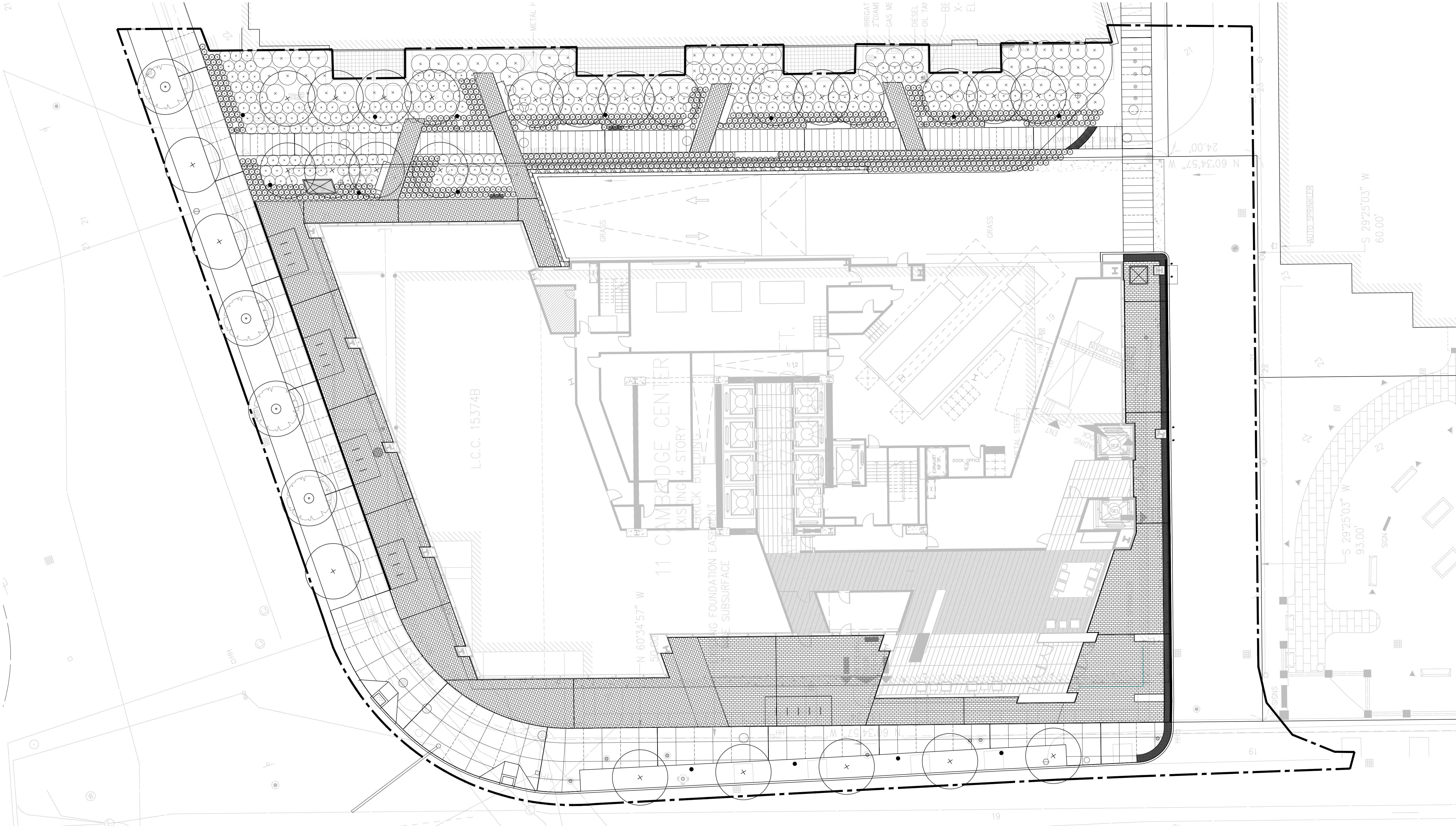
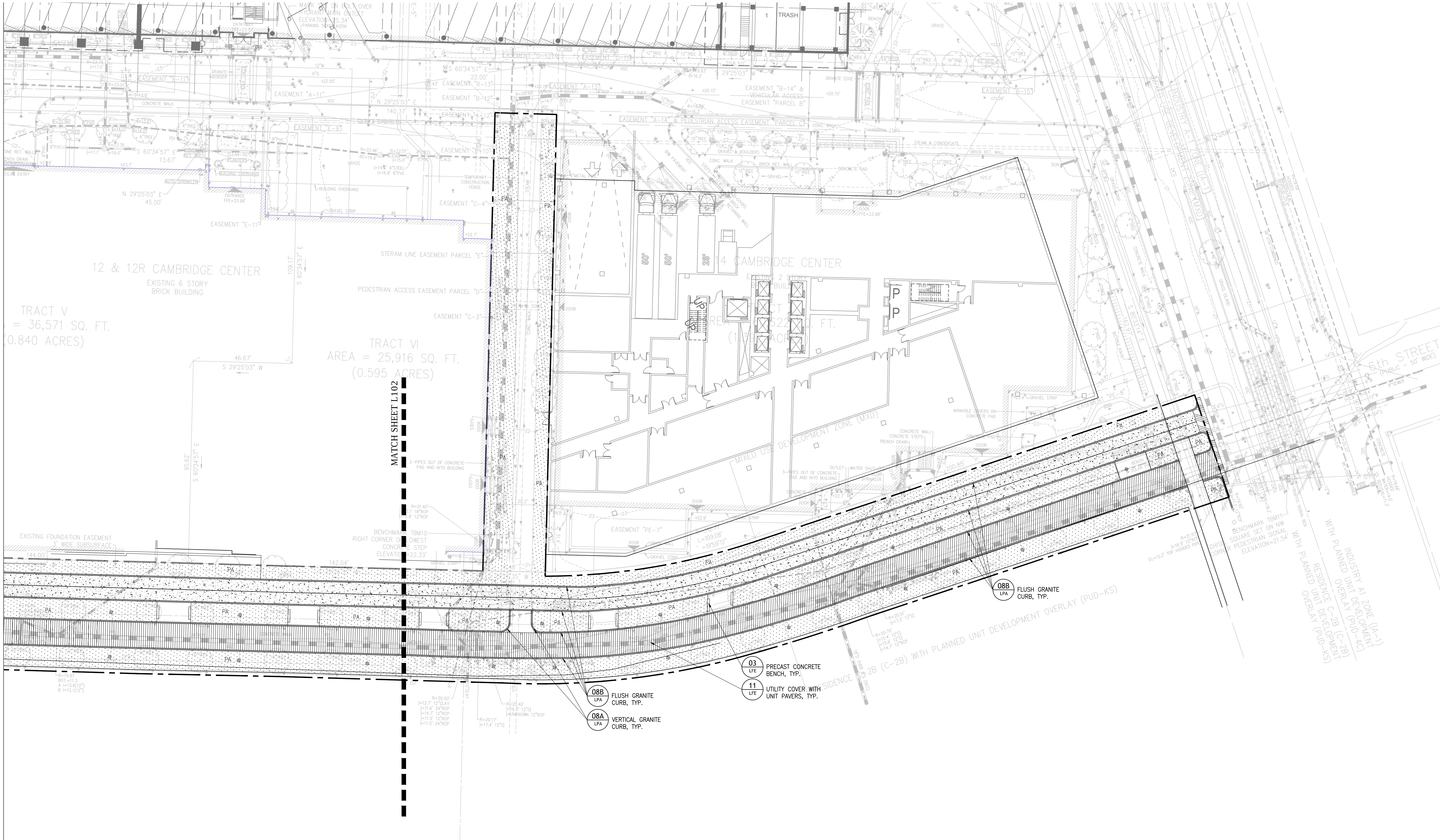
R2.2 **145 BROADWAY LANDSCAPE**

