125CPD

125 CAMBRIDGEPARK DRIVE

APPLICATION FOR SPECIAL PERMIT: **VOLUME 1**
PLANNING BOARD NUMBER: [TBD]

SUBMITTED: JULY 18, 2022
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SUBMITTED TO: CITY OF CAMBRIDGE

SUBMITTED BY: LONGFELLOW REAL ESTATE PARTNERS

PREPARED BY: ELKUS MANFREDI ARCHITECTS

ELKUS | MANFREDI ARCHITECTS

LONGFELLOW

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REVIVAL
125
CAMBRIDGEPARK DRIVE

SECTION 1

Application Forms

1A. Cover Letter

LONGFELLOW™

July 18, 2022

Chair Catherine Preston Connolly
and Members of the Cambridge Planning Board
344 Broadway
Cambridge, MA 02139

Re: 125 CambridgePark Drive

Dear Chair Connolly:

Longfellow Real Estate Partners (the "Applicant") on behalf of PPF OFF 125 Cambridge Park Drive, LLC are pleased to submit the enclosed special permit application and related materials for the proposed redevelopment of an existing building located 125 CambridgePark Drive Cambridge, Massachusetts (the "Site") including construction of an approximately 33,000-SF addition to certain building upgrades and site improvements (the "Project").

The enclosed application is presented in three volumes, structured as follows:

- **Volume 1** contains various supporting written materials for issuance of the requested special permits, including special permit forms, a general site history and Project description, a summary of the requested special permits and detailed responses to applicable special permit approval criteria.
- **Volume 2** contains our project plans and illustrations including our massing, parking, and sustainability plans. Volume 2 also includes our proposed ground floor activation, architectural character and landscape plans.
- **Volume 3** contains Article 22 Green Building Report.

The building is the third technical office building in the applicant's portfolio on CambridgePark Drive, which also includes 100 and 150 CambridgePark Drive, as well as the parking garage at 140 CambridgePark Drive. Over the last several years, the Applicant has implemented numerous upgrades to all three buildings. In addition, significant site improvements have been completed and are underway on both sides of CambridgePark Drive. The Project brings to completion these efforts as well as the work begun in 2018—the initial improvements to the northern edge of the Site establishing the pedestrian connection to the Alewife Reservation—by bringing the open space deep into the Site with pedestrian connections to the Building, CambridgePark Drive and the Alewife triangle area. The Project thus completes the missing piece needed to realize the full potential of the Site.

The Project has been designed in accordance with the provisions of the Wetlands Protection Act and the City's Floodplain Zoning Ordinance for land subject to flooding. In response to the City of Cambridge Climate Change Vulnerability Assessment initial recommendations, the Project has been designed for anticipated flooding events and flood elevations for the Year 2070. Additionally, the Project has been designed with regards to the City of Cambridge Climate Change Vulnerability Assessment recommendations for the following: Prepared Community, Adapted Buildings, Resilient Infrastructure, and Resilient Ecosystems. In accordance with the Envision Alewife Plan, the Project incorporates certain sustainable features, including solar photovoltaic (PV) panels, Electric Vehicle charging stations and green roofs, and the Project is targeting LEED Gold.

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Special Permits and Amendments Sought

The Applicant respectfully requests that the following special permits and minor amendment be granted by the Planning Board to permit the redevelopment of the Site into the Project:

- Special Permit under Section 20.70 of the Ordinance for construction in the Flood Plain Overlay District.
- Special Permit under Section 20.95.1 of the Ordinance to allow a Floor Area Ratio (“FAR”) of approximately 1.75.
- Special Permit under Section 20.95.2(6) of the Ordinance to allow for a maximum building height of up to 85 feet.
- Amendment to the existing Special Permit #PB26 to reflect a reduction in the number of spaces on the Site from 176 to 85, while maintaining up to 200 dedicated spaces within the adjacent parking garage located at 140 CambridgePark Drive.
- Amendment to the Existing Special Permit under Section 20.94.1 to reflect an expansion of the existing restaurant space resulting from the construction of an approximately 1,300-square-foot patio.

In order to submit a complete and informative set of materials, the Applicant has met with neighborhood groups and consulted with many City departments and officials, including the Community Development Department, the Traffic, Parking and Transportation Department, the Water Department, the Department of Public Works, the Fire and Police Departments and the City Arborist, in preparing the enclosed application.

For the reasons set forth in the enclosed application, the Project is consistent with the City’s planning goals and complies with the applicable criteria for the relief requested. Accordingly, we respectfully request that the Planning Board schedule the enclosed application for the Board’s earliest available meeting to begin review of the same.

Thank you for your consideration of this application. We look forward to presenting to the City of Cambridge Planning Board.

Very truly yours,

Matt Lerner
Senior Project Manager
Longfellow

Enclosures

1B. Cover Sheet

CITY OF CAMBRIDGE, MASSACHUSETTS

PLANNING BOARD

CITY HALL ANNEX, 344 BROADWAY, CAMBRIDGE, MA 02139

SPECIAL PERMIT APPLICATION • COVER SHEET

In accordance with the requirements of the City of Cambridge Zoning Ordinance, the undersigned hereby petitions the Planning Board for one or more Special Permits for the premises indicated below.

Location of Premises:	125 Cambridgepark Drive
Zoning District:	Office-2A (O-2A), Alewife Overlay District 6 (AOD-6) Flood Plain
Applicant Name:	Matt Lerner, Longfellow Real Estate Partners
Applicant Address:	260 Franklin Street, Suite 1920, Boston, MA 02210
Contact Information:	617 303 2900 (Telephone #) mlerner@lfrep.com (Email Address) (Fax #)

List all requested special permit(s) (with reference to zoning section numbers) below. *Note that the Applicant is responsible for seeking all necessary special permits for the project. A special permit cannot be granted if it is not specifically requested in the Application.*

1.Special Permit under Section 20.70 of the Ordinance for construction in the Flood Plain Overlay District. 2.Special Permit under Section 20.95.1 of the Ordinance to allow a Floor Area Ratio ("FAR") of approximately 1.75. 3.Special Permit under Section 20.95.2(6) of the Ordinance to allow for a maximum building height of up to 85 feet. 4.Amendment to the Existing Special Permit under Section 20.97.2 to reflect a reduction in the number of spaces within the Surface Lot from approximately 179 to 85.

List all submitted materials (include document titles and volume numbers where applicable) below.

Volume 1: Cover Sheet, Dimensional Form, Ownership Certificates, Fee Schedule, Project Narrative, Neighborhood Outreach
Volume 2: Site Survey, Site Plan, Existing Conditions Photos, Building Floor Plans and Elevations, Perspective Renderings, Landscape Plans, Bicycle Facilities, Green Roofs, Sustainability Tree Study
Volume 3: Green Building Report: Narrative, LEED Checklist, Energy Model

Signature of Applicant:

For the Planning Board, this application has been received by the Community Development Department (CDD) on the date specified below:

Date Signature of CDD Staff

1C. Ownership Certificate

OWNERSHIP CERTIFICATE

Project Address: 125 Cambridgepark Drive **Application Date:**

This form is to be completed by the property owner, signed, and submitted with the Special Permit Application:

I hereby authorize the following Applicant: Longfellow Real Estate Partners
at the following address: 260 Franklin St Suite 1920, Boston, MA 02110
to apply for a special permit for: See Attached.
on premises located at: 125 Cambridgepark Drive
for which the record title stands in the name of: PPF OFF 125 CAMBRIDGE PARK DR, LLC
whose address is: 150 Cambridgepark Dr., Cambridge, MA 02140

by a deed duly recorded in the:
Registry of Deeds of County: Middlesex S. Book: 69471 Page: 366
OR Registry District of the Land Court, Certificate No.: Book: Page:

Signature of Land Owner (If authorized Trustee, Officer or Agent, so identify)

To be completed by Notary Public:

State of New York
~~Commonwealth of Massachusetts~~, County of New York

The above named Jennie Friend personally appeared before me,

on the month, day and year April 26, 2022 and made oath that the above statement is true.

Notary:

My Commission expires: 07/17/2022

JULIE F ZEITLIN
Notary Public - State of New York
NO. 01ZE6149901
Qualified In New York County
My Commission Expires

1D. Fee Schedule

FEE SCHEDULE

Project Address: 125 Cambridgepark Drive **Application Date:** 07/15/22

The Applicant must provide the full fee (by check or money order) with the Special Permit Application. Depending on the nature of the proposed project and the types of Special Permit being sought, the required fee is the larger of the following amounts:

- If the proposed project includes the creation of new or substantially rehabilitated floor area, or a change of use subject to Section 19.20, the fee is ten cents ($0.10) per square foot of total proposed Gross Floor Area.
- If a Flood Plain Special Permit is being sought as part of the Application, the fee is one thousand dollars ($1,000.00), unless the amount determined above is greater.
- In any case, the minimum fee is one hundred fifty dollars ($150.00).

Fee Calculation

New or Substantially Rehabilitated Gross Floor Area (SF): 33,056	× $0.10 =	$3,306
Flood Plain Special Permit	Enter $1,000.00 if applicable:	$1,000
Other Special Permit	Enter $150.00 if no other fee is applicable:	$ 150
TOTAL SPECIAL PERMIT FEE	**Enter Larger of the Above Amounts:**	$3,306

PROPOSED GFA	**216,981 SF**
EXISTING GFA	**183,925 SF**
NEW GFA	**33,056 SF**

1E. Dimensional Form

	Existing	Allowed or Required (max/min)	Proposed	Permitted
Lot Area (sq ft)	126,595 SF	126,595 SF	126,595 SF	
Lot Width (ft)	300 ft	300 ft	300 ft	
Total Gross Floor Area (sq ft)	183,925 SF	148,243 SF	216,981 SF	
Residential Base	N/A	N/A	N/A	
Non-Residential Base	183,925 SF	148,243 SF	216,981 SF	
Inclusionary Housing Bonus	N/A	N/A	N/A	
Total Floor Area Ratio	1.45	1.25	1.75	
Residential Base	N/A	N/A	N/A	
Non-Residential Base	1.45	1.25	1.75	
Inclusionary Housing Bonus	N/A	N/A	N/A	
Total Dwelling Units	N/A	N/A	N/A	
Base Units	N/A	N/A	N/A	
Inclusionary Bonus Units	N/A	N/A	N/A	
Base Lot Area / Unit (sq ft)	N/A	N/A	N/A	
Total Lot Area / Unit (sq ft)	N/A	N/A	N/A	
Building Height(s) (ft)	85 ft	85 ft	85 ft	
Front Yard Setback (ft)	5.85 ft	74 ft	5.85 ft	
Side Yard Setback (ft)	23.10 ft	49 ft	23.10 ft	
Side Yard Setback (ft)	23.10 ft	49 ft	23.10 ft	
Rear Yard Setback (ft)	205.72 ft	74 ft	185 ft	
Open Space (% of Lot Area)	19.8 %	15 % Min	28.6 %	
Private Open Space	N/A	N/A	N/A	
Permeable Open Space	19.8 %	25%	28.6 %	
Other Open Space (Specify)				
Off-Street Parking Spaces	379	230 to 460	279	
Long-Term Bicycle Parking	N/A	49	68	
Short-Term Bicycle Parking	N/A	17	40	
Loading Bays	1	2	3	

1F. Project Team

Owner/Project Proponent
Longfellow Real Estate Partners

Master Planner/Architect
Elkus Manfredi Architects

Legal Counsel
Goulston Storrs

Landscape Architect
OJB

Civil & Transportation Engineer
VHB

MEP/FA/FP Engineers
Vanderweil Engineers

Sustanability Consultant
The Green Engineer

Wind Consultant
RWDI Consulting Engineers

Code Consultant
Code Red

Acoustic Consultant
Acentech

Preconstruction Services
PIDC Construction

Geotechnical Engineers
Haley & Aldrich

SECTION 2

Project Narrative

2A. Project Overview

INTRODUCTION

Longfellow Real Estate Partners (the "Applicant") on behalf of PPF OFF 125 Cambridge Park Drive, LLC (the “Owner”) hereby submits this Application for Special Permit at 125 CambridgePark Drive (the “Project Site”), to authorize the construction of an approximately 33,056-SF addition (the “Addition”) expanding on the existing approximately 183,925-SF building (the “Building”) which is currently used for technical office use, in addition to certain building upgrades and site improvements (collectively, the “Project”). The Project Site is in the Office 2-A District, the Alewife Overlay District 6 and the Flood Plain Overlay District, as set forth in the Cambridge Zoning Ordinance (the “Ordinance”). The Building was constructed pursuant to Special Permit PB #26, filed with the City Clerk on September 15, 1982, and recorded with the Middlesex County Registry of Deeds at Book 14759, Page 134 (as amended as described below, the “Existing Special Permit”).

The Building is the third technical office building in the Applicant’s portfolio on CambridgePark Drive, which also includes 100 and 150 CambridgePark Drive, as well as the parking garage at 140 CambridgePark Drive. Over the last several years, the Applicant has implemented numerous upgrades to all three buildings. In addition, significant site improvements have been completed and are underway on both sides of CambridgePark Drive. The Project is a component of larger effort intended to reposition the Building (the “Overall Improvements”), as described in more detail below. The Overall Improvements will bring the overall campus to completion.

The Applicant seeks zoning relief from the Planning Board with respect to the Project, as described in Section 2B below. No additional relief is required for any other components of the Overall Improvements and accordingly this application only relates to the Project. The Project has been designed to be in conformance to the objectives, criteria and guidelines as defined in the 2019 Envision Cambridge: Alewife District Plan and current zoning requirements, as described in more detail below. The Project provides additional technical office space that will attract innovative companies to the district (achieving the goal of economic growth for the entire community), while reducing surface parking and providing new open space for the public, pedestrian and bicycle connectivity, improved vehicular flow and access, streetscape enhancements and sustainability upgrades to the Building and Project Site

EXISTING CONDITIONS

The approximately 126,621-SF Project Site is currently improved with the approximately 183,925-SF Building currently used for technical office (4.3.4.F) as well as a surface parking lot with approximately 179 spaces (the "Surface Lot"). The Project Site provides a unique opportunity to encourage multi-modal transportation and recreational use of the adjacent neighborhood amenities. Located less than a quarter mile from the Alewife MBTA station (as well as four bus lines that serve the Station, which include the Number 62, 67, 76 and 350 Buses), the Applicant seeks to encourage Building occupants to utilize public transportation by reducing the number of surface parking spaces and implementing an extensive Transportation Demand Management program. Further, the Project Site's ready access to the Alewife Reservation and its extensive bicycle and pedestrian trails in Cambridge, Arlington, and Watertown allow the Project's pedestrian and bicycle friendly design to create diverse commuting and recreational options for Building occupants. The Project brings to completion the work begun in 2018—the initial improvements to the northern edge of the Project Site establishing the pedestrian connection to the Alewife Reservation—by bringing the open space deep into the Project Site with pedestrian connections to the Building, CambridgePark Drive and the Alewife Triangle area. The Project thus completes the missing piece needed to realize the full potential of the Project Site.

ENTITLEMENT HISTORY

The Existing Special Permit granted a Flood Plain Special Permit and authorized the construction of the Building, which was originally served by surface parking on the Project Site and another lot across CambridgePark Drive. The Existing Special Permit was subsequently amended four times to modify the parking provisions for the Project Site as the adjacent surface parking was redeveloped into office and residential buildings with structured parking facilities. As described in the Existing Special Permit, as amended, the Building and the nearby buildings located at 88, 100, 130, 150 and 160 CambridgePark Drive share a total of 1,818 parking spaces located in surface lots and structured parking facilities across such parcels. Of these, the Building is allocated up to 179 spaces located in the Surface Lot, as well as up to 200 spaces within the shared parking facility located at 140 CambridgePark Drive (the "140 CPD Garage"). The Existing Special Permit was amended a fifth time in 2018 to allow retail use in the Alewife Overlay District to permit portions of the first floor of the Building to be used as a café and full-service restaurant pursuant to §4.35 of the Ordinance. The 2018 amendment permitted certain alterations to the Building façade and the construction of an approximately 1,300-SF outdoor patio along a portion of the frontage of the Project Site along CambridgePark Drive, located underneath an overhang of the Building.

OVERALL IMPROVEMENTS

The Overall Improvements comprise three components, which are to be pursued as separate and distinct undertakings. The first component of the Overall Improvements involves the tenant fit-out of approximately 60,000 SF within the Building. Certain mechanical, electrical and plumbing engineering improvements to the Building (including upgrades to rooftop mechanical equipment) is currently being done to the Building to facilitate this work. The entire area of the Building will remain technical office use (4.3.4.F) and there are no exterior changes to the Building other than the rooftop mechanical upgrades. Approximately 120,000-SF of currently-leased space within the Building will not be affected by the first component work. This work has already been permitted by City of Cambridge.

The second component of the Overall Improvements comprises the Project, as described in the following section.

The final component of the Overall Improvements will include certain improvements to ground-floor lobby and retail components to reorient the lobby and to relocate the café and restaurant spaces to face CambridgePark Drive. All work comprising the final component will be internal to the Building and there will not be an expansion of the total area dedicated to restaurant use within the Building.

PROJECT DESCRIPTION

The Project, which is the subject of the present special permit application, comprises the Addition, certain upgrades to the Building, and a reduction in surface parking, resulting in a return of the existing paved Surface Lot to open green space.

The Addition will be located on the north-west corner of the Building. The Addition will include a new loading dock with three enclosed bays (two for loading and one for trash), which will replace an existing exposed loading dock and freestanding dumpster, the existing trash storage currently located in the parking area. The Addition will pose no visual impact to CambridgePark Drive, will match the Buildings 13'-1" floor-to-floor heights and total height of 85 feet, and will reference the horizontality of the existing precast concrete and ribbon window architecture, with white horizontal metal panels aligning with the existing precast panels, while modestly increasing the amount of glazing along the northern perimeter. The Addition will also incorporate a 20-foot mechanical penthouse, which will enclose mechanical equipment. Three cooling towers and an emergency generator will be located on the penthouse roof. Rooftop equipment will feature acoustic screen walls facing the residential neighbors to the west to mitigate visual and noise impacts. Consistent with the Applicant's goal of enhancing the connectivity to the adjacent Alewife Reservation and bike path, the Project will incorporate 68 long-term bicycle spaces and 40 short-term bicycle parking spaces, which exceeds the requirements of the Ordinance with respect to the entire approximately 221,000 gross floor area that will exist at the Project Site upon completion of the Project.

The Project will also incorporate certain upgrades to the existing Building. The restaurant patio on the south side of the Property will be expanded to accommodate more outdoor seating. Similar to the existing patio, the expansion of the patio will be located underneath the overhang of the Building and will therefore represent an expansion of the gross floor area of restaurant use. The Project will also convert the ten existing balconies at the Building to green roofs, of which up to 15% will be used to provide private outdoor open space. Several new balconies built as part of the Addition will conform to the same criteria. The Project will employ several locations for on-site Solar Power Generation. A 10,000 SF, 175 kW Solar Array will be installed above the pervious parking spaces in the Surface Lot, generating renewable power while also providing shade.

The Project will also incorporate certain site work and parking reconfiguration aimed at enhancing the pedestrian connectivity between the Building, the neighborhood and the adjacent Alewife Reservation. The Project will extend northward the recent landscape upgrades between all three buildings. The Surface Lot will be reconfigured, reducing the amount of parking by half (from approximately 179 to 79) and providing substantial new open space to create a strong pedestrian connection to the Alewife Reservation along the property's northern perimeter. The landscape will play an important role in the overall stormwater strategy by creating a network of meandering low areas, similar to the rocky dry creek beds already on campus. Pervious Pavement will be used in portions of the surface parking field to maximize permeability. Seating areas are nestled within the landscape and a network of paths connects to the open space taking shape between neighboring sites to the east, 87 and 101 CambridgePark Drive currently under construction.

Finally, the Project will incorporate utility upgrades to the Project Site. The Project will include the addition of a new electric service yard in the rear of the Building to fully replace the existing yard servicing the Building. This new yard will consist of exterior rated transformer and switchgear equipment which will be sized and coordinated with Eversource Electric to service the Existing Building as well as the Addition. The existing natural gas meter is intended to be upgraded by Eversource Gas, and set on a new concrete pad adjacent to the existing building structure at its current location.

The Project has been designed in accordance with the provisions of the Wetlands Protection Act and the City's Floodplain Zoning Ordinance for land subject to flooding. In response to the City of Cambridge Climate Change Vulnerability Assessment initial recommendations, the Project has been designed for anticipated flooding events and flood elevations for the Year 2070. Additionally, the Project has been designed with regards to the City of Cambridge Climate Change Vulnerability Assessment recommendations for the following: Prepared Community, Adapted Buildings, Resilient Infrastructure, and Resilient Ecosystems. In accordance with the Envision Alewife Plan, the Project incorporates certain sustainable features, including solar photovoltaic (PV) panels, Electric Vehicle charging stations and green roofs, and the Project is targeting LEED Gold.

2B. Compliance with Zoning

The Project Site is located in the Office 2A Zoning District (O-2A), as well as the Alewife Overlay District 6 (AOD-6) and the Floor Plain Overlay District as defined in Sections 20.90 and 20.70 of the Ordinance, respectively. The current and proposed technical office for research and development/laboratory and research facility use is permitted as-of-right, and the existing restaurant uses are permitted by the Existing Special Permit. The Project's compliance with the Ordinance's dimensional requirements is summarized in the Dimensional Forms submitted with this Application. The Applicant is requesting an amendment to the Existing Special Permit and the following new special permits in connection with the Project (collectively, the "Special Permits"), to include the following relief under the Ordinance in connection with the Project:

1. Special Permit under Section 20.70 of the Ordinance for construction in the Flood Plain Overlay District.

2. Special Permit under Section 20.95.1 of the Ordinance to allow a Floor Area Ratio ("FAR") of approximately 1.75.

3. Special Permit under Section 20.95.2(6) of the Ordinance to allow for a maximum building height of up to 85 feet.

4. Amendment to the Existing Special Permit under Section 20.97.2 to reflect a reduction in the number of spaces within the Surface Lot from approximately 179 to 79, while maintaining up to 200 dedicated spaces within the 140 Garage.

5. Amendment to the Existing Special Permit under Section 20.94.1 to reflect an expansion of the existing restaurant space resulting from the construction of an approximately 1,300-square-foot patio.

2C. Zoning Requirements for Granting Requested Relief

The provisions of the Ordinance set forth below apply to the requested Special Permits. Application of each provision to the Project follows the provision in italics.

1. GENERALLY APPLICABLE CRITERIA FOR APPROVAL OF A SPECIAL PERMIT (SECTION 10.43)

Pursuant to Section 10.43 of the Ordinance, special permits will normally be granted where the specific provisions of the Ordinance are met, except when the Planning Board finds that the a particular location or use for which relief is sought would be to the detriment of the public interest due to any of the following:

1) It appears that requirements of this Ordinance cannot or will not be met.

With the requested Special Permits, the Project will meet all requirements of the Ordinance.

2) Traffic generated or patterns of access or egress would cause congestion, hazard or substantial change in established neighborhood character.

The Project will result in an overall reduction in traffic, as total parking for the Building is being reduced by approximately 100 spaces (from approximately 179 to 79). Further, the flow of traffic will be reversed from its current clockwise movement, to run counter-clockwise. With all arriving traffic coming from the east, the inbound service road will now be the first service drive encountered, on the east of the Building. As a result, the outbound vehicular egress will occur via the west service drive. This flow improves the arrival experience for building occupants and visitors by welcoming them with the landscape and open space, and creating a direct view of the Building lobby entrance. Passenger vehicles and trucks alike will use a singular outer loop to minimize pedestrian, bicycle and vehicular interactions.

3) The continued operation of or the development of adjacent uses as permitted in the Ordinance would be adversely affected by the nature of the proposed use.

The Project will not adversely affect continued operation or future development of adjacent uses. The Project Site is surrounded on the west, south and east by existing commercial and residential uses that are also located within the Alewife Overlay District 6, and the Project Site abuts the Alewife Reservation to the north. The Project will complement the existing adjacent uses by enhancing pedestrian connectivity between the nearby commercial and residential uses and provide opportunities to increase commuting and recreational use of the Alewife Reservation.

4) Nuisance or hazard would be created to the detriment of the health, safety and/or welfare of the occupant of the proposed use or the citizens of the City.

The Project will not create any nuisance or hazard to the detriment of the health, safety and/or welfare of the occupants of the Project or the citizens of the City. To the contrary, the Project will replace portions of the Surface Lot with pervious open green space and pedestrian paths that will provide safe pedestrian connectivity to the Alewife Reservation and enhance the vibrancy of the district. Further, as noted above, the Project will result in a decrease in expected traffic in the area, and the flow of traffic through the Project Site will be enhanced to minimize pedestrian, bicycle and vehicular interactions. A minimum ten-foot-high noise barrier panels will be positioned on the west and north faces of the Building to mitigate noise impacts. With these measures in place, acoustic analysis predicts sound levels of less than 50 dBA to the nearest residential dwelling unit, complying with the Cambridge Noise Ordinance's 60 dBA "daytime" and 50 dBA "all other times" facing the residential neighbor. Finally, to minimize risks associate with predicted temperature increases, the Project will aim to reduce urban heat island effect through high-albedo roofing and paving and minimize cooling loads by high performance envelope for the Building facades.

5) For other reasons, the proposed use would impair the integrity of the district or adjoining district, or otherwise derogate from the intent and purpose of this Ordinance.

The Project will not impair the integrity of any of the districts in which it is located or any adjoining district, nor will the Project derogate from the intent and purpose of the Ordinance. The construction of the Project will enhance and further the purposes of the districts in which it is located and all adjoining districts.

Alewife Overlay District 6 – *As discussed in more detail below, the Project furthers the intent of the Alewife Overlay District, including to: encourage development that will facilitate and encourage walking, biking and transit use and reduce the growth of auto trips; preserve and enhance the capacity to store floodwater, recharge groundwater and manage the collection and disposal of stormwater; minimize the negative impact of new development on adjacent residential neighborhoods while introducing new amenities and services that will benefit the residents of such neighborhoods; integrate the entire area through the creation of new pedestrian paths, roadways, green spaces and bridges that will facilitate movement within the several Districts and beyond; and create an identity and sense of place that parallels the development of the historic urban centers that characterize much of Cambridge.*

Flood Plain Overlay District – *As discussed in more detail below, the Project furthers the intent of the Flood Plain Overlay District, including to: protect the health, safety, and general welfare, to protect human life and property from the hazards of periodic flooding, to preserve the natural flood control characteristics and the flood storage capacity of the flood plain, to preserve and maintain the ground water recharge areas within the Flood Plain, and to ensure the appropriate design and location of flood water retention systems and their relationship to other surrounding development. The Project falls within the 100-year floodplain of the Little River, and has submitted a Notice of Intent ("NOI") to the Cambridge Conservation Commission in advance of hearing on July 25, 2022. The Project has been designed to provide compensatory flood storage per the Massachusetts Wetland Protection Act. More detail regarding the Project's conformance with the intent of the Flood Plain Overlay District is provided below.*

6) The new use or building construction is inconsistent with the Urban Design Objectives set forth in Section 19.30.

As described in more detail below, the Project is consistent with the City's broader health, safety and welfare goals as set forth in Section 19.30 (Citywide Urban Design Objective) of the Ordinance to foster development which is responsive to the existing or anticipated pattern of development, is designed for pedestrian and bicycle access, mitigates adverse environmental impacts upon its neighbors, and provides open space amenities.

2. CRITERIA FOR FLOOD PLAIN OVERLAY DISTRICT SPECIAL PERMIT (SECTION 20.75)

Pursuant to Section 20.75 of the Ordinance, the Planning Board shall grant a Special Permit for development in the Flood Plain Overlay District if the Board finds that such development has met the following criteria in addition to other criteria specified in Section 10.40:

1) No filling or other encroachment shall be allowed in Zone AE areas or in the floodway which would impair the ability of these Special Flood Hazard Areas to carry and discharge flood waters, except where such activity is fully offset by stream improvements such as, but not limited to, flood water retention systems as allowed by applicable law.

The Project is anticipated to provide an additional 1,844 cubic feet of flood storage on the Project site.

2) Displacement of water retention capacity at one location shall be replaced in equal volume at another location on the same lot, on an abutting lot in the same ownership, on a noncontiguous lot in the same ownership, or in accordance with the following requirements.

All displaced capacity is replaced (with surplus) on the same lot.

3) All flood water retention systems shall be suitably designed and located so as not to cause any nuisance, hazard, or detriment to the occupants of the Project Site or abutters. The Planning Board may require screening, or landscaping of flood water retention systems to create a safe, healthful, and pleasing environment.

Compensatory flood storage areas will be located within the proposed open space on the Project Site. The Project will include stormwater management best practices that will be designed to provide subsurface detention in the open space and Surface Lot. The Project also anticipates adequate screening of landscape features to promote stormwater management.

4) The proposed use shall comply in all respects with the provision of the underlying zoning district, provisions of the State Building Code, Wetlands Protection Act, and any other applicable laws.

