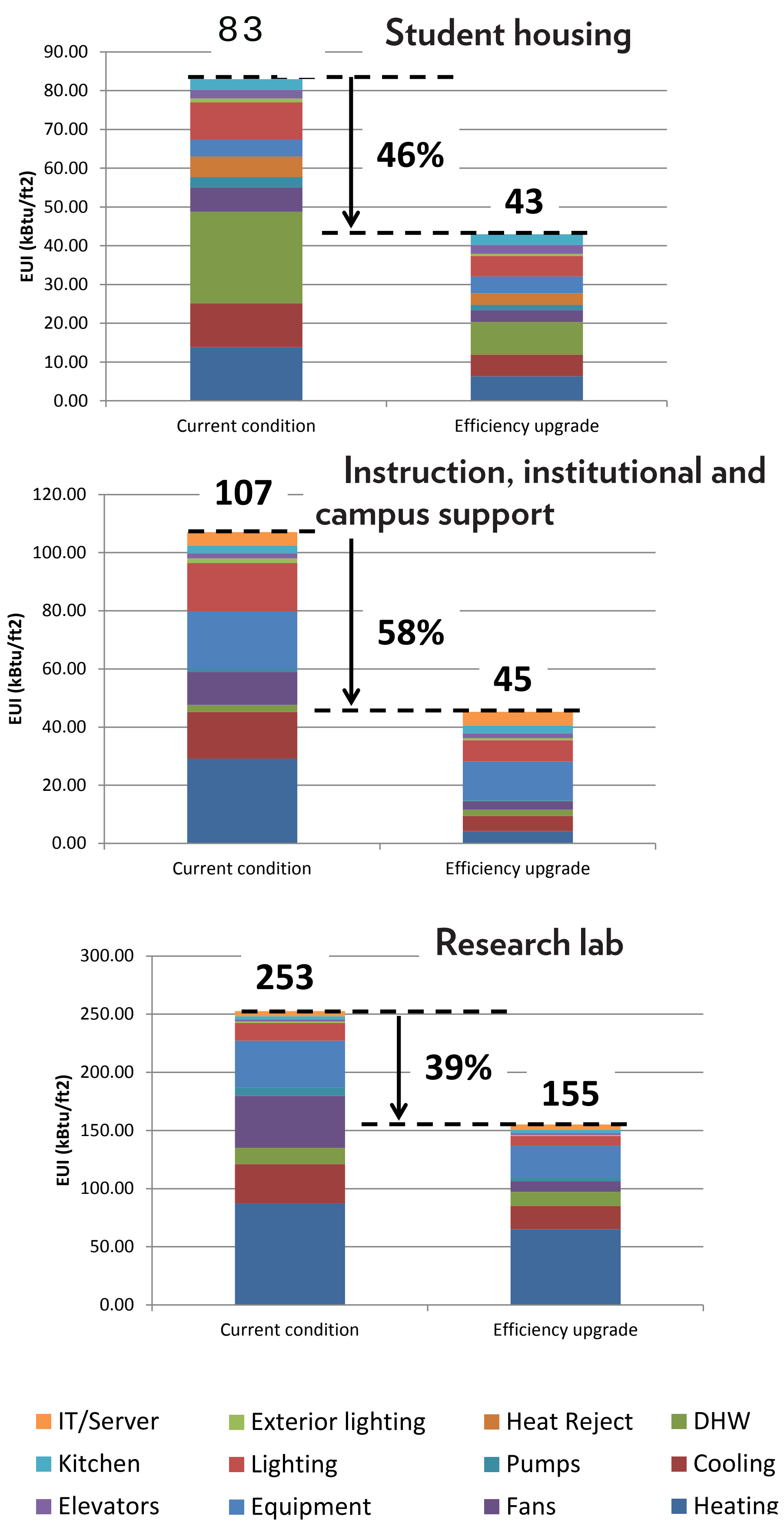
Mechanical systems for research labs:

- Convert any constant air volume (CAV) systems to variable air volume (VAV) systems for large fan power savings
- Create and enable economizer control on all VAV systems
- Install heat/energy recovery on exhaust. This is particularly important in laboratories, which have a high heat load due to high ventilation rates
- Re-zone mechanical systems, where appropriate, to reduce reheat requirements and improve thermal comfort
- Replace or seal leaky ductwork to reduce losses and fan power
- Insulate ductwork where practical
- Shade all unshaded rooftop ductwork where practical
- Insulate all chilled water and heating hot water pipework in buildings
- Insulate or replace all uninsulated chilled water and steam heat exchangers
- Install variable frequency drives (VFDs) on all air handling unit (AHU) fans, chilled water pumps and heating hot water pumps to allow systems to modulate output and save energy during low load periods
- Install a centralized building energy management system (for mechanical and lighting systems) with direct digital controls (DDC), where not currently found. Target the largest campus buildings first
- Remove all electric resistance heating
- Install occupancy sensors on all fume hoods
- Enable sash-interlocked, constant face velocity fume hood control
- Install VAV systems interlocked with fume hood exhaust for effective turndown of supply air
- Install low static pressure control valves
- Implement wind velocity based exhaust exit velocity control
- Optimize HVAC zoning between wet labs, dry labs and office spaces

Lighting for all building typologies:

- Implement lighting upgrades to achieve a 25 percent improvement over California Building Code requirements
- Implement enhanced daylighting measures, which could include refractive films or light shelves, heliostats, light-wells, solar tubes or fiber-optic collectors
- Replace all light fixtures with light emitting diodes (LEDs)

Figure 6.9 EUI FOR EXISTING BUILDINGS AND EFFICIENCY UPGRADES



- Install vacancy sensing controls throughout
- Install daylight dimming controls in perimeter spaces that receive sufficient daylight for dimming to regularly occur
- Install centralized lighting management systems in all buildings over 50,000 ft^2
- Implement a "lights off" policy at night (possibly with incentives)

Lighting for instruction, institutional and campus support buildings:

- Install low power lighting, utilizing low ambient light levels with task lighting, daylight dimming and vacancy sensing

Mechanical systems for instruction, institutional and campus support buildings:

- Several constant air volume systems remain on campus. Convert any CAV to VAV systems for large fan power savings
- Apply demand control ventilation (DCV) to greatly reduce fan power in laboratories and offices during unoccupied periods
- Create and enable economizer control on all VAV systems
- Install heat/energy recovery on exhaust
- Re-zone mechanical systems, where appropriate, to reduce reheat requirements and improve thermal comfort
- Replace or seal leaky ductwork to reduce losses and fan power
- Insulate ductwork where practical
- Shade all unshaded rooftop ductwork where practical
- Insulate all chilled water and heating hot water pipework in buildings
- Insulate or replace all uninsulated chilled water and steam heat exchangers
- Install VFDs on all AHU fans, chilled water pumps and heating hot water pumps to allow systems to modulate output and save energy during low load periods
- Install a centralized building energy management system (for mechanical and lighting systems) with DDC, where not currently found. Target the largest campus buildings first
- Remove all electric resistance heating
- Install local condensing boilers to replace steam network connection

Mechanical systems for student housing:

- Convert heating and cooling systems to variable refrigerant flow (VRF), radiant or hydronic fan coil systems
- Insulate all chilled water and heating hot water pipework
- Install VFDs on all chilled water and heating hot water pumps
- Install a centralized building energy management system unless living units are served by single-zone units
- Remove any electric resistance heating
- Replace any non-condensing boilers with condensing boilers

Envelope upgrades for all building typologies:

- Many older campus buildings have glazing that does not control solar gain through selective reflection of infra-red and ultraviolet light. This raises building cooling loads if not shaded effectively. Where practical, solar film should be applied (target 0.22 solar heat gain coefficient (SHGC)) or external shading installed (to effectively meet the equivalent SHGC target) on glazing units that admit a high level of solar radiation
- Heating load from overnight and morning warm up is found to be a particular problem at UC Riverside. Draughts from leaky building envelopes greatly increase unwanted building heat loss and gain. High infiltration doors and windows should be replaced to reduce infiltration to a perimeter space target of 0.25 to 0.1 air changes per hour (ACH), dependent on envelope.
- UC Riverside buildings receive an extremely high amount of solar gain through their roofs due to the high number of sunny days. This is a particular issue in the summer. Roof heat gain can be greatly

reduced by increasing reflectance, through painting or application of reflective coating/layer. An aged solar reflectance index (SRI) of 0.63 should be targeted.

- In addition to improving roof reflectance, roof insulation should be raised to a target U-factor of 0.031 Btu/hr-ft^2-F, or that which is commensurate with construction.
- UC Riverside has a large number of heavyweight buildings due to concrete construction. This thermal mass should be utilized for its temperature-moderating effect through exposure of concrete walls, ceilings and floors, where possible. Phase change materials, preferably in steel-cased ceiling tiles, should be applied in spaces with low thermal mass and the potential to reach an air temperature, at night, below 63 °F for heat rejection.
- As part of a whole-building upgrade, the potential to improve wall insulation should be investigated. Where practical, cavity insulation or furred-out envelope constructions should be applied to decrease U-factor in high heat loss walls. Thermal bridging should be addressed as part of this process. A U-factor of 0.064 Btu/hr-ft^2-F should be targeted.
- Where practical, enable natural ventilation in cellular offices, open-plan offices, break rooms and dormitory rooms, through installation of operable windows. Operation to be coordinated with systems control through window actuation or contacts to disengage mechanical systems.

Additional measures:

- For instruction, institutional and campus support: reduce equipment gains through low power work stations and hot desking where possible.
- For Student Housing: Install solar hot water arrays and tanks to achieve 60 – 80 percent solar fraction
- Install comprehensive sub-metering throughout. This will give facilities staff a much clearer view of which buildings are performing well or poorly and why. It will also allow the visibility of building energy use be increased through use of energy data dashboards and displays. This will promote awareness among building occupants and allow self-regulation of building energy use.
- Behavior change programs should be invested in to bridge the gap between technological upgrades and desired EUI targets. This should include a campus awareness campaign and potentially incentives for building energy use reduction
- In addition to the major measures listed above, some minor renovations may be made to new or relatively recently renovated buildings.

Minor Renovations of all building typologies:

- Retro-commissioning of mechanical controls
- Retro-commissioning of lighting controls
- Heat/energy recovery on exhausts if not present
- Replacement of all light fixtures with LEDs
- Installation of lighting, daylight dimming and vacancy sensing controls

STRATEGIES TO OPTIMIZE NEW BUILDING PERFORMANCE

New buildings must adhere to the California Building Code which sets stringent requirements on energy performance. However, in order for the University to achieve carbon neutrality in operations the following measures should be considered in order to achieve the EUI targets stated in Fig. 6.10.

Figure 6.10 EUI BENCHMARKS, EXISTING BUILDING AVERAGE EUI'S AND EXISTING BUILDING TARGET EUI'S

	Title 24 Building Code compliant EUIs	UC System target EUIs	Modeled high performance building EUIs
Instruction, Institutional and Campus Support	65	33	39
Student Housing	57	30	34
Research Lab	149	155	136

Passive design:

- Orient buildings east/west, where possible, with low window-to-wall ratios (WWRs) on east and west facades.
- Design improved facades to minimize annual heating demands and cooling demands and maximize daylighting. This must be determined with detailed energy modeling that seeks the lowest-energy solution through determining optimal values for façade and roof elements' U-values, glazing window-to-wall ratio and solar heat gain coefficient, external shading and daylight enhancement through refractive films or light shelves.
- Natural ventilation in cellular offices, open-plan offices, break rooms and student housing units. Operation to be coordinated with systems control.
- Expose thermal mass or phase change material in wall/ceiling elements to reduce internal temperature fluctuation.

Interior lighting for all buildings:

- Lighting upgrades to achieve a 25% improvement over California Building Code requirements
- Enhanced daylighting measures, which could include refractive films or light shelves, heliostats, light-wells, solar tubes or fiber-optic collectors
- Replacement of all light fixtures with LEDs
- Install lighting, daylight dimming and vacancy sensing controls
- Install a centralized building energy management system
- Office spaces: Low power lighting, utilizing low ambient light levels with task lighting, daylight dimming and vacancy sensing

Mechanical systems for instruction, institutional and campus support buildings:

- Radiant heating and cooling, through radiant panels or exposed floor/ceiling slabs, with dedicated outdoor air for ventilation.

Mechanical systems for student housing:

- Conversion to VRF, radiant or fan coil systems
- Insulation of all pipework
- Installation of VFDs on all chilled water and heating hot water pumps
- Installation of a centralized building energy management system unless housing units are isolated
- Installation of condensing boilers and high efficiency chillers

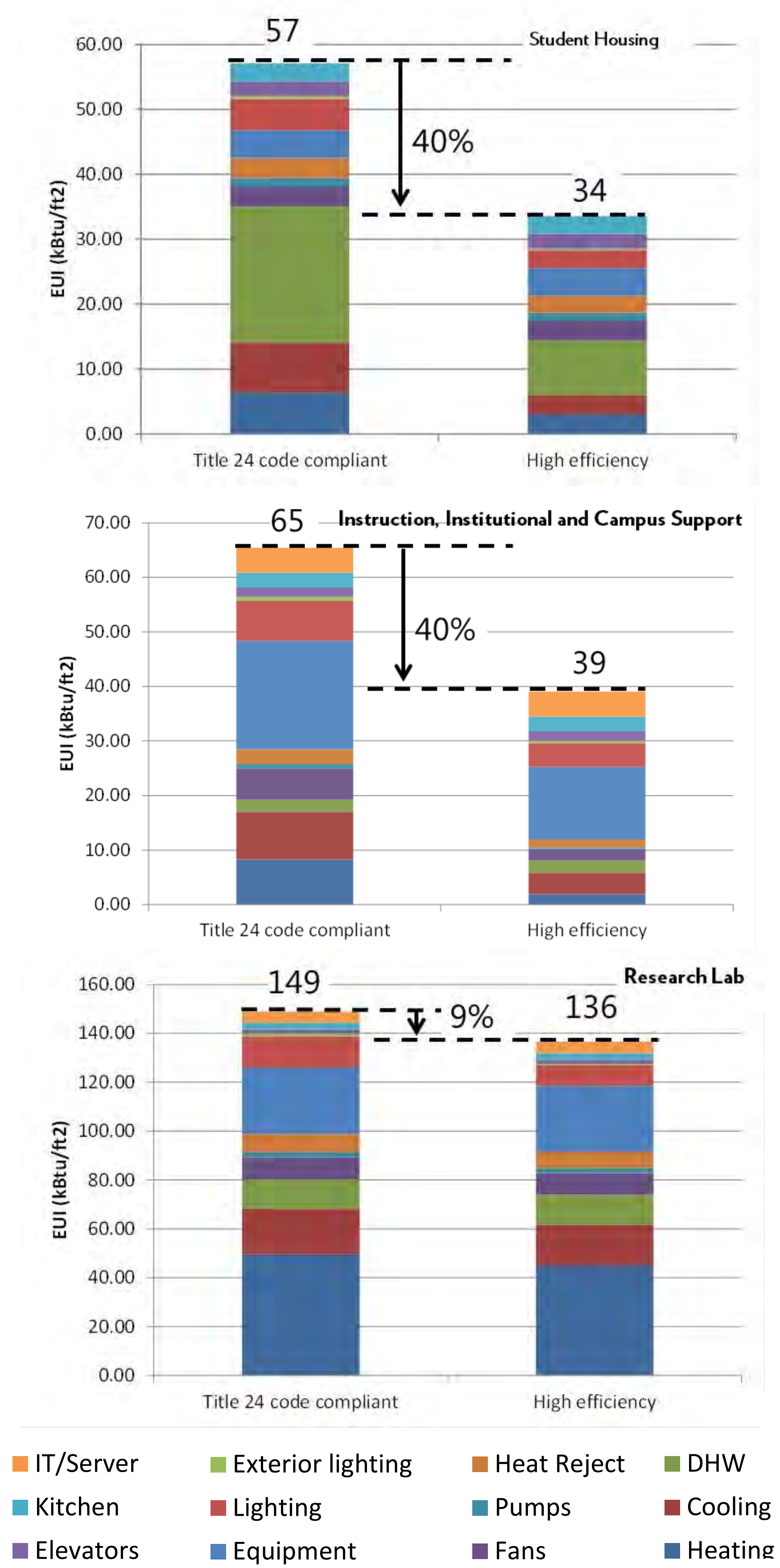
Mechanical systems for research labs:

- Chilled beams, where structure allows
- Transfer air from offices to labs for reduced total air requirement
- Fumehood occupancy sensors
- Sash-interlocked, constant face velocity fumehood control
- VAV interlocked with fumehood exhaust for effective turndown of supply air
- Low static pressure control valves
- Wind velocity based exhaust conditioning
- Improved heating, ventilation and air coniditoning (HVAC) zoning between wet labs, dry labs and office spaces
- Heat recovery on exhaust

Additional measures:

- Offices: reduce equipment gains through low power work stations and hot desking where possible.
- For residential buildings: install solar hot water arrays and tanks to achieve 60 – 80 percent solar fraction
- Laboratories: specify low power equipment where practical
- Install comprehensive sub-metering throughout

Figure 6.11 EUI FOR NEW BUILDINGS AND EFFICIENCY UPGRADES



Open plan offices allow for ample daylight and nurture collaboration

Existing solar thermal PV installation at Glen Mor

STRATEGIES FOR ENHANCED PERFORMANCE CONSIDERATIONS

As well as the specific measures listed above, campus building design guidelines should be applied to support an integrated low carbon strategy.

