Civil Utility Master Plan Final Report
CU Work Order #422523

University of Colorado at Boulder

Client Representative Gil Fike

Boyle Engineering Corporation

Project Manager Mary Stahl

Project Engineers Jeffrey Bandy
Daniel Rice

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BOYLE 215 Union Blvd, Suite 500 Lakewood, CO 80228

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Executive Summary

This Civil Utilities Master Plan evaluates the ability of the existing water and sewer systems on portions of the Main and East Campuses to serve existing demands, both normal and fire flow conditions, as well as the ability to serve projected future demands under both normal and fire flow conditions. Future conditions were estimated using information from Campus Planning and the Campus Master Plan. This Executive Summary presents the major results of the analysis for both the water and the sewer systems.

Potable Water System

The potable water system was evaluated through use of a computer model. This model should be considered no more accurate than within 15%. The model provides relative indications of problem areas throughout the system as well as the ability of proposed alternatives to relieve those problem areas. The model, however, cannot be considered to give an exact pressure and flow at a single point within the system, rather the results can be considered to be within about 15%.

The potable water system on the East Campus was determined to provide acceptable service for existing and Build-out conditions. This is due primarily to the high pressures provided by the City to the East Campus and the fact that many buildings are served domestically and/or for fire directly from City mains.

The existing potable water system on the Main Campus is of varying age, ranging from over 50 years old to constructed this year. The system is sufficient to meet estimated normal demands, defined as peak demands during a weekday during the school year. The system is in relatively good shape, given the age of pipe, but the older portions are in need of replacement. In addition, the system does not have the ability to provide the desired fire flow demands, as defined by the Campus Fire Marshal, under existing conditions. The reasons for the deficiencies are:

- The City cannot provide more than about 650 gpm above a pressure of 70 psi to the Penn and UMC Meters (meters serving the west side of campus). Note that fire flows of 1,500 to 3,000 gpm, in addition to normal demands, are desired.

- Pipe near the Norlin Quad is old and is thought to be heavily tuberculated, based both on apparent pipe roughness factors (which correlated with available test data) and staff observations when repairing breaks.

- The elevation and hydraulic gradeline on the west side of campus is such that the Reed and Folsom meters do not readily provide water west of about the Norlin library. Thus, the west side of campus is reliant on the Penn and UMC meters.

It should be noted that a number of buildings on campus rely on hydrant flow from City hydrants to meet the desired fire flow demand. Where buildings were within 500 feet and had a direct line of sight to a City main, this was considered acceptable. If a building is greater than 500 feet or did not have a direct line of sight to a City main, it was assumed that the University's system needed to provide all of the desired fire flow demand.

The system also experiences deficiencies under future projected conditions, both 10-year and Build-out. The primary reason for the deficiencies under future conditions, assuming that recommended improvements for existing conditions are implemented, is that the City of Boulder is projecting a decline in service pressures near the Main Campus in 2020. This decline in service pressures is in the range of about 15 psi. Service provided by the City at the meters is still well within industry accepted parameters, yet the decrease in pressure significantly affects the ability of the University's system to provide fire flow internally. Additionally, the Campus Fire Marshal has indicated that campus sprinkler systems are typically designed with a 10 psi "safety factor." Obviously, a decline in service pressure greater than 10 psi raises questions about the ability of sprinkler systems to function as intended. In response to the projected decrease in supply pressures from the City, the following are recommended:

- Maintain a relationship with the City and investigate improvements to the City's system that may be mutually beneficial.
- Monitor and test sprinkler systems on a regular basis.
- Use a safety factor of 20 psi on all future sprinkler systems installed on campus.

If and when pressures from the City drop to a point that the sprinkler systems may be affected, the University can then evaluate whether sprinkler systems should be replaced, sprinkler systems should be modified, or a fire pump installed near the Reed meter. By taking the above approach, money is not spent unnecessarily nor is a maintenance intensive piece of equipment (a fire pump) installed prior to its actual need.

The following are recommended under all alternatives:

- Install a parallel pipe from the Penn meter to the Norlin Quad. It is recommended that this pipe be tied in to the Quad loop on the southwest side, thus providing two points of service to the system from the Penn meter. Estimated cost is $104,000.
- Install a pipe completing a loop near Fleming Law and the Kittredge Complex loop. Estimated cost is $76,000.
- Install pipe loop to serve the proposed central utility plant. Estimated cost for two phases is $138,000 and $193,000.

To mitigate system deficiencies with regards to providing desired fire flow, the following alternatives are presented:

- Install a fire pump at the Penn meter.
- Install an 8-inch pipe from the UMC meter to the Norlin Quad to provide flow from more than one meter to the older parts of campus. In addition, a number of buildings that are not currently sprinkled need to be sprinkled so that the maximum fire flow desired throughout campus is 1,500 gpm, except for those buildings that can rely on City hydrants.

Advantages and disadvantages of the two options, as well as estimated costs are shown in Table ES-1.

Table ES-1: Advantages and Disadvantages of Alternatives

Alternative	Advantage	Disadvantage
Install fire pump at Penn meter. Estimated Cost - $500,000.	Greatly increases available fire flow over a large part of campus. No retrofitting of existing buildings for sprinkler systems is required.	Fire pump must be maintained and tested on a regular basis, increasing work for University staff. Fire pumps are not a passive system and rely on sensors and moving mechnical parts to work, as well as requiring back-up power supply. No benefit to the system under normal conditions.
Install additional piping. Install sprinkler systems in specific buildings. Estimated Cost - $164,000 plus the cost of sprinkler systems.	Improves flow in northwest part of campus under normal conditions. Improves fire and life safety in buildings in which sprinkler systems are installed. Decreases the required flow needed to be supplied by the University’s system, thus reducing stress on old piping. Passive system that does not rely on a pump (assumes sprinkler heads “pop” by melting under a certain temperature).	May be difficult to retrofit some buildings with sprinkler systems.

Without any improvements, fire flow deficiencies are significant for most of the campus under the projected future conditions. With the proposed improvements, few additional capital improvements are needed, other than those to serve specific development. In particular, the largest future demand is from the proposed power plant east of the Coors Events Center. A looped pipe is recommended for service to the proposed power plant, with a portion of the loop installed in the initial phase and the remaining length to be installed as water demands by the power plant increase. The estimated cost is $138,000 for the initial phase and $193,000 for the completion of the loop.

Total costs for the recommended water system improvements are $511,000 plus the cost of the chosen alternative to remedy fire flow deficiencies.

In addition, as noted above, many pipes have reached the end of their useful life. A replacement program was developed as shown in Table ES-2.

Table ES-2: Potable Water System Replacement Program Cost Estimates

Year	Length to Replace per Year	Estimated Cost per Year (inflated at 4%/yr)
2004 – 2005	1,700 feet	$265,000
2006 – 2010	1,500 feet	$274,000
2011 – 2015	1,700 feet	$378,000
2016 – 2020	1,800 feet	$486,000

It should be noted that projected conditions within the campus itself can be affected by a number of factors, most of which would likely decrease the projected normal peak day water demand. Because the campus is close to Build-out with regards to available space, there are not any anticipated factors that would significantly increase demands within the study period. Factors that could reduce demands include renovations that install low-use water fixtures, changes in personal habits of staff and students, completing the change over to non-potable water for the irrigation system, and installation of water conserving cooling units. Of these factors, the one that has the greatest potential for reducing water demands is the installation of water conserving cooling fixtures and the removal of once-through cooling units. After evaluation, it was determined that installation of water conserving cooling fixtures would not significantly affect the ability of the potable water system to deliver desired fire flows. However, it is recognized that there are significant positive effects to the University in replacing these systems with regards to the cost of potable water and the future cost and ease of obtaining taps from the City for future buildings.

Sanitary Sewer System

The University's sanitary sewer system is a gravity system that discharges to the City's system at several locations. The sanitary sewer system was evaluated for capacity and condition of pipe. A rating system was developed that categorizes pipes in need of repair or replacement and also prioritizes those repairs within a given category. Alternatives for improvement include replacement, installation of parallel piping, or slip-lining. Where a pipe is physically obstructed or caved-in, slip-lining is not an option. Recommended improvements and estimated costs are shown in Table ES-3.

The estimated costs for improvements to the sanitary sewer in priority groups 1, 2, and 3 are $321,000, $100,000, and $100,000 respectively, which all represent pipe replacement.

In addition to the improvements identified in this study a maintenance program is presented for the sanitary sewer. It consists of a cleaning and inspection program and a repair and replacement program. The cleaning and inspection program would encompass one-third of the campus sewer every year. The estimated annual cost is $7,000. The estimated annual cost of the repair and replacement program is shown in Table ES-4.

In addition, the City's system can affect the University's system, primarily where City sewers are surcharged and potentially cause a back-up into the University's system. There are three locations that warrant further monitoring and discussions with the City. The area behind the Powerhouse is known to be over capacity and with the future projections could be problematic for service to this part of campus. The areas in 28th Street need to be monitored in relation to future development on campus. This collector will serve both the Law Addition and new Utility Plant, and future capacity needs to be ensured. The area near Math and on East Campus are not expected to see future development; however, surcharging during wet weather with 2025 projected flows could cause problems for the campus. It is recommended that the University work with the City to correct these problem areas.

Table ES-3: Proposed Sanitary Sewer Improvements

Pipe	Improvement	Trenching Length	Cost to Trench	Lining Length	Cost to Slip[1]
Priority 1					
0118-0117	Obstruction	10	$5,000	Not Applicable	Not Applicable
0233-0232	Obstruction	10	$5,000	Not Applicable	Not Applicable
0315-0222	Obstruction	10	$5,000	Not Applicable	Not Applicable
0217-0216	Obstruction	10	$5,000	Not Applicable	Not Applicable
0171-0172	Obstruction	10	$5,000	Not Applicable	Not Applicable
0311-0141	Crushed/Cave-in	10	$5,000	Not Applicable	Not Applicable
0101-0100	Obstruction	10	$5,000	Not Applicable	Not Applicable
0130-0129	Obstruction	10	$5,000	Not Applicable	Not Applicable
0051-0049	Crushed/Cave-in	10	$5,000	Not Applicable	Not Applicable
0276-0277	Capacity/Slope	548	$219,000	Not Applicable	Not Applicable
0245-0244	Break, Future Cap.	142	$57,000	Not Applicable	Not Applicable
	Priority 1 Total		***$321,000***		*N/A*
Priority 2					
0201-0200	Breaks	20	$10,000	87	$8,000
0208-0207	Breaks	20	$10,000	231	$9,000
0100-0099	Breaks	20	$10,000	288	$11,500
0133-0129	Breaks, Hole	20	$10,000	238	$9,500
0242-0241	Break	10	$5,000	219	$9,000
0224-0223	Break	10	$5,000	297	$12,000
0215-0214	Break	10	$5,000	125	$8,000
0134-0133	Break	10	$5,000	144	$8,000
0039-0040	Hole	10	$5,000	23	$8,000
0040-0042	Break	10	$5,000	153	$8,000
0249-0248	Break	10	$5,000	152	$8,000
co432-0232	Hole	10	$5,000	310	$12,500
0200-0199	Break	10	$5,000	79	$8,000
0139-0140	Hole	10	$5,000	116	$8,000
0122-0121	Hole	10	$5,000	159	$8,000
0129-0127	Hole	10	$5,000	155	$8,000
	Priority 2 Total		***$100,000***		***$143,500***
Priority 3					
0237-0238-City	Future Capacity	251	$100,000	Not Applicable	Not Applicable
	Priority 3 Total		***$100,000***		*N/A*

1) Costs for Sliplining are based on repair of the entire pipe between manholes.
This technology is more cost effective if the entire pipe is repaired in one setup.

Table ES-4: Sanitary Sewer Repair and Replacement Program Cost Estimates

Year	Length to Replace per Year	Estimated Cost per Year (inflated at 4%/yr)
2004 – 2005	350 feet	$146,000
2006 – 2010	300 feet	$146,000
2011 – 2015	500 feet	$296,000
2016 – 2020	650 feet	$468,000
2021 – 2030	400 feet	$394,000
2031 – 2040	350 feet	$511,000
2041 – 2050	730 feet	$1,577,000

Introduction

Historically, the University of Colorado's water distribution and sanitary sewer systems have served a campus of approximately 570 acres. This acreage includes the Main Campus, East Campus, and Williams Village consisting of classrooms, labs, housing, administration and service buildings, recreation facilities, and green spaces. An initial master plan was developed as early as 1919 and involved two buildings and two additions on the Main Campus. In 1962, the University reported approximately 3 million square feet of developed space that has grown to over 9 million today with over 200 buildings on the Main Campus. With the campus having tripled in size since the early 60s, the potable water distribution system and the sanitary sewer are being relied on to provide ever-increasing service. In addition to the increase in demands in recent years, many of the campus utility components are aging and are in need of repair or replacement. The University has chosen to undertake an evaluation of the Main and East Campus potable water distribution and sanitary sewer systems. This evaluation is designed to aid University staff in making informed decisions about existing infrastructure and potential development as well as provide for budget planning.

Purpose and Scope

The purpose of the Civil Utilities Master Plan is to provide an analysis of the existing potable water and sanitary sewer systems to identify problem areas due to insufficient capacity and/or poor condition in specific areas of the Main and East Campuses. The specific study areas on the Main and East Campuses are shown in Figures 1 and 2. In addition, both the potable water and sanitary sewer systems were analyzed for the 10-year and Build-out conditions, as defined in the overall Campus Master Plan (March 2001) and by Campus Planning. The 10-year conditions, as defined in the Campus Master Plan, is approximately 2010. Build-out does not have a defined time period.

The potable water system has not been studied in a "master plan" type approach since the early 1970's when the campus water system was moved from the City of Boulder's Zone 3 (higher pressure) to the City's Zone 2 (medium pressure). Specific purpose and scope items for the potable water system include:

- Identify areas of poor service due to poor condition of water mains.
- Identify system attributes such as age of system piping.
- Identify areas where the system cannot meet desired fire flows (i.e., desired flow at a specified minimum pressure).
- Identify improvements needed to serve existing facilities adequately (i.e., desired flow within 10 psi of existing pressures).

- Identify improvements needed to serve future facilities as identified by University Planning staff as 10-year future construction as well as potential development areas that are identified in the Campus Master Plan.

- Develop a tool for Facilities Management personnel to use for continuing evaluations of proposed changes in the system (i.e., a computer model).

- Develop a prioritized capital improvements list with associated costs.

Swanson-Rink & Associates performed the most recent assessment of the entire Campus sanitary sewer system in 1964 as part of the Utilities Investigation and Report. WRC Engineering assessed the portion of the system served by the City of Boulder 28th Street collector for capacity in 2001. The purpose of this study is to assess the physical condition and capacity of the entire system serving the Main Campus and East Campus near Marine Street. Specific purpose and scope items for the sanitary sewer system include:

- Review and assess sewer conditions based on Closed Caption TV videotapes and reports.
- Identify areas of missing data in the sewer database.
- Develop a hydraulic sanitary sewer model in spreadsheet format to assess capacity of system. Provide model for use by University staff.
- Identify capacity of existing system and its ability to meet existing and future loads.
- Identify improvements to system to meet future loads as identified by the University for 10-year and Build-out conditions.
- Identify improvements to physical condition of system.
- Identify capacities in City of Boulder system and relate these to future conditions identified by University Planning staff.

Project Approach

The project approach for both the potable water and sanitary sewer systems is based on using existing information available from the University in the form of reports, facility demand data, and CAD files. Computer models of both the potable water and sanitary sewer systems were developed to assist in the analysis of capacity and the ability of each system to provide service under expected conditions. The computer model for each system was given to the University at the conclusion of the project for continued use by University staff in analyzing potential changes to the system, either in system configuration or new demands.

Potable Water System Approach

For the potable water system, the project approach specifically consisted of: using CAD files to determine the size and location of existing buildings, pipes, valves, and fire hydrants on the Main and East Campuses. The University provided two computer models to be used as a basis for developing a new model: one developed in the early 1990's that was calibrated against hydrant test data and one developed in recent years but not calibrated. From the CAD files and previous model work, a model of the existing potable water system was developed in EPANet. This model was not calibrated against meter or hydrant data specific to this project but was compared to readily available data to determine the level of accuracy provided by the model (determined to be within 15%, based on hydrant flow and pressure test data).

The model was used to analyze the water system under estimated existing conditions and projected 10-year and Build-out conditions for Peak Day demands and fire flow conditions. The model was also used to analyze proposed improvements to the system.

Sanitary Sewer Approach

The University's CAD files and sewer pipe database were used to develop the structure and attributes used in the sewer hydraulic model. Water demand estimates used in the potable water system analysis were used as input data for the sewer loading. The sewer model was not calibrated to monitored flow data, but rather a conservative approach was used based upon a one-to-one pass through of the potable water demand with an additional peaking factor applied along with an estimated infiltration and inflow value. The model was used to analyze existing loads as well as projected loads under 10-year development, Build-out development, and with potential demand reductions.

The physical condition assessment was developed by applying a rating method to known problems in the system. These problems were identified by viewing CCTV videotapes (taken 7/02 to 8/02) and the corresponding summary sheets that detailed conditions of the pipe.

Background Information

Background information for both the potable water and sanitary sewer systems consisted primarily of CAD files, previous reports, and staff knowledge.

Potable Water System

The existing CAD files on the potable water system were considered by University staff to be sufficiently accurate for use in this study. In addition, University staff provided a hand-marked drawing indicating the approximate ages of existing piping. Previous reports on the potable water system made available for this study include:

- City of Boulder Treated Water Master Plan, December 2000, Integra Engineering.
- Technical Report Phase 2 Study: Hydraulic Model Calibration, February 1993, William B. DeOreo, P.E.
- Program Plan for Utility Systems Improvements, Boulder Campus, Fiscal Year 1974-75, R.W. Beck & Associates.
- Program Plan for Domestic Water Pressure Change, Boulder Campus, Fiscal Year 1973-74, R.W. Beck & Associates.
- Water Utility Master Plan, Part 1 Domestic Water, Boulder Campus, December 1972, R.W. Beck & Associates.
- Utilities Investigation and Report, Boulder Campus, December 1964, Swanson-Rink & Associates.

The 1993 DeOreo report was the basis for the calibrated model provided by the University. Information contained in the DeOreo report, specifically field test data, was used in determining the accuracy of the model developed in this study as well as for the pressure supplied by the City at the Main Campus meters. The University does not have more recent data available nor was there time or budget available to obtain additional data as part of this project.

The 2000 City of Boulder Treated Water Master Plan was used for the following:

- Determining the major improvements in the City's system planned in the vicinity of the Main and East Campuses.
- Determining that no major changes (such as a change in pressure zones or available storage) in the City's system are planned in the vicinity of the Main and East Campuses.

In addition, the City provided a copy of the 2020 computer model for their proposed system. This model was used "as is" with no verification, testing, or calibration. The City's model was used to determine expected pressures at campus master meters and availability of hydrant flows from City mains under future conditions.

Sanitary Sewer

The University provided CAD files and an associated sewer pipe database detailing the sanitary sewer pipe layout and attributes including length, diameter, material and manhole inverts. The CAD files were used to develop the structure of the sanitary sewer hydraulic model. The database was mostly complete with available data. The database was also reviewed for accuracy by the project staff in cooperation with University Staff.

Previous reports made available for use in the sanitary sewer study include:

- City of Boulder Wastewater Collection System Master Plan (WWCSMP) Update, July 2003, Brown and Caldwell.
- CCTV Inspection videotapes and report sheets from sewer cleaning and surveying program, Summer 2002.
- 28th Street Sanitary Sewer Study, August 2001, WRC Engineering .
- Utilities Investigation Report Boulder Campus, December 1964, Swanson Rink & Associates.

The City of Boulder WWCSMP Update was used to identify potential problem areas of collector capacity serving University Sewers. The WWCSMP Update was also used to estimate infiltration and inflow rates for the campus sanitary sewer. The CCTV videos and reports were summarized and incorporated into the condition assessment of the sanitary sewer system.

Regulatory Requirements

Regulatory codes and requirements from the following sources were reviewed:

- 2000 International Plumbing Code
- 2000 International Building Code
- 2000 International Fire Code
- 2001 National Fire Code (NFPA International)
- 1997 Uniform Fire Code (Incorporated by reference into 2001 NFPA)
- Colorado Department of Public Health and Environment
- City of Boulder Design and construction Standards (2000)

The codes and regulations were reviewed with respect to the potable water and sanitary sewer systems on the Main and East Campuses as applicable to mains only and not to service lines or individual buildings.

Applicable details from the codes and their direct application to the University's systems are shown in Table 1.

Table 1: Regulatory Code Review

Code	Summary	Applicability to University's System
2000 International Plumbing Code:	Minimum acceptable building water pressure is 20 psi. Maximum acceptable building water pressure is 80 psi. Backflow should be prevented. Cross-connections are prohibited. Non-potable pipes, fixtures and appurtenances should be appropriately identified. Water used for cooling or other non-consumptive uses shall not be returned to potable lines. It shall be discharged to waste or to a non-potable system. Temperature of wastes should be less than 140º F (i.e., so special materials are not needed for sewer lines). Neutralizing devices are required for corrosive wastes (again so special materials are not needed for sewer lines).	Minimum residual pressure in system during fire flows is 20 psi. Most buildings on the Main Campus and all buildings on the East Campus need PRVs on the service lines. Backflow preventers should be installed on building services. Irrigation system piping (raw water) should be clearly marked as non-potable. Cooling systems must discharge to sanitary sewer system, whether once-through or recycle. University policy should be that laboratories must handle waste properly prior to discharge to the sanitary sewer.
2000 International Building Code:	For standpipes and sprinkler systems, water system shall be capable of supplying the system demand. Water supply shall be capable of supplying domestic demand and sprinkler demand simultaneously.	System was analyzed assuming sprinkler and domestic demands simultaneously. Sprinkler system should be designed for projected system conditions (i.e., lower pressure – see later section).

Table 1 (continued) Regulatory Code Review		
Code	**Summary**	**Applicability to University's System**
2000 International Fire Code:	Water supply shall be capable of supplying required flow. Fire flow requirements shall be determined by approved method. Fire hydrant spacing shall be less than 400 feet. If buildings are sprinkled, spacing shall be less than 600 feet. Clear space around hydrants shall be 3 feet.	Water system analyzed per desired flows as determined by University Fire Marshal. Review of hydrants was outside the scope of this report but University staff should note requirements. Water system analyzed with domestic and sprinkler demands simultaneously.
2000 International Fire Code:	Bollards or other approved devices shall be used where hydrants are subject to impact by motor vehicle. For standpipes and sprinkler systems, water system shall be capable of supplying the system demand. Water supply shall be capable of supplying domestic demand and sprinkler demand simultaneously. Hydrants shall be located such that connection to the hydrants does not obstruct access to other fire apparatus. Required fire flow ranges from 1,500 to 8,000 gpm, dependent on a number of factors. The required flow can be reduced up to 75%, but not less than 1,500 gpm, with approved automatic sprinkler system.	
2001 National Fire Code (NFPA International):	Underground pipe should conform to American Water Works Association standards. Underground pipe should be rated equal to or greater than 150 psi. Water system components, in general, should be rated equal to or greater than 175 psi.	Design of pipe is outside the scope of this study but University staff should note requirements. Review of hydrants is beyond the scope of this study but University staff should note requirements.

Table 1 (continued) Regulatory Code Review		
Code	**Summary**	**Applicability to University's System**
2001 National Fire Code (NFPA International):	Underground pipe should not be installed under buildings unless special precautions are taken. Hydrants shall be of an approved type. Hydrants shall have a connection of not less than 6-inch with the main. A valve shall be installed in the hydrant connection. Hydrants shall be provided and spaced per the authority having jurisdiction. Hydrants shall be placed a minimum of 40 feet from the buildings they are protecting (exceptions are allowed). Water supply shall be of adequate pressure and flow for required duration. The minimum supply shall be per the authority having jurisdiction. Drains for fire protection systems should not be directly interconnected with any sewer system. Classification of fire and explosion hazards, ventilation requirements, extent of area, and the electrical classification. In general, sanitary sewers have possible ignition of flammable gases and floating flammable liquids but are not normally ventilated.	System was analyzed for desired fire/sprinkler flows and pressures per the University Fire Marshal's direction.
Colorado Department of Public Health and Environment (CDPHE):	The University of Colorado's system is considered a Public Water System by the CDPHE under the Safe Drinking Water Act (SDWA). *Design Criteria for Potable Water Systems* (CDPHE, March 1997).	The University needs to apply for an identification number with the CDPHE. The University will need to show proof of contaminant testing as required under the SDWA and possibly implement other programs, such as backflow prevention.

Table 1 (continued)
Regulatory Code Review

Code	Summary	Applicability to University's System
Colorado Department of Public Health and Environment (CDPHE):	*Design Criteria Considered in the Review of Wasterwater Treatment Facilities, Policy 96-1* (CDPHE, May 2000).	The CDPHE does allow for other entities to perform testing, etc., such as the City of Boulder. However, the University may need to formalize current practices with a contract or a memorandum of understanding. The design criteria are largely inapplicable since the University does not provide treatment, storage, or pumping. However, the design criteria should be reviewed when replacing or expanding the system.
City of Boulder:	*City of Boulder Design and Construction Standards* (City of Boulder Planning and Development Services, November 2000).	Because the University's sewer and water systems are private systems, these standards are not requirements, but do act as a guideline for future design and construction. In addition, in the event that the City of Boulder would adopt the University system, it is likely the meeting of these standards would be a condition of incorporation into the City system. These standards are summarized as they apply to the campus sewer and water systems in Appendix B.

Existing System

The existing potable water and sanitary sewer systems range from greater than 50 years old to construction just prior to the time of this study (2003). The areas specifically studied for this report include the Main Campus south of University Avenue and the East Campus north of Boulder Creek. Other campus areas were specifically excluded from this report.

Potable Water

Existing System Description – Main Campus

The University of Colorado's existing water system serving the Main Campus is mostly looped with a few dead ends. In general, piping is 6-inch and 8-inch and is cast iron or ductile iron, with the newer pipe being PVC. The system is fed by the City of Boulder's water distribution system via four meters as shown in Table 2. As a customer of the City, the University relies on the City to provide finished water at sufficient service pressures as well as storage to meet peaking demands and fire flows. Figure 1 shows the existing potable water piping layout of the Main Campus.

Table 2: Main Campus Meter Information

Meter	Location	Size	City Main Size (inches)	Elevation (feet)	Average Pressure (psi)*
Penn Street	Broadway and Pennsylvania	6 inch	14	5427	80
UMC	Euclid and Broadway	4 inch w/ 8 inch fire flow by-pass meter	14	5412	82
Reed	Cockerell Drive in front of Reed Hall	4 inch w/ 8 inch fire flow by-pass meter	16	5376	95
Folsom	Folsom Street and Stadium Drive	6 inch	16	5314	125

*Per testing done as part of the 1993 DeOreo work. These pressures are still typical based on 1999-2001 fire flow testing.

The University's system is located in the City's pressure zone 2 and is primarily bounded on the north and south by Baseline Road and Arapahoe Avenue and extends from Broadway to the west to 28th Street to the east. The scope of this study was limited to the Main Campus south of University Avenue. Elevations within pressure zone 2, the City's medium pressure zone, generally slope southwest to northeast across the Main Campus towards Boulder Creek. Theoretically, water can be delivered to any point on the Main Campus from any of the City's four supply taps. However, as seen from the model results and University staff experience, the Penn meter typically serves areas west of Norlin and the Reed and Folsom meters have difficulty delivering water to the Norlin Quadrangle area. Three of the four supply taps are located on the edge of campus while the Reed meter is located in the center of the campus. The Reed meter is connected to a 16-inch city distribution line that bisects the campus and is located in the center of Old Folsom Street.

Existing System Description – East Campus

The University of Colorado's existing water system serving the East Campus is comparatively much smaller than the Main Campus. The system is also younger than the Main Campus with most buildings constructed around 1960. As with the Main Campus, the East Campus is a customer of the City and also relies on the City to provide finished water at sufficient pressure as well as storage to meet peaking demands and fire flows. The City's Treated Water Master Plan shows that this area is in the center of the City's pressure zone 2 and having a close proximity to Boulder Creek with associated lower elevations, this portion of the system experiences much greater pressures than the Main Campus. The assumed pressures from the City were based on a hydraulic gradeline of 5555 feet, as described later.

The University's East Campus is bounded by Arapahoe Avenue on the north and Colorado Avenue on the south. The campus runs east to west from Foothills Parkway to 30th Street. Boulder Creek crosses the northwestern section of the campus. The scope of this study was limited to the portion of the system north of Boulder Creek. This portion of the system north of Boulder Creek runs from Marine to 30th Street and bounded by Arapahoe Avenue on the north. Figure 2 shows the existing water layout of the East Campus.

This northwest portion of the system is simple having several direct supply connections to the City's system off of Arapahoe Avenue and 30th Street. Only one portion of the system is looped and runs from the intersection of Arapahoe Avenue and Marine Street to the intersection of Marine Street and 30th Street. Several East Campus buildings are served from this looped portion that consists of a single pipe in Marine Street. The Marine Street Pipe has 6-inch and 12-inch segments made of cast iron and ductile iron. Many buildings also have dedicated fire service lines.

Sanitary Sewer

The sewer collection system in this study serves the Boulder Main Campus to the area south of University Avenue (approximate), and the East Campus north of Boulder Creek (the Marine Street area). It is comprised of sewer collectors owned and maintained by the University of Colorado (service lines from buildings to collectors were not included, nor were City collectors crossing Campus as these are out of the scope of this study). Figures MP1 and MP2 (found in map pocket) detail the University's Main and East Campus sanitary sewer system including location, length, size, and material.

The Campus sanitary sewer system (sewer) is a gravity wastewater collection system with pipes ranging in size from 6-inches to 18-inches in diameter, with the majority of pipes 6-inches or 8-inches in diameter. The system is constructed of typical sewer pipe materials including vitrified clay pipe (VCP), Polyvinyl Chloride (PVC), concrete, cast iron, and some ductile iron pipe. The majority of pipes on campus are VCP or PVC. The Campus sewer system feeds into the City of Boulder collection system at multiple locations, at which point the City is then responsible for the transport of the waste to the City's wastewater treatment facility.

Existing Water Demands and Sewer Loads

Demands on the potable water system for specific buildings were estimated for this report using existing information. Installing temporary meters or other devices to estimate peak flows was beyond the scope of this report. The majority of the Main and East Campuses are irrigated by non-potable water and thus, in general, potable water demand reflects indoor water use. Almost 100% of indoor water use is returned to the sanitary sewer system through sinks, toilets, showers, pass-through cooling systems, etc. For most water systems, typically less than 2% of potable water demand is lost through indoor consumption (i.e., drinking or cooking). It was assumed that this was also the case for the University with little water consumption occurring in laboratories and research. Therefore, these demands were then applied to the sanitary sewer system on a 1:1 basis, except for a few buildings (as described below).

Main Campus Potable Water Demands

The demands for the Main Campus were collected from existing KYPipe and EPANet models that were supplied by the University. The demands in the two models were compared and discussed with the University before being confirmed and inserted into the model. In addition, the demand for the fiscal year 2000-2001 was converted to a peak demand in gpm using the same factors as are used to estimate peak demand for future buildings. These factors were supplied by the University. In general, the highest demand from the three sources was chosen to be taken forward in the modeling. Exceptions to this were when the highest demands did not appear to match the actual use of the building. In addition, peak demands less than 10 gpm were not included in the modeling because they were considered insignificant in model runs, particularly with regards to modeling fire flows. The demand modeled is a weekday demand occurring during normal classroom hours (i.e., daytime) and is considered the Peak Day demand. As such, no demand was modeled at the Stadium and the Coors Events Center, since these buildings see peak use during evening or weekend hours. Main Campus demands are shown in Table 3.

According to the DeOreo report, as of 1990, the majority of the Main Campus irrigation demands have been supplied by raw water from Boulder Creek using the University's Anderson Ditch water right rather than being supplied by the City's municipal system. Of the 108 irrigated acres on the University's Main Campus approximately 90 acres use the Anderson Ditch supply. The remaining 18 acres that are irrigated by the potable system, are under the control and responsibility of the University's Housing Department and are typically outside the study area for this report.

Table 3: Modeled Demands - Main Campus, Existing Conditions

Building	Peak Day Demand (gpm)
Aden, Brackett, Cockerell Halls	25
Andrews	80
Baker Hall	28
Buckingham	30
Cheyenne Arapaho Hall	32
Commons / Kittredge West	29
Economics Building, Museum, Education	20
Ekeley	24
ESC Courtyard	85
Farrand Hall	40
Fleming Law	17
Grounds	14
Hallet Hall	30
Heat Plant	300
Hellems / Chemistry	95
JILA and Annex	66
Ketchum (based on buildings of similar size and use)	20
LASP & Annex	111
Libby Hall	40
Macky Auditorium and McKenna	10
MCD Biology	40
Old Main	13
Porter Bio Science	25
Recreation Center South	41
Regent Administrative Center	40
Sewall Hall	15
Smith (based on buildings of similar size and use)	15
UMC	30
Wardenburg Student Health	15

Required fire flows vary throughout the campus and depend on building use and whether or not the building is partially or fully sprinkled. The University requested that the system be analyzed for the following hydrant flows:

- 3,000 gpm – Business, Fine Arts, Hellems, Coors Events Center, Regent Auto Park, and Fleming Law

- 2,500 gpm – Clare Small, Education, Carlson, and Balch Field House

- 2,000 gpm – McKenna, Economics, Henderson, University Club, and the Dance part of Theater and Dance.

- 1,500 gpm – Minimum flow for all other buildings

The University also indicated that the minimum acceptable pressure for a hydrant flow is 25 psi.

The University did not supply the desired duration for each fire flow. The University relies on the City's system to provide storage for fire fighting; analyzing City storage was beyond the scope of this project.

Sprinkler flows also vary by building type and use, but in general, the University desires a minimum sprinkler flow of 400 gpm. The University also requested that normal operating pressures throughout the system vary less than 10 psi between existing conditions and future conditions. This is primarily because the existing sprinkler systems were designed with a 10 psi safety factor and there is concern that those existing sprinkler systems will not function as expected should pressures be lower.

The University also indicated that available fire flows (sprinkler and hydrant) are acceptable on the East Campus due to the relatively high pressures and the close proximity of City mains to all the buildings within the study area.

Lastly, with regards to fire demands, the University provided direction that City mains may be considered for providing some or all of the required hydrant flow. Therefore, for buildings within 500 feet of a City main, this study assumed that partial flow would come from the City main when the University's system could not provide the desired fire flow.

East Campus Potable Water Demands

The demands for the East Campus were supplied by the University in the form of a spreadsheet that listed campus water usage for fiscal year 2001-2002. The demands were converted to a peak demand in gpm using the same factors as are used to estimate peak demand for future buildings. All peak demands less than 10 gpm were not included in the modeling because they were considered insignificant in model runs. The peak demand to be modeled is a weekday demand during normal classroom hours (i.e., daytime) and is considered the Peak Day demand. East Campus demands are shown in Table 4.

Table 4: Modeled Demands – East Campus, Existing Conditions

Building	Peak Day Demand (gpm)
Housing System Maintenance Center	10
Institute of Behavioral Genetics - East	110
Life Sciences Research Lab No 2	25
Life Sciences Research Lab No. 4	15
Litman Research Lab No. 1	15
Marine Street Science Center - South - newly relocated tap	45

Sanitary Sewer Loads

Loads on the campus sewer system are the sum of all tributary inflows from buildings, after the application of a peaking factor, and the infiltration and inflow into the sewer system. These loads are summarized in Table 5 for the portion of the University System analyzed in this study.