The Addition within the existing FEMA floodplain will elevate the ground floor elevation to be above the FEMA floodplain elevation of 18.46 CCB, and elevated above the City of Cambridge 2070 projected 10-year flood event of elevation 22.0 CCB.

5) Applicants for development in the Alewife area shall be familiar with area-specific and general city-wide land use plans and policy objectives (e.g. Concord-Alewife Plan, A Report of the Concord Alewife Planning Study, November 2005; Toward a Sustainable Future, Cambridge Growth Policy, 1993, Update 2007; Section 19.30 – Urban Design Objectives of this Zoning Ordinance) and shall demonstrate how their plan meets the spirit and intent of such documents in conjunction with the requirements of this Section 20.70 – Flood Plain Overlay District and Section 20.90 – Alewife Overlay Districts 1-6.

The Applicant is aware of such City documents and will work with the City to meet these objectives to the maximum extent practicable. The Project will meet MassDEP stormwater standards for the redevelopment, however, the Applicant has received verbal agreement of a land use waiver from the Cambridge Department of Public Works ("DPW") from the local Cambridge stormwater management requirements, due to numerous restrictions on site.

6) The requirement of Section 20.74(3) has been met (i.e., Certification and supporting documentation by a Massachusetts registered professional engineer demonstrating that any encroachment of the floodway shall not result in any increase in flood levels during the occurrence of the 100-year flood).

Certification will be provided by the Civil Engineer through the NOI submitted to the Conservation Commission on June 29, 2022, that the Project does not result in any increase in flood levels during the occurrence of the 100-year flood. The Project is scheduled to be on the agenda for the Cambridge Conservation Commission meeting on July 25, 2022.

3. CRITERIA FOR APPROVAL OF AN ALEWIFE OVERLAY DISTRICT SPECIAL PERMIT (SECTION 20.93.2)

In reviewing applications for Alewife Overlay District special permits, the Planning Board shall be guided by the objectives, criteria, and guidelines contained in the publication Concord-Alewife Plan in addition to the requirements of Section 10.40 (Special Permits) and Section 20.90. These guidelines are also intended to assist in shaping any contemplated physical change within the Alewife Overlay Districts. With respect to consistency with the Concord-Alewife Plan, special emphasis shall be placed on preservation of key rights-of-way for infrastructure projects as indicated in the Priority Infrastructure Plan.

1) The Concord-Alewife objectives, criteria and guidelines, generally and for the "Triangle District" (in which the Project Site is located), include the following:

(a) Break large blocks into smaller blocks, of sizes similar to those in surrounding Cambridge neighborhoods, to improve circulation and to be compatible with surrounding neighborhoods.

The Project will create an enhanced pedestrian experience by enlivening the Surface Lot with open space and pedestrian connectivity. Close proximity to Alewife Station, area parks and trails, and retail shopping facilitates walking, biking and transit use and minimizes negative impacts on surrounding neighborhoods. Further, the expansion of the patio for use by the existing restaurant tenants will create a vibrant, active street edge along CambridgePark Drive that will create a pleasant, walkable pedestrian experience. With respect to vehicular circulation, the flow of traffic will be modified to minimize pedestrian, bicycle and vehicular interactions.

(b) Vary the design of individual buildings to create an architecturally diverse district and create building height/façade setbacks between 85' and 105'.

The Building and Addition will be set at a height (as defined in the Ordinance) of approximately 85 feet. The existing Building design incorporates varied setbacks, thereby creating a rhythm along CambridgePark Drive.

(c) Street-level facades should include active uses such as frequent residential entrances, with setbacks for stoops and porches; neighborhood-serving retail including shops, restaurants, cafés; services for the public or for commercial offices such as fitness centers, cafeterias, day care centers; community spaces such as exhibition or meeting spaces; and commercial lobbies and front entrances. Provide small setbacks (5' to 15') from the right-of-way for café seating, benches, or small open spaces.

The ground floor Revival café and Mothership restaurant will be re-oriented to face CambridgePark Drive. An expansion to the patio will be introduced to activate the street, providing ample seating areas and accessible means of egress. This work follows on the heels of work at 100 and 150 CambridgePark Drive, thereby playing an important role in the diversity and range of uses on the ground floor, activating both sides of the street.

(d) Encourage awnings/canopies to provide shelter and enliven ground-floor façades.

The expansion of the patio will be covered by the overhang of the Building, providing shelter to the restaurant use and further facilitating the enlivening of the ground-floor façade.

(e) Design residential buildings with individual units and front doors facing street, including row-house units on the lower levels of multifamily residences. Create a pedestrian-friendly environment along CambridgePark Drive.

Not applicable.

(f) Encourage sustainable and green building design and site planning.

The Project continues the Applicant's commitment to sustainability in the neighborhood. In compliance with Article 22 of the Ordinance, the development team has coordinated with Community Development Department (CDD) staff to incorporate Green Building elements into the Project. A Green Building Report for the Project was submitted by CDD *herewith. The Project will comply with the City's ongoing requirements for Green Building compliance as the Project progresses to the building permit and certificate of occupancy stages of development. In addition, the Project is currently tracking a LEED Gold rating, and introduces numerous innovative measures including green roofs, stormwater retention, on-site renewable energy production, measures to reduce of heat island effect, climate resiliency design and inclusion of ample electric vehicle charging stations.*

- *Green Roofs: The Project will convert the existing ten (10) balconies at the Building to Green Roofs, of which up to 15% will be used to provide private outdoor open space. Several new balconies will be introduced, conforming to the same criteria.*

- *Stormwater Retention: As discussed in more detail below, the Project will minimize the amount of stormwater run-off through the use of best management practices for stormwater management*

- *On-site Renewable: The Project will employ several locations for on-site Solar Power Generation. A 10,000 SF, 175 kW Solar Array will be installed above the pervious parking spaces in the Surface Lot, generating renewable power while also providing shade. In addition, the Project will install a 27,000 SF, 470 kW Solar Array over the top Level of the 140 CambridgePark Drive Parking Garage. In Combination this will account for a Load Offset of almost 28%.*

- *Heat Island Reduction: To minimize risks associate with predicted temperature increases, the Project will aim to reduce urban heat island effect through high-albedo roofing and paving and minimize cooling loads by high performance envelope for the Building facades.*

- *Climate Resiliency Planning: The City of Cambridge has developed the Climate Change Preparedness & Resilience Plan (CCPR), which is intended to commit to prepare the community for impacts to anticipated climate change. In part to the CCPR, the City has developed an online FloodViewer (v3.0), which provides anticipated flood event elevations for the year 2070. The Project team has reviewed the 2070 resiliency elevations within the current Cambridge FloodViewer for both Precipitation and Sea Level Rise / Storm Surge (SLR/SS). In review of the existing Project Site, the current 2070 10-year storm event is equal to elevation 22.0 CCB, and the 2070 100-year storm event is equal to elevation 23.3 CCB. The majority of the Surface Lot and drive aisles are within the existing 100-year FEMA floodplain. The proposed project will redesign the surface lot and provide surface flood storage greater than or equal to the existing flood* *storage volume on a foot-by-foot basis, per Conservation Commission requirements. The Building and Addition ground floor elevation will be elevated above the existing 100-year FEMA floodplain. The existing building first floor elevation is roughly elevation 22.1. The Project is designed to set the Addition's Finished Floor Elevation (FFE) to a minimum elevation of 22.5 CCB. This elevation will allow for the Addition to be resilient towards the 2070 10-year storm elevation projected by the City of Cambridge. In order for the Building to respond to the 2070 100-year flood event, temporary flood barriers and controls will be proposed for flood protection at all proposed and existing doorways. Additionally, critical infrastructure such as electric switchgear and transformers will be raised to a minimum of elevation 23.3 CCB on the Project Site or within the proposed building to be set above the projected 2070 100-year storm event by the City of Cambridge. At locations where it will not be feasible for the Project to meet the 2070 100-year flood elevation, such as the proposed loading docks, temporary deployable flood measures will be installed to provide additional resiliency at these critical locations.*

- *EV Charging: Twenty electric vehicle charging stations will be provided, with the balance of sixty spaces designed to be EV ready.*

(g) Use low-impact-development principles in building and site design as a way to meet city, state, and federal stormwater requirements.

The building and site design are designed to make use of water-conserving plumbing and minimize the amount of stormwater run-off through the use of best management practices for stormwater management.

(h) Use site design that preserves future rights-of-way identified in the Circulation Concept Plan. Locate new development to preserve right-of-way for future crossing of the railroad tracks to connect the Triangle and Quadrangle. Provide pedestrian links that strengthen physical connections to Alewife Reservation, consistent with its master plan. Strengthen bicycle and pedestrian links to adjacent areas. Provide links that strengthen physical and visual connections to open space resources.

As discussed below, the Project will enhance pedestrian connectivity to the Alewife Reservation, thereby facilitating walking and biking transportation opportunities to the Alewife Triangle area. This will bring to completion the initial improvements to the northern edge of the Project Site, begun in 2018, connecting the Project Site to the Alewife Reservation.

(i) Improve existing streets to meet City standards, including streetscape improvements.

The Project will improve the streetscape through activation of the ground-floor uses along CambridgePark Drive by orienting the restaurant toward the street and expanding the deck to create opportunities for outdoor dining.

(j) Screen service areas from CambridgePark Drive.

The Project will screen service areas by bringing a currently exposed loading dock and freestanding dumpster into an enclosed loading area within the Addition.

(k) Parking below grade is preferred. If above grade parking is to be provided, design it so it is not visible from nearby residential neighborhoods, from public streets, or from pathways. Line above-ground structured parking with active uses (shops, cafés, lobbies) along important public ways; use parking structures to provide visual and acoustical screening between the railroad tracks and the rest of the area.

The quantity of off-street parking spaces will be reduced by approximately 95 spaces (from approximately 179 to 79) by converting the majority of the existing impervious parking lot on the Project Site into open space. Handicap spaces will be provided close to the north entrance.

(l) Design and locate lighting and signage to support the district's pedestrian-friendly quality.

The project will continue the new site lighting approach installed between 100, 125 and 150 CPD providing code-required light levels, while also minimizing night sky pollution.

2) The regulations contained in Section 20.90 are intended to harness the opportunities presented with the redevelopment of private property in ways that will:

(a) Encourage forms of development, mix of uses, and range of improvements that will facilitate and encourage walking, biking and transit use and reduce the growth of auto trips in an area already burdened with regional vehicular traffic passing through to other destinations in the metropolitan region.

The Project will result in an overall reduction in traffic, as total parking for the Building is being reduced by 100 spaces (from approximately 179 to 79). The

Project will replace portions the Surface Lot with pervious open green space and pedestrian paths that will provide enhanced pedestrian connectivity to the Alewife Reservation and create additional opportunities for bike and pedestrian commuting. Further, as noted above, the flow of traffic through the Project Site will be enhanced to minimize pedestrian, bicycle and vehicular interactions. The Project's unique transit-oriented location and extensive Transportation Demand Management program will encourage residents to utilize public transportation.

(b) Preserve and enhance the capacity to store floodwater, recharge groundwater and manage the collection and disposal of stormwater in ways that add to the quality and visual appeal of the built environment as well as to the quality of the water itself.

As discussed in more detail above, the Project's compensatory flood storage has been designed to ensure no decrease in the Project Site's flood storage capacity in a safe, healthful and pleasing environment for the occupants of the Project and abutters.

(c) Minimize the negative impact of new development on the adjacent Cambridge Highlands residential neighborhood while introducing new amenities and services that will benefit the residents of that neighborhood.

The Project will facilitate walking, biking and public transit use and discourage vehicular use as detailed above, thereby reducing the amount of vehicular trips and minimizing negative impacts on nearby residential neighborhoods. Further, the Project will reorient the existing restaurant into a new and vibrant setting and enliven the streetscape on CambridgePark Drive.

(d) Integrate the entire area through the creation of new pedestrian paths, roadways, green spaces and bridges that will facilitate movement within the several Districts and beyond to the Cambridge Highlands, North Cambridge and Neighborhood Nine neighborhoods and the Fresh Pond Reservation.

Project will replace portions of the Surface Lot with pervious open green space and pedestrian paths that will provide safe pedestrian connectivity to the Alewife Reservation and enhance the vibrancy of the district.

(e) Introduce a significant component of residential living and support retail services to enhance the area's appeal for all persons who come to work, shop as well as live within the Districts.

The Project will bring an existing Restaurant into a new and vibrant setting and enliven the streetscape on CambridgePark Drive.

(f) Create an identity and sense of place for the Alewife Districts that parallels the development of the historic urban centers that characterize much of Cambridge.

The Project will restore areas that are currently impervious pavement to a pedestrian path and green space. The Project will create an identity and sense of place that parallels the development of the historic urban centers that characterize much of Cambridge.

4. CRITERIA FOR APPROVAL OF AMENDMENT TO EXISTING SPECIAL PERMIT FOR REDUCTION OF PARKING IN THE SURFACE LOT WHILE MAINTAINING POOLED PARKING (20.97.2)

In granting a special permit for pooled parking pursuant to Section 20.97.2 of the Ordinance, the Planning Board shall consider the following:

1) The facility advances the objectives of the Concord-Alewife Plan.

2) A shared facility is established that aids in implementation of effective Transportation Demand Management measures to reduce dependence on the single-occupancy automobile.

3) The facility is appropriately located to serve the development it serves.

4) The facility is well designed, does not diminish the pedestrian-friendly quality of the area around it, and is otherwise consistent with the urban design objective of the Concord-Alewife Plan.

Providing shared structured parking for the mix of uses in the Alewife district is a strategy that has been implemented for the Building and other sites along CambridgePark Drive, and has resulted in an overall reduction in the number of parking spaces dedicated to office users in the area, further helping mitigate traffic concerns and promote greater use of alternative transportation. The Project furthers this objective by eliminating approximately 100 surface parking spaces, while maintaining the shared parking arrangement at the 140 Garage providing up to 200 spaces for use by tenants and visitors to the Building.

2D. Compliance with the Citywide Urban Design Objectives

1) Pursuant to Section 19.31 of the Ordinance, new projects should be responsive to the existing or anticipated pattern of development. Indicators include:

(a) Heights and setbacks provide suitable transition to abutting or nearby residential zoning districts that are generally developed to low scale residential uses.

The Project exceeds the stated setbacks, and increases the setbacks to the west on the upper levels and penthouse to minimize impact on residential neighbors. The Addition will match the existing buildings 13'-1" floor-to-floor heights. Acoustic screen walls will face the residential neighbors to the west to ensure that there is a suitable transition to these nearby abutters.

(b) New buildings are designed and oriented on the lot so as to be consistent with the established streetscape on those streets on which the project lot abuts. Streetscape is meant to refer to the pattern of building setbacks and heights in relationship to public streets.

The Project's heights will have no impact to the public street as it is located on the north side of the lot facing the reservation. As noted above, site connectivity will be improved by reversing the traffic.

(c) In mixed-use projects, uses are to be located carefully to respect the context, e.g. retail should front onto a street, new housing should relate to any adjacent existing residential use, etc.

The restaurant use will be reoriented and expanded outward to better engage with the streetscape. Service and storage uses within the Building will be moved away from the streetscape and will be adequately screened.

(d) Where relevant, historical context is respected, e.g. special consideration should be given to buildings on the Project Site or neighboring buildings that are preferably preserved.

There are no neighboring historic buildings or buildings that are preferably preserved on or adjacent to the Project Site.

2) Pursuant to Section 19.32 of the Ordinance, development should be pedestrian and bicycle-friendly, with a positive relationship to its surroundings. Indicators include:

(a) Ground floors, particularly where they face public streets, public parks, and publicly accessible pathways, consist of spaces that are actively inhabited by people, such as retail stores, consumer service businesses and restaurants where they are allowed, or general office, educational or residential uses and building lobbies. Windows and doors that normally serve such inhabited spaces are encouraged to be a prominent aspect of the relevant building facades. Where a mix of activities are accommodated in a building, the more active uses are encouraged facing public streets, parks and pathways. In commercial districts, such active space consists of retail and consumer service stores and building lobbies that are oriented toward the street and encourage pedestrian activity on the sidewalk. However, in all cases such ground floor spaces should be occupied by uses (a) permitted in the zoning district within which the building is located, (b) consistent with the general character of the environment within which the structure is located, and (c) compatible with the principal use for which the building is designed.

The ground floor of the Building will be activated by re-orienting the existing Revival Café tenant to face CambridgePark Drive and the build of current shell space to house the expanded Mothership Restaurant, increasing visibility to the street. Lobby improvements will include a revolving door and accessible entrances, new flooring and alignment a repositioned north entrance to provide a more direct connection to the Alewife Reservation.

(b) Covered parking on the lower floors of a building and on-grade open parking, particularly where located in front of a building, is discouraged where a building faces a public street or public park, and publicly accessible pathways.

The Project will result in a significant reduction in the on-grade open parking. As is the case currently, none of the remaining on-grade parking will face any public streets. The improvements to the Surface Lot are intended to screen on-grade parking from the pedestrian path as much as possible.

(c) Ground floors should be generally 25-50% transparent. The greatest amounts of glass would be expected for retail uses with lesser amounts for office, institutional or residential use.

The ground floors will be at least 35% transparent, to provide visibility for the Café and Restaurant spaces on the south side, and visibility to the Long Term Bicycle Parking from the North. Parking areas will be screened by vegetation, and a portion of the parking field will be covered with a solar array.

(d) Entries to buildings are located so as to ensure safe pedestrian movement across streets, encourage walking as a preferred mode of travel within the city and to encourage the use of public transit for employment and other trips. Relating building entries as directly as possible to crosswalks and to pathways that lead to bus stops and transit stations is encouraged; siting buildings on a lot and developing site plans that reinforce expected pedestrian pathways over the lot and through the district is also encouraged.

Pedestrian movement is improved via the new north entrance, additional lobby doors, wider lobby corridors and views south to 150 CambridgePark Drive. An additional entrance to the Restaurant is provided at the south east corner along CPD for convenient access for neighboring residents. The sitework between 100, 125 and 150 CPD has been recently improved to provide a clear crosswalk across CambridgePark Drive. The reversal of the site traffic flow to be counter-clockwise, also minimizes pedestrian and vehicular cross-traffic. As described in more detail below, pedestrian movement to and through the Project Site will be provided for in a safe manner.

(e) Pedestrians and bicyclists are able to access the Project Site safely and conveniently; bicyclists should have, secure storage facilities conveniently located on-site and out of the weather. If bicycle parking is provided in a garage, special attention must be paid to providing safe access to the facilities from the outside.

Pedestrians and bicyclists will be able to access the Project safely and conveniently. The Project Site is directly adjacent to the Alewife Reservation, and has ready access to the extensive bicycle and pedestrian trails in Cambridge, Arlington, and Watertown. The project will provide generous bicycle facilities. On the east side of the Building 40 covered Short Term Bicycle Parking Spaces will be provided. Internal to the Addition, 68 Long-Term Bicycle Parking Spaces, which will include shower facilities. A 19-dock BlueBike Station along the north edge will provide a convenient location for the general public using the Fitchburg Cut-off, Alewife Reservation and nearby Linear Park. Several other BlueBike Stations are in close proximity to the Project Site, and one is anticipated to be installed across the open space to the east at 87/101 CPD.

(f) Alternate means of serving this policy objective 19.32 through special building design, siting, or site design can be anticipated where the building form or use is distinctive such as freestanding parking structures, large institutional buildings such as churches and auditoriums, freestanding service buildings, power plants, athletic facilities, manufacturing plants, etc.

Not applicable.

3) Pursuant to Section 19.33 of the Ordinance, the building and site design should mitigate adverse environmental impacts of a development upon its neighbors. Indicators include:

(a) Mechanical equipment that is carefully designed, well organized or visually screened from its surroundings and is acoustically buffered from neighbors. Consideration is given to the size, complexity and appearance of the equipment, its proximity to residential areas, and its impact on the existing streetscape and skyline. The extent to which screening can bring order, lessen negative visual impacts, and enhance the overall appearance of the equipment should be taken into account. More specifically:

(i) Reasonable attempts have been made to avoid exposing rooftop mechanical equipment to public view from city streets. Among the techniques that might be considered is the inclusion of screens or a parapet around the roof of the building to shield low ducts and other equipment on the roof from view.

(ii) Treatment of the mechanical equipment (including design and massing of screening devices as well as exposed mechanical elements) that relates well to the overall design, massing, scale and character of the building.

(iii) Placement of mechanical equipment at locations on the Project Site other than on the rooftop (such as in the basement), which reduces the bulk of elements located on the roof; however, at-grade locations external to the building should not be viewed as desirable alternatives.

(iv) Tall elements, such as chimneys and air exhaust stacks, which are typically carried above screening devices for functioning reasons, are carefully designed as features of the building, thus creating interest on the skyline.

(v) All aspects of the mechanical equipment have been designed with attention to their visual impact on adjacent areas, particularly with regard to residential neighborhoods and views and vistas.

A minimum ten-foot-high noise barrier panels will be positioned on the west and north faces of the Building. With these measures in place, acoustic analysis predicts sound levels of less than 50 dBA to the nearest residential dwelling unit, complying with the Cambridge Noise Ordinance's 60 dBA "daytime" and 50 dBA "all other times" facing the residential neighbor.

(b) Trash that is handled to avoid impacts (noise, odor, and visual quality) on neighbors, e.g. the use of trash compactors or containment of all trash storage and handling within a building is encouraged.

The Project will internalize trash/recycling storage within the Building, which will reduce noise, odor, and visual impacts on the neighbor's and tenants of the Building. The Project will include an enclosed loading dock bay dedicated to trash and recycling, a 30-yard container dumpster will be picked up, up to 4 times per week. Longfellow and its tenants will continue to use "Green Network Exchange" in Cambridge for electronic recycling. A dedicated "E-Waste" Box will be included in the Project, at the future loading dock for future E-waste.

(c) Loading docks that are located and designed to minimize impacts (visual and operational) on neighbors.

The Building's loading docks have been carefully redesigned and internalized to the Building to minimize both visual and operational impact on the neighbors. The Addition will internalize the loading docks on the west side of the Building. Trucks will circulate counter-clockwise, and back-up at 45 degrees to two enclosed loading docks. A third enclosed bay, oriented 90 degrees to the west service drive will provide and an internal trash bay. Loading (including trash) will be adequately screened.

(d) Stormwater Best Management Practices and other measures to minimize runoff and improve water quality are implemented.

Under existing conditions, the Project Site is currently developed and predominantly covered by impervious surfaces comprised of building roof areas and surface parking lots. The existing building on the Project Site does not contain any form of known *stormwater management in the existing condition. Stormwater is conveyed via enclosed pipe roof conduit and surface sheet flow to local catch basin structures on site. Stormwater discharges into the DPW-owned 24-inch storm drain within CambridgePark Drive, without any known form of stormwater quality or quantity management.*

The proposed stormwater management system will be designed to comply with the MA DEP Stormwater Management Policy for redevelopment projects and the City of Cambridge standards to the maximum extent practicable. Based on a meeting held on June 29, 2022; DPW has agreed in principl that a Land Disturbance wiaver will beb granted to the Project, granting relief for the "25 to 2" local stormwater management requirement due to existing constraints on site. Additional documentation has been provided within a memorandum date July 7, 2022 submitted to DPW.

Under proposed conditions, the Project Site will not produce changes in either the pattern of or rate of stormwater runoff. Stormwater management controls will be established in compliance with MassDEP and DPW standards. The Project is not designed to result in the introduction of any peak flows, pollutants, or sediments that would potentially impact the receiving waters of the local municipal stormwater drainage system.

For the current design, the Addition's roof areas will discharge through a rainwater harvesting cistern on site, designed to reduce peak stormwater rates and volumes in addition to reducing the total phosphorus load from the Project Site. The rainwater will be used to help irrigate the landscaped areas on site. Infiltration will promote groundwater recharge and reduce stormwater peak rates and volumes, in addition to reducing total phosphorus load from the Project Site.

The final design will incorporate facilities to reduce phosphorus on-site by 65 percent compared to the existing conditions, in compliance with DPW standards. These facilities may include added pervious area, pervious pavement, stormwater filters, and/or stormwater harvesting tanks. The Project will implement stormwater Best Management Practices (BMPs) in conformance with DEP's Stormwater Management Standards.

The Project's construction documents will include measures and specifications regarding erosion and sediment controls and barriers (e.g. silt fence, silt sacks). Construction dewatering discharges will be appropriately controlled and discharged in accordance with National Pollutant Discharge Elimination System (NPDES) and state and local dewatering standards.

The Project will undergo in detailed design review with DPW throughout the design process. The detailed stormwater management report is anticipated to be coordinated with DPW throughout final design and submitted in part to the NOI and SWCP process, prior to Building Permit submission.

(e) Landscaped areas and required Green Area Open Space, in addition to serving as visual amenities, are employed to reduce the rate and volume of stormwater runoff compared to pre-development conditions.

The Project will increase the square footage of landscaping and Green Area Open Space from the pre-development condition. Pervious materials allow greater infiltration and slow the rate of stormwater runoff compared to pavement and roof. The change in surface coverage will result in a reduction to the volume and rate of stormwater runoff for the site from the pre-development condition.

(f) The structure is designed and sited to minimize shadow impacts on neighboring lots, especially shadows that would have a significant impact on the use and enjoyment of adjacent open space and shadows that might impact the operation of a Registered Solar Energy System as defined in Section 22.60 of the Ordinance.

The Project will have minimal impact on neighboring lots due to its location on the northern portion of the Project Site.

(g) Changes in grade across the lot are designed in ways that minimize the need for structural retaining walls close to property lines.

The Project minimizes changes in grade across the property. There are no retaining walls close to property lines.

(h) Building scale and wall treatment, including the provision of windows, are sensitive to existing residential uses on adjacent lots.

The Building is set back further adjacent to the neighboring residences to the west. Windows and balconies are provided on the upper levels, while the loading dock and mechanical equipment is screened.

(i) Outdoor lighting is designed to provide minimum lighting and necessary to ensure adequate safety, night vision, and comfort.

The project will continue the new site lighting approach installed between 100, 125 and 150 CPD providing code-required light levels, while also minimizing light pollution.(j) The creation of a Tree Protection Plan that identifies important trees on the Project Site, encourages their protection, or provides for adequate replacement of trees lost to development on the Project Site.

As part of the Special Permit application, a Tree Study has been commissioned and is included herein. The first project undertaken by the Applicant was the rebuilding of the northern edge of this property, and the addition of 10 new trees. The scope of that project also include the addition of 8 new street trees along Cambridgepark drive, along with curb-to-curb street scape improvements. The Tree Study and Tree Protection Plan have been submitted to the City Arborist. The project will continue its commitment to planting more trees than exist on site today.

4) Pursuant to Section 19.34 of the Ordinance, projects should not overburden the City infrastructure services, including neighborhood roads, city water supply system, and sewer system. Indicators include:

(a) The building and site design are designed to make use of water-conserving plumbing and minimize the amount of stormwater run-off through the use of best management practices for stormwater management.

As described above, the Project will use low flow plumbing and the Project's stormwater management system has been designed to incorporate best management practices and has been approved by the Cambridge Conservation Commission.

(b) The capacity and condition of drinking water and wastewater infrastructure systems are shown to be adequate, or the steps necessary to bring them up to an acceptable level are identified.

Water Service Infrastructure

The domestic water estimate for the Project is based on the projected approximate daily wastewater flow for the Project. As shown in Table 1 (See Volume 1, Page 58) , the approximate net new demand for water is 5,556 gallons per day (GPD). The existing building domestic water and fire protection service is supplied to the Building via a private 10-inch water main connecting to the existing Cambridge Water Department ("CWD") 10-inch water main within CambridgePark Drive, with a 10-inch by 10-inch by 10-inch anchor tee and valve configuration. The Project proposes to utilize this existing 10-inch water main, and provide redundancy at the CWD water main via installation of one (1) mainline gate valve. The building is served by this 10-inch private water main with an existing 4-inch domestic water service and 10-inch fire protection service. The proposed condition will include an upsized 6-inch domestic water service and the existing 10-inch fire protection service will remain. Both services will continue to be fed from this existing 10-inch private water main. Prior to construction hydrant flow tests will be completed to verify adequate flow and pressure for the Building's sprinkler system. The Project also proposes to add a new hydrant along the eastern drive aisle per CWD standards. The proposed water meter room location with be closely coordinated with CWD during final design. The new water meter configuration will be abutting the building wall, as required by CWD. Any existing domestic water and fire protection services will be discontinued prior to the erection of the addition (except for the 10 inch service being preserved) meeting CWD standards. All existing service connections 4-inches or larger, will cut out the existing anchor tee at the water main and replace with new water pipe, following CWD standards. At this time, no services have been identified for discontinuance at the CWD water main. The Applicant will work with CWD on the development of the Project design and submit plot plans for formal approval prior to the issuance of the Building Permit for the Project.