Design guidelines:

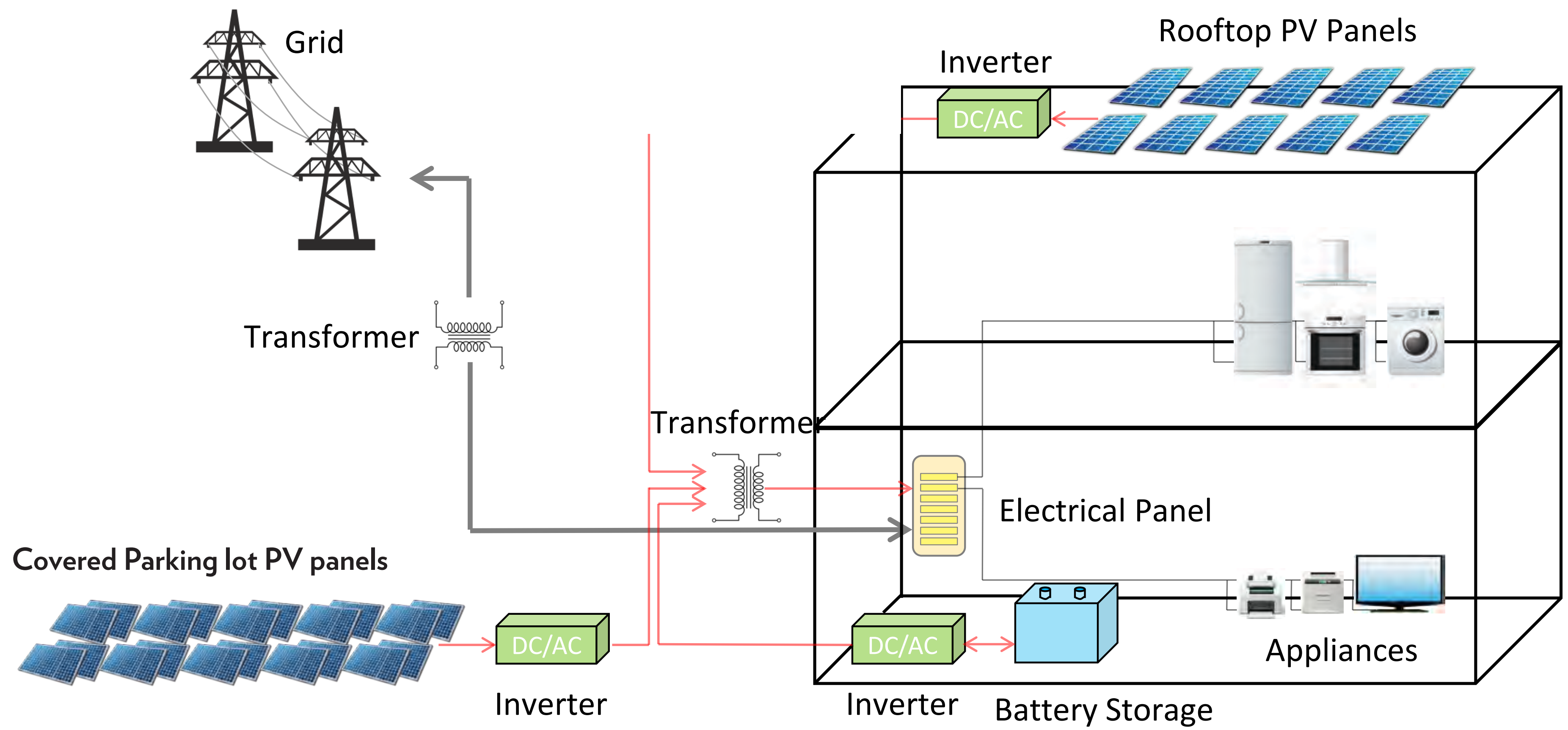
- Include demand reduction strategies using any combination of controls or batteries to reduce demand under peak conditions by 20 percent based on a signal from the campus energy management system
- Commercial / administrative buildings: integrate photovoltaic panels
- Residential buildings: incorporate solar thermal technologies
- Incorporate site photovoltaic elements where identified in the Master Plan Study
- Achieve UC-mandated EUI targets in new buildings

Net zero energy building strategy:

The campus has the option to require all new buildings to achieve net zero energy. This can be achieved through the following measures:

- Minimize building EUI
- Maximize photovoltaic roof coverage (consider photovoltaic canopy)
- Create adjacent covered parking lot photovoltaic arrays where possible
- Create remote photovoltaic arrays for virtual connection where required
- Fund ground mount arrays as part of building projects

Figure 6.12 NET ZERO ENERGY BUILDING ILLUSTRATION



6.4 Campus Cooling

EXISTING SYSTEMS

A range of cooling techniques are used across the campus. Residence halls and most buildings outside Core Campus are locally cooled through a range of technologies, depending on the building's age and renovation history. For instance, student housing units in Glen Mor are cooled by modern reversible heat pumps; whereas Aberdeen-Inverness Hall utilizes constant air volume (CAV) systems, served by local centrifugal chillers and a cooling tower.

Buildings in Core Campus are cooled by water supplied through the chilled water network. The network is served by three thermal energy stores (TES). The stores operate in "full storage mode", being charged by chillers at night and then discharged to meet load during the day. A summary of the campus chilled water system is given below:

- Steam plant chiller capacity: 5 x 1250 ton chillers (6250 ton). Chillers 1 to 3 in parallel arrangement with flow through chillers 4 and 5 in series
- Satellite chiller plant capacity correction: 6000 ton capacity
- TES1: 2.2 Mgal storage and 9000 GPM discharge
- TES2: 2.7 Mgal storage and 9000 GPM discharge
- TES3: 2 Mgal storage and 6000 GPM discharge
- Flow and return temperatures 39°F and 60°F (although often 54°F)

METHODOLOGY AND FINDINGS - CAMPUS CHILLED WATER SYSTEM CAPACITY

In order to better understand the potential spare capacity in the campus chilled water network and central plant, a static load model was developed and compared to calculated capacities throughout the network.

Chilled water supply to campus buildings is generally not logged. However, indicative loads were recorded by the facilities team for a range of buildings in the early afternoon of April 30th and May 1st. These values are displayed in Fig. 6.13.

Figure 6.13 CHILLED WATER LOADS MEASURED FOR SELECTED BUILDINGS BETWEEN 2:30 AND 4:30 PM, 04/30/2014

Building	Chilled water load (tons)
Materials Science and Engineering Building	305
Orbach Science Library	260
Chemical Sciences	492
Olmsted Hall	388
Psychology Building	129
School of Medicine Research Bldg.	56
Hinderaker Hall	48
Highlander Union Building	299

The average per-square-foot value was obtained for each building typology and then multiplied across the gross floor areas of buildings on each leg of the chilled water network. Accepting that the recorded values represented a lower-than-absolute peak value, when the entire network load was summed, the resultant value was compared to the recorded peak output from the chilled water stores, 10,980 tons as discharged simultaneously from TES 1 and 2. The calculated network load was found to be significantly less than the peak chilled water store discharge load. A derived adjustment factor of 0.46 was therefore multiplied by each normalized typology load (ft^2/ton) such that the total network load equaled the peak chilled water store discharge. This raised each typology load to an estimated peak value. See Fig. 6.14.

Figure 6.14 DERIVED AVERAGE PEAK ON CHILLED WATER NETWORK

Typology	Load (ft^2/ton)
Laboratory	258
Office/Academic	341
Social	185

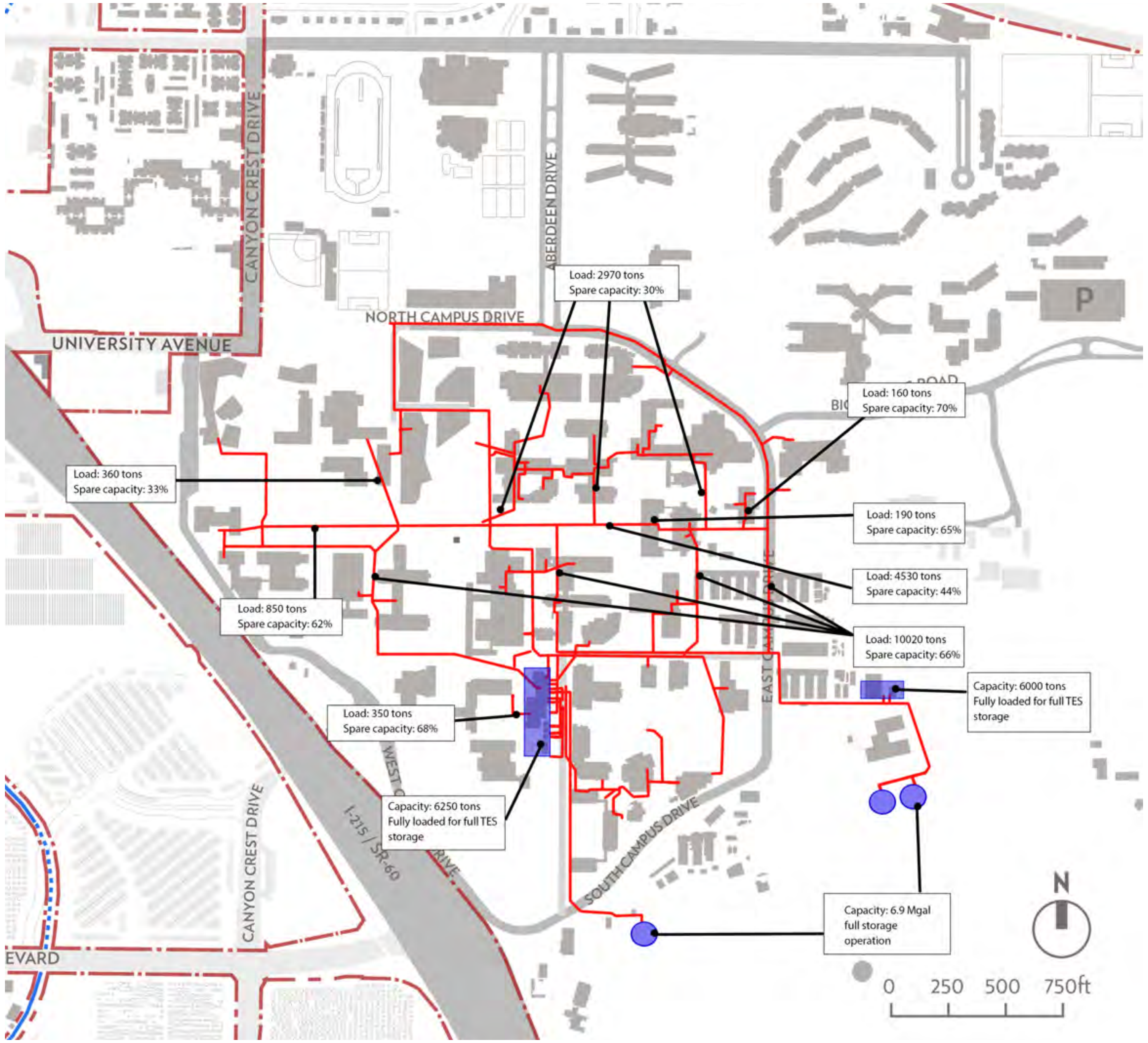
This allowed for comparison to the calculated capacity on each leg of the network, calculated by assuming a flow and return differential of 21°F and referencing the following table for assumed maximum flow rate in each pipe diameter case.

Figure 6.15 ASSUMED MAXIMUM FLOW RATES IN CHILLED WATER NETWORK PIPES

Pipe Diameter (in.)	Maximum flow (GPM)	Maximum capacity (kBtu/h)	Maximum capacity (tons)
24	15039	158036	13170
20	10398	109266	9105
18	8366	87913	7326
16	6610	69461	5788
12	3653	38387	3199
10	2304	24211	2018
8	1265	13293	1108
6	613	6442	537
4	207	2175	181
3	100	1051	88
2.5	56	588	49

Fig. 6.16 displays estimated chilled water network leg capacities.

Figure 6.16 CURRENT CHILLED WATER NETWORK LEG CAPACITIES (ESTIMATED)



This figure is a diagrammatic representation of an infrastructure network that is based available drawings and in person conversations with UCR personnel. They are representative and likely to have some inaccuracies.

It is important to note that these figures are not derived from comprehensive recorded data or an accurate dynamic model. Rather they are derived from the assumptions and calculation method described previously. Values should be taken as indicative and with a wide error margin. General conclusions may be drawn but a detailed study of particular network legs should be undertaken before new buildings are considered for connection.

The chilled water system generally has capacity to support additional load, both in the network (over 50 percent spare capacity on most legs) and at the central plant.

The three thermal energy stores currently operate in full storage mode. Switching to a load-levelling operation would roughly double the system plant capacity by allowing chillers and thermal stores to meet the campus load in parallel.

STRATEGY OPTIONS FOR CAMPUS COOLING

Options for cooling are essentially based on the following considerations:

- Centralized campus service vs. local cooling
- Efficiency level of chiller

Options for campus cooling have been divided between Core Campus and the North District. The following cooling options were assessed:

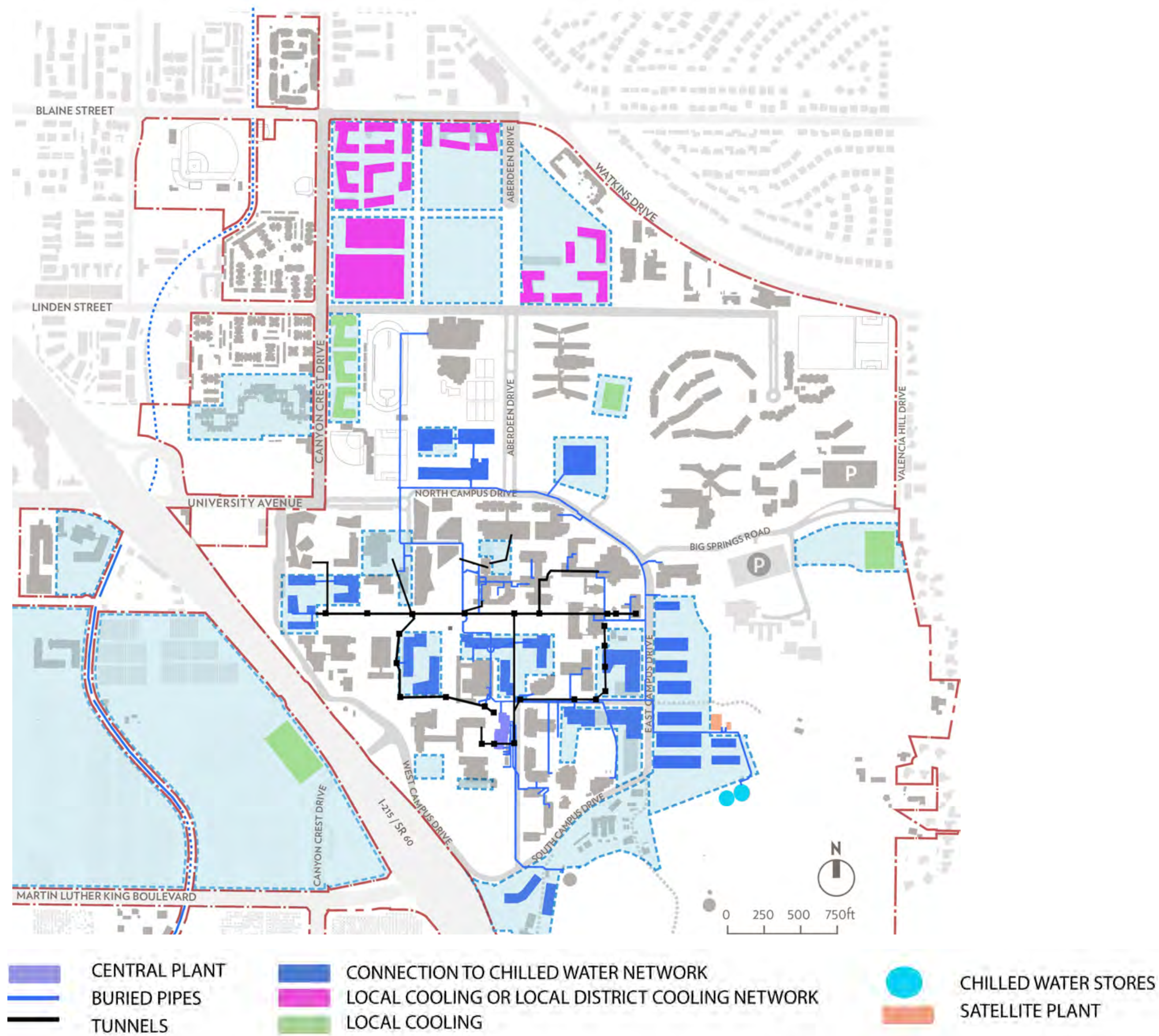
Core Campus:

- Local chillers: There is little advantage gained from using local chillers for core campus buildings, given the existing chilled water network.
- Centralized chillers: The existing chilled water network efficiently provides chilled water to Core Campus buildings and has sufficient capacity for more buildings to be added to most legs, depending on size. The large combined load provides the option to replace current chillers with more efficient models for large efficiency savings in the future.
- High efficiency chillers: Magnetic bearing chillers could replace Core Campus chillers for an efficiency gain that would yield a total campus carbon reduction of around 7 percent. Replacement could be timed for completion just prior to 2025, thus making the most cost-effective use of existing chillers.

North District:

- Local chillers: These are the most cost-effective solution for cooling the North District, given that a chilled water network does not currently exist there. Local cooling would give flexibility and spread capital investment over multiple buildings.
- Centralized chillers: An efficiency gain can be made combining buildings on a small local loop so that larger, more efficient chillers can serve those building from a central plant.
- High efficiency chillers: Centralization of cooling in the North District would allow for high efficiency chillers to be installed with a total campus carbon reduction of around 3 percent.

Figure 6.17 FUTURE CAMPUS COOLING STRATEGY OPTIONS



This figure is a diagrammatic representation of an infrastructure network that is based available drawings and in person conversations with UCR personnel. They are representative and likely to have some inaccuracies.