Sewer loads for each building in the study were estimated by one of two methods: as a percentage of treated water demands, or by a fixture count method. The water demand method was applied to all buildings in the study with the exception of the Stadium and Coors Events Center. The water demand method assigned a one to one pass through ratio for all buildings with demands greater than 10 gpm, with the exception of the Powerhouse. This ratio is based on the fact that the majority of irrigation on campus uses raw water rather than treated water. The Powerhouse is assigned a sewer load equivalent to a thirty percent pass through ratio. The remaining fraction is either recycled or lost through steam generation. The fixture unit method applied to the Stadium and Coors Events Center estimates a total sewer load based on the number and type of fixtures in a building. The values for the loading are from the 2001 Uniform Plumbing Code. Peak flows for the Stadium and Coors Events Center are assumed to occur at a different time of day than the rest of campus; therefore these flows are analyzed independently of the rest of the system (presented separately in Table 5). A peaking factor of 2.0 was applied to all sewer loads in the system when incorporated into the hydraulic sewer model. This peaking factor is in addition to the conservative estimate of a one-to-one pass through of Potable Water demands that are already peaked at a peak to average ratio of 1.6 (Peaking factor used by University in estimating potable water demands as provided by University).

Infiltration/Inflow (I/I) was applied to all sewer pipes in the hydraulic model based on an estimated rate per length and diameter of the sewer pipe. This estimation was based on the total 2-yr storm infiltration for the City of Boulder sanitary sewer system. The infiltration factor used in this estimate was 34,000 gpd/(mile length – inch diameter) or 0.0045 gpm/(ft-in). This factor applied over the Main Campus results in approximately 755 gpm of I/I for the Main Campus and 75 gpm for the East Campus (for areas included in this study).

Table 5. Modeled Sanitary Sewer Loads – Existing Conditions

Pipe / Manhole		Infiltration / Inflow	Existing Peak Flows
From	To	GPM	GPM
MAIN CAMPUS			
FLEMING LAW, KITTREDGE			
SS0253	SS0250	7.5	18.9
SS0250	SS0249	1.6	20.5
SS0252	SS0251	1.3	36.6
SS0251	SS0249	3.9	40.6
SS0249	SS0248	5.4	96.5
SS0248	SS0247	9.9	106.5
SS0247	SS0246	3.8	110.2
SS0246	SS0245	1.3	171.5
SS0245	SS0244	5.1	176.6
SS0244	SS0241	8.2	184.8
SS0243	SS0242	2.6	162.6
SS0242	SS0241	5.9	168.5
SS0241	SS0240	16.7	370.0
UCB POLICE / COORS EVENTS			
SS0234	SS0235	6.9	6.9
SS0235	SS0236	3.4	10.4
SS0236	SS0237	3.0	13.3
SS0239	SS0323	5.4	5.4
SS0323	SS0325	4.9	10.3
SS0325	SS0324	6.4	16.7
SS0324	SS0237	0.8	17.5
SS0237	SS0238	5.4	36.2
SS0238	CITYB60	3.6	39.8
ENGINEERING CENTER			
SS0233	SS0232	6.4	27.6
CO-B432s	SS0232	11.1	32.3
SS0232	SS0231	5.4	65.3
SS0231	SS0226	5.4	70.7
SS0226	SS0225	2.6	73.3
SS0225	SS0315	0.6	158.9
SS0315	SS0222	7.4	166.4
SS0222	SS0313	4.1	170.5
SS0224	SS0223	8.0	50.5
SS0223	SS0313	3.9	54.4
SS0313	SS0314	3.9	228.8
SS0314	SS0221	4.7	233.5

Table 5 Cont'd			
Pipe / Manhole		Infiltration / Inflow	Existing Peak Flows
From	To	GPM	GPM
KITTREDGE WEST / FISKE PLANETARIUM			
SS0263	SS0261	4.0	4.0
SS0262	SS0261	2.1	2.1
SS0261	SS0260	3.7	9.9
SS0260	SS0259	2.6	12.4
REGENT, WILLARD, HALLETT			
SS0217	SS0216	7.6	61.6
SS0216	SS0320	5.0	66.6
SS0320	SS0215	1.8	94.4
SS0215	SS0214	4.5	98.9
SS0214	SS0213	6.9	105.8
SS0213	SS0211	8.0	173.8
LIBBY, FARRAND, ENG QUAD			
SS0208	SS0207	8.3	110.3
SS0207	SS0202	9.0	221.2
SS0206	SS0204	0.9	80.9
SS0205	SS0204	4.7	84.7
SS0204	SS0203	8.4	174.0
SS0203	SS0202	4.3	178.4
SS0202	SS0199	3.8	420.1
SS0201	SS0200	3.1	19.8
SS0200	SS0199	2.8	39.3
SS0199	SS0198	8.9	468.2
UNIV CLUB, EUCLID, 18TH ST			
SS0171	SS0172	2.7	12.7
SS0172	SS0173	1.6	54.3
SS0173	SS0174	0.8	55.0
SS0178	SS0179-77	1.5	1.5
WARD / CHEY-ARAP / IMIG / ENV. DES. / POWER			
SS0187	SS0188	3.7	3.7
SS0191	SS0190	6.0	70.0
SS0194	SS0329	0.6	0.6
JILA, LASP			
SS0158	SS0155	2.5	134.5
SS0155	SS0154	2.0	136.4
SS0154	SS0109	5.0	141.4
HELLEMS, UMC, SIBELL, CRISTOL			
SS0138	SS0139	2.6	29.3
SS0139	SS0140	3.1	32.4
SS0140	SS0311	1.8	34.2
SS0311	SS0141	2.1	36.4
SS0141	SS0142	6.8	43.1
SS0142	SS0143	3.4	56.5

Table 5 Cont'd			
Pipe / Manhole		Infiltration / Inflow	Existing Peak Flows
From	To	GPM	GPM
SS0143	SS0312	4.4	135.9
SS0147	MID-SS0146	0.3	0.3
SS0146	SS0145	7.1	82.4
SS0145	MID-SS0312	0.3	82.7
MID-SS0312	SS0312	0.7	83.4
SS0312	SS0144	2.9	222.2
SS0144	SS0148	3.3	225.5
SS0151	SS0150	2.2	2.2
SS0150	SS0148	2.7	4.9
SS0148	SS0321	6.6	236.9
SS0321	SS0153	3.0	239.9
EKELEY, KETCHUM			
SS0316	SS0124	1.6	25.6
SS0124	SS0122	0.5	26.1
SS0122	SS0121	4.3	30.4
SS0121	SS0120	0.3	30.7
SS0120	SS0118	3.2	74.0
SS0119	SS0118	2.5	2.5
SS0118	SS0117	4.1	80.6
SS0117	SS0116	1.2	81.8
SS0116	SS0115	2.0	83.8
COLORADO AVE-FOLSOM			
SS0113	SS0112	2.9	2.9
SS0326	SS0309	0.3	40.3
SS0309	SS0322	3.4	43.8
SS0308	SS0317	0.8	90.8
SS0317	SS0318	3.9	94.6
SS0318	SS0319	3.7	98.3
SS0319	SS0107	6.3	104.7
SS0107	SS0104	1.4	106.0
SS0106	SS0105	1.0	1.0
SS0105	SS0104	1.4	2.4
SS0103	SS0102	1.4	1.4
SS0097	SS0098	1.1	1.1
SS0098	City Pipe	0.5	1.6
SS0101	SS0100	8.5	64.5
SS0100	SS0099	7.7	72.2
SS0099	SS0096	3.0	75.2
SS0096	SS0095	1.2	76.4
SS0094	SS0093	1.7	1.7
GUGGENHEIM/ECON - STADIUM/FOLSOM			
SS0132	SS0130	7.5	7.5
SS0132	SS0131	1.2	1.2

Table 5 Cont'd			
Pipe / Manhole		Infiltration / Inflow	Existing Peak Flows
From	To	GPM	GPM
SS0131	SS0130	7.2	8.4
SS0130	SS0129	7.2	23.1
SS0137	SS0136	0.9	14.2
SS0136	SS0135	3.2	30.8
SS0135	SS0134	1.5	32.3
SS0134	SS0133	3.9	49.5
SS0133	SS0129	6.4	55.9
SS0129	SS0127	4.2	83.2
SS0128	SS0127	6.0	19.3
SS0127	SS0125	1.4	103.9
SS0126	SS0125	0.7	24.7
SS0125	SS0058	3.2	131.8
SS0058	SS0057	21.9	153.6
SS0057	SS0059	15.3	168.9
SS0059	SS0060	19.7	188.7
SS0060	SS0061	24.1	212.7
SS0064	INT SS0061	9.2	9.2
SS0061	SS0062	4.9	226.8
SS0065	SS0063	7.2	7.2
SS0063	SS0062	2.5	9.6
SS0062	SS0067	13.6	250.0
SS0066	SS0067	3.1	85.1
SS0067	SS0069	10.5	345.7
SS0069	SS0070	3.9	349.5
SS0068	SS0070	2.5	2.5
SS0070	SS0071	9.8	361.9
SS0071	SS0072	1.7	363.5
SS0072	SS0073	12.0	375.5
SS0073	SS0074	12.1	387.7
SS0074	SS0075	10.2	397.9
SS0075	SS0310	4.8	402.7
SS0310	SS0078	7.8	410.5
SS0076	SS0078	2.5	2.5
SS0078	SS0079	6.7	447.7
SS0079	SS0080	10.1	457.8
SS0080	SS0082	17.4	475.3
SEWALL, REC CENTER			
SS0051	SS0049	2.8	32.8
SS0050	SS0049	1.2	1.2
SS0049	SS0048	2.3	36.4
KOENIG, HALE, MACKY			
SS0034	SS0033	4.7	4.7
SS0035	SS0036	3.5	16.5

Table 5 Cont'd			
Pipe / Manhole		Infiltration / Inflow	Existing Peak Flows
From	To	GPM	GPM
SS0036	SS0037	2.1	18.6
SS0037	SS0038	3.0	21.6
SS0038	SS0040	3.6	25.2
SS0039	SS0040	0.6	13.6
SS0040	SS0042	4.1	42.9
SS0041	SS0042	1.0	1.0
SS0042	SS0045	4.2	48.0
SS0047	SS0046	2.7	22.7
SS0046	SS0045	2.9	25.5
SS0045	SS0044	1.5	75.0
EAST CAMPUS			
30TH & MARINE			
SS0268	SS0269	1.3	221.3
SS0267	SS0266	6.7	86.7
SS0265	SS0264	4.5	34.5
MARINE STREET			
SS0270	SS0271	6.3	36.3
SS0271	SS0272	4.6	40.9
SS0272	SS0273	6.6	107.5
SS0273	SS0274	6.4	113.9
SS0274	SS0275	6.5	120.5
SS0275	SS0276	0.9	121.3
SS0276	SS0277	9.9	151.3
SS0277	SS0278	9.7	160.9
SS0278	SS0279	5.8	166.8
SS0279	SS0280	5.6	172.4
Event Loads for Stadium and Coors Events Center Peaks			
UCB POLICE / COORS EVENTS			
SS0234	SS0235	6.9	6.9
SS0235	SS0236	3.4	10.4
SS0236	SS0237	3.0	13.3
SS0239	SS0323	5.4	385.4
SS0323	SS0325	4.9	390.3
SS0325	SS0324	6.4	396.7
SS0324	SS0237	0.8	397.5
SS0237	SS0238	5.4	416.2
SS0238	CITYB60	3.6	419.8
STADIUM SOUTH			
SS0097	SS0098	1.1	133.1
SS0098	City Pipe	0.5	133.6
STADIUM / FIELD HOUSE			
SS0068	SS0070	2.5	134.5

Table 5 Cont'd			
Pipe / Manhole		Infiltration / Inflow	Existing Peak Flows
From	To	GPM	GPM
SS0070	SS0071	9.8	144.3
SS0071	SS0072	1.7	146.0
SS0072	SS0073	12.0	158.0
SS0073	SS0074	12.1	170.1
SS0074	SS0075	10.2	180.3
SS0075	SS0310	4.8	185.2
SS0310	SS0078	7.8	192.9
SS0076	SS0078	2.5	138.5
SS0078	SS0079	6.7	338.2
SS0079	SS0080	10.1	348.3
SS0080	SS0082	17.4	365.7

Projected Conditions

Future conditions were determined from information supplied by Campus Planning. Campus Planning specifically identified new buildings (and thus new potable water demands and sanitary sewer loads) for the 10-year time frame and also indicated general plans for “Build-out” on the Main Campus. Thus the two planning periods for this Civil Utilities Master Plan are 10-year and Build-out.

Projected Potable 10-Year Conditions

Campus Planning supplied a spreadsheet that listed proposed 10-year improvements, location, estimated enclosed gross square footage and the type of use. From the gross square footage and type of use, a water usage in gallons per minute was calculated using the same factors as used in developing existing demands. Results are summarized in Table 6.

Table 6: Peak Potable Water Demands Based on Building Size

Type of Use	Potable Water (gal/sq. foot)	Potable Water (gal/sq. foot/hr)	Potable Water (gal/sq. foot/min)
Research / Lab	66	0.012	0.0002
Classroom	16	0.003	0.00005
Housing	68	0.012	0.0002
Office	2.5	0.0005	0.000008
Museum	16	0.003	0.00005

The majority of the increased demands involving 10-year growth correspond to construction north of Franklin Drive involving a stadium addition and the Athletics Field House as well as the potential for a new law building northeast of the intersection of Broadway and Baseline Road. Also, additional increased demands are the result of expansion in the Fine Arts Complex. The only 10-year future demand that was not calculated using the gross square footage method, was the Central Utility Plant. The utility plant is to be constructed in two phases over a 25-30 year time period. It was assumed the first phase would be constructed in the next ten years and the initial demand of 352 gpm was inserted into the model as a 10-year future demand. Based on the 10-year future conditions supplied by Campus Planning, there appears to be no significant construction planned for the East Campus. Projected 10-year future demands for the Main Campus are shown in Table 7.

Table 7: Modeled Demands – Main Campus, Projected Conditions

Building	Projected 10-year Conditions Peak Day Demand (gpm)	Projected Build-Out Conditions Peak Day Demand (gpm)
Aden, Brackett, Cockerell Halls	25	25
Andrews	80	82
Baker Hall	28	28
Buckingham	30	30
Central Facility Plant	352	658
Cheyenne Arapaho Hall	32	32
Commons / Kittredge West	29	30
Economics Building, Museum, Education	20	2
Ekeley	24	26
ESC Courtyard	85	85
Farrand Hall (new location)	40	40
Fleming Law and Proposed New Law Building	25	31
Grounds, Proposed Athletic Field House, and Stadium East Addition	25	25
Hallet Hall	30	31
Heat Plant and Proposed Visual Arts	310	310
Hellems / Chemistry	95	95
JILA and Annex	66	66
Ketchum (based on buildings of similar size and use)	20	20
LASP & Annex	111	111
Libby	40	40
Macky Auditorium and McKenna	10	10
MCD Biology	40	40
Old Main	13	13
Porter Bio Science	25	25
Recreation Center South	41	41
Regent Administrative Center	40	41
Sewall Hall	15	18
Smith (based on buildings of similar size and use)	15	15
UMC and Proposed University Club Chilling	50	51
Wardenburg Student Health	15	17

Projected Potable Build-out Conditions

Build-out conditions were based on available land and possible building renovations. Build-out demands were calculated in the same manner as the 10-year future demands as described above. The gross square footages of potential development areas were determined from an electronic version of the proposed Build-out conditions that was supplied by the University. The Build-out demand for the Central Utility Plant was inserted into the model with a 658 gpm demand as supplied by the University.

Proposed Build-out on the East Campus north of Boulder Creek involves a small amount of new construction and several renovated spaces but does not significantly affect water demands. Build-out demands are shown in Table 7.

Potential Potable Demand Reductions

Projected demands can be influenced by a number of factors, including renovations that install low-use water fixtures, changes in personal habits of staff and students, completing the change over to non-potable water for the irrigation system, and installation of water conserving cooling units. Of these factors, the one that has the greatest potential for reduction in water demands is installation of water conserving cooling fixtures and removal of once-through cooling units. The scope of this Master Plan thus evaluated the conservation effects of replacing cooling units for the three buildings with the largest cooling water demand. These buildings, and the potential water savings are:

- JILA (including Annex) – up to 25 mg/year or 80% of total water use
- Duane Physics – up to 5.6 mg/year or 45% of total water use
- Cristol Chemistry – up to 10 mg/year or 35% of total water use

Applying the percent savings to the estimated existing water demands results in a total water savings under the modeled conditions of about 100 gpm. This represents about 7.5% of the total estimated existing water demand. These numbers also represent about 12% of the water demand in the immediate vicinity of JILA and Physics. The Cristol water savings represents about 14% of the water demand in the immediate vicinity. Given that the model is only considered accurate within 10 to 15% and that fire flow demands were the controlling parameter in developing improvements, there is little effect on the potable water distribution system. However, there is a significant positive effect to the University in replacing these systems with regards to the cost of potable water and the future cost and ease of obtaining taps from the City for future buildings.

Projected Sanitary Sewer Loads

The resulting sewer loads for the future scenarios were calculated in the same way the existing conditions loads were, based on potable water demands. The additional 10-year loads were thus: 10 gpm for the Visual Arts Complex, 11 gpm for Stadium East, 8 gpm for the Law Addition, 106 gpm for the New Utility Plant (Utility Plant load based on 30% pass through), and an increase of 20 gpm at the UMC.

The additional loads for Build-out conditions are 10 gpm for the Business School addition, an additional 6 gpm at Law, and an additional 91 gpm at the New Utility Plant (and an additional 1gpm at the UMC).

The effect of implementing conservation measures to three water intense buildings on the Main Campus was evaluated. Reduction in water demands for JILA, Duane Physics, and Cristol Chemistry resulted in a reduction in sewer loads. The sewer lines serving these buildings already had a capacity rating of 1, that is, peak design flow was less than 50% of capacity (see Analysis section). Therefore, reductions in loads had no effect on the capacity rating of the pipes in the University system and were not evaluated further. Projected sewer loads for 10-year and Build-out conditions are shown in Table 8.

Table 8 Modeled Sanitary Sewer Loads – Projected Conditions

Pipe / Manhole		Infiltration / Inflow	10-Year Peak Flows	Buildout Peak Flows
From	To	GPM	GPM (includes I/I)	GPM (includes I/I)
MAIN CAMPUS				
FLEMING LAW, KITTREDGE				
SS0253	SS0250	7.5	18.9	18.9
SS0250	SS0249	1.6	20.5	20.5
SS0252	SS0251	1.3	36.6	36.6
SS0251	SS0249	3.9	40.6	40.6
SS0249	SS0248	5.4	96.5	96.5
SS0248	SS0247	9.9	122.5	134.5
SS0247	SS0246	3.8	126.2	138.2
SS0246	SS0245	1.3	187.5	199.5
SS0245	SS0244	5.1	192.6	204.6
SS0244	SS0241	8.2	200.8	212.8
SS0243	SS0242	2.6	162.6	162.6
SS0242	SS0241	5.9	168.5	168.5
SS0241	SS0240	16.7	386.0	395.9
UCB POLICE / COORS EVENTS				
SS0234	SS0235	6.9	6.9	6.9
SS0235	SS0236	3.4	10.4	10.4
SS0236	SS0237	3.0	13.3	13.3
SS0239	SS0323	5.4	5.4	5.4
SS0323	SS0325	4.9	10.3	10.3
SS0325	SS0324	6.4	16.7	16.7
SS0324	SS0237	0.8	17.5	17.5
SS0237	SS0238	5.4	247.4	431.0
SS0238	CITYB60	3.6	251.0	434.6
ENGINEERING CENTER				
SS0233	SS0232	6.4	27.6	47.6
CO-B432s	SS0232	11.1	32.3	32.3
SS0232	SS0231	5.4	65.3	85.3
SS0231	SS0226	5.4	70.7	90.7
SS0226	SS0225	2.6	73.3	93.3
SS0225	SS0315	0.6	158.9	178.9
SS0315	SS0222	7.4	166.4	186.4
SS0222	SS0313	4.1	170.5	190.5
SS0224	SS0223	8.0	50.5	50.5
SS0223	SS0313	3.9	54.4	54.4
SS0313	SS0314	3.9	228.8	248.8
SS0314	SS0221	4.7	233.5	253.5

Table 8 Cont'd				
Pipe / Manhole		Infiltration / Inflow	10-Year Peak Flows	Buildout Peak Flows
From	To	GPM	GPM (includes I/I)	GPM (includes I/I)
KITTREDGE WEST / FISKE PLANETARIUM				
SS0263	SS0261	4.0	4.0	4.0
SS0262	SS0261	2.1	2.1	2.1
SS0261	SS0260	3.7	9.9	9.9
SS0260	SS0259	2.6	12.4	12.4
REGENT, WILLARD, HALLETT				
SS0217	SS0216	7.6	61.6	61.6
SS0216	SS0320	5.0	66.6	66.6
SS0320	SS0215	1.8	94.4	94.4
SS0215	SS0214	4.5	98.9	98.9
SS0214	SS0213	6.9	98.9	105.8
SS0213	SS0211	8.0	166.9	173.8
LIBBY, FARRAND, ENG QUAD				
SS0208	SS0207	8.3	110.3	110.3
SS0207	SS0202	9.0	221.2	221.2
SS0206	SS0204	0.9	80.9	80.9
SS0205	SS0204	4.7	84.7	84.7
SS0204	SS0203	8.4	174.0	174.0
SS0203	SS0202	4.3	178.4	178.4
SS0202	SS0199	3.8	420.1	420.1
SS0201	SS0200	3.1	19.8	19.8
SS0200	SS0199	2.8	39.3	39.3
SS0199	SS0198	8.9	468.2	468.2
UNIV CLUB, EUCLID, 18TH ST				
SS0171	SS0172	2.7	19.3	19.7
SS0172	SS0173	1.6	87.6	89.3
SS0173	SS0174	0.8	88.4	90.0
SS0178	SS0179-77	1.5	1.5	1.5
WARD / CHEY-ARAP / IMIG / ENV. DES. / POWER				
SS0187	SS0188	3.7	3.7	3.7
SS0191	SS0190	6.0	70.0	70.0
SS0194	SS0329	0.6	0.6	0.6
JILA, LASP				
SS0158	SS0155	2.5	134.5	134.5
SS0155	SS0154	2.0	136.4	136.4
SS0154	SS0109	5.0	141.4	141.4
HELLEMS, UMC, SIBELL, CRISTOL				
SS0138	SS0139	2.6	29.3	29.3
SS0139	SS0140	3.1	32.4	32.4
SS0140	SS0311	1.8	34.2	34.2
SS0311	SS0141	2.1	36.4	36.4
SS0141	SS0142	6.8	43.1	43.1
SS0142	SS0143	3.4	63.2	63.5

Table 8 Cont'd				
Pipe / Manhole		Infiltration / Inflow	10-Year Peak Flows	Buildout Peak Flows
From	To	GPM	GPM (includes I/I)	GPM (includes I/I)
SS0143	SS0312	4.4	142.6	142.9
SS0147	MID-SS0146	0.3	0.3	0.3
SS0146	SS0145	7.1	82.4	82.4
SS0145	MID-SS0312	0.3	82.7	82.7
MID-SS0312	SS0312	0.7	83.4	83.4
SS0312	SS0144	2.9	228.9	229.2
SS0144	SS0148	3.3	232.1	232.5
SS0151	SS0150	2.2	22.2	22.2
SS0150	SS0148	2.7	24.9	24.9
SS0148	SS0321	6.6	263.6	263.9
SS0321	SS0153	3.0	266.1	266.9
EKELEY, KETCHUM				
SS0316	SS0124	1.6	25.6	25.6
SS0124	SS0122	0.5	26.1	26.1
SS0122	SS0121	4.3	30.4	30.4
SS0121	SS0120	0.3	30.7	30.7
SS0120	SS0118	3.2	74.0	74.0
SS0119	SS0118	2.5	2.5	2.5
SS0118	SS0117	4.1	80.6	80.6
SS0117	SS0116	1.2	81.8	81.8
SS0116	SS0115	2.0	83.8	83.8
COLORADO AVE-FOLSOM				
SS0113	SS0112	2.9	2.9	2.9
SS0326	SS0309	0.3	40.3	40.3
SS0309	SS0322	3.4	43.8	43.8
SS0308	SS0317	0.8	90.8	90.8
SS0317	SS0318	3.9	94.6	94.6
SS0318	SS0319	3.7	98.3	98.3
SS0319	SS0107	6.3	104.7	104.7
SS0107	SS0104	1.4	106.0	106.0
SS0106	SS0105	1.0	1.0	1.0
SS0105	SS0104	1.4	2.4	2.4
SS0103	SS0102	1.4	1.4	1.4
SS0097	SS0098	1.1	1.1	1.1
SS0098	City Pipe	0.5	1.6	1.6
SS0101	SS0100	8.5	64.5	64.5
SS0100	SS0099	7.7	72.2	72.2
SS0099	SS0096	3.0	75.2	75.2
SS0096	SS0095	1.2	76.4	76.4
SS0094	SS0093	1.7	1.7	1.7
GUGGENHEIM/ECON - STADIUM/FOLSOM				
SS0132	SS0130	7.5	7.5	7.5
SS0132	SS0131	1.2	1.2	1.2

Table 8 Cont'd				
Pipe / Manhole		Infiltration / Inflow	10-Year Peak Flows	Buildout Peak Flows
From	To	GPM	GPM (includes I/I)	GPM (includes I/I)
SS0131	SS0130	7.2	8.4	8.4
SS0130	SS0129	7.2	23.1	23.1
SS0137	SS0136	0.9	14.2	14.2
SS0136	SS0135	3.2	30.8	30.8
SS0135	SS0134	1.5	32.3	32.3
SS0134	SS0133	3.9	49.5	49.5
SS0133	SS0129	6.4	55.9	55.9
SS0129	SS0127	4.2	83.2	83.2
SS0128	SS0127	6.0	19.3	19.3
SS0127	SS0125	1.4	103.9	103.9
SS0126	SS0125	0.7	24.7	24.7
SS0125	SS0058	3.2	131.8	131.8
SS0058	SS0057	21.9	153.6	153.6
SS0057	SS0059	15.3	168.9	168.9
SS0059	SS0060	19.7	188.7	188.7
SS0060	SS0061	24.1	212.7	212.7
SS0064	INT SS0061	9.2	9.2	9.2
SS0061	SS0062	4.9	226.8	226.8
SS0065	SS0063	7.2	7.2	7.2
SS0063	SS0062	2.5	9.6	9.6
SS0062	SS0067	13.6	250.0	250.0
SS0066	SS0067	3.1	85.1	85.1
SS0067	SS0069	10.5	345.7	345.7
SS0069	SS0070	3.9	349.5	349.5
SS0068	SS0070	2.5	2.5	2.5
SS0070	SS0071	9.8	361.9	361.9
SS0071	SS0072	1.7	363.5	363.5
SS0072	SS0073	12.0	375.5	375.5
SS0073	SS0074	12.1	387.7	387.7
SS0074	SS0075	10.2	397.9	397.9
SS0075	SS0310	4.8	402.7	402.7
SS0310	SS0078	7.8	410.5	410.5
SS0076	SS0078	2.5	2.5	2.5
SS0078	SS0079	6.7	447.7	447.7
SS0079	SS0080	10.1	457.8	457.8
SS0080	SS0082	17.4	475.3	475.3
SEWALL, REC CENTER				
SS0051	SS0049	2.8	32.8	32.8
SS0050	SS0049	1.2	1.2	1.2
SS0049	SS0048	2.3	36.4	36.4
KOENIG, HALE, MACKY				
SS0034	SS0033	4.7	4.7	4.7
SS0035	SS0036	3.5	16.5	16.5

Table 8 Cont'd				
Pipe / Manhole		Infiltration / Inflow	10-Year Peak Flows	Buildout Peak Flows
From	To	GPM	GPM (includes I/I)	GPM (includes I/I)
SS0036	SS0037	2.1	18.6	18.6
SS0037	SS0038	3.0	21.6	21.6
SS0038	SS0040	3.6	25.2	25.2
SS0039	SS0040	0.6	13.6	13.6
SS0040	SS0042	4.1	42.9	42.9
SS0041	SS0042	1.0	1.0	1.0
SS0042	SS0045	4.2	48.0	48.0
SS0047	SS0046	2.7	22.7	22.7
SS0046	SS0045	2.9	25.5	25.5
SS0045	SS0044	1.5	75.0	75.0
EAST CAMPUS				
30TH & MARINE				
SS0268	SS0269	1.3	221.3	221.3
SS0267	SS0266	6.7	86.7	86.7
SS0265	SS0264	4.5	34.5	34.5
MARINE STREET				
SS0270	SS0271	6.3	36.3	36.3
SS0271	SS0272	4.6	40.9	40.9
SS0272	SS0273	6.6	107.5	107.5
SS0273	SS0274	6.4	113.9	113.9
SS0274	SS0275	6.5	120.5	120.5
SS0275	SS0276	0.9	121.3	121.3
SS0276	SS0277	9.9	151.3	151.3
SS0277	SS0278	9.7	160.9	160.9
SS0278	SS0279	5.8	166.8	166.8
SS0279	SS0280	5.6	172.4	172.4

Table 8 cont'd				
Event Loads for Stadium and Coors Events Center Peaks				
Man Hole		Infiltration	10-year peak design flows	Existing Pk Des Flow
From	To	GPM	GPM (includes I/I)	GPM (includes I/I)
UCB POLICE / COORS EVENTS				
SS0234	SS0235	6.9	6.9	6.9
SS0235	SS0236	3.4	10.4	10.4
SS0236	SS0237	3.0	13.3	13.3
SS0239	SS0323	5.4	385.4	385.4
SS0323	SS0325	4.9	390.3	390.3
SS0325	SS0324	6.4	396.7	396.7
SS0324	SS0237	0.8	397.5	397.5
SS0237	SS0238	5.4	627.4	815.7
SS0238	CITYB60	3.6	631.0	821.1
STADIUM SOUTH				
SS0097	SS0098	1.1	133.1	133.1
SS0098	City Pipe	0.5	133.6	133.6
STADIUM / FIELD HOUSE				
SS0068	SS0070	2.5	134.5	134.5
SS0070	SS0071	9.8	144.3	144.3
SS0071	SS0072	1.7	146.0	146.0
SS0072	SS0073	12.0	158.0	158.0
SS0073	SS0074	12.1	170.1	170.1
SS0074	SS0075	10.2	180.3	180.3
SS0075	SS0310	4.8	185.2	185.2
SS0310	SS0078	7.8	192.9	192.9
SS0076	SS0078	2.5	138.5	138.5
SS0078	SS0079	6.7	338.2	338.2
SS0079	SS0080	10.1	348.3	348.3
SS0080	SS0082	17.4	387.7	387.7

Analysis of Potable Water System

There were two separate analyses of the potable water system. The first was a hydraulic analysis of the system to determine if capacity was sufficient both during normal operating conditions (i.e., peak weekday) and fire flow demands. The second was an analysis of the age of pipe to determine a repair and replacement program so that the water system can continue to provide adequate service into the future.

Hydraulic Model Development

The University provided two electronic models for the piping on the Main Campus. The first was a KYPipe model that was not the calibrated model (as compared to output in the 1993 DeOreo Report). The second was an EPANet model that was not complete. The two models were compared. The EPANet model included more pipes and was a closer representation to actual piping than the KYPipe model. Because the software to be used for the Master Plan was H2ONet (readily converts between EPANet) and because the EPANet model was more complete, it served as the basis for the development of the Main Campus existing system model.

The pipe roughness factors in the EPANet model were modified to reflect the pipe roughness factors used in the calibrated KYPipe model (as documented in the 1993 DeOreo Report). There were areas, however, in which it was felt the KYPipe model did not accurately represent the system. In these areas, the KYPipe roughness factor was not used directly but was modified using engineering judgement prior to being applied to the new model.

The pressure at the City mains, under existing conditions, was assumed to be the same as measured as part of the 1993 DeOreo project. Pressures at the City mains are not expected to have changed significantly over the last ten years. This was confirmed by the University staff.

The East Campus model was developed by examining University supplied AutoCAD as-built drawings, the City's Treated Water Master Plan model, and discussions with University staff. The East Campus model was developed with the layout as shown on the as-built drawings. University staff corrected several locations where pipes were either abandoned or incorrectly shown on the as-built drawings. Several buildings on the East Campus have had new piping installed recently and the model reflects these changes. A pipe roughness coefficient or "C" factor of 130 was modeled for all pipes on the East Campus. It is believed there is little degradation of the piping on East Campus, therefore this coefficient was used.

The City of Boulder provided an H2ONet model of their system that simulates a Peak Day demand in 2020. This model was used to predict the pressures at the tap points for the East Campus. These pressures are shown in Table 9. It should be noted, that based on results of the City's model near the Main Campus, these pressures are likely 10 to 15 psi lower than existing pressures. However, no data was available to provide a more accurate estimate of existing City pressures near the East Campus. Therefore, the model of existing conditions on the East Campus is probably conservative.

Table 9: Estimated Pressure from City of Boulder Existing and Projected Conditions on East Campus

Location	Pressure (psi)	HGL (feet)
30th St. and Arapahoe Ave.	125	5560
30th St. just south of Boulder Cr.	112	5550
38th Street and Arapahoe Ave.	134	5560

To simulate the City's system in the East Campus model, a fixed head reservoir was inserted at each of the above locations. The hydraulic grade line of each of the reservoirs was set to 5555 feet in order to provide a constant pressure to the campus for modeling purposes. There are several service lines to East Campus buildings that are direct taps off of the City main in 30th Street. Setting a constant pressure at the reservoirs was done in order to avoid modeling fixed head reservoirs at every 30th Street service tap.

Model Accuracy

The scope of work for this project did not include calibration of the model. However, the general accuracy of the model did need to be determined to indicate if the results of the current model were adequate for use in planning purposes. The University and Boyle discussed that an accuracy of about 15 percent is adequate for planning purposes. There were three ways of evaluating model accuracy given the data available from the University for this project:

- Simulate the same fire flows as were simulated in the KYPipe model (as shown in the output reports in the Appendices of the DeOreo report) and compare results;
- Compare static pressure readings available from hydrant tests (1998-2001) to the model output; and/or
- Compare hydrant test results (1998-2001) to model results.

The first option would compare EPANet simulation results to KYPipe simulation results. This would result in knowing that the two models provided similar results but not necessarily that the model developed for this report simulated actual conditions. The remaining two options compare actual data to the results of the new model, providing an indication that the model simulates actual conditions within the accuracy desired. A limitation to the last two options was that it was not known what the pressures were at the connections with the City mains when the hydrant tests were performed. Therefore it was not expected that the model simulation would give exact results but would provide indication of how well the model represents the physical system.

Comparing static pressure readings for the years available indicated that, in general, the model simulation provides results similar to actual pressure readings. This is shown in Table 10.

Table 10: Comparison of Static Pressure Readings to Model Simulation of Existing Conditions

Year	Average difference between the model and the static pressure reading*		Number of Sample Points	Number of Sample points where difference greater than or equal to 10%**
	PSI	Percent		
1998	3.4	4	15	1
1999	1.8	1.9	16	1
2000	-6.9	-6.6	16	4
2001	3.6	3.9	14	1

*A positive value indicates the model results in higher pressures than field data. A negative value indicates the model results in lower pressures than field data.