Sanitary Sewer Service Infrastructure

The Project Site currently hosts an existing six-story technical office space with a first-floor café. The Project design anticipates the existing building structure will be preserved for the construction of the new six-story technical office addition.

The existing building sanitary sewage is served via an existing 6-inch diameter sewer service, which discharges into the existing 10-inch diameter municipal sewer main within CambridgePark Drive, abutting the Project Site. In the final condition, the sanitary sewage from the existing building structure and the new addition will flow through this existing 6-inch PVC sanitary sewer service on site, in addition to a new dedicated

6-inch lab waste service. The existing service and new lab waste service will connect via an on-site manhole structure located on the existing 6-inch service adjacent to the property line fronting CambridgePark Drive, allowing for the existing sanitary sewer infrastructure within the City right-of-way to be utilized in the final condition.

The Project's sanitary sewer generation has been estimated using design sewage flow rates obtained from 310 CMR 15.000: Septic Systems ("Title 5"). The Project proposes to generate approximately 30,749 GPD of sanitary sewer compared to 25,698 GPD within the existing condition, totaling a net increase of approximately 5,051 GPD of sanitary sewer generation for the proposed development. The estimated sanitary sewer generation is summarized in Table 1 below (See Volume 1, Page 58)*. The sanitary sewer generation threshold for DPW Inflow/Infiltration (I/I) mitigation is 15,000 GPD. The Project does not anticipate a need for I/I mitigation, as the proposed net new sewer generation is less than this threshold.*

5) Pursuant to Section 19.35 of the Ordinance, new construction should reinforce and enhance the complex urban aspects of Cambridge as it has developed historically. Indictors include:

(a) New educational institutional construction that is focused within the existing campuses.

Not applicable.

(b) Where institutional construction occurs in commercial areas, retail, consumer service enterprises, and other uses that are accessible to the general public are provided at the ground (or lower) floors of buildings. Where such uses are not suitable for programmatic reasons, institutional uses that encourage active pedestrian traffic to and from the Project Site.

Not applicable.

(c) In large, multiple-building non-institutional developments, a mix of uses, including publicly accessible retail activity, is provided where such uses are permitted and where the mix of uses extends the period of time the area remains active throughout the day.

Not applicable.

(d) Historic structures and environments are preserved.

Not applicable.

(e) Preservation or provision of facilities for start-up companies and appropriately scaled manufacturing activities that provide a wide diversity of employment paths for Cambridge residents as a component of the development; however, activities heavily dependent on trucking for supply and distribution are not encouraged.

The Project will continue to be a complementary use to the existing, and future, residential and commercial use in the area. The Project will provide ideal space for start-up companies as a result of new infrastructure that can support diverse tenant demands

6) Pursuant to Section 19.36 of the Ordinance, expansion of the inventory of housing in the city is encouraged. Indicators include:

(a) Housing is a component of any large, multiple building commercial development. Where such development abuts residential zoning districts substantially developed to low-scale residential uses, placement of housing within the development such that it acts as a transition/buffer between uses within and without the development.

Not applicable.

(b) Where housing is constructed, providing affordable units exceeding that mandated by the Ordinance. Targeting larger family-sized middle income units is encouraged.

Not applicable.

7) Pursuant to Section 19.37 of the Ordinance, enhancement and expansion of open space amenities in the city should be incorporated into new development in the city. Indicators include:

(a) On large-parcel commercial developments, publicly beneficial open space is provided.

(b) Open space facilities are designed to enhance or expand existing facilities or to expand networks of pedestrian and bicycle movement within the vicinity of the development.

(c) A wider range of open space activities than presently found in the abutting area is provided.

The Project enhances and expands open space amenities in the City and enhances pedestrian connectivity. The Project will convert an open air parking lot to a pedestrian pathway that may be used by the public for pedestrian and bicycle access to the Alewife Reservation. The Project will provide generous bicycle facilities. On the east side of the Building 20 covered Short Term Bicycle Parking Spaces will be provided. Internal to the addition, 68 Long-Term Bicycle Parking Spaces which will include shower facilities. A 19-dock BlueBike Station along the north edge will provide a convenient location for the general public using the Fitchburg Cut-off, Alewife Reservation and nearby Linear Park. Several other BlueBike Stations are in close proximity to the Project Site, and one is anticipated to be installed across the open space at 87/101 CPD.

CONCLUSION

As described above, the Project is appropriate to the Project Site and surroundings. It provides needed additional technical office use as part of this transit oriented development.. The Project will result in an improvement in transportation impact on the area roadways. The Project will create a network of new pedestrian pathway to enhance connectivity to the Alewife Reservation. In short, the Project furthers the objectives of the Zoning Ordinance and applicable planning studies of the area in several significant ways. Accordingly, for the reasons set forth above, the Applicant respectfully requests that the Board find that the Project satisfies all applicable requirements of the Ordinance in connection with the granting of the requested Special Permits.

SECTION 3

Community Outreach

3A. Letters of Support

March 25th, 2022

Planning Board
City of Cambridge
344 Broadway
Cambridge, MA 02139

Re: 125 CambridgePark Drive/Special Permit Case No. PB###

Dear Chairperson and Members of the Planning Board:

The undersigned are the co-owners of Revival Cafe + Kitchen and Mothership Beer Hall, both of which are located within the building at 125 CambridgePark Drive. We are writing to express our strong support for the petitioner in the above-referenced matter.

We have met with the petitioner and its architect to review the proposed project. We are excited about the positive impacts this project will have on the our businesses and the surrounding area. We would like to go on record in support of petitioner's project, and urge you to approve the requested special permits and relief.

Please contact us with any questions. Thank you.

Sincerely,

Liza Shirazi and Steve "Nookie" Postal, Co-owners

March 27, 2022

Planning Board
City of Cambridge
344 Broadway
Cambridge, MA 02139

Re: 125 CambridgePark Drive/Special Permit Case No. PB###

Dear Chairperson and Members of the Planning Board:

I am a resident of Cambridge and a tenant in the building located at 160 Cambridgepark Dr, Cambridge, MA and am writing to express my strong support for the petitioner in the above-referenced matter.

I have met with the petitioner to review the proposed project. I am excited about the positive impacts this project will have on the surrounding area. I would like to go on record in support of petitioner's project, and urge you to approve the requested special permits and relief.

Thank you very much for your consideration.

Sincerely,

Adeline Shin

3B. Early Community Engagement Meeting

Early Community Engagement Meeting

Virtual Open House

May 18, 2022 @ 6:00PM

You are invited to attend a virtual Open House, hosted by Longfellow Real Estate Partners to learn about their proposal to construct a 40,000SF addition, expanding on the existing 183,946 SF building's technical office use at 125 Cambridge Park Drive.

In addition to representatives from Longfellow, the project architect will be in attendance to present the proposed plans for this building and answer questions.

This proposal will require a Special Permit from the Cambridge Planning Board and approval from the Cambridge Conservation Commission.

For additional information, please contact Matt Lerner at 617-631-2600 or by email at mlerner@lfrep.com

Early Community Engagement Meeting

Virtual Open House

July 7, 2022 @ 6:00PM

You are invited to attend a virtual Open House, hosted by Longfellow Real Estate Partners to learn about their proposal to construct a 40,000SF addition, expanding on the existing 183,946 SF building's technical office use at 125 Cambridge Park Drive.

In addition to representatives from Longfellow, the project architect will be in attendance to present the proposed plans for this building and answer questions.

This proposal will require a Special Permit from the Cambridge Planning Board and approval from the Cambridge Conservation Commission.

Members of the public can participate or view the meeting remotely using the Zoom Webinar Link: https://elkus-manfredi.zoom.us/j/81453756877?pwd=WWt3SmpYSDF2ZzhjcVlKWHFMNlZPZz09

Meeting ID: 814 5375 6877 Passcode: 259959

One tap mobile: +19292056099,,81453756877# US

For additional information, please contact Matt Lerner at 617-631-2600 or by email at mlerner@lfrep.com

SECTION 4

Appendix

4A. Transportation Memo

July 15, 2022

Ref: 15596.00

Mr. Joseph Barr
Mr. Adam Shulman

Traffic, Parking, and Transportation Department
City of Cambridge
344 Broadway
Cambridge, MA 02139

Re: 125 Cambridgepark Drive Development
Transportation Memo

Dear Mr. Barr and Mr. Shulman:

150 Cambridgepark Drive LLC has retained VHB to prepare a technical Transportation Memorandum for the proposed 125 Cambridgepark Drive commercial development in Cambridge, Massachusetts. This document considers the improvements planned at 125 Cambridgepark Drive including an approximately 35,000 SF addition inclusive of a proposed freight elevator and new loading dock as well as other interior improvements and a 100-space reduction to the existing approximate 179-space surface parking lot located at the rear of the building. To support these improvements, the project also proposes to reverse the one-way directionality of the site driveways to support more efficient pedestrian/bicycle access and open space improvements in the rear parking lot. The Project will also be supported by approximately 68 long-term bicycle parking spaces and approximately 46 short-term bicycle parking spaces in exceedance of Article 6.0 of zoning. Table 1 provides a summary of the proposed program and the proposed site location is shown in Figure 1.

This Project is not required to submit and receive Certification of a TIS. However, the Proponent is seeking a Special Permit as required by the change in use and several transportation elements are briefly analyzed in the following sections including site planning, trip generation, driveway sight distance, vehicle parking, and bicycle parking in support of their Article 19 Special Permit application.

Mr. Joseph Barr

Ref: 15596.00
May 4, 2022
Page 2

Table 1: Summary of Program

Project Component	Existing Program (Size/Quantity)	Proposed Program (Size/Quantity)	Net-New Program (Size/Quantity)
Technical Office (R&D)	175.7 KSF	207.3 KSF	+ 31.6 KSF
Restaurant	8.3 KSF	9.6 KSF	+ 1.3 KSF[1]
Total	**184.0 KSF**	**216.9 KSF**	**+ 32.9 KSF**
Vehicle Parking	179 surface lot spaces 200 garage spaces **379 total parking spaces**	79 surface lot spaces 200 garage spaces **279 total parking spaces**	**(- 100) total parking spaces**

[1]Proposed GFA is inclusive of the patio space, but the restaurant portion of the Project is not expected to function differently from today

Project Site Planning

As shown in Figure 1, the site has been carefully laid out to reduce the number of parking spaces while increasing open space, improving access and circulation throughout the site and increase bicycle parking supply both of short-term (visitor) and long-term spaces (employees).

Trip Generation Analysis

To estimate traffic generated by the Project, Institute of Transportation Engineers (ITE) *Trip Generation Manual*, 11th Edition, fitted curve trip generation rates for Research & Development Center (LUC 760) was applied.
The restaurant portion of the Project is not expected to function differently from today, so no trip rates were applied for this land use. A summary of the resulting unadjusted vehicle trips including weekday morning, and evening peak hour trips for the Project are presented in Table 2.

Table 2: Unadjusted Trip Generation Summary

	Existing Site		**Proposed Site**	
	AM Peak	**PM Peak**	**AM Peak**	**PM Peak**
Technical Office (R&D)				
Entering	148	28	171	32
Exiting	33	145	38	167
Total	**181**	**173**	**209**	**199**

The 2017 National Household Travel Survey provides the national Average Vehicle Occupancy (AVO) of 1.18 for work trips will be used to convert the unadjusted vehicle trips to person trips. Local HOV AVO for the area has been calculated to be 2.17 based on data from the 2013-2017 American Commuting Survey (ACS) 5-Year Estimates for the census tract 3549, Middlesex County, MA.

Mode splits based on average of 200 Cambridgepark Drive 2018 PTDM Annual Report Summary and Discovery Park 2018 PTDM monitoring reports. The mode splits are presented in Table 3.

Table 3: Mode Share

Mode	Technical Office (R&D)
Drive Alone	58%
Carpool	2%
Transit	23%
Bike	6%
Walk	4%
Other	7%
Total	100%

Average of 200 Cambridgepark Drive 2018 PTDM Annual Report Summary and Discovery Park 2018 PTDM monitoring reports

The unadjusted vehicle trips, shown in Table 2 above, are converted to person trips by applying the national AVO of 1.18. Person trips are split in accordance with the mode shares, presented in Table 3, to yield trips by mode estimated to be generated by the Project. Vehicle-person trips are adjusted back to vehicle trips by applying the calculated local HOV AVO of 2.17. The estimated net-new vehicle trips are presented in Table 4.

Table 4: Total Net-New Vehicle Trips

	AM Peak	PM Peak
Technical Office (R&D)		
Entering	16	3
Exiting	4	16
Total	**20**	**19**

Driveway Sight Distance

Sight lines were evaluated at the driveway exiting the site in accordance with City of Cambridge guidelines. The point of analysis for the site guidelines represents the driver's eye when the front bumper of the driver's vehicle reaches the back of the sidewalk. The sight lines from this point of analysis should be 20 feet east and 20 feet west of the nearest edge of the driveway, at the midpoint of the sidewalk (halfway between the front of the curb and the back of the sidewalk), at the intersection of the midpoint of the driveway exit and the midpoint of the sidewalk, and eight feet behind the back of the sidewalk at the midpoint of the exit driveway. A representation of the site lines analysis is found in Figure 2. The sight lines are met and therefore acceptable.

Vehicle Parking Analysis

Supply

The Project will include a 100-space reduction to the existing approximate 179-space surface parking lot located at the rear of the building, resulting in a new surface lot with a capacity of 79 surface parking spaces. There are also 200 parking spaces in a nearby garage designated for 125 Cambridgepark Drive use as noted in Table 1.

Demand

A parking demand analysis was conducted for the Project to compare the City's off-site parking space requirements per zoning to the expected parking demand based on the anticipated number of employees and automobile mode share (see Table 6). The proposed mode share (58% SOV) is used in the analysis for comparison. For this type of land use development, the expected number of employees is anticipated to total approximately 2.5 employees per 1,000 GFA[1] based on review of employee densities that have been documented in other, similar Cambridge R&D buildings (which yields a total of approximately 519 employees). Applying an automobile mode share of 58% SOV and 2% HOV results in an expected unconstrained parking demand of 306 vehicle spaces. This demand falls between the vehicle parking space maximum and minimum in the City of Cambridge's Vehicle Parking Zoning Ordinance (165-330 spaces) for Office – 2A and is slightly greater than the number of spaces that are proposed by the Project (Table 6).

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[1] Weighted average calculations by VHB based on 2018 PTDM Monitoring Reports for 4 comparable sites provided by the City of Cambridge

Table 6: Vehicle Parking Requirements for the Project, Based on Different Parking Rates: Expected Vehicle Mode Share; Zoning Requirements

	Parking Demand		Parking Supply		
	Expected/ Proposed Vehicle Mode Shares (58% SOV, 2% HOV)	Envision Alewife Goal Vehicle Mode Shares (40% vehicle mode share[1])	City of Cambridge Min. Parking Requirement	City of Cambridge Max. Parking Requirement	Parking Provided by Project
Rate	2.5 employees per 1,000 GFA, at mode shares noted above		1 per 1,050 GFA	1 per 525 GFA	1 per 743 GFA
Parking Spaces	306	208	197	395	279

City of Cambridge Parking Requirements are stated in the Zoning Ordinance Article 6.36 and Article 17.34 for Office-2A.

Parking Management

The parking provided by the Project will be restricted to use by the tenant employees and visitors. Spaces will not be available for commercial (public parking) use.

Bicycle Parking Analysis

The Project will also be supported by a total of approximately 68 long-term bicycle parking spaces and approximately 46 short-term bicycle parking spaces. This bicycle parking program proposes a quantity of bicycle parking spaces that exceed requirements of city zoning (Article 6.0) to support the full build-out of the Project. Table 7 provides a summary of the required minimum bicycle parking ratios by zoning.

Table 7: Bicycle Parking Summary

Land Use	Parking Ratios[1]		# of Long-term Bicycle Spaces	# of Short-term Bicycle Spaces
	Long-Term	Short-term		
Technical Office	0.22 spaces per 1,000 sf	0.06 spaces per 1,000 sf	46	13
Restaurant	0.10 spaces per 1,000 sf	0.60 spaces per 1,000 sf	2	10
Total Required			**48**	**23**
Total Proposed			**68**	**46**

[1]Source: City of Cambridge Zoning Ordinance Article 6.107

Located in the Appendix are plans that illustrate the location and layout of the long-term and short-term bicycle parking spaces.

In addition, the Project proposes to provide a 19-dock Bluebikes to support the Project as shown in the Appendix.

Transportation Demand Management

The Project Proponent is committed to optimizing the transit-oriented opportunity afforded by the Project site to minimize auto travel and encourage alternative travel modes. The reduction in the auto parking ratio is expected to have a significant positive impact in this regard.

The Proponent will support a program of transportation demand management (TDM) actions to reduce single occupancy vehicle (SOV) automobile trips, encourage car/van-pooling, and expand the use of transit, biking and walking.

The following potential TDM programs could be implemented as part of the proposed Project to encourage Project employees and visitors to use alternatives to SOV travel:

- Charge market rate monthly parking fees consistent with structured parking facilities used for technical office/lab use in the Alewife Area.
- Continue membership in the Alewife TMA, including emergency ride home and ride-matching benefits to all employees through the Alewife TMA or other provider acceptable to TP&T.
- Office/lab and retail tenants will be encouraged to provide 50% transit subsidies to employees.
- Transit screen app to be subsidized by proponent for use by employees and visitors.
- Designate a Transportation Coordinator for the site responsible for:
    - Aggressively promoting and marketing non-SOV modes of transportation to employees
    - Overseeing the marketing and promotion of transportation options such as posting information on the Project's web site, social media, and property newsletters
    - Responding to individual requests for information
    - Performing annual transportation surveys
    - Coordinating with Alewife TMA
    - Providing up to date information to all new employees through a New Employee Packet
- Encourage employees to provide Bluebikes corporate membership (minimum Gold level) for employees that choose to become Bluebikes members.

- Dedicate up to 2 carpool/vanpool parking spaces. If actual experience shows that the carpool/vanpool spaces are fully utilized, add additional spaces to satisfy demand.
- Update existing bicycle parking to meet City standards for quantity and design requirements.

The Proponent will continue to work with TP&T to develop and agree upon an appropriate mitigation package.

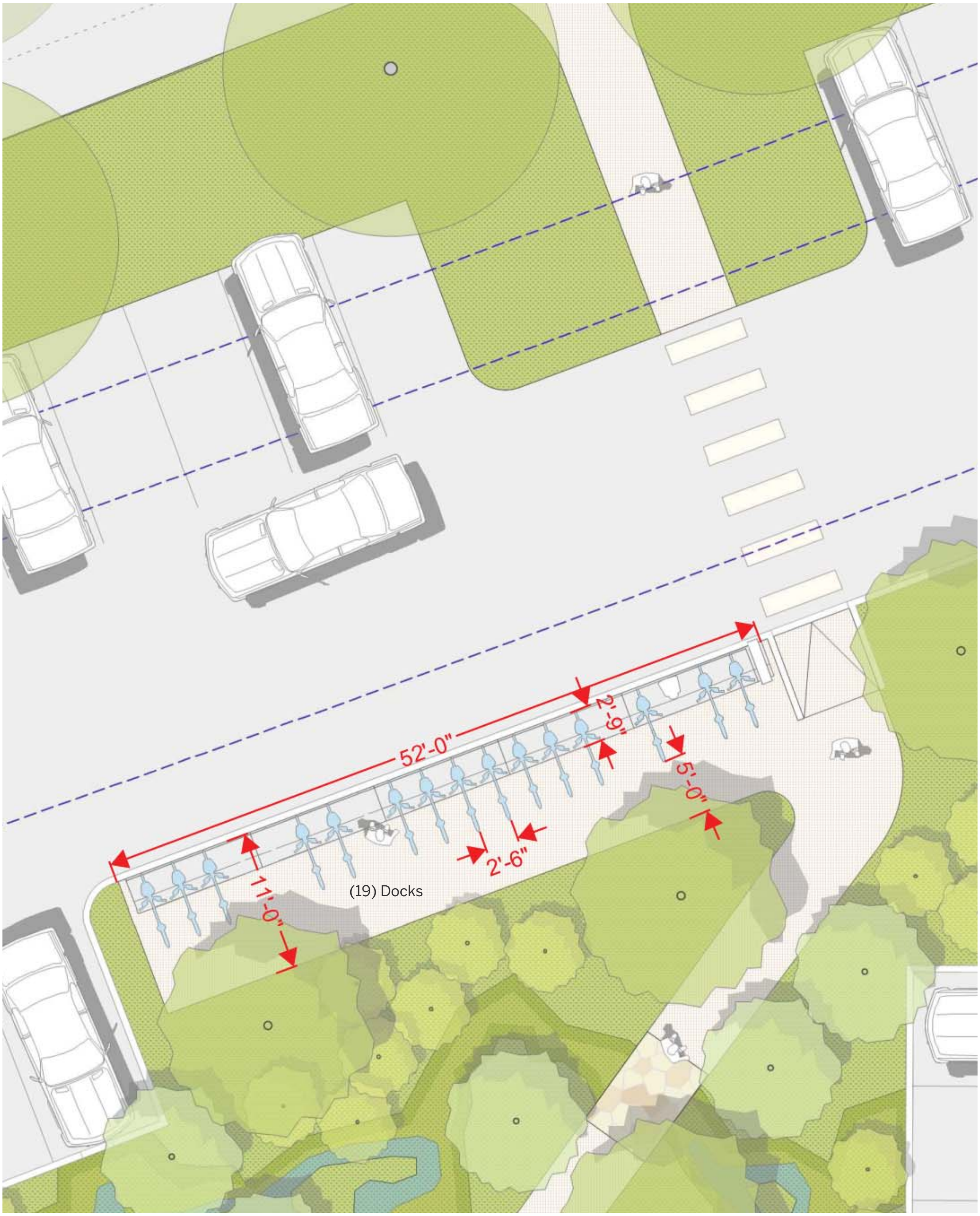
Parking Lot Entrance
Parking Lot Exit
Loading Dock
Pedestrian Access Point
Bike Room Access Point