PROPOSED CAMPUS COOLING STRATEGY

Core Campus: It is recommended that buildings on development pads within and adjacent to the Core Campus be connected to the existing chilled water network. Connection to the network has the following advantages:

- The chilled water network is extensive in the Core Campus, meaning that any opportunity sites located in and around the core can be added for relatively low cost.
- The proximity of Core Campus opportunity sites to existing network legs means that new branches will be short, which leads to higher efficiency distribution.
- Useable program space is maximized in buildings because a cooling plant is not required.
- A reduction in maintenance and efficient plant operation are achieved due to centralization. Local cooling would not bring a significant carbon saving and does not give the option of central chiller replacement with high efficiency magnetic bearing chillers. Replacement should be timed for completion at the end of 2024.
- North District: It is recommended that a chiller plant with chilled water storage be built to serve North District buildings. The primary benefit of this would be the ability to use high efficiency magnetic bearing chillers which require a high combined cooling load. Furthermore, reductions in maintenance and an increase in useable program space give additional advantage to this scheme.

Figure 6.18 CAMPUS COOLING OPTIONS AND CARBON SAVINGS

Campus cooling options	Total campus carbon saving (%)
Central plant chiller replacement 6,250 ton turbocor magnetic bearing chiller set	7%
North Precinct: 3,200 ton turbocor magnetic bearing chiller plant with 1.4 Mgal chilled water store	3%

6.5
Campus Heating

EXISTING SYSTEMS

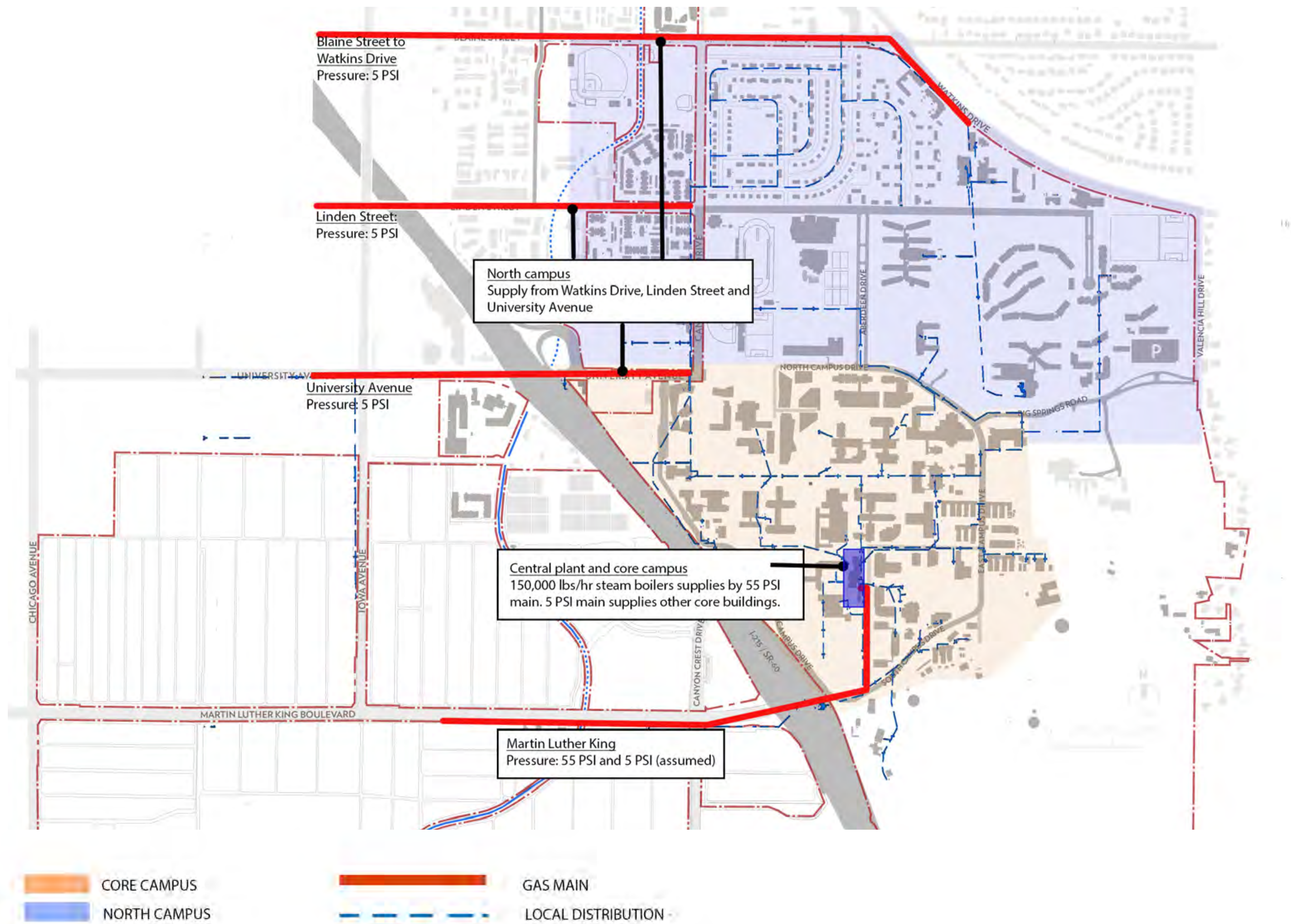
As with cooling, a range of methods for heating are employed across campus. Buildings outside the Core Campus are typically heated by gas boilers, as in the case of Aberdeen-Inverness Hall which has constant air volume (CAV) supply. An example of an alternative is the heat pump system employed in Glen Mor.

Buildings in the Core Campus are generally served by the steam network which is supplied by boilers located in the central steam plant. Notable exceptions include the Campus Surge Building which has gas-fired packaged variable air volume (VAV) units for heating. The steam plant is summarized below:

- Boilers 2 & 3: 30,000 lb/hr each.
- Boiler 4: 40,000 lb/hr.
- Boiler 5: 50,000 lb/hr.
- Total: 150,000 lb/hr[1]
- Boilers typically operate at 80 percent efficiency

Gas is supplied to the campus by SoCal Gas. Supply lines run west to east along Blaine Street, Linden Street, University Avenue and Martin Luther King Boulevard. Local gas lines are extensively laid in the North District and Core Campus. Most supply lines are assumed to be at around 5 PSI standard pressure. Martin Luther King Boulevard has two trunk lines, one at 55 PSI for supply to steam plant boilers and the other at 5 PSI for Core Campus supply. Capacity in the supply lines is estimated to be sufficient to support any near and medium term expansion in the Core Campus, North District and West Campus.

Figure 6.19 EXISTING GAS NETWORK (ESTIMATED)



This figure is a diagrammatic representation of an infrastructure network that is based available drawings and in person conversations with UCR personnel. They are representative and likely to have some inaccuracies.

[1] Boiler 1 is currently off line

METHODOLOGY AND FINDINGS - CAMPUS STEAM SYSTEM CAPACITY

Similar to the chilled water capacity assessment, the steam network was analyzed through development of a static load model and comparison to network capacities. Indicative steam loads were recorded by the facilities team for a range of buildings in the early afternoon of April 30th and May 1st. These values are displayed in Fig. 6.20.

Figure 6.20 STEAM LOADS MEASURED FOR SELECTED BUILDINGS BETWEEN 2:30 AND 4:30 PM, 04/30/2014

Building	Steam (lbs/hr)
Materials Science and Engineering Building	3,000
Orbach Science Library	4,400
Olmsted Hall	455
Psychology Building	1,000
School of Medicine Research Bldg.	600
Highlander Union Building	1,300

The average per-square-foot value was obtained for each building typology and then multiplied across the gross floor areas of buildings on each leg of the steam network. When the entire network load was summed, the resultant value was compared to the recorded peak output from the steam boilers, 147,441 kBtu/hr as supplied by boilers 2, 3, 4, and 5 simultaneously. The calculated network load was found to be significantly less than the peak boiler output. A derived adjustment factor of 1.85 was therefore multiplied by each normalized typology load (Btu/h-ft^2) such that the total network load equaled the peak boiler output. This raised each typology load to an approximately peak value. See Fig. 6.21.

Figure 6.21 DERIVED AVERAGE PEAK LOADS FOR EACH BUILDING TYPOLOGY ON STEAM NETWORK

Typology	Load (Btu/h.ft^2)
Research Lab	27
Instruction, Institutional and Campus Support	37
Social	24
Greenhouse	60

This allowed for comparison to the calculated capacity on each leg of the network, calculated by assuming steam pressure of 95 PSI and maximum velocity of 6000 fpm and referencing the following table for calculated maximum capacity in each pipe diameter case.

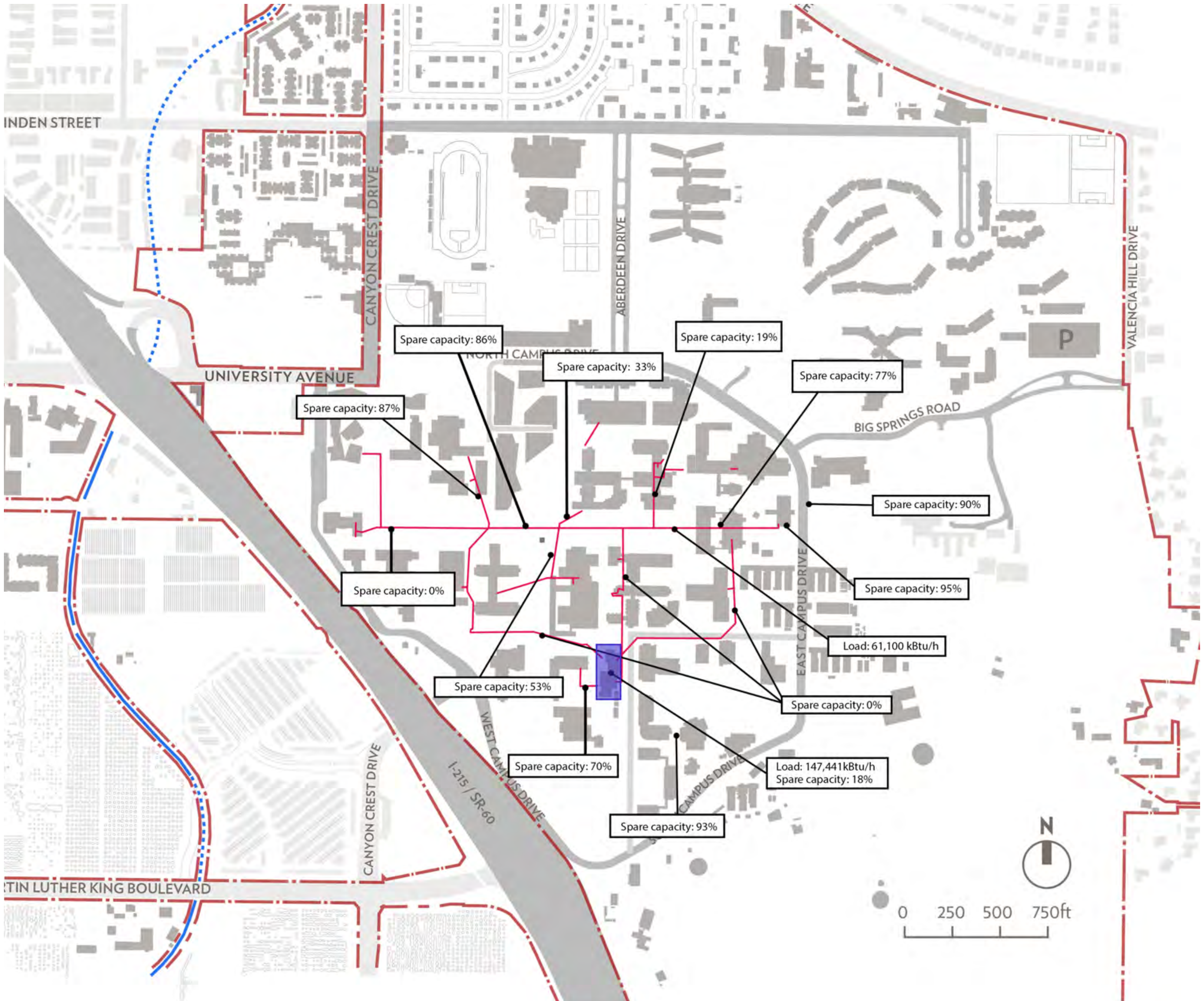
Figure 6.22 ASSUMED MAXIMUM CAPACITY PER PIPE DIAMETER IN STEAM NETWORK.

Pipe diameter (in.)	Flow rate (ft^3/hour)	Maximum capacity (Btu/h)
24	1,130,400	333,790,571
20	785,000	231,799,007
18	635,850	187,757,196
16	502,400	148,351,365
12	282,600	83,447,643
10	196,250	57,949,752
8	125,600	37,087,841
6	70,650	20,861,911
5	49,063	14,487,438
4	31,400	9,271,960
3	17,663	5,215,478
2.5	12,266	3,621,859

The resulting network capacity is discussed in the following section. It is important to note that these figures are not derived from comprehensive recorded data or an accurate dynamic model. Rather they are derived from the assumptions and calculation method described in the previous section. Values should be taken as indicative and with a wide error margin. General conclusions may be drawn but a detailed study of particular network legs should be undertaken before new buildings are considered for connection.

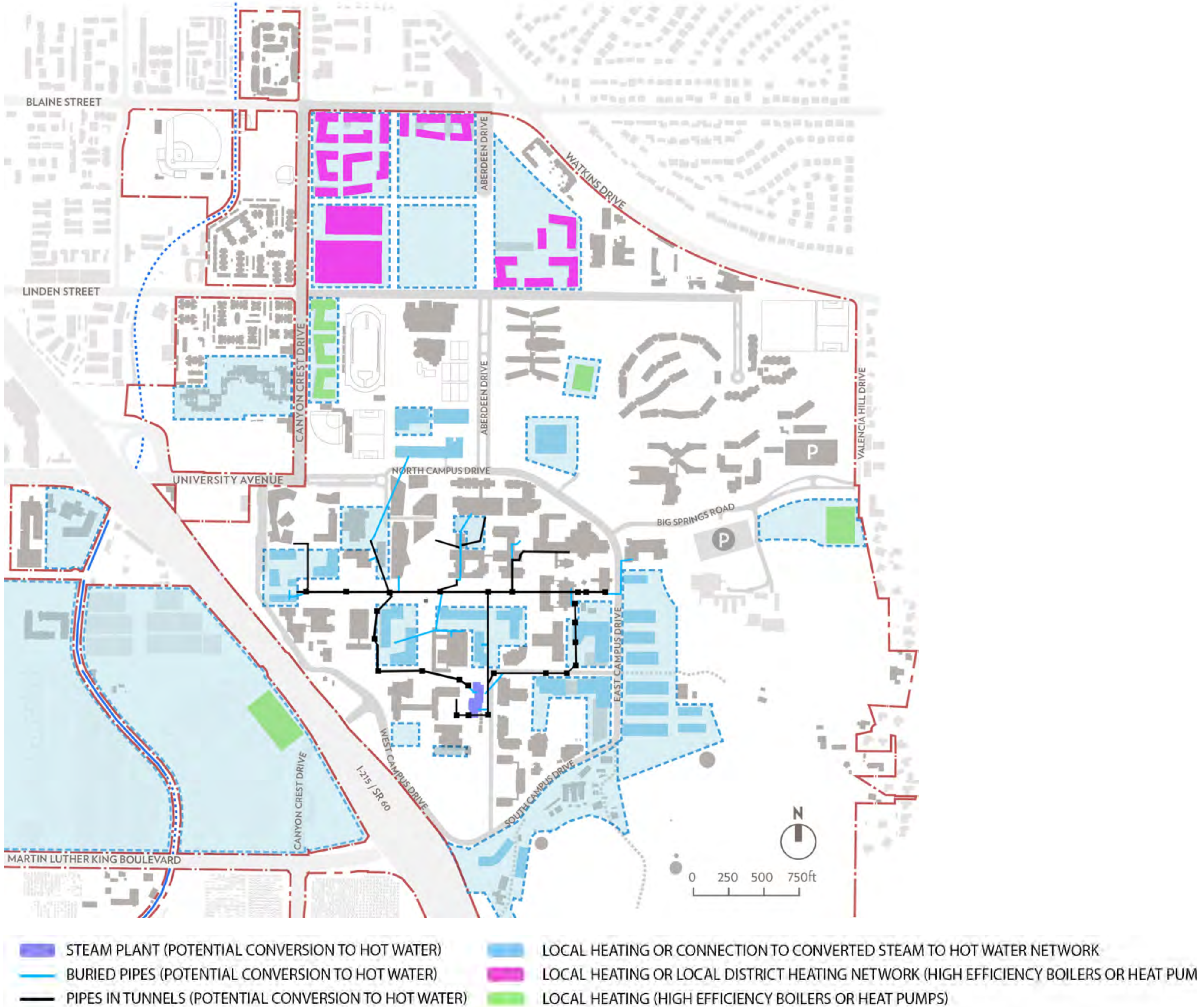
The steam network and plant has a large excess of capacity due to a move towards gas and electric heating on campus. The steam plant has around 18 percent spare capacity. The network appears to have even more spare capacity. A potential pinch-point exists in the central trunk line between tunnels 6 and 26, since this central part of the network may have insufficient capacity to serve all loads downstream.

Figure 6.23 EXISITING STEAM NETWORK CAPACITY (ESTIMATED)



This figure is a diagrammatic representation of an infrastructure network that is based available drawings and in person conversations with UCR personnel. They are representative and likely to have some inaccuracies.

Figure 6.24 CAMPUS HEATING STRATEGY OPTIONS



This figure is a diagrammatic representation of an infrastructure network that is based available drawings and in person conversations with UCR personnel. They are representative and likely to have some inaccuracies.