SITE PLAN

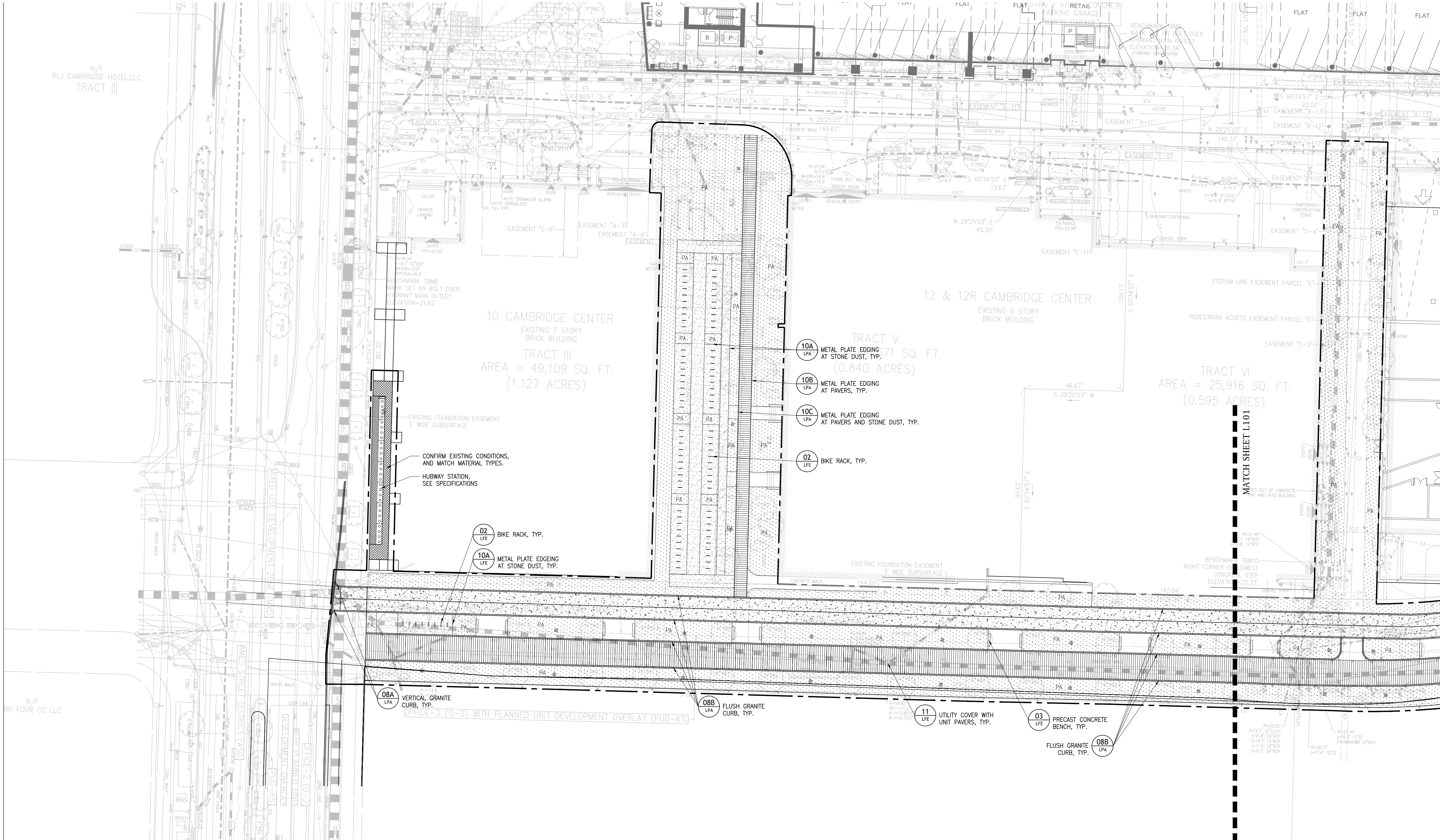


R2.3 6TH STREET CONNECTOR

PLANS

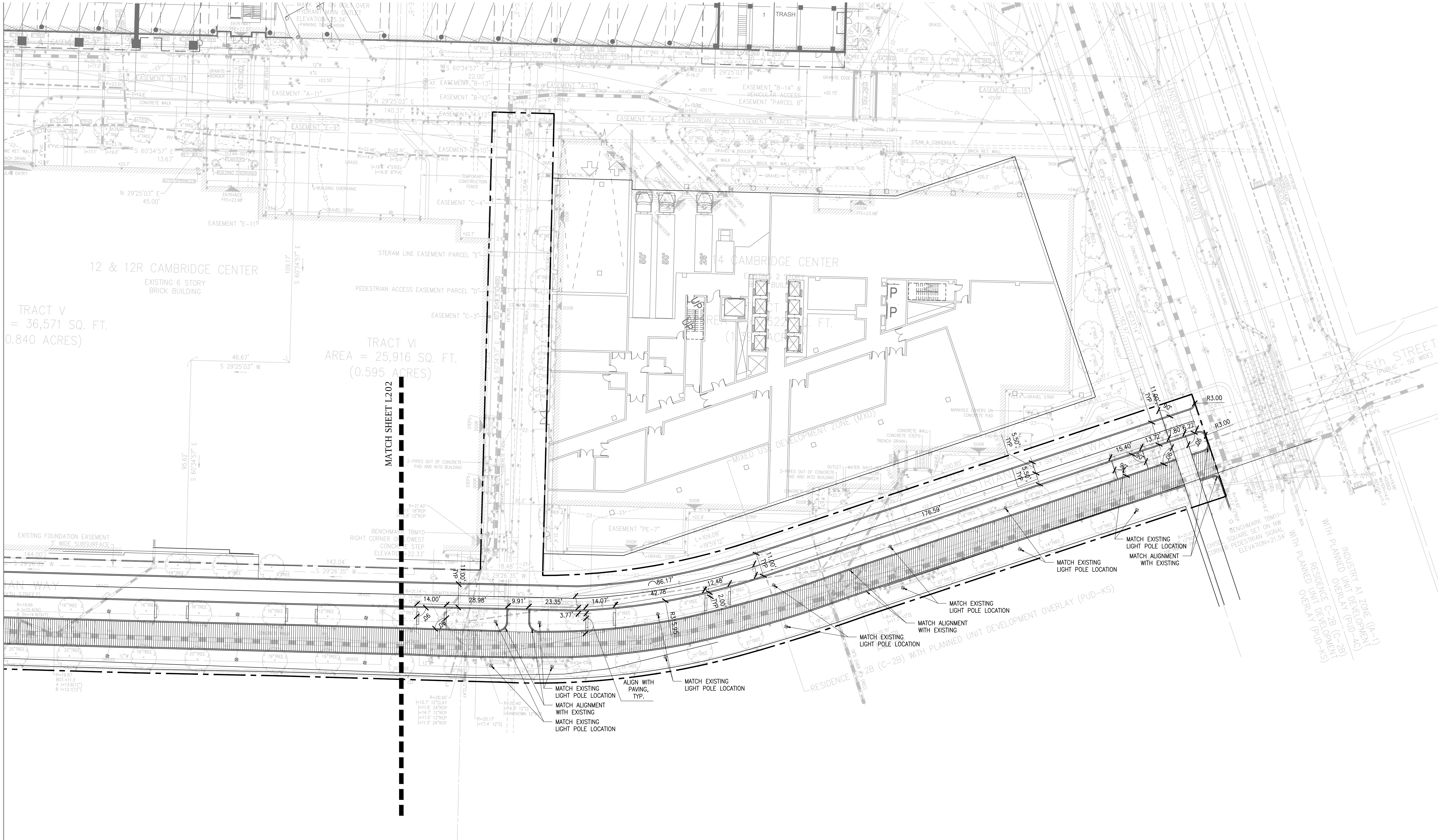


2.3 6TH STREET CONNECTOR
PLANS



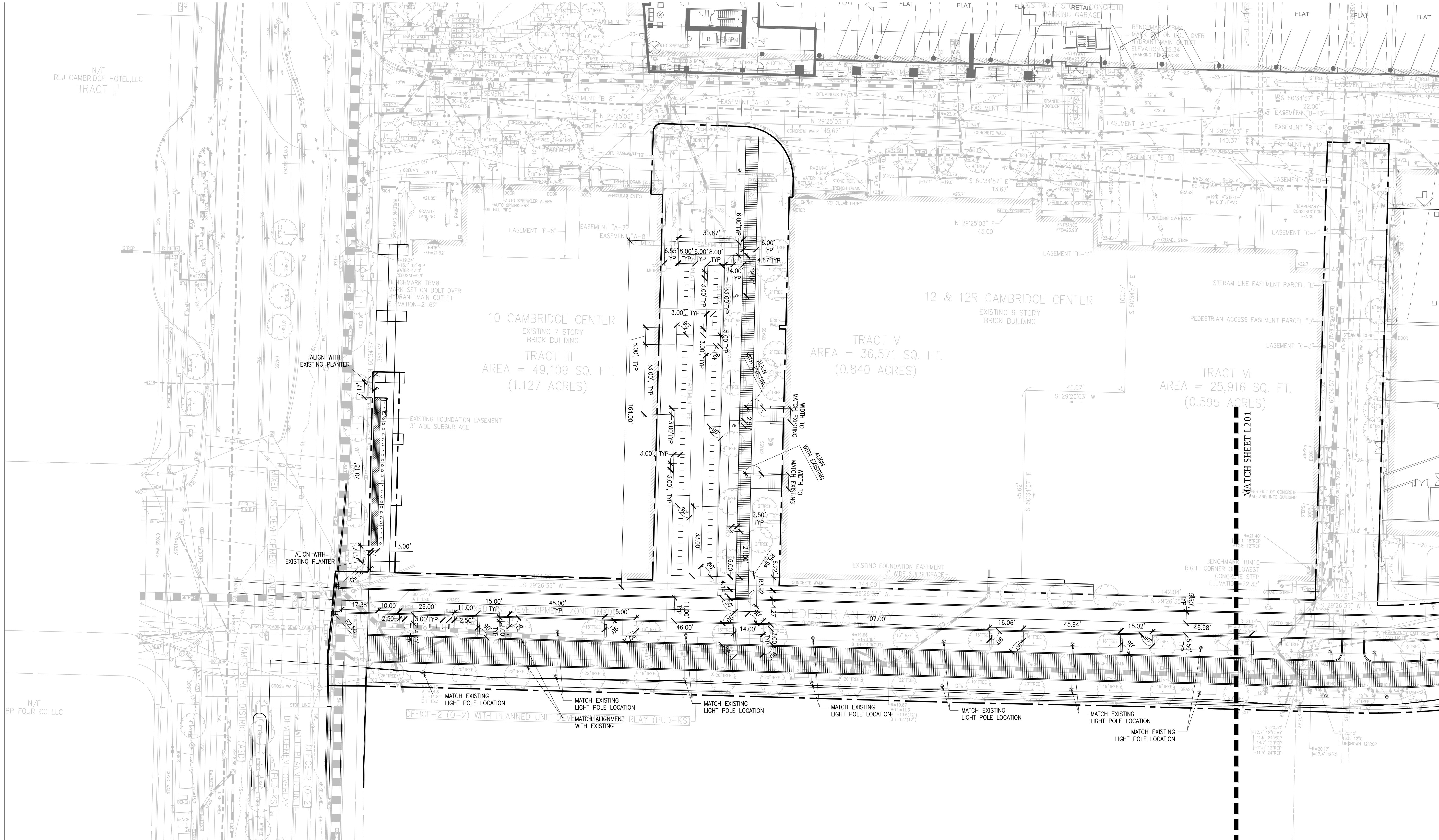
2.3 6TH STREET CONNECTOR

PLANS



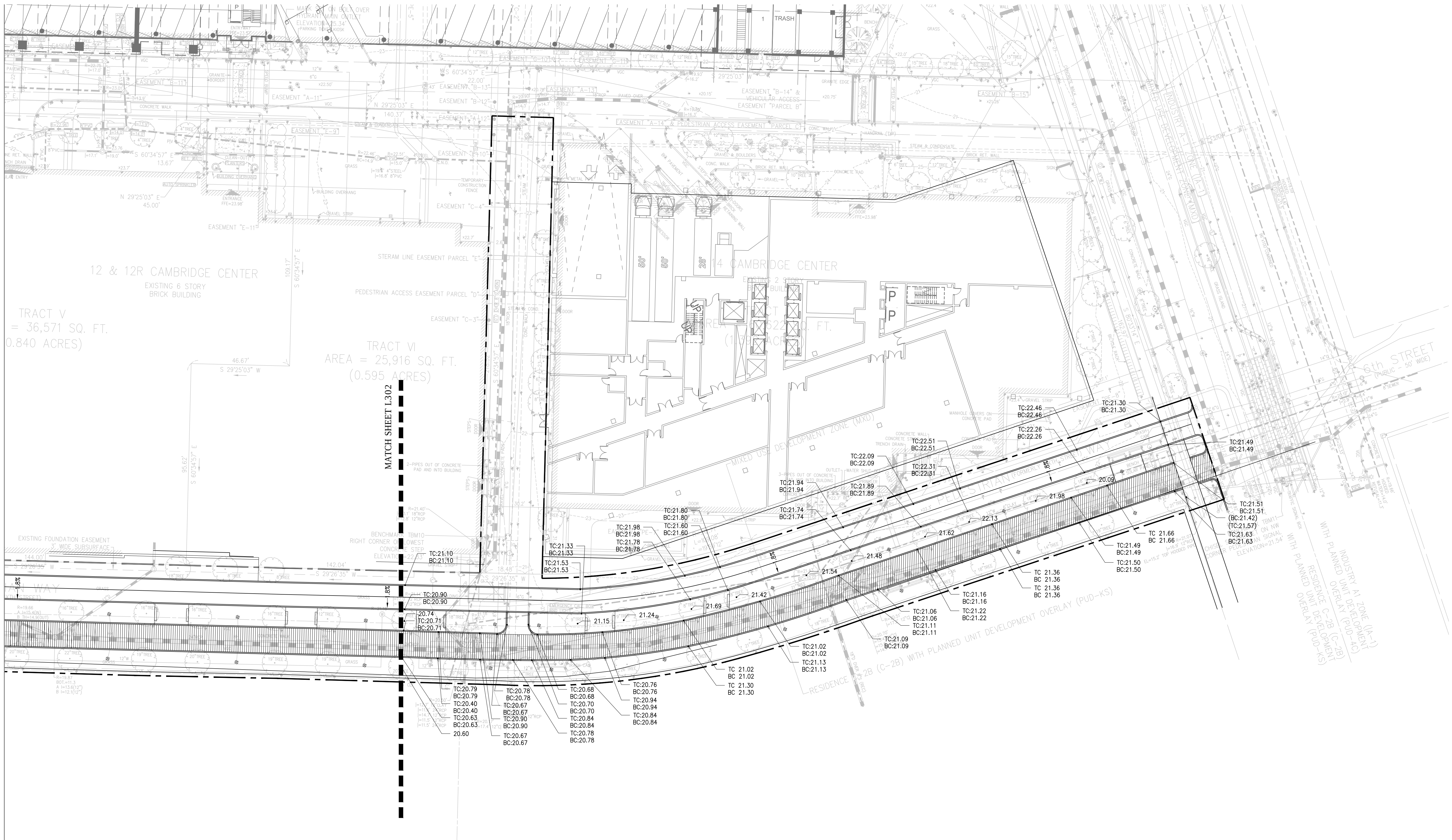
2.3 6TH STREET CONNECTOR

PLANS

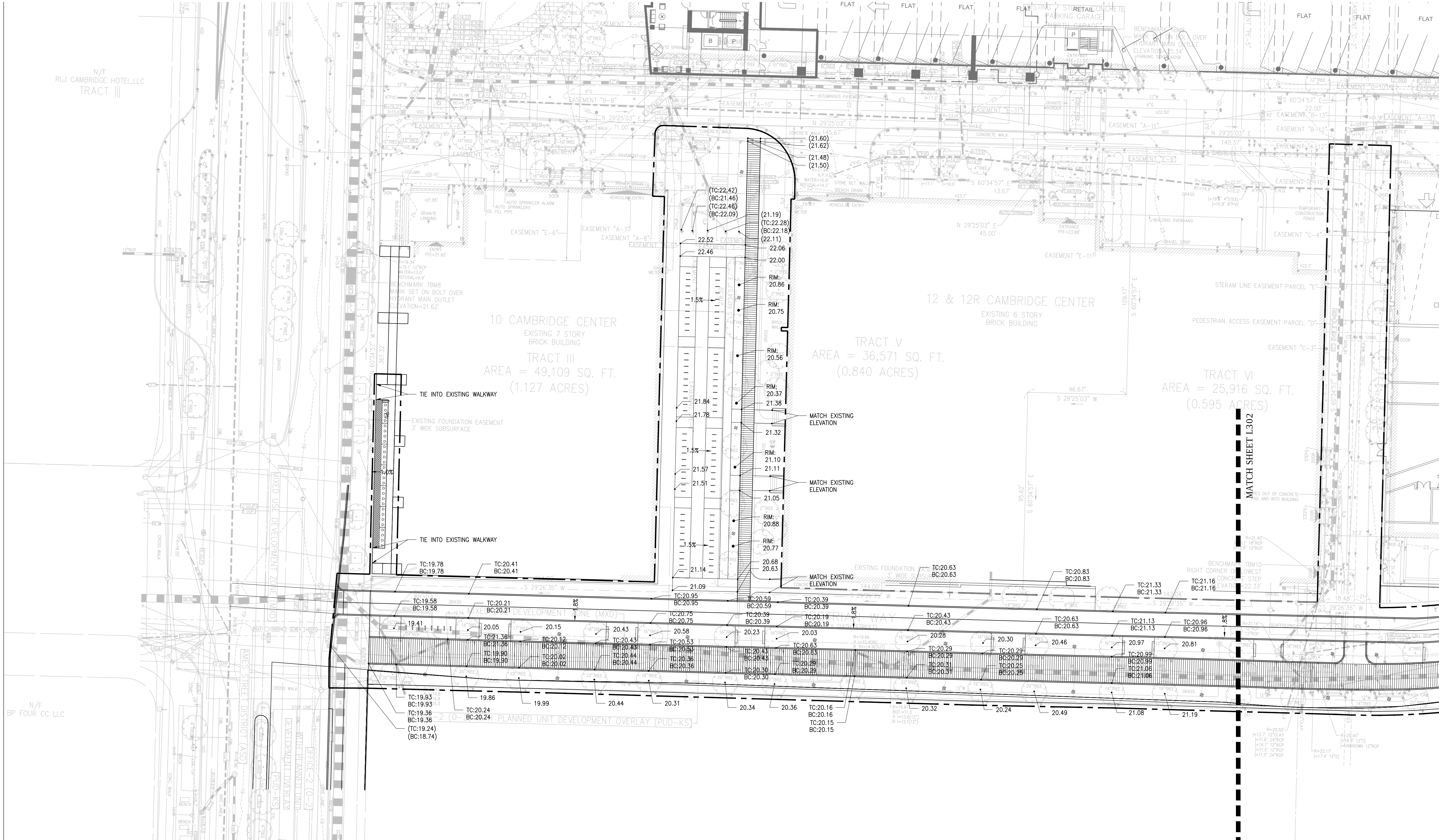


2.3 6TH STREET CONNECTOR

PLANS

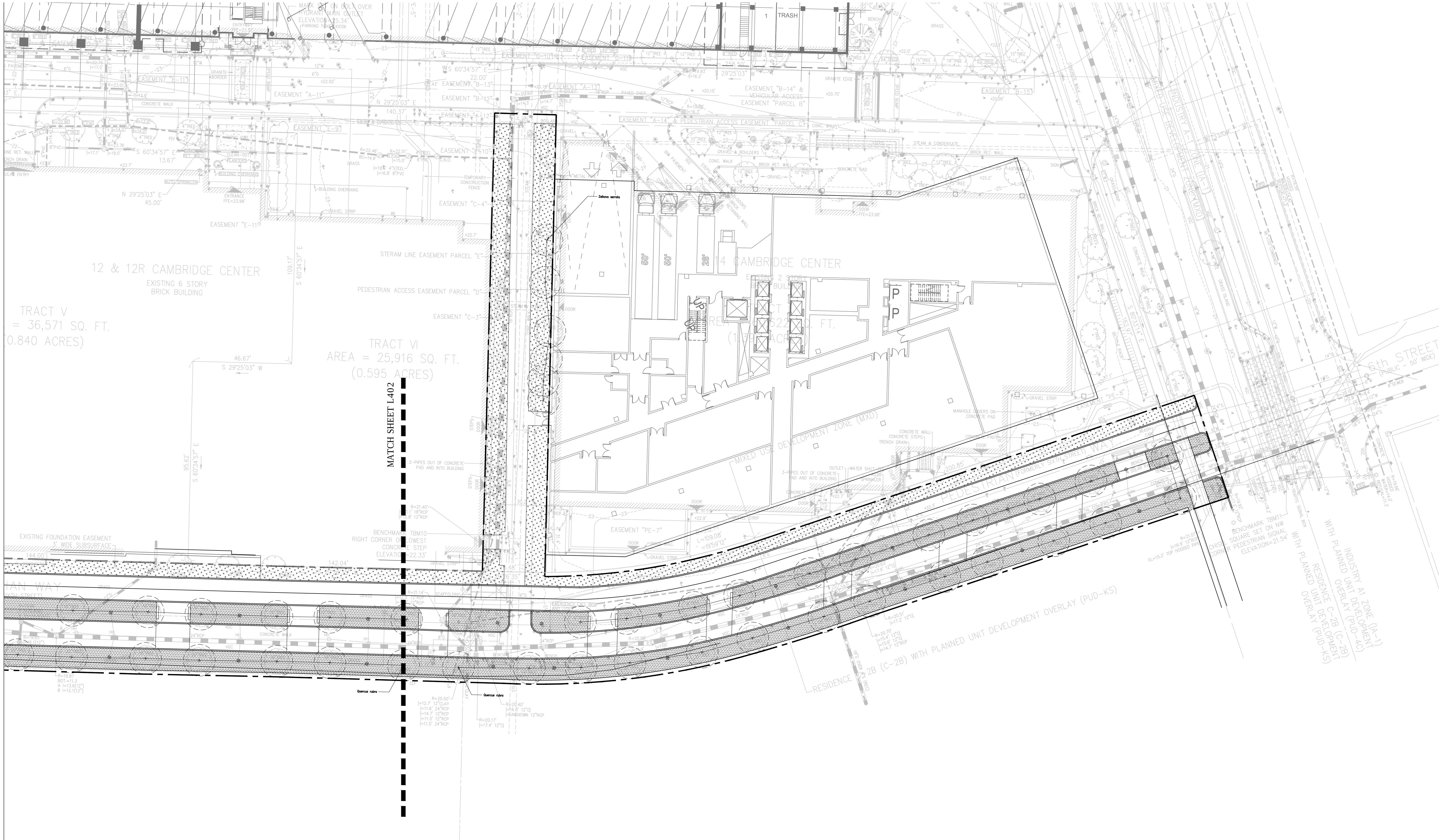


2.3 6TH STREET CONNECTOR
PLANS



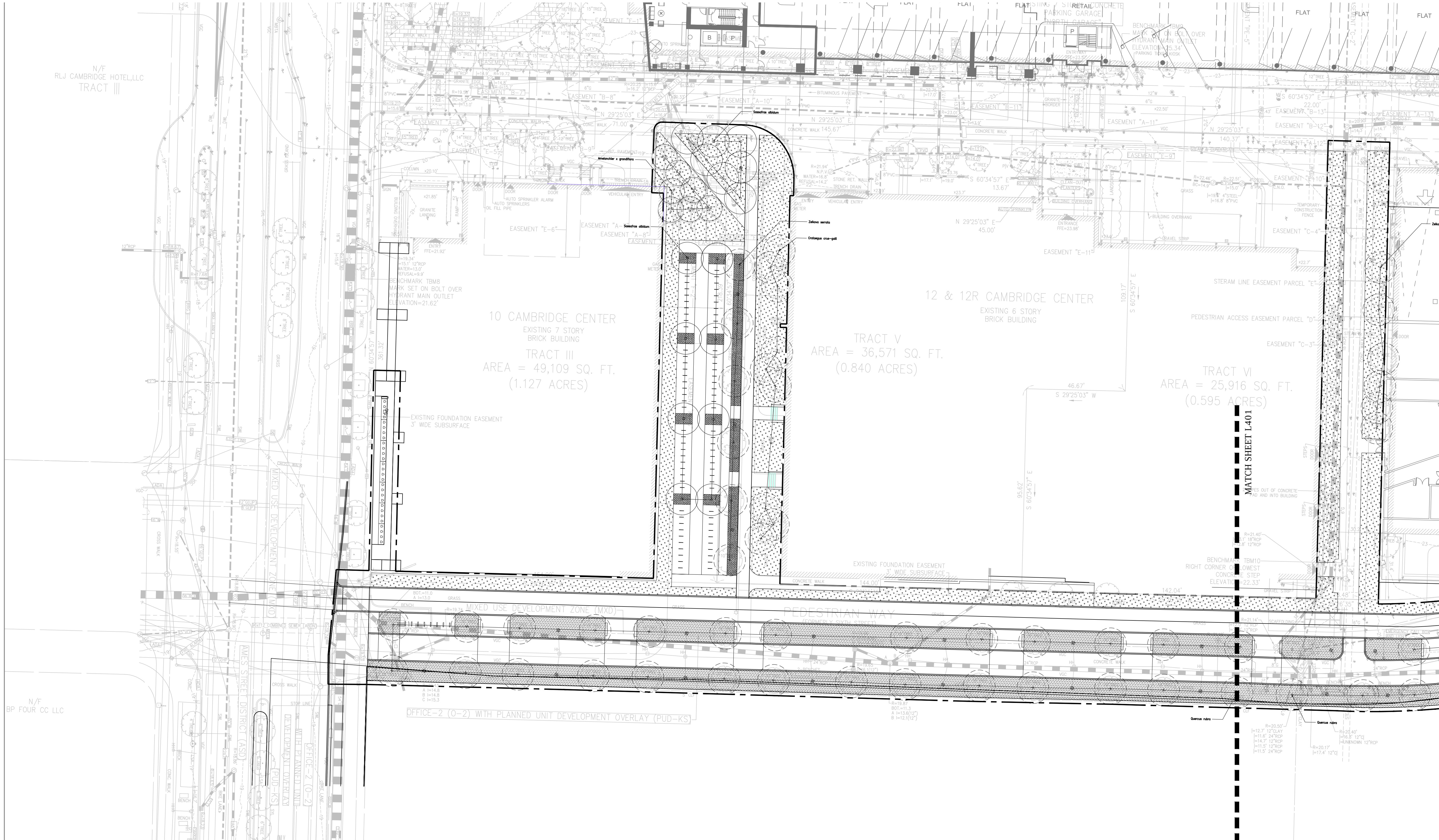
2.3 6TH STREET CONNECTOR

PLANS



2.3 6TH STREET CONNECTOR

PLANS



3. SUSTAINABILITY

R3.1 SUSTAINABILITY

NARRATIVE

Applicant received comments and expression of concern about the sustainability of the building and its potential LEED point allocation. Applicant also received comments about ensuring both