**Maximum percent difference at any point was 14 percent

The second method was to use the model to generate a fire flow contour map for various pressures. Three pressures were chosen for development of fire flow contour maps based on the most numerous data points available: 60 psi (11 data point), 80 psi (14 data points), and 87 psi (6 data points). The available fire flow generated by the model at each residual pressure was then compared to the hydrant test data for all data points that were within 2 psi of the modeled residual pressure. Model results were within 20% of the 1998 and 1999 data points, with the majority within 10%. This indicated the model was a reasonable representation of the actual system and how it reacts under the stress of a fire demand. However, there was little correlation with the 2000 data points. The 2000 data points also did not correlate with the 1998 and 1999 data. For example, at one location, the fire flow was 578 gpm at about 80 psi in 1998 but 1,511 gpm at about 80 psi in 2000 (note that the model indicated about 600 gpm). Boyle proposed not using the 2000 data for determining model accuracy for the following reasons:

- The 2000 data implies much higher available fire flows than either the model or the data from 1998 and 1999. This could result in overestimating the available fire flow at any point on campus and give a false sense of the ability of the water system to respond to fire demands.

- The 2000 data did not correlate with the other data available from 1998 and 1999.

In addition to the above, the fire flow contour maps were used to compare fire flow from the model to the model results reported in the 1993 DeOreo Report. All of the modeled fire flows were less than those reported in the DeOreo report, by an average of about 35%. This means that the model developed for this study will result in slightly more conservative estimates of flows and pressures but ensures that the available fire flow (or other stress on the system) is not overestimated.

The above indicates that the model can be used with a degree of confidence to predict problems in the system and to simulate proposed improvements. It should be noted that because the model has not been calibrated, the results are not precise and the model should not be used to predict an exact fire flow or pressure at any one given point in the system. Rather the model can be used to provide general information about areas of campus.

Evaluation Criteria

The University's water distribution system was evaluated using pressure, velocity, and headloss criteria. The pressure requirements were based on the existing system, while the velocity and headloss requirements are based on those generally accepted by municipal utilities. The evaluation criteria for peak day conditions are as follows:

- *Minimum Pressure* – within 10 psi of existing conditions.
- *Maximum Velocity* – 5 fps.
- *Headloss* – Maximum headloss through a pipe is 5 feet per 1000 feet.

It should be noted that even with the proposed improvements, as discussed in subsequent sections, there were some instances where the headloss criterion was slightly exceeded. In these instances, if desired pressure and fire flow conditions were met, additional improvements were deemed to not be cost-effective and thus were not evaluated.

Fire flow criteria were to meet the University's desired fire flow and pressure as described in Existing Water Demands and Sewer Loads.

Results – Existing Conditions

Modeling the existing system showed that portions of the University's distribution system on the west side of the Main Campus are deficient, specifically in the area surrounding the Pennsylvania Street meter known as the Norlin Quadrangle. According to University staff, this area has historically been the "weakest area" within the distribution system. The model indicated that pressure, velocity, and head loss criteria could be met during Peak Day conditions. However, when fire flow conditions were applied to the system, this area appeared to be deficient in providing adequate fire flows and sprinkler flows. It was observed that a large portion of the Norlin Quadrangle could not be supplied with desired fire flows at a pressure of 25 psi. Figures 3 and 4 show the existing conditions.

The Norlin Quadrangle deficiencies are three-fold. One, the pipes in this portion of the distribution system may be heavily tuberculated due to their age (confirmed by staff as evidenced in breaks and that the modeled "C" values were 50 to 90). Two, the pipe from the Penn meter is undersized and in poor condition. Three, the City's model indicates that it can only provide approximately 650 gpm at 70 psi at the Penn and UMC meters. These flows are acceptable with regards to City requirements, but the University system under fire flow conditions needs a larger supply at greater pressures. It should also be noted that due to the system grade, with this area being hydraulically higher than the rest of the Main Campus, the Norlin Quadrangle receives the vast majority of its water supply from the Penn Street meter.

The model indicates there are other buildings on campus that cannot be supplied with the desired fire flow. Some of these buildings could be supplied from hydrants on City mains. Where a building was within 500 feet of a City main and had a direct line-of-sight, it was assumed that part or all of fire flow would be supplied directly from the City main. The City's model indicated that a minimum of 3,000 gpm at 25 psi could be obtained from the City mains surrounding and through campus.

There are buildings, however, that are too far from City mains to be supplied with fire flow directly from the City and that also cannot receive the desired fire flow from the University's system. These are shown in Figure 4.

Modeling performed on the East Campus indicates the distribution system adequately supplies offices, labs, and classrooms with required demands at substantial pressures. Pressure, velocity, and headloss criteria were met with the exception of a 3-inch line leading to the Institute of Behavioral Genetics Building. The velocities in this pipe were acceptable, however headloss exceeded criteria. Modeled pressures on the East Campus during maximum day conditions were observed to be high ranging from 120 to 130 psi. Fire and sprinkler flow requirements were observed to meet critieria on the East Campus, in part, because many of the buildings have fire connections directly to City mains. Figure 5 shows East Campus under existing conditions (as well as 10-year and Build-out condtitions.)

Model Development for Projected Conditions

The projected 10-year future conditions and the Build-out conditions were modeled using the developed existing models of the Main and East Campuses as baselines. To mimic 10-year conditions, existing demands were augmented with additional demand as shown in Table 7. To imitate Build-out conditions, the 10-year future model demands were increased further for both the Main and East Campuses as shown in Table 7. The modeled characteristics of the existing distribution system, including layout, roughness, and pipe diameters, were not modified. Based on the City's model of future conditions, pressures will be reduced by 10 to 15 psi at each of the University's master meters. The modeled pressure at each meter is shown in Table 11.

Table 11: Anticipated Pressure from City of Boulder – Future Conditions

Meter	Anticipated City Hydraulic Gradeline (feet)	Anticipated City Pressure (PSI)
Penn	5566	63
UMC	5566	61
Reed	5566	81
Folsom	5565	99

Results – 10-year Projected Conditions

Modeling the distribution system with projected 10-year demands in place showed again that portions of the system on the west side of the Main Campus in the vicinity of the Norlin Quadrangle are of concern. Velocity and head loss criteria could be met during maximum day. When fire flow conditions were modeled there was a significant portion of the system on the west side of the Main Campus that did not meet desired fire flows and minimum sprinkler flows. Buildings that cannot receive desired fire flows are shown in Figure 6. As noted earlier, the Campus distribution system's inability to provide adequate fire and sprinkler flows may be in part due to the City's system along Broadway being unable to supply greater than about 650 gpm at 60 psi at the Penn and UMC meters, as well as the age and condition of pipe in the Norlin Quadrangle.

Results – Projected Build-Out Conditions

Examining fire flow conditions placed on the Build-out model, as illustrated on Figure 7, indicates a significant portion of the Main Campus system does not meet desired fire and sprinkler flows at desired pressures. This deficiency may be attributed to significant areas along Broadway between Euclid Avenue and Kittredge Loop Road being considered potential development areas as well as the large demand placed on the system by the new power plant. Currently, the majority of this area is used as parking space. The Build-out model shows that the Kittredge Complex area is also of concern under fire flow conditions. Sizeable potential development areas, as illustrated in the 2001 Campus Master Plan, exist both on the north and south sides of Kittredge Loop Road.

Modeling performed on the East Campus involving Build-out conditions indicates the distribution system performs well. As with the existing model, pressure, velocity, and headloss criteria were met with the exception of the 3-inch line leading to the Institute of Behavioral Genetics building. This line exceeds headloss requirements. Due to the small amount of future development in both 10-year and Build-out scenarios, as well as its physical layout, the East Campus appears to have no significant problems. It appears that any additional development on the East Campus would simply result in small increases in velocities and headlosses and a small reduction in pressures, which are currently high. Also, there are no indications that fire and sprinkler flow requirements could not be met if direct fire connections with City mains are continued.

Alternatives Analysis

Alternatives were developed to address the deficiencies on the Main Campus noted in the above results. The primary system deficiencies are related to obtaining desired fire and sprinkler flows and thus, improvements are focused on increasing available fire and sprinkler flow.

Proposed Alternatives – Existing Conditions

Proposed Improvement 1 - Under all alternatives evaluated under existing (and future conditions), improved capacity from the Penn meter is desired. This capacity could be obtained by either replacing the existing pipe from the meter to the pipe loop on the northwest side of the Quad or by paralleling the pipe and connecting to the pipe loop on the southwest side of the Quad. Paralleling the pipe and connecting to the southwest corner of the existing loop (near Economics):

- Cost is almost identical due to similar lengths of pipe.
- Parallel pipes increase redundancy in the system and reduce the possibility of losing service. This is particularly important in this part of campus that is not served well by the other meters due to elevation and distance from the other meters.
- Parallel pipes provide for greater flow without having to increase the diameter of the pipe.

Proposed Improvement 2- In addition, a pipe is recommended to complete the loop near the Fleming Law and Kittredge West buildings. Although these areas could have fire flows supplied directly from City mains, a pipe is recommended to increase the available flow from the University's system as well as improve flows for sprinkler systems, existing or future.

Proposed Alternatives - Fire Flow Improvements

Two types of alternatives were considered to increase fire flows under existing conditions. Alternative A is to install fire pumps, either a main fire pump at the Penn meter that serves most of campus or individual fire pumps at each building. The University has indicated that individual fire pumps are not desired due to extensive maintenance and testing required for individual pumps. Therefore, installing a main fire pump was evaluated. A fire pump was modeled near the Penn meter, as this is the area with the greatest deficiencies in fire flow. This fire pump would provide for an increase in flows from City mains, up to 3,000 gpm. The design head on the modeled fire pump was no greater than 10 psi over existing, normal day conditions, so as to limit problems with pipe breaks within CU's system. The results of installing a fire pump are shown in Figure 8.

Alternative B is to install additional piping throughout the system to increase the ability of the system to convey flows. However, given the constraints on the City's system in providing flows to the Penn and UMC meters, additional piping alone will not provide the desired fire protection at some buildings. Therefore, in conjunction with additional piping, the second alternative requires the installation of sprinkler systems in some buildings so as to reduce the required hydrant fire flow to 1,500 gpm. In addition to the new supply pipe from the Penn meter, a second pipe is needed that provides a more direct connection between the Norlin Quadrangle and the UMC meter. Although the UMC meter is at a similar hydraulic gradeline to the Penn meter, little flow from the UMC meter reaches the Norlin Quadrangle due to the circuitous path between them. The results of the additional piping, as well as which buildings would require sprinkler systems, are shown in Figure 9.

The advantages and disadvantages of each alternative are presented in Table 12.

Table 12: Advantages and Disadvantages of Potable Water Improvement Alternatives to Improve Existing Fire Flow Conditions

Alternative	Advantage	Disadvantage
A - Install fire pump at Penn meter.	Greatly increases available fire flow over a large part of campus. No retrofitting of existing buildings.	Fire pump must be maintained and tested on a regular basis, increasing work for University staff. Fire pumps are not a passive system and rely on sensors and moving mechanical parts to work. No benefit to the system under normal conditions.
B - Install additional piping. Install sprinkler systems in specific buildings.	Improves flow in northwest part of campus under normal conditions. Improves fire and life safety in buildings in which sprinkler systems are installed. Decreases the required flow needed to be supplied by the University's system, thus reducing stress on old piping. Passive system that does not rely on a pump (assumes sprinkler heads "pop" by melting under a certain temperature).	May be difficult to retrofit some buildings with sprinkler systems.

Proposed Alternatives – Projected 10-year Conditions

As with existing conditions, the projected 10-year conditions could use either fire pumps (Alternative A) or additional pipes in conjunction with construction of sprinkler systems in specific buildings (Alternative B). The two alternatives are shown in Figures 10 and 11.

Additionally, under 10-year conditions, the proposed power plant needs to be served. The following were evaluated:

- Looped line from City main in 28th Street – due to a lower hydraulic gradeline (as indicated by the City's model) in this main, there would be no flow from 28th Street except under extreme conditions, such as a fire.

- Dedicated line from 28th Street – by not connecting into the existing University system, the hydraulic gradeline issue is circumvented. However, a dedicated line is not desired because it does not improve conditions on campus and leaves the power plant vulnerable with only one flow path for service.

- Tie-in to existing system from southeast side of Regent Drive Autopark – this option would be extended to complete a loop around the south side of Coors Event Center as the demand at the power plant increases. Thus, this option improves the overall system on the east side of the Main Campus and also provides for two directions of flow to the power plant, increasing reliability of service.

Other options that provided looping within the existing system were also evaluated, including paralleling pipes and creating other loops. The model indicated that all the alternatives provided approximately the same results with regards to pressure under normal conditions and fire flow availability. The option described above, connecting to the southeast side of the Autopark was the shortest length of pipe, and, thus, the most cost effective and is shown on Figures 10 and 11 as *Proposed Improvement 3*.

Proposed Alternatives – Build-out Conditions

As with existing conditions, the Build-out conditions could use either fire pumps or additional pipes in conjunction with construction of sprinkler systems in specific buildings. The two alternatives are shown in Figures 12 and 13.

Proposed Alternatives - Other Issues

In addition to the above, concern was expressed by the University's Fire Marshal with regards to decreased pressures under future conditions. The Fire Marshal has indicated that the University's sprinkler systems were designed with a 10 psi "safety factor." Should pressures in the future drop greater than 10 psi from existing pressures, the functionality and responsiveness of the sprinkler systems may be decreased.

All of campus is projected to experience a drop in pressure of 10 to 15 psi by the year 2020. This pressure drop is a result of pressure dropping in the City's system that is expected to occur gradually over time. Thus, no amount of additional piping, parallel or looped, will maintain pressures on campus similar to existing. The University has the following options with regards to this:

- Work with the City to improve the City's system such that pressures do not drop in the future.

- Monitor and test sprinkler systems on a regular basis. If, and when, sprinkler systems are not performing adequately, the University can then evaluate whether to replace the sprinkler system, modify the sprinkler system, or install fire pump(s).

- Plan on installing a fire pump at the Reed meter.

Given that the proposed pressure drops are only projected (and with a model of unknown accuracy that was developed by others), it may be many years into the future before this becomes an issue. Also, some or all of the affected sprinkler systems may need major repairs or replacement prior to seeing a significant pressure drop and could be redesigned for a lower supply pressure at that time. Therefore, it is recommended that the University do the following:

- Maintain relationship with the City and investigate improvements to the City's system that may be mutually beneficial.
- Monitor and test sprinkler systems on a regular basis.

It is strongly recommended that any future sprinkler systems be designed with at least a 20 psi "safety factor" for the following reasons:

- The sprinkler system will accommodate the projected pressure drop in supply to the Campus.
- The sprinkler system will have a greater "cushion" for operation if the test pressures were taken on a day of low demands, and thus high pressures.

The Campus Fire Marshal has indicated that parts of Macky Auditorium and Cristol Chemistry contain High Hazard areas. The minimum sprinkler flow for High Hazard buildings is 600 gpm. (Both Macky and Cristol are partially sprinkled). If future conditions of decreased flow and pressure are realized, these buildings may need "building-specific" improvements to provide minimum fire flows of 600 gpm to the High Hazard areas of the building. It is recommended that these buildings as well as any other High Hazard areas on campus be closely monitored for a decrease in flow in the future. If, at a given time flows do decrease, improvements to these buildings will need to be addressed.

Repair and Replacement Program

In addition to needing improvements for capacity reasons, the University should have a repair and replacement program that provides for improving the existing infrastructure prior to having catastrophic breaks. In recent years, required repairs have remained relatively steady. Therefore, the University should continue budgeting for repairs based on historic levels of work. Replacement programs do not necessarily increase the capacity of a system (although they can increase capacity due to better pipe conditions). Replacement programs do ensure that the integrity of the system stays intact, service interruptions to customers are minimized, and staff time is not consumed with responding to emergencies.

The proposed program is based on an assumed 50-year service life for pipes and valves and is detailed in Table 13 and Figures 14 and 15.

Table 13: Water Distribution Piping – Replacement Program

Replacement Period	Total Length of Pipe to Replace in Time Period
Main Campus	
2004-2005	3,400
2006-2010	7,400
2011-2015	8,700
2016-2020	3,400
East Campus	
2016-2020	5,500

As part of the repair and replacement program, University staff desired to have a guideline for when a section of pipe should be replaced rather than continually repaired. A break rate, (number of breaks per year per length), was estimated to determine at what point a pipe should be replaced rather than continually repaired. If service is interrupted at a rate of 1.5 to 2 breaks per year per 500 feet of pipe, it would be economically better to replace the pipe rather than continue to repair the pipe regardless of its actual age or scheduled replacement date.

Conclusion

The University's existing potable water system on both the Main and East Campuses is adequate to supply Peak Day demands under existing and projected conditions. The system appears to be deficient, however, in supplying the desired fire flows at desired pressures.

Proposed improvements include:

1. Improve supply from the Penn Meter with additional piping.
2. Improve flow area near Fleming Law by completing a pipe loop.
3. Install pipe to supply the proposed Central Power Plant. This pipe can be installed in two phases.

Two alternatives were presented to resolve fire flow deficiencies:

A. Install fire pump at the Penn Meter.

B. Install additional piping from the UMC Meter to the Norlin Quadrangle and sprinkle buildings as shown in Figures 8-13.

The City is projecting a decrease in supply pressure of 10-15 psi by 2020. This could affect the ability of existing sprinkler systems on Campus to function as desired and intended. It is recommended that the

University monitor and test sprinkler systems. If and when pressures do decrease to the point that sprinkler function is affected, the University can evaluate whether to install a fire pump (or pumps) or modify/replace individual sprinkler system.

Lastly, a replacement program for approximately 28,400 feet of pipe between 2004 and 2020 is presented.

Analysis of Sanitary Sewer System

Analysis of the sanitary sewer system included a visual review of CCTV videotapes of most of the sewers, as provided by the University, for the condition of pipe, and a computer model of the system to evaluate capacity. In addition, capacity conditions of the City sewers can affect the performance of University sewers; thus City Sewers serving campus were evaluated for capacity and backwater potential.

Visual Review of Sanitary Sewer System

In the summer of 2002, a cleaning and Closed Caption TV (CCTV) program was implemented for approximately 113 sanitary sewer pipes on the University Campus. The CCTV videotapes total about 16 hours of inspection footage. The results of the inspection were recorded in the sewer pipe database and incorporated into the condition assessment performed as part of this study. Pipe conditions noted and recorded included sags, cracks, breaks, cave-ins, holes, obstructions, protrusions, offsets, and major root masses. The definitions of these conditions are discussed in more detail in the Condition Assessment section. The pipes on the Main Campus that were part of the 2002 CCTV survey are shown in Figure 16. No pipes on the East Campus were included in the CCTV survey. The results of the physical condition assessment are presented in Table 20 in the Condition Assessment section.

Model of Existing Sewer System

Development

The University's sanitary sewer system is a gravity flow system. The tool used for the analysis of the existing and future conditions is a gravity flow hydraulic model developed using Microsoft Excel. A spreadsheet model was chosen for this study so that the University could maintain and expand the model without needing to purchase specialized software and train personnel in the use of the software. An electronic copy of the final model has been provided to the University in addition to this report.

The sanitary sewer network and the associated pipe attributes from the sanitary sewer database were incorporated into the spreadsheet model. Figures MP-1 and MP-2 show the sewer pipe network and associated pipe attributes. The loads for the system were developed as described earlier based on water use estimates and infiltration and inflow estimates. Capacities for each pipe were calculated in the model based on the pipe attributes using standard hydraulic methods. The accepted hydraulic model for estimating capacities in gravity flow systems is Manning's equation for open channel flow. This was the method used in the spreadsheet model to calculate the capacity of the sanitary sewer system. Simply stated, Manning's equation calculates the capacity of each individual pipe in the system based on the slope of the pipe, the diameter, an assumed depth of flow (100% in the case of 'full flow' calculations), and an estimated roughness factor based on the pipe material.

The University provided Boyle an AutoCad drawing and database detailing the sanitary sewer system. The AutoCad drawing was used to develop the pipe network and the flow paths in the model. The database provided information on connectivity, upper and lower invert elevations, pipe diameter, length, and material. These factors were used in the gravity model to calculate flow capacities for the system.

A key variable in the Manning equation for open channel flow is the Manning's Roughness Coefficient, or *n*. The roughness coefficient is a measure of the friction incurred along the channel or pipe and through the flow profile. A higher value of *n* results in a greater friction loss in the channel. Generally accepted values for various pipe materials are published in most hydraulics textbooks or references. For the pipe materials modeled in this sewer model, two values were used: a value of 0.011 for pipes made of PVC, and 0.013 for pipes made of vitrified clay, concrete, and ductile or cast iron. These values were used for all modeling conditions, existing and future.

Several University sewer lines and buildings tie-in to City trunks running across or near campus. In order to characterize the potential impacts (i.e. back-ups from surcharged pipes) that City flows may have on University sewer lines, these trunks were included in the spreadsheet model. However, reliable information for these specific City lines was not available at the time of this study, and a complete integration of the two systems was not feasible. To measure the potential effects on University sewers, an alternate approach was taken – assumed depths of flows of 25%, 50%, and 100% were assumed in the receiving City sewer, and backwater calculations were performed to characterize the potential for back-up in the campus sewer past the first manhole.

In the event that more detailed flow information (estimated flows, invert elevations) is available from the City in the future, the spreadsheet model currently includes the trunks crossing campus, and would thus allow an integrated analysis of Campus and City flows.

The City was able to provide results from the Wastewater Collection System Master Plan Update summarizing sanitary sewers known to be over capacity under existing and future conditions. These results are discussed below in the section titled City of Boulder Sanitary Sewers Serving Campus.

Model Description

The spreadsheet model was first developed for the existing conditions sewer loads and then expanded for the two future scenarios and the demand reduction scenario. The model structure has three primary sheets in the workbook. The first is used to calculate and distribute sewer loadings based on the water use demands and applies the peaking factor. The second sheet is a collection of lookup tables used in the calculations and checks in the gravity model. These lookup tables assign pipe roughness coefficients based on pipe material, infiltration values, and also the minimum slope design criteria based on diameter of pipe. The main computational sheet is the gravity model itself. This is the spreadsheet representation of the sanitary sewer network. It is organized into areas of campus that collect into the same sewer trunk. For example, the Kittredge area is organized as a group flowing to the City of Boulder trunk in 28th

Street. Each pipe is represented by its upper and lower manhole number. Attributes of the pipe including upper and lower invert elevation, length, diameter, and material are input into the model. These attributes are used to calculate the maximum capacity of each individual pipe. The loads to this pipe from contributing buildings, infiltration, and upstream pipes are also calculated in this part of the model. The analysis is then a comparison of the actual loading of the pipe with the maximum capacity of the pipe. Hypothetical flow depths other than full depth and the associated capacity are also calculated, and these capacities are used in the analysis of capacity conditions. For example, the loading of the sewer is compared to the capacity of the pipe at 50% and 75% depth as well as at 100% depth.

Two additional calculations, or checks, are made in the spreadsheet model for comparison to standard design criteria. The first check is that the actual slope of the pipe segment meets or exceeds the minimum design slope. The second is that the minimum velocity in the pipe at 100% capacity is 2 fps. These are included solely for additional information and are not included in the hydraulic calculations or condition assessments.

In addition to the sheets associated with the capacity calculations, several sheets are included that evaluate the potential for backwater curves inundating upstream manholes for lines that tie-in with the City. The model used to calculate the length of the backwater curves is a one-step Direct Step Method.

A total of 174 University sanitary sewer lines are included in the spreadsheet model. The model is also structured to accommodate analysis of a number of City sewer pipes, if in the future invert elevations and loading data become available and the University finds it useful to model City flows across campus.

Model Results – Existing Conditions

The peak design flows, or loads, are compared to the theoretical capacity of the sewer as calculated by the hydraulics model in order to apply a capacity condition rating. Three theoretical capacities for each pipe were calculated: the flow capacity at 50%, 75%, and 100% depth of flow in the pipe. The peak flow in the pipe is compared against these three values to determine the rating. The rating is based on a scale of 1 to 5 with 5 being the most severe. (This scale is used to integrate with the Primary Rating discussed later in this report.) If the peak design flow is less than the capacity at 50% depth, the rating is 1. Flows greater than 50% depth, but less than 75% depth are rated 2. Flows greater than 75% depth, but less than capacity at 100% depth are rated 3. Any pipe flowing at greater than 100% full is surcharged, and rated at 5 (most severe). Table 14 shows how these ratings are assigned. The peak design flow and capacities at these depths are presented for each pipe in Table 15. The associated flow condition and rating are also presented. Flows and ratings for the Stadium and Coors Events Center under event flows are presented separately at the end of Table 15.

Table 14: Capacity Rating Table

Percent of Full Capacity	Capacity Rating
0% - 50%	1
50% - 75%	2
75% - 100%	3
> - 100%	5

In general, the loads on the sanitary sewer are below 50% capacity (rating of 1) for existing loading. There are twelve pipes with a category ‘2’ rating, one with a category ‘3’ rating, and one with a rating of ‘5’. Those pipes with the 3 and 5 rating, and the majority of those with a 2 rating are the result of shallow slopes for the size of pipe in place (either not meeting typical design criteria or on the low end of acceptance). The remaining category 2 pipes are 6-inch diameter pipes. Those pipes that exceeded 50% capacity (rating 2) are not suggested for improvements unless there is a history of clogging or other maintenance problems. The higher rated pipes (3 and 5 rating) are discussed in the alternatives for improvement below. Existing load conditions and capacity ratings for the Main and East Campuses are shown in Figures 17 and 18.

Table 15. Existing Conditions Capacity Rating

Pipe / Manhole		Pk Q	Q 0.5D	Q 0.75D	Q Full	Flow Depth	Capacity
From	To	GPM	GPM	GPM	GPM	Condition	Rating
MAIN CAMPUS							
FLEMING LAW, KITTREDGE							
SS0253	SS0250	18.9	130	237	260	UNDER 50%	1
SS0250	SS0249	20.5	268	488	536	UNDER 50%	1
SS0252	SS0251	36.6	127	232	254	UNDER 50%	1
SS0251	SS0249	40.6	130	236	260	UNDER 50%	1
SS0249	SS0248	96.5	274	498	548	UNDER 50%	1
SS0248	SS0247	106.5	224	408	448	UNDER 50%	1
SS0247	SS0246	110.2	266	484	532	UNDER 50%	1
SS0246	SS0245	171.5	574	1045	1149	UNDER 50%	1
SS0245	SS0244	176.6	102	185	204	OVER 50%	2
SS0244	SS0241	184.8	308	561	617	UNDER 50%	1
SS0243	SS0242	162.6	127	232	254	OVER 50%	2
SS0242	SS0241	168.5	129	235	258	OVER 50%	2
SS0241	SS0240	370.0	292	531	584	OVER 50%	2
UCB POLICE / COORS EVENTS							
SS0234	SS0235	6.9	225	410	451	UNDER 50%	1
SS0235	SS0236	10.4	182	332	365	UNDER 50%	1
SS0236	SS0237	13.3	266	485	533	UNDER 50%	1
SS0239	SS0323	5.4	422	768	844	UNDER 50%	1
SS0323	SS0325	10.3	389	708	778	UNDER 50%	1
SS0325	SS0324	16.7	257	468	514	UNDER 50%	1
SS0324	SS0237	17.5	374	681	749	UNDER 50%	1
SS0237	SS0238	36.2	220	400	440	UNDER 50%	1
SS0238	CITYB60	39.8	810	1475	1620	UNDER 50%	1
ENGINEERING CENTER							
SS0233	SS0232	27.6	154	280	308	UNDER 50%	1
CO-B432s	SS0232	32.3	288	524	576	UNDER 50%	1
SS0232	SS0231	65.3	322	587	645	UNDER 50%	1
SS0231	SS0226	70.7	213	387	426	UNDER 50%	1
SS0226	SS0225	73.3	476	867	952	UNDER 50%	1
SS0225	SS0315	158.9	550	1002	1101	UNDER 50%	1
SS0315	SS0222	166.4	487	886	973	UNDER 50%	1
SS0222	SS0313	170.5	351	639	702	UNDER 50%	1
SS0224	SS0223	50.5	264	481	529	UNDER 50%	1
SS0223	SS0313	54.4	205	374	411	UNDER 50%	1
SS0313	SS0314	228.8	389	708	778	UNDER 50%	1
SS0314	SS0221	233.5	479	871	957	UNDER 50%	1

Table 15 cont'd							
Pipe / Manhole		Pk Q	Q 0.5D	Q 0.75D	Q Full	Flow Depth	Capacity
From	To	GPM	GPM	GPM	GPM	Condition	Rating

KITTREDGE WEST / FISKE PLANETARIUM							
SS0263	SS0261	4.0	127	231	254	UNDER 50%	1
SS0262	SS0261	2.1	197	358	394	UNDER 50%	1
SS0261	SS0260	9.9	44	79	87	UNDER 50%	1
SS0260	SS0259	12.4	243	442	486	UNDER 50%	1
REGENT, WILLARD, HALLETT							
SS0217	SS0216	61.6	586	1067	1173	UNDER 50%	1
SS0216	SS0320	66.6	357	650	715	UNDER 50%	1
SS0320	SS0215	94.4	358	651	715	UNDER 50%	1
SS0215	SS0214	98.9	520	947	1041	UNDER 50%	1
SS0214	SS0213	105.8	195	354	389	UNDER 50%	1
SS0213	SS0211	173.8	1254	2282	2508	UNDER 50%	1
LIBBY, FARRAND, ENG QUAD							
SS0208	SS0207	110.3	294	535	587	UNDER 50%	1
SS0207	SS0202	221.2	295	536	589	UNDER 50%	1
SS0206	SS0204	80.9	111	201	221	UNDER 50%	1
SS0205	SS0204	84.7	187	340	373	UNDER 50%	1
SS0204	SS0203	174.0	413	751	825	UNDER 50%	1
SS0203	SS0202	178.4	497	904	994	UNDER 50%	1
SS0202	SS0199	420.1	805	1465	1610	UNDER 50%	1
SS0201	SS0200	19.8	362	659	724	UNDER 50%	1
SS0200	SS0199	39.3	650	1183	1300	UNDER 50%	1
SS0199	SS0198	468.2	986	1795	1972	UNDER 50%	1
UNIV CLUB, EUCLID, 18TH ST							
SS0171	SS0172	12.7	142	258	284	UNDER 50%	1
SS0172	SS0173	54.3	255	464	510	UNDER 50%	1
SS0173	SS0174	55.0	305	555	610	UNDER 50%	1
SS0178	SS0179-77	1.5	302	550	604	UNDER 50%	1
WARD / CHEY-ARAP / IMIG / ENV. DES. / POWER							
SS0187	SS0188	3.7	58	105	115	UNDER 50%	1
SS0191	SS0190	70.0	361	658	723	UNDER 50%	1
SS0194	SS0329	0.6	204	372	409	UNDER 50%	1
JILA, LASP							
SS0158	SS0155	134.5	212	385	423	UNDER 50%	1
SS0155	SS0154	136.4	245	446	491	UNDER 50%	1
SS0154	SS0109	141.4	678	1235	1357	UNDER 50%	1
HELLEMS, UMC, SIBELL, CRISTOL							
SS0138	SS0139	29.3	80	145	160	UNDER 50%	1
SS0139	SS0140	32.4	196	357	392	UNDER 50%	1
SS0140	SS0311	34.2	143	261	286	UNDER 50%	1
SS0311	SS0141	36.4	223	406	446	UNDER 50%	1
SS0141	SS0142	43.1	290	528	580	UNDER 50%	1

Table 15 cont'd							
Pipe / Manhole		Pk Q	Q 0.5D	Q 0.75D	Q Full	Flow Depth	Capacity
From	To	GPM	GPM	GPM	GPM	Condition	Rating
SS0142	SS0143	56.5	151	274	301	UNDER 50%	1
SS0143	SS0312	135.9	240	436	479	UNDER 50%	1
SS0147	MID-SS0146	0.3	605	1101	1210	UNDER 50%	1
SS0146	SS0145	82.4	89	162	178	UNDER 50%	1
SS0145	MID-SS0312	82.7	423	770	847	UNDER 50%	1
MID-SS0312	SS0312	83.4	1075	1957	2150	UNDER 50%	1
SS0312	SS0144	222.2	258	470	517	UNDER 50%	1
SS0144	SS0148	225.5	658	1198	1317	UNDER 50%	1
SS0151	SS0150	2.2	153	278	306	UNDER 50%	1
SS0150	SS0148	4.9	240	437	480	UNDER 50%	1
SS0148	SS0321	236.9	596	1086	1193	UNDER 50%	1
SS0321	SS0153	239.9	1242	2260	2484	UNDER 50%	1
EKELEY, KETCHUM							
SS0316	SS0124	25.6	129	235	258	UNDER 50%	1
SS0124	SS0122	26.1	132	241	264	UNDER 50%	1
SS0122	SS0121	30.4	226	412	453	UNDER 50%	1
SS0121	SS0120	30.7	670	1220	1341	UNDER 50%	1
SS0120	SS0118	74.0	149	271	298	UNDER 50%	1
SS0119	SS0118	2.5	122	223	245	UNDER 50%	1
SS0118	SS0117	80.6	58	105	115	OVER 50%	2
SS0117	SS0116	81.8	56	102	113	OVER 50%	2
SS0116	SS0115	83.8	329	599	659	UNDER 50%	1
COLORADO AVE-FOLSOM							
SS0113	SS0112	2.9	329	599	658	UNDER 50%	1
SS0326	SS0309	40.3	194	352	387	UNDER 50%	1
SS0309	SS0322	43.8	124	226	248	UNDER 50%	1
SS0308	SS0317	90.8	443	807	887	UNDER 50%	1
SS0317	SS0318	94.6	374	680	748	UNDER 50%	1
SS0318	SS0319	98.3	380	691	759	UNDER 50%	1
SS0319	SS0107	104.7	323	589	647	UNDER 50%	1
SS0107	SS0104	106.0	1039	1890	2077	UNDER 50%	1
SS0106	SS0105	1.0	1576	2868	3151	UNDER 50%	1
SS0105	SS0104	2.4	825	1501	1650	UNDER 50%	1
SS0103	SS0102	1.4	314	572	628	UNDER 50%	1
SS0097	SS0098	1.1	722	1314	1444	UNDER 50%	1
SS0098	City Pipe	1.6	491	894	983	UNDER 50%	1
SS0101	SS0100	64.5	202	367	403	UNDER 50%	1
SS0100	SS0099	72.2	224	407	447	UNDER 50%	1
SS0099	SS0096	75.2	337	613	673	UNDER 50%	1
SS0096	SS0095	76.4	187	340	374	UNDER 50%	1
SS0094	SS0093	1.7	588	1071	1177	UNDER 50%	1
GUGGENHEIM/ECON - STADIUM/FOLSOM							