STRATEGY OPTIONS FOR CAMPUS HEATING

There are several options for heating the campus. These have been divided between the Core Campus and North District. The following heating options were assessed:

Core Campus:

- Local gas boilers: Installation of local condensing boilers is the standard, low cost option to address new heating loads on campus. Gas mains have capacity to cover additional loads. However, this option does not help bring the campus to carbon neutrality due to the continued reliance on combustion.
- Retaining/extending existing steam network: The steam network reliably provides high grade heat to Core Campus buildings but is very inefficient, with a likely whole-system efficiency of 70 percent or lower. The continued use of this network impedes progress towards carbon reduction goals
- Hot water network: There is a large efficiency gain to be found by converting the Core Campus steam network to hot water. A 3 percent total campus carbon savings is predicted but this likely requires replacement of all existing steam pipework (i.e. no direct conversion, which entails a high capital cost.
- Biomass and/or waste: Replacement of steam boilers with biomass/waste boilers plus hot water store, to cover campus base heating load would yield a large carbon reduction benefit but requires steam to hot water conversion, to be efficient. With steam to hot water conversion this scheme could yield a maximum of 23 percent total campus carbon reduction.
- Biogas: There is a large carbon reduction potential from supplying most of the total campus gas demand with biogas. This would require steam to hot water conversion to be efficient, and would yield a total campus carbon reduction savings of up to 22 percent. However, there is currently very little biogas for purchase in California and this situation is unlikely to change in the near future. The UC Office of the President has approved investment in a bulk biogas purchase and the generation of its own biogas. Current indications are, however, that yields will be small in comparison to demand. Note: On-site biogas generation from anaerobic digestion of food waste and agricultural arisings will not yield a significant proportion of the campus demand.

- Combined Heat and Power (CHP): Replacement of steam boilers with a CHP plant plus hot water store to cover campus base heating load yields a small carbon reduction potential when the low electricity grid carbon factor is considered. This would require steam to hot water conversion to be efficient, with a total campus carbon reduction of 12 percent.
- Centralized heat pumps: Large heat pumps are now being integrated into advanced district heating networks for large carbon savings when combined with renewable power. This option combined with a hot water store to cover campus base heating load would bring a significant carbon reduction due to the progressively decarbonized power supplied by Riverside Public Utilities. Installation requires steam to hot water conversion to be efficient, but would yield an 11 percent total campus carbon reduction.
- Local heat pumps: Local heat pumps also bring a significant carbon reduction due to the favorable grid carbon factor and avoids campus heat network investment, as well as spreading capital investment between buildings. If installed on a local scale, heat pumps could be sized to cover the total heating load of a building, with the potential addition of gas top-up for higher temperature process requirements. An estimated 20 percent total campus carbon reduction could be achieved if all buildings were converted. Local heat pumps could also be integrated into a geothermal system, to be assessed on a building by building basis, for further increased efficiency.

North District:

Heating options for the North District are similar to those for Core Campus, without consideration of the steam network. A central heating plant would not bring significant benefit unless powered by biomass or biogas. Local heat pumps would bring a significant carbon reduction, as compared to combustion.

Table 6.25 CAMPUS HEATING OPTIONS AND ASSOCIATED CARBON SAVINGS

Campus heating options	Total campus carbon saving (%)
Steam to hot water network conversion and central plant HX installation	3%
Steam to hot water network conversion, 20 MMBtu/h CHP installation + 200,000 gal hot water store installation to replace equivalent boiler capacity	12%
Steam to hot water network conversion, 20 MMBtu/h biomass installation + 200,000 gal hot water store installation to replace equivalent boiler capacity	22%
Steam to hot water network conversion, 20 MMBtu/h heat pump installation + 200,000 gal hot water store installation to replace equivalent boiler capacity	11%
Laying of North District hot water network, 10 MMBtu/h North District central boiler plant, 4 MMBtu/h CHP installation with 65,000 gal hot water store	1.7%
Laying of North District hot water network, 10 MMBtu/h North District central boiler plant, 4 MMBtu/h biomass installation with 65,000 gal hot water store	5%
Laying of North District hot water network, 10 MMBtu/h North District central boiler plant, 4 MMBtu/h heat pump with 65,000 gal hot water store	2%
Anaerobic digestion plant (est. 24 ton/day) plus 250 kW steam turbine	0.9%
Local heat pumps for all buildings	20%

PROPOSED CAMPUS HEATING STRATEGY

It is recommended that the steam network be progressively decommissioned and that campus heating be provided at the building level by electric heat pumps in both the North District and Core Campus. Geothermal heat pumps should be assessed for installation on a building by building basis.

By investing in a transfer from centralized steam to localized heat pumps the University will make large strides toward its carbon reduction goals, as well as create a pathway that spreads capital investment. Heat pumps are also expected to reduce their per unit heat carbon emissions over time in line with the increasing renewables mix from grid-supplied electricity.

6.6 Campus Power

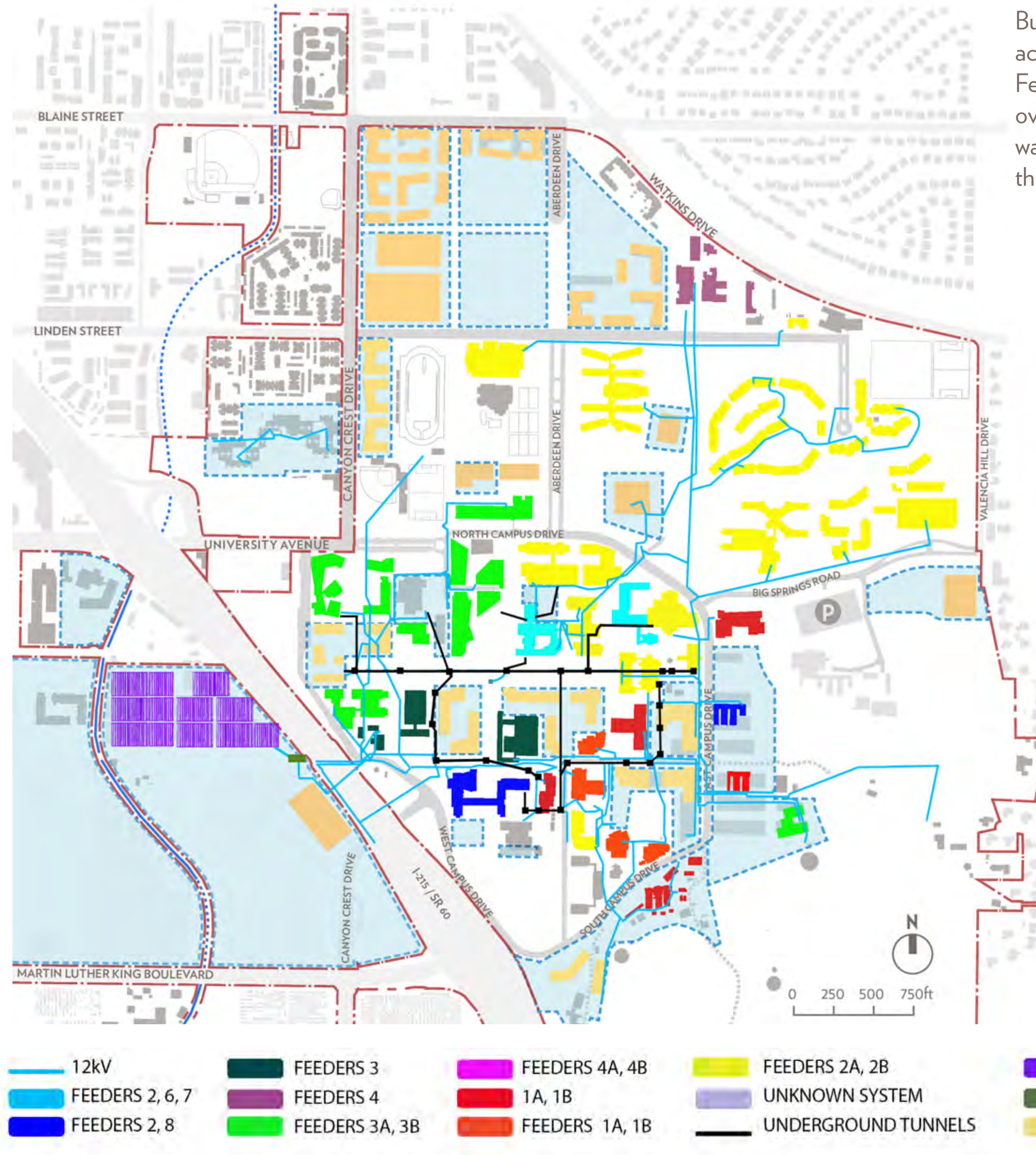
EXISTING POWER INFRASTRUCTURE

UC Riverside accounts for 6 percent of total city demand supplied by Riverside Public Utilities. The University purchases electricity for 0.1 $/kWh. The campus is mostly served by a 12.47 kV network, following the recent conversion of the previous 4.16 kV network to 12.47 kV. As the campus at UC Riverside has expanded in recent years, the power infrastructure has been reduced the to less than 100 percent redundancy. There is currently 80 percent redundancy in the existing sub-station, located on West Campus. This represents an operational choke point. Feeders run from the substation on West Campus to service electrical needs on East Campus. The feeders are grouped in pairs for redundancy but are likely to have reached a load at which both feeders in each pair are simultaneously needed at peak load. It has already been determined that feeders 2A and 2B have exceeded redundant capacity.

The campus has significant on-site power generation, with some distributed rooftop photovoltaic arrays and (2) 1.5 MW solar arrays, located adjacent to the main sub-station on West Campus. Maximum output of the large arrays is around 2.2 to 2.6 MW (DC) total. Expansion into agricultural land would be difficult or impossible.

The Physical Plant team proposes that power infrastructure solutions target 100 percent redundancy, through efficiency upgrades in buildings, local renewables generation, etc. Increasing electrical distribution capacity should be avoided if possible. There is therefore an opportunity to use peak load reduction measures and local power generation to reduce carbon emissions and increase network redundancy.

Figure 6.26 CAMPUS POWER STRATEGY



Buildings color coded according to serving feeder. Feeder positions can change over time. This image is what was observed at the time of this planning effort.

This figure is a diagrammatic representation of an infrastructure network that is based available drawings and in person conversations with UCR personnel. They are representative and likely to have some inaccuracies.

STRATEGIES FOR CAMPUS POWER

In order to reduce the load on the power infrastructure the Planning Team recommends that the University pursue an aggressive policy of energy efficiency measures on new and existing buildings, as well as localized PV generation and storage. Demand-side management should be combined with these initiatives to effectively reduce and shift load, such that redundancy is restored to the grid. This approach becomes particularly important when the recommended move toward local heat pumps is considered. Heat pumps will add power load to the existing network so peak reductions through other means must be initiated as soon as possible.

A new sub-station to serve the North District will likely be required irrespective of load reduction achieved in the Core Campus. This is due to location and anticipated load.

Note: In order to inform campus expansion the Planning Team recommends that the University undertake a feeder load study. This will allow stressed feeders to be identified so that upgrades can be made, or load reductions applied, where necessary.

6.7
Stormwater Quality and Management

EXISTING STORM DRAIN SYSTEM

The UC Riverside campus is divided into two watersheds separated by I-215/SR-60. The East Campus is located in the University Arroyo watershed to the northeast of I-215, whereas the West Campus is located in the Box Spring Arroyo watershed to the southwest of I-215. Onsite and offsite stormwater is collected and discharged through overland flow, underground storm drains, and natural arroyos.

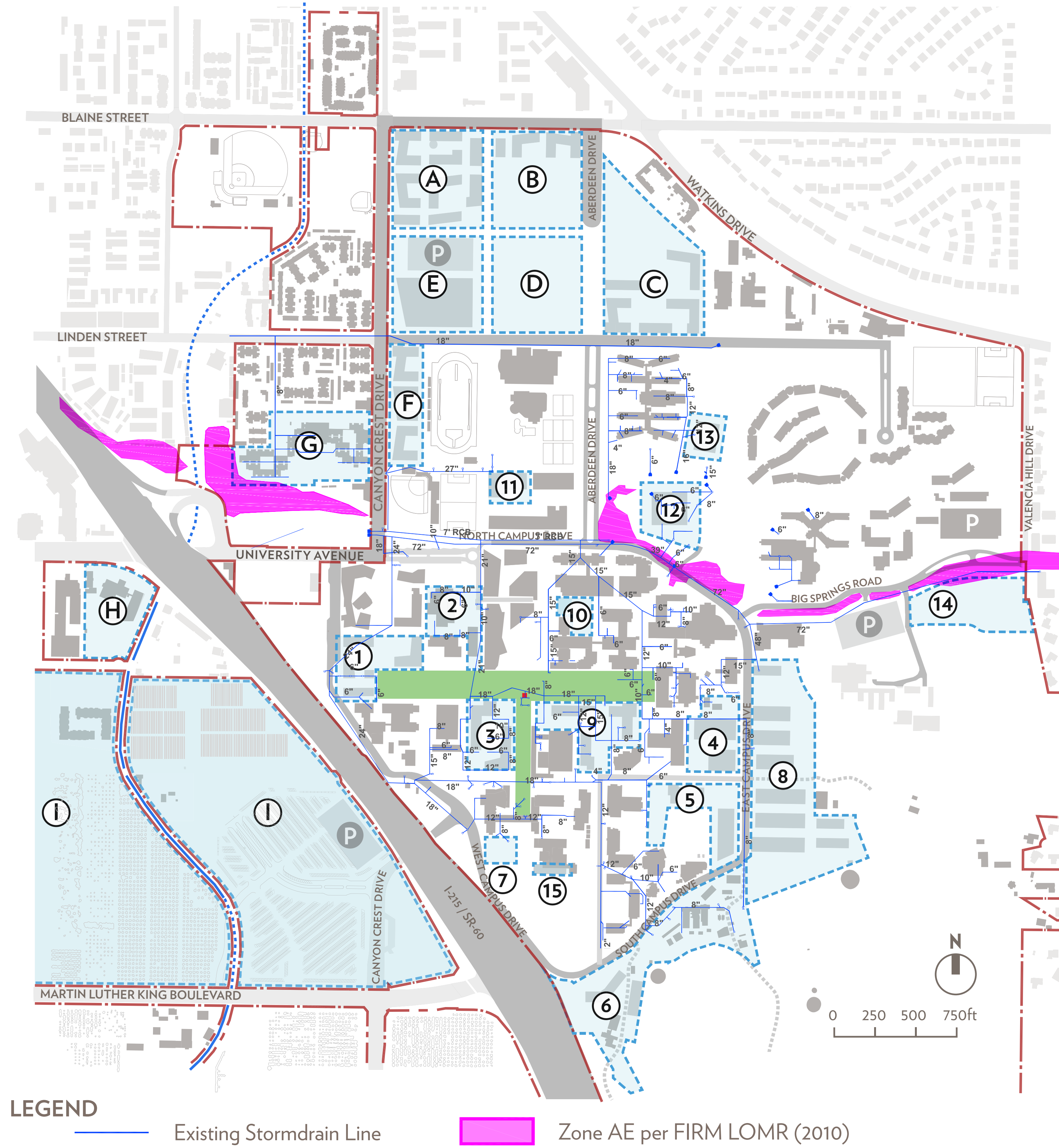
The East Campus is bounded on the north and east by residential neighborhoods, separated by Blaine Street and Valencia Hill Drive/ Watkins Drive respectively. The majority of stormwater runoff coming from the east is collected as surface runoff near Valencia Hill Drive and Big Springs Road by an inlet structure and is discharged to the Gage Detention Basin north of University Avenue at Canyon Crest Drive through above-ground swales, a 72" pipe, and finally a 7' box culvert.

The existing storm drain network serving the campus is made up from a mixture of local (UC Riverside), city, and county drainage facilities. The campus generally drains as a mixture of surface flows and underground storm drain conveyances that ultimately discharge to open channel arroyos and large diameter backbone county drainage infrastructure.

According to the Federal Flood Hazard Boundary / Flood Insurance Rate Map (FIRM), some areas in the vicinity of North Campus Drive, east of Aberdeen Drive are located within the 100-year flood plain. In order to comply with the Federal Emergency Management Agency requirements, future growth in this area will be located outside of the 100-year flood plain; and the improvements will not impede or redirect flood flows within a 100-year flood hazard area.

The future development projects and project limits are illustrated in the Fig 6.29: Future Site Development. Additional above-ground and below-ground storm drain improvements will be required in order to support the future growth, potentially including new academic buildings, parking lots, athletic fields, retail spaces, other support facilities, associated site work and landscape. Detailed hydraulic

Figure 6.29 FUTURE SITE DEVELOPMENT



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

analyses of existing storm drain facilities should be performed with each project. Development projects' impact on existing facilities upstream and downstream should be studied. It may be necessary to construct additional storm drain improvements or upsize existing facilities outside of new project limits in order to ensure that adequate stormwater flood prevention is provided.

UC Riverside is governed by federal, state, and regional stormwater regulations, promulgated under the Clean Water Act. Several regulations are overarching in nature and do not require specific permitting measures as their requirements have been incorporated into other regulations. These include:

- Clean Water Act (Federal)
- Antidegradation Policy (Federal and State)
- Porter-Cologne Water Quality Control Act (State)

A summary of regulations is presented in Appendix 6.7-B, *Stormwater Quality Report,* performed as part of the Master Plan Study.

METHODOLOGY

In order to perform a concept-level hydrology analysis, the Riverside County Flood Control District guidelines were used to calculate the 2, 10, 25, 50, and 100-year peak flow rates within the campus limits. The campus watershed was divided into several drainage sub-areas and runoff was calculated for both existing and future conditions. Reference Appendix 6.7-A for the Hydrology Report performed as part of the Master Plan Study.

Low Impact Development Best Management Practices (LID BMP) Methodology is a design approach which minimizes the impacts of the proposed project on its surroundings by closely mimicking the predevelopment hydrology, thus reducing the downstream erosion and also significantly reducing the pollutants in runoff from the site.

The Riverside County LID BMP calculation methodology was used to calculate the required treatment flows and volumes, referred to herein as the Mitigated Flow Rate (QBMP) and Mitigated Volume (VBMP), respectively. The mitigated flow rate and volumes were calculated for each of the future development sites as shown in following Fig 6.30. For further information and analysis refer to Appendix 6.7-B for the Stormwater Quality Report performed as part of the Master Plan Study.