an aesthetically interesting exterior while maintaining a commitment to sustainability. For clarity, the building has been registered as LEED Version 3 Gold but will achieve LEED Version 4 Gold consistent with the MXD IDCP Sustainability guidelines. An updated LEED Version 4 Gold scorecard can be found on R.3.2. The updated scorecard shows additional points related to energy and atmosphere. In addition to high performance glass curtain wall, 145 Broadway will feature a chilled beam mechanical system resulting in substantial energy savings.

In addition to a revised LEED score card and a commitment to the more stringent standards introduced by LEED Version 4, Applicant has provided the following studies consistent with the requirements of the IDCP Sustainability Guidelines:

A **Resiliency Plan** can be found on R3.3

A **Pathway to Net Zero Plan** can be found on R3.4

A **Ground Source Heat Pump Analysis** can be found on R3.5

Comment Reference: PLNBoard7, PLNBoard14, PLNBoard12

LEED v4 for Core and Shell Development

Project Name: **Commercial Building A at 145 Broadway**
Address: Cambridge, MA
Date of Issue: **11/21/2016**

Yes	Maybe	No			
1	0	0		**Integrative Process**	1
1			Credit 1	**Integrative Process**	1

Yes	Maybe	No			
16	4	0		**Location and Transportation**	20
		0	Credit 1	**LEED for Neighborhood Development Location**	20
2			Credit 2	**Sensitive Land Protection**	2
	3		Credit 3	**High Priority Site**	3
6			Credit 4	**Surounding Density and Diverse Uses**	6
6			Credit 5	**Access to Quality Transit**	6
1			Credit 6	**Bicycle Facilities**	1
	1		Credit 7	**Reduced Parking Footprint**	1
1			Credit 8	**Green Vehicles**	1

Yes	Maybe	No			
5	4	2		**Sustainable Sites**	11
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
1			Credit 1	**Site Assessment**	1
		2	Credit 2	**Site Development; Protect or Restore Habitat**	2
	1		Credit 3	**Open Space**	1
	3		Credit 4	**Rainwater Management**	3
2			Credit 5	**Heat Island Reduction**	2
1			Credit 6	**Light Pollution Reduction**	1
1			Credit 7	**Tenant Design and Construction Guidelines**	1

Yes	Maybe	No			
8	0	3		**Water Efficiency**	11
Y			Prereq 1	**Outdoor Water Use Reduction**	Required
Y			Prereq 2	**Indoor Water Use Reduction**	Required
Y			Prereq 3	**Building-level Water Metering**	Required
2			Credit 1	**Outdoor Water Use Reduction**	2
3		3	Credit 2	**Indoor Water Use Reduction**	6
2			Credit 3	**Cooling Tower Water Use**	2
1			Credit 4	**Water Metering**	1