Table 15 cont'd							
Pipe / Manhole		Pk Q	Q 0.5D	Q 0.75D	Q Full	Flow Depth	Capacity
From	To	GPM	GPM	GPM	GPM	Condition	Rating
SS0132	SS0130	7.5	179	325	357	UNDER 50%	1
SS0132	SS0131	1.2	257	468	514	UNDER 50%	1
SS0131	SS0130	8.4	150	273	300	UNDER 50%	1
SS0130	SS0129	23.1	223	406	447	UNDER 50%	1
SS0137	SS0136	14.2	471	857	941	UNDER 50%	1
SS0136	SS0135	30.8	137	248	273	UNDER 50%	1
SS0135	SS0134	32.3	158	287	316	UNDER 50%	1
SS0134	SS0133	49.5	216	393	432	UNDER 50%	1
SS0133	SS0129	55.9	188	342	376	UNDER 50%	1
SS0129	SS0127	83.2	205	373	410	UNDER 50%	1
SS0128	SS0127	19.3	187	340	374	UNDER 50%	1
SS0127	SS0125	103.9	206	375	412	UNDER 50%	1
SS0126	SS0125	24.7	217	394	433	UNDER 50%	1
SS0125	SS0058	131.8	593	1080	1186	UNDER 50%	1
SS0058	SS0057	153.6	2567	4672	5134	UNDER 50%	1
SS0057	SS0059	168.9	1646	2996	3293	UNDER 50%	1
SS0059	SS0060	188.7	2353	4282	4705	UNDER 50%	1
SS0060	SS0061	212.7	3212	5846	6424	UNDER 50%	1
SS0064	INT SS0061	9.2	5436	9893	10872	UNDER 50%	1
SS0061	SS0062	226.8	2631	4789	5263	UNDER 50%	1
SS0065	SS0063	7.2	319	580	637	UNDER 50%	1
SS0063	SS0062	9.6	1319	2401	2638	UNDER 50%	1
SS0062	SS0067	250.0	2513	4573	5026	UNDER 50%	1
SS0066	SS0067	85.1	224	408	449	UNDER 50%	1
SS0067	SS0069	345.7	2428	4420	4857	UNDER 50%	1
SS0069	SS0070	349.5	2743	4993	5487	UNDER 50%	1
SS0068	SS0070	2.5	573	1043	1146	UNDER 50%	1
SS0070	SS0071	361.9	2543	4629	5087	UNDER 50%	1
SS0071	SS0072	363.5	8231	14981	16462	UNDER 50%	1
SS0072	SS0073	375.5	5478	9970	10956	UNDER 50%	1
SS0073	SS0074	387.7	2796	5089	5592	UNDER 50%	1
SS0074	SS0075	397.9	3624	6596	7249	UNDER 50%	1
SS0075	SS0310	402.7	1399	2546	2798	UNDER 50%	1
SS0310	SS0078	410.5	4589	8351	9177	UNDER 50%	1
SS0076	SS0078	2.5	664	1209	1328	UNDER 50%	1
SS0078	SS0079	447.7	1787	3253	3575	UNDER 50%	1
SS0079	SS0080	457.8	1734	3156	3468	UNDER 50%	1
SS0080	SS0082	475.3	2260	4114	4521	UNDER 50%	1
SEWALL, REC CENTER							
SS0051	SS0049	32.8	770	1401	1540	UNDER 50%	1
SS0050	SS0049	1.2	1125	2048	2250	UNDER 50%	1
SS0049	SS0048	36.4	609	1108	1217	UNDER 50%	1

Table 15 cont'd							
Pipe / Manhole		Pk Q	Q 0.5D	Q 0.75D	Q Full	Flow Depth	Capacity
From	To	GPM	GPM	GPM	GPM	Condition	Rating
KOENIG, HALE, MACKY							
SS0034	SS0033	4.7	671	1221	1341	UNDER 50%	1
SS0035	SS0036	16.5	311	566	622	UNDER 50%	1
SS0036	SS0037	18.6	142	258	284	UNDER 50%	1
SS0037	SS0038	21.6	153	278	306	UNDER 50%	1
SS0038	SS0040	25.2	158	287	315	UNDER 50%	1
SS0039	SS0040	13.6	188	341	375	UNDER 50%	1
SS0040	SS0042	42.9	283	514	565	UNDER 50%	1
SS0041	SS0042	1.0	49	88	97	UNDER 50%	1
SS0042	SS0045	48.0	567	1033	1135	UNDER 50%	1
SS0047	SS0046	22.7	498	906	996	UNDER 50%	1
SS0046	SS0045	25.5	487	886	973	UNDER 50%	1
SS0045	SS0044	75.0	570	1037	1140	UNDER 50%	1
EAST CAMPUS							
30TH & MARINE							
SS0268	SS0269	221.3	126	229	252	OVER 50%	2
SS0267	SS0266	86.7	181	329	362	UNDER 50%	1
SS0265	SS0264	34.5	119	216	237	UNDER 50%	1
MARINE STREET							
SS0270	SS0271	36.3	288	525	577	UNDER 50%	1
SS0271	SS0272	40.9	231	421	462	UNDER 50%	1
SS0272	SS0273	107.5	194	353	388	UNDER 50%	1
SS0273	SS0274	113.9	196	357	392	UNDER 50%	1
SS0274	SS0275	120.5	185	336	370	UNDER 50%	1
SS0275	SS0276	121.3	403	733	806	UNDER 50%	1
SS0276	SS0277	151.3	40	73	80	PRESSURE	5
SS0277	SS0278	160.9	138	251	276	OVER 50%	2
SS0278	SS0279	166.8	172	312	343	UNDER 50%	1
SS0279	SS0280	172.4	172	312	343	OVER 50%	2
UCB POLICE / COORS EVENTS							
SS0234	SS0235	6.9	225	410	451	UNDER 50%	1
SS0235	SS0236	10.4	182	332	365	UNDER 50%	1
SS0236	SS0237	13.3	266	485	533	UNDER 50%	1
SS0239	SS0323	385.4	422	768	844	UNDER 50%	1
SS0323	SS0325	390.3	389	708	778	OVER 50%	2
SS0325	SS0324	396.7	257	468	514	OVER 50%	2
SS0324	SS0237	397.5	374	681	749	OVER 50%	2
SS0237	SS0238	416.2	220	400	440	OVER 75%	3
SS0238	CITYB60	419.8	810	1475	1620	UNDER 50%	1
STADIUM SOUTH							
SS0097	SS0098	133.1	722	1314	1444	UNDER 50%	1
SS0098	City Pipe	133.6	491	894	983	UNDER 50%	1

Table 15 cont'd							
Pipe / Manhole		Pk Q	Q 0.5D	Q 0.75D	Q Full	Flow Depth	Capacity
From	To	GPM	GPM	GPM	GPM	Condition	Rating
STADIUM / FIELD HOUSE							
SS0068	SS0070	134.5	573	1043	1146	UNDER 50%	1
SS0070	SS0071	144.3	2543	4629	5087	UNDER 50%	1
SS0071	SS0072	146.0	8231	14981	16462	UNDER 50%	1
SS0072	SS0073	158.0	5478	9970	10956	UNDER 50%	1
SS0073	SS0074	170.1	2796	5089	5592	UNDER 50%	1
SS0074	SS0075	180.3	3624	6596	7249	UNDER 50%	1
SS0075	SS0310	185.2	1399	2546	2798	UNDER 50%	1
SS0310	SS0078	192.9	4589	8351	9177	UNDER 50%	1
SS0076	SS0078	138.5	664	1209	1328	UNDER 50%	1
SS0078	SS0079	338.2	1787	3253	3575	UNDER 50%	1
SS0079	SS0080	348.3	1734	3156	3468	UNDER 50%	1
SS0080	SS0082	365.7	2260	4114	4521	UNDER 50%	1

Model of Future Conditions

The analysis of the impacts of future development on the existing sanitary sewer system assumes the new buildings will tie-in to the nearest existing line. If a result of this analysis is overcapacity of the existing system, then alternatives providing additions to the system were evaluated.

Two future model scenarios were created, 10-year and Build-out. The projected 10-year model incorporated additional loads at manholes SS0151, SS0080, SS0237, and SS0248. The projected Build-out scenario incorporated additional loads at the same locations as the 10-year scenario as well as SS0233.

Results – Future Conditions

The additional flows associated with the 10-year and Build-out scenarios did affect the capacity rating of some of the pipes serving these areas. The pipes affected are presented in Table 16. Figures 19 and 20 show sanitary sewer future loads and capacity ratings for the Main Campus for the 10-year and Build-out conditions. These groups of pipes are lower in the respective collection systems, so an impact was expected. The New Utility Plant will surcharge pipe SS0237-SS0238, and will require either a new connection to the City sewer or an upsizing of the existing pipe. The Law Addition at Build-out would surcharge pipe SS0245-SS0244, and would likely require an upsizing and/or correction in slope. In addition, pipe SS0241 – City will change to a rating of 2, over 50% capacity, and may benefit from upsizing in the future if other repairs are warranted. Alternatives for these improvements are discussed below.

Table 16: Pipes Affected in Future Condition Scenarios

Pipe	Projected 10-year Conditions (Rating)	Projected Build-out Conditions (Rating)
SS0237 – SS0238	Over 100% (5)	Over 100% (5)
SS0238 – City	No Change (1)	Over 50% (2)
SS0245 – SS0244	Over 75% (3)	Over 100% (5)
SS0241 – City	Over 50% (2)	Over 50% (2)

Sewer Pipe Condition Assessment Methodology

Pipe Capacity/Physical Condition Rating

A rating system for the capacity and physical condition of individual pipes in the system was developed. The rating system is based on information gathered by review of video inspections and the associated summary reports of the inspections and the results of the capacity modeling. This assessment applies to the existing conditions only. Two numerical values were developed to assess the condition of the pipe, a “Primary Rating Score” and a “Secondary Rating Score”.

The “Primary Rating Score” reflects the severity of the condition and urgency for repair. Values for this category are on a scale of 1 to 5. The Primary Rating is assigned the most severe rating of any of the individual categories (for example, a pipe in good condition without any prolems receives a Primary Rating of 1, whereas a pipe that is crushed receives a Primary Rating of 5). The second value, the “Secondary Rating Score”, reflects the severity of the overall pipe condition. The purpose of the Secondary Rating is to compare the relative severity of pipes within the same Primary Rating. Unlike the Primary Rating, the Secondary Rating Score does not have an upper value. The following explains the individual ratings of all categories considered, and how these ratings are applied to the Primary and Secondary Rating Score. To reiterate, the Primary score is used to identify overall severity of the condition, and the Secondary score is to prioritize pipes within the same Primary grouping.

Primary Rating

The Primary Rating of 1 to 5 is based on the most severe condition occurring in a pipe. If the pipe is in good condition without significant sags, cracks, etc. then the rating is 1. If however, the pipe is caved-in or obstructed, the pipe would receive a rating of 5, regardless of the number of caved-in sections or other maintenance problems. The value of the Primary Rating is the maximum of the ratings assigned to any problem occurring in the pipe. The values assigned to each specific problem and their severities are detailed below.

Secondary Rating

The Secondary Rating Score is a summary of the total problems seen in a pipe. This is where the additive effect of deficiencies in a pipe is reflected. The rating value assigned to each maintenance issue, and the number of occurrences of each, are summed to determine the total score. The Secondary Rating pertains primarily to a set of pipes within the same Primary Rating class. For example, given a set of pipes with a Primary Rating of 5 (the most severe), the Secondary score could be used to further rank, or prioritize these pipes for maintenance. It is stressed here that the Secondary score should not be used in place of the Primary Rating to determine severity of damage or priority in maintenance outside of the same Primary Rating group.

Capacity Rating

The capacity rating of each pipe as explained in the Modeling Results section is also incorporated into the condition rating. The capacity condition ratings are based on a scale of 1-5 (values of 1, 2, 3, and 5).

Backwater Condition

The potential for backwater impacts from City sewers is applied as a condition rating. The severity of backwater effects given a downstream condition of 100% flow are more severe than the effects at 50%; However, given the greater likelihood of a 50% flow to occur, this condition is assigned a more severe rating. The backwater effect ratings are summarized in the following Table 17:

Table 17: Backwater Rating Table

B/W Impact	Rating
No Backwater impact	1
B/W Impact at 100% Flow Depth	3
B/W Impact at 50% and below Flow Depth	5

Visual Inspection of the System

Crushed/Caved-In - A crushed or caved-in pipe is perhaps the most severe condition of a pipe. A cave-in will lead to an obstruction in the pipe, if not already having occurred, then likely in the near future. In addition to the damaged pipe of the cave-in, further damage could occur to more length of pipe in the vicinity by way of scouring or progressive caving if not repaired immediately. The value given to each crushed or caved-in section of a pipe in the Secondary Score is a 5 (e.g., 5 for every occurrence). The occurrence of a crush/cave-in results in an automatic 5 in the Primary Rating.

Obstruction/Protrusion - An obstruction or other protrusion into a pipe can cause back-ups and clogging. These also are assigned a Primary Rating of 5. Examples of obstructions are other utility pipes crossing the sewer line, service lines protruding into the sewer, construction materials from a repair, etc. These are more severe than roots or other material that may be removed by maintenance cleaning. (It is believed that roots can be managed by a routine maintenance schedule, and as such are not given a condition rating; however, the occurrence of root masses is noted in the rating spreadsheet.) The value given to each obstruction in a sewer in the Secondary Rating Score is a 5 (e.g., 5 for every occurrence).

Breaks and Holes - Breaks and holes are identified separately but both have a Primary Rating of 4. The value given to each break or hole in a pipe in the Secondary Rating Score is a 4 (e.g., 4 for every occurrence of either). A break is defined for these purposes as a piece of pipe wall that is loose, or a series of closed cracks, that look as if they could be pried apart. A hole is defined as an area of pipe wall where surrounding soil is exposed. Breaks and holes are given high values of severity for several reasons. The primary reason is that these conditions can be the precursor to a cave-in or obstruction of pipe, and eventually a back-up. Increased infiltration through a hole is also more likely. Exfiltration of wastewater to the surrounding soil is also a concern, especially if in the vicinity of drinking water utilities.

Offset / Displacement - Pipe offsets and displacements at joints decrease the capacity of the sewer pipe. However, because these do not necessarily result in damaged pipe or more severe conditions, the rating assigned to an offset is 1 for the Primary Rating. If zero displacements exist, then Primary Rating score for this category is 0. Each offset in a pipe segment is counted in the calculation of the Secondary Rating Score.

Cracks - Cracks in sewer pipes are identified as either longitudinal or circumferential. For use in the rating, the occurrences of each are summed to a total number of cracks per 100 feet of pipe. This value is then used to assign a rating of 1 to 3, with 3 being the worst. Table 18 shows how the ratings are applied. The value given for cracks in the Secondary Rating Score is the same value used in the Primary Rating, 1 to 3 for the entire pipe.

Table 18: Crack Rating Table

# Cracks/ 100ft	Crack Rating
Less than 3	1
3 - 7	2
More than 7	3

Pipe Sag

Sag in a pipe is an increasing concern if the flow in the pipe approaches the design capacity due to the decrease in actual capacity. Pipe Sag is less of an issue if the pipe is not in danger of exceeding the design capacity; however, at lower flows the potential still exists for solids accumulation and clogging. The rating of a sag is therefore correlated to the Capacity Rating of the pipe. In order to accomplish this correlated rating, two types of Sag Ratings were developed, the first being a length of sag per pipe rating (1-5; 5 most severe), and the second the Final Sag Rating (1-5), which incorporates the Capacity Rating with the pipe sag. If the Capacity Rating is a 1, then the Final Sag Rating is a 1, regardless of the severity of the pipe sag. Conversely, if the pipe sag rating is 5, then the Final Sag Rating is a 5, for any Capacity Rating above 1. The following matrix (Table 19) is used to assign the Final Sag Rating. To use the matrix, one first finds the Capacity Rating in the leftmost column, and then finds the Final Sag Rating corresponding to the pipe sag rating.

Table 19: Pipe Sag Rating Table

	Pipe Sag Rating				
Capacity Rating	**1**	**2**	**3**	**4**	**5**
1	*1*	*1*	*1*	*1*	*1*
2	*2*	*2*	*3*	*4*	*5*
3	*3*	*3*	*4*	*5*	*5*
5	*5*	*5*	*5*	*5*	*5*

Condition Assessment Results

Table 20 details the results of the condition assessment under existing conditions. The table details the number of occurances of damaged sections, and the rating as applied to each category. The color-coding reflects the severity of each rating (blue=good; red=severe). The final two columns reflect the Primary Rating (overall severity) and the Secondary Rating (cumulative score of all conditions). Of the 174 pipes included in the assessment:

- 11 have ratings of 5 (most severe);
- 17 rate 4;
- 8 rate 3;
- 10 rate 2; and
- 128 rate 1 (good condition).

Figures 21 and 22 show the resulting condition rating applied to each of the pipes on campus for existing conditions. Capacity and backwater ratings only are applied to 77 of the 174 pipes assessed. These 77 pipes were not part of the CCTV survey, and thus will need to be updated if they are surveyed for physical condition information. The condition rating spreadsheet is set up to allow the addition of information on condition and or capacity as it becomes available.

Table 20: Sewer Condition Assessment Results

Severity Color Code: 1 | 2 | 3 | 4 | 5

Pipe ID	Campus Area	SIZE (IN)	MATERIAL	LENGTH (FT)	Video Inspection Results: Crushed/ Caved-in	Video Inspection Results: Obstruct. / Protr.	Video Inspection Results: Breaks	Video Inspection Results: Hole	Video Inspection Results: Offset/ Displcmnt	Video Inspection Results: Crack Rating	Rate of Sag (w/Q)	Capacity Rank	Backwater Effect	Primary Rating Score	Secondary Rating Score
				Value Assigned to Condition / Capacity:	(5)	(5)	(4)	(4)	(1)	(1-3)	(1-5)	(1-5)	(1-5)	(1-5)	
					Number of Occurrences (Shading indicated severity)										
ss0241-ss0240	Fleming / Kitt	8	conc	466	0.0	0.0	0.0	0.0	0.0	1	2	2	1	2	6
ss0242-ss0241	Fleming / Kitt	6	cip	219	0.0	0.0	1.0	0.0	0.0	1	2	2	1	4	10
ss0243-ss0242	Fleming / Kitt	6	cip	98	0.0	0.0	0.0	0.0	0.0	1	2	2	1	2	6
ss0244-ss0241	Fleming / Kitt	8	conc	228	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0245-ss0244	Fleming / Kitt	8	conc	142	0.0	0.0	1.0	0.0	0.0	1	2	2	1	4	10
ss0246-ss0245	Fleming / Kitt	8	conc	37	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0247-ss0246	Fleming / Kitt	8	conc	105	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0248-ss0247	Fleming / Kitt	8	conc	278	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0249-ss0248	Fleming / Kitt	8	conc	152	0.0	0.0	1.0	0.0	0.0	1	1	1	1	4	8
ss0250-ss0249	Fleming / Kitt	8	conc	46	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0251-ss0249	Fleming / Kitt	6	cip	146	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0252-ss0251	Fleming / Kitt	6	cip	49	0.0	0.0	0.0	0.0	0.0	3	1	1	1	3	6
ss0253-ss0250	Fleming / Kitt	6	conc	281	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0324-ss0237	UCB Police / Coors Events	8	pvc	22	0.0	0.0	0.0	0.0	0.0	1	2	2	1	2	6
ss0325-ss0324	UCB Police / Coors Events	8	pvc	179	0.0	0.0	0.0	0.0	0.0	1	2	2	1	2	6
ss0323-ss0325	UCB Police / Coors Events	8	pvc	137	0.0	0.0	0.0	0.0	0.0	1	2	2	1	2	6
ss0239-ss0323	UCB Police / Coors Events	8	pvc	151	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0234-ss0235	UCB Police / Coors Events	6	pvc	258	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0235-ss0236	UCB Police / Coors Events	6	pvc	128	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0236-ss0237	UCB Police / Coors Events	8	dip	83	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0237-ss0238	UCB Police / Coors Events	8	pvc	151	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0238-COB60	UCB Police / Coors Events	8	pvc	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	1	3	4
ss0222-ss0313	Engineering Center	8	pvc	115	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0223-ss0313	Engineering Center	6	vcp	146	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0224-ss0223	Engineering Center	6	vcp	297	0.0	0.0	1.0	0.0	2.0	1	1	1	1	4	10
ss0225-ss0315	Engineering Center	8	vcp	17	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0226-ss0225	Engineering Center	8	vcp	73	0.0	0.0	0.0	0.0	1.0	1	1	1	1	1	5
ss0231-ss0226	Engineering Center	8	vcp	151	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0232-ss0231	Engineering Center	8	vcp	150	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0233-ss0232	Engineering Center	6	vcp	237	0.0	1.0	0.0	0.0	0.0	1	1	1	1	5	9
CO-B432cs - ss0232	Engineering Center	8	vcp	310	0.0	0.0	0.0	1.0	0.0	1	1	1	1	4	8
ss0313-ss0314	Engineering Center	8	pvc	110	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0314-ss0221	Engineering Center	8	pvc	130	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0315-ss0222	Engineering Center	8	vcp	208	0.0	1.0	0.0	0.0	0.0	1	1	1	1	5	9
ss0260-ss0259	Kit West / Fiske	6	vcp	96	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0261-ss0260	Kit West / Fiske	4	vcp	209	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0262-ss0261	Kit West / Fiske	4	vcp	120	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0263-ss0261	Kit West / Fiske	4	vcp	223	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0213-ss0211	Regent / Willard / Hallett	10	vcp	179	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0214-ss0213	Regent / Willard / Hallett	8	vcp	194	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0215-ss0214	Regent / Willard / Hallett	8	vcp	125	0.0	0.0	1.0	0.0	0.0	2	1	1	1	4	9
ss0216-ss0320	Regent / Willard / Hallett	8	vcp	140	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0320-ss0215	Regent / Willard / Hallett	8	vcp	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0217-ss0216	Regent / Willard / Hallett	8	vcp	212	0.0	1.0	0.0	0.0	0.0	1	1	1	1	5	9
ss0199-ss0198	Libby / Farrand / Eng. Quad	12	vcp	165	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4

Table 20: Sewer Condition Assessment Results

Severity Color Code: 1, 2, 3, 4, 5

Pipe ID	Campus Area	SIZE (IN)	MATERIAL	LENGTH (FT)	Video Inspection Results: Crushed/ Caved-in	Obstruct. / Protr.	Breaks	Hole	Offset/ Displcmnt	Crack Rating	Rate of Sag (w/Q)	Capacity Rank	Backwater Effect	Primary Rating Score	Secondary Rating Score
				Value Assigned to Condition / Capacity:	(5)	(5)	(4)	(4)	(1)	(1-3)	(1-5)	(1-5)	(1-5)	(1-5)	
					Number of Occurrences (Shading indicated severity)										
ss0200-ss0199	Libby / Farrand / Eng. Quad	8	pvc	79	0.0	0.0	1.0	0.0	0.0	1	1	1	1	4	8
ss0201-ss0200	Libby / Farrand / Eng. Quad	8	vcp	87	0.0	0.0	2.0	0.0	0.0	1	1	1	1	4	12
ss0202-ss0199	Libby / Farrand / Eng. Quad	12	vcp	71	0.0	0.0	0.0	0.0	0.0	3	1	1	1	3	6
ss0203-ss0202	Libby / Farrand / Eng. Quad	8	vcp	121	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0204-ss0203	Libby / Farrand / Eng. Quad	8	vcp	235	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0205-ss0204	Libby / Farrand / Eng. Quad	8	vcp	131	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0206-ss0204	Libby / Farrand / Eng. Quad	6	vcp	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0207-ss0202	Libby / Farrand / Eng. Quad	8	vcp	251	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0208-ss0207	Libby / Farrand / Eng. Quad	8	vcp	231	0.0	0.0	2.0	0.0	0.0	1	1	1	1	4	12
ss0171-ss0172	Univ. Club / Euclid / 18th	6	vcp	100	0.0	1.0	0.0	0.0	0.0	1	1	1	1	5	9
ss0172-ss0173	Univ. Club / Euclid / 18th	6	vcp	59	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0173-ss0174	Univ. Club / Euclid / 18th	8	pvc	21	0.0	0.0	0.0	0.0	0.0	1	1	1	3	3	6
ss0178-ss0179-77	Univ. Club / Euclid / 18th	6	vcp	56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0187-ss0188	Ward / Chey Arap	4	vcp	207	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0191-ss0190	Ward / Chey Arap	8	vcp	169	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0194-ss0329	Ward / Chey Arap	6	vcp	22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	5	5	6
ss0154-ss0109	JILA / LASP	8	vcp	139	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0155-ss0154	JILA / LASP	8	vcp	55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0158-ss0155	JILA / LASP	8	vcp	69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0138-ss0139	Hellems / UMC	4	pvc	147	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0139-ss0140	Hellems / UMC	6	pvc	116	0.0	0.0	0.0	1.0	0.0	1	1	1	1	4	8
ss0140-ss0311	Hellems / UMC	6	pvc	67	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0141-ss142	Hellems / UMC	6	pvc	253	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0142-ss143	Hellems / UMC	6	pvc	127	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0143-ss0312	Hellems / UMC	6	pvc	163	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0144-ss0148	Hellems / UMC	8	pvc	91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0145-MIDss0312	Hellems / UMC	6	vcp	10	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0146-ss0145	Hellems / UMC	6	vcp	265	0.0	0.0	0.0	0.0	1.0	1	1	1	1	1	5
ss0147-MIDss0146	Hellems / UMC	6	vcp	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0148-ss0321	Hellems / UMC	12	pvc	123	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0150-ss0148	Hellems / UMC	6	cip	99	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0151-ss0150	Hellems / UMC	6	cip	82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0311-ss0141	Hellems / UMC	6	pvc	80	1.0	0.0	0.0	0.0	0.0	1	1	1	1	5	9
MIDss0312-ss0312	Hellems / UMC	8	pvc	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0312-ss0144	Hellems / UMC	8	pvc	80	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0321-ss0153	Hellems / UMC	12	pvc	55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0116-ss0115	Ekeley / Ketchum	6	vcp	75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0117-ss0116	Ekeley / Ketchum	6	vcp	45	0.0	0.0	0.0	0.0	0.0	1	2	2	1	2	6
ss0118-ss0117	Ekeley / Ketchum	6	vcp	153	0.0	1.0	0.0	0.0	0.0	1	2	2	1	5	11
ss0119-ss0118	Ekeley / Ketchum	6	vcp	93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0120-ss0118	Ekeley / Ketchum	6	vcp	121	0.0	0.0	0.0	0.0	1.0	1	1	1	1	1	5
ss0121-ss0120	Ekeley / Ketchum	6	vcp	12	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0122-ss0121	Ekeley / Ketchum	6	pvc	159	0.0	0.0	0.0	1.0	0.0	1	1	1	1	4	8
ss0124-ss0122	Ekeley / Ketchum	6	pvc	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0316-ss0124	Ekeley / Ketchum	6	pvc	60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2

Table 20: Sewer Condition Assessment Results

										Severity Color Code:	1	2	3	4	5
Pipe ID	Campus Area	SIZE (IN)	MATERIAL	LENGTH (FT)	Video Inspection Results Crushed/ Caved-in	Obstruct. / Protr.	Breaks	Hole	Offset/ Displcmnt	Crack Rating	Rate of Sag (w/Q)	Capacity Rank	Backwater Effect	Primary Rating Score	Secondary Rating Score
				Value Assigned to Condition / Capacity:	(5)	(5)	(4)	(4)	(1)	(1-3)	(1-5)	(1-5)	(1-5)	(1-5)	
					Number of Occurrences (Shading indicated severity)										
ss0094-ss0093	Colorado Ave. - Folsom	8	vcp	48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0096-ss0095	Colorado Ave. - Folsom	6	vcp	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	3	3	4
ss0097-ss0098	Colorado Ave. - Folsom	6	pvc	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0098-City Pipe	Colorado Ave. - Folsom	6	pvc	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0099-ss0096	Colorado Ave. - Folsom	6	vcp	110	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0100-ss0099	Colorado Ave. - Folsom	6	vcp	288	0.0	0.0	2.0	0.0	0.0	1	1	1	1	4	12
ss0101-ss0100	Colorado Ave. - Folsom	6	vcp	317	0.0	1.0	0.0	0.0	0.0	1	1	1	1	5	9
ss0103-ss0102	Colorado Ave. - Folsom	8	vcp	38	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	3	3	4
ss0105-ss0104	Colorado Ave. - Folsom	8	vcp	40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0106-ss0105	Colorado Ave. - Folsom	8	vcp	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0107-ss0104	Colorado Ave. - Folsom	10	pvc	31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0113-ss0112	Colorado Ave. - Folsom	6	vcp	107	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0308-ss0317	Colorado Ave. - Folsom	6	dip	28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0309-ss0322	Colorado Ave. - Folsom	6	dip	128	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	3	3	4
ss0317-ss0318	Colorado Ave. - Folsom	10	pvc	87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0318-ss0319	Colorado Ave. - Folsom	10	pvc	82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0319-ss0107	Colorado Ave. - Folsom	10	pvc	142	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0326-ss0309	Colorado Ave. - Folsom	6	pvc	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0057-ss0059	Gugg - Econ - Stadium	15	vcp	228	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0058-ss0057	Gugg - Econ - Stadium	15	conc	326	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0059-ss0060	Gugg - Econ - Stadium	15	vcp	245	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0060-ss0061	Gugg - Econ - Stadium	18	conc	299	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0061-ss0062	Gugg - Econ - Stadium	18	conc	61	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0062-ss0067	Gugg - Econ - Stadium	18	conc	169	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0063-ss0062	Gugg - Econ - Stadium	8	vcp	69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0064-NT ss0061	Gugg - Econ - Stadium	15	vcp	137	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0065-ss0063	Gugg - Econ - Stadium	8	vcp	200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0066-ss0067	Gugg - Econ - Stadium	6	vcp	115	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0067-ss0069	Gugg - Econ - Stadium	18	conc	131	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0068-ss0070	Gugg - Econ - Stadium	6	vcp	93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0069-ss0070	Gugg - Econ - Stadium	18	conc	48	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0070-ss0071	Gugg - Econ - Stadium	18	conc	122	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0071-ss0072	Gugg - Econ - Stadium	18	conc	21	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0072-ss0073	Gugg - Econ - Stadium	18	pvc	149	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0073-ss0074	Gugg - Econ - Stadium	15	pvc	181	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0074-ss0075	Gugg - Econ - Stadium	15	conc	152	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0075-ss0310	Gugg - Econ - Stadium	15	pvc	72	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0076-ss0078	Gugg - Econ - Stadium	6	vcp	94	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0078-ss0079	Gugg - Econ - Stadium	15	conc	100	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0079-ss0080	Gugg - Econ - Stadium	15	conc	151	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0080-ss0082	Gugg - Econ - Stadium	15	conc	260	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0125-ss0058	Gugg - Econ - Stadium	6	vcp	119	0.0	0.0	0.0	0.0	1.0	1	1	1	1	1	5
ss0126-ss0125	Gugg - Econ - Stadium	6	vcp	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0127-ss0125	Gugg - Econ - Stadium	6	vcp	53	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0128-ss0127	Gugg - Econ - Stadium	6	vcp	223	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4

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Pipe ID	Campus Area	SIZE (IN)	MATERIAL	LENGTH (FT)	Video Inspection Results: Crushed/ Caved-in	Obstruct. / Protr.	Breaks	Hole	Offset/ Displcmnt	Crack Rating	Rate of Sag (w/Q)	Capacity Rank	Backwater Effect	Primary Rating Score	Secondary Rating Score
				Severity Color Code:							1	2	3	4	5
				Value Assigned to Condition / Capacity:	(5)	(5)	(4)	(4)	(1)	(1-3)	(1-5)	(1-5)	(1-5)	(1-5)	
					Number of Occurrences (Shading indicated severity)										
ss0129-ss0127	Gugg - Econ - Stadium	6	vcp	155	0.0	0.0	0.0	1.0	0.0	1	1	1	1	4	8
ss0130-ss0129	Gugg - Econ - Stadium	6	vcp	270	0.0	1.0	0.0		0.0	1	1	1	1	5	9
ss0131-ss0130	Gugg - Econ - Stadium	6	vcp	270	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0132-ss0130	Gugg - Econ - Stadium	6	vcp	279	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0132-ss0131	Gugg - Econ - Stadium	6	vcp	43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0133-ss0129	Gugg - Econ - Stadium	6	vcp	238	0.0	0.0	1.0	1.0	0.0	1	1	1	1	4	12
ss0134-ss0133	Gugg - Econ - Stadium	6	vcp	144	0.0	0.0	1.0	0.0	0.0	2	1	1	1	4	9
ss0135-ss0134	Gugg - Econ - Stadium	6	vcp	56	0.0	0.0	0.0	0.0	0.0	2	1	1	1	2	5
ss0136-ss0135	Gugg - Econ - Stadium	6	vcp	120	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0137-ss0136	Gugg - Econ - Stadium	6	vcp	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0310-ss0078	Gugg - Econ - Stadium	15	pvc	116	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0049-ss0048	Sewell, Rec Center	6	vcp	87	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0050-ss0049	Sewell, Rec Center	6	vcp	44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0051-ss0049	Sewell, Rec Center	6	vcp	106	1.0	0.0	0.0	0.0	0.0	1	1	1	1	5	9
ss0034-ss0033	Hale, Koenig, Macky	6	vcp	174	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0035-ss0036	Hale, Koenig, Macky	6	vcp	132	0.0	0.0	0.0	0.0	1.0	1	1	1	1	1	5
ss0036-ss0037	Hale, Koenig, Macky	6	cip	78	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0037-ss0038	Hale, Koenig, Macky	6	vcp	110	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0038-ss0040	Hale, Koenig, Macky	6	vcp	134	0.0	0.0	0.0	0.0	0.0	1	1	1	1	1	4
ss0039-ss0040	Hale, Koenig, Macky	6	vcp	23	0.0	0.0	0.0	1.0	0.0	2	1	1	1	4	9
ss0040-ss0042	Hale, Koenig, Macky	6	vcp	153	0.0	0.0	1.0	0.0	1.0	1	1	1	1	4	9
ss0041-ss0042	Hale, Koenig, Macky	4	vcp	55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0042-ss0045	Hale, Koenig, Macky	6	vcp	155	0.0	0.0	0.0	0.0	1.0	1	1	1	1	1	5
ss0045-ss0044	Hale, Koenig, Macky	8	vcp	41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0046-ss0045	Hale, Koenig, Macky	6	vcp	107	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0047-ss0046	Hale, Koenig, Macky	6	vcp	99	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0265-ss0264	30th & Marine	6	vcp	169	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	3	3	4
ss0267-ss0266	30th & Marine	6	vcp	251	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0268-ss0269	30th & Marine	6	vcp	50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	1	2	3
ss0270-ss0271	Marine Street	8	vcp	177	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0271-ss0272	Marine Street	8	vcp	128	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0272-ss0273	Marine Street	8	vcp	184	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0273-ss0274	Marine Street	8	vcp	180	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0274-ss0275	Marine Street	8	vcp	183	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0275-ss0276	Marine Street	8	vcp	24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0276-ss0277	Marine Street	8	vcp	278	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	1	5	6
ss0277-ss0278	Marine Street	8	vcp	270	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	1	2	3
ss0278-ss0279	Marine Street	8	vcp	163	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	1	1	2
ss0279-ss0280	Marine Street	8	vcp	156	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	1	2	3

N/A indicates that pipe has not been surveyed with CCTV, therefore no physical condition rating is applied.
Pipe Material Legend: conc = concrete, cip = cast iron pipe, pvc = polyvinyl chloride, vcp = vitrified clay pipe, dip = ductile iron pipe

City of Boulder Sanitary Sewers Serving Campus

The City of Boulder recently completed its Wastewater Collection System Master Plan Update (July 2003), which presents results of an existing conditions and future conditions capacity evaluation. The City modeled flow projections based on 2001 and 2025 population estimates. Results are presented for 2001 Dry Weather Flow, 2025 Dry Weather Flow, and 2025 2-yr storm events, 2025 5-yr storm events, 2025 10-yr storm events, 2025 25-yr storm events, 2025 50-yr storm events, and 2025 100-yr storm events. The criteria used by the City for overcapacity is greater than 70% in dry weather, and 100% capacity in wet weather flows. Four locations where the University Campus is served by the City sewers are identified as overcapacity (>70%) for the 2001 Dry Weather projections. These locations are the main running behind the Powerhouse, two locations in the 28th Street sewer serving the Kittredge and EH&S locations, and the main serving the eastern part of East Campus. These pipes, with the addition of the collector running near Math also are overcapacity for 2025 Dry Weather projections as well as all 2025 Wet Weather projections.