Figure 6.30 MITIGATION FLOW RATE AND VOLUME

	Site	Area (acre)	VBMP (cf)	QBMP (cfs)
Core Campus	Site-1	3.488	4,966	0.4
	Site-2	3.091	4,519	0.4
	Site-3	2.992	4,404	0.4
	Site-4	3.252	4,661	0.4
	Site-5	3.780	5,725	0.5
	Site-6	11.588	15,131	1.3
	Site-7	0.705	796	0.1
	Site-8	13.785	19,583	1.7
	Site-9	4.223	6,048	0.5
	Site-10*	-	-	-
	Site-11	1.174	1,890	0.2
	Site-12	2.698	3,926	0.3
	Site-13	1.478	2,140	0.2
	Site-14*	-	-	-
	Site-15*	-	-	-
North District	Site-A	8.186	12,135	1.1
	Site-B	7.964	9,917	0.9
	Site-C	11.997	16,537	1.5
	Site-D	8.117	9,157	0.8
	Site-E	8.400	12,323	1.1
	Site-F	4.347	6,301	0.6
	Site-G	7.418	8,369	0.7
	Site-H	4.678	5,277	0.5
Total		113.361	153,811	13.60

ft³: cubic feet **cfs:** cubic feet per second

Note:
* Future Development Sites not included in the current analysis, referenced per Chapter 3 for information only.

FINDINGS

The existing natural arroyos, streets, and detention basins within the campus were identified as opportunities for a campus-wide approach to stormwater treatment. The arroyos and detention basins currently serve as a way to convey and contain the 100-year flood storm generated by the campus and upstream properties, and therefore will be maintained as such. Similarly, roadways are necessary to support campus circulation and must remain in place. However, they can also provide opportunities for centralized stormwater treatment.

Future development project sites need to incorporate pre-treatment systems before discharging into the treatment areas identified below, and ultimately the Gage Basin. Future and existing streets and malls included as part of future development plans, as well as future and existing storm drains, will be used to pre-treat and transport runoff to the identified treatment areas. Additional information and descriptions of various types of BMPs can be found in Appendix 6.7-B.

Conveyance systems and treatment areas will be designed to provide multiple benefits beyond their traditional purposes, including stormwater treatment, detention, and conveyance. It shall be the responsibility of project design team to confirm the stormwater quality requirements for each project based on the final project scope of work. Not all Best Management Practices (BMPs) are practical or suitable for all project sites due to poor soil permeability, steep slopes, and small project footprints.

STRATEGIC PRIORITIES

The following summarizes recommended BMPs and water quality mitigation measures for the future development areas. Graphic locations of the future stormwater treatment systems are illustrated on Figure 6.32: Stormwater LID Treatment and Conveyances.

TR1 (Existing Great Glen Basin)

The Great Glen Basin currently receives flows from a natural arroyo which serves a portion of the campus as well as an offsite residential area to the northeast, approximately 100 acres in total. The 85th percentile treatment storm from development areas 4, 5 and 8 will be collected and conveyed by various drainage systems, including underground storm drains and surface conveyance through the Science Walk Extension pedestrian mall. Stormwater runoff which exceeds the treatment flow will overflow to future and existing storm drain conveyance systems which serve the existing sites and maintain existing drainage patterns. Only the Mitigated Volume (VBMP) from the treatment storm will be diverted to the existing Great Glen Basin, so that the existing basin will not be overburdened during larger storm events. Based on Federal Emergency Management Agency (FEMA) Flood Zone Map No. 06065C0727G, the Great Glen Basin is located within the 100-year flood plain. Adding the Mitigated Volume (VBMP) from the upstream development sites will increase the stormwater volume held on the basin. During a 100-year storm event, this could negatively affect the 100-year flood plain water level. Therefore, it is necessary to increase the volume of the basin to accommodate the additional stormwater. A detailed analysis is necessary to determine the impacts.

The capacity of the basin can be increased by increasing its depth, widening the edges, or combination of both. Subsurface storage such as a gravel storage area at the bottom of the basin would also aid in increasing capacity with minimal land disturbance. However, there may be State and Federal agency reviews or permits implicated by the modification of the basins in the ways noted above. It will be necessary to consult with these agencies to determine requirements as part of the design and implementation of the recommended stormwater improvements.

The existing Great Glen Basin currently functions as a stormwater basin only, with natural features and plantings which require little maintenance. Similarly, the basin is not programmed for other institutional uses. Noted adjustments to the capacity of the basin shall be respective of its existing function and provide considerations for reestablishment of a more natural state. However, since the basin is not programmed as a pedestrian space, it may be more acceptable to provide stormwater storage on the surface of the basin, rather than underneath in a gravel layer as noted above. Since the site is not mowed or used for recreation, any modifications to the inlet structure to attenuate drainage from varying storm events can take place at the surface level or above.

TR2 (Existing Glade Basin)

The Glade Basin currently accepts flows from a 40-acre portion of the campus to its north. The 85th percentile treatment storm from development areas 11, 12, 13, C and D will be collected in underground storm drains and conveyed by a vegetated swale along Aberdeen Drive to the existing detention basin. Stormwater runoff which exceeds the treatment flow will overflow to future and existing storm drain conveyance systems which serve the existing sites and maintain existing drainage patterns. Similar to TR1, only the Mitigated Volume (VBMP) from the treatment storm will be diverted to the existing Glade Basin, so that the existing basin will not be overburdened during larger storm events. Based on Federal Emergency Management Agency (FEMA) Flood Zone Map No. 06065C0727G, the Glade Basin is also located within the 100-year flood plain. Adding the Mitigated Volume (VBMP) from the upstream development sites will increase the storm water volume held on the basin. During a 100-year storm event, this could negatively affect the 100-year flood plain water level. Therefore, it is necessary to increase the volume of the basin to accommodate the additional stormwater. A detailed analysis is necessary to determine the impacts.

The capacity of the basin can be increased by increasing its depth, widening the edges, or combination of both. Subsurface storage such as a gravel storage area at the bottom of the basin would also aid in increasing capacity with minimal land disturbance. However, there may be State and Federal agency reviews or permits implicated by the modification of the basins as noted above. It will be necessary to consult with these agencies to determine requirements as part of the design and implementation of the recommended storm water improvements.

Modifications to the Glade Basin area shall also be coordinated with the UC Riverside Facilities Management as it is used for many events, and needs to remain accessible as such. Similarly, any modifications to the basin must consider its function as a gathering and recreation space. Stormwater storage shall occur beneath the surface in a gravel layer or similar as noted above. Inlet structure modifications to attenuate drainage from varying storm events shall be designed so as not to inhibit mowing or programmatic uses.

TR3 (Proposed Freeway Buffer)

The existing area of the Proposed Freeway Buffer consists of narrow parking separating the 215 Freeway and West Campus Drive. The Master Plan Study proposes replacement of the existing parking with a 40' to 50' wide buffer consisting of trees, a multi-use area and an area designated for stormwater treatment as illustrated in Fig 4.42 of Section 4.4 "Beautify and Activate Campus Edges." The 85th percentile treatment storm from development areas 1, 2, 3, 6, 7, and 9 will be collected and conveyed through various landscape spaces, pedestrian malls and underground storm drains. The stormwater treatment buffer will be designed to treat stormwater in a similar fashion to a vegetated swale while conveying it from south to north, to a future detention basin located south of Parking Lot 1.

The Freeway Buffer and downstream basin will be designed to function as a vegetated swale and detention basin, respectively, as defined by the Riverside County LID BMP Design Handbook.

TR4 (Proposed Canyon Crest Drive Linear Treatment System)

The Proposed Canyon Crest Drive Linear Treatment System will modify the existing Canyon Crest Drive to include an area for stormwater treatment as part of its cross-section. The 85th percentile treatment storm from development areas A, B, D, E and F will be collected and conveyed through landscape spaces, pedestrian malls and underground storm drains. The stormwater treatment strip will be designed to treat stormwater, similar to a vegetated swale, while conveying it from north to south, to the existing Gage Basin.

The Linear Treatment System will need to be designed to function as a vegetated swale or similar bio-treatment facility as defined by the Riverside County LID BMP Design Handbook.

The following Fig 6.31 provides a summary of anticipated treatment totals at each treatment location resulting from the future development projects. The required treatment flows and volumes are referred to as the Mitigated Flow Rate (QBMP) and Mitigated Volume (VBMP), respectively:

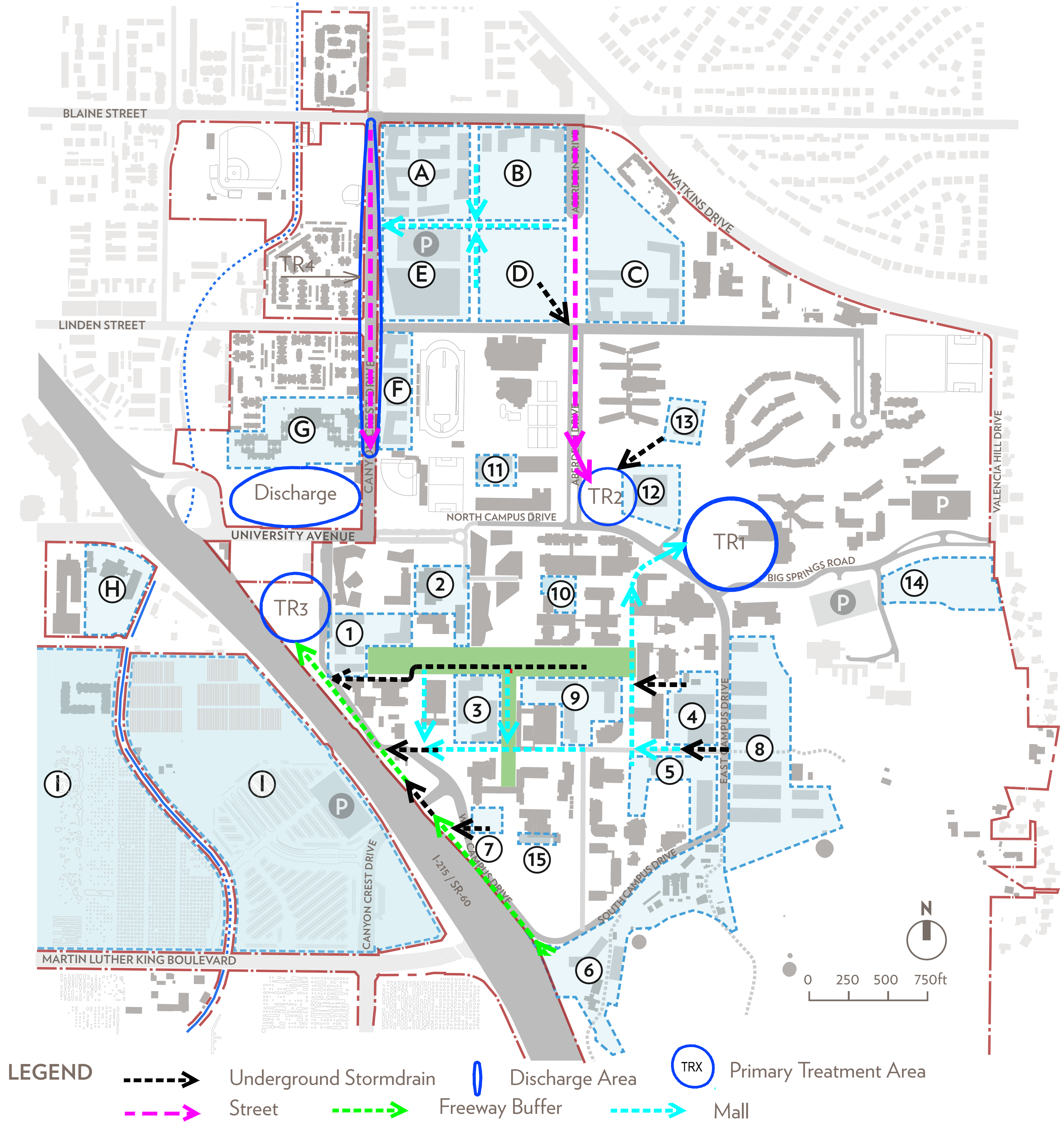
Figure 6.31 STORMWATER TREATMENT SUMMARY

Treatment Area	Development Areas	VBMP	QBMP
		(cf)	(cfs)
TR1	4, 5, 8	29,968	2.6
TR2	C, D*, 11, 12, 13	29,079	2.6
TR3	1, 2, 3, 6, 7, 9	35,864	3.1
TR4	A, B, D*, E, F	45,255	4.1

ft³: cubic feet **cfs:** cubic feet per second

Note:
* Assumed 50% of Area D will drain to this Location

Figure 6.32 PROPOSED STORMWATER LOW IMPACT DEVELOPMENT TREATMENT AND CONVEYANCES



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

6.8 Sanitary Sewer

EXISTING SANITARY SEWER INFRASTRUCTURE

The campus's sanitary sewer is served by three major arteries: a 15-inch main located in North Campus Drive, an 8-inch main located in Canyon Crest Drive serving the North District, and an 8-inch main branching out from the 15-inch main and serving the heart of the campus. There is an additional 8-inch sewer line that also branches out from the 15-inch main and serves some areas adjacent to West Campus Drive. Several lateral pipes branching out from the main lines serve various parts of the campus.

Although North Campus Drive is part of the campus, the underlying 15-inch sewer is owned by the City of Riverside. The 15-inch line serves as an interceptor for the whole campus and also receives sewage effluent from the residential neighborhood upstream of the campus. The 8-inch main along Canyon Crest Drive is also owned by the city. The remaining pipes serving the campus are owned and maintained by the University. The existing sewer mains are identified in Fig 6.35 Existing Sanitary Sewer Network.

METHODOLOGY

The buildings on campus were classified into various categories based on use. Flow from all the non-academic buildings was determined using local planning factors. The remainder of the flow from the academic buildings was prorated based upon population density. The population density analysis is presented in Fig 6.33: Population Density. The total existing building area was estimated from campus aerial topography. A peaking factor of 3.5 was applied to determine the peak flow rates. The on-site sanitary sewer system was mapped per existing utility documentation provided by UC Riverside. Multiple sources were used to identify the location of the existing sewer lines including survey data, electronic design files and the East Campus Infrastructure Project Report provided by the University. The material of the existing pipes was assumed to be Vitrified Clay Pipe (VCP) which corresponds to a Manning coefficient of 0.014. Manning's equation was used to calculate the capacity of pipes based on full flow capacity. The existing sanitary sewer system is identified in Figure 6.35.

Figure 6.33 POPULATION DENSITY

Student Headcount (2014) [1]	21,669
Faculty and Staff FTE [2]	4,201
Total Campus Population FTE	25,870
Total Existing Building Area [3] (GSF)	15,000,000 [3]
Population Density Per 1000 GSF	1.73
Sewage Flow at 20 GPD Per Student (GPD/1000GSF)	35

GSF: gross square feet **GPD:** gallon per day **FTE:** full-time equivalent

Note:
[1] Student headcount based on Fall 2014 enrollment data
[2] Faculty and Staff FTE based on UC Riverside website
[3] Estimated from campus aerial topography

A sanitary sewer capacity analysis was performed for sewer mains and laterals which correspond to Areas "0" through "28". Refer to Appendix 6.8-A for the sewer analysis performed as part of the Master Plan Study. Appendix 6.8-A includes a summary of the existing campus buildings' square footage, occupancy, occupancy type, average daily flow rate, and peak flow rate generated on campus. Based upon the population density analysis, the existing average daily flow rate generated from offsite and on-campus buildings is calculated at 1,701,211 gallons per day (gpd), which is equivalent to a peak flow rate of 2.632 cubic feet per second (cfs.) The North District includes the existing Canyon Crest Family Student Housing facility and for the Master Plan Study analysis, sewer flows were determined based on local planning factors for residential buildings. Considering the facility is comprised of older, World War II-era buildings, the average daily and peak flow rates for the facility may be much lower if the University were to perform an analysis based on their fixture unit count.

The sanitary sewer system was evaluated with the addition of future buildings. Appendix 6.8-A includes a summary of the future campus buildings' square footage, occupancy type, average daily flow rate, and peak flow rate. Based upon the population density analysis performed, the future average daily flow rate generated from existing offsite and future on-campus buildings is calculated at 1,586,045 gallons per day (gpd), which is equivalent to a peak flow rate of 2.454 cubic feet per second (cfs.)

FINDINGS

The sewage flow rates from the existing buildings are within the capacity of the campus' sewer system, with the exception of the 8-inch main running along Canyon Crest Drive, which will be serving the North District.