Yes	Maybe	No			
18	4	11		**Energy and Atmosphere**	33
Y			Prereq 1	**Fundamental Commissioning and Verification**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Building-level Energy Metering**	Required
Y			Prereq 4	**Fundamental Refrigerant Management**	Required
6			Credit 1	**Enhanced Commissioning**	6
7	1	10	Credit 2	**Optimize Energy Performance**	18
1			Credit 3	**Advanced Energy Metering**	1
1	1		Credit 4	**Demand Response**	2
	2	1	Credit 5	**Renewable Energy Production**	3
1			Credit 6	**Enhanced Refrigerant Management**	1
2			Credit 7	**Green Power and Carbon Offsets**	2

Yes	Maybe	No			
3	5	6		**Materials and Resources**	14
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
Y			Prereq 2	**Construction and Demolition Waste Management Planning**	Required
	3	3	Credit 1	**Building Life-cycle Impact Reduction**	6
1	1		Credit 2	**Building Product Disclosure and Optimization**-Environmental Product Declarations	2
		2	Credit 3	**Building Product Disclosure and Optimization**-Sourcing of Raw Materials	2
	1	1	Credit 4	**Building Product Disclosure and Optimization**-Material Ingrediants	2
2			Credit 5	**Construction and Demolition Waste Management**	2

Yes	Maybe	No			
4	1	5		**Indoor Environmental Quality**	10
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
2			Credit 1	**Enhanced IAQ Strategies**	2
1		2	Credit 2	**Low-Emitting Materials**	3
1			Credit 3	**Construction IAQ Management Plan**	1
		3	Credit 7	**Daylight**	3
	1		Credit 8	**Quality Views**	1

Yes	Maybe	No			
6	0	0		**Innovation**	6
1			Credit 1	**Exemplary Performance in SSc2**	1
1			Credit 2	**Exemplary Performance in SSc4.1**	1
1			Credit 3	**Exemplary Performance in SSc7.1**	1
1			Credit 4	**ID Credit: Green Cleaning**	1
1			Credit 5	**ID Credit: Integrated Pest Management**	1
1			Credit 6	**LEED Accredited Professional**	1

Yes	Maybe	No			
0	4	0		**Regional Priority**	4
			Regional Priority: Cambridge		
	1		Credit 1	**EAc5 Renewable energy production (2 pts)**	1
	1		Credit 2	**EAc2 Optimize energy performance (8 pts)**	1
	1		Credit 3	**MRc1 Building Life-Cycle Impact Reduction (2pts)**	1
	1		Credit 4	**SSc4 Rainwater management (2 pts)**	1

Yes	Maybe	No			
61	22	27			110

Certified: 40-49 points, **Silver:** 50-59 points, **Gold:** 60-79 points, **Platinum:** 80+ points

145 Broadway
Resiliency Narrative
November 21, 2016
The Green Engineer

The site design measures included in the Sustainability Guidelines in Chapter 8 of the MXD IDCP are aimed at making the each proposed building less vulnerable to climate change. These site design measures work in combination with building design measures to increase the building's resiliency. 145 Broadway has been designed to mitigate and respond to the potential impacts of climate change including extreme rain and storm events, flooding and sea level rise, high winds, and the accompanying potential power outages and demands on utilities.

The resiliency measures implemented at 145 Broadway include the following:

To reduce the heat island effect:
- Highly reflective hardscape
- Low-albedo roof
- Shade trees and planted areas

To reduce overall energy and water consumption:
- High performance envelope
- Daylighting
- High performance lighting and controls
- High performance equipment
- High performance HVAC systems including chilled beams and heat recovery
- Building wide power dimming
- Low flow water fixtures
- High-efficiency irrigation system

To ensure the integrity of critical building systems during a severe storm or power outage:
- Podium setback and overhangs to reduce the effects of high winds
- Finish floor elevation and garage entrance established above the local flood elevation
- Waterproof materials at storefront sills
- Emergency mechanical equipment placed above flood levels
- Emergency generator
- Buried utilities
- Infiltration tank
- On site retention system
- Hazard removal and protected landscapes

- Water tight utility conduits
- Waste water back flow preventers
- Storm water back-flow preventers

Pathway to Net Zero Ready

Executive Summary

The purpose of this study is to outline a potential pathway to "net zero energy ready" for the 145 Broadway project. "Net zero energy ready" is understood to be a building that has a low site energy consumption and uses no fossil fuels. The current design for 145 Broadway creates a low site energy building (EUI less than 30 kbtu/sf/yr) but relies on natural gas for heating. Future advances in lighting and control technology, and the use of air source heat pumps, could allow the building to be converted to all electric in the future. In addition there is opportunity for a small amount of onsite solar to be incorporated, but not enough to bring the building to zero net onsite.

Current Model Results

A preliminary energy model has been performed by TMP Engineers for the 145 Broadway project. In this effort, the current proposed design has been compared against a baseline building designed to meet ASHRAE 90.1-2013.

The baseline building shows the following model results:

Baseline				
	Elec (kWh)	Gas (Therms)	Total (kBTU)	% of Total
Space Heating	1,140	20,054	2,009,276	16.9%
Space Cooling	256,102		870,747	7.3%
Heat Rejection	42,961		146,067	1.2%
Fans	345,499		1,174,697	9.9%
Receptacles	1,186,446		4,033,916	33.8%
Interior Lighting	917,135		3,118,259	26.2%
Parking Garage Lighting	138,990		472,566	4.0%
Pumps	27,731		94,285	0.8%
Totals	2,916,004	20,054	11,919,814	
		Site EUI	**32.9**	**Kbtu/sf/yr**

The proposed design incorporates a large number of energy efficiency measures including: high efficiency condensing boilers, high efficiency chillers, a chilled beam hydronic heating and cooling distribution system, low lighting power density and an improved building envelope.

The proposed building shows the following model results:

Proposed					
	Elec (kWh)	Gas (Therms)	Total (kBTU)	% of Total	% Reduction vs baseline
Space Heating	1,111	19,651	1,968,877	19.2%	2.0%
Space Cooling	121,824		414,202	4.0%	52.4%
Heat Rejection	52,577		178,762	1.7%	-22.4%
Fans	310,964		1,057,278	10.3%	10.0%
Receptacles	1,186,446		4,033,916	39.3%	0.0%
Interior Lighting	655,096		2,227,326	21.7%	28.6%
Parking Garage Lighting	87,783		298,462	2.9%	36.8%
Pumps	25,476		86,618	0.8%	8.1%
Totals	2,441,277	19,651	10,265,442		13.9%
		Site EUI	**28.3**	**kBTU/sf/y**	

Future Options

Four opportunities for future improvement of 145 Broadway have been identified.

1) Lighting technology continues to improve, as LED technology and automatic lighting controls become commonplace. We assume that over time, future lighting improvements will reduce both interior lighting and parking garage lighting by about 50%.
2) Receptacle loads represent the biggest single energy end use in the proposed building, due to the high numbers of computers, monitors, printers, etc. expected in the building. Currently plug loads are growing and continue to grow, as phones, tablets, etc proliferate, along with the phantom loads their chargers create. We assume that this trend will reverse over time, and estimate a future plug load savings at 25%
3) While not currently economically feasible, the project coud eventually be converted to air source heat pump technology for

heating and cooling. We would expect this to occur at the end of life of the original HVAC systems.