Figure 1: Proposed Site Plan

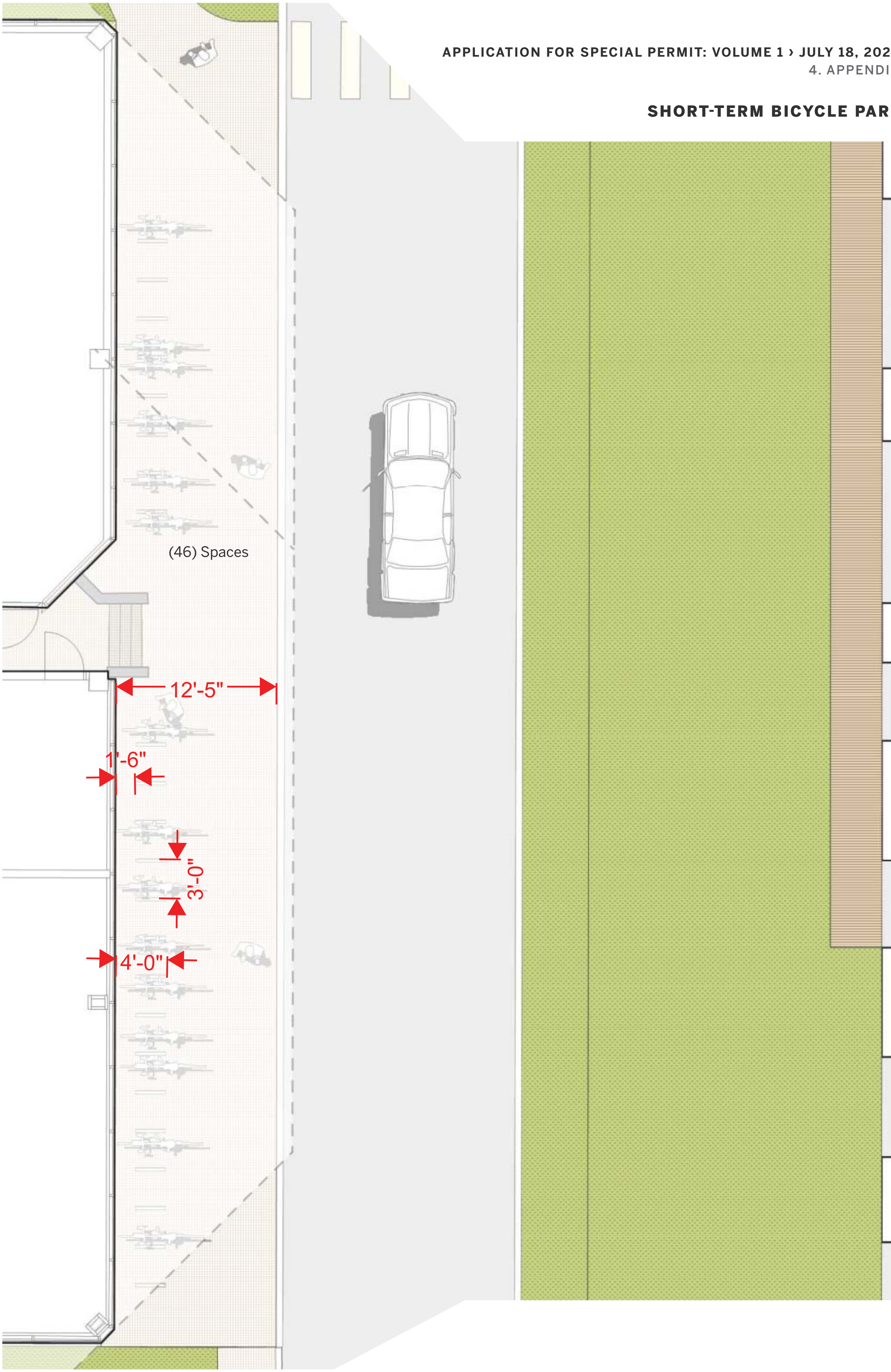
125 Cambridgepark Drive | Cambridge, MA

7/14/2022

BLUE BIKE STATION



SHORT-TERM BICYCLE PARKING



LONG-TERM BICYCLE PARKING

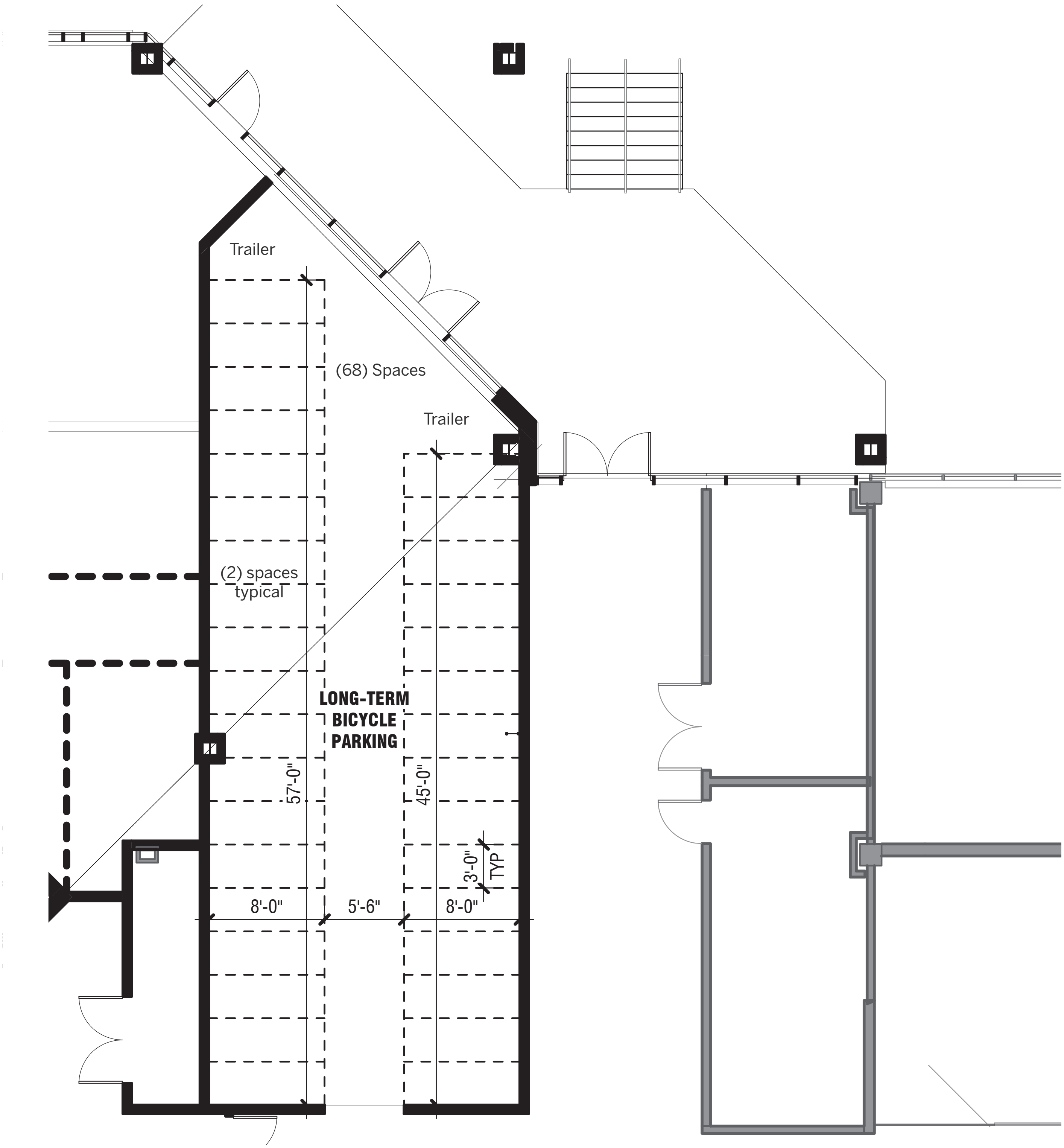
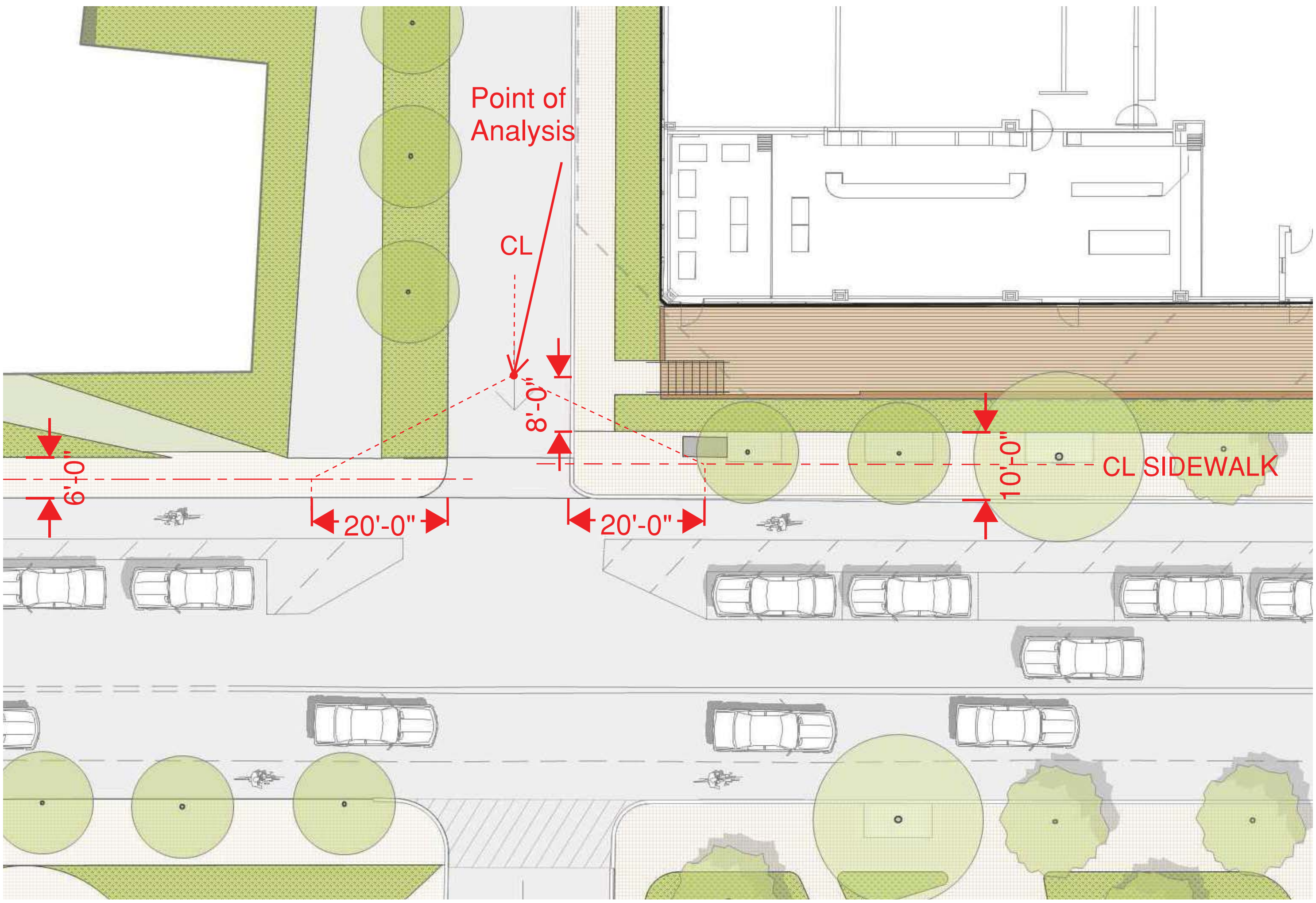


Figure 2: Site Lines Analysis

125 Cambridgepark Drive | Cambridge, MA

7/14/2022



4B. Infrastructure Narrative

The following narrative describes the existing and proposed infrastructure systems within and surrounding the Project Site and discusses utility requirements for the Project and potential impacts to this infrastructure.

The Project will connect to existing City of Cambridge and private utility company systems in the adjacent public streets. As design progresses, all required engineering analyses will be conducted, and the final design will adhere to all applicable protocols and design standards to the maximum extent practicable, ensuring that the proposed building is properly supported by this infrastructure. Detailed design of the Project's utility systems will proceed in conjunction with the design of the building and interior mechanical and plumbing systems.

The systems described herein include those owned or managed by the City of Cambridge Department of Public Works (DPW), Cambridge Water Department (CWD), Eversource Electric, Eversource Gas, private telecommunication systems, and on-site infrastructure. Existing infrastructure systems will be reviewed with the appropriate agencies to ensure that they are adequately sized to accept any increase in demand associated with the Project.

Table 1

Proposed Program	Unit/Area	DEP Category	Generation Rate*	Total Generation (GPD)
Wet Lab	86,550 SF	Lab**	200 GPD / KSF	17,310
Office	86,550 SF	Office Building	75 GPD / KSF	6,491
Lobby/BOH	43,300 SF	Office Building	75 GPD / KSF	3,248
Restaurant	104 Seats	Restaurant***	35 GPD / Seat	3,640
			TOTAL Proposed	**30,640**

Existing Program	Unit/Area	DEP Category	Generation Rate*	Total Generation (GPD)
Wet Lab	68,400 SF	Lab**	200 GPD / KSF	13,680
Office	68,400 SF	Office Building	75 GPD / KSF	5,130
Lobby/BOH	43,300 SF	Office Building	75 GPD / KSF	3,248
Restaurant	104 Seats	Restaurant***	35 GPD / Seat	3,640
		TOTAL Proposed		**25,698**
		Net New Sewer		**4,991**
		Proposed Water		**5,490**

* 314 CMR7.00 Sewer System Extension and Connection Permit Program.
** Assumed lab use rate.
*** Restaurant seating capacity assumes 15 SF per 1 occupant per IBC 2015 Chapter 10.

SANITARY SEWER INFRASTRUCTURE

The Project Site currently hosts an existing six-story technical office space with a first-floor café. The Project design anticipates the existing building structure will be preserved for the construction of the new six-story technical office addition.

The existing building sanitary sewage is served via an existing 6-inch diameter sewer service, which discharges into the existing 10-inch diameter municipal sewer main within Cambridgepark Drive, abutting the Project Site. In the final condition, the sanitary sewage from the existing building structure and the new addition will flow through this existing 6-inch PVC sanitary sewer service on site, in addition to a new dedicated 6-inch lab waste service. The existing service and new lab waste service will connect via an on-site manhole structure located on the existing 6-inch service adjacent to the property line fronting Cambridgepark Drive, allowing for the existing sanitary sewer infrastructure within the City right-of-way to be utilized in the final condition.

The Project's sanitary sewer generation has been estimated using design sewage flow rates obtained from 310 CMR 15.000: Septic Systems ("Title 5"). The following flow criteria has been evaluated for existing and proposed anticipated gallons per day (GPD) of sanitary sewer usage:

› 75 GPD per 1,000 SF for Office

› 200 GPD per 1,000 SF of Wet Lab

• This is an assumed rate based on similar Cambridge area projects

› 75 GPD per 1,000 SF for Back-of-House

› 35 GPD per One (1) Seat of Restaurant

The Project proposes to generate approximately 30,689 GPD of sanitary sewer compared to 25,698 GPD within the existing condition, totaling a net increase of approximately 4,991 GPD of sanitary sewer generation for the proposed development. The estimated sanitary sewer generation is summarized in Table 1 below.

The sanitary sewer generation threshold for local Cambridge DPW Inflow/Infiltration (I/I) mitigation is 15,000 GPD. The Project does not anticipate a need for I/I mitigation, as the proposed net new sewer generation is less than this threshold.

WATER SERVICE INFRASTRUCTURE

The domestic water estimate for the Project is based on the projected approximate daily wastewater flow for the project. As shown in Table 1 above, the approximate net new demand for water is 5,490 gallons per day (GPD).

The existing building domestic water and fire protection service is supplied to the building via a private 10-inch water main connecting to the existing CWD 10-inch water main within Cambridgepark Drive, with a 10-inch by 10-inch by 10-inch anchor tee and valve configuration. The project proposes to utilize this existing 10-inch water main, and provide redundancy at the CWD water main via installation of one (1) mainline gate valve. The building is served by this 10-inch private water main with an existing 4-inch domestic water service and 10-inch fire protection service. The proposed condition will include an upsized 6-inch domestic water service and the existing 10-inch fire protection service will remain. Both services will continue to be fed from this existing 10-inch private water main.

Prior to construction hydrant flow tests will be completed to verify adequate flow and pressure for the building's sprinkler system. The project also proposes to add a new hydrant along the eastern drive aisle per CWD standards.

The proposed water meter room location with be closely coordinated with CWD during final design. The new water meter configuration will be abutting the building wall, as required by CWD.

Any existing domestic water and fire protection services will be discontinued prior to the erection of the addition (except for the 10" service being preserved) meeting CWD standards. All existing service connections 4-inches or larger, will cut out the existing anchor tee at the water main and replace with new water pipe, following CWD standards. At this time, no services have been identified for discontinuance at the CWD water main.

The Applicant will work with CWD on the development of the Project design and submit plot plans for formal approval prior to the issuance of the Building Permit for the Project.

STORMWATER MANAGEMENT

Under existing conditions, the Project Site is previously developed and predominantly covered by impervious surfaces comprised of building roof areas and surface parking lots. The existing building on the Project Site does not contain any form of known stormwater management in the existing condition. Stormwater is conveyed via enclosed pipe roof conduit and surface sheet flow to local catch basin structures on site. Stormwater discharges into the DPW-owned 24-inch storm drain within Cambridgepark Drive, without any known form of stormwater quality or quantity management.

The proposed stormwater management system will be designed to comply with the MA DEP Stormwater Management Policy for redevelopment projects and the City of Cambridge standards to the maximum extent practicable. Based on a meeting held on April 6, 2022; the Applicant intends to apply for a stormwater peak rate and volume waiver from the Land Disturbance bylaw prior to submission of the Notice of Intent (NOI) with the Cambridge Conservation Commission. The waiver is being submitted due to limiting factors on site such as restricted site area with existing City of Cambridge and MWRA easements, an existing Activity and Use Limitation (AUL), high seasonal groundwater and poor soil conditions, low topography, and high existing drainage inverts.

The Project anticipates evaluating storm events using rainfall volumes based on the National Oceanic and Atmospheric Administration (NOAA) Atlas Type III, 24-hour storm event for Boston (Station – Boston Logan International Airport). Local Cambridge rainfall depths may be evaluated for the year 2070 storm events, as requested by Cambridge DPW.

Under proposed conditions, the Project Site will not produce changes in either the pattern of or rate of stormwater runoff. Stormwater management controls will be established in compliance with DPW standards. The Project is not designed to result in the introduction of any peak flows, pollutants, or sediments that would potentially impact the receiving waters of the local municipal stormwater drainage system.

For the current design, the proposed and existing building roof areas will discharge through a rainwater harvesting cistern on site, designed to reduce peak stormwater rates and volumes in addition to reducing the total phosphorus load from the project site. The rainwater will be used to help irrigate the landscaped areas on site. Porous pavement will also be used on site within parking stalls to allow for groundwater recharge. Infiltration will promote groundwater recharge and reduce stormwater peak rates and volumes, in addition to reducing total phosphorus load from the Project Site.

The final design will incorporate facilities to reduce phosphorus on-site by 65 percent compared to the existing conditions, in compliance with DPW standards. These facilities may include added pervious area, pervious pavement, stormwater filters, and/or stormwater harvesting tanks. The Project will implement stormwater Best Management Practices (BMPs) in conformance with DEP's Stormwater Management Standards.

The Project's construction documents will include measures and specifications regarding erosion and sediment controls and barriers (e.g. silt fence, silt sacks). Construction dewatering discharges will be appropriately controlled and discharged in accordance with National Pollutant Discharge Elimination System (NPDES) and state and local dewatering standards.

The Project anticipates detailed design review with DPW throughout the design process. The detailed stormwater management report is anticipated to be coordinated with DPW throughout final design and submitted in part to the NOI and SWCP process, prior to Building Permit submission.

TABLE 2

Elevation Range (CCB)	Existing Condition (CF)	Proposed Condition (CF)	Delta (CF)
18.46 - 17.46	24,195	24,903	(+) 708
17.46 - 16.46	121	1,256	(+) 1,135
16.46 - 15.46	0	0	0
Total	**24,316**	**26,159**	**(+) 1,843**

Compliance to Article 20:70 - Floodplain Overlay District

Based on a review of the Federal Emergency Management Agency (FEMA) maps and current topographic information, nearly the entirety of the Project Site is located within the limits of the Special Flood Hazard Area designated as Zone AE according to the Middlesex County Flood Insurance Rate Map (#25017C0419E dated June 4, 2010) issued by FEMA. This flood elevation is defined by FEMA as elevation +6.8’ NAVD88 datum (+18.46’ CCB datum). This narrative serves to summarize the anticipated impact on the floodplain, as identified in the City of Cambridge Zoning Article 20.70 – Floodplain Overlay District.

The current 100-year flood elevation is +18.46’ Cambridge City Base (CCB) datum. This elevation has been depicted within the Project Site existing conditions plans based upon a field survey performed by VHB from March 2018 to February 2022. The 100-year flood elevation limit based on field-measured elevations is generally consistent with the limits shown on the FEMA mapping. For the purposes of this narrative, impacts are measured based on the surveyed current 100-year flood elevation of +18.46’ CCB.

As indicated below with Table 2 below, the Project is currently proposing a net increase of flood storage in the final condition on a foot-by-foot within the Project Site and adjacent City right-of-way (ROW). The final compensatory flood storage calculation in Table 2, have been submitted to the Cambridge Conservation Commission as part of the Notice of Intent (NOI) for the Project, the initial hearing is anticipated on July 25, 2022.

The proposed site grading will be designed to mitigate impacts to the existing flood storage volume, while providing resiliency to the Cambridge 2070 flood elevations.

As currently proposed, the project is generally consistent with the requirements of the City of Cambridge Zoning Article 20.70 – Floodplain Overlay District.

CAMBRIDGE 2070 RESILIENCY

The City of Cambridge has developed the Climate Change Preparedness & Resilience Plan (CCPR), which is intended to commit to prepare the community for impacts to anticipated climate change. In part to the CCPR, the City has developed an online FloodViewer (v3.0), which provides anticipated flood event elevations for the year 2070.

The Project team has reviewed the 2070 resiliency elevations within the current Cambridge FloodViewer for both Precipitation and Sea Level Rise / Storm Surge (SLR/SS). In review of the existing Project Site, the current 2070 10-year storm event is equal to elevation 22.0 CCB, and the 2070 100-year storm event is equal to elevation 23.3 CCB.

The Project is designed to set the proposed building addition Finished Floor Elevation (FFE) to a minimum elevation of 22.5 CCB. This elevation will allow for the proposed and existing building to be resilient towards the 2070 10-year storm elevation. Additional flood barriers and controls will be proposed for flood protection at doorways for the 100-year flood elevation. Additionally, critical infrastructure such as electric switchgear and transformers will be raised to a minimum of elevation 23.3 CCB on the Project Site or within the proposed building to be resilient toward the 2070 100-year storm event.

At locations where it will not be feasible for the Project to meet the 2070 100-year flood elevation, such as the proposed loading docks, temporary deployable flood measures will be installed to provide additional resiliency at these critical locations.

OTHER UTILITIES

In addition to water service and stormwater management infrastructure, the proposed addition will also require natural gas, electrical, and telecommunication services, which are available via connections to the existing 125 Cambridgepark Drive. The project will propose the addition of a new electric yard in the rear of the building to fully replace the existing yard servicing 125 Cambridgepark Drive. This new yard will consist of transformer and switchgear equipment which will be sized and coordinated with Eversource Electric to service the existing building as well as the addition. The existing natural gas meter is intended to be upgraded by Eversource Gas, and set on a new concrete pad adjacent to the existing building structure at its current location.

4B. Tree Inventory

125 Cambridge Park Drive
Tree Inventory Summary Report | 2022

Submitted by:
Bartlett Tree Experts

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EXECUTIVE SUMMARY

In March 2022, Longfellow Real Estate Partners retained Bartlett Tree Experts to perform a re-inventory of trees at 125 Cambridge Park Drive in Cambridge, MA. The initial inventory was done in 2019. Team Kat Cummings visited the site on March 8 to conduct the new inventory.

The inventory included:

- identifying trees and assigning a Tree ID number (Tree ID numbers ranging from 1 to 39);
- identifying the trees' condition, health, and vigor;
- mapping the trees using GPSr hardware and Geographic Information System (GIS) software, and Bartlett Tree Experts' ArborScope™ web-based management system

We identified 39 trees which included 9 species. The attributes that we collected include tree latitude and longitude, size, age and condition class, and a visual assessment of tree structure, health, and **vigor**.

We conducted the attribute collection using a sub-meter accuracy Global Positioning Satellite Receiver (GPSr) device with an error-in-location potential of not greater than three meters. Our recommendations for the subject trees are based on the number of desired management cycles. All tree work activities will comply with current American National Standards Institute (ANSI) Z133.1 requirements for safety.

Limitations of the Plan

The service was conducted to assist the Client (and/or Owner) with its tree care needs. This service did not include a tree risk assessment. As such, no trees were assessed for risk in accordance with industry standards, nor were any tree risk ratings or risk mitigation recommendations provided within this plan.

The purpose of this inventory was to help the Owner understand the specified attributes of each tree or groups of trees selected at the time of the inventory, not to identify tree risk or failure potential, or to classify the potential for tree risk or failure in accordance with industry standards. While observed defects were part of the overall condition rating for each tree, this inventory is not meant to declare any tree to be “safe” or unlikely to be hazardous. As such, the Owner should not infer that any tree not identified as having a condition class of poor or dead, or not having a tree and shrub work phase of ASAP, 1, or 2, is “safe” or will not fail in any manner.

GOALS & OBJECTIVES

An effective management plan communicates clear goals and the specific objectives designed to carry out those goals. We intend "goal" to mean the overall aim or result we expect to achieve for the client in producing the inventory and management plan. The objectives are the specific actions taken or recommended to support goal completion. The table below describes each goal and its corresponding objective(s).

GOALS & OBJECTIVES

GOAL	OBJECTIVES TO ACCOMPLISH GOAL
Establish a new tree inventory (per numbers agreed) at 125 Cambridge Park Drive.	• Using Trimble® Geo GPSr hardware and ArborScope™ Inventory Management Tools, collect data such as tree name, location, size, age class, and condition class. • Assign a Tree ID number to each tree inventoried.
Provide mechanism for managing inventory, recommendations, and related budget planning.	• Provide map or maps of the inventoried trees to assist the client in managing property areas. • Submit a summary report that documents and organizes findings and provides other resources to assist the client in efficient use of the information.
Maximize client understanding and implementation of report.	• Include in report specific explanations and visuals related to plan recommendations. • Provide appended resources that address health, procedures, and standards related to tree care. • Make periodic contact with client to follow up and answer any questions about the management plan's contents.
Maximize immediate and long-term tree health and aesthetics.	Implement recommended plant-health-care program that uses • integrated pest management

DATA COLLECTION & TREE INSPECTION METHODOLOGY

In conducting the inventory, we used specialized equipment and software and followed specific procedures to determine tree characteristics, risk evaluations, and recommendations. The following explanation will assist the reader in interpreting the findings of this report.

Data Collection Equipment & Attribute Data

The Inventory Team used Trimble® Geo GPSr hardware units, TerraSync® and GPS Pathfinder® Office GIS software, and Bartlett Tree Experts' ArborScope™ web-based management system to inventory the trees. The attribute data we collected on site are listed below.

- botanical name and regional common name according to local ISA Chapter Tree Species List
- tree location based on GPS coordinate system
- tree ID number
- diameter at breast height (**DBH**)
- canopy radius
- age class
- height class
- condition class
- plant health care recommendations
- noted defects/observations
- observed pests/diseases

Specifications/Definitions

Age Class

New Planting	Tree not yet established
Young	Established tree but not in the landscape for many years
Semi-mature	Established tree but has not yet reached full growth potential
Mature	Tree within its full growth potential
Over-mature	Tree that is declining or beginning to decline due to its age

Height Class

Small	Less than 15 feet
Medium	15 to 40 feet
Large	Greater than 40 feet

Condition Class

Dead	
Poor	Most of the canopy displays dieback and undesirable leaf color, inappropriate leaf size or inadequate new growth. Tree or parts of tree are in the process of failure.
Fair	Parts of canopy display undesirable leaf color, inappropriate leaf size, and inadequate new growth. Parts of the tree are likely to fail.

Good Tree health and condition are acceptable.

STAND DYNAMICS RESULTS

STAND DYNAMICS RESULTS

In reviewing the results and recommendations, the reader will find useful the specifications and definitions detailed in the preceding methodology above. We used the following categories to organize the stand dynamics results, which are displayed in tables:

- **Subject Trees Summarized According to:**
  - Tree Species Identified
  - Condition Class
  - Age Class
  - Tree Size per DBH

Where appropriate, we have included explanations, photos, drawings, or other information to illuminate the table contents.

Stand Dynamics

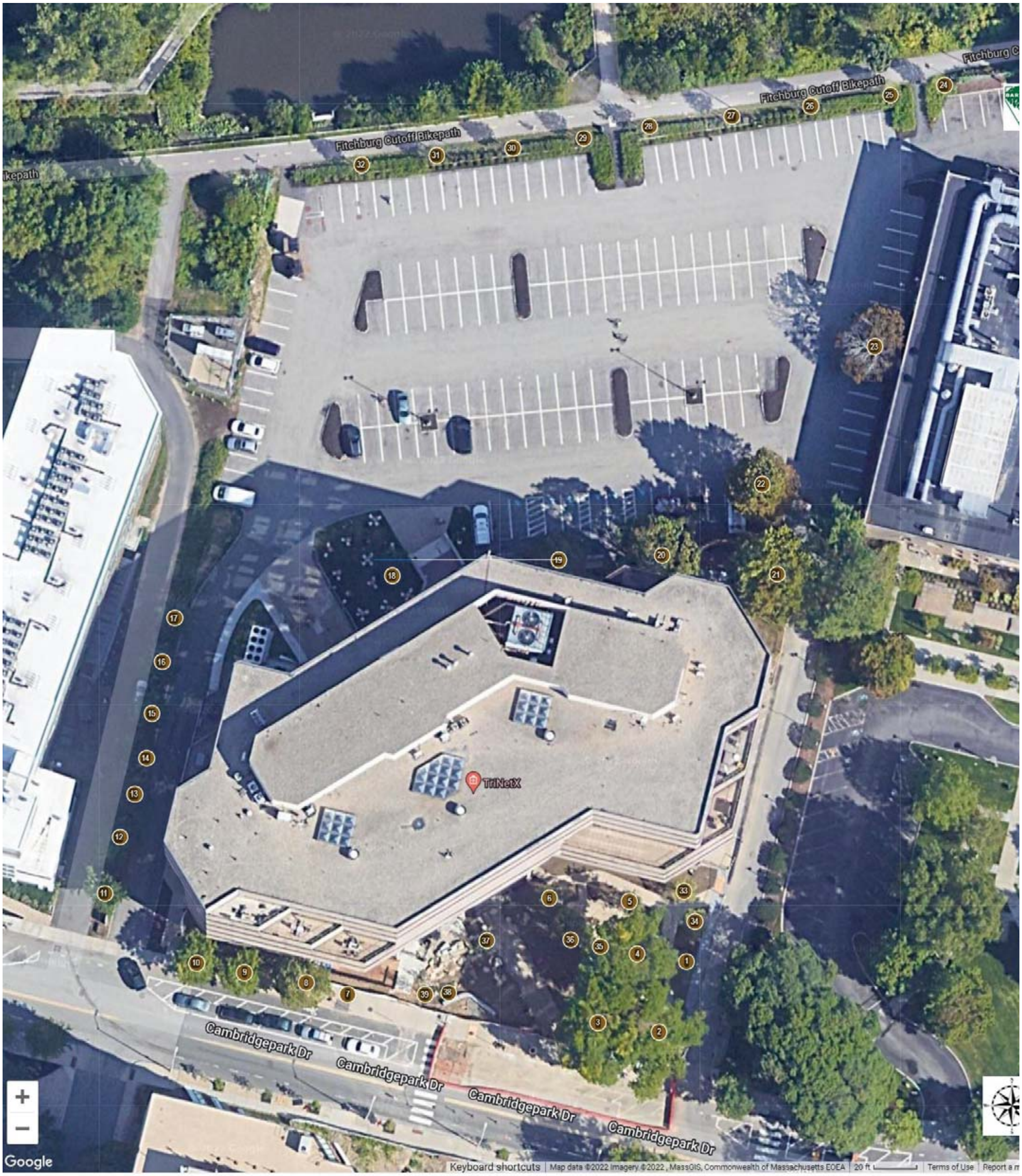
Tree Species Identified

Our inventory revealed 9 species of trees, as detailed in the following table:

TREE SPECIES IDENTIFIED

Genus	Species	Common Name	Count	% Distribution Total
Acer	*platanoides*	Maple-Norway	5	13%
	rubrum	Maple-Red	9	23%
***Acer* Total**			**14**	**36%**
Amelanchier	*canadensis*	Serviceberry	4	10%
Betula	*nigra*	Birch-River	4	10%
Gleditsia	*triacanthos* var. inermis	Honeylocust-Thornless Common	6	15%
Morus	*rubra*	Mulberry-Red	1	3%
Quercus	*palustris*	Oak-Pin	3	8%
Tilia	*cordata*	Linden-Littleleaf	1	3%
Ulmus	*americana*	Elm-American	6	15%
Grand Total			**39**	**100%**