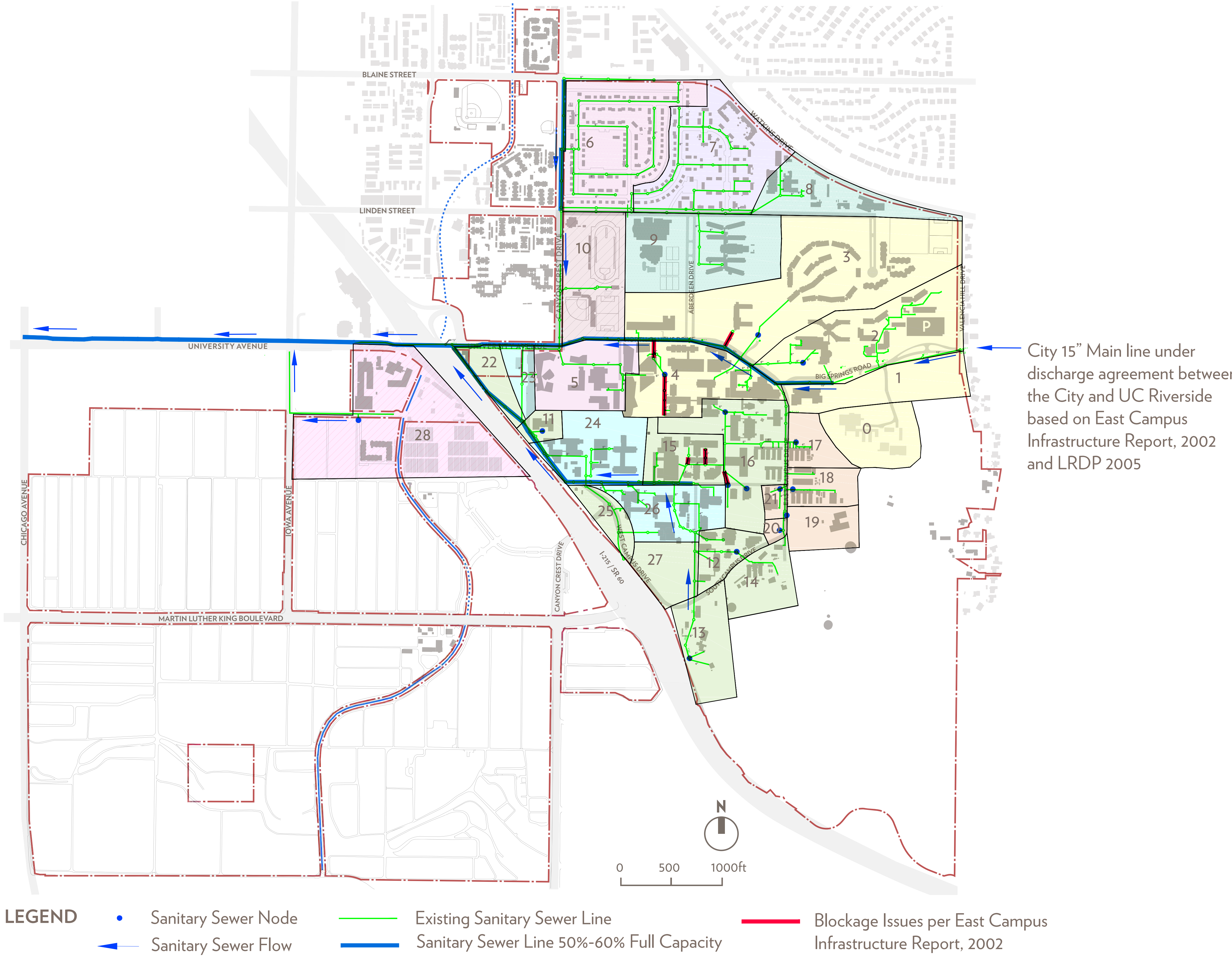
The analysis of the future sewer demands based on planning factors reveal that the anticipated sewage flow rates decrease by nearly 10%. The main reason for the reduction in the sewage flow rate is the use of planning factors for modeling the existing residential development in the North District. A detailed analysis using fixture counts and meter readings may reveal a lower existing average daily flow rate. The following Fig 6.34: Sanitary Sewer Flow Summary provides a summary of the total sanitary sewer flow for both existing and future conditions.

Figure 6.34 SANITARY SEWER FLOW SUMMARY

University of California Riverside (East Campus)	Peak Flow GPD	Peak Flow CFS	Peak Flow GPM
Existing Campus Generated Sewer Flows	5,956,120	9.217	4,137
Proposed Campus Generated Sewer Flows	5,405,014	8.364	3,754
Net Increase	-551,106	-0.853	-383

GPD: gallons per day **CFS:** cubic feet per second **GPM:** gallon per minute

Figure 6.35 EXISTING SANITARY SEWER NETWORK



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

STRATEGIC PRIORITIES

The East Campus Infrastructure Project Report (Project No. 950403) provides recommendations for continued maintenance and inspection of the sewer system in order to ensure its service in the future, and should continue to be followed.

The following are recommendations for improvements to the existing sanitary sewer system in order to maintain service to the existing buildings:

- The existing 8-inch main sewer line running along the Canyon Crest Road has an average slope of 0.27% and according to analysis presented herein, at peak flow, the pipe section will exceed its current full flow capacity. Upsize the existing 8-inch pipe to 15-inch pipe (with an absolute minimum slope of 0.5%) to meet the minimum velocity requirements and adequately serve the existing buildings.

- The condition of the existing 8-inch sewer lateral pipes serving the Spieth Hall needs to be further investigated in order to provide any recommendations.

- The existing 8-inch sewer pipe serving Pierce Hall is reported to have blockage issues. The condition of the pipe needs to be evaluated in order to provide any recommendations.

- Several sanitary sewer laterals have continuous drainage and blockage problems. It is recommended that the University further investigates the existing pipe conditions in order to improve the drainage conditions. Pipe replacement is recommended when future developments are planned within the area.

In order to service the future development in the Core Campus, the following improvements need to be undertaken. Recommendations include relocation, demolition and replacement of various sewer pipes to accommodate expansion of the campus. See Figure 6.36 and 6.37 for conceptual illustrations of the recommendations. Pipe sections shown in blue denote new sanitary sewer pipes to be constructed, replaced, or relocated to accommodate future building needs.

- **Opportunity Sites A, B, D, & E:** In order to provide a clear site for future development in the North District, remove the existing sanitary mains and laterals currently serving the Canyon Crest Family Student Housing. The existing system can be cut at MH-1. An 8-inch lateral main connection along the new 15-inch sewer main on Canyon Crest Drive will be necessary, as shown in Figure 6.37. This 8-inch lateral will serve as a main sewer line to provide POC's to various sites in the North District.

- **Opportunity Site C:** Replace the existing 6-inch sewer lateral with a new 6-inch sewer lateral, with a minimum slope of 0.5% and provide POC for future development.

- **Opportunity Site F:** Install an 8-inch stub-out from the 15-inch sewer main to serve the future development.

- **Opportunity Site 1:** Remove the existing 8-inch lateral currently serving Hinderaker Hall and provide an 8-inch stub out to serve the future development.

- **Opportunity Site 3:** Install a 6-inch stub out from 8-inch sewer main to serve the future development.

- **Opportunity Site 4:** Install a 6-inch stub-out to serve the future development.

- **Opportunity Site 5:** Remove the existing 4-inch sewer lateral currently serving Fawcett Laboratory and provide a 6-inch stub-out to serve the future development.

- **Opportunity Site 6:** Relocate the 6-inch sewer lateral to provide a clear site for future development, and install a 6-inch stub out.

- **Opportunity Site 9:** Relocate the 8-inch sewer lateral currently serving Spieth Hall and the Life Sciences building to provide a clear site for the future development.

- **Opportunity Site 11:** In order to serve future development, a 6-inch lateral will be installed. This 6-inch lateral will be connected to the existing 6-inch sewer lateral.

- **Opportunity Site 12:** Replace the existing 8-inch sewer lateral with a new 8-inch sewer lateral, with minimum slope of 0.5% and provide POC for future development.
- **Opportunity Site 13:** Install a 6-inch lateral to serve future development in the Core Campus and provide a 6-inch stub out to serve the future development.

The recommendations presented herein include removal, replacement, and construction of new sanitary sewer pipes in order to adequately serve the existing buildings as well as future developments in the Core Campus. Further investigations may be needed for the existing sanitary sewer main lines which have a potential to exceed maximum capacity. The findings and recommendations are determined for master planning analysis with assumed peak flow rates. If the proposed building designs yield larger flow rates than presented herein, it is recommended that the University re-evaluate the data analysis and findings.

BUILDING OPPORTUNITY SITES

Sites 9 to 15

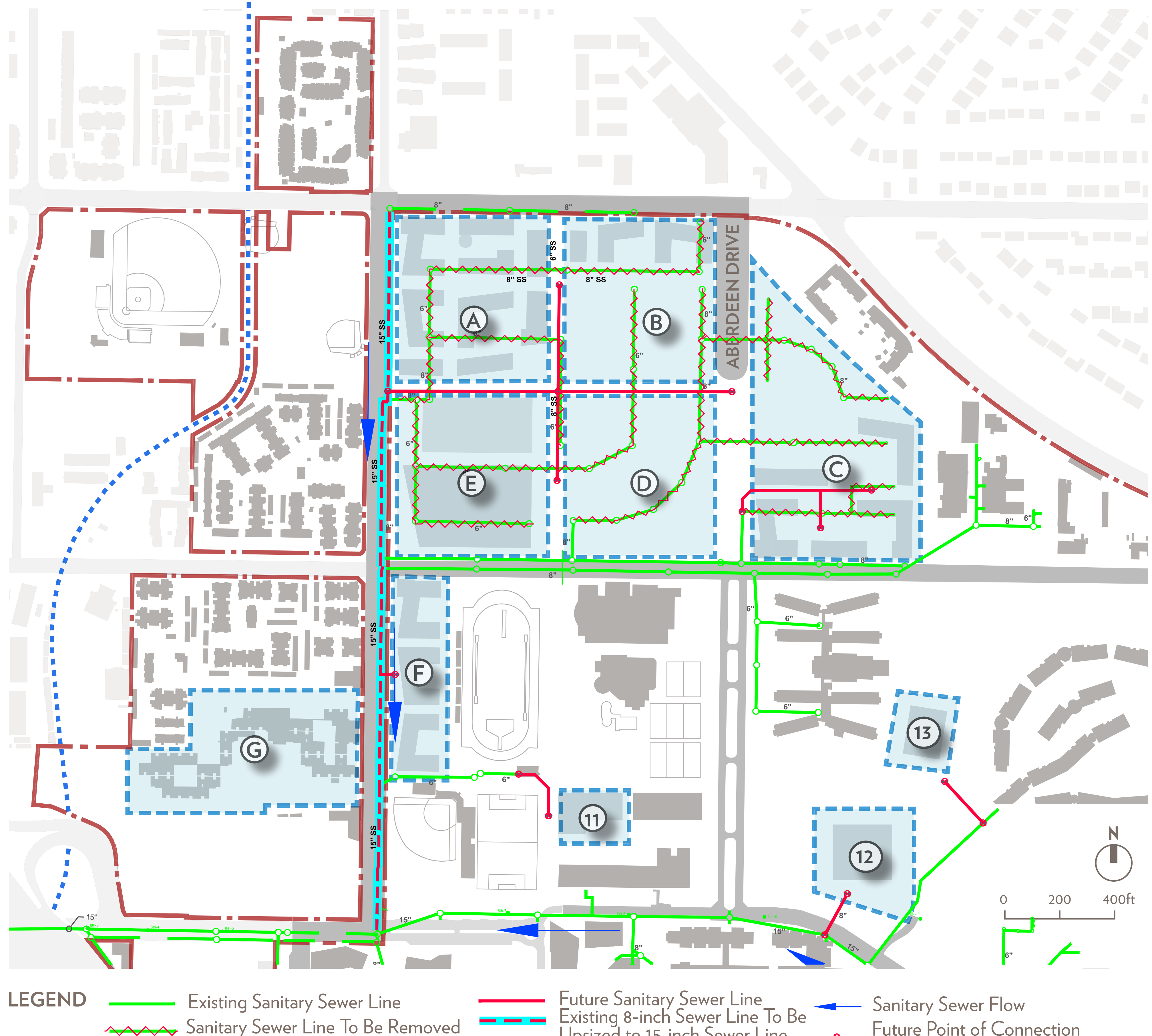
These sites' primary contribution to the Master Plan Study is capacity for additional square footage.

NORTH DISTRICT

Sites A to G

North District Opportunity Sites.

Figure 6.36 PROPOSED SANITARY SEWER NETWORK (NORTH DISTRICT)



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

BUILDING OPPORTUNITY SITES

CORE CAMPUS

1. Carillon Mall West
Shape the intersection of Arts Mall and the Carillon Mall on the site of Hinderaker Hall.

2. Gateway Link
Bridge between transit, student life and the Carillon Mall.

3. Core Campus Nexus
Create new lines of sight into the heart of campus from the perimeter.

4. Eucalyptus Walk Science Area
Transform a “back door” into a “front door” at the perimeter of East Campus.

5. Picnic Hill Science Area
Reframe a popular outdoor gathering space.

6. Core Campus South Extension
Enhance institutional identity on the southern hillside.

7. Citrus Mall Portal
Reinforce the intersection of Citrus Mall and the Carillon Mall.

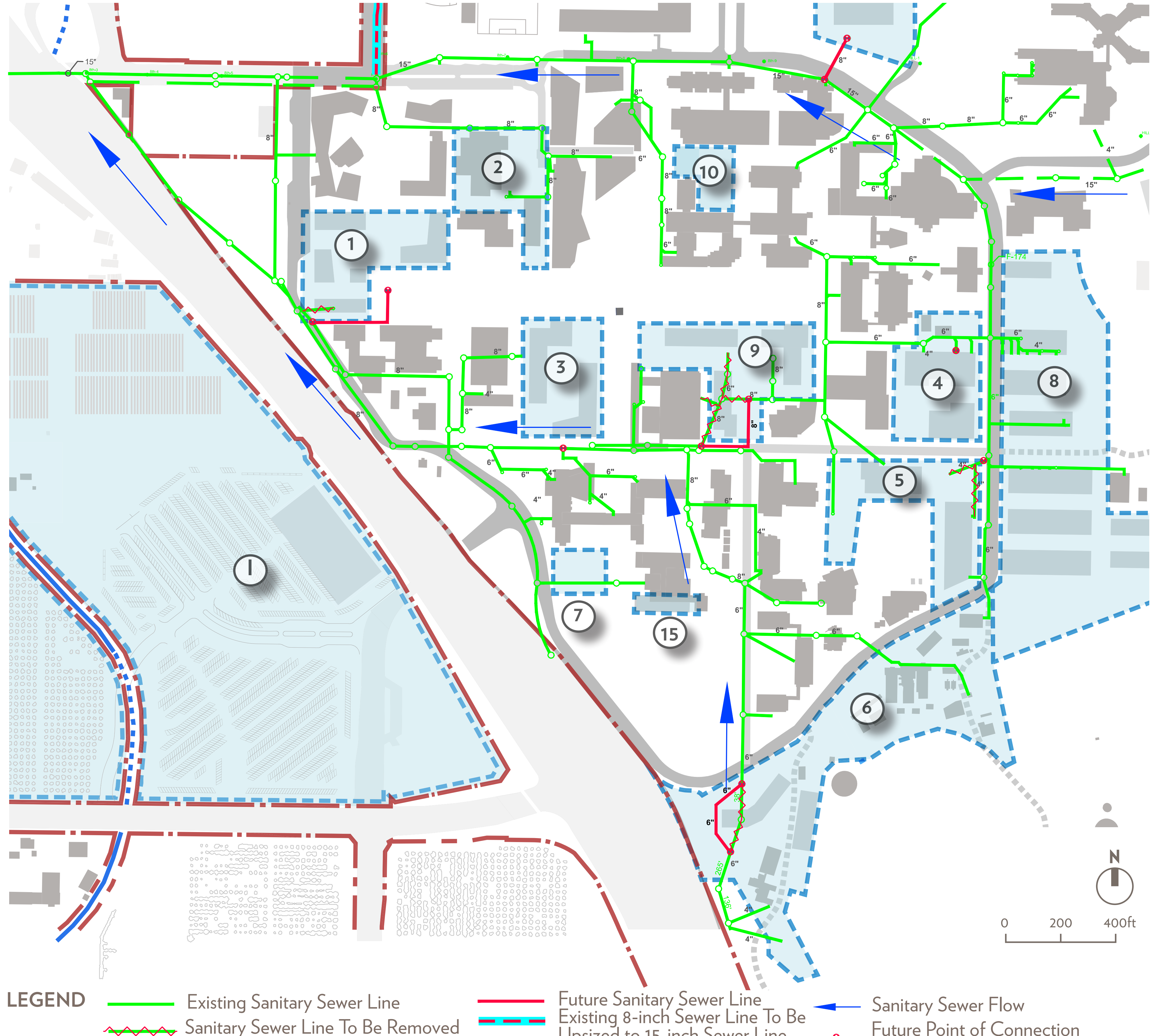
8. Science Area Greenhouses
Re-envision a science and research district.

Sites 9 to 15
These sites’ primary contribution to the Master Plan Study is capacity for additional square footage.

WEST CAMPUS

Sites H and I
West Campus Opportunity Sites.