Incorporating these three changes would give this approximate energy consumption:

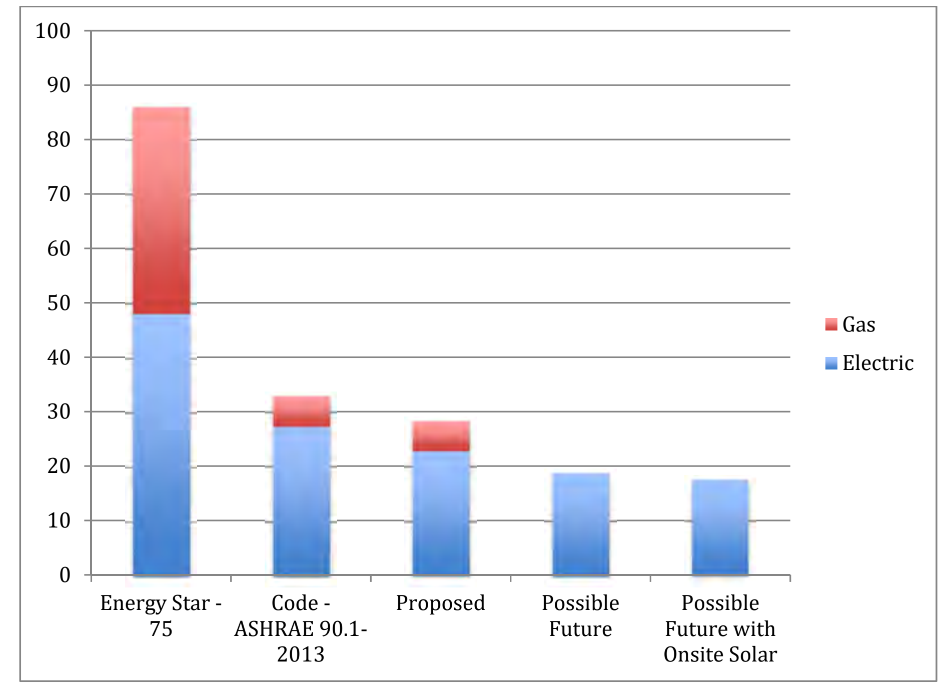
Future					
	Elec (kWh)	Gas (Therms)	Total (kBTU)	% of Total	% Reduction vs baseline
Space Heating	184,135	0	626,059	6.1%	68.8%
Space Cooling	121,824		414,202	4.0%	52.4%
Heat Rejection	52,577		178,762	1.7%	-22.4%
Fans	310,964		1,057,278	10.3%	10.0%
Receptacles	889,835		3,025,437	29.5%	25.0%
Interior Lighting	327,548		1,113,663	10.8%	64.3%
Parking Garage Lighting	43,892		149,231	1.5%	68.4%
Pumps	25,476		86,618	0.8%	8.1%
Totals	1,956,250	0	6,651,250		44.2%
		Site EUI	**18.3**	**kBTU/sf/yr**	

4) In addition, there is opportunity for some onsite solar. We estimate about 60kWp capacity is available based on current PV technology.

Future + Onsite Solar					
	Elec (kWh)	Gas (Therms)	Total (kBTU)	% of Total	% Reduction vs baseline
Space Heating	184,135	0	626,059	6.1%	68.8%
Space Cooling	121,824		414,202	4.0%	52.4%
Heat Rejection	52,577		178,762	1.7%	-22.4%
Fans	310,964		1,057,278	10.3%	10.0%
Receptacles	889,835		3,025,437	29.5%	25.0%
Interior Lighting	327,548		1,113,663	10.8%	64.3%
Parking Garage Lighting	43,892		149,231	1.5%	68.4%
Pumps	25,476		86,618	0.8%	8.1%
Solar	-75,000		-255,000	-2.5%	n/a
Totals	1,881,250	0	6,396,250		46.3%
		Site EUI	**17.6**	**kBTU/sf/yr**	

Any further carbon emission reductions would have to come through greening of grid electricity and/or carbon offsets.

In context we see that the current proposed design is low energy, compared to a typical office building scoring 75 on the Energy Star scale.



Conclusions

The current design results in a low energy building. Advances in technology will further reduce consumption. The future conversion to heat pump technology would allow the building to be “net zero energy ready”. While there are some opportunities for onsite renewables it is not expected to be sufficient to meet all the buildings future energy needs. To achieve carbon neutrality, greening of grid electricity or the purchase of carbon offsets would have to occur.

Ground Source Heat Pump Analysis

Executive Summary

145 Broadway is designed with a high-efficiency heating and cooling system including high-efficiency condensing boilers, water-cooled chillers, and cooling towers. An alternative ground source heat pump (GSHP) cooling system has been analyzed. The analysis shows that the GSHP system would increase capital costs by more than $1 million dollars, and energy costs by about $10,000 per year, while reducing carbon emissions by less than 1%. In addition an area of more than 1 acre would be required for the well field. Based on these results the GSHP alternative does not appear attractive.

Analysis

Our analysis is based on energy modeling result tabulated by TMP Consulting engineers. Peak and annual loads from their model have been post-processed to estimate the change in energy consumption. This is intended to be a conceptual level analysis – full simulation of the GSHP has not been performed.

The base design is the conventional systems shown in the current design documents. This includes 95% efficient condensing boilers and water-cooled chillers with an efficiency of approximately 0.59 kW per ton. The alternative system proposed would replace the boilers and chillers with water-to-water ground source heat pumps. The heat pump efficiencies are estimated to be 3.4 COP for heating and 18.2 EER for cooling (Based on Climate Master Tranquility Series).

Utility rates are estimated as follows:
Natural gas – $1.10 per therm,
Electricity - $0 .17 per kilowatt-hour.

Our analysis assumes an estimated cooling load of about 600 tons, and estimated heating load of 4.6 million BTU per hour.

The table below shows the results of our analysis.

	Gas Consumption (Therms)	Electricity Consumption (kWh)	Energy Cost ($)	Source Energy (kBTU)
Baseline	19,721	370,757	$84,722	6,028,909
GSHP	0	562,645	$95,650	6,006,803
Savings	19,721	-191,888	-$10,928	22,106

These numbers represent the consumption for the heating and cooling plant only. The energy penalty represents an increase in total energy costs of about 2.7%

Installation Costs

A rough estimate of installation costs for the GSHP system has also been performed. The 600-ton cooling load would require about 150 separate 400 foot deep boreholes. The cost of each borehole is estimated to be in the range of $10,000, generating a total cost of the well field of $1.5 million. Assuming a 20-foot spacing between wells, the well field would be approximately one acre in size.

Other costs are assumed to be roughly equal between the base system and the GSHP system the cost of heat pumps would be roughly offset by the savings in eliminating the boilers and chillers.

Other Considerations

The primary advantage of the GSHP is that it would eliminate the use of fossil fuels on site. It should also be noted that utility rates change, and an increase in the price of natural gas relative to electricity would make the GSHP more financially attractive.

Conclusions

While GSHP systems are typically very efficient, the proposed chiller-boiler system is also highly efficient, and shows lower energy costs in both the heating and cooling seasons. The elimination of fossil fuels is a worthy long term goal but the very high initial costs and the lack of any energy cost savings make this a difficult investment to undertake. In addition the size of the well field itself presents a challenge on this constrained site. All factors considered, the GSHP alternative does not appear attractive.

4. ENVIRONMENTAL IMPACT

R4.1 ENVIRONMENTAL IMPACT

NARRATIVE

Applicant received questions about the wind study provided in the MXD Infill Development Concept Plan submitted on August 9, 2016 and comments about potential canopies along the Western facade and other proposed mitigations. Consistent with representations in the MXD IDCP Response, Applicant has provided a wind study of 145 Broadway within the Existing Conditions wind tunnel study provided in the MXD IDCP Response. As is often the case, some unfavorable wind conditions have been forecasted in the winter months in parts of Broadway Park, the pedestrian connector path north of 145 Broadway and some parts of Galileo. The wind tunnel study that is included with this 145 Broadway Design Review Submission does not include landscaping or additional wind mitigation structures that are commonly used to address forecasted, unfavorable winter wind conditions. However, this study will inform the location of additional mitigation measures to address any unfavorable winter wind conditions.