Three of the City locations identified above warrant further monitoring and discussions with the City. The area behind the Powerhouse is known to be overcapacity and with the future Wet Weather projections could be problematic for service to this part of Campus. The areas in 28th Street need to be monitored in relation to future development on Campus. This collector will serve both the Law Addition and New Utility Plant, and future capacity needs to be ensured. The areas near Math and on East Campus are not expected to see future development; however, surcharging during wet weather with 2025 projected flows could cause problems for the Campus.

Figures 23 and 24 show the capacity assessment of the City of Boulder's sanitary sewer serving the Main and East Campuses.

The backwater analysis described in the Condition Assessment highlighted six potential areas of concern if City flows were to exceed capacity. These areas may warrant further monitoring as City loads increase in the future. The buildings being served by these sewers are Imig, UMC, Benson Earth Sciences, Duane Physics, MCD Biology, and Litman Research Lab No. 1 on East Campus. The building of most concern is Imig Music because it is served by the collector running behind the Powerhouse. University staff has indicated this collector is of known concern. Imig is considerably upstream, however, the potential for flow to back-up exists. The other areas are of lesser concern as they have not been identified as over capacity, either in the past or in the City's WWCSMP Update. It suggested that these areas are monitored in the future, and improvements made if necessary.

Alternatives Analysis

Description of Alternatives

Alternatives for repairing damaged pipes identified in the CCTV survey were considered. The two alternatives, with differing applicability, were trenching and replacing the damaged pipe section, or a trenchless rehabilitation. The trenchless technology is a cast in place synthetic lining running the entire length of the pipe between manholes. Trenching and replacing damaged sections was considered for damaged pipe segments discovered to be caved-in, obstructed, and with holes or breaks. The trenchless rehab method was considered for pipes with holes or breaks only, because this method requires an open flow path and sufficient structural integrity of the existing pipe. Cost estimates for the trenchless rehab alternative involved lining the entire pipe segment between manholes, where the trench and replace alternative could be performed on the damaged section only.

Capacity problems in this system are a result of three primary causes. The first being inadequate slope of the pipe, that is, it is too shallow. The second is the existence of pipe sag combined with a flow above 50% capacity. The third cause of overcapacity is the projected future loads on a section of sanitary sewer. Alternatives for fixing capacity issues can include upsizing the pipe, replacement of pipe with pipe of adequate slope, running a parallel pipe, or redirecting flow with new systems or tie-ins to the City collection system. For this study, and cost estimates, these solutions would cost nearly the same because they all involve placing new pipe in the ground. For this reason, the solutions are all presented as replacement of pipe, either with an upsized diameter, or a correction of slope. If under final design additional circumstances warrant realignment, then additional tie-ins or parallel pipes may be an appropriate alternative. It is recommended that before any steps to design or replace pipe with capacity problems are taken, that a detailed survey to confirm the existing construction of the pipe is made. For example, an issue of a shallow slope may be the result of inaccurate or obsolete as-built drawings, and there may in fact not be an issue of overcapacity.

Repair and Replacement Program

In addition to making the improvements identified in this study, it is suggested the University implement a Sanitary Sewer Repair and Replacement Program to keep the campus sewer well maintained. A repair and replacement program will enable the University to budget funds to repair the inevitable degradation of the system over time. It is also recommended that in addition to a repair and replacement program, that a cleaning and inspection program be implemented. A program to clean and video survey one-third of the pipes on Campus per year is suggested. This would result in every pipe being surveyed on average, once every three years. The repair and replacement program would then fall into place, with problem areas having been identified by the survey. This is the benefit of a combined program for sanitary sewers – repair and replacement funds are applied to known areas of concern, rather than an arbitrary replacement based on age. For cost estimating reasons, a service life span of 50 years was assumed for sanitary sewer pipes. This life span, combined with the age of pipes on Campus, produced the repair and replacement program presented in Table 21.

Table 21: Sanitary Sewer – Repair and Replacement Program

Year	Total Length of Pipe to Replace in Time Period
2004 – 2005	700 feet
2006 – 2010	1500 feet
2011 – 2015	2500 feet
2016 – 2020	3250 feet
2021 – 2030	4000 feet
2031 – 2040	3500 feet
2041 – 2050	7300 feet

Conclusions

The University of Colorado Sanitary Sewer System is in good general condition. The system has been designed and maintained to provide adequate capacity for sewer flows. There are, as with any system, areas that need maintenance and repair. This report and the tools used to aid in the analysis have been developed with the intent of continued maintenance. The spreadsheet model can be easily updated and changed, as new data is made available. The condition assessment is intended to be incorporated into the sewer database maintained by the University and used to identify and prioritize future maintenance programs.

Probable Estimate of Costs

Cost estimates were developed for the various alternatives. The basis for cost estimates for the potable water system are:

- Pipe installation - $150 per linear foot for 8-inch pipe, with an assumed 4 foot cover.
- Pump stations - $100,000 per mgd
- Sprinkler systems – a general cost estimate cannot be developed because retrofitting of existing buildings is unique and very dependent on building size and construction.

The basis for cost estimates for the sanitary sewer system are:

- Repairing a damaged section of pipe, requiring 10 feet of trenching and replacement pipe is $5,000.
- Pipe installation (replacement or new pipe) - $400 per linear foot, including manhole replacement or repair.
- Rehabilitation by slip lining - $ 40 per linear foot with a minimum of $8,000 per set-up.

The above estimates include the following:

- Surface repair
- Mobilization and demobilization (assumed at 20%)
- Engineering/Administrative/Etc. (assumed at 22%)
- Contingency (15%)

The above estimates are for repairing or replacing individual problem areas. It is foreseeable that grouping multiple jobs together into one contract could reduce the individual cost per repair.

Using the above unit costs, the cost estimates for potable water alternatives and the potable water replacement program are shown in Tables 22 and 23. Cost estimates for the sanitary sewer system improvements and the sewer repair and replacement program are shown in Table 24 and 25.

Table 22: Cost Estimates for Potable Water System Alternatives

Improvement	Description	Length	Unit Cost per LF	Accessories Cost	Total
Improvements Required in Conjunction With Fire Pump or Additional Piping Alternative – Installed before 2005					
1	8" pipe connecting Penn Meter and Economics Dead End	525	$150	$25,000	$104,000
2	8" pipe connecting Fleming Law Dead End to Kittredge Complex Loop	375	$150	$20,000	$76,000
Subtotal					*$180,000*
Improvement Alternatives Needed before 2005 to Improve Fire Flow					
Alt. A	Fire Pump at Penn Meter	N/A	N/A	$500,000	$500,000
Alt. B	Install 8" pipe from UMC Meter to Norlin Quadrangle Install Sprinkler Systems in Required Buildings *Subtotal Alt B.*	925 N/A	$150 N/A	$25,000 Not known	$164,000 Not known *$164,000 + Sprinkler Systems*
Improvements Required in Conjunction with Either Fire Pump or Additional Piping Alternative – Installed for New Power Plant					
3	Central Utility Plant Supply Line – Initial Phase	750	$150	$25,000	$138,000
3	Central Utility Plant Supply Line – Build-Out Phase	1,150	$150	$20,000	$193,000
Subtotal					*$331,000*
Total for Required Improvements					
Alternative A			***$1,011,000***		
Alternative B			***$675,000 + Sprinkler Systems***		

Table 23: Potable Water System Replacement Program Cost Estimates

Year	Length to Replace per Year	Estimated Cost per Year (inflated at 4%/yr)
2004 – 2005	1,700 feet	$265,000
2006 – 2010	1,500 feet	$274,000
2011 – 2015	1,700 feet	$378,000
2016 – 2020	1,800 feet	$486,000

Table 24: Proposed Sanitary Sewer Improvements

Pipe	Improvement	Trenching Length	Cost to Trench	Lining Length	Cost to Slip[1]
Priority 1					
0118-0117	Obstruction	10	$5,000	Not Applicable	Not Applicable
0233-0232	Obstruction	10	$5,000	Not Applicable	Not Applicable
0315-0222	Obstruction	10	$5,000	Not Applicable	Not Applicable
0217-0216	Obstruction	10	$5,000	Not Applicable	Not Applicable
0171-0172	Obstruction	10	$5,000	Not Applicable	Not Applicable
0311-0141	Crushed/Cave-in	10	$5,000	Not Applicable	Not Applicable
0101-0100	Obstruction	10	$5,000	Not Applicable	Not Applicable
0130-0129	Obstruction	10	$5,000	Not Applicable	Not Applicable
0051-0049	Crushed/Cave-in	10	$5,000	Not Applicable	Not Applicable
0276-0277	Capacity/Slope	548	$219,000	Not Applicable	Not Applicable
0245-0244	Break, Future Cap.	142	$57,000	Not Applicable	Not Applicable
Priority 1 Total			***$321,000***		*N/A*
Priority 2					
0201-0200	Breaks	20	$10,000	87	$8,000
0208-0207	Breaks	20	$10,000	231	$9,000
0100-0099	Breaks	20	$10,000	288	$11,500
0133-0129	Breaks,Hole	20	$10,000	238	$9,500
0242-0241	Break	10	$5,000	219	$9,000
0224-0223	Break	10	$5,000	297	$12,000
0215-0214	Break	10	$5,000	125	$8,000
0134-0133	Break	10	$5,000	144	$8,000
0039-0040	Hole	10	$5,000	23	$8,000
0040-0042	Break	10	$5,000	153	$8,000
0249-0248	Break	10	$5,000	152	$8,000
co432-0232	Hole	10	$5,000	310	$12,500
0200-0199	Break	10	$5,000	79	$8,000
0139-0140	Hole	10	$5,000	116	$8,000
0122-0121	Hole	10	$5,000	159	$8,000
0129-0127	Hole	10	$5,000	155	$8,000
Priority 2 Total			***$100,000***		***$143,500***
Priority 3					
0237-0238-City	Future Capacity	251	$100,000	Not Applicable	Not Applicable
Priority 3 Total			***$100,000***		*N/A*
1) Costs for Sliplining are based on repair of the entire pipe between manholes.					
This technology is more cost effective if the entire pipe is repaired in one setup.					

Table 25: Sanitary Sewer Repair and Replacement Program Cost Estimates

Year	Length to Replace per Year	Estimated Cost per Year (inflated at 4%/yr)
2004 – 2005	350 feet	$146,000
2006 – 2010	300 feet	$146,000
2011 – 2015	500 feet	$296,000
2016 – 2020	650 feet	$468,000
2021 – 2030	400 feet	$394,000
2031 – 2040	350 feet	$511,000
2041 – 2050	730 feet	$1,577,000

Recommendations

Potable Water System Recommendations

The University's potable water system currently has the capacity to meet normal demands. However, the system does not meet the desired fire flows stated by the University Fire Marshal. In addition, the system is an aging system, with many pipes at or near their assumed 50-year lifespan. As such, the following recommendations are made:

- Install a parallel pipe from the Penn meter to the Norlin Quadrangle ($104,000) – Proposed Improvement 1.
- Complete a piping loop near the Fleming Law Building ($76,000) – Proposed Improvement 2.
- Install piping to serve the proposed power plant, when said power plant is built ($138,000 for initial phase and $193,000 for Build-out phase) – Proposed Improvement 3.
- Improve fire flows through either installation of a fire pump at the Penn meter (Alternative A) or an additional pipe and sprinkler systems (Alternative B).
- Implement Replacement Program as presented to maintain system into the future.
- Monitor pressures throughout campus and the ability of existing sprinkler systems to function as designed as supply pressures from the City decrease into the future.
- Maintain a good working relationship with the City of Boulder and take advantage of partnering opportunities to improve flow to each campus from the City's system.

Sanitary Sewer System Recommendations

The University's sanitary sewer collection system has the ability to carry current levels of loading. If future development on Campus is realized, a few areas of the sewer system will require improvements. In addition, the system is an aging system, and as such, is experiencing degradation of physical condition. The following improvements are recommended to maintain and provide for current and future capacity. The priority of these improvements is detailed in Figures 25 and 26 and the estimated capital costs of each are presented in Table 23.

- Pipes with a Primary Rating of 5, indicating cave-ins or obstructions are in Priority 1, and should be the first to be repaired.
- Replacement Priority 2 is for pipes with cracks and holes and Primary Ratings of 4.

- The Priority 3 repair is for 2 sections of pipe that would in the future experience capacity issues with the construction of the New Utility Plant.

Additional continued maintenance and observations of the sanitary sewer system are also recommended to the University. These are:

- It is recommended that the University continue with a cleaning and CCTV surveying program. A good start was made in this effort with the program in 2002, when over half of the pipes were surveyed. It is recommended that one-third of the pipes be cleaned and surveyed every year to maintain a current database of physical issues and to maintain the maximum conveyance in each pipe. At a rate of one-third per year, every pipe would on average be cleaned and surveyed every three years. The estimated cost of CCTV surveying and jet cleaning one-third of the Campus sanitary sewer per year is $7,000.

- As a result of implementing a cleaning and CCTV survey program, a repair and replacement (R & R) program of broken and damaged pipes can easily be implemented. The R&R program would simply follow the survey program by fixing newly identified problem areas. It is recommended that the funds for the sewer R & R program described earlier be applied to problem areas identified in the CCTV survey. The cost estimates for the R & R program are presented in Table 24.

- It is also recommended that the University work with the City of Boulder to monitor areas identified as potential backwater problems and where City pipes are overcapacity. This study has identified potential problem areas where City infrastructure may impact University facilities, but because these are derived from the best available data and an estimation of flows, they are not a substitution for actual monitoring. Spot checking manholes during storm events, or monitoring flows in pipes provides concrete evidence of the existence or absence of capacity issues.

Appendix A - Figures

Appendix B – Potobal Water Distribution System and Sanitary Sewer Design Standards

The following is a summary of sanitary sewer system and potable water distribution system design standards published by the Colorado Department of Public Health and Environment and the City of Boulder. The complete documents are published as: Colorado Department of Public Health and Environment, *Design Criteria for Potable Water Systems* (CDPHE, March 1997); *Design Criteria Considered in the Review of Wastewater Treatment Facilities, Policy 96-1* (CDPHE, May 2002); and *City of Boulder Design and Construction Standards* (City of Boulder, November 2000).

Separation of Water and Sewer Utilities

City of Boulder criteria specifies horizontal and vertical spacing of water mains and sanitary and storm sewers. The horizontal spacing is 10 feet for sanitary sewers and 5 feet for storm sewers. The minimum vertical spacing for water mains crossing either type of sewer is 18 inches, with the water main crossing above the sewer. The minimum vertical spacing for sanitary and storm sewers is 6 inches with the following additional criteria: 1) if the storm sewer line is below the sanitary line, both pipe materials will be of pressure-class pipe, 2) if the vertical separation is less than 18 inches, structural support will be included. CDPHE potable water criteria for water main crossings are more conservative with respect to storm sewers. CDPHE refers to sewers of both sanitary and storm classifications. The minimum horizontal and vertical spacing is 10 feet and 18 inches, respectively.

City of Boulder Sanitary Sewer Design Standards

<u>Design Flows:</u>

- Wastewater collection mains shall convey the peak flow. Details of what flows may be connected and the estimated value are found in Section 6.04 of the *City of Boylder Design and Construction Standards*. Of particular note, the *Design Criteria* state that cooling water should not discharge to the wastewater collection system.

<u>Collection Mains:</u>

- The wastewater collection system should be designed with a Manning's "roughness coefficient" of 0.013 to account for pipe material, joints, and future pipe condition.
- Collection mains shall pass the peak flow with a flow depth of 50% pipe diameter.
- Pressurized or surcharged pipes are prohibited.
- The minimum diameter for collection mains shall be 8 inches.
- All pipe size changes require a manhole.
- All mains shall be located in public rights-of-way or easements.
- All platted lots shall front on a collection main.

- The minimum and maximum cover for collection mains shall be 3 feet and 18 feet, respectively, measured from the pipe top to final surface grade.
- For collection mains with less than 4 feet of cover, in areas where live loading is of concern, special pipe materials or other structural measures shall be provided.
- Collection mains shall be designed to provide service to basements of buildings.
- Minimum and maximum slopes for various pipe sizes are presented:

Pipe Diameter (inches)	**Minimum Slope (%, ft/100ft)**	**Maximum Slope (%, ft/100ft)**
8”	0.332	8.299
10”	0.247	6.164
12”	0.193	4.833
15”	0.144	3.590
18”	0.113	2.815
21”	0.092	2.292
24”	0.077	1.918

- The minimum allowable slope should provide a velocity of 2 feet per second when the pipe is flowing half-full or full. The maximum allowable slope should result in a maximum velocity of 10 feet per second.
- All collection mains shall be laid at a constant slope between manholes.
- All changes in slope require a manhole at the slope change connection.
- Collection mains shall be laid in a straight line between manholes. All changes in alignment require a manhole.
- Curvilinear collection mains shall not be allowed.
- Groundwater barriers shall be required where the possibility that ground water may be diverted exists.
- Wastewater mains shall be extended to the far edge of the property or platted subdivision, whichever is greater.

<u>Manholes:</u>

- Manholes shall be placed at the upper end of all wastewater collection mains, changes in pipe size, grade, slope, or alignment.
- Manholes are required at the following minimum spacing:
    - 400 feet for diameters 15 inches and smaller,
    - 450 feet for diameters 18 to 21 inches,
    - 500 feet for diameters 24 inches and larger.
- Manholes shall be required at all service connections of 8 inches or larger.

- Manholes shall not be located in areas prone to flooding, from floodplains, surface runoff, or ponding.

Drop manholes should be avoided whenever possible. If unavoidable, drop manholes shall be required at pipe-manhole differences of 2 feet vertically.

Colorado Department of Public Health and Environment Sanitary Sewer Design Standards

Sewer Design:

- The minimum size of sewer pipes shall be 8 inches except in special cases.
- Sewer pipes should be deep enough to drain basements and lower level bathroom facilities and to prevent freezing.
- All sewers should be designed with a slope that will provide a minimum velocity of 2 feet per second to prevent solids deposition. This slope between manholes should be uniform. Where these criteria are not practical, for example in the case of low flow areas, sewer pipes of 8-inch diameter should be laid with a minimum slope of 0.4%.
- Sewers should be laid in a straight line between manholes. In areas where this is not possible, minimum radii of curvature as presented by the CDPHE or pipe manufacturer should be applied.
- When a sewer line increase in size, the invert of the larger pipe should be placed so as to maintain the same energy gradient (larger pipe invert lower).
- Provisions should be made to protect pipes from shock and erosion where velocities are above 15 feet per second.

Manhole Design:

- Manholes should be installed at the end of each line. They should also be placed at all changes in grade, size, alignment, and at all pipe intersections. For entities without sewer cleaning programs, manhole distances should not be greater than 400 feet for diameters 15 inches and smaller, and 500 feet for diameters 18 to 30 inches. Cleanouts should not be substituted for manholes.
- For sewers entering the manhole at 24 inches or more above the manhole invert should use an outside drop pipe. For heights less than 24 inches, the entrance should be filleted to avoid solids deposition.
- The minimum inside diameter of manholes should be 48 inches.

Protection of Water Supplies:

- There shall be no connection between any public or private water supply system and a sewer.
- See the above section regarding separation of sewers and water mains.

Special Design Problems:

- Refer to section 2.6.0 of Policy 96-1 for design considerations in the event of underwater gravity systems, stream crossings, or bridge crossings.

City of Boulder Potable Water Distribution Systems Design Standards

Design Flow:

- The minimum pressure should be 20 psi at ground level under maximum-day demand flow plus fire flow.
- The minimum pressure should be 40 psi under maximum-hour demand flow without fire flow.
- The City of Boulder Utilities Division should be contacted for design flows of existing and future major distribution systems. The City also presents average day and peaking factors for forecasting design flows.

Corrosion Protection:

- Corrosion protection is required for system improvements where corrosive soils exist.

Distribution Mains:

- Distribution mains shall be at least 8 inches in diameter.
- All water mains shall be located in public rights-of way or easements. All platted plots shall front a distribution main.
- All distribution mains shall have between 4.5 to 10 feet of cover, measured from the top of pipe to final surface grade.
- All taps on distribution mains shall be installed under “wet tap” conditions to maintain service at all times.
- Valves shall be installed as necessary to ensure the following: 1) no more than 600 feet of water main is between isolation zones, 2) no more than two fire hydrants are located between isolation zones, 3) no more than 3 valves will require closure to isolate any section of a distribution main, 4) where possible, valves are to be aligned with extensions of property lines or rights-of-way lines.
- Valves shall not be located in areas of routine parking or storage. Valves shall be located for maximum access in emergencies.
- Distribution mains shall be looped into existing and proposed distribution systems.
- The maximum terminal length of a distribution main shall be 600 feet.
- All terminal mains shall have a fire hydrant located at the end of the main, and offset.
- Service taps on a terminal lane shall not be closer than 3 feet to the end.
- Water main extensions shall extend to the end of the property line, or to the edge of the platted subdivision, whichever is greater.
- Future main connections provided for by a “stub out” or terminal connection shall be valved so that only one valve must be closed when the main is extended.

Fire Protection:

- All fire hydrants shall be placed within public rights-of-way or easements.
- The placement of hydrants shall comply with the Uniform Fire Code and the following requirements: 1) hydrants shall be placed at the entrance or intersection of each street and on both sides of a divided roadway, 2) in single family residential areas the maximum distance between hydrants shall be 500 feet with no dwelling at more than 250 feet from fire access, 3) in other areas the maximum distance between hydrants shall be 350 feet with no structure at more than 175 feet from fire access.
- Hydrants shall be aligned with an extension of property lines.
- Hydrants shall be no farther than 5 feet beyond the curb outside of any fenced area, and shall have a 10-foot radius of clearance.
- The lowest water outlet of a hydrant shall be between 18 and 30 inches from the final ground elevation.
- Fire sprinkler lines shall be a separate line tapped at the water distribution main.
- No service taps shall be located on a fire sprinkler line.

Cross-Connection Regulations:

The cross connection regulations are provided to protect against contamination of the City's potable water distribution system. The regulations primarily specify what types buildings are subject to these regulations and which type of backflow control device are required. Refer to Section 5.11 of the Boulder design criteria for further detail.

Colorado Department of Public Health and Environment Potable Water Distribution Systems Design Standards

Water Main Design:

- The normal working pressure in the distribution system should be between 35 and 60 psi, and should maintain a minimum pressure at ground level of 20 psi at all points in the system.
- The minimum diameter of water main serving fire hydrants should be 6 inches. Larger mains may be necessary to maintain minimum pressure in the event of withdrawal of fire flow.
- Fire protection should be in accordance with the requirements of the Insurance Service Office at Denver, Colorado.
- Dead ends should be minimized by looping of all mains whenever practical.
- Where dead ends occur, they should be provided with a hydrant or flushing hydrant as appropriate; No flushing device shall be connected directly to any sewer.

Valves:

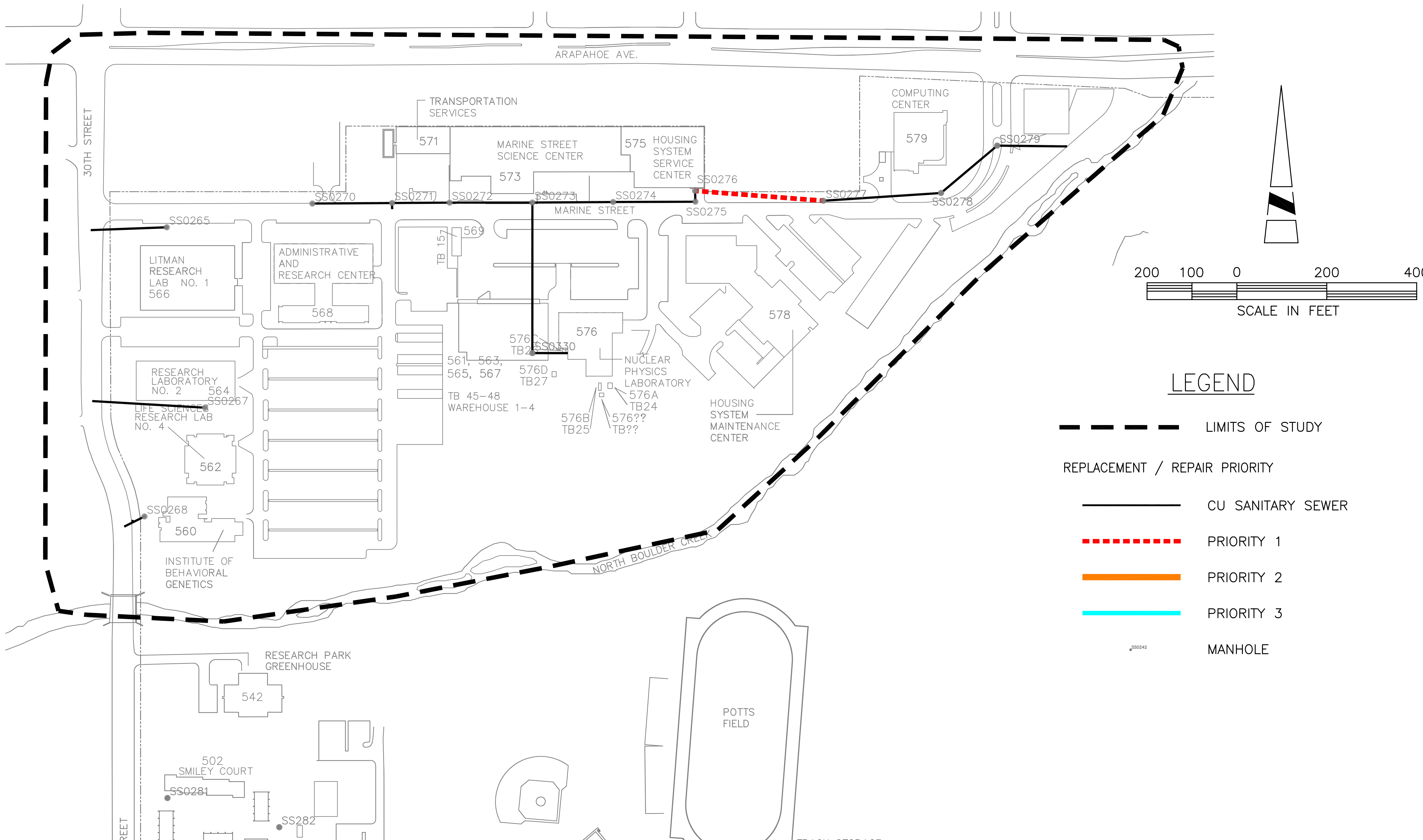
- Shut-off valves should be located to minimize inconvenience and sanitary hazards during repair. Valves should be located not more than 500 feet apart in commercial districts and 800 feet apart in other districts.

Hydrants:

- Hydrants should be located at every intersection and intermediate points as recommended by the State Insurance Office. Hydrant spacing may range from 350 to 600 feet.
- Water mains not designed to carry fire flow should not have hydrants.
- Hydrants should conform to with the National Fire Protection Association standards.

Installation of Mains:

- Uniform bedding should be provided in the trench for all pipe.
- Cover for pipes should be sufficient to prevent freezing.



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DATE:	06-24-03		
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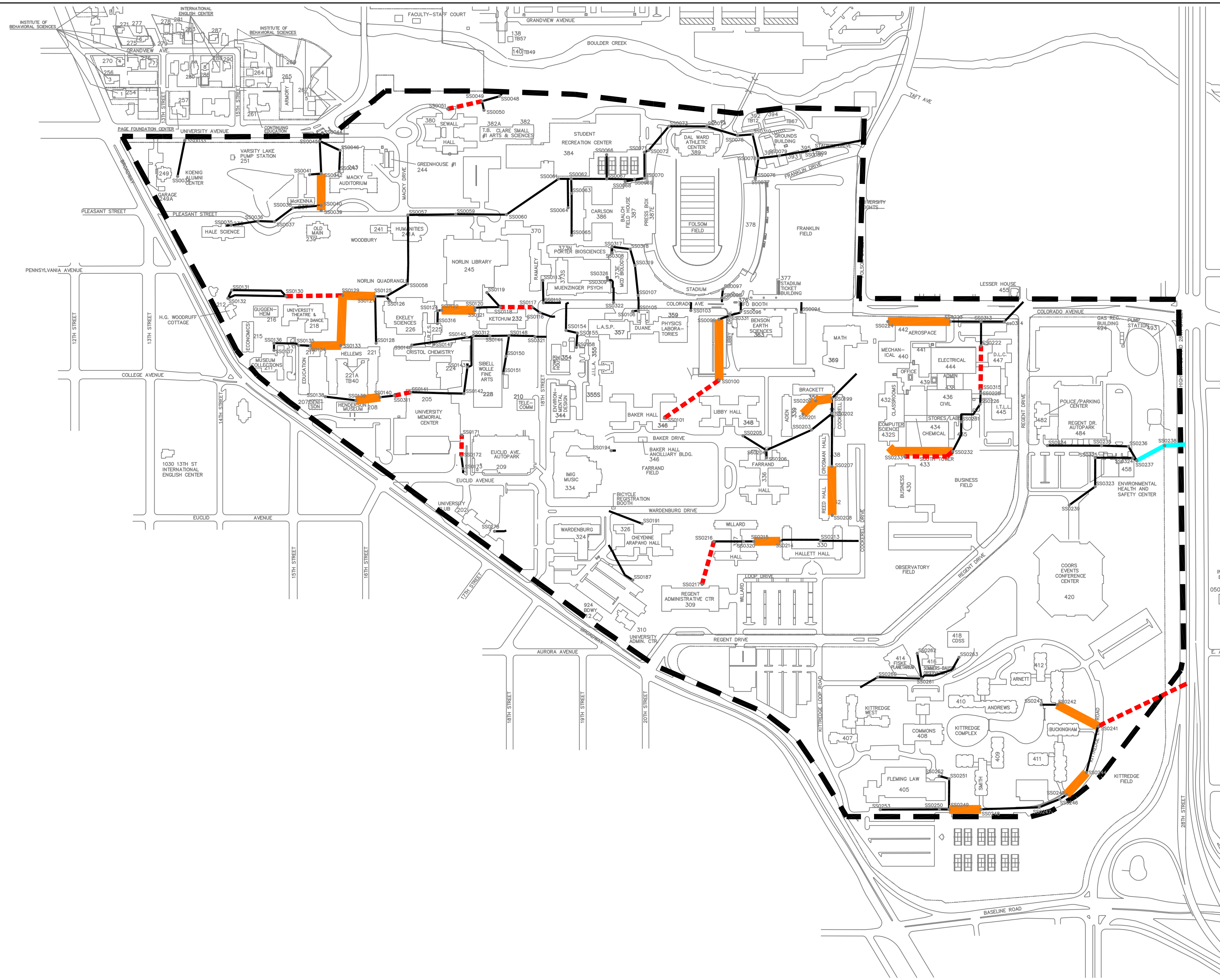
CU W.O. #	422523		

BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

EAST CAMPUS - SANITARY SEWER
REPAIR PRIORITY

FIGURE-26



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LEGEND

LIMITS OF STUDY

REPLACEMENT / REPAIR PRIORITY

CU SANITARY SEWER

PRIORITY 1

PRIORITY 2

PRIORITY 3

SS0242 MANHOLE

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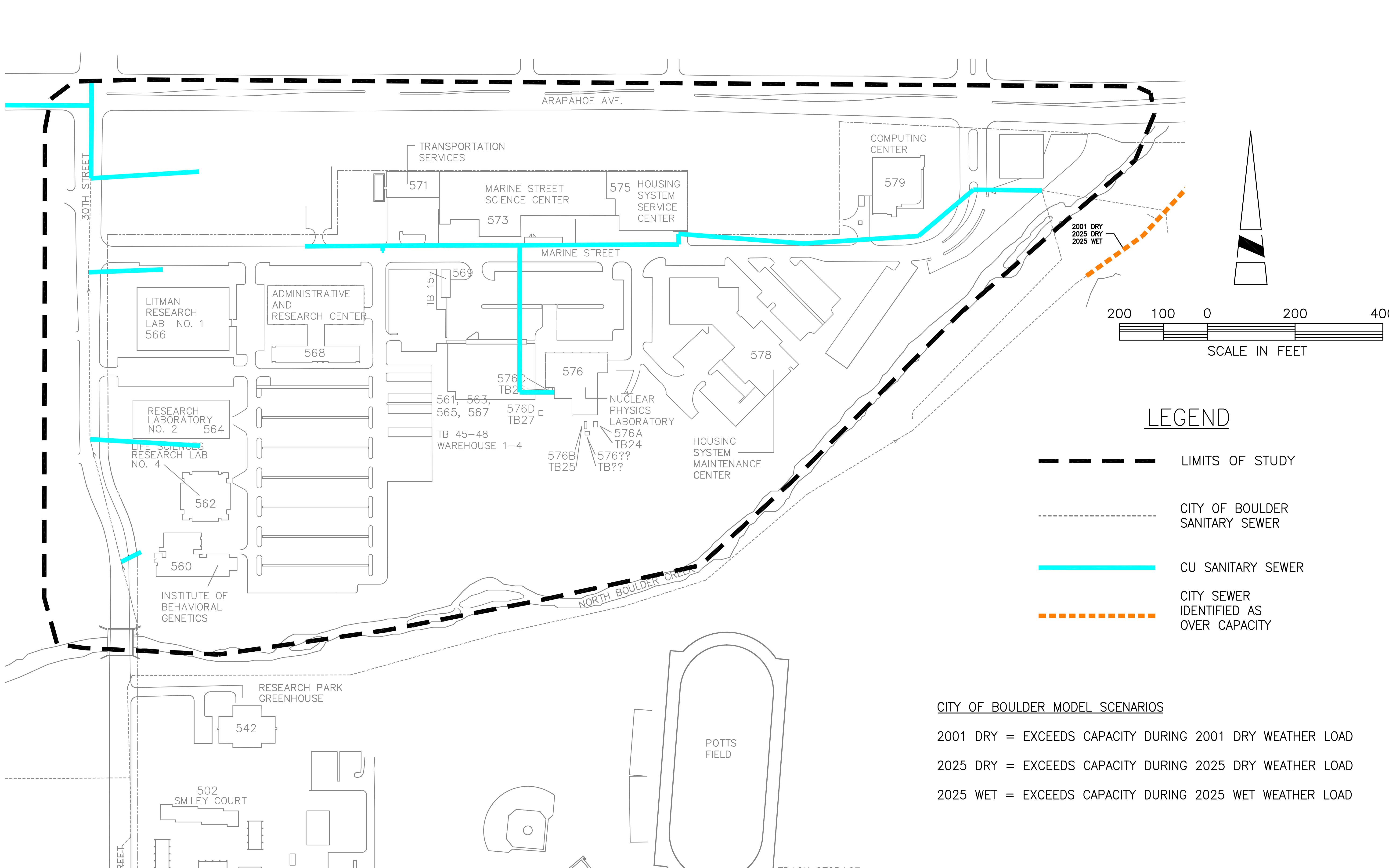
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - SANITARY SEWER
REPAIR PRIORITY

FIGURE-25



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JOB NO.	DN-C09-401-20
CU W.O. #	422523

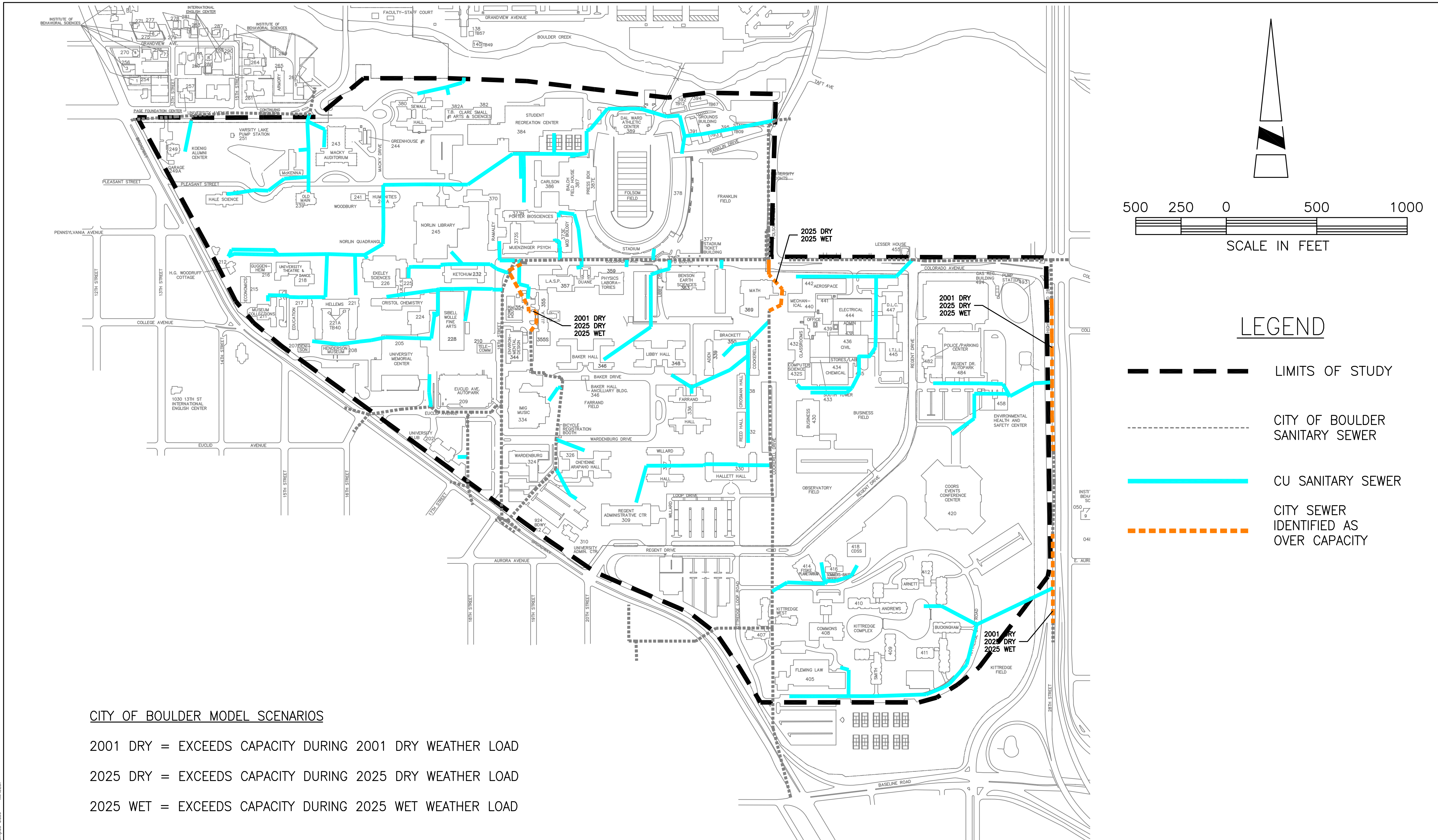
REVISION	DATE

BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

EAST CAMPUS
CAPACITY ASSESSMENT OF CITY OF BOULDER SANITARY SEWER SERVING CU

FIGURE-24



CITY OF BOULDER MODEL SCENARIOS

2001 DRY = EXCEEDS CAPACITY DURING 2001 DRY WEATHER LOAD

2025 DRY = EXCEEDS CAPACITY DURING 2025 DRY WEATHER LOAD

2025 WET = EXCEEDS CAPACITY DURING 2025 WET WEATHER LOAD

DESIGNED: JB DRAWN: GKP DATE: 06-24-03 JOB NO. DN-C09-401-20 CU W.O. # 422523	REVISION	DATE	BOYLE ENGINEERING CORPORATION	University of Colorado at Boulder

MAIN CAMPUS
CAPACITY ASSESSMENT OF CITY OF BOULDER SANITARY SEWER SERVING CU

FIGURE-23

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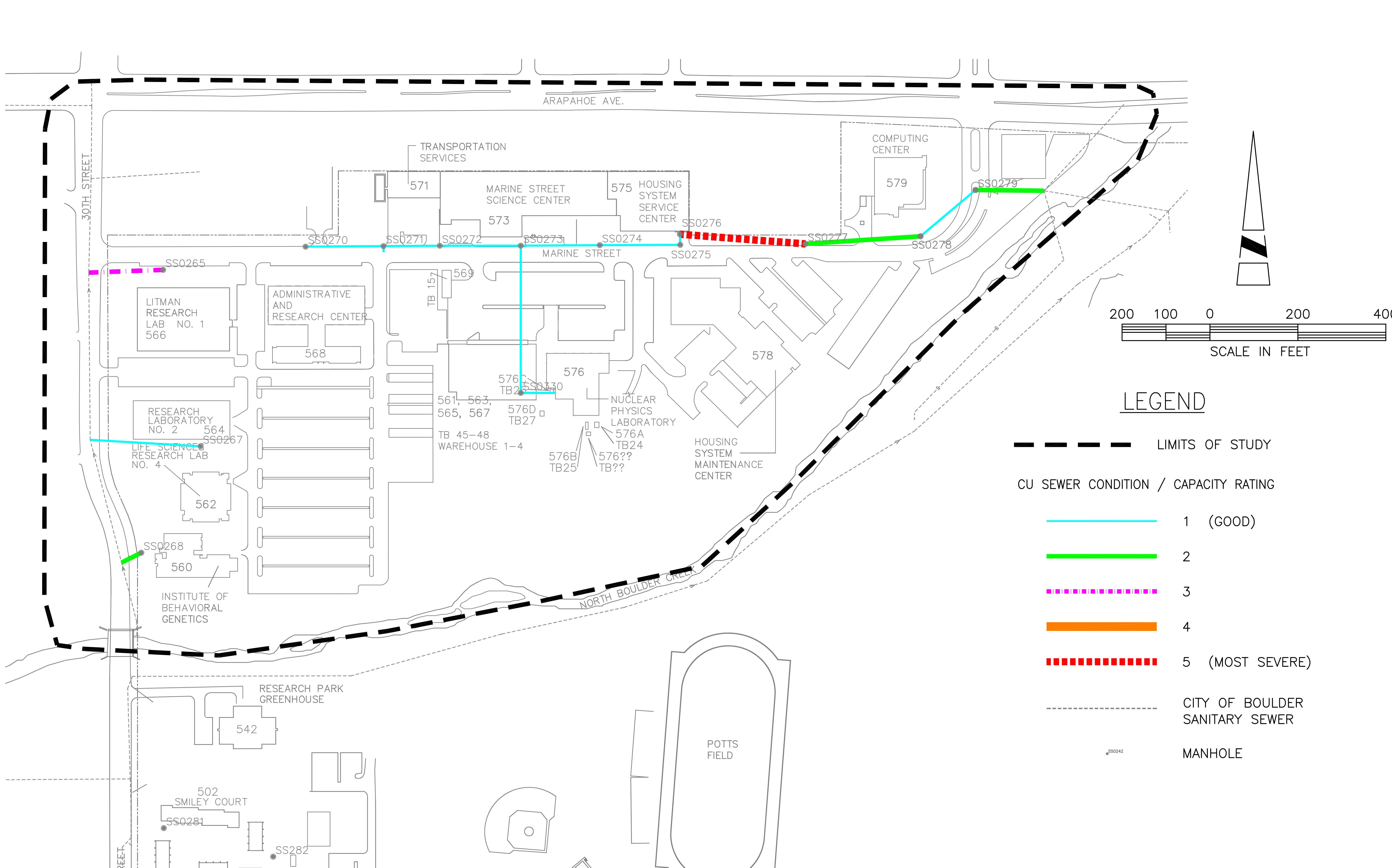

DWG: Z:\CU\Masterplan-C09401xx\Sewer\drawings\FINAL-8-18-03\FIGURE-21&22.dwg USER: estrand
DATE: Oct 13, 2003 3:45pm XREFS: campus base IMAGES:

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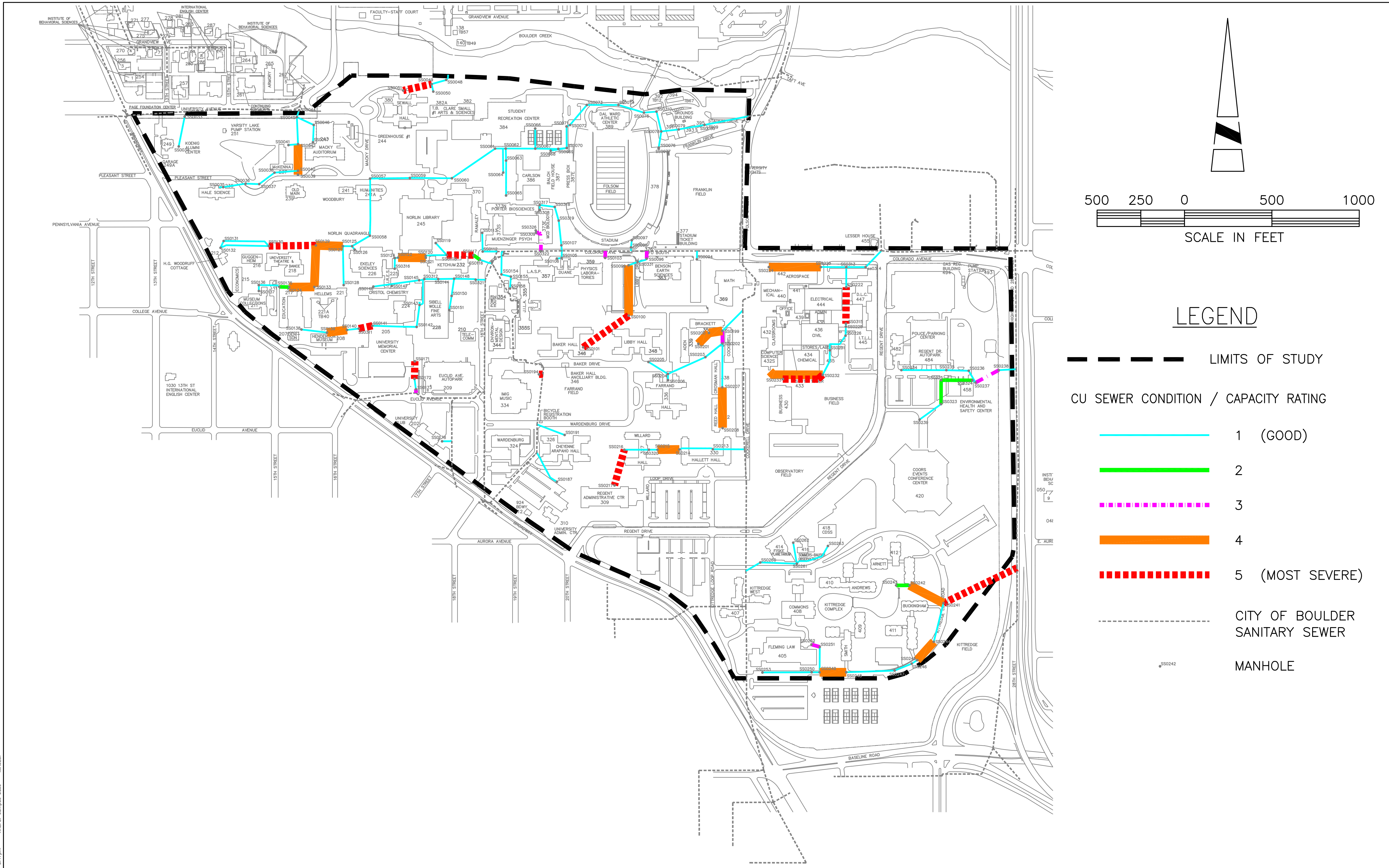
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

EAST CAMPUS - SANITARY SEWER
EXISTING CONDITIONS RATING

FIGURE-22



DWG: Z:\CU\Masterplan-C09401xx\Sewer\drawings\FINAL-8-18-03\FIGURE-21&22.dwg USER: estrand
DATE: Oct 13, 2003 3:47pm XREFS: campus base IMAGES:

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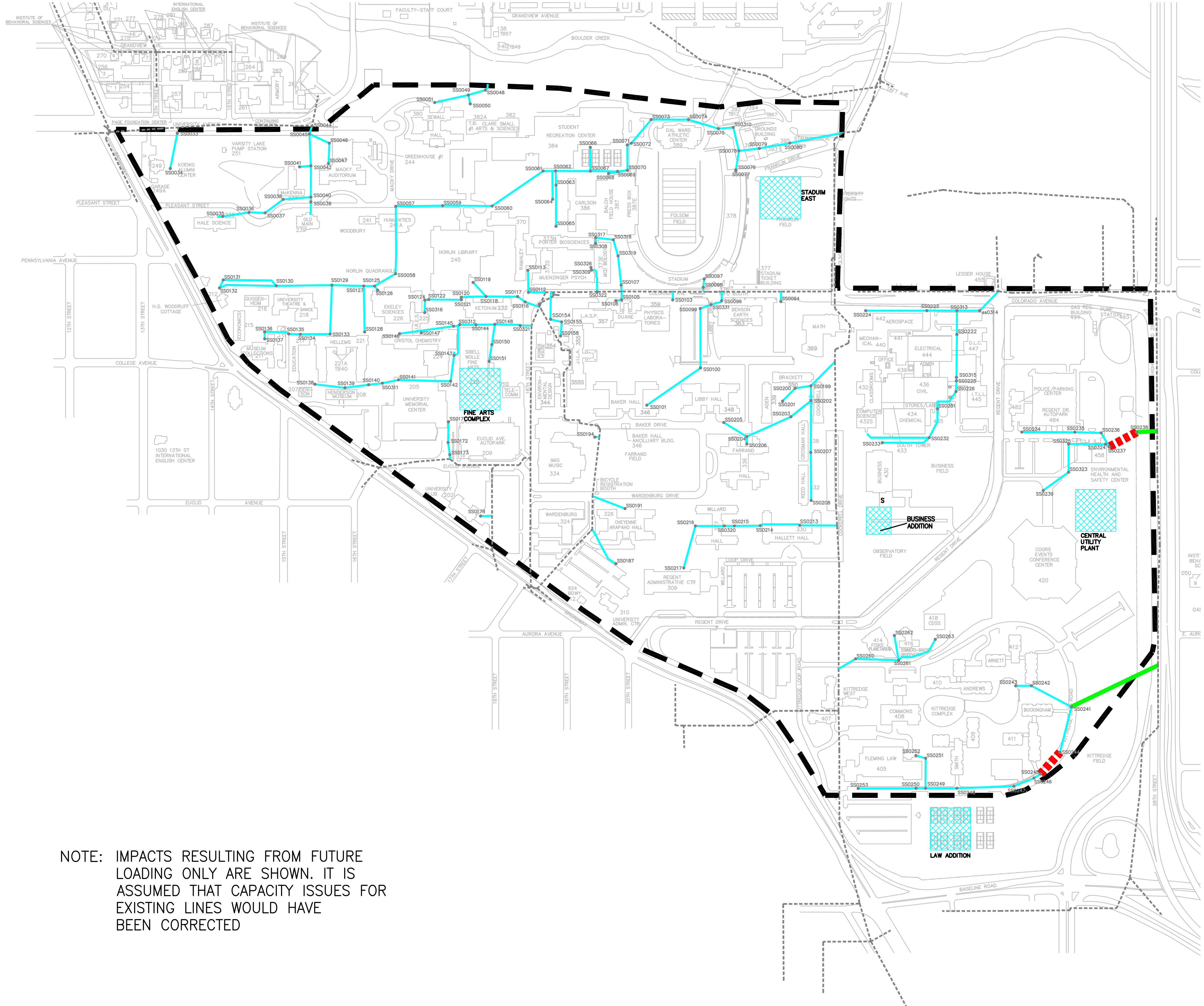
CU W.O. #	422523		

BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - SANITARY SEWER
EXISTING CONDITIONS RATING

FIGURE-21



SCALE IN FEET: 500 250 0 500 1000

LEGEND

LIMITS OF STUDY

CU SEWER CAPACITY RATING

1 (GOOD)

2

3

4

5 (MOST SEVERE)

CITY OF BOULDER SANITARY SEWER

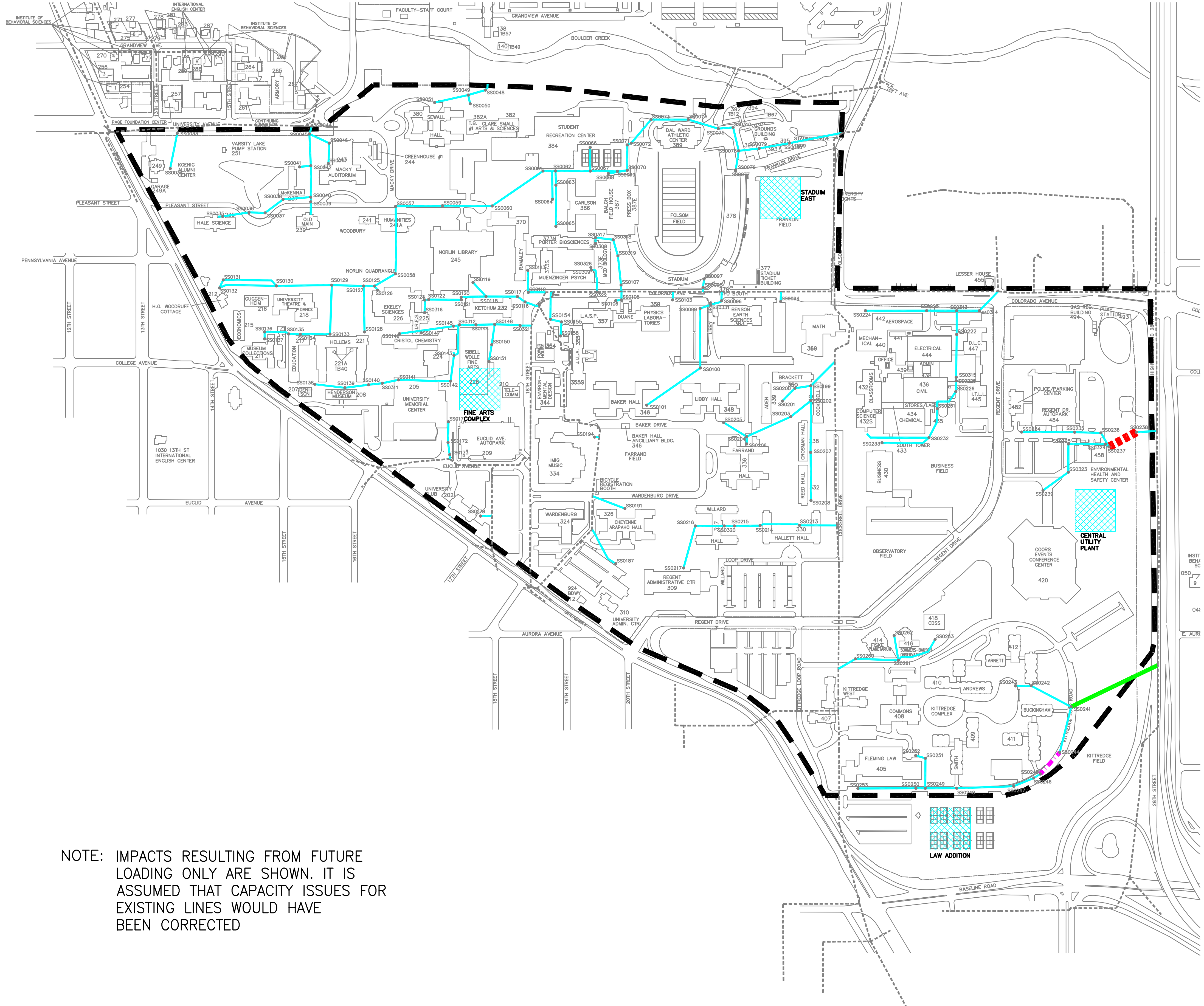
MANHOLE

FUTURE BUILDING LOCATION

NOTE: IMPACTS RESULTING FROM FUTURE LOADING ONLY ARE SHOWN. IT IS ASSUMED THAT CAPACITY ISSUES FOR EXISTING LINES WOULD HAVE BEEN CORRECTED

DWG: Z:\CU\Masterplan-C09401xx\Sewer\drawings\FINAL-8-18-03\FIGURE-20.dwg USER: estrand
DATE: Oct 13, 2003 3:45pm XREFS: campus base IMAGES:

DESIGNED: JB DRAWN: GKP DATE: 06-24-03 JOB NO. DN-C09-401-20 CU W.O. # 422523	REVISION / DATE	BOYLE ENGINEERING CORPORATION	University of Colorado at Boulder	MAIN CAMPUS - SANITARY SEWER FUTURE BUILD-OUT LOADS CAPACITY RATING	FIGURE-20



500 250 0 500 1000

SCALE IN FEET

LEGEND

(black dashed line)	LIMITS OF STUDY
	CU SEWER CAPACITY RATING
(cyan line)	1 (GOOD)
(green line)	2
(magenta dashed line)	3
(orange line)	4
(red dashed line)	5 (MOST SEVERE)
(grey dotted line)	CITY OF BOULDER SANITARY SEWER
SS0242	MANHOLE
(hatched box)	FUTURE BUILDING LOCATION

NOTE: IMPACTS RESULTING FROM FUTURE LOADING ONLY ARE SHOWN. IT IS ASSUMED THAT CAPACITY ISSUES FOR EXISTING LINES WOULD HAVE BEEN CORRECTED

DWG: Z:\CU\Masterplan-C09401xx\Sewer\drawings\FINAL-8-18-03\FIGURE-19.dwg USER: estrand
DATE: Oct 13, 2003 3:44pm XREFS: campus base IMAGES:

		REVISION	DATE
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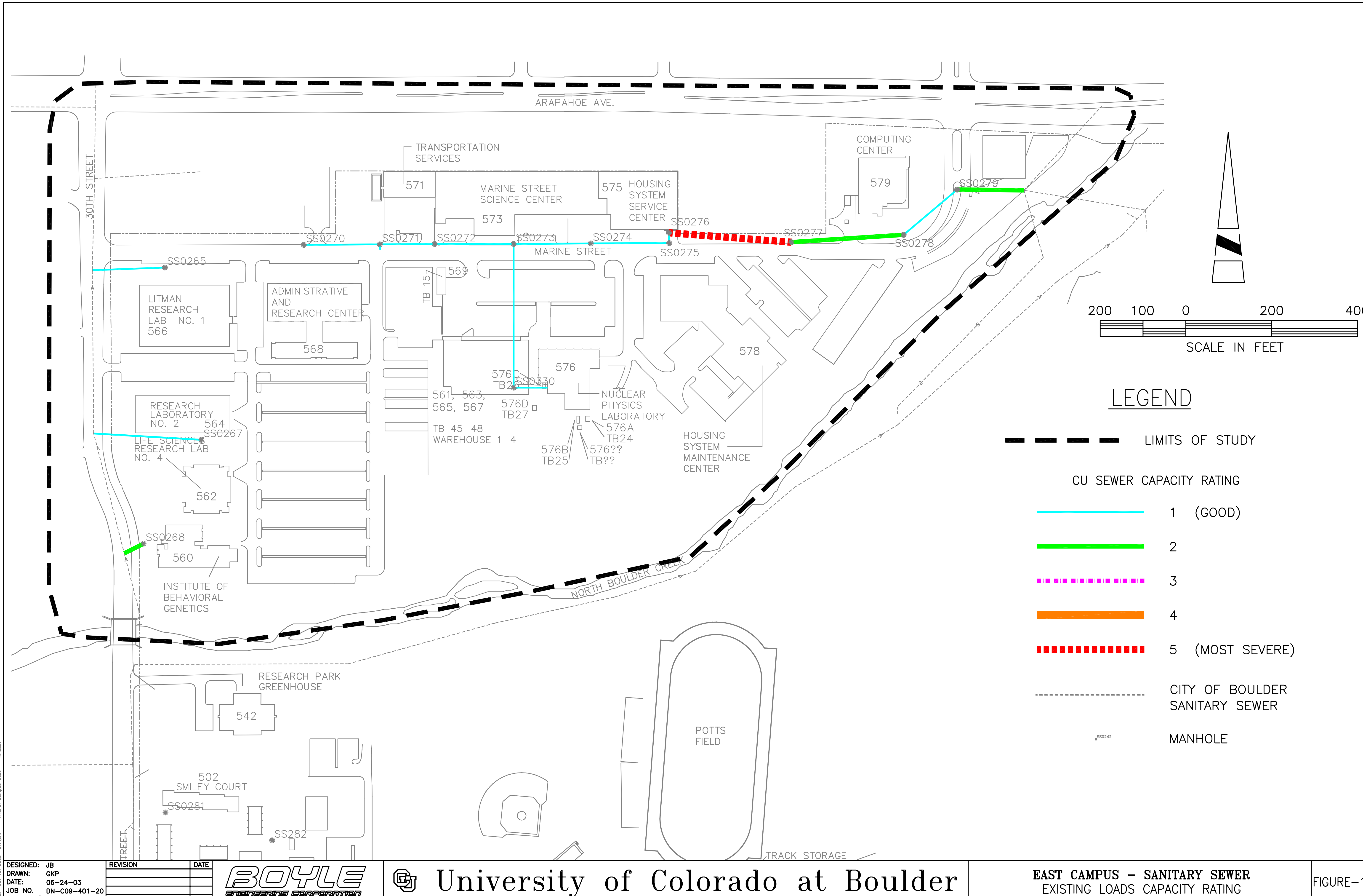
CU W.O. #	422523		

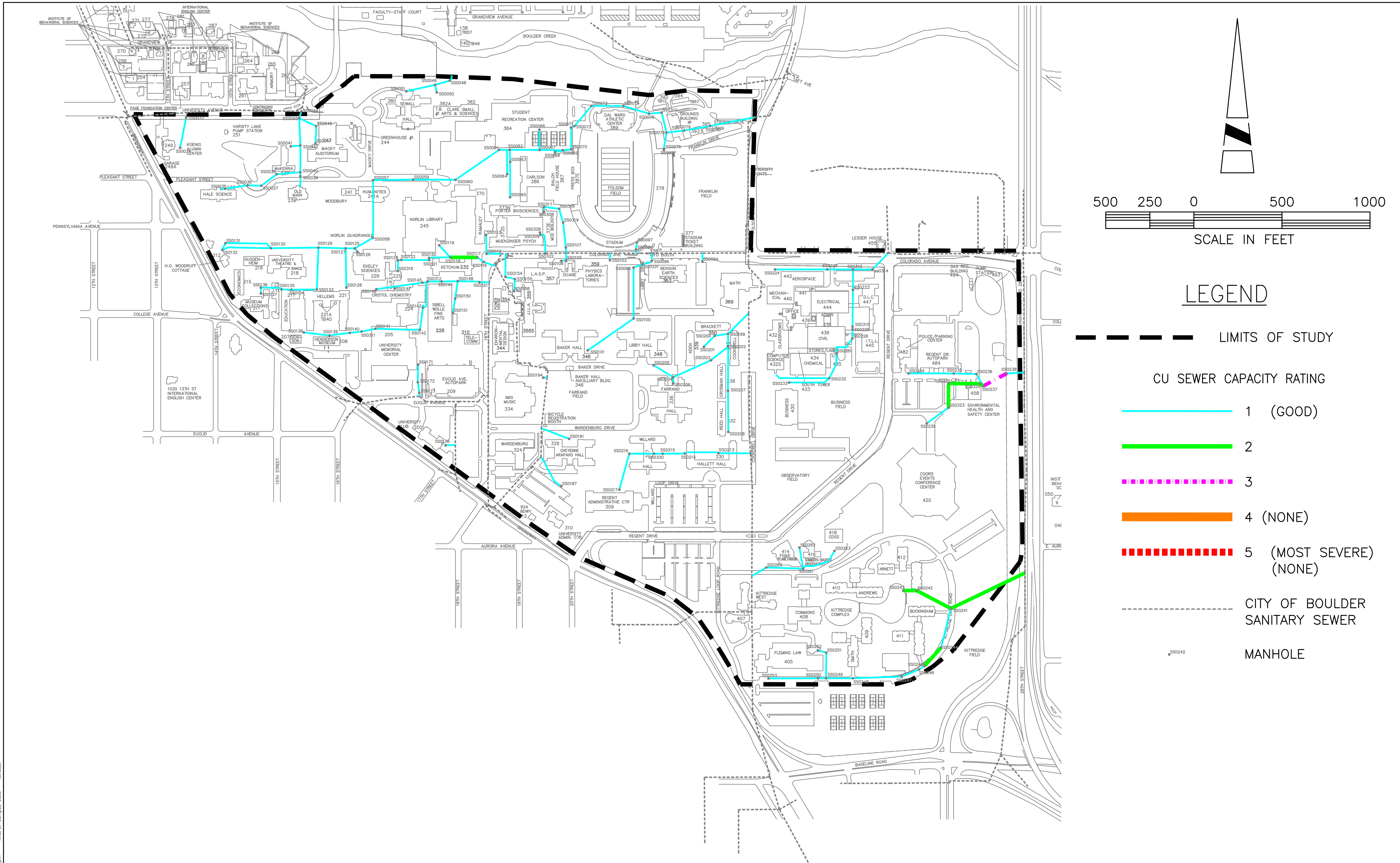
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - SANITARY SEWER
FUTURE (10-YEAR) LOADS CAPACITY RATING

FIGURE-19


ARAPAHOE AVE.
30TH STREET
MARINE STREET
TRANSPORTATION SERVICES
571
MARINE STREET SCIENCE CENTER
573
575 HOUSING SYSTEM SERVICE CENTER
COMPUTING CENTER
579
SS0265
SS0270
SS0271
SS0272
SS0273
SS0274
SS0275
SS0276
SS0277
SS0278
SS0279
LITMAN RESEARCH LAB NO. 1
566
ADMINISTRATIVE AND RESEARCH CENTER
568
TB 15
569
576
576C
TB26
SS0330
561, 563, 565, 567
576D
TB27
TB 45-48
WAREHOUSE 1-4
NUCLEAR PHYSICS LABORATORY
576A
TB24
576B
TB25
576??
TB??
578
HOUSING SYSTEM MAINTENANCE CENTER
RESEARCH LABORATORY NO. 2
564
SS0267
LIFE SCIENCE RESEARCH LAB NO. 4
562
SS0268
560
INSTITUTE OF BEHAVIORAL GENETICS
NORTH BOULDER CREEK
RESEARCH PARK GREENHOUSE
542
502
SMILEY COURT
SS0281
SS282
POTTS FIELD
TRACK STORAGE
200 100 0 200 400
SCALE IN FEET
LEGEND
LIMITS OF STUDY
CU SEWER CAPACITY RATING
1 (GOOD)
2
3
4
5 (MOST SEVERE)
CITY OF BOULDER SANITARY SEWER
SS0242
MANHOLE
DESIGNED: JB
DRAWN: GKP
DATE: 06-24-03
JOB NO. DN-C09-401-20
CU W.O. # 422523
REVISION
DATE
BOYLE ENGINEERING CORPORATION
University of Colorado at Boulder
EAST CAMPUS - SANITARY SEWER
EXISTING LOADS CAPACITY RATING
FIGURE-18



DWG: Z:\CU\Masterplan-C09401xx\Sewer\drawings\FINAL-8-18-03\FIGURE-17.dwg USER: estrand
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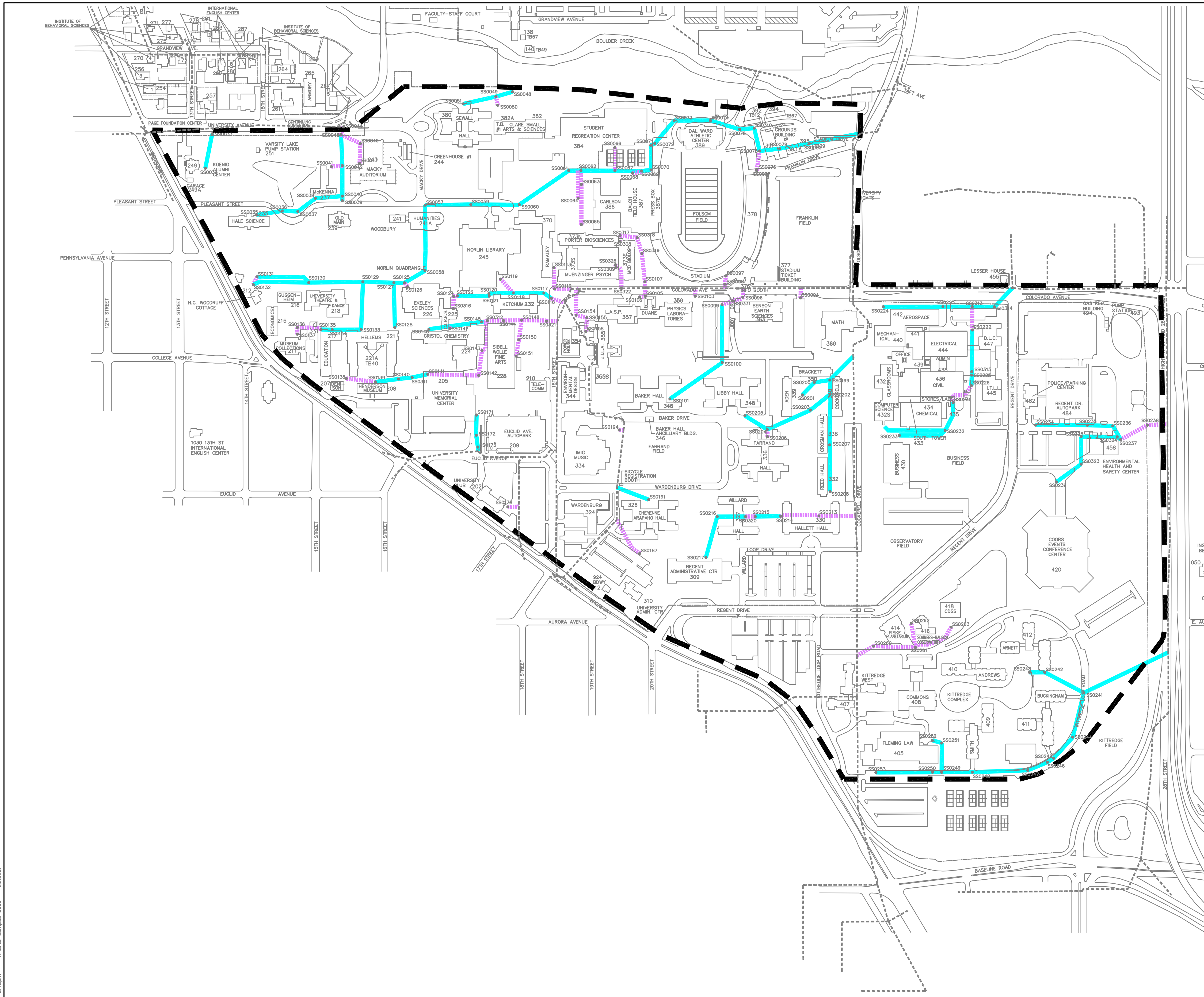
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - SANITARY SEWER
EXISTING LOADS CAPACITY RATING

FIGURE-17



LEGEND

LIMITS OF STUDY

PIPE WITH VIDEO INSPECTION

PIPE WITHOUT VIDEO INSPECTION

CITY OF BOULDER SANITARY SEWER

SS0242 MANHOLE

500 250 0 500 1000

SCALE IN FEET

DWG: Z:\CU\Masterplan-C09401xx\Sewer\drawings\FINAL-8-18-03\FIGURE-16.dwg USER: estrand
DATE: Oct 13, 2003 3:43pm XREFS: campus base IMAGES:

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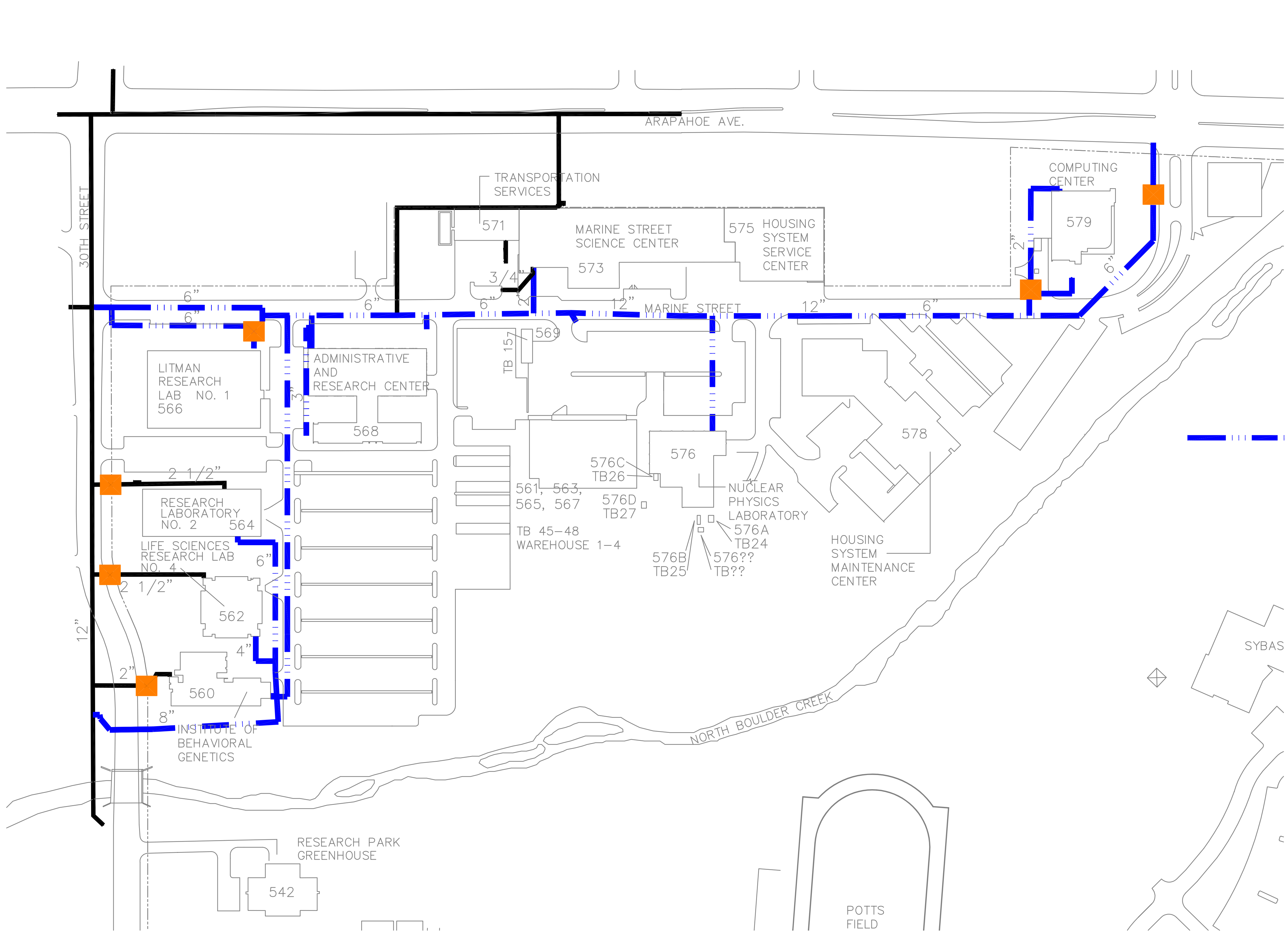
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - SANITARY SEWER
VIDEO INSPECTION

FIGURE 16



200 100 0 200 400

SCALE IN FEET

LEGEND

REPLACE 2016 – 2020, PIPE AGE 1965 – 1970 + "PRE–1978"

DWG: Z:\CU\Masterplan–C09401xx\Water\Model Files\Figures – Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 15.DWG USER: estrand
DATE: Oct 13, 2003 3:41pm XREFS: campus base IMAGES:

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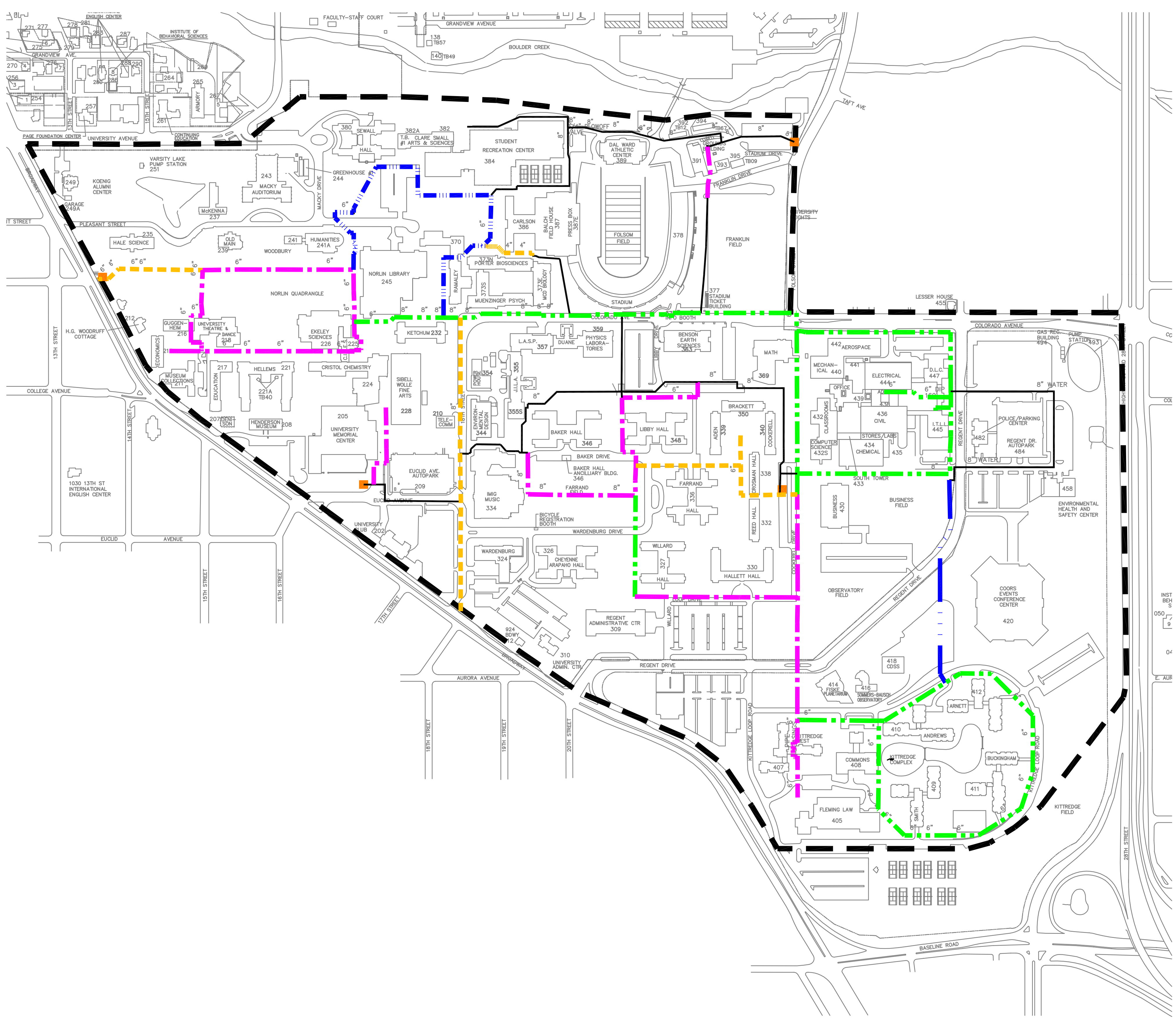
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

EAST CAMPUS
PROPOSED REPLACEMENT PROGRAM

FIGURE 15



LEGEND

(orange dashed line)	REPLACE 2004 & 2005, PIPE OLDER THAN 1947, EXCEPT LINE FROM PENN METER
(magenta dash-dot line)	REPLACE 2006 – 2008, PIPE AGE 1947 – 1958
(green dash-dot-dot line)	REPLACE 2010 – 2015, PIPE AGE 1958 – 1965
(blue dashed line)	REPLACE 2016 – 2020, PIPE AGE 1965 – 1970 + "PRE–1978"
(black dashed line)	STUDY LIMITS

500 250 0 500 1000

SCALE IN FEET

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures – Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 14.DWG USER: estrand
DATE: Oct 13, 2003 3:41pm XREFS: campus base IMAGES:

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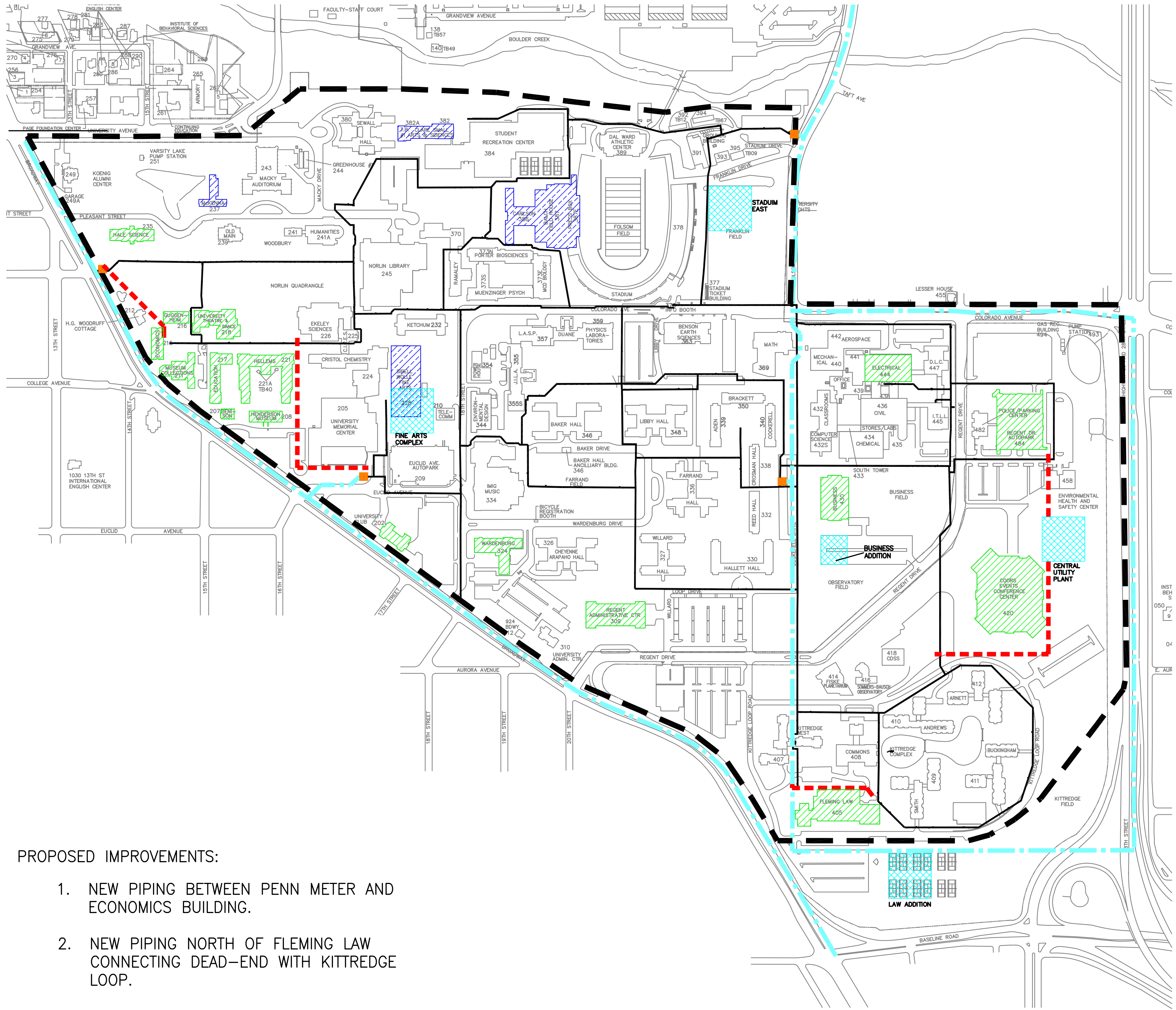
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS
PROPOSED REPLACEMENT PROGRAM

FIGURE 14



500 250 0 500 1000

SCALE IN FEET

LEGEND

(solid black line)	UNIVERSITY PIPE
(red dashed line)	PROPOSED IMPROVEMENT
(cyan dash-dot line)	CITY OF BOULDER WATER PIPE
(black dashed line)	STUDY LIMITS
(blank box)	BUILDING HAS ADEQUATE FIRE FLOW
(blue hatched box)	BUILDING NEEDS TO HAVE FIRE SPRINKLER SYSTEM INSTALLED
(green hatched box)	BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS
(cyan crosshatched box)	FUTURE BUILDING LOCATION

PROPOSED IMPROVEMENTS:

1. NEW PIPING BETWEEN PENN METER AND ECONOMICS BUILDING.
2. NEW PIPING NORTH OF FLEMING LAW CONNECTING DEAD-END WITH KITTREDGE LOOP.
3. LOOP SERVING PROPOSED CENTRAL UTILITY PLANT.

ALTERNATIVE B IMPROVEMENTS INCLUDE:

1. NEW PIPING BETWEEN UMC METER AND NORLIN QUAD.
2. INSTALLATION OF SPRINKLER SYSTEMS AS SHOWN.
3. ASSUMES REPLACEMENT PLAN IS EXECUTED.

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 13.DWG USER: estrand
DATE: Oct 13, 2003 3:40pm XREFS: campus base IMAGES:

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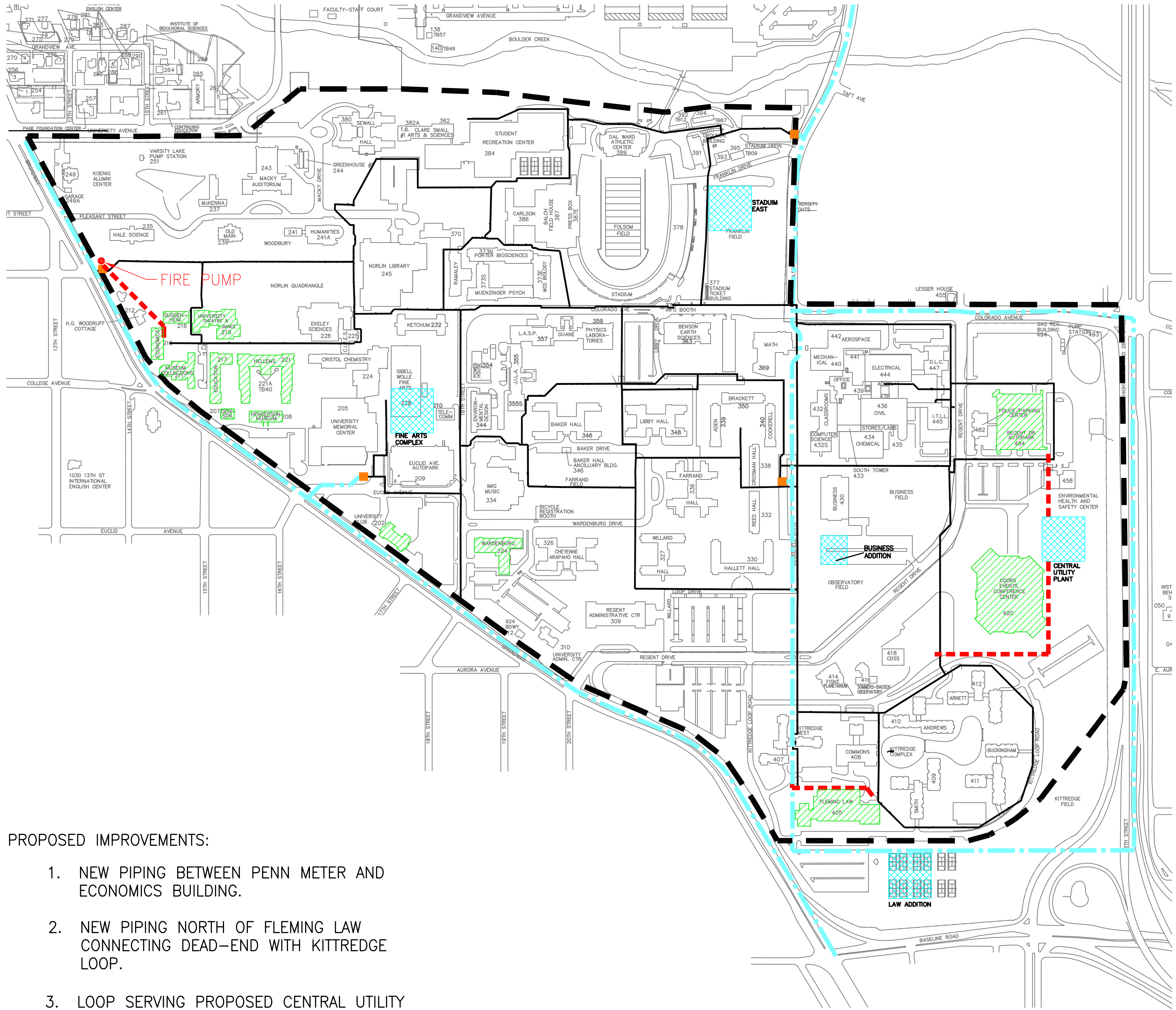
CU W.O. #	422523		

BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - BUILD OUT CONDITIONS
FIRE FLOW CONDITIONS WITH ALTERNATIVE B IMPROVEMENTS

FIGURE 13



PROPOSED IMPROVEMENTS:

1. NEW PIPING BETWEEN PENN METER AND ECONOMICS BUILDING.
2. NEW PIPING NORTH OF FLEMING LAW CONNECTING DEAD-END WITH KITTREDGE LOOP.
3. LOOP SERVING PROPOSED CENTRAL UTILITY PLANT.

500 250 0 500 1000

SCALE IN FEET

LEGEND

- UNIVERSITY PIPE
- PROPOSED IMPROVEMENT
- CITY OF BOULDER WATER PIPE
- STUDY LIMITS
- BUILDING HAS ADEQUATE FIRE FLOW
- BUILDING HAS INSUFFICIENT FIRE FLOW
- BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS
- FUTURE BUILDING LOCATION

ALTERNATIVE A IMPROVEMENTS INCLUDE:

1. FIRE PUMP AT THE PENN METER LOCATION.

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 12.DWG USER: estrand
DATE: Oct 13, 2003 3:40pm XREFS: campus base IMAGES:

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DRAWN: GKP		
DATE: 06-06-03		
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CU W.O. # 422523		

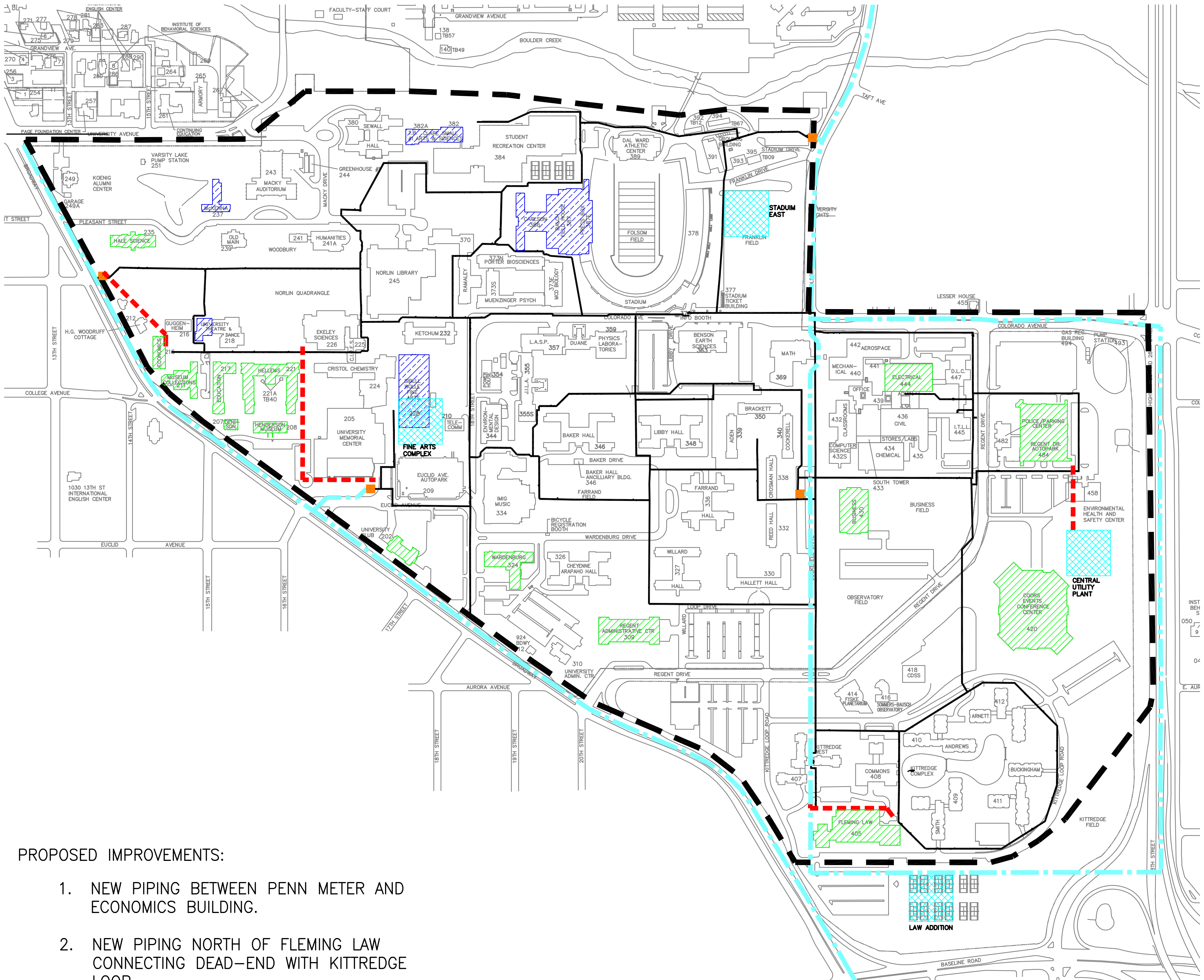
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - BUILD OUT CONDITIONS
FIRE FLOW CONDITIONS WITH ALTERNATIVE A IMPROVEMENTS

FIGURE 12

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 11.DWG USER: estrand
DATE: Oct 13, 2003 3:39pm XREFS: campus base IMAGES:



SCALE IN FEET: 500 250 0 500 1000

LEGEND

- UNIVERSITY PIPE
- PROPOSED IMPROVEMENT
- CITY OF BOULDER WATER PIPE
- STUDY LIMITS
- BUILDING HAS ADEQUATE FIRE FLOW
- BUILDING NEEDS TO HAVE FIRE SPRINKLER SYSTEM INSTALLED
- BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS
- FUTURE BUILDING LOCATION

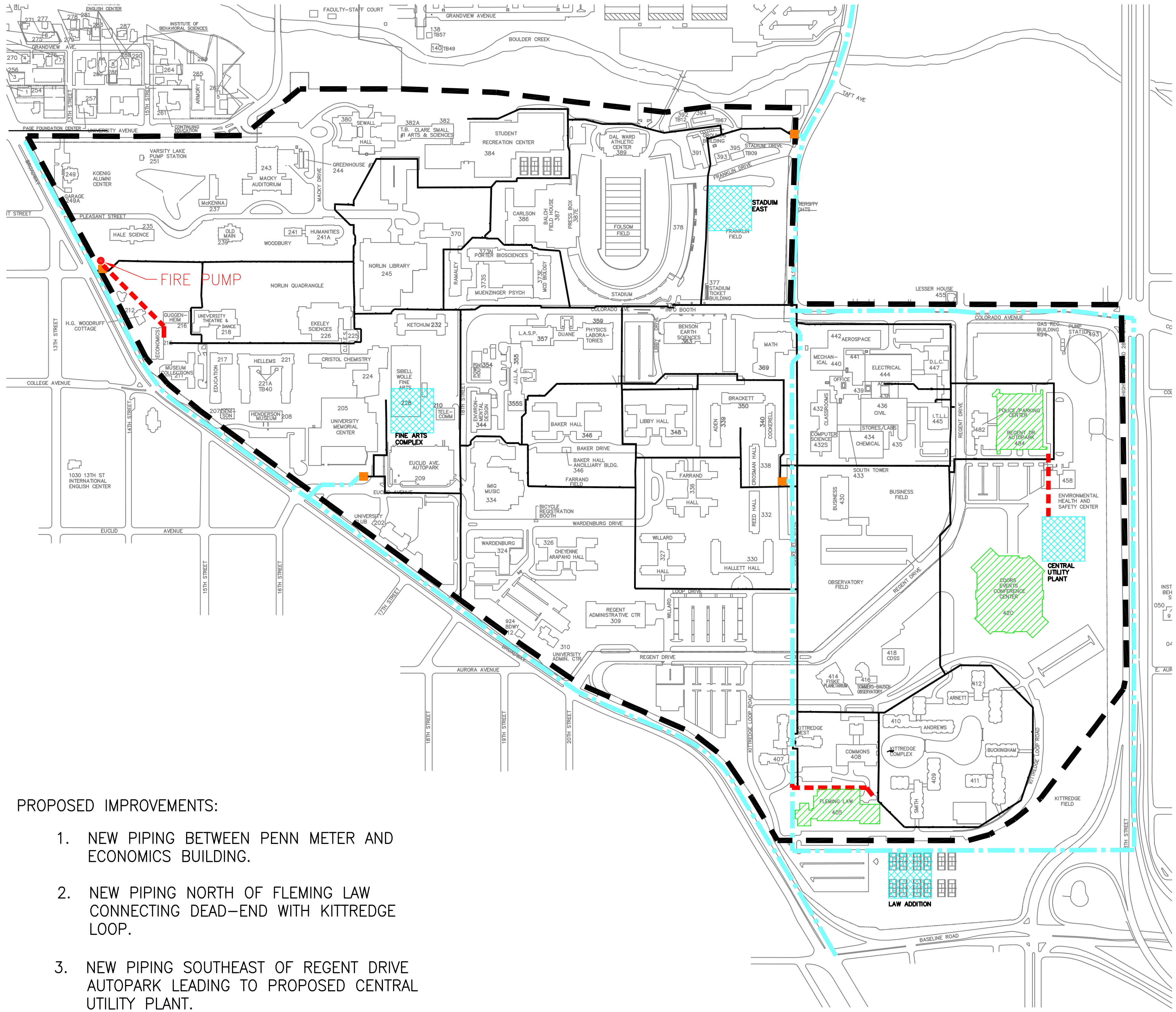
PROPOSED IMPROVEMENTS:

1. NEW PIPING BETWEEN PENN METER AND ECONOMICS BUILDING.
2. NEW PIPING NORTH OF FLEMING LAW CONNECTING DEAD-END WITH KITTREDGE LOOP.
3. NEW PIPING SOUTHEAST OF REGENT DRIVE AUTOPARK LEADING TO PROPOSED CENTRAL UTILITY PLANT.

ALTERNATIVE B IMPROVEMENTS INCLUDE:

1. NEW PIPING BETWEEN UMC METER AND NORLIN QUAD.
2. INSTALLATION OF SPRINKLER SYSTEMS AS SHOWN.
3. ASSUMES REPLACEMENT PLAN IS EXECUTED.

DESIGNED: DR DRAWN: GKP DATE: 06-06-03 JOB NO. DN-C09-401-10 CU W.O. # 422523	REVISION	DATE	BOYLE ENGINEERING CORPORATION	University of Colorado at Boulder	MAIN CAMPUS - 10-YEAR FUTURE CONDITIONS FIRE FLOW CONDITIONS WITH ALTERNATIVE B IMPROVEMENTS	FIGURE 11



LEGEND

(solid black line)	UNIVERSITY PIPE
(red dashed line)	PROPOSED IMPROVEMENT
(cyan dash-dot line)	CITY OF BOULDER WATER PIPE
(black dashed line)	STUDY LIMITS
(white box)	BUILDING HAS ADEQUATE FIRE FLOW
(pink box)	BUILDING HAS INSUFFICIENT FIRE FLOW
(green hatched box)	BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS
(cyan cross-hatched box)	FUTURE BUILDING LOCATION

PROPOSED IMPROVEMENTS:

1. NEW PIPING BETWEEN PENN METER AND ECONOMICS BUILDING.
2. NEW PIPING NORTH OF FLEMING LAW CONNECTING DEAD-END WITH KITTREDGE LOOP.
3. NEW PIPING SOUTHEAST OF REGENT DRIVE AUTOPARK LEADING TO PROPOSED CENTRAL UTILITY PLANT.

ALTERNATIVE A IMPROVEMENTS INCLUDE:

1. FIRE PUMP AT THE PENN METER LOCATION.

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 10.DWG USER: estrand
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CU W.O. # 422523

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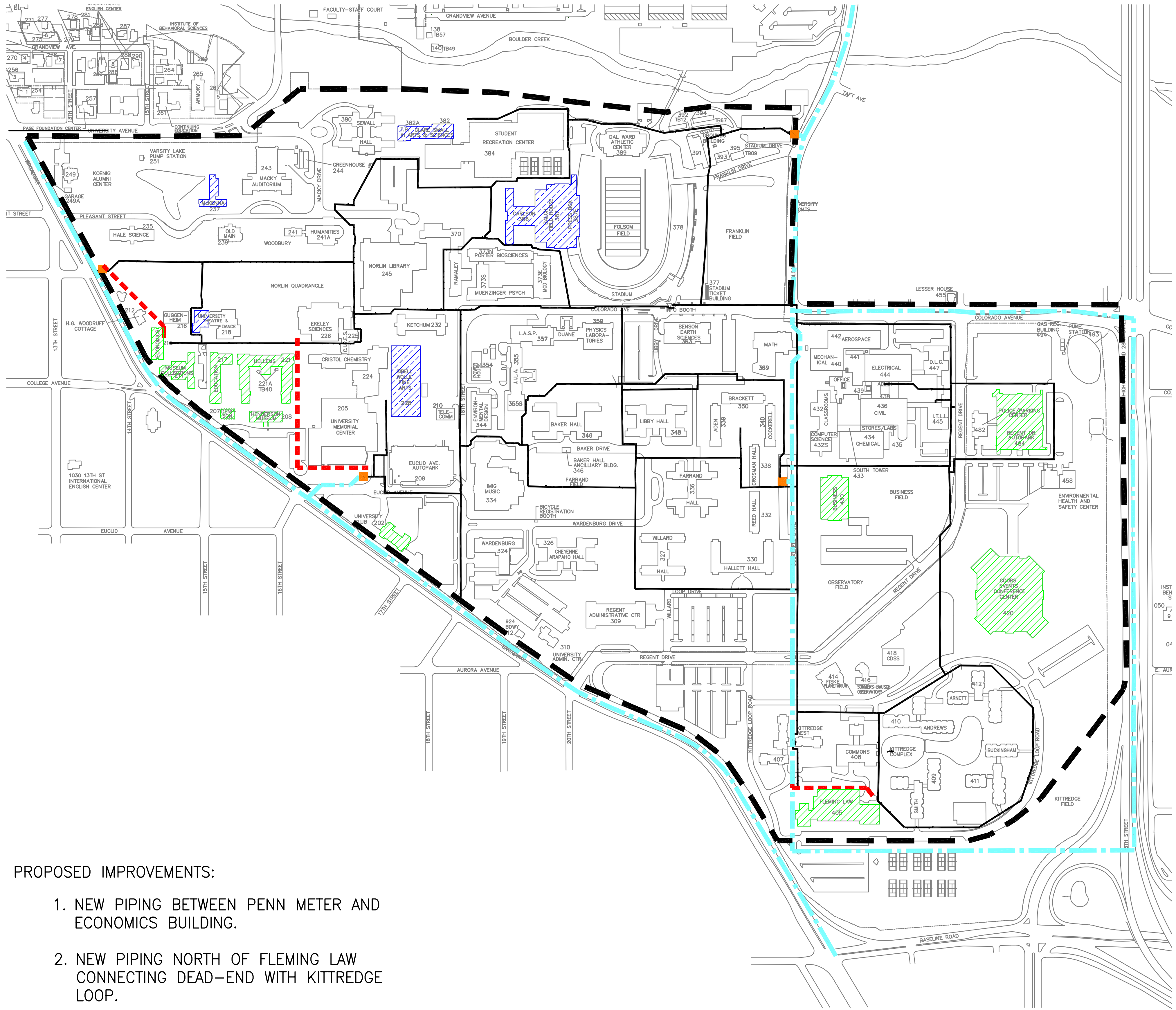
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - 10-YEAR FUTURE CONDITIONS
FIRE FLOW CONDITIONS WITH ALTERNATIVE A IMPROVEMENTS

FIGURE-10



PROPOSED IMPROVEMENTS:

1. NEW PIPING BETWEEN PENN METER AND ECONOMICS BUILDING.
2. NEW PIPING NORTH OF FLEMING LAW CONNECTING DEAD-END WITH KITTREDGE LOOP.

SCALE IN FEET (500 250 0 500 1000)

LEGEND

- UNIVERSITY PIPE
- PROPOSED IMPROVEMENT
- CITY OF BOULDER WATER PIPE
- STUDY LIMITS
- BUILDING HAS ADEQUATE FIRE FLOW
- BUILDING NEEDS TO HAVE FIRE SPRINKLER SYSTEM INSTALLED
- BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS

ALTERNATIVE B IMPROVEMENTS INCLUDE:

1. NEW PIPING BETWEEN UMC METER AND NORLIN QUAD.
2. INSTALLATION OF SPRINKLER SYSTEMS AS SHOWN.

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 09.DWG USER: estrand
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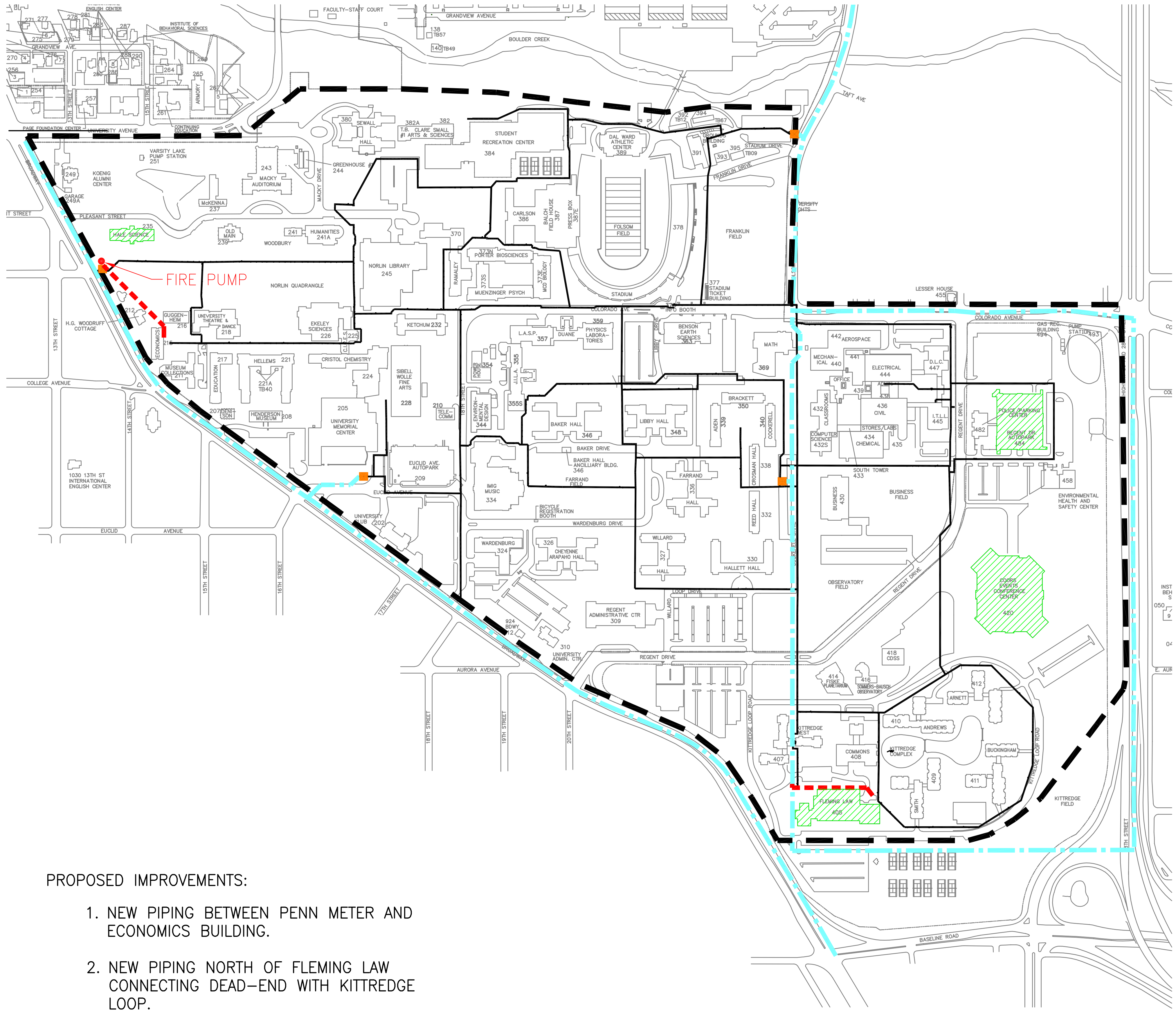
CU W.O. # 422523		

BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - EXISTING CONDITIONS
FIRE FLOW CONDITIONS WITH ALTERNATIVE B IMPROVEMENTS

FIGURE-9



500 250 0 500 1000

SCALE IN FEET

LEGEND

(solid black line)	UNIVERSITY PIPE
(red dashed line)	PROPOSED IMPROVEMENT
(cyan dash-dot line)	CITY OF BOULDER WATER PIPE
(black dashed line)	STUDY LIMITS
(white box)	BUILDING HAS ADEQUATE FIRE FLOW
(red box)	BUILDING HAS INSUFFICIENT FIRE FLOW
(green hatched box)	BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS

PROPOSED IMPROVEMENTS:

1. NEW PIPING BETWEEN PENN METER AND ECONOMICS BUILDING.

2. NEW PIPING NORTH OF FLEMING LAW CONNECTING DEAD-END WITH KITTREDGE LOOP.

ALTERNATIVE A IMPROVEMENTS INCLUDE:

1. FIRE PUMP AT THE PENN METER LOCATION.

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 08.DWG USER: estrand
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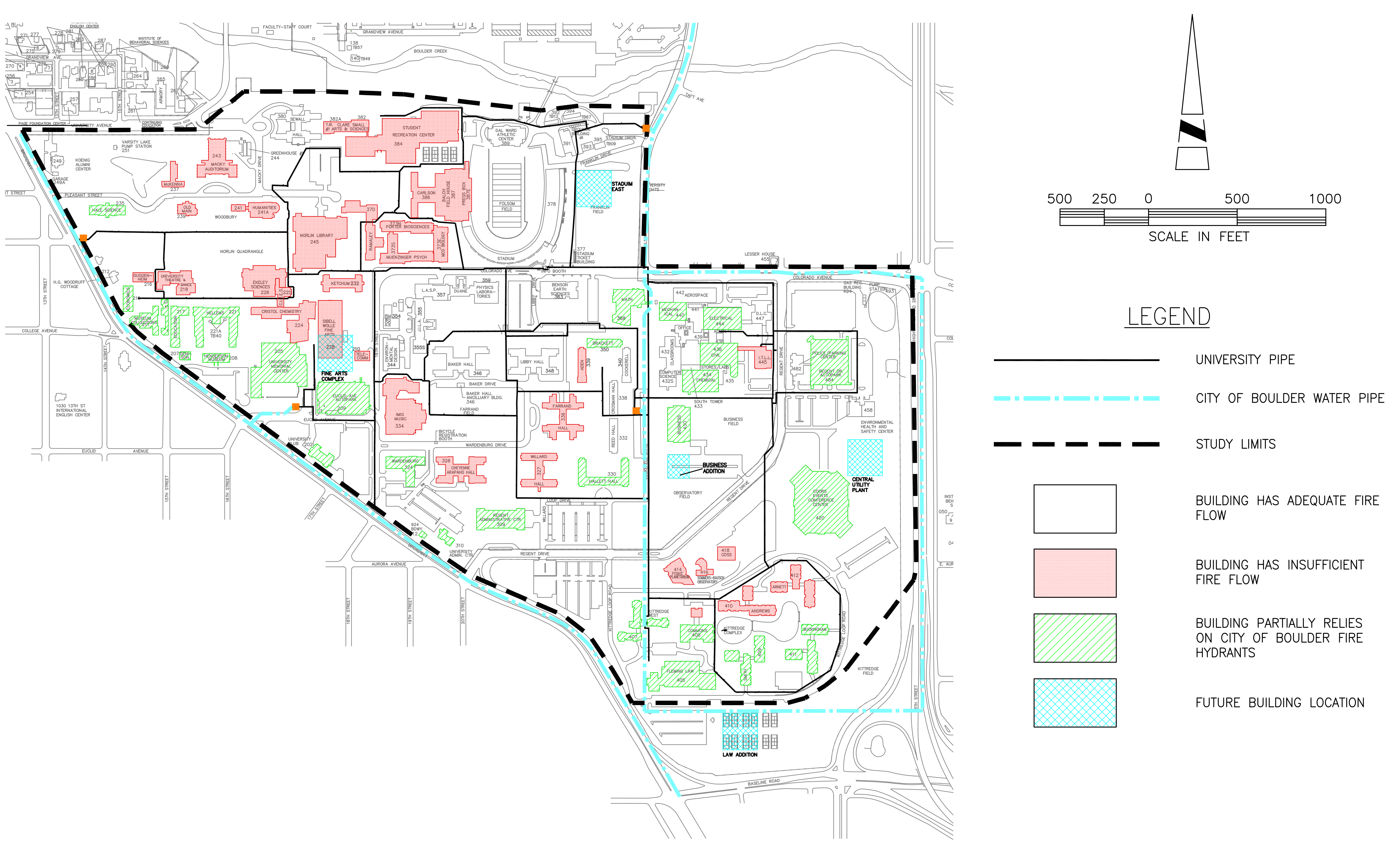
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - EXISTING CONDITIONS
FIRE FLOW CONDITIONS WITH ALTERNATIVE A IMPROVEMENTS

FIGURE-8



DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 07.DWG USER: estrand
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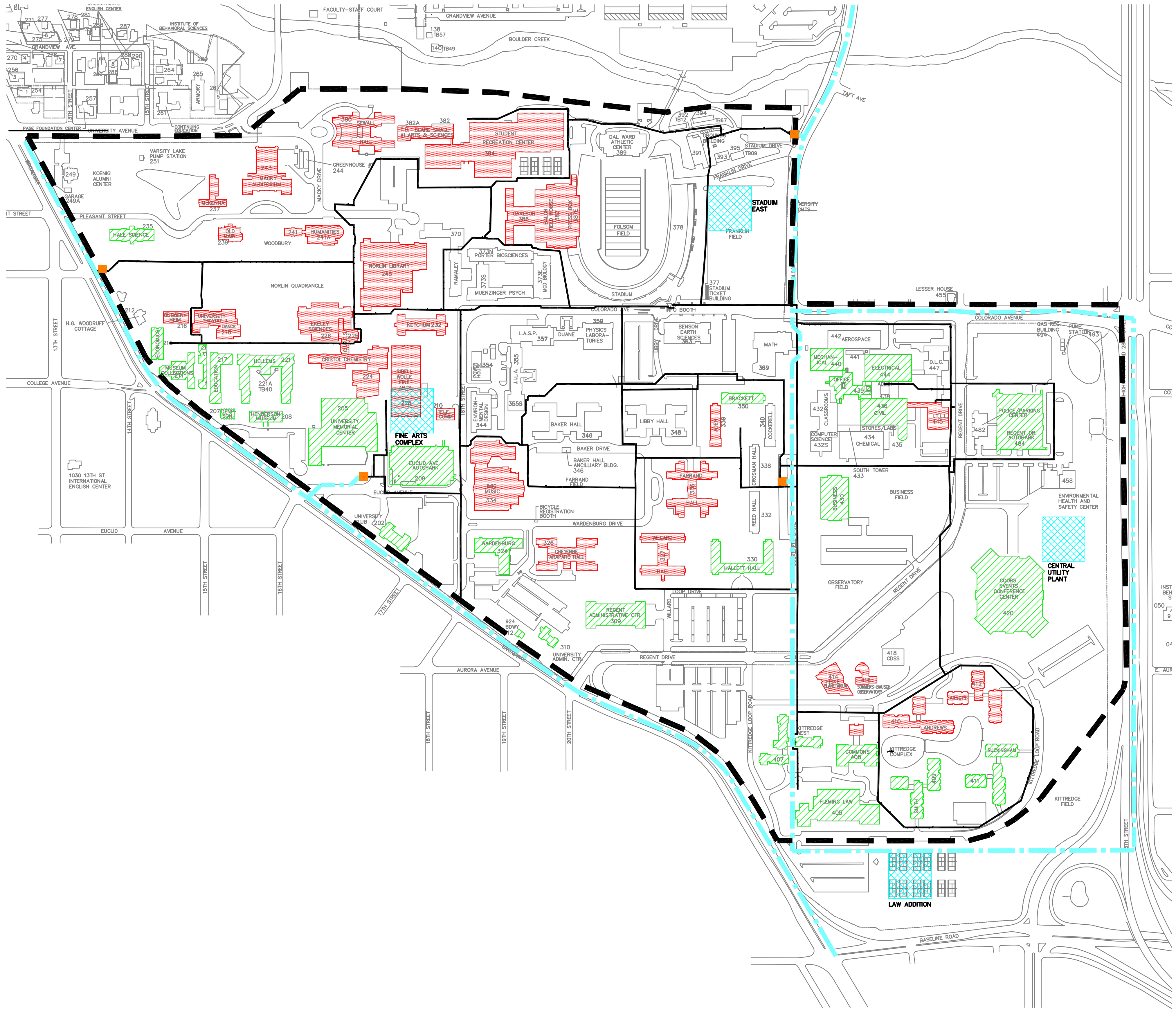
CU W.O. #	422523		

BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - BUILD OUT CONDITIONS
FIRE FLOW CONDITIONS WITH NO IMPROVEMENTS

FIGURE-7



SCALE IN FEET

500 250 0 500 1000

LEGEND

- UNIVERSITY PIPE
- CITY OF BOULDER WATER PIPE
- STUDY LIMITS
- BUILDING HAS ADEQUATE FIRE FLOW
- BUILDING HAS INSUFFICIENT FIRE FLOW
- BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS
- FUTURE BUILDING LOCATION

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 06.DWG USER: estrand
DATE: Oct 13, 2003 3:36pm XREFS: campus base IMAGES:

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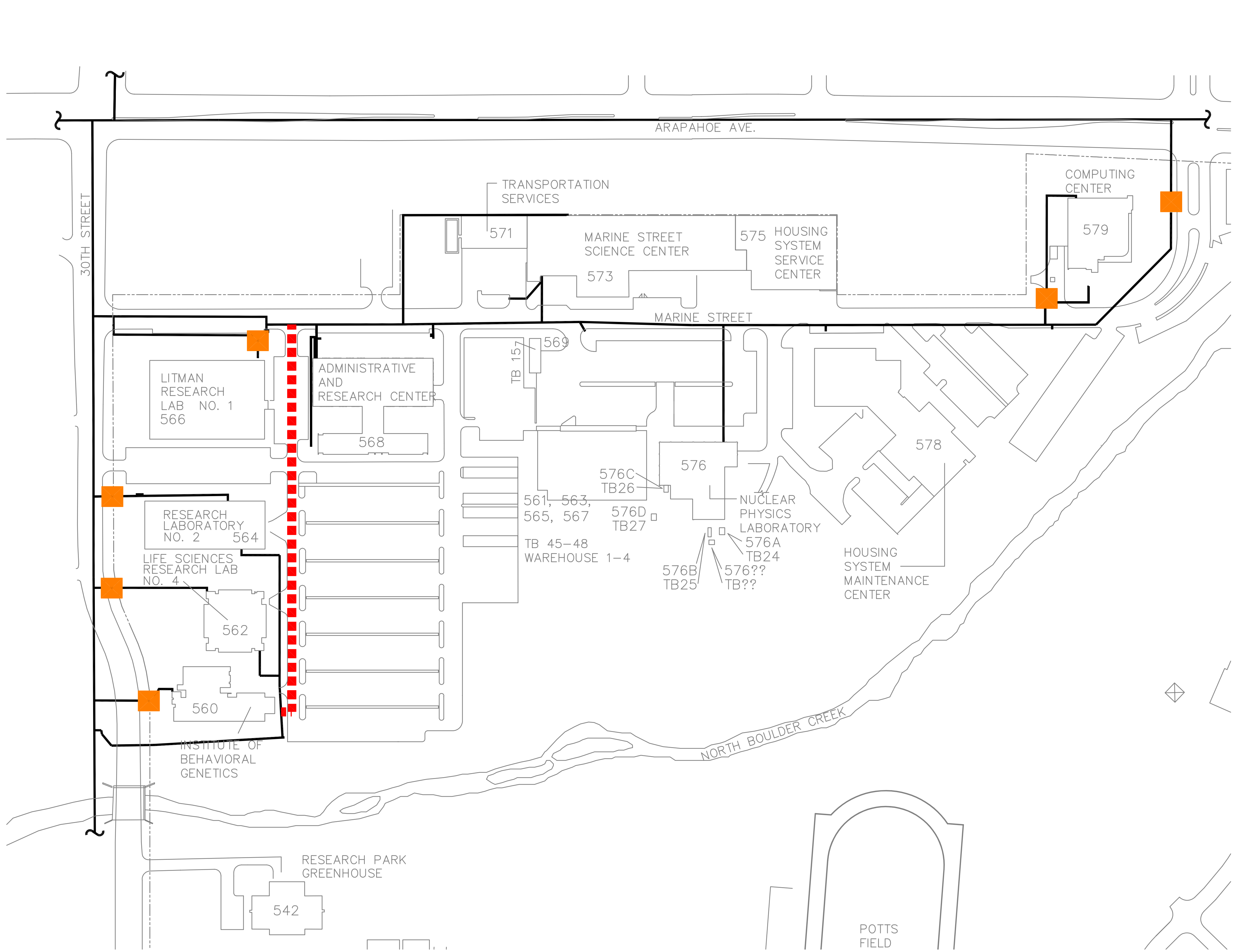
CU W.O. #	422523		

BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

MAIN CAMPUS - PROJECTED 10-YEAR CONDITIONS
FIRE FLOW CONDITIONS WITH NO IMPROVEMENTS

FIGURE-6



200 150 0 200 400

SCALE IN FEET

LEGEND

UNIVERSITY PIPE

OVER-CAPACITY PIPES UNDER PEAK DAY CONDITIONS (POOR CONDITION OR UNDER-SIZED)

NOTES

1. PRESSURES GREATER THAN 100 psi FOR ALL MAINS AND ALL SERVICE LINES
2. FIRE FLOW MEETS UNIVERSITY DESIRED QUANTITY.

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 05.DWG USER: estrand
DATE: Oct 13, 2003 3:35pm XREFS: campus base IMAGES:

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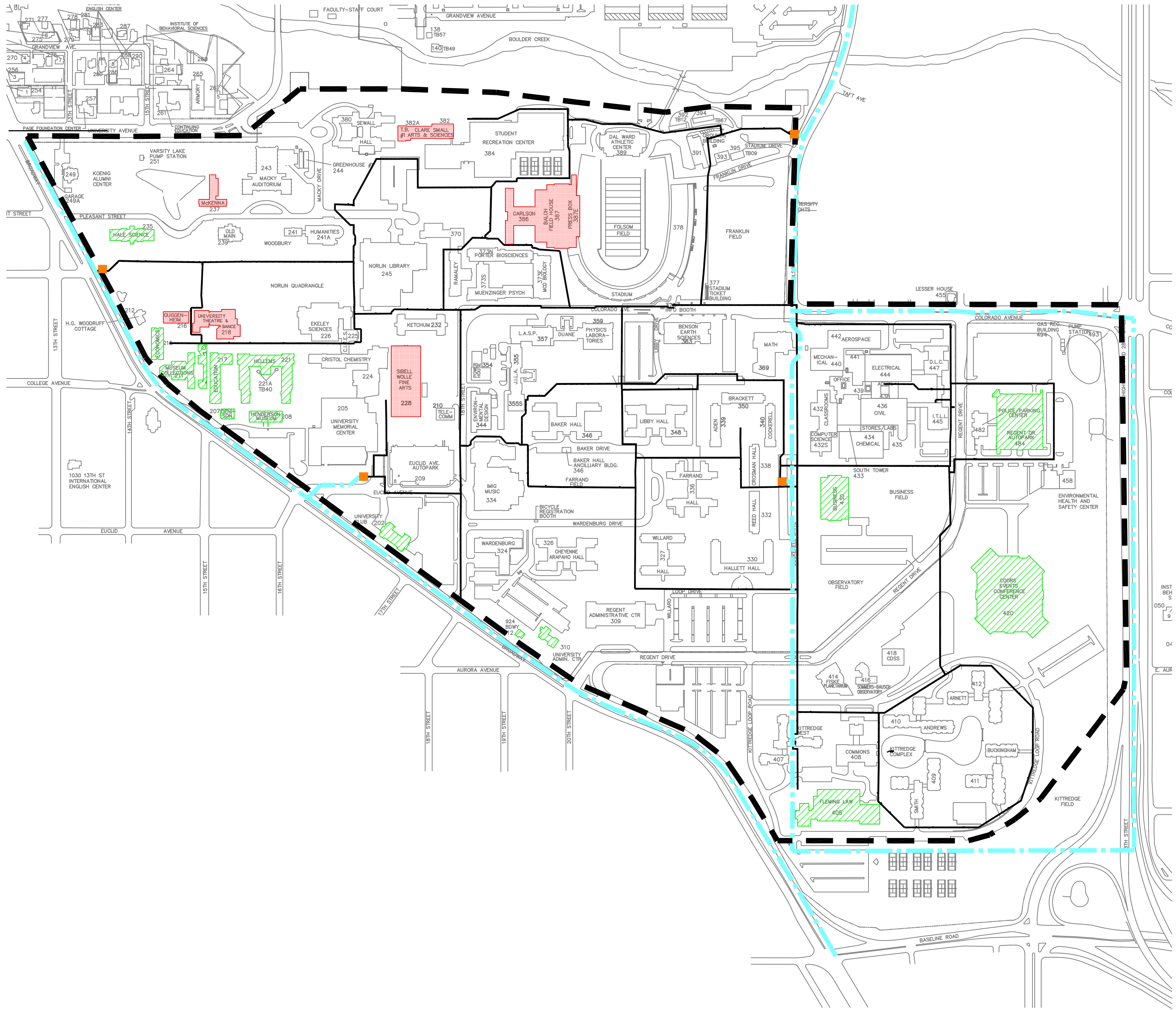
BOYLE ENGINEERING CORPORATION

University of Colorado at Boulder

EAST CAMPUS - EXISTING CONDITIONS
EXISTING, 10-YEAR, AND BUILD-OUT

FIGURE-5



500 250 0 500 1000

SCALE IN FEET

LEGEND

UNIVERSITY PIPE

CITY OF BOULDER WATER PIPE

STUDY LIMITS

BUILDING HAS ADEQUATE FIRE FLOW

BUILDING HAS INSUFFICIENT FIRE FLOW

BUILDING PARTIALLY RELIES ON CITY OF BOULDER FIRE HYDRANTS

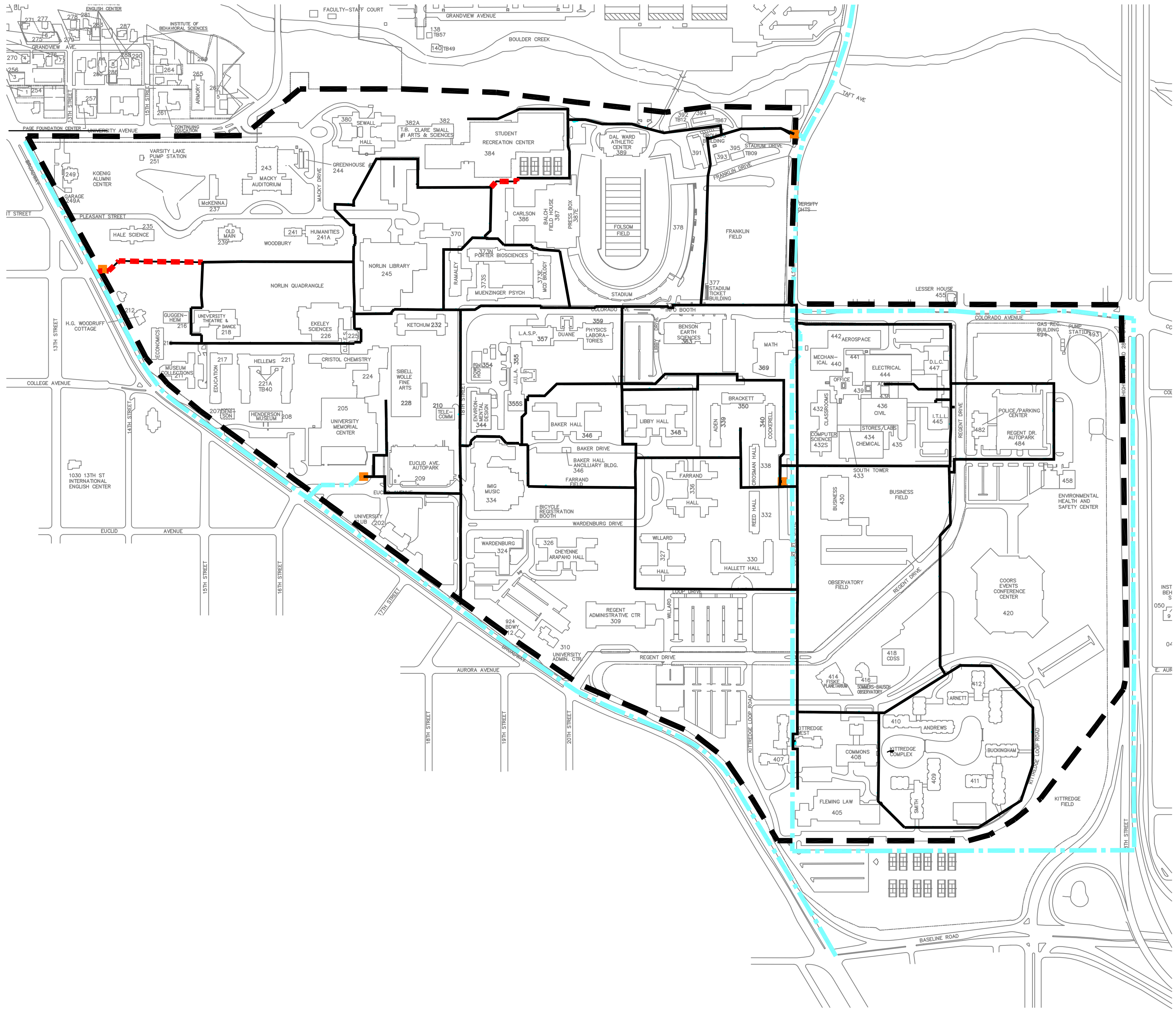
DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 04.DWG USER: estrand
DATE: Oct 13, 2003 3:34pm XREFS: campus base IMAGES:

DESIGNED: DR	REVISION	DATE	BOYLE ENGINEERING CORPORATION
DRAWN: GKP			
DATE: 06-06-03			
JOB NO. DN-C09-401-10			
CU W.O. # 422523			

University of Colorado at Boulder

MAIN CAMPUS - EXISTING CONDITIONS
FIRE FLOW CONDITIONS WITH NO IMPROVEMENTS

FIGURE-4



500 250 0 500 1000

SCALE IN FEET

LEGEND

UNIVERSITY PIPE

LIMITS OF STUDY

OVER-CAPACITY PIPES UNDER PEAK DAY CONDITIONS (POOR CONDITION OR UNDER-SIZED)

CITY OF BOULDER WATER PIPE

DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 03.DWG USER: estrand
DATE: Oct 13, 2003 3:34pm XREFS: campus base IMAGES:

DESIGNED: DR	REVISION	DATE
DRAWN: GKP		
DATE: 06-06-03		
JOB NO. DN-C09-401-10		
CU W.O. # 422523		

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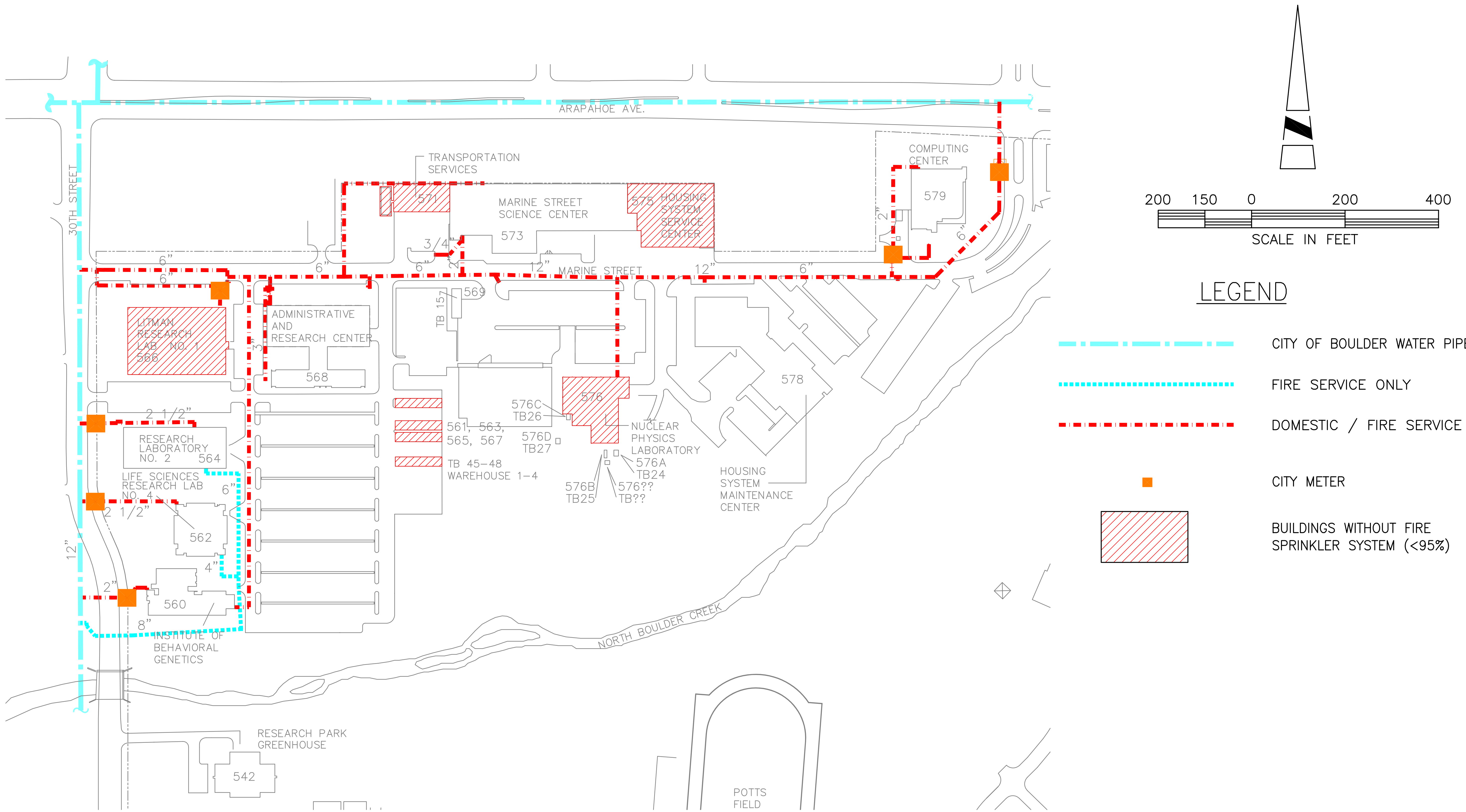
University of Colorado at Boulder

MAIN CAMPUS
EXISTING CONDITIONS WITH NO IMPROVEMENTS

FIGURE-3



DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures – Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 02.DWG USER: estrand
DATE: Oct 13, 2003 3:33pm XREFS: campus base IMAGES:

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DRAWN:	GKP
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CU W.O. #	422523

REVISION	DATE

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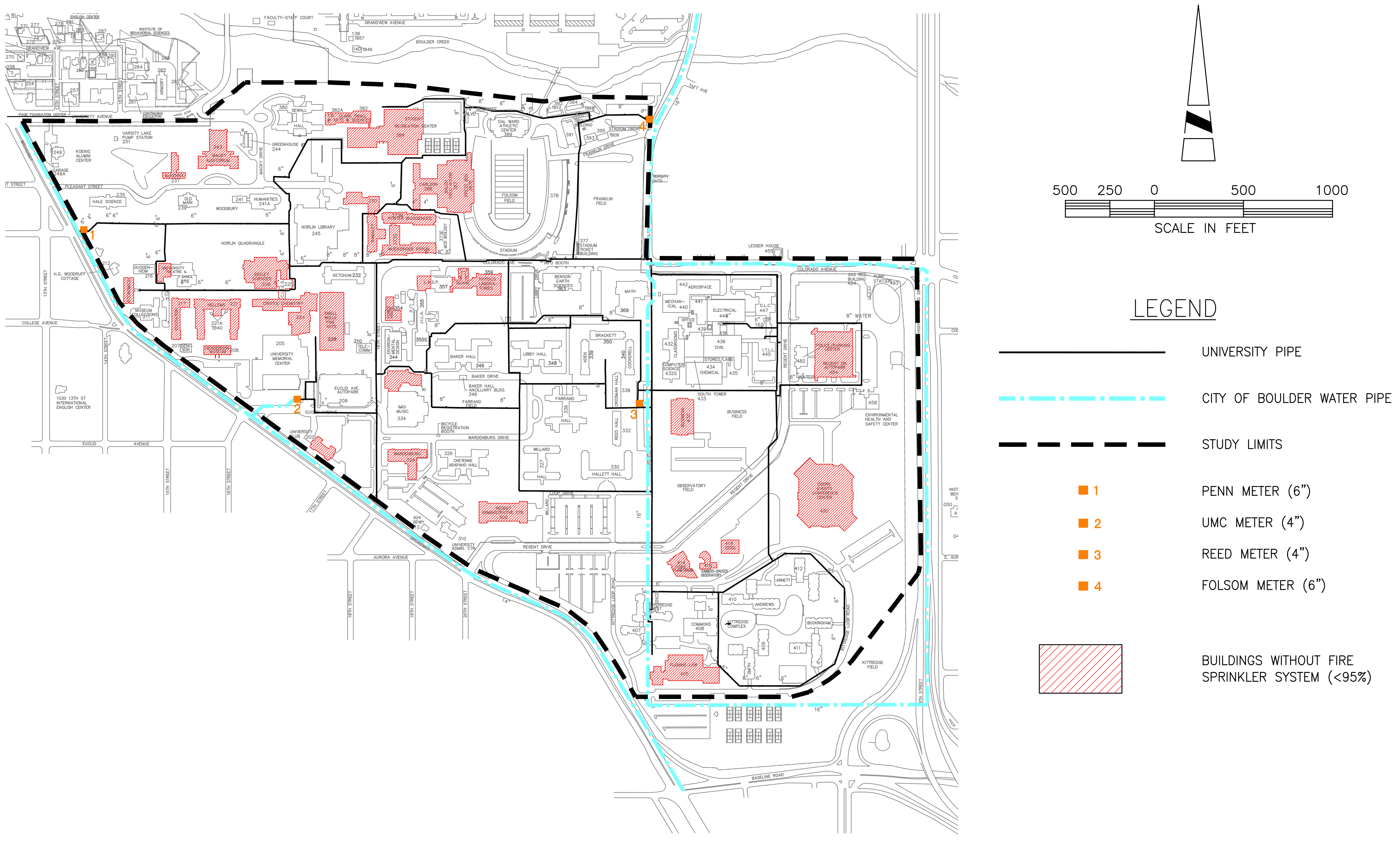
EAST CAMPUS
EXISTING WATER SYSTEM LAYOUT

FIGURE-2



DWG: Z:\CU\Masterplan-C09401xx\Water\Model Files\Figures - Water Layout\MAIN CAMPUS\FINAL 8_18_03\FIGURE 01.DWG USER: estrand
DATE: Oct 13, 2003 3:29pm XREFS: campus base IMAGES:

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DATE:	06-06-03		
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MAIN CAMPUS
EXISTING WATER SYSTEM LAYOUT

FIGURE-1