Figure 6.37 PROPOSED SANITARY SEWER NETWORK (CORE CAMPUS)



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

Arroyo at Glen Mor

6.9
Water Distribution

EXISTING DOMESTIC WATER INFRASTRUCTURE

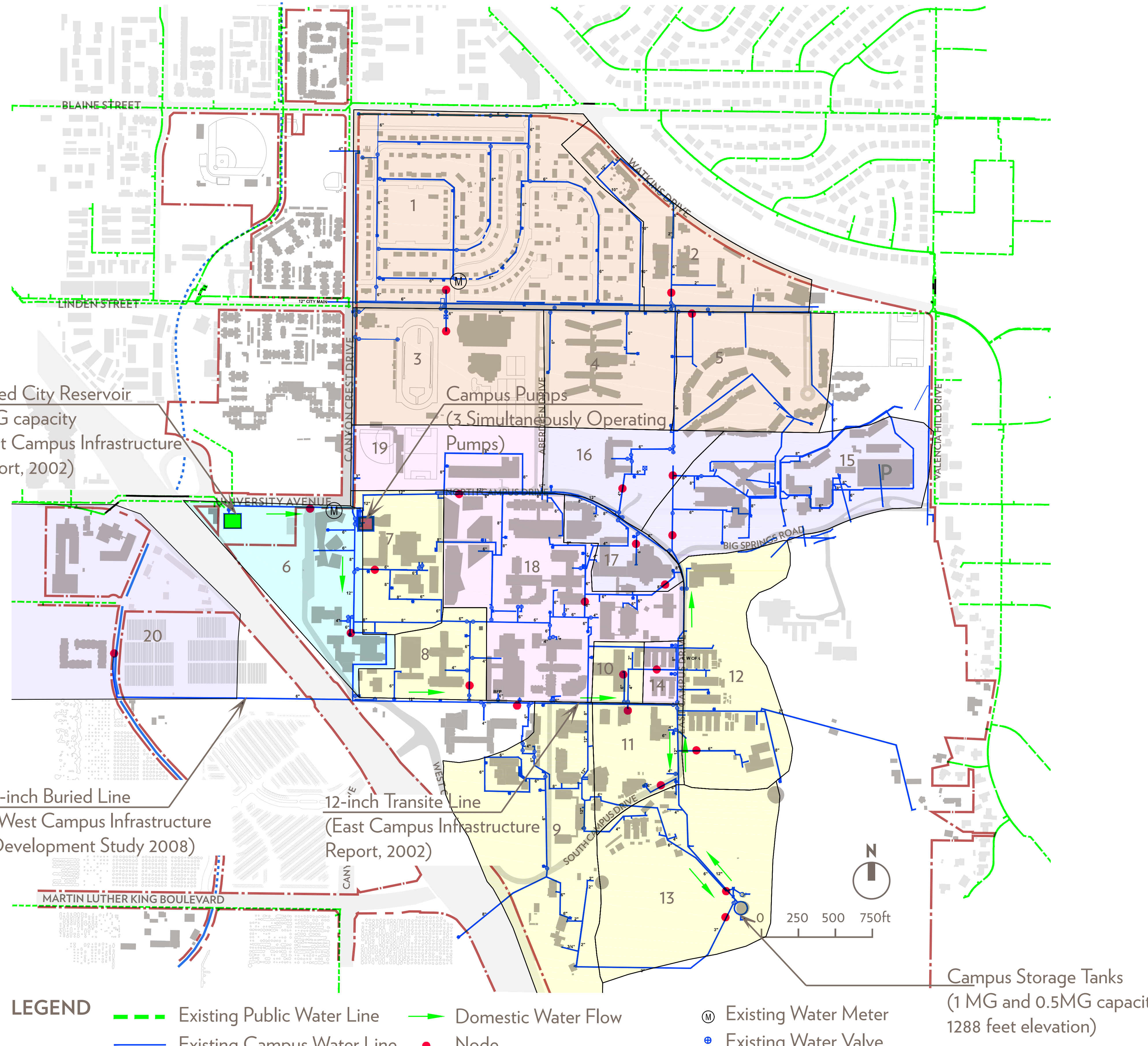
UC Riverside's domestic, irrigation, and fire water needs are fulfilled by 5,000,000-gallon city reservoir, which is buried just south of University Avenue and East of I-215 / SR-60. The University also has rights to the ground water. The treated water from the reservoir is supplied to the campus domestic water pumping station through a 15-inch concrete pipe. The pumping station is located east of the intersection of University Avenue and Canyon Crest Drive. This pumping station consists of the main city 12-inch water meter, two reduced backflow preventers, and four 100 HP pumps per East Campus Infrastructure Project Report.

The campus has two domestic water storage tanks, with capacities of 1,000,000 gallons and 50,000 gallons each. A 12-inch transite pipe (concrete with asbestos) serves as the main water line for water distribution to the main campus as well as feeds the two campus storage tanks located south east of the campus. When the storage tanks are full, the pumps shut off, and the storage tanks act as the main water source for the campus. When the water level drops below a pre-determined level, the pumps start once again to fill the tanks as well as supply water to the campus.

A separate 12-inch city water line also runs along Linden Street, which connects to the existing campus domestic water system at the corner of Florida Street and Linden Street through a city water meter and valve. This 12-inch water line serves as a backup supply to the campus main water network system. It also services the offsite residential neighborhood just east of the campus, which is beyond the scope of this study.

Several water laterals ranging from 4-inch to 8-inch branch out from the 12-inch transite line and serves the water demand of the Core Campus. The North District is mainly served by an 8-inch asbestos cement water line running along the Canyon Crest Drive, and provides the main point of connection to the 6-inch service line at the corner of Florida Street and Linden Street.

Figure 6.38 EXISTING WATER DISTRIBUTION NETWORK



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

METHODOLOGY

Methods for estimating water flows and modeling water usage are based on common engineering principles. Domestic water flows by on-site buildings for the campus were estimated based on the existing building square footage. An average of 25 Gal/SF was used to determine the average daily flow produced by the buildings. A peaking factor of 3.0 was used to determine the maximum daily demand. Fig 6.39 summarizes the results of average water consumption based on Energy Star Data Trends.

Figure 6.39 AVG. WATER CONSUMPTION SUMMARY

Building Type	Gal/GSF
Laboratory Facility	60
Residence Hall	35
Office	12
K-12 School	10
Retail	8
Average	25

GPD: gallons per day **CFS:** cubic feet per second **GPM:** gallon per minute

Computer models were created with EPANET 2.0 to determine the minimum pressure values at the nodes, which approximately serves the total water service area. The estimated maximum daily flow demands for the campus were applied to various nodes based on the maximum usage of the service area. The models tested the existing system's ability to satisfy the domestic water and fire water needs for the existing campus and future developments.

The existing water distribution network is identified in Fig 6.38: Existing Water Distribution Network. Based on the operational procedures of the current water system, two scenarios were taken into consideration. In order to meet the water demand for Scenario "A", the campus water system was supplied by pumps only with the exclusion of storage tanks. In Scenario "B", two fire hydrants were added to the water system at strategic locations with a demand of 1500 gpm each. The storage tank was also assumed to be connected the main water system, which serves as a backup for the fire water demands.

Two computer models were created with EPANET 2.0 to illustrate the existing conditions on campus. Appendix 6.9-A includes a summary of the results of the computer model for Scenario "A" and Scenario "B." Fig 6.9 (a) & (b):Existing Water Distribution – Pipe and Node Map (Core Campus), corresponds to the existing system model Scenario "A" provided in Appendix 6.9-A, whereas Fig 6.9 (c) & (d): Existing Water Distribution – Pipe and Node Map (North District), illustrates the existing system model Scenario "B" provided in Appendix 6.9-A.

The water system was evaluated with the addition of proposed buildings Based on the future development presented in the Master Plan Study, recommendations have been made to construct new water pipes, and to relocate and demolish various existing water lines. This is conceptually illustrated in Fig 6.40 Master Plan Study Future Domestic Water North District, and Fig 6.41 Master Plan Study Future Domestic Water Core Campus.

Scenario "A" and Scenario "B" as discussed in the existing water analysis section were used to create computer models using EPANET 2.0 in order to illustrate the future conditions on campus. Appendix 6.9-A includes a summary of the results of the computer model for Scenario "A" and Scenario "B." Fig 6.9 (e) & (f): Future Water Distribution – Pipe and Node Map (Core Campus), corresponds to the future system model Scenario "A" provided in Appendix 6.9-A, whereas Fig 6.9 (g) & (h): Future Water Distribution – Pipe and Node Map (North District) illustrates the future system model Scenario "B" provided in Appendix 6.9-A.

FINDINGS

An evaluation of the water models revealed that the existing water system adequately supports the demand for existing buildings and the future developments as depicted in the Master Plan Study with no significant pipe losses due to size or elevation. In addition, the existing water pressures throughout the campus satisfy the Riverside County Fire Department minimum requirement of 20 psi as shown under the "Pressure" column of the data analysis table included in Appendix 6.9-A.

STRATEGIC PRIORITIES

Based on the findings above, the existing water network system adequately supports the demand for the existing buildings on campus. However, if UC Riverside wishes to pursue the future developments as depicted in the Master Plan Study, the following recommendations need to be considered in order to provide service connections to the future buildings, re-routing water lines, and replacing old pipes as illustrated in Fig 6.40 Proposed Domestic Water Network North District, and Fig 6.41 Proposed Domestic Water Network Core Campus.

- **Opportunity Site A, B, D, & E:** In order to serve future developments in the North District, remove the existing network of 6-inch water lines currently serving Canyon Crest Family Student Housing, and install a 6-inch water main connected to the existing water system at the Linden Street and Florida Street intersection. Several service connections along the new 6-inch line will be provided to service future developments in the North district.

- **Opportunity Site C:** Install a 6-inch lateral and service connection to serve future developments in the North district just west of the Corporation Yard.

- **Opportunity Site F:** Provide a service connection to future developments from the existing 12-inch transite line west of the UC Riverside Track Facility.

- **Opportunity Site 1:** Install a new service connection to serve future developments from the existing 8-inch water main.

- **Opportunity Site 3:** To provide a clear site for future developments, remove the 4-inch water line and install a new service connection to serve the future building.

- **Opportunity Site 4:** To provide a clear site for future developments, remove the existing 6-inch lateral pipe serving the greenhouses and install a new 6-inch water service loop and a service connection for the future building.

- **Opportunity Site 5:** Provide a service connection to the future developments.

- **Opportunity Site 6:** To provide a clear site for future developments, relocate the 6-inch water line in conflict with the future building next to College Building North and provide a service connection for the future building.
- **Opportunity Site 9:** Install a new 6-inch lateral and service connection to serve the future developments.
- **Opportunity Site 11:** Provide a service connection to the future developments from the existing 8-inch loop north of North Campus Drive.
- **Opportunity Site 12:** To provide a clear site for future developments, remove the water line and provide a new service connection from the existing 6-inch water line.
- **Opportunity Site 13:** Provide a service connection to the future developments from the existing 8-inch water line.

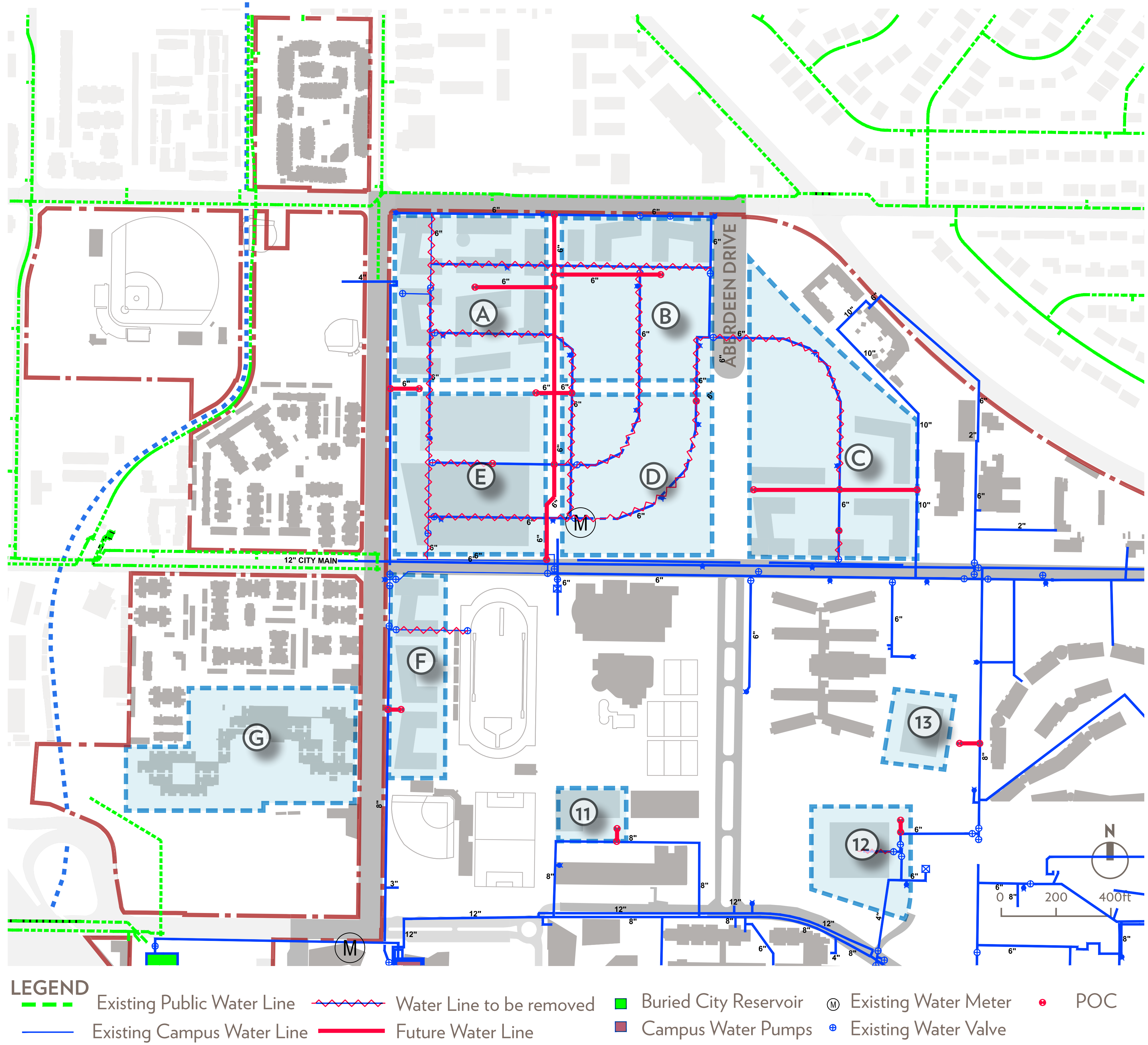
The recommendations presented herein include removal, replacement, and construction of new water lines. The findings and recommendations are determined for master planning analysis with assumed water demands. If the proposed building designs yield larger flow rates than presented herein, it is recommended that the university re-evaluate the data analysis and findings.

WATER CONSERVATION STRATEGIES

Benefits of using stormwater, greywater and/or blackwater include:

- Conserving groundwater by replacing potable water with stormwater and/or greywater for irrigation
- Reducing water costs
- Reducing costs for complying with new stormwater management requirements LID/SUSMP for roadway improvements and public school parking lot upgrades
- Reducing runoff pollution to area waterways
- Creating educational opportunities

Figure 6.40 PROPOSED DOMESTIC WATER NETWORK (NORTH DISTRICT)

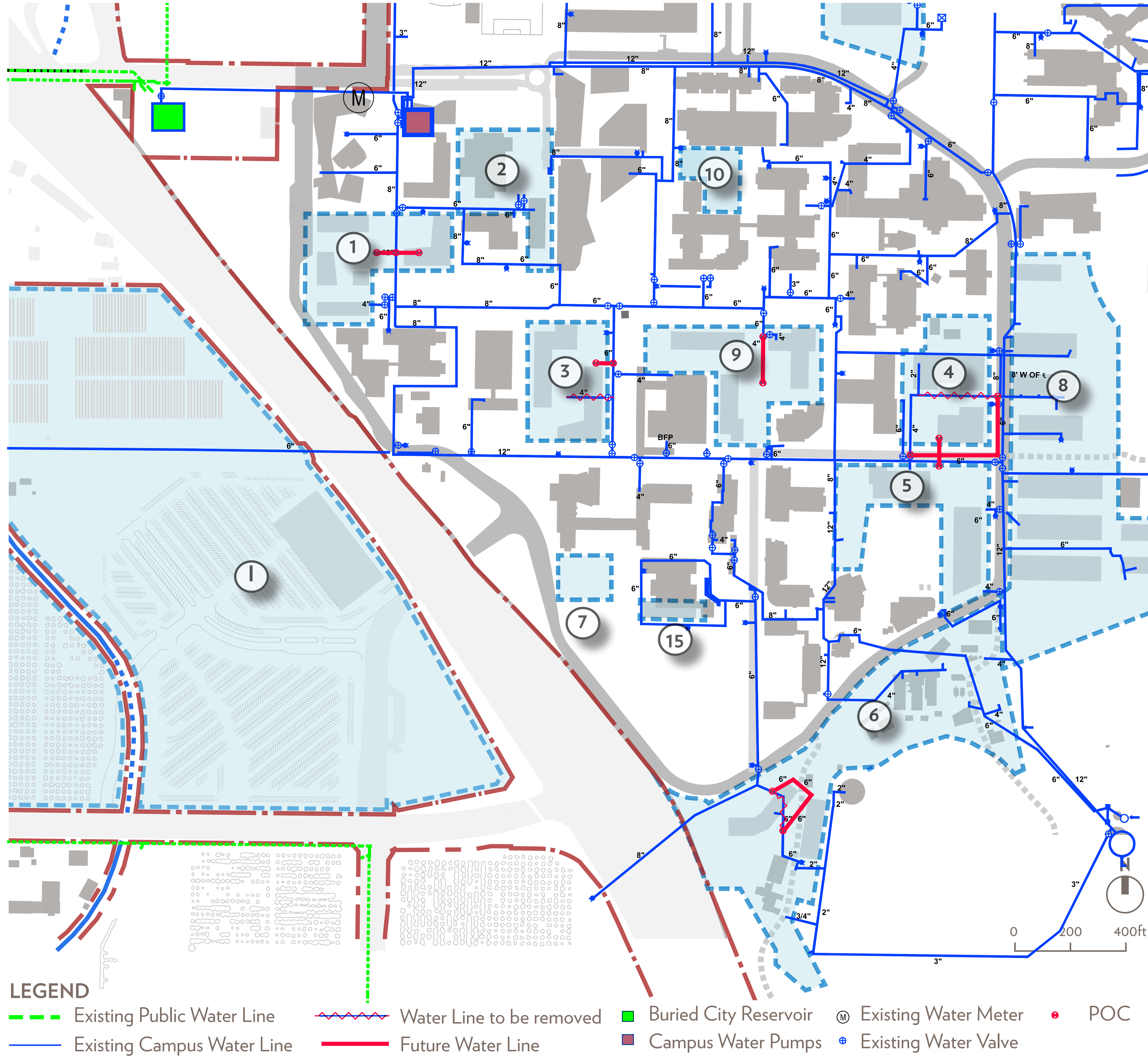


Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

The following are strategies for reducing domestic water usage:

- Retrofit standard urinals with more efficient models.
- Upgrade sanitary fixtures with high efficiency models including high-efficiency toilets, water saving sinks, waterless urinals etc.
- Reuse greywater and stormwater for non-potable applications such as landscaping irrigation, toilets and urinal flushing
- Implement a reuse system that collects rainwater from the roof, air handler condensate discharge, and water rejected from a reverse osmosis system used to generate pure water for laboratory experiments
- Reuse blackwater by implementing systems such as a Living Machine. Waste solids settle in a primary tank and non-potable water is pumped out though the treatment system for use in toilet flushing, disposal, or subsurface landscape irrigation. Typically, these systems require a certified operator and regularly-scheduled testing, sometimes up to three times per week. The operations and maintenance of such system will need to be further investigated.