R4.3 shows an Axonometric model with proposed mitigations to address wind conditions forecasted in winter months including the addition and expansion of canopy structures along with the inclusion of marcesent trees that maintain their foliage into late fall and winter months in select locations.

Comment Reference: PLNBoard1, PLNBoard17

RWDI WIND COMFORT CRITERIA

Comfort Category	GEM Speed (mph)	Description
Sitting	≤ 6	Calm or light breezes desired for outdoor restaurants and seating areas where one can read a paper without having it blown away
Standing	≤ 8	Gentle breezes suitable for main building entrances and bus stops
Strolling	≤ 10	Moderate winds that would be appropriate for window shopping and strolling along a downtown street, plaza or park
Walking	≤ 12	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering
Uncomfortable	> 12	Strong winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended

Notes: (1) Gust Equivalent Mean (GEM) speed = *max*(mean speed, gust speed/1.85); and
(2) GEM speeds listed above are based on a seasonal exceedance of 20% of the time between 6:00 and 23:00.

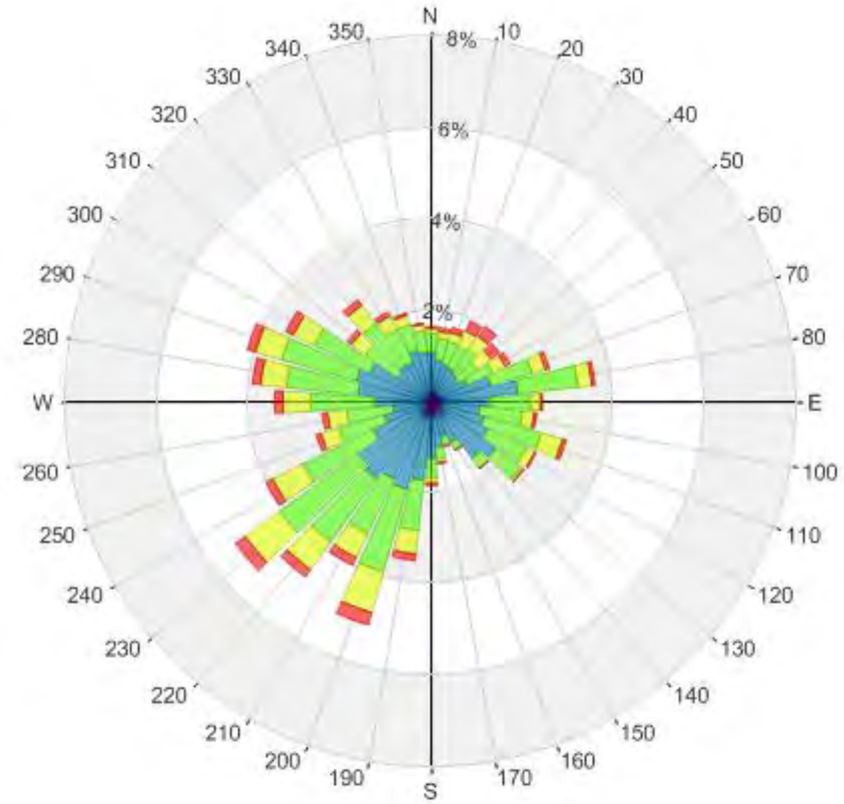
Safety Criterion	Gust Speed (mph)	Description
Exceeded	> 56	Excessive gust speeds that can adversely affect a pedestrian's balance and footing. Wind mitigation is typically required.

Note: Based on an annual exceedance of 9 hours or 0.1% of the time for 24 hours a day.

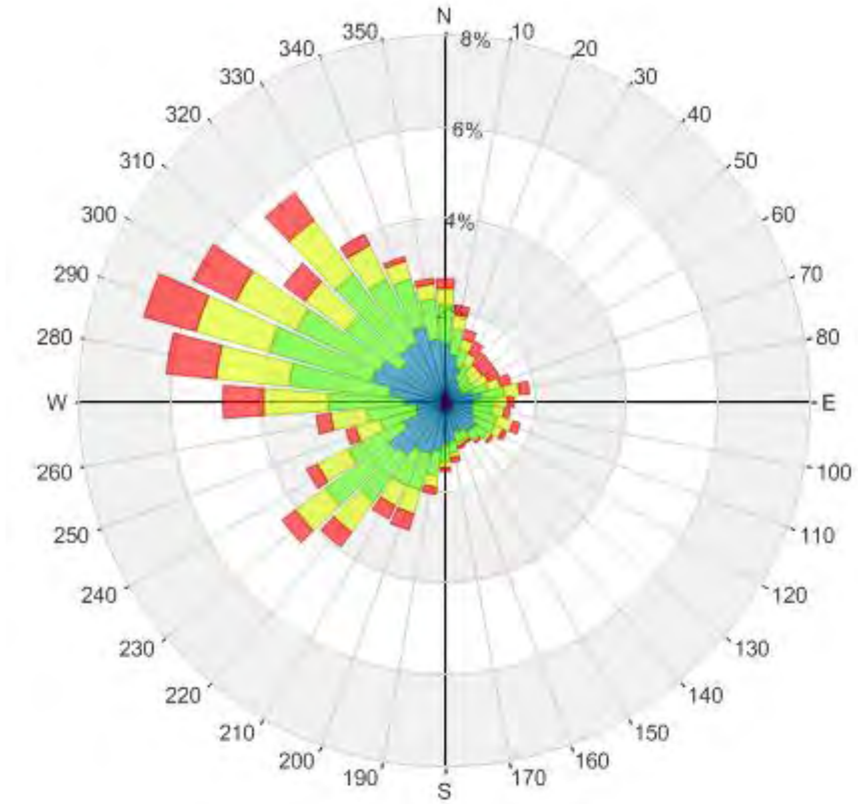
A few additional comments are provided below to further explain the wind criteria and their applications.

- Both mean and gust speeds can affect pedestrian's comfort and their combined effect is typically quantified by a Gust Equivalent Mean (GEM) speed, with a gust factor of 1.85.
- Instead of standard four seasons, two periods of summer (May to October) and winter (November to April) are adopted in the wind analysis, because in a moderate or cold climate such as that found in Cambridge, there are distinct differences in pedestrian outdoor behaviors between these two time periods.
- Nightly hours between midnight and 5 o'clock in the morning are excluded from the wind analysis for wind comfort since limited usage of outdoor spaces is anticipated.
- A 20% exceedance is used in these criteria to determine the comfort category, which suggests that wind speeds would be comfortable for the corresponding activity at least 80% of the time or four out of five days.

- Only gust winds need to be considered in the wind safety criterion. These are usually rare events, but deserve special attention in city planning and building design due to their potential safety impact on pedestrians.
- These criteria for wind forces represent average wind tolerance. They are sometimes subjective and regional differences in wind climate and thermal conditions as well as variations in age, health, clothing, etc. can also affect people's perception of the wind climate. Comparisons of wind speeds for different building configurations are the most objective way in assessing local pedestrian wind conditions.



Summer
(May - October)



Winter
(November - April)

Wind Speed (mph)	Probability (%) Summer	Winter
Calm	3.2	2.7
1-5	8.9	6.7
6-10	36.7	28.4
11-15	33.9	31.2
16-20	13.0	19.5
>20	4.2	11.5

Directional Distribution (%) of Winds (Blowing From)
Boston Logan International Airport (1995 - 2015)

Kendall Square Masterplan – Cambridge, MA

Project #1603158

Figure No. 2

Date: November 16, 2016

RWDI

PEDESTRIAN WIND ASSESSMENT

Wind Tunnel Study Model **Existing**		Figure No. 1a	
Kendall Square Masterplan – Cambridge, MA	Project #1603158	Date: November 16, 2016	RWDI