2022 TREE INVENTORY

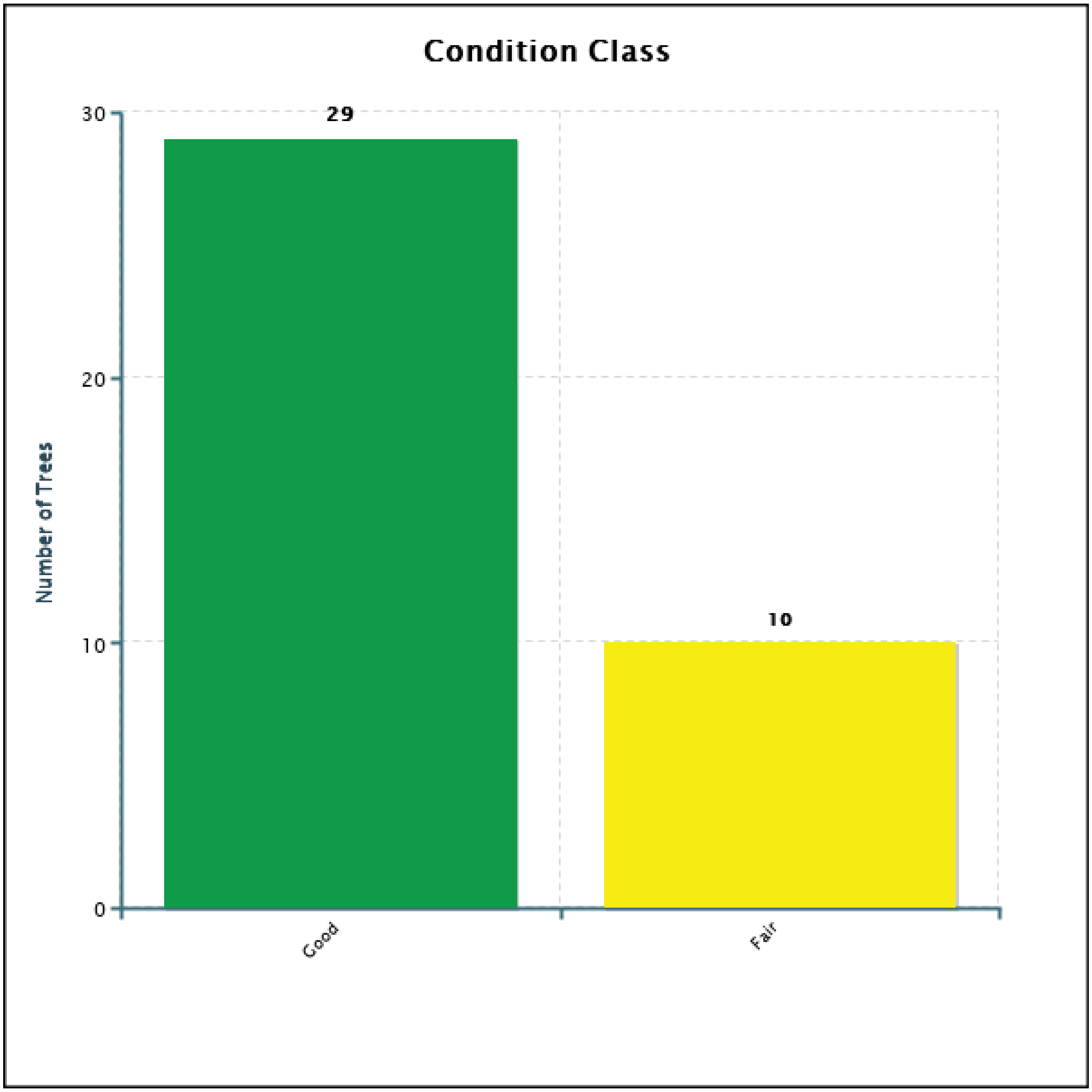


Condition Class

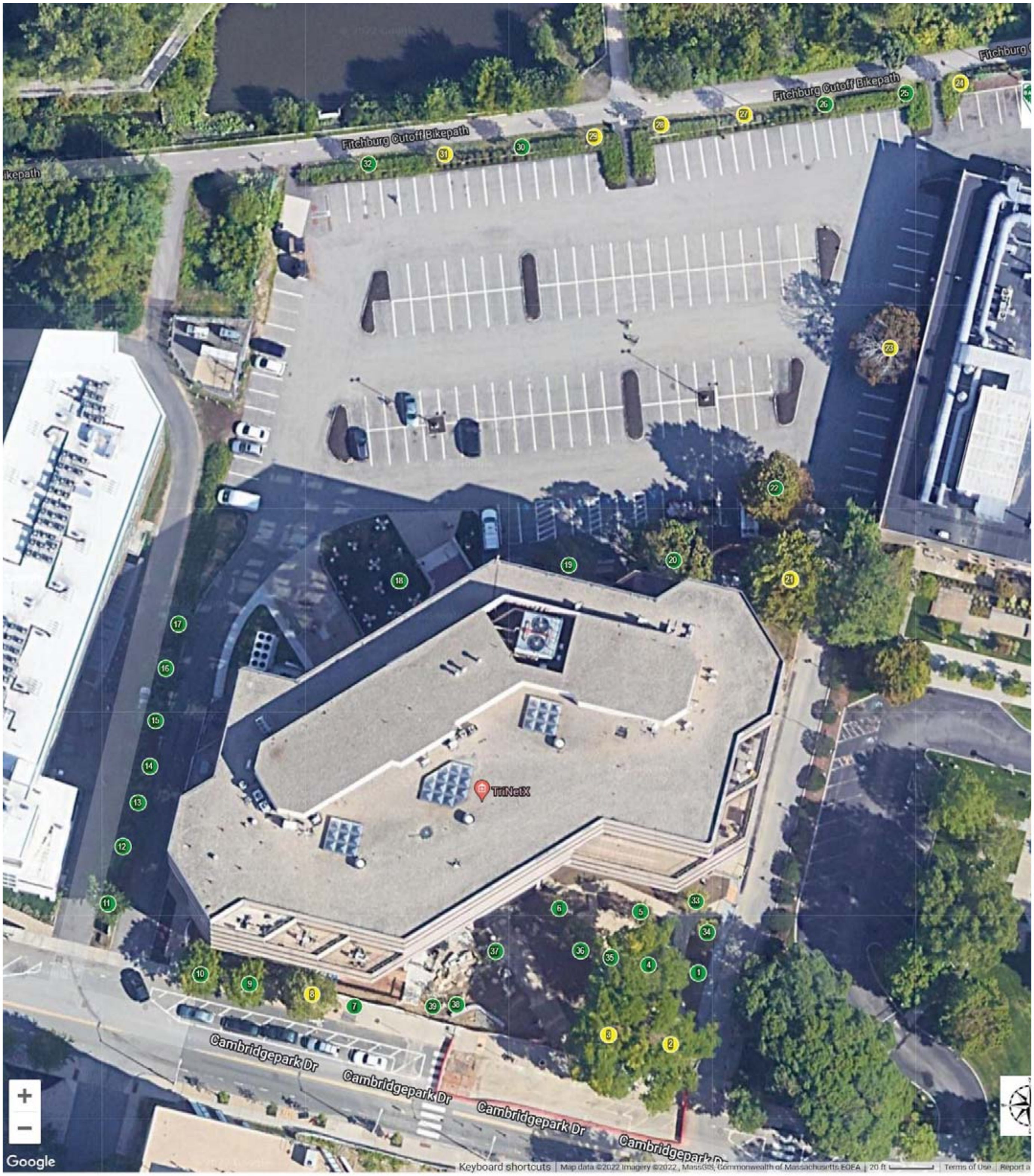
The breakdown of tree condition follows:

CONDITION CLASS BREAKDOWN

Condition Class	Quantity	% of Total
Good	29	74%
Fair	10	26%



INVENTORIED TREES BY CONDITION CLASS



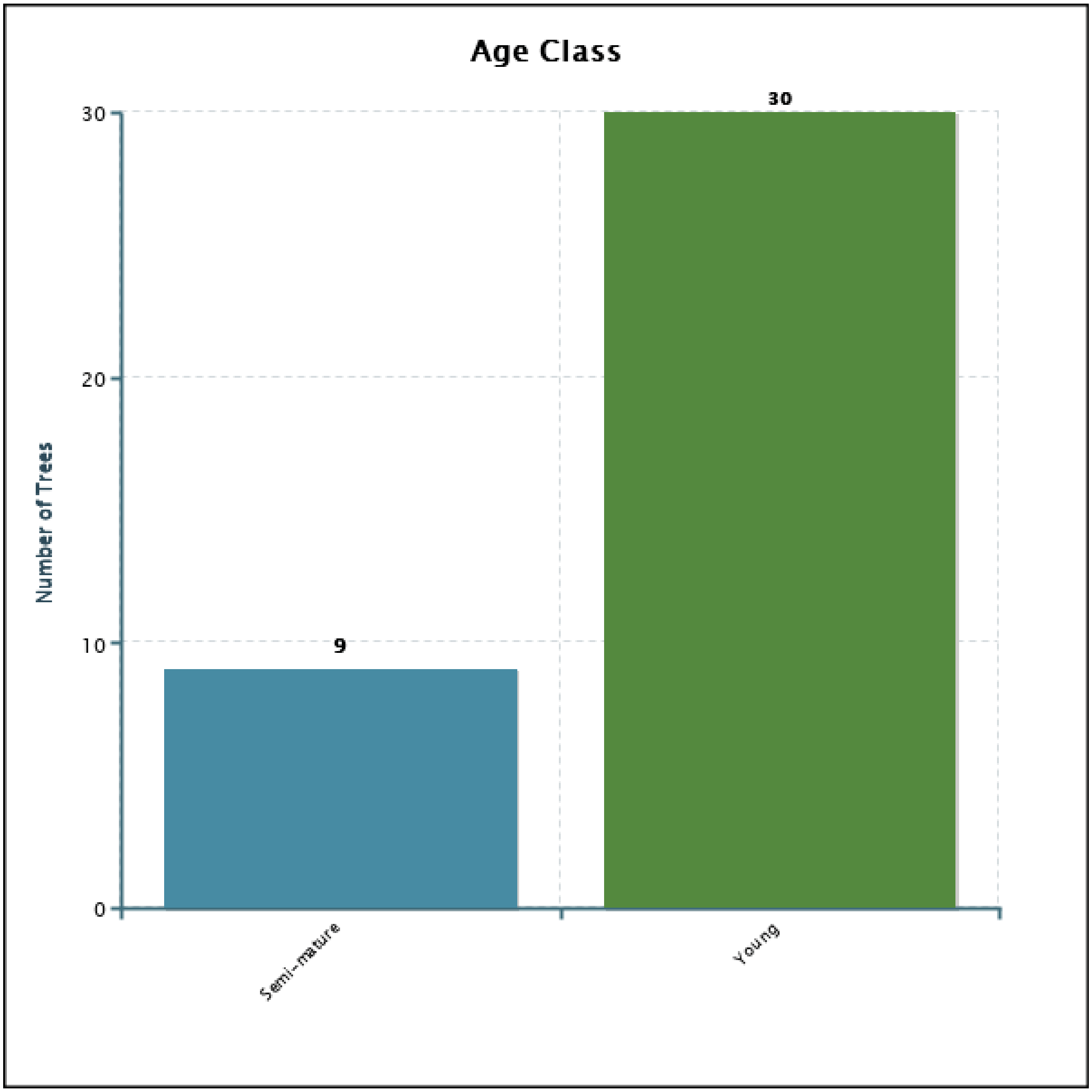
Condition: Good Fair

Age Class

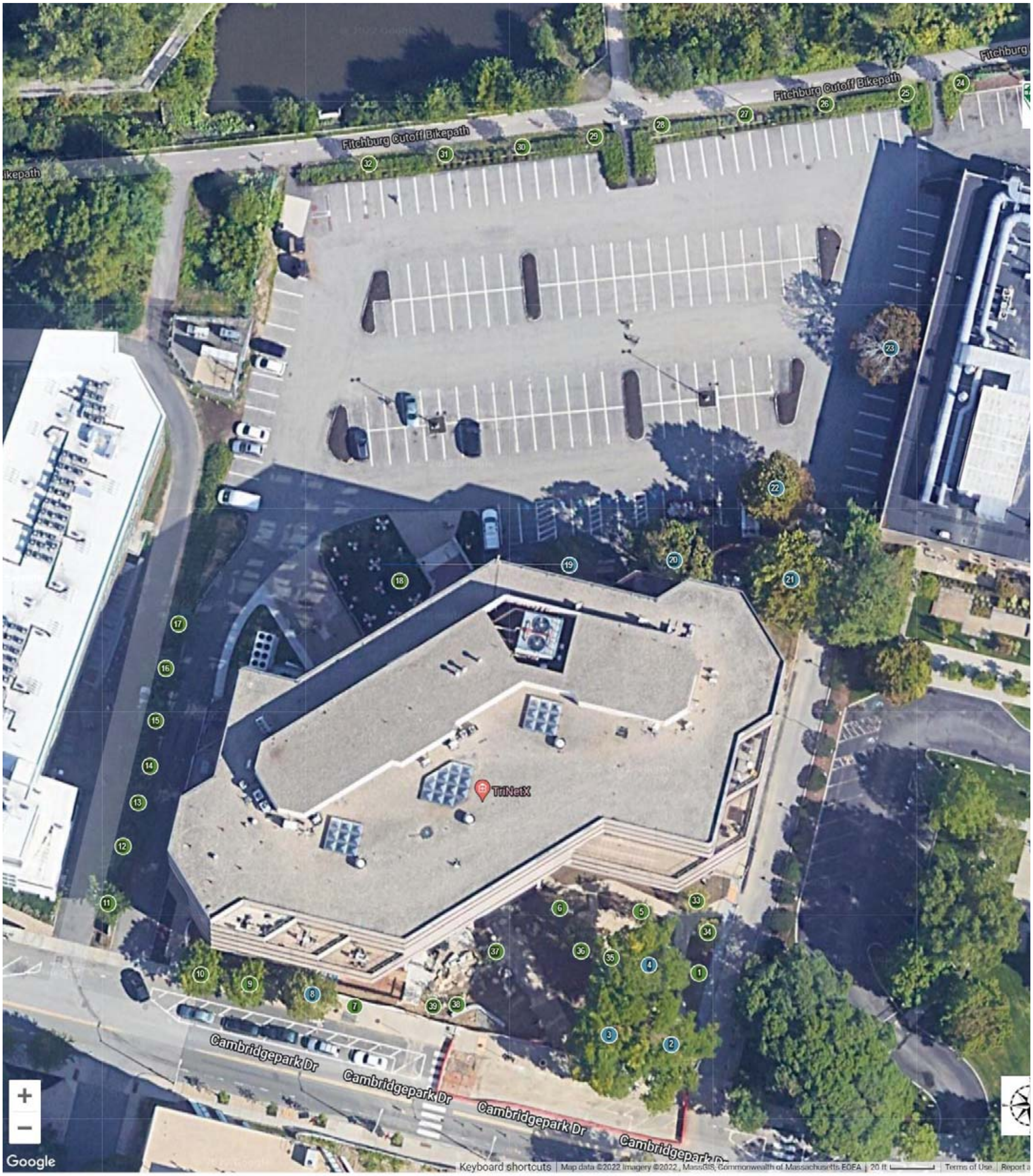
The breakdown of tree age class follows:

AGE CLASS BREAKDOWN

Age Class	Quantity	% of Total
Semi-mature	9	23%
Young	30	77%



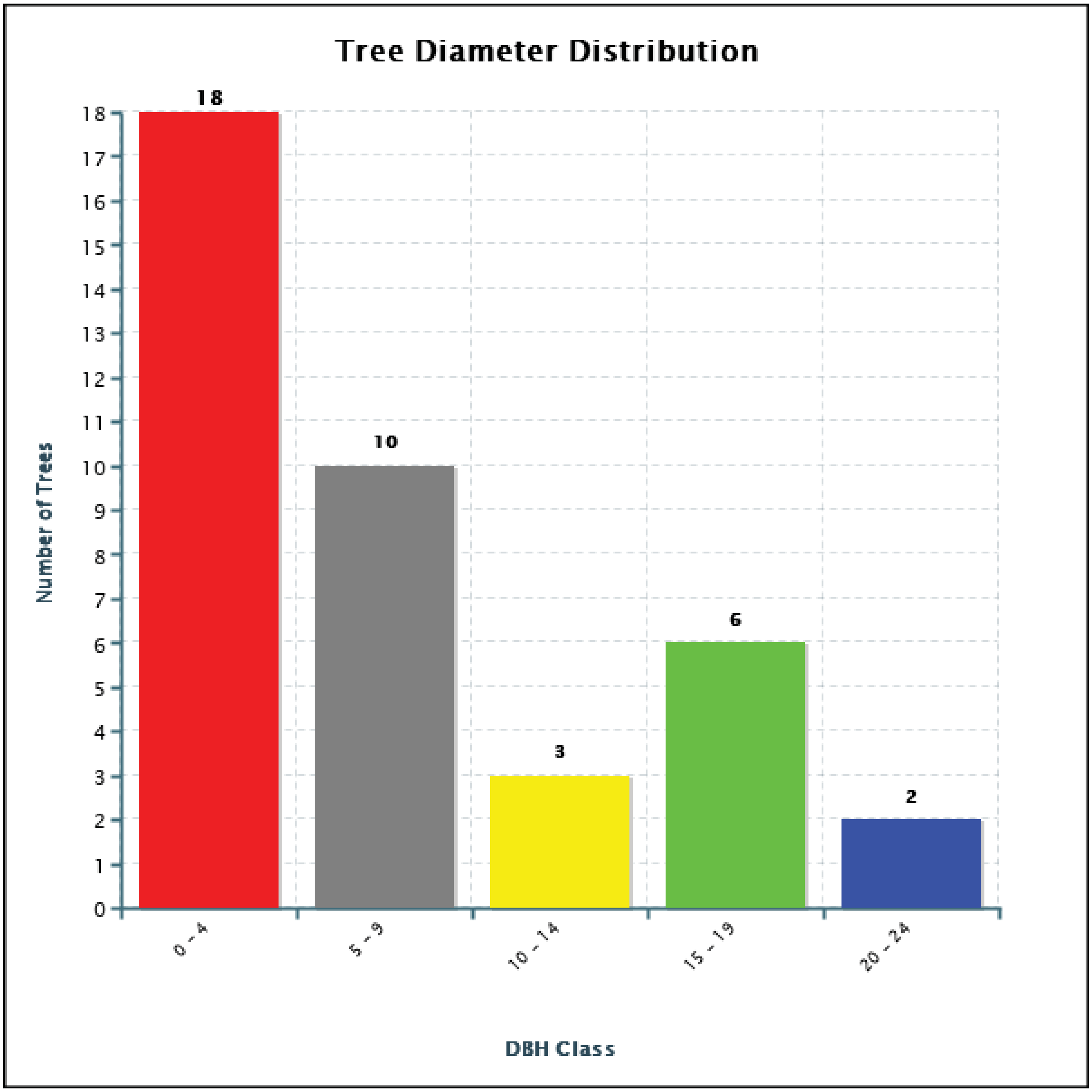
INVENTORIED TREES BY AGE CLASS



Age: Young Semi-mature

Tree Size (DBH)

The following chart illustrates numbers of trees according to size per DBH:



RECOMMENDATIONS

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TREE EXPERTS

SCIENTIFIC TREE CARE SINCE 1907

RECOMMENDATIONS

Plant Health Care

The Inventory Team recommends Plant Health Care (PHC) programs for trees in the formal landscape. In addition, an Integrated Pest Management (IPM) program monitors for potentially damaging insects, diseases and cultural problems that are often seasonal and may not have been evident during our inventory visit. Plant Health Care treatments should be applied as soon as possible, therefore they do not have a Tree & Shrub Work phase. These pests and diseases include, but are not limited to, the following:

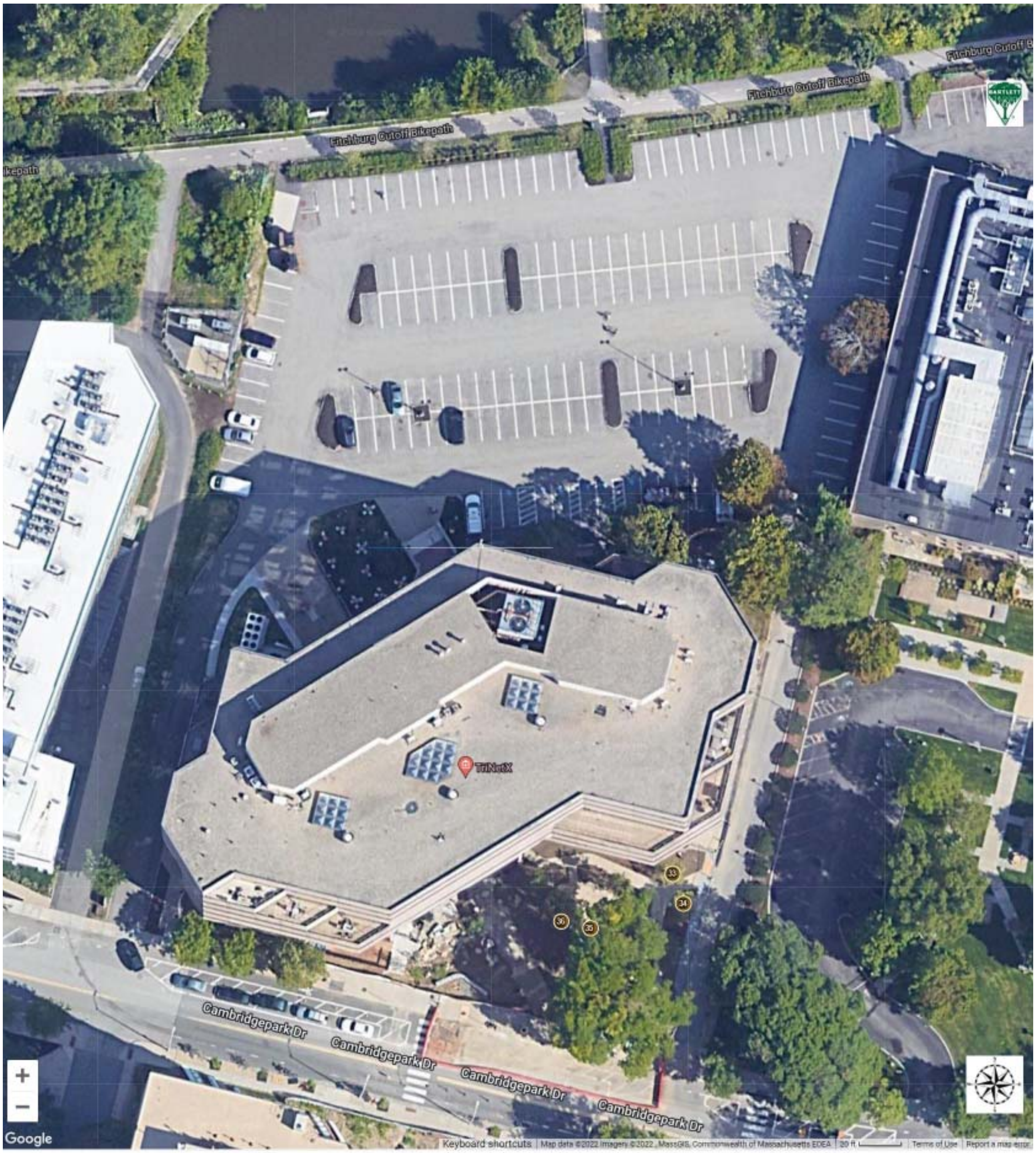
- Anthracnose - on a variety of species
- Aphids - on a variety of species
- Bacterial Leaf Scorch - on trees within red oak group
- Bagworms - on a variety of tree species
- Boring Insects - on a variety of tree species
- Caterpillar Defoliators - on a variety of tree species, especially oak
- Gall Insects - on a variety of species
- Lacebugs - on a variety of species
- Scab and Rust Fungi - on crabapple and apple species.
- Suspected Phytophthora Root Rot and Canker - on a variety of tree species, especially beech species
- Scale Insects - on a variety of tree species, especially oak
- Spider Mites - on a variety of tree species

We identified pests or diseases and/or provided plant health care recommendations on the following inventoried trees at the time of the inventory:

INVENTORIED TREES IDENTIFIED FOR PLANT HEALTH CARE (4 Trees)

Tree ID	Common Name	DBH	Plant Health Care	Pest(s) or Disease(s)
33	Serviceberry	2,2,2,2,2,1	• Fungicide treatment	• Rust
34	Serviceberry	2,2,2,2,2,1	• Fungicide treatment	• Rust
35	Serviceberry	2,2,2,2,2,1	• Fungicide treatment	• Rust
36	Serviceberry	3,3,2,2,3,2	• Fungicide treatment	• Rust

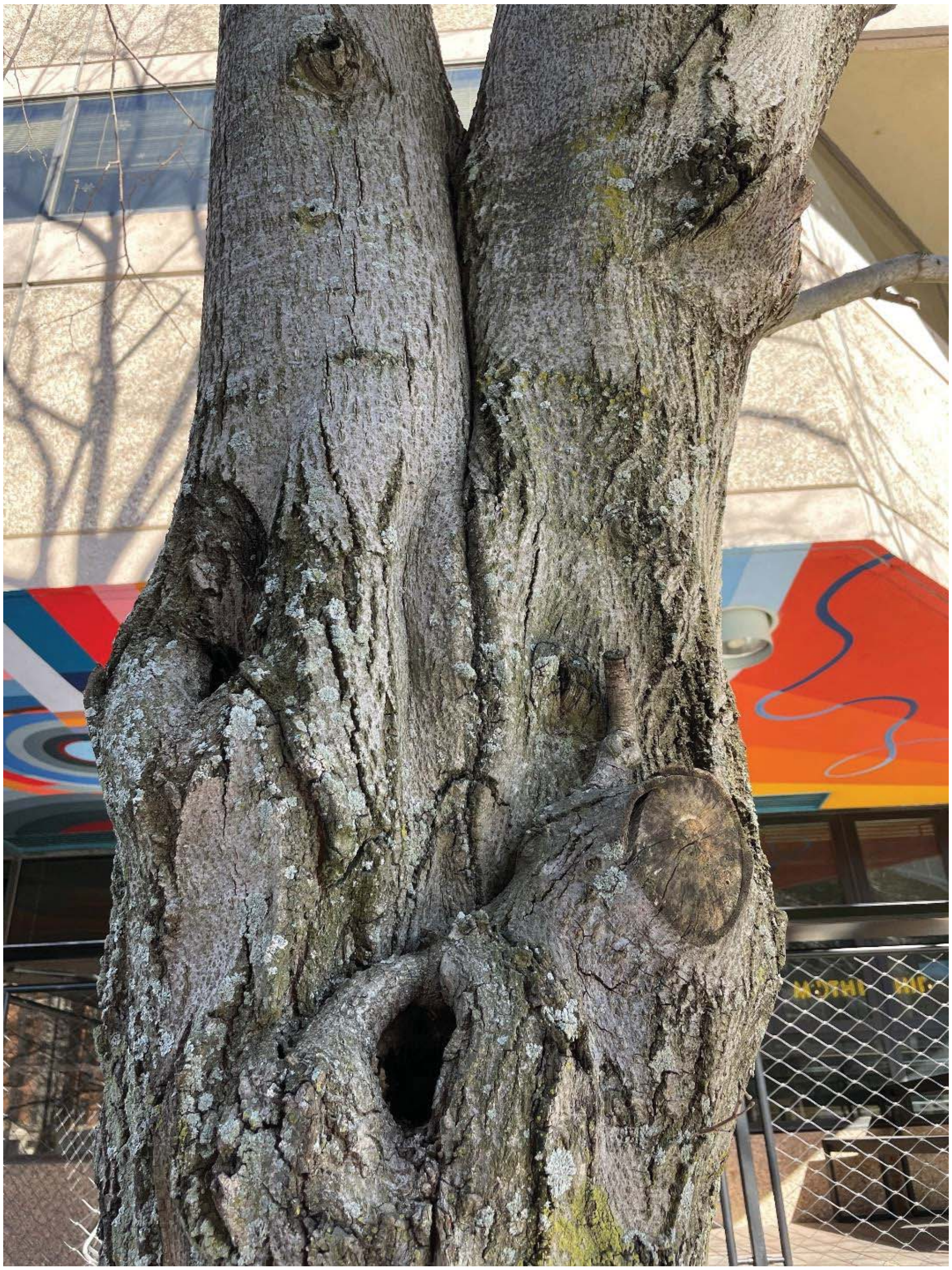
INVENTORIED TREES IDENTIFIED FOR PLANT HEALTH CARE



DEFECTS OR OBSERVATIONS

DEFECTS OR OBSERVATIONS

The following table lists inventoried trees for which we noted defects, observations, or other structural issues. All trees in this inventory had noted defects; some individuals had more than others. Generally, older trees and stressed trees tend to have more defects.



Tree #8 exhibiting multiple defects. There are multiple old wounds on the stem where decay can be seen. There are also co-dominant stems with included bark present.

Tree #28 exhibiting a lower stem wound and a buried root collar. Planting material was also noted; guys should be removed from the young tree before the stem grows too large and the staking material begins to girdle the tree. In this example, one side of the guy system is already broken and just leaning against the other so the system as a whole is not achieving the intended purpose.

INVENTORIED TREES WITH DEFECTS, OBSERVATIONS, OR OTHER STRUCTURAL ISSUES (39 Trees)

Tree ID	Common Name	DBH	Defect(s) or Observation(s)
1	Oak-Pin	5	• Buried root collar • Dead branches <=2 • Poor branch structure
2	Honeylocust-Thornless Common	16	• Broken branch(s) • Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure
3	Honeylocust-Thornless Common	18	• Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure • Uneven crown
4	Honeylocust-Thornless Common	20	• Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure
5	Oak-Pin	6	• Buried root collar • Dead branches <=2 • Wound-stem
6	Oak-Pin	5	• Buried root collar • Poor branch structure
7	Honeylocust-Thornless Common	4	• Poor branch structure • Uneven crown
8	Linden-Littleleaf	14	• Co-dominant stems • Decay-stem • Girdling roots present • Included bark • Poor branch structure • Uneven crown
9	Honeylocust-Thornless Common	6	• Dead branches <=2 • Girdling roots present • Poor branch structure • Uneven crown
10	Honeylocust-Thornless Common	7	• Co-dominant stems • Dead branches <=2 • Girdling roots present • Poor branch structure • Wound-root

Tree ID	Common Name	DBH	Defect(s) or Observation(s)
11	Elm-American	10	• Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure • Wound-branch
12	Elm-American	9	• Buried root collar • Co-dominant stems • Dead branches <=2 • Included bark • Poor branch structure
13	Elm-American	8	• Buried root collar • Co-dominant stems • Dead branches <=2 • Included bark • Poor branch structure • Wound-branch
14	Elm-American	9	• Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure • Wound-branch
15	Elm-American	9	• Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure
16	Elm-American	9	• Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure
17	Mulberry-Red	10	• Buried root collar • Co-dominant stems • Dead branches <=2 • Poor branch structure
18	Birch-River	4,4,3,2,2	• Buried root collar • Co-dominant stems • Poor branch structure
19	Maple-Norway	18	• Buried root collar • Co-dominant stems • Poor branch structure • Uneven crown
20	Maple-Norway	21	• Co-dominant stems • Girdling roots present • Poor branch structure • Seam

Tree ID	Common Name	DBH	Defect(s) or Observation(s)
21	Maple-Norway	19	• Buried root collar • Co-dominant stems • Dead branches <=2 • Decay-root flare • Girdling roots present • Poor branch structure
22	Maple-Norway	16	• Co-dominant stems • Dead branches <=2 • Girdling roots present • Poor branch structure
23	Maple-Norway	16	• Co-dominant stems • Dead branches >2 • Girdling roots present • Low vigor • Poor branch structure • Seam
24	Maple-Red	4	• Buried root collar • Poor branch structure • Wound-stem
25	Maple-Red	4	• Buried root collar • Overextended branch • Planting material • Wound-stem
26	Maple-Red	4	• Buried root collar • Dead branches <=2 • Planting material • Poor branch structure • Wound-stem
27	Maple-Red	4	• Buried root collar • Dieback (moderate) • Poor branch structure
28	Maple-Red	4	• Buried root collar • Dieback (moderate) • Planting material • Wound-stem
29	Maple-Red	4	• Buried root collar • Dieback (moderate) • Poor branch structure • Wound-stem
30	Maple-Red	4	• Buried root collar • Dead branches <=2 • Poor branch structure • Wound-stem

Tree ID	Common Name	DBH	Defect(s) or Observation(s)
31	Maple-Red	4	• Buried root collar • Dead branches <=2 • Dieback (moderate) • Wound-stem
32	Maple-Red	4	• Buried root collar • Dead branches <=2 • Dieback (moderate) • Poor branch structure • Wound-stem
33	Serviceberry	2,2,2,2,2,1	• Buried root collar • Co-dominant stems • Poor branch structure
34	Serviceberry	2,2,2,2,2,1	• Buried root collar • Co-dominant stems • Poor branch structure
35	Serviceberry	2,2,2,2,2,1	• Buried root collar • Co-dominant stems • Dead branches <=2 • Flush cuts • Poor branch structure
36	Serviceberry	3,3,2,2,2,2	• Buried root collar • Co-dominant stems • Poor branch structure
37	Birch-River	2,2,2	• Buried root collar • Co-dominant stems
38	Birch-River	2,2,2	• Buried root collar • Co-dominant stems • Poor branch structure • Uneven crown
39	Birch-River	2,2,2	• Buried root collar • Co-dominant stems • Poor branch structure

ENTIRE INVENTORY

ENTIRE INVENTORY (39 Trees)

Tree ID	Common Name	Genus	Species	DBH	Height Class	Age Class	Condition Class
1	Oak-Pin	*Quercus*	*palustris*	5	Medium	Young	Good
2	Honeylocust-Thornless Common	*Gleditsia*	*triacanthos* var. inermis	16	Large	Semi-mature	Fair
3	Honeylocust-Thornless Common	*Gleditsia*	*triacanthos* var. inermis	18	Large	Semi-mature	Fair
4	Honeylocust-Thornless Common	*Gleditsia*	*triacanthos* var. inermis	20	Large	Semi-mature	Good
5	Oak-Pin	*Quercus*	*palustris*	6	Medium	Young	Good
6	Oak-Pin	*Quercus*	*palustris*	5	Medium	Young	Good
7	Honeylocust-Thornless Common	*Gleditsia*	*triacanthos* var. inermis	4	Medium	Young	Good
8	Linden-Littleleaf	*Tilia*	*cordata*	14	Medium	Semi-mature	Fair
9	Honeylocust-Thornless Common	*Gleditsia*	*triacanthos* var. inermis	6	Medium	Young	Good
10	Honeylocust-Thornless Common	*Gleditsia*	*triacanthos* var. inermis	7	Medium	Young	Good
11	Elm-American	*Ulmus*	*americana*	10	Medium	Young	Good
12	Elm-American	*Ulmus*	*americana*	9	Medium	Young	Good
13	Elm-American	*Ulmus*	*americana*	8	Medium	Young	Good
14	Elm-American	*Ulmus*	*americana*	9	Medium	Young	Good
15	Elm-American	*Ulmus*	*americana*	9	Medium	Young	Good
16	Elm-American	*Ulmus*	*americana*	9	Medium	Young	Good
17	Mulberry-Red	*Morus*	*rubra*	10	Medium	Young	Good
18	Birch-River	*Betula*	*nigra*	4,4,3,2,2	Medium	Young	Good
19	Maple-Norway	*Acer*	*platanoides*	18	Large	Semi-mature	Good
20	Maple-Norway	*Acer*	*platanoides*	21	Large	Semi-mature	Good
21	Maple-Norway	*Acer*	*platanoides*	19	Large	Semi-mature	Fair
22	Maple-Norway	*Acer*	*platanoides*	16	Large	Semi-mature	Good
23	Maple-Norway	*Acer*	*platanoides*	16	Large	Semi-mature	Fair
24	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Fair
25	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Good
26	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Good
27	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Fair
28	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Fair
29	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Fair
30	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Good
31	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Fair
32	Maple-Red	*Acer*	*rubrum*	4	Medium	Young	Good
33	Serviceberry	*Amelanchier*	*canadensis*	2,2,2,2,2,1	Medium	Young	Good
34	Serviceberry	*Amelanchier*	*canadensis*	2,2,2,2,2,1	Medium	Young	Good
35	Serviceberry	*Amelanchier*	*canadensis*	2,2,2,2,2,1	Medium	Young	Good
36	Serviceberry	*Amelanchier*	*canadensis*	3,3,2,2,2,2	Medium	Young	Good

Tree ID	Common Name	Genus	Species	DBH	Height Class	Age Class	Condition Class
37	Birch-River	*Betula*	*nigra*	2,2,2	Medium	Young	Good
38	Birch-River	*Betula*	*nigra*	2,2,2	Medium	Young	Good
39	Birch-River	*Betula*	*nigra*	2,2,2	Medium	Young	Good

4D. Noise Mitigation Narrative

ACENTECH

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16 March 2022

Jacob Kain AIA
Associate
Elkus Manfredi Architects
25 Drydock Avenue
Boston, MA 02210

Subject: 125 CambridgePark Drive Repurposing, Phases 1 and 2
Report on Rooftop Equipment Noise Controls and Exterior Noise Levels
Acentech reference: 633896-125CPD-Exterior Noise.docx

Dear Jacob:

This letter presents a summary of our assessment of the noise levels expected to be emitted by the exterior rooftop mechanical equipment proposed for the 125 CambridgePark Drive repurposing project. Longfellow Real Estate Partners, developer of the project, is planning to convert the building from its existing office-only use to a flexible mix of laboratory and office use, over the next 3 to 7 years, as existing office leases expire and new lab begin to occupy the building. It is envisioned that changes in the building infrastructure needed to accommodate the changeover to lab space will take place in two major phases: Phase 1 will entail changes to existing MEP systems and the addition of a limited amount of new mechanical equipment to support some new lab tenants, then Phase 2 will involve the addition of more new MEP equipment to support the full build-out to a 50/50 lab and office mix. This report will cover the acoustical aspects of both phases of the work.

Figure 1, below, shows the 125 CambridgePark Drive project in the context of the overall CambridgePark Drive neighborhood. Nearby residential properties are denoted by green labels.

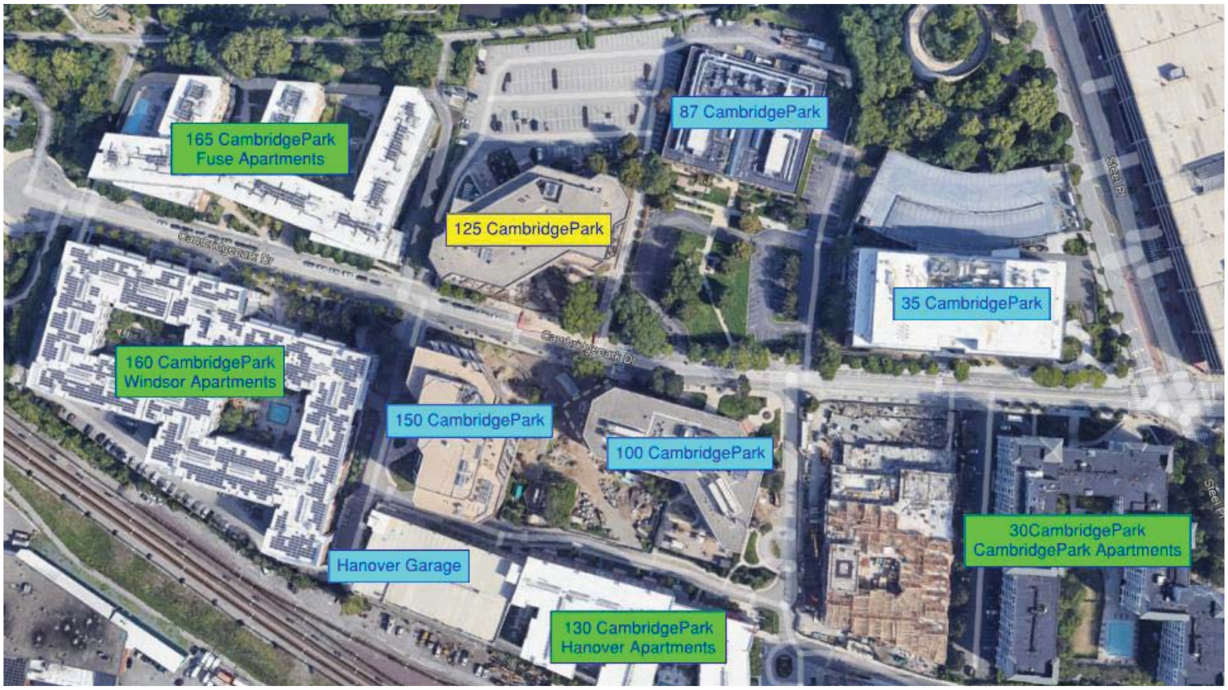

Figure 1: CambridgePark Drive Area

The acoustical analyses for the 125 CambridgePark Drive project are based on manufacturers' data on the acoustical performance of the equipment to be installed and the effects of the various noise controls we have recommended that have been incorporated into the architectural and mechanical design of the building.

Upon the completion of each of the two phases of the project, the overall sound levels produced by the building will comply with the noise level limits established in the City of Cambridge Noise Ordinance, as well as the environmental noise guidelines outlined by the Massachusetts Department of Environmental Protection (MassDEP).

APPLICABLE NOISE REGULATION AND REQUIREMENTS

Massachusetts

The Massachusetts Department of Environmental Protection (MassDEP) prohibits facilities from creating a condition of "noise pollution." A noise source will be considered to be violating the Department's noise regulation (310 CMR 7.10) if the source:

- Increases the broadband sound level by more than 10 dB(A) above ambient, or
- Produces a "pure tone" condition – when any octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more.

These criteria are measured both at the property line and at the nearest inhabited residence. "Ambient" is defined as the background A-weighted sound level that is exceeded 90% of the time, measured during equipment operating hours, but may also be established by other means with consent of the Department.

City of Cambridge

The City of Cambridge Noise Ordinance regulates levels of noise allowed to be emitted from one property to another. The Ordinance establishes maximum permissible sound levels at the lot line of the property receiving the noise, depending on the use of the receiving property. Table 1, below, presents the sound limits established for Residential and Business/Commercial uses.

Octave Band Center Frequency of Measurement (Hz)	Residential Use, Daytime* (dB)	Residential Use, All Other Times (dB)	Commercial/Business, Anytime (dB)
31.5	76	68	79
63	75	67	78
125	69	61	73
250	62	52	68
500	56	46	62
1000	50	40	56
2000	45	33	51
4000	40	28	47
8000	38	26	44
Single Number Equivalent	60 dBA	50 dBA	65 dBA

*Daytime is defined as the period between 7AM and 6PM daily except Sundays and holidays.

Table 1: City of Cambridge Maximum Allowable Octave Band Sound Pressure Levels

Because of the density of rooftop ventilation equipment on the many nearby biotech facilities in the area, and its proximity to both Route 2 to the north and the MBTA commuter rail tracks to the south, the existing back-ground sound levels in the area are expected to be high enough in the project area that meeting the City of Cambridge Noise Ordinance will be the more stringent regulatory criteria.

ROOFTOP MECHANICAL EQUIPMENT

The Phase 1 renovation will include the installation of one new roof-mounted central air handling unit (AHU), one new roof-mounted exhaust air handling unit (EAHU), one new chiller, and two new cooling towers; two new chilled water pumps, two new condenser water pumps and supporting equipment will be located inside a mechanical penthouse. A new emergency generator will be installed on the roof as well. Phase 1 does not require modifications to the existing heating hot water plant, but two existing cooling towers, all chilled water and condenser water pumps, and the existing atrium smoke control fans will be removed.

A list of the Phase 1 outdoor rooftop mechanical equipment most likely to affect community sound levels in the area surrounding the 125 CambridgePark Drive project site is presented below:

- One new insulated-casing air handling unit (AHU), 98,000 cfm, manufactured by BASX, Buffalo, Environmental Air Systems, or Haakon, with an array of fifteen 40" backward-inclined plenum fans drawing outside air through inlet airflow straighteners to reduce fan inlet and discharge sound power levels.
- One insulated-casing exhaust air handling unit (EAHU), 98,000 cfm total capacity, manufactured by Ventrol, Haakon, Engineered Air Systems, or Greenheck, with three exhaust fans equipped with variable-frequency drives; each fan discharges to an exhaust stack equipped with tubular exhaust silencer similar to Vibro-Acoustics Model 48-CD-AR.
- Two one-cell induced-draft, crossflow cooling towers, manufactured by Amcol Cooling Tower, Baltimore Aircoil, or Marley, with specially-designed quiet fan technology on variable frequency drives.
- One new 300 kW Caterpillar C9 Diesel Generator with Level 2 sound enclosure

Figure 2, below, presents a layout plan of the Phase 1 mechanical equipment located on the roof of the 125 CambridgePark Drive building. The heavy blue line shows the outline of the enclosed mechanical equipment penthouse.

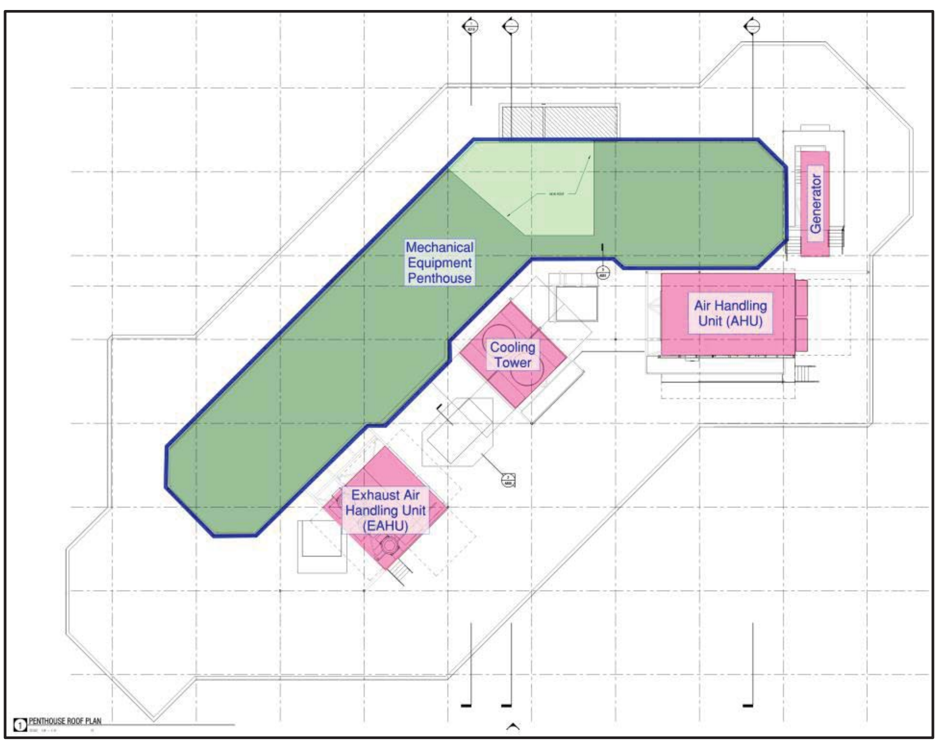

Figure 2 – 125 CambridgePark Drive: Outdoor Rooftop Mechanical Equipment, Phase 1

The Phase 2 renovation will include the addition of a second AHU, a second EAHU, two chillers, and one cooling tower; new chilled water pumps and condenser water pumps will also be added in the mechanical penthouse. A new emergency generator will also be installed on the roof. Phase 2 will require the complete decommissioning and demolition of the legacy mechanical systems still in operation after the completion of Phase 1, including two existing chillers, two penthouse air handling units, and miscellaneous pumps, fans, and other mechanical equipment. Phase 2 will also include the addition of a stair pressurization system for each of the two stairwells. A 10-foot tall noise barrier will be erected along the western edge of the Phase 2 building extension to shield the apartment building to the west from noise made by the relocated cooling towers and new emergency generator

The following is a list of Phase 2 outdoor rooftop mechanical equipment most likely to affect community sound levels in the area surrounding the 125 CambridgePark Drive project site:

- One additional new insulated-casing air handling unit (AHU), 98,000 cfm, manufactured by BASX, with an array of fifteen 40” backward-inclined plenum fans drawing outside air through inlet airflow straighteners to reduce fan inlet and discharge sound power levels. The unit will be installed in a fan room on the sixth floor of the Phase 2 extension of the building.
- One additional insulated-casing exhaust air handling unit (EAHU), 98,000 cfm total capacity, manufactured by Ventrol, with three exhaust fans equipped with variable-frequency drives; each fan discharges to an exhaust stack equipped with tubular exhaust silencer similar to Vibro-Acoustics Model 48-CD-AR.
- One additional one-cell induced-draft, crossflow cooling towers, manufactured by Baltimore Aircoil, with specially-designed quiet fan technology on variable frequency drives. All three cooling towers will be relocated to a position north of the mechanical penthouse on the roof of the Phase 2 extension of the building.
- One new 800 kW Caterpillar C27 Diesel Generator with Level 2 sound enclosure.

Figure 3, below, presents a layout plan of the Phase 2 mechanical equipment located on the roof of the 125 CambridgePark Drive building. Again, the heavy blue line shows the outline of the enclosed mechanical equipment penthouse.

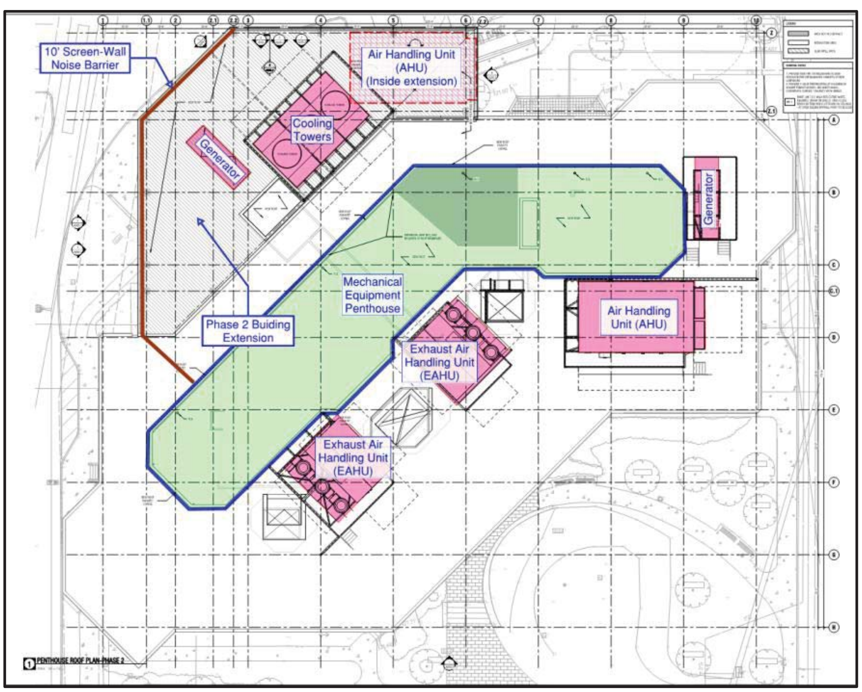

Figure 3 – 125 CambridgePark Drive: Outdoor Rooftop Mechanical Equipment, Phase 2

PREDICTED EQUIPMENT SOUND LEVELS, PHASE 1

The physical locations and acoustical performance data (supplied by the project's mechanical engineers) for the major noise sources associated with Phase 1 of the 125 CambridgePark Drive repurposing project were entered into the computer noise model, CadnaA, along with a 3-D representation of the project buildings and those in the surrounding neighborhood. CadnaA uses industry-standard acoustical propagation calculations to estimate the resultant sound levels at various positions around the site. Figure 4, below, presents a "bird's eye" view of the building geometry used by the model to estimate the sound levels produced by the daytime and nighttime operation of the Phase 1 rooftop mechanical equipment. Emergency generators will be tested only during daytime hours.

Figure 4 – "Bird's-Eye" view of CadnaA noise model geometry, Phase 1

Figures 5 and 6, below, present graphical representations – as sound level contours – of the community sound levels predicted by the CadnaA model, for the "nighttime" and "daytime" periods, respectively. The nighttime results include the acoustical contributions from all Phase 1 rooftop equipment except the emergency generators; the "daytime" results include noise produced by the Phase 1 emergency generator.

In both figures, the predicted sound levels from the rooftop mechanical equipment associated with Phase 1 of the repurposing project are shown in the circled numbers on the residential buildings in the immediate vicinity of 125 CambridgePark Drive. The first number is the predicted maximum level at any point on the building façade produced by the operation of all equipment except the Phase 1 emergency generator (essentially the maximum "nighttime" level at the building); the second (higher) number is the maximum level predicted when the Phase 1 emergency generator is added to the mix. (The circled numbers are the same in both figures; only the sound level contours reflect the different nighttime and daytime sound levels predicted.)

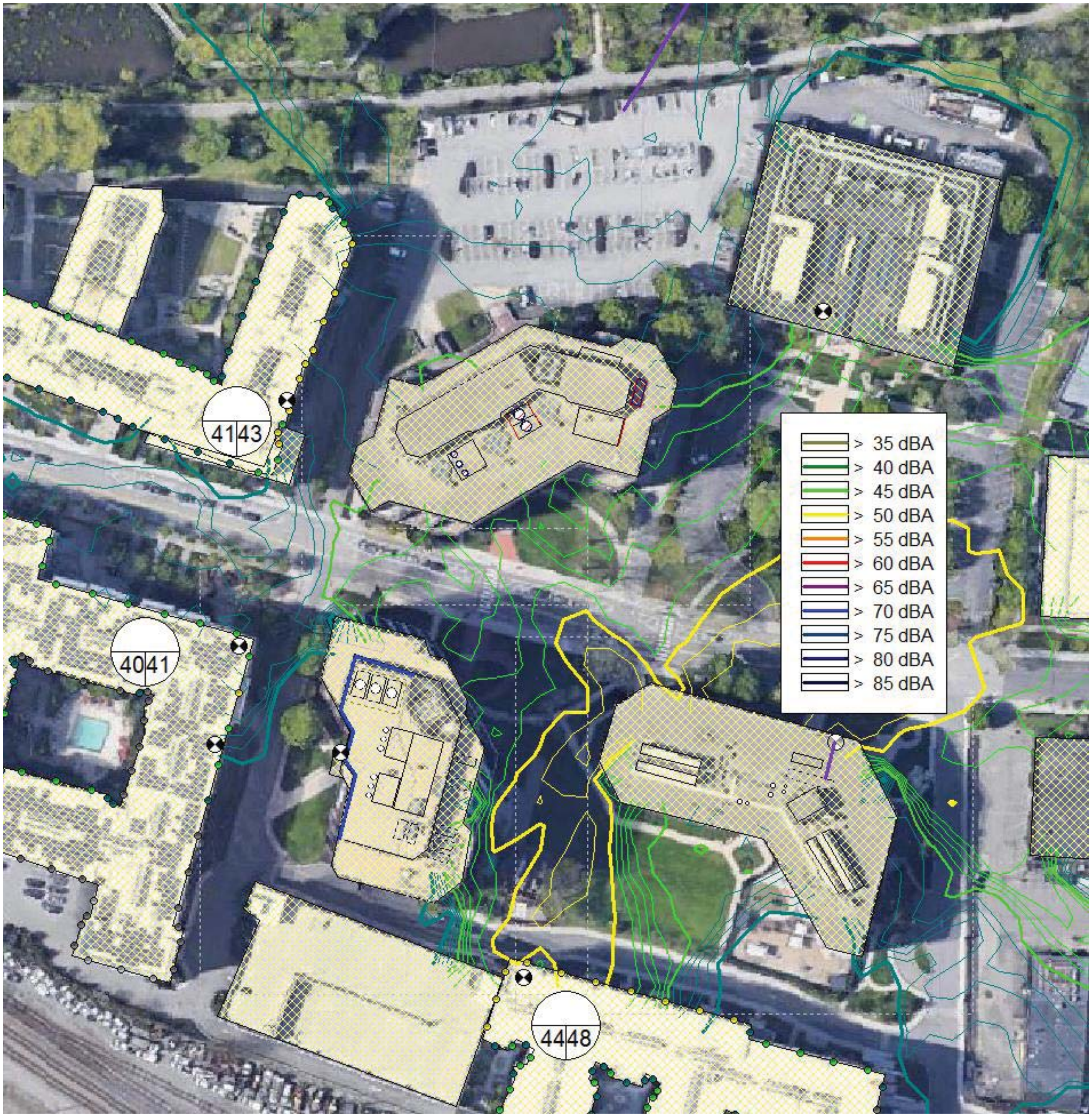

Figure 5 – Predicted equipment noise levels from 125 CambridgePark Drive, Phase 1, (nighttime): All equipment operating except emergency generators

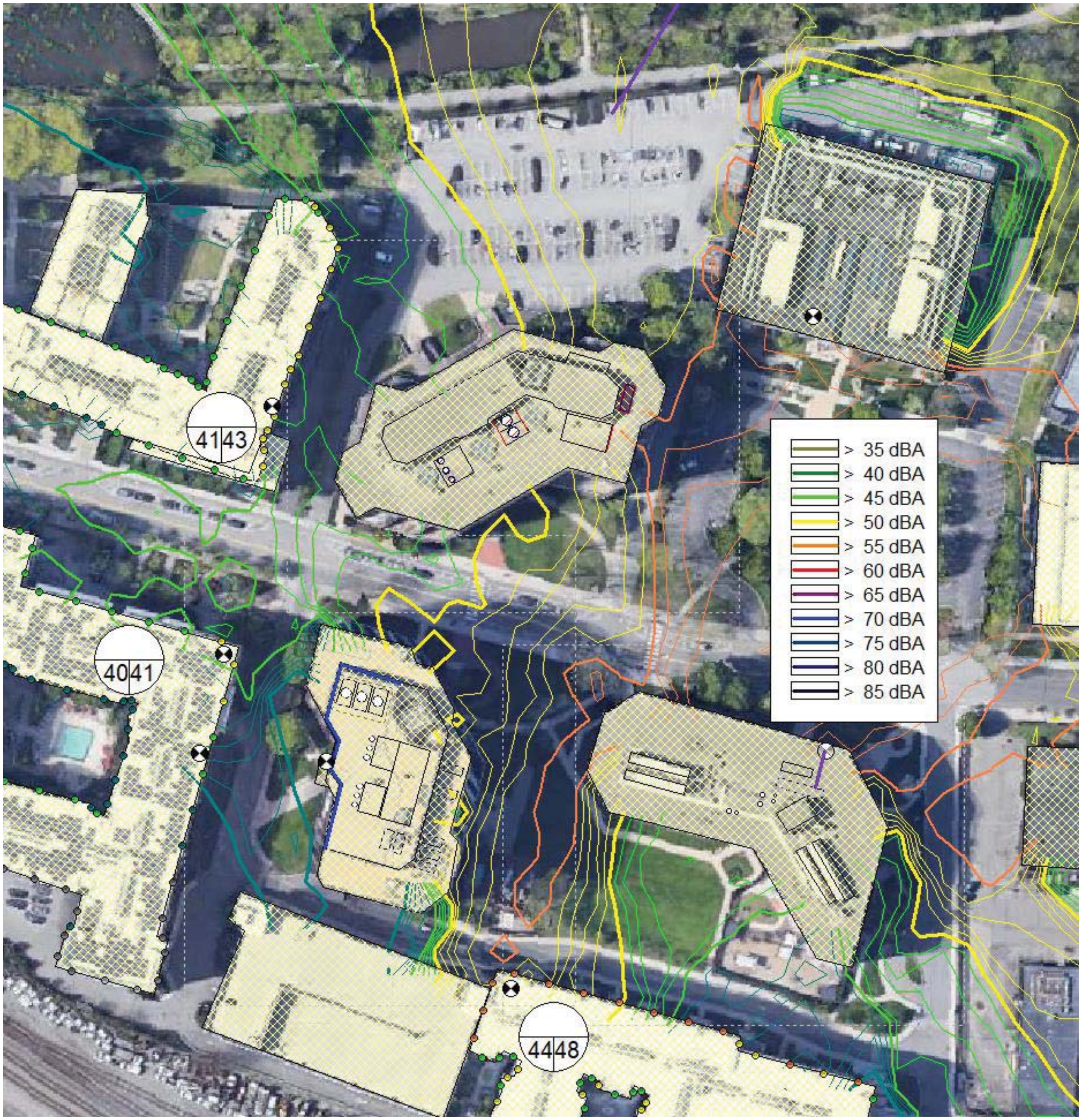

Figure 6 – Predicted equipment noise levels, 125 CambridgePark Drive, Phase 1, (daytime): All equipment operating including emergency generators

As can be seen, the normal (daytime and nighttime) operation of CambridgePark Drive's phase 1 rooftop mechanical equipment is predicted to produce sound levels of less than 50 dBA at the nearest residential dwelling units: levels of 41, 40, and 44 dBA are predicted at the apartment buildings to the west, southwest, and south of the project site, respectively. Exercising of the Phase 1 emergency generator for normal periodic maintenance – expected for a period of about one hour per month – will cause an increase in the overall sound levels produced by the building, but is still expected to result in sound levels of less than 50 dBA at the nearby residential properties: levels of 43, 41, and 48 dBA are projected at the apartments to the west, southwest, and south, respectively, during periods when the emergency generator is run. As such, compliance with the Cambridge Noise Ordinance's 50 dBA residential property-line limits is expected at all times after the completion of Phase 1 of the 125 CambridgePark Drive repurposing project.

PREDICTED EQUIPMENT SOUND LEVELS, PHASE 2

As was done for the Phase 1 equipment, acoustical performance data for the major noise sources associated with Phase 2 of the 125 CambridgePark Drive repurposing project (again supplied by the project's mechanical engineers), as well as their physical locations (including the relocation of the cooling towers) and were input into the computer noise model, CadnaA, using the same 3-D representation of the project buildings and those in the surrounding neighborhood as was used for the Phase 1 equipment. Figure 7, below, presents a "bird's eye" view of the Phase 2 building geometry used by the model to estimate the sound levels produced by the daytime and nighttime operation of the Phase 2 rooftop mechanical equipment. Again, emergency generators will be tested only during daytime hours.

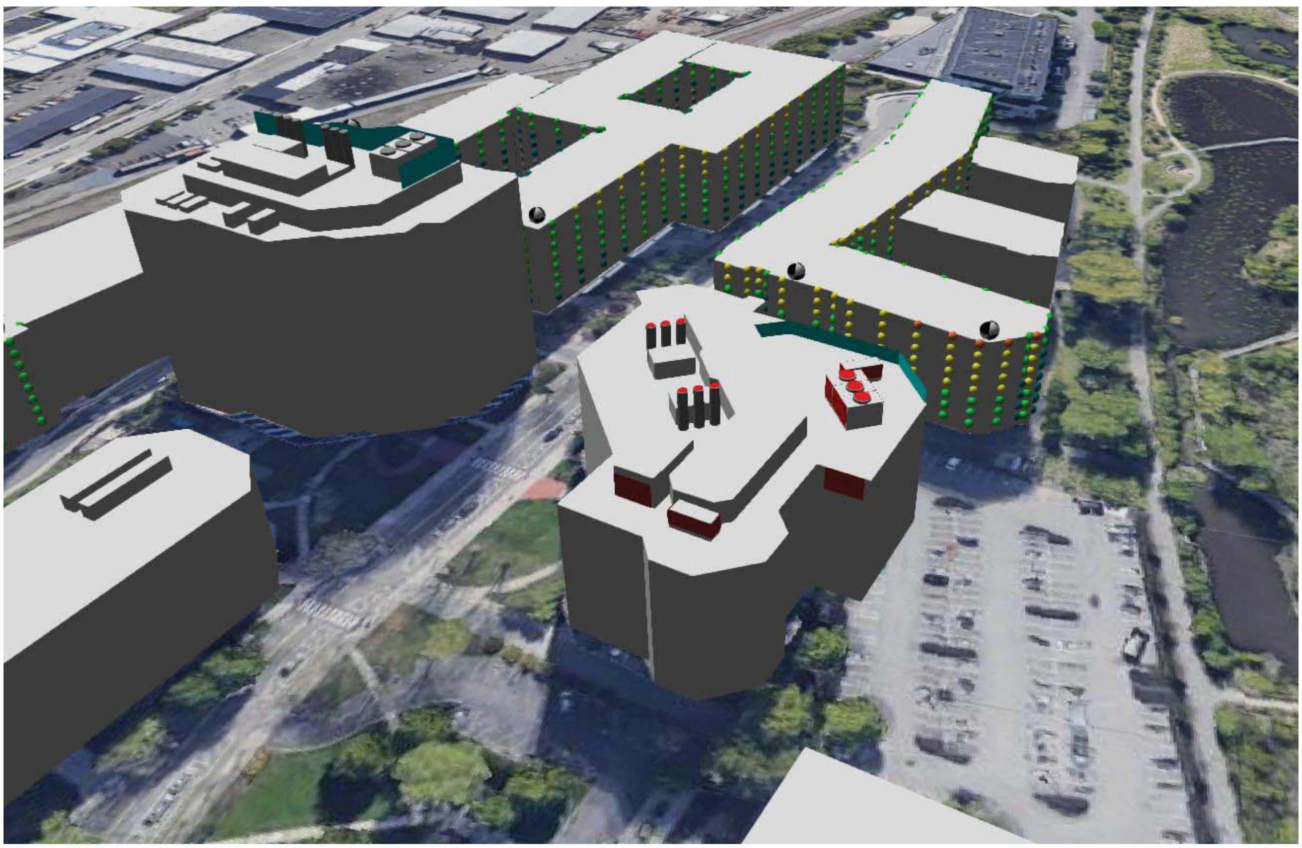

Figure 7 – "Bird's-Eye" view of CadnaA noise model geometry, Phase 2

Figures 8 and 9, below, present the predicted sound level contours of the community sound levels generated by the CadnaA model, for the "nighttime" and "daytime" periods, respectively, of the Phase 2 rooftop equipment. Again, the "nighttime" results include the acoustical contributions from all Phase 2 rooftop equipment except the two emergency generators; the "daytime" results include noise produced by the two emergency generators operating simultaneously.

In both figures, the predicted sound levels from the Phase 2 rooftop mechanical equipment are shown in the circled numbers on the residential buildings in the immediate vicinity of the 125 CambridgePark Drive site. The first number is the predicted maximum level at any point on the building façade produced by the operation of all equipment except the emergency generators (essentially the maximum "nighttime" level at the building); the second (higher) number is the maximum level predicted when the emergency generators are added to the mix. (Again, the circled numbers are the same in both figures; only the sound level contours reflect the different nighttime and daytime sound levels predicted.)

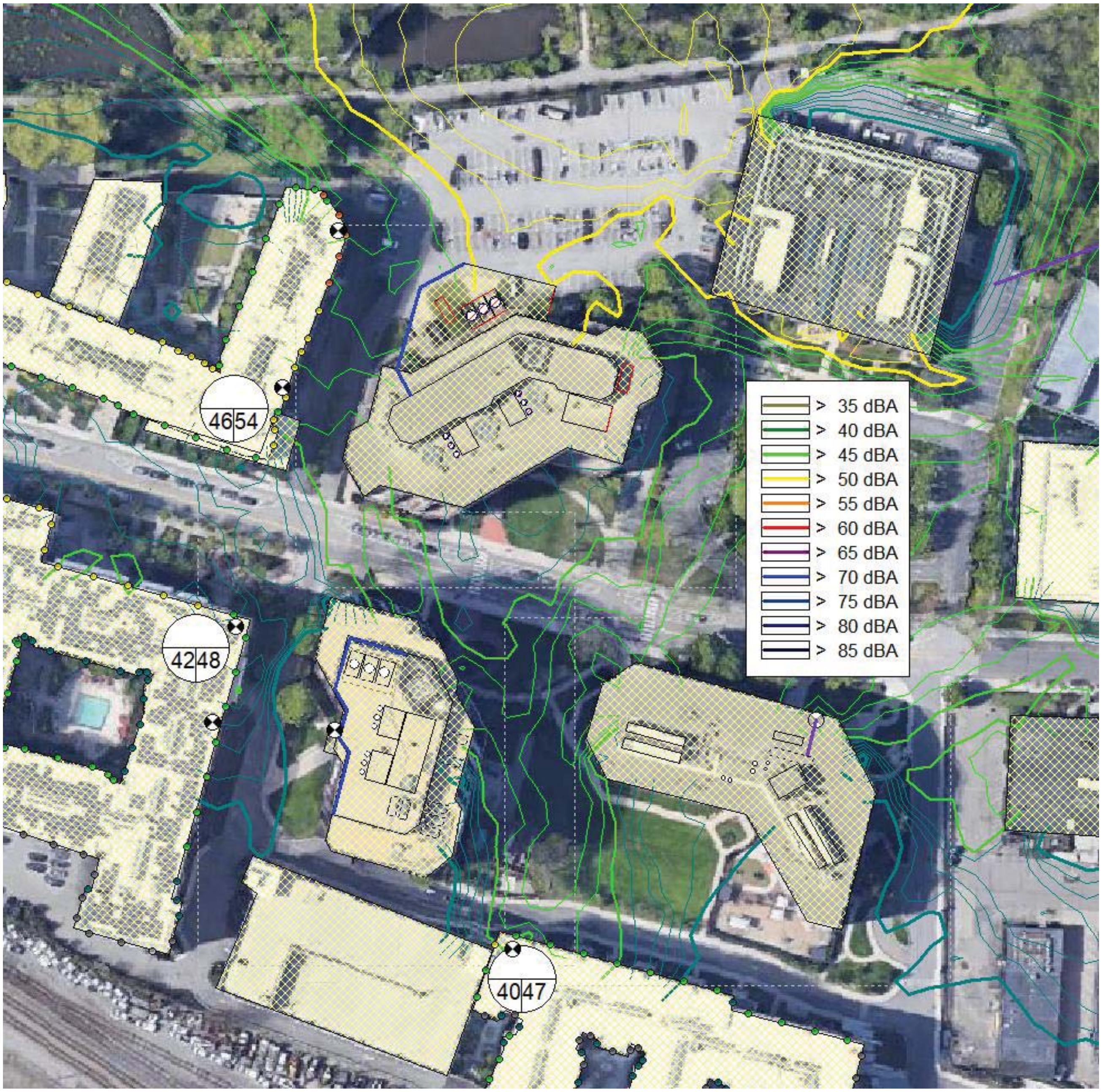

Figure 5 – Predicted 125 CambridgePark Drive, Phase 2 equipment noise levels, (nighttime): All equipment operating <u>except</u> emergency generators

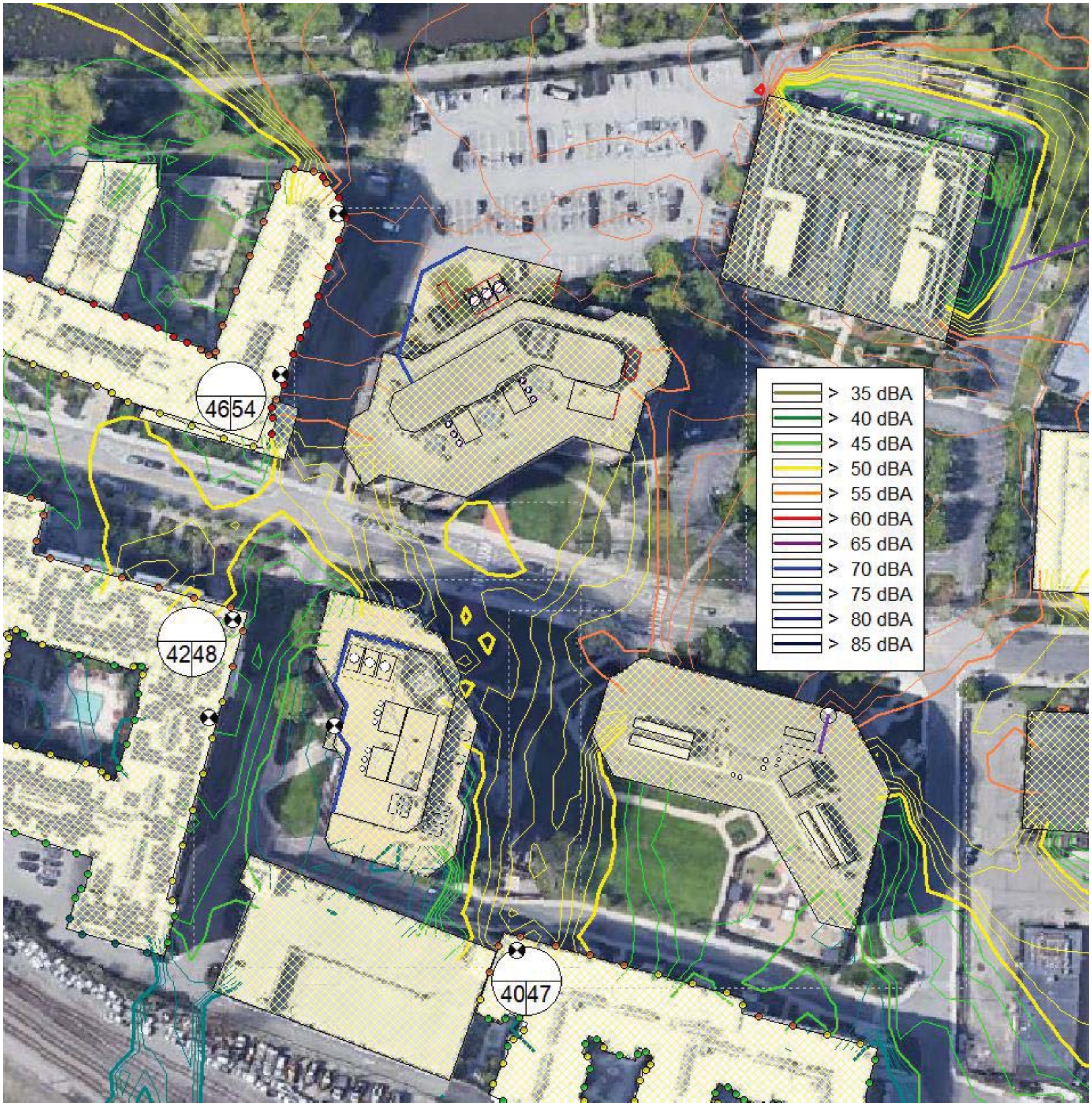

Figure 6 – Predicted 125 CambridgePark Drive, Phase 2 equipment noise levels, (daytime): All equipment operating <u>including</u> emergency generators

As can be seen, the normal operation of CambridgePark Drive's Phase 2 rooftop mechanical equipment is predicted to produce sound levels of less than 50 dBA at the nearest residential dwelling units: levels of 46, 42, and 40 dBA are predicted at the apartment buildings to the west, southwest, and south of the project site, respectively. Exercising of the Phase 1 and Phase 2 emergency generators for normal periodic maintenance – planned for the daytime hours only for a period of about one hour per month – will cause an increase in the overall sound levels produced by the building, but is still expected to result in sound levels of less than 60 dBA at the nearby residential properties: levels of 54, 48, and 47 dBA are projected at the apartments to the west, southwest, and south, respectively, during periods when the emergency generators are run. As such, compliance with the Cambridge Noise Ordinance's 60 dBA "daytime" and 50 dBA "all other times" residential property-line limits is expected at all times after the completion of Phase 2 of the 125 CambridgePark Drive repurposing project.

Pure Tone Evaluation

Based on the equipment sound data and the predicted sound levels to the closest receivers, we do not anticipate the equipment to emit tonal sound as defined by MassDEP.

CONCLUSION

The A-weighted sound levels predicted offsite from the operation of the rooftop mechanical equipment planned for the two phases of the 125 CambridgePark Drive repurposing project will everywhere comply with the property-line sound level limits set in the Cambridge Noise Ordinance, both during the daytime and at "all other times." In addition, project noise emissions are expected to comply with the MassDEP's "10 dB over background" limits and will not result in a "pure tone" condition.

* * * * *

I trust this letter provides the information that you need at this time. If you have questions, please call me on my direct line at 617-499-8028, or e-mail me at rberens@acentech.com.

Sincerely,

Robert Berens
Principal Consultant

FINAL REPORT

4E. Wind Analysis/Exhaust Dispersion Report

125 CAMBRIDGEPARK DRIVE

CAMBRIDGE. MA

EXHAUST DISPERSION & DESIGN
RWDI # 2100989
November 12, 2021

SUBMITTED TO

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EXECUTIVE SUMMARY

Numerical exhaust dispersion modeling was completed to assess air quality conditions and provide recommendations related to the exhaust and intake design of the 125 Cambridgepark Drive renovation and addition in Cambridge, MA. The primary conclusions and recommendations from the assessment are summarized below:

Proposed 300 kW and 800 kW Emergency Diesel Generators (Sources G1-G2):

- The proposed 300 kW and 800 kW Emergency Diesel Generators met health criteria for all wind conditions.
- The odor criteria were met at the rooftop air intakes for winds that occur up to 25% of the time during routine testing scenarios.
- Options for reducing the potential for odors include:
  - Increase the stack height of G1 by 6 ft to discharge 30 ft above the roof and increase the stack height of G2 by 8 ft to discharge 32 ft above the roof.
  - Operational protocols including scheduling of testing during periods of low building occupancy.
  - Emission control technology, including the use of DPF/DOC on the engines to reduce odor strength at the source.
  - Using activated carbon filters on the rooftop air handling units.

Proposed three (3) 5,000 MBH Natural Gas Boilers (Sources B1-B3):

- The three proposed natural gas boilers met health criteria at all receptors for all wind conditions. No design modifications are recommended.

Proposed three (3) 465-Ton Cooling Towers (Sources CT1-CT3):

- The three proposed 465-ton cooling towers (two units installed in phase 1 and a third unit installed in phase 2) met health-based dilution criteria at all receptors for all wind conditions. No design modifications are recommended.

Proposed two (2) Manifolded Laboratory Fume Hood Exhausts (EAHU-1 & 2, Sources L1-L2):

- The two proposed manifolded laboratory fume hood exhausts (one installed during phase 1 and a second installed during phase 2) met health and odor-based dilution criteria at all receptors for all wind conditions while operating at 100% fan flow (32,670 cfm per fan).
- It was determined that the laboratory exhausts can operate at a minimum of 50% fan flow (16,330 cfm per fan) while still meeting all health and odor-based criteria.

Preferred Phase 2 AHU-2 Intake Location

- Based on predominant winds, the preferred AHU-2 intake location is on the west façade of the addition, depicted by R4 on Figure 2 (attached).

EXHAUST DISPERSION & DESIGN
125 CAMBRIDGEPARK DRIVE

RWDI #2100989
November 12, 2021

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1 INTRODUCTION

Rowan Williams Davies & Irwin Inc. (RWDI) was retained by Elkus Manfredi to conduct an exhaust dispersion assessment for the proposed 125 Cambridgepark Drive renovation and addition in Cambridge, MA. The proposed project will be carried out in two phases: Phase 1 will convert the existing 6-story office building into a multi-tenant lab/office space while Phase 2 will include an addition on the north side of the building.

The purpose of this assessment was to evaluate the potential for air quality impacts from the proposed exhaust sources on 125 Cambridgepark Drive at the proposed and existing air sensitive receptors (e.g., outside air handling units and balconies). Where applicable, recommendations are made to improve dispersion of the exhausts. Representative exhaust sources on the adjacent 101 and 150 Cambridgepark Drive were also considered for potential impacts at the proposed intakes based on previous work RWDI has completed in the area.

This final report presents the background, objectives, results, and recommendations from the assessment.

2 BACKGROUND AND APPROACH

2.1 Dispersion Modeling

This assessment was accomplished by performing numerical dispersion modeling combined with RWDI's experience in wind tunnel testing, wind flow around buildings, and knowledge of building air quality issues. The numerical modeling involves the use of two proprietary models developed by RWDI: one based on the methodologies published in the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Handbook of Applications, and one based on a Gaussian plume model.

The ASHRAE building-wake dispersion equations are semi-empirical, based on wind tunnel tests on generic building shapes with rooftop exhausts. ASHRAE equations are best suited for receptors on the same roof or lower than the exhaust point on the same building.

The Gaussian plume model is typically employed to evaluate elevated receptors that are situated above the exhaust discharge points and are often used to assess grade-level impacts from elevated exhaust stacks. This model is patterned after similar models from the U.S. EPA (e.g., ISC, AERMOD). Since there is some uncertainty in using Gaussian models near buildings, the plume model was evaluated over a range of receptor heights.

2.2 Criteria

For design purposes, RWDI applies dilution criteria to assess dispersion from various types of exhaust sources. Exhaust dilution (*D*), is defined as the ratio of source concentration (C_o) to the concentration predicted at a receptor (*C*). In other words:

$$D = \frac{C_o}{C}$$

Dilution criteria for good design practice are developed for each exhaust source and are based on specific pollutant and/or odor emissions, air quality exposure limits, and/or odor thresholds. The design objective is for the exhaust to be well diluted, at a level equal to or greater than the criteria, at all important receptors to achieve acceptable air quality. The dilution criteria applied for each of the exhaust sources are summarized along with the modeling results in Section 3 and are discussed in detail in Appendix A.

2.3 Exhaust Sources and Receptors

RWDI assessed the dispersion performance from the following proposed exhaust sources of concern. Locations of the exhausts are shown in Figures 1 and 2.

Phase 1 Exhausts:

- Proposed 300 kW Emergency Diesel Generator (Source G1)[1]
- Two (2) proposed 465-ton Cooling Towers (Sources CT1-CT2)
- Proposed Manifolded Laboratory Fume Hood Exhausts (EAHU-1, Source L1)[1]
- Three (3) 5,000 MBH Natural Gas Boilers (Sources B1-B3)[1]

Phase 2 Exhausts:

- Proposed 800 kW Emergency Diesel Generator (Source G2)
- Three (3) proposed 465-ton Cooling Towers (Sources CT1-CT3)
- Proposed Manifolded Laboratory Fume Hood Exhaust (EAHU-2, Source L2)

Outside air will be supplied to 125 Cambridgepark Drive through the installation of a single rooftop air handling unit for Phase 1 (R1 in Figure 1). A second air handling unit will be included in the upper level of the Phase 2 addition with air being drawn through louvers (possible locations indicated by R2-R4 in Figure 2). In addition to the proposed air intakes, other receptors considered in the assessment included existing balconies on the upper levels of 125 Cambridge Park Drive and representative intakes and balconies on the adjacent buildings at 101, 150, and 165 Cambridge Park Drive.

[1] Source was added in phase 1 of construction and remains in place during phase 2 of construction

2.4 Meteorological Data

RWDI reviewed wind data from the Boston Logan International Airport to estimate wind conditions at the site. This is the closest meteorological station with a substantial and recent data set. A summary of the directional distribution of winds over a period from 1945 to 2021 is shown below. The wind directions in the figure refer to the direction from which the wind blows, while the annual frequency of a given wind direction is shown as a distance radially from the center.

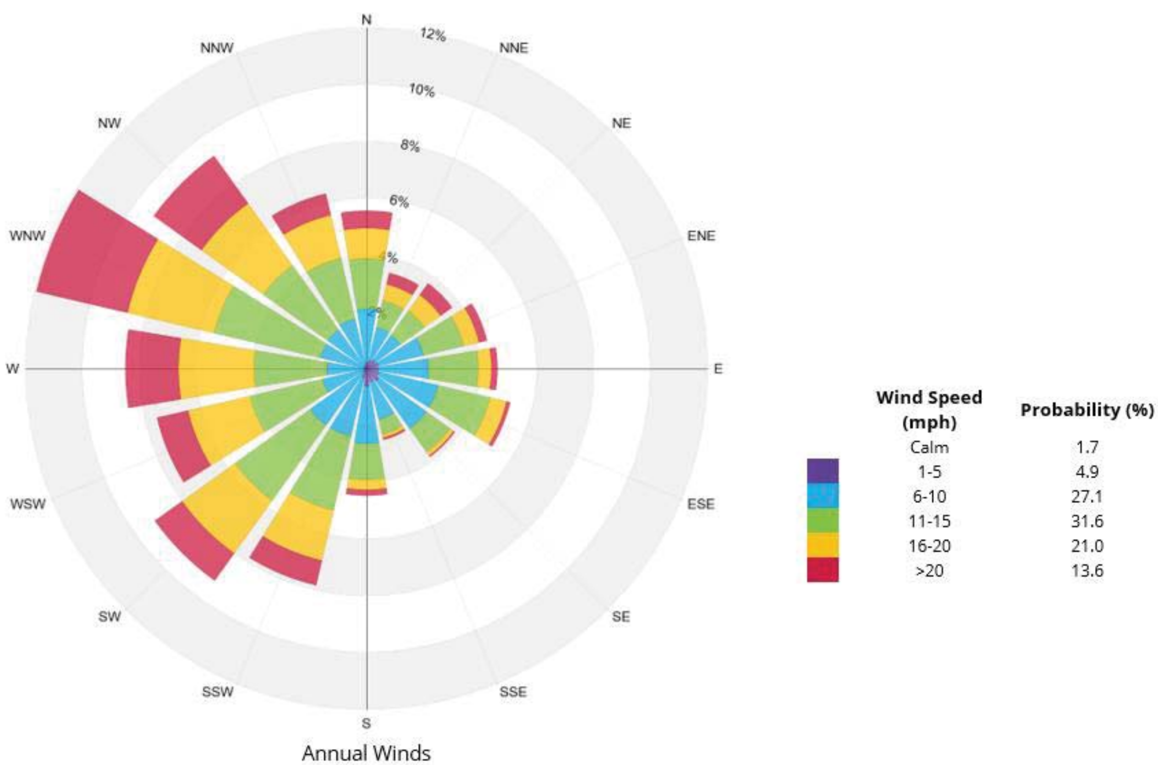


Image 1: Directional Distribution (%) of Winds from Station at the Boston Logan International Airport, Boston, MA (1945-2021)

While predominant winds originate from the southwest through northwesterly directions, modeling was completed for all directions to predict the overall worst case result. The wind data was used to estimate of the percent of time that wind conditions resulting in dilution levels less than the indicated dilution criteria are expected to occur. Frequency is defined as the annual percentage of wind conditions that may result in dilution levels less than the given criterion at a receptor. For example, a 50% frequency means that there is a 1 in 2 chance of winds that will result in the indicated dilution criterion not being met. In this example, 50% of winds represents approximately 4,380 hours per year (i.e. 8,760 x 50%).

3 RESULTS AND DISCUSSION

3.1 Proposed Rooftop Exhausts

Dispersion modeling results are presented and discussed on a source-by-source basis in Tables 1 and 2 for Phase 1 and Phase 2, respectively. Results are presented in the form of worst-case predicted dilution level compared to criteria developed for each exhaust source. Exhaust locations are illustrated in Figures 1 and 2. Additional discussion is provided following the table.

Phase 2 of the renovation includes the installation of a second air handling unit in the upper level of the addition. Since the final location of the intake louvers has not been selected, representative positions shown as Receptors R2-R4 in Figure 2 have been assessed.

Table 1: Summary of Modeling Results for Phase 1 - 125 Cambridgepark Drive Renovation and Addition

Exhaust Source Description	Dilution Criterion	Worst-Case Dilution Level (Receptor)	Meets Criterion?
300 kW Diesel Generator (Source G1) Flow Rate: 2,460 cfm[1] Exit Velocity: 7,050 fpm[1] Stack Height: 24 ft Above Roof (12 ft above enclosure)[2]	280:1 (Health) 1,500:1 (Odor Recognition) 3,000:1 (Odor Detection)	330:1 (R1)	**Health:** Yes **Odor:** No
465-Ton Cooling Towers (2) **(Sources CT1-CT2)** Flow Rate: 121,400 cfm (per cell) Exit Velocity: 1,340 fpm Stack Height: 24 ft Above Roof[2]	10:1 (Health/Odor)	23:1 (R1)	Yes
Manifolded Laboratory Exhausts **(EAHU-1, Source L1)** Flow Rate: 32,670 cfm (per stack) Exit Velocity: 3,000 fpm[1] Stack Height: 28 ft Above Roof (14 ft above penthouse) [2]	3,000:1 (Health/Odor)	10,600:1 (R1) – 100% Fan Flow 5,300:1 (R1) – 50% Fan Flow	Yes
5,000 MBH Natural Gas Boilers (3) **(Sources B1-B3)** Flow Rate: 1,040 cfm (per flue)[1] Exit Velocity: 970 fpm[1] Stack Height: 10 ft Above Penthouse Roof[2]	50:1 (Health)	180:1 (R1)	Yes

[1] Exhaust parameters estimated based on typical values for similar sized equipment
[2] Grade is referenced to Level 1, as per drawing A201.1 issued on October 1, 2021

Table 2: Summary of Modeling Results for Phase 2 - 125 Cambridgepark Drive Renovation and Addition

Exhaust Source Description	Dilution Criterion	Worst-Case Dilution Level (Receptor)	Meets Criterion?
800 kW Diesel Generator (Source G2) Flow Rate: 6,060 cfm[1] Exit Velocity: 11,120 fpm[1] Stack Height: 24 ft Above Roof (12 ft above enclosure, assumed)[2]	320:1 (Health) 1,500:1 (Odor Recognition) 3,000:1 (Odor Detection)	550 :1 (R4)	**Health:** Yes **Odor:** No
465-Ton Cooling Towers (3) (Sources CT1-CT3) Flow Rate: 121,400 cfm (per cell) Exit Velocity: 1,340 fpm Stack Height: 19 ft Above Roof[2]	10:1 (Health/Odor)	15:1 (R3/R4)	Yes
Manifolded Laboratory Fume Hoods (EAHU-1 & 2, Sources L1 & L2) Flow Rate: 32,670 cfm Exit Velocity: 3,000 fpm[1] Stack Height: 28 ft Above Roof (14 ft Above Penthouse Roof)[2]	3,000:1 (Health/Odor)	10,000:1 – 100% Fan Flow 5,000:1 – 50% Fan Flow	Yes

[1] Exhaust parameters estimated based on typical values for similar sized equipment
[2] Grade is referenced to Level 1, as per drawing A201.1 issued on October 1, 2021

3.1.1 Proposed 300 kW and 800 kW Emergency Diesel Generators (Sources G1-G2)

The proposed 300 kW and 800 kW Emergency Diesel Generators (Source G1-G2) were evaluated for potential re-entrainment of diesel exhaust at the proposed air handling units. RWDI's recommended health-based targets were met all receptors for all wind conditions with the proposed stack design (approximately 24 ft above the roof).

The odor recognition and detection criteria are not expected to be met at the proposed intakes and intakes on the adjacent buildings for some wind conditions. For example, winds that would direct the 300 kW generator exhaust toward the rooftop intake R1 are expected to occur about 10% of the time. Predominant westerly winds would direct the exhaust toward the adjacent 101 Cambridgepark approximately 20% of the time. For the Phase 2 800 kW unit, the odor criterion would not be met at the adjacent residential building to the west, although wind conditions that direct the exhaust towards the west are not frequent. Predominant westerly winds would direct the exhaust toward the rooftop intake R1 and at the adjacent 101 Cambridgepark Drive approximately 25% of the time.

It is understood that the proposed air handling units would not be operational during emergencies. This signifies that the only potential for diesel odors to infiltrate the building would be during a routine testing scenario. Therefore, if generator testing occurs once per month and a frequency of problematic winds occurs 10% of the time at the rooftop air handling units, approximately 1 odor event could be expected in a given year. Options for reducing the risk of odors reaching nearby intakes include:

1. **Increased stack height:**
   a. Increase the stack height of G1 by 6 ft to discharge 30 ft above the roof level to meet the odor recognition target (1,500:1)
   b. Increase the stack height of G2 by 8 ft to discharge 32 ft above the roof level to meet the odor recognition target (1,500:1).

2. **Operational Protocols:**
   a. Scheduling routine testing during periods of low building occupancy such as weekends and early mornings.

3. **Emission Control Technology:** Odor emissions control technology, in the form of a combined diesel particulate filter and diesel oxidation catalyst (DPF/DOC) have been shown to reduce the strength of odors in diesel exhaust. Additional details about DPF/DOC equipment are provided in Appendix A.

4. **Activated Carbon Filtration:** Activated carbon filters have been shown to be an effective mitigation strategy for reducing the strength of odors. Provided that there is sufficient space and fan capacity in the air handling units to accommodate carbon filters, they can be installed on a wait-and-see basis, should odors become problematic after the building is operational. RWDI recommends that the design team consult a filter manufacturer/vendor to ensure that the selected filters will be effective for addressing potential diesel odors.

3.1.2 Cooling Towers (Sources CT1-CT3)

Exhaust from the proposed cooling towers met the recommended criterion for commonly used treatment chemicals at the proposed intakes for both Phase 1 and Phase 2 designs. It is recommended that the treatment guidelines and best practices outlined by ASHRAE and the CTI be followed. No design changes are recommended.

3.1.3 Natural Gas Fired Boilers (Sources B1-B3)

The proposed boiler exhaust flues met the recommended criterion for both Phase 1 and Phase 2 designs. It is recommended that the flues discharge vertically without fixed rain caps. No design changes are recommended.

3.1.4 Manifolded Laboratory Fume Hood Exhausts (Sources L1-L2)

The final phase 2 design includes two sets of manifolded laboratory fume hood exhausts (Sources L1-L2) each with three exhaust fans. The exhausts were initially evaluated operating at 100% fan flow (32,670 cfm per fan) to identify potential health and odor concerns at the rooftop air intakes. Results were compared to RWDI's recommended dilution target of 3,000:1 for laboratory fume hood exhausts, which represents a worst-case emission scenario including a liquid chemical spill in a fume hood. Refer to Appendix A for further discussion of the criterion applied.

Both laboratory exhausts met the recommended dilution criterion at all receptors with the proposed stack design, while operating at 100% fan flow. No design modifications are recommended. Given the positive results, fan flow turndown rates were also evaluated. It was determined that the laboratory exhausts can operate at a minimum of 50% fan flow (16,300 cfm per fan) while still meeting all recommended health and odor-based targets.

3.2 Other Sources Considered

3.2.1 Existing and Proposed Kitchen Exhaust

It is understood that there is an existing kitchen hood that currently exhausts from a louver on the building façade at the lower level. An additional kitchen hood will be installed during one of the construction phases, but its exhaust location has yet to be finalized. Current options include discharging at the existing façade louver or routing the exhaust to discharge from the roof. If the façade location is maintained, the risk of kitchen odors reaching outdoor terrace locations is expected to be similar to the existing condition (RWDI is not aware if there are currently odor issues). If the exhaust is routed to the roof, the exhausts would be in close proximity to rooftop intakes and would likely require a tall stack to minimize odor issues. Regardless of the discharge location, odor control technology such as pollution control units (PCUs) should be considered. It is recommended that the PCUs include a two-stage system with both high efficiency grease removal and gaseous odor removal (such as activated carbon).

3.2.2 101 Cambridgepark Drive Exhausts

Based on previous work completed by RWDI, it is understood that the adjacent site to the east may be developed to include a laboratory building of similar height to 125 Cambridgepark Drive in the future. Representative rooftop exhaust future sources such as a Tier 2 emergency diesel generator, natural gas boilers, and large manifolded laboratory exhausts were considered at the proposed 125 Cambridgepark Drive rooftop intakes. It is expected that suggested criteria for these source types will be met at the proposed 125 Cambridgepark Drive rooftop intake, with the exception of the diesel generator odor criterion. However, wind conditions directing the exhaust towards the proposed intakes are expected to occur infrequently (approximately 15% of the time).

3.2.3 150 Cambridgepark Drive Exhausts

RWDI understands that future renovations are planned at the 150 Cambridgepark Drive building located south of 125 Cambridgepark Drive to include the addition of Tier 2 emergency diesel generators, laboratory exhausts, and natural gas boilers on the roof. The roof is located at an elevation that is considerably higher than the rooftop air intakes on 125 Cambridgepark Drive, and it is expected that sufficient dilution of these exhausts will be achieved at the proposed rooftop intakes on 150 Cambridge Park Drive.

3.2.4 Future Tenant Specialty Exhaust

A section of the roof of the Phase 2 addition located to the west of the proposed 800 kW diesel generator (Source F), is to be used for future tenant specialty exhausts. The selected area is well placed with respect to the rooftop AHU-1 intake and the potential intake locations for AHU-2. In general, it is recommended that any future tenant exhaust stacks discharge above the penthouse roof. Additional study is recommended once future tenant exhaust requirements are known to evaluate dispersion and provide specific stack height recommendations.

3.3 Preferred Intake Location for AHU-2

During Phase 2 of construction, a new air handling unit (AHU-2) will be installed in the upper level of the addition. Three proposed locations for AHU-2 were assessed during this study including to the north, east and west façades of the new addition (represented by receptors R2-R4). While various intake locations have been considered, based on modeling results and the prevailing wind conditions on the site, locating the intake louver on the west façade of the addition, which corresponds to R4 is the preferred location. At this location, the intake would be up wind of the proposed rooftop exhausts during predominant westerly winds. Additionally, this location would offer protection from existing laboratory exhausts situated on the roof of 87 Cambridgepark Drive which is located northeast of 125 Cambridgepark Drive.

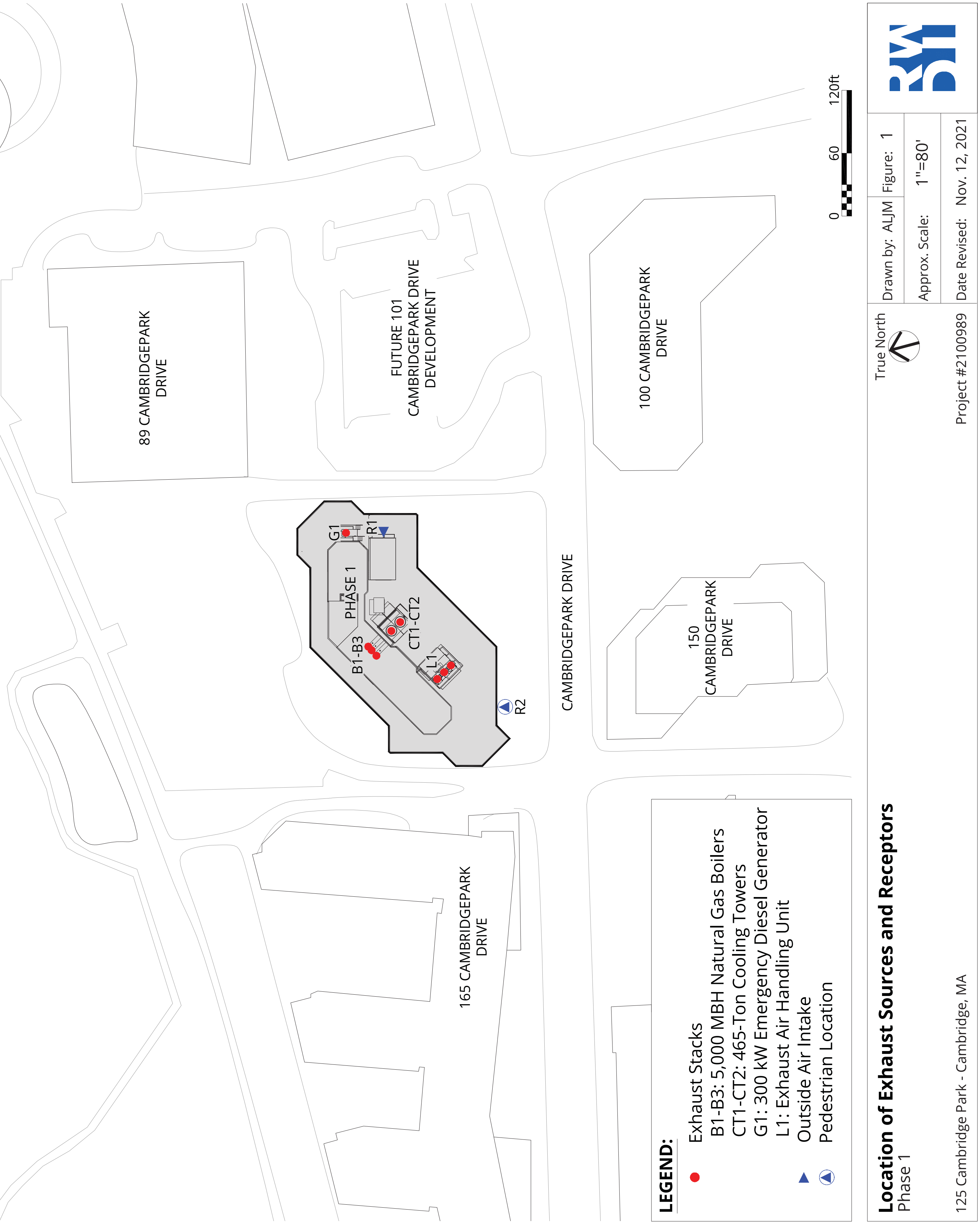
4 STATEMENT OF LIMITATION

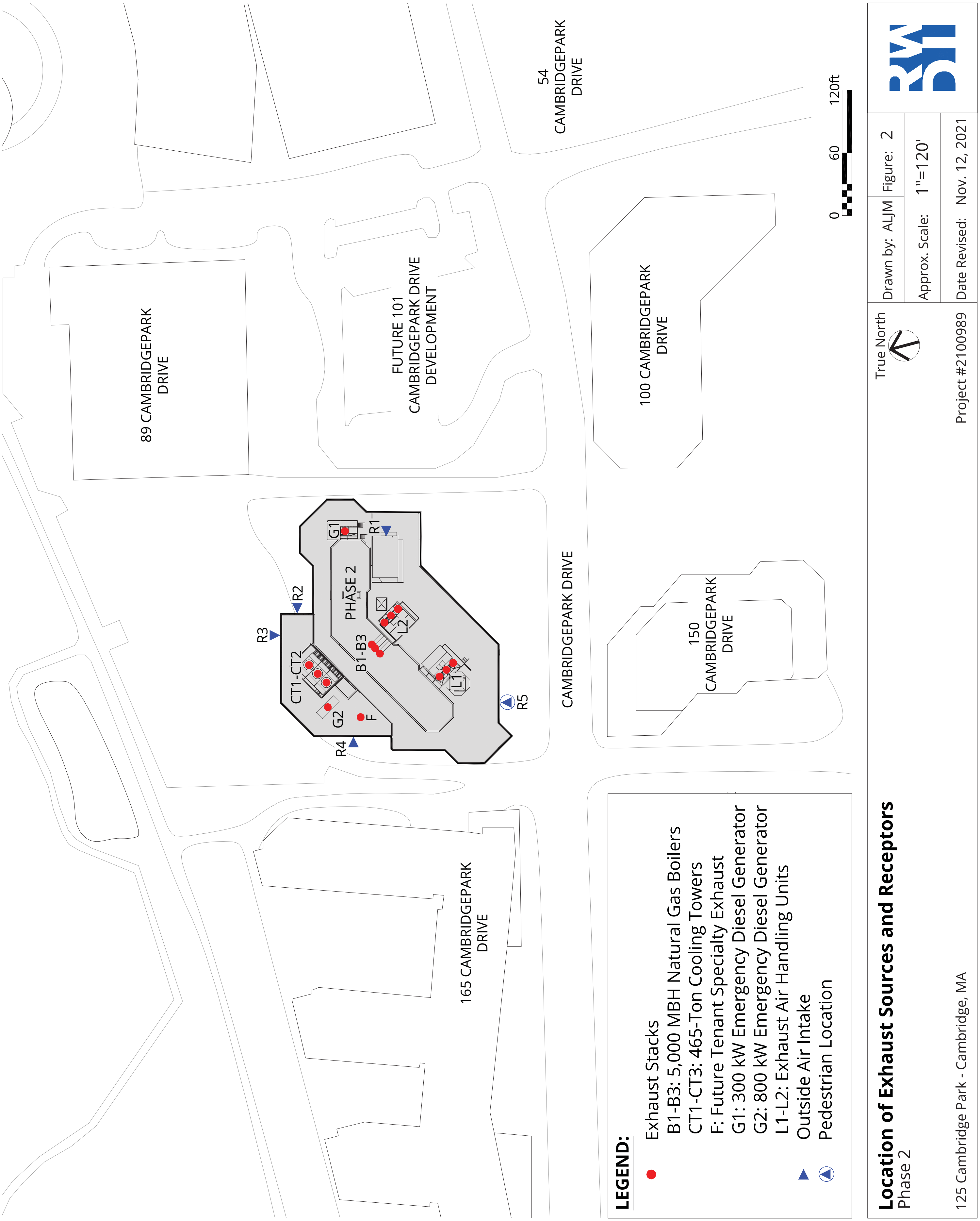
This report entitled 125 Cambridgepark Drive Exhaust Dispersion and Design Final Report was prepared by RWDI for Elkus Manfredi ("Client"). The findings and conclusions presented in this report have been prepared for the Client and are specific to the project described herein ("Project"). The conclusions and recommendations contained in this report are based on the information available to RWDI when this report was prepared. Because the contents of this report may not reflect the final design of the Project or subsequent changes made after the date of this report, RWDI recommends that it be retained by Client during the final stages of the project to verify that the results and recommendations provided in this report have been correctly interpreted in the final design of the Project.

The conclusions and recommendations contained in this report have also been made for the specific purpose(s) set out herein. Should the Client or any other third party utilize the report and/or implement the conclusions and recommendations contained therein for any other purpose or project without the involvement of RWDI, the Client or such third party assumes any and all risk of any and all consequences arising from such use and RWDI accepts no responsibility for any liability, loss, or damage of any kind suffered by Client or any other third party arising therefrom.

Finally, it is imperative that the Client and/or any party relying on the conclusions and recommendations in this report carefully review the stated assumptions contained herein and to understand the different factors which may impact the conclusions and recommendations provided.

FIGURES


89 CAMBRIDGEPARK DRIVE
FUTURE 101 CAMBRIDGEPARK DRIVE DEVELOPMENT
100 CAMBRIDGEPARK DRIVE
150 CAMBRIDGEPARK DRIVE
165 CAMBRIDGEPARK DRIVE
CAMBRIDGEPARK DRIVE
PHASE 1
G1
R1
CT1-CT2
B1-B3
L1
R2
LEGEND:
Exhaust Stacks
B1-B3: 5,000 MBH Natural Gas Boilers
CT1-CT2: 465-Ton Cooling Towers
G1: 300 kW Emergency Diesel Generator
L1: Exhaust Air Handling Unit
Outside Air Intake
Pedestrian Location
0
60
120ft
True North
Drawn by: ALJM
Figure: 1
Approx. Scale: 1"=80'
Date Revised: Nov. 12, 2021
Project #2100989
Location of Exhaust Sources and Receptors
Phase 1
125 Cambridge Park - Cambridge, MA


54 CAMBRIDGEPARK DRIVE
89 CAMBRIDGEPARK DRIVE
FUTURE 101 CAMBRIDGEPARK DRIVE DEVELOPMENT
100 CAMBRIDGEPARK DRIVE
PHASE 2
G1
R1
R2
R3
R4
R5
L1
L2
B1-B3
CT1-CT2
G2
F
CAMBRIDGEPARK DRIVE
150 CAMBRIDGEPARK DRIVE
165 CAMBRIDGEPARK DRIVE
0
60
120ft
LEGEND:
Exhaust Stacks
B1-B3: 5,000 MBH Natural Gas Boilers
CT1-CT3: 465-Ton Cooling Towers
F: Future Tenant Specialty Exhaust
G1: 300 kW Emergency Diesel Generator
G2: 800 kW Emergency Diesel Generator
L1-L2: Exhaust Air Handling Units
Outside Air Intake
Pedestrian Location
True North
Drawn by: ALJM
Figure: 2
Approx. Scale: 1"=120'
Date Revised: Nov. 12, 2021
Project #2100989
Location of Exhaust Sources and Receptors
Phase 2
125 Cambridge Park - Cambridge, MA

APPENDIX A

APPENDIX A: DISCUSSION OF DILUTION CRITERIA

Laboratory Exhausts

Laboratory Chemical Fume Hood Exhausts

For laboratory fume hood exhausts, RWDI suggests a minimum target dilution of 3,000:1, referenced to a 1,000 cfm exhaust flow rate. This dilution criterion is applied for design purposes and assumes that only one major spill (spill volume of several hundred milliliters) of any particular chemical would occur in any one fume hood at any one time. The one major spill can also represent the accumulated small, routine emissions from multiple fume hoods simultaneously if certain chemicals are used in many fume hoods at the same time.

RWDI analyzed more than 300 chemicals to predict the minimum required exhaust dilution to meet applicable exposure limits and/or odor thresholds given a major spill of one of the chemicals. The 300 chemicals are commonly used liquids and gases that have known short term health effects (8-hour or less) or that have strong odors. Solid compounds are not included due to their low rate of emissions to the atmosphere.

The above criterion value (3,000:1) addresses odor thresholds and occupational health limits for about 89% of chemicals in the list compiled by RWDI. While this level of dilution does not cover all chemicals on the list, it is RWDI's opinion that 3,000:1 is a reasonably protective target to apply for design purposes for laboratories. Further details on estimating emissions, developing a dilution criterion for fume hood exhausts, and RWDI's chemical list are provided in Appendices B and C. Note that the 3,000:1 target may not be sufficiently stringent for specialty laboratories using highly hazardous substances.

There is some benefit from internal dilution for the fume hood exhausts on this building. The design dilution target corresponds to a typical 1,000 cfm stack. For example, if the minimum exhaust flow rate of a manifolded fume hood exhaust fan was 10,000 cfm, an internal dilution of 10:1 would occur within the stack (assuming that only one spill of a given chemical occurs in one hood at a time). In this case the predicted stack-to-intake dilution from 10,000 cfm fans would be multiplied by 10 to account for internal dilution before comparison to the design criterion of 3,000:1. This internal dilution factor has been incorporated into the results of the exhaust dispersion analysis, where applicable.

It is important to note that a stack design meeting the above recommended dilution criterion for chemical fume hood exhausts would not guarantee that odors or health effects will not occur. Further, the design criterion does not exclude the possibility that emission rates may be larger than predicted from the spill scenario or that other chemicals not on the list provided to RWDI list will be used. Ultimately, it is the responsibility of the owners of the facility to determine if the suggested dilution criterion is suitable for the level of activities taking place within the facility.

Cooling Towers

There are two air quality issues associated with cooling tower exhausts: 1) the potential but unlikely spread of legionnella bacteria causing an outbreak of Legionnaires' Disease (legionellosis); and 2) evaporative emissions of cooling water treatment chemicals. Icing, fogging, and moisture loading at building intakes may also be issues related to the high relative humidity of cooling tower exhaust.

All cooling towers should have effective controls to prevent the spread of bacteria causing Legionnaires' Disease. The most effective control against Legionnaires' disease is to reduce the growth of bacteria by using treatment chemicals following the guidelines and suggested maintenance practices outlined ASHRAE[1] and the Cooling Technology Institute[2] and any local regulatory requirements.

To deal with the evaporative emissions of water treatment chemicals, RWDI recommends that cooling tower exhaust be diluted by a factor of 10:1. These chemicals are used to control scaling and biological growth (i.e. legionella bacteria) in the cooling tower system. The 10:1 criterion does not apply to the control of Legionnaires' Disease nor guarantee that an outbreak of Legionnaires' Disease will not occur. There is no dilution criterion that would be effective in preventing Legionnaires' Disease during an outbreak in which legionella bacteria levels are out of control. In the case of a true Legionnaires' Disease outbreak, a dilution level of 10:1 is likely to be entirely inadequate.

Air pollutant emissions (resulting from the treatment chemicals used) from cooling towers can adversely affect indoor air quality through exhaust re-entrainment at nearby air intakes and can also affect pedestrian areas in close proximity to the cooling towers. The air pollutants are primarily emitted from the cooling towers in gaseous form as the invisible part of the evaporative exhaust plume.

A small amount of the pollutants can also be discharged in the form of water droplets. These droplets can contain dissolved particulate and chemical additives and will drop out of the exhaust airstreams downwind of the tower. The release of these water droplets from cooling towers is often referred to as drift loss.

The design of cooling towers includes drift eliminators: a series of baffles that serve to reduce the release of water droplets from the towers. The efficiency of modern drift eliminators can reduce this drift loss to less than 0.0005% of the circulating water flow. However, drift loss from an older existing cooling tower or a tower with less efficient drift eliminators can be as high as 0.2% of the circulating water flow. **In general, the modeling and prediction of potential impacts from cooling towers focuses on the concentration of the gaseous-phase emissions contained in the exhaust air plume from the cooling towers.**

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1 ASHRAE. Guideline 12-2000. Minimizing the Risk of Legionellosis Associated with Building Water Systems. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia

2 Cooling Technology Institute. July 2008. Legionellosis Guideline: Best Practices for Control of Legionella.

Vanderheyden and Schuyler[3] provided a range of required dilutions based on the gaseous-phase emissions for commonly used cooling tower treatment chemicals. Based on their data, the 10:1 criterion meets the dilution requirements for the majority of commonly used treatment chemicals, assuming that highly odorous chemicals (such as glutaraldehydes) are not used. The actual dilution that is needed for a given cooling tower system depends on the type of treatment chemicals being used, the concentration of the chemicals in the cooling water and the air quality criteria that are applied (e.g., occupational health limits, state legislated air toxics limits, or published odor thresholds), but can be difficult to ascertain since many water treatment products are proprietary mixtures.In general, RWDI recommends that less toxic and low odor chemicals be used in water treatment programs where available.

Combustion Exhausts

The primary pollutants associated with combustion exhausts are nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (PM) and sulfur dioxide (SO_2). Odor is also a concern for exhaust sources that use diesel or jet fuel, such as generators, trucks, buses, and helicopters. Gasoline and natural gas combustion sources have negligible odor emissions.

Health Criteria

Occupational and ambient air quality standards should be considered when determining the health based criteria for combustion exhaust. It is our opinion, however, that the application of occupational standards may not be sufficiently stringent for the higher risk demographic that can be found in the general population including children, the elderly, or other individuals that are more susceptible to respiratory ailments or other health effects of poor air quality (e.g., those with chronic obstructive pulmonary disorder (COPD) or asthma). In most cases NO_2 is the limiting pollutant, meaning that it has the highest ratio of source concentration to allowable concentration and requires the most dilution. By designing to meet the recommended target for NO_2, recommended thresholds for other criteria pollutants would typically also be met.

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3 Vanderheyden, M.D., and Schuyler, G,D., 1994. Evaluation and Quantification of the Impact of Cooling Tower Emission on Indoor Air Quality. ASHRAE Transactions.

Several studies, as summarized by the California Environmental Protection Agency[4,5], have been published citing the acute health effects of NO_2 in humans exposed to varying concentrations in non-occupational settings. These studies demonstrated that short-term exposure of individuals with compromised respiratory systems to concentrations of NO_2 as low as 338 µg/m³ affected airway responsiveness. Based on this evidence, RWDI recommends applying a not-to-exceed target of 338 µg/m³ for NO_2 emissions from intermittent combustion exhaust sources unless a stricter national or state standard exists.

For continuously operating sources such as boilers, co-generation systems, or generators that are used for peak shaving, RWDI recommends applying a stricter 1-hour standard of 188 µ/m³ due to the potential for longer-term exposure. This is equivalent to the 1-hour National Ambient Air Quality Standard (NAAQS) established by the US Environmental Protection Agency (EPA), and is stricter than both RWDI's recommended 338 µg/m³ target for intermittent sources, and applicable longer-term (e.g., 24-hour and annual) air quality standards for criteria pollutants. Note that for intermittent sources, the EPA has expressed the view that the 1-hour standard of 188 µ/m³ for NO_2 may be too strict and not necessarily applied to such sources as generators that are only used for emergency purposes[6]. For NO_2 and intermittent sources, the not-to-exceed target of 338 µg/m³ is recommended instead as discussed above.

While the thresholds and limits imposed by regulatory standards have been consulted to establish design criteria, it is important to note that regulatory modeling has not been undertaken, and RWDI is not aware of specific requirements that may apply. RWDI recommends that the permitting aspect be considered, as different criteria, modeling procedures, and background air quality levels may need to be considered.

Emergency Generator

For the proposed 300 kW Tier 3 emergency diesel generator the exhaust must be diluted by a factor of 280:1 to meet the suggested short-term limit of 338 µg/m³. This health-based dilution criterion was developed using an estimated 'not-to-exceed' nitrogen oxides (NO_x) emission rate of 5.27 g/bhp-hr at 100% load.

For the proposed 800 kW Tier 2 emergency diesel generator, the exhaust must be diluted by a factor of 320:1 to meet the suggested short-term 338 µg/m³ NO_2 limit. This health-based dilution criterion was developed using an estimated 'not-to-exceed' nitrogen oxides (NO_x) emission rate of 6.31 g/bhp-hr.

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4 California Environmental Protection Agency (CalEPA), Air Resources Board (ARB) and Office of Environmental Health Hazard Assessment (OEHHA). January 2007. Review of the California Ambient Air Quality Standard for Nitrogen Dioxide. Technical Support Document Available online at http://www.arb.ca.gov/research/aaqs/no2-rs/no2tech.pdf

5 California Environmental Protection Agency (CalEPA), Air Resources Board (ARB) and Office of Environmental Health Hazard Assessment (OEHHA). January 2007. Review of the California Ambient Air Quality Standard for Nitrogen Dioxide