Figure 6.41 PROPOSED DOMESTIC WATER NETWORK (CORE CAMPUS)



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

6.10

Irrigation Water System

EXISTING IRRIGATION SYSTEM

All potable, fire water, and irrigation services are connected to the on-campus private system throughout the campus. During the summer months when school is not in session irrigation water is a greater percentage of the overall water used. During the fall, winter, and spring months when school is in session, less irrigation is necessary and the percentage of water used for irrigation is less. Therefore, based on the analysis of existing water meter readings for the year 2014 presented in Fig 6.42: Historic Campus Water Usage 2014, the Planning Team assumes that 50% of the water used for the entire campus is for irrigation purposes with the remaining 50% for potable and fire purposes.

Figure 6.42 HISTORIC CAMPUS WATER USAGE 2014

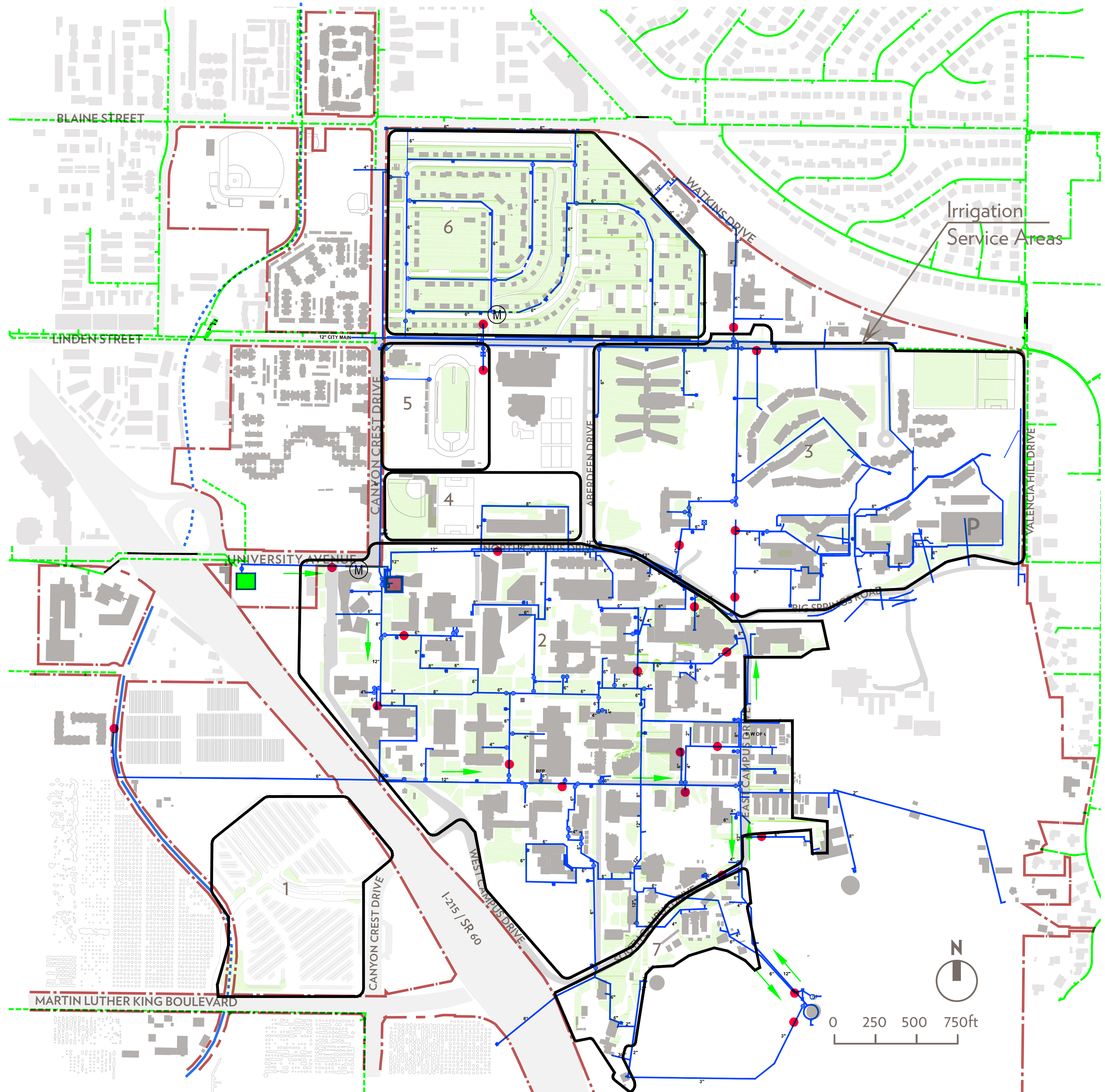
Connection	Size	CCF/YR	Gal/yr
12" Water Meter	12"	489,032	366,040,452

Gal/yr: gallons per year CCF/yr: 100 cubic feet per year

METHODOLOGY

The existing combined water distribution network is identified in Fig 6.43: Existing Irrigation and Domestic Water Network. The combined water demands for the campus were estimated based on an analysis of meter readings over a recent 12-month period. Results of this analysis are summarized in Fig 6.44: Historical Campus Irrigation Water Usage 2014.

Figure 6.43 EXISTING IRRIGATION AND DOMESTIC WATER NETWORK



LEGEND
- Existing Public Water Line
- Existing Campus Water Line
- Domestic Water Flow
- Node
- Buried City Reservoir
- Campus Water Pumps
- Existing Water Meter
- Existing Landscaping

Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

Figure 6.44 HISTORIC CAMPUS IRRIGATION WATER USAGE 2014

POC	Usage	Size	Annual		Peak Months		8-hour Irrigation	
			Avg Day	Avg Usage	Avg Day	Avg Usage	Max Day	Max Usage
			GPD	GPM	GPD	GPM	GPD	GPM
12" Water Meter	Irrigation	12"	501,425	348	587,361	408	1,762,084	1,224

GPD: gallons per day **GPM:** gallons per minute

The "annual average day" column is based on the average annual daily usage. The "peak month average day" considers only the higher meter readings for the dry months between June and November. The average peak month demands were assumed to be generated over eight hours a day to get the maximum daily water usage for irrigation. The 8-hour maximum daily water usage is calculated to be 1224 gallons per minute.

Refer to the Fig 6.45: Peak Flow Density, for the total campus landscaping area including turf and planters (estimated using Google Earth and aerial map.) The peak flow density per 1000 square feet was calculated based on the total landscaping area and 8-hour maximum daily usage, which was then used to estimate the irrigation usage for the future site development as depicted in the Master Plan Study.

Figure 6.45 PEAK FLOW DENSITY

Annual Avg. Daily (GPD)	293,681
Peak Months Avg. Daily (GPD)	587,361
8-hours Avg. Daily (GPD)	1,762,084
8-hours Max. Daily (GPM)	1,224
Total Landscape Area (GSF)	2,712,575
Peak Flow Per 1000SF (GPM)	0.4511

A computer model of the combined domestic and irrigation water system was created with EPANET 2.0 to determine the minimum pressure values at the nodes, which approximately serves the demands of the service area. The estimated maximum daily flow demands for domestic water in Appendix 6.10-A, and irrigation demands as calculated in Table A-1 were applied to various nodes based on the maximum usage of the service area. The models tested the existing system's ability to satisfy the domestic water and firewater needs for the existing campus and future developments. Appendix 6.10-A, summarizes the irrigation water usage allocation based on the irrigation service areas. The results from the computer model for the existing combined water system are shown in the Appendix 6.10-A. Fig 6.10 (i) & (j): Existing Irrigation and Domestic Water Distribution – Pipe and Node Map corresponds to the existing system model provided in Table Appendix 6.10-A.

The combined water system as shown in Fig 6.46 and 6.47 was evaluated with the addition of proposed landscaping area. Appendix 6.10-A, summarizes the irrigation water usage allocation based on the irrigation service areas. Fig 6.10 (k) & (l): Future Irrigation and Domestic Water Distribution – Pipe and Node Map corresponds to the existing system model provided in Table Appendix 6.10-A. The results from the computer model for the combined future water system are also shown in Appendix 6.10-A.

FINDINGS

The existing water system adequately supports the combined irrigation and domestic water demands for existing buildings and the future developments as depicted in the Master Plan Study. In addition, the existing water pressures throughout the campus satisfy the Riverside County Fire Department minimum requirement of 20 psi.

STRATEGIC PRIORITIES

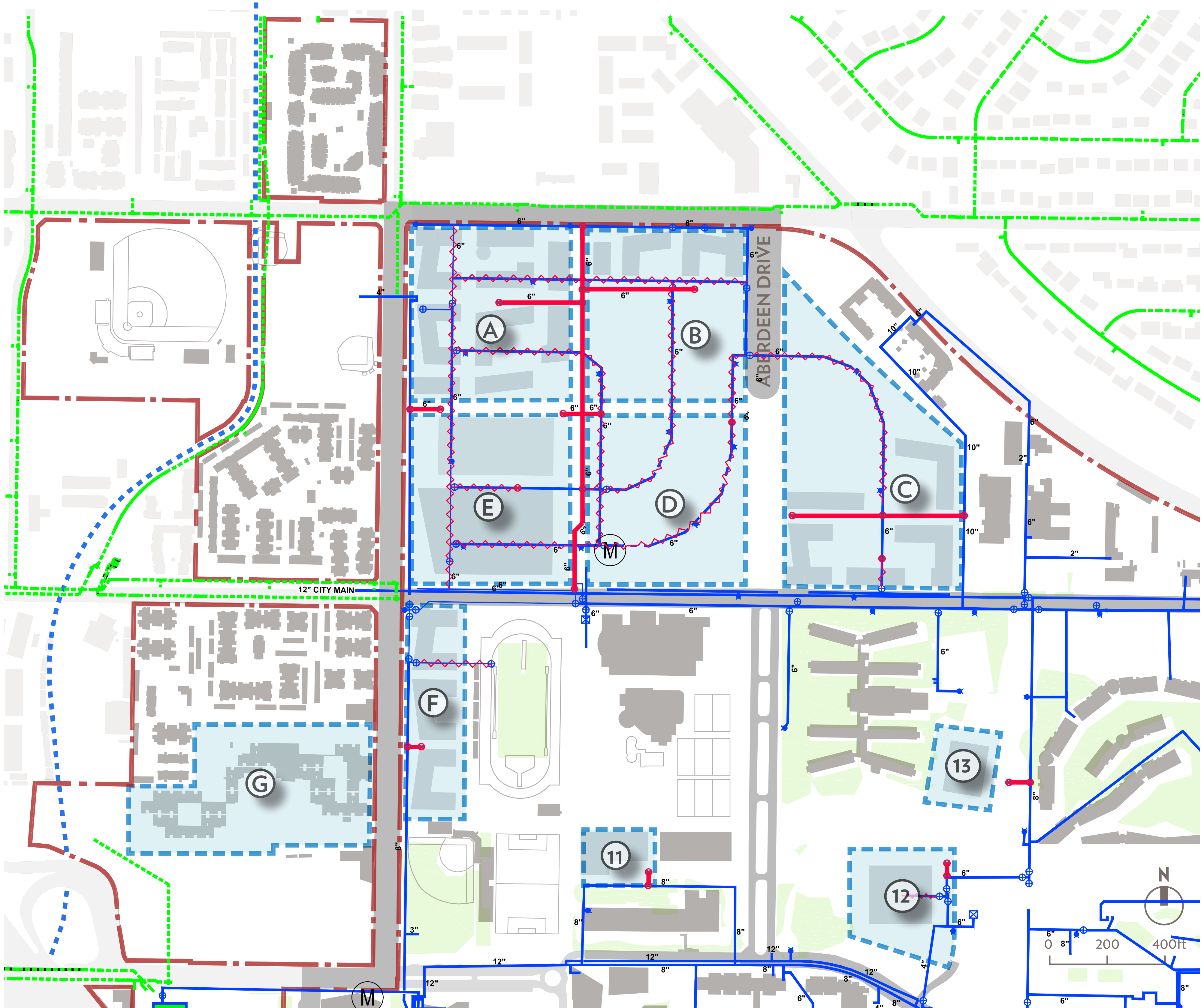
An evaluation of the existing water system revealed that the existing water services adequately support the demand of existing buildings and landscape areas with no significant pipes losses due to pipe size or elevation. The existing water system can also adequately support the demand for proposed buildings, landscape areas, and practice fields as depicted in the Master Plan Study. Since the potable and irrigation water is a combined water distribution network, recommendations provided under domestic water system are relevant for the irrigation system as well.

Irrigation usage on campus has been estimated based on the water usage data provided by the University; actual irrigation demand could vary substantially. The ratio of irrigation-to-potable usage is a general overall campus comparison and may not be applicable at every point of connection. Therefore, we recommend that each irrigation connection be sub-metered in order to ascertain more precisely how much water is currently being used for irrigation purposes campuswide. Furthermore, sub-metering allows for campus personnel to evaluate zones which are operating inefficiently or identify points of connection or mains which require maintenance. Utilizing these more accurate irrigation usage quantities, more precise water savings can be calculated.

The following are strategies for reducing irrigation water usage

- Incorporate xeriscaping - landscaping based on native, water-efficient plants to minimize the need for irrigation.
- Introduce drought-tolerant landscaping and plant materials according to the landscape strategic priorities presented in Chapter 4.

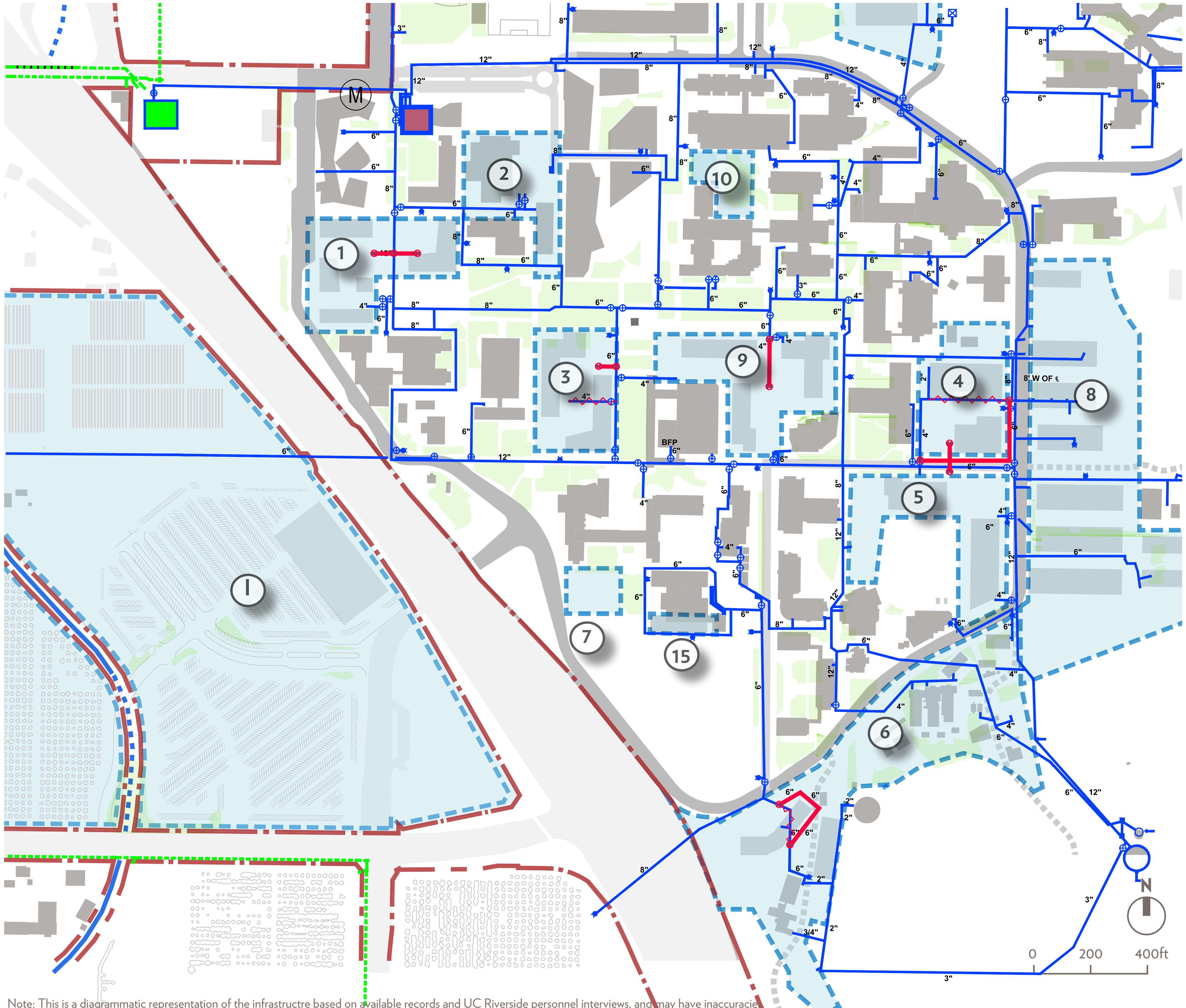
Figure 6.46 PROPOSED IRRIGATION AND DOMESTIC WATER NETWORK (NORTH DISTRICT)



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

LEGEND
- Existing Public Water Line
- Existing Campus Water Line
- Water Line to be removed
- Future Water Line
- Buried City Reservoir
- Campus Water Pumps
- Existing Water Meter
- Existing Landscaping
- POC

Figure 6.47 PROPOSED IRRIGATION AND DOMESTIC WATER NETWORK (CORE CAMPUS)



Note: This is a diagrammatic representation of the infrastructre based on available records and UC Riverside personnel interviews, and may have inaccuracies.

LEGEND

- Existing Public Water Line
- Existing Campus Water Line
- Water Line to be removed
- Future Water Line
- Buried City Reservoir
- Campus Water Pumps
- Existing Water Meter
- Existing Landscaping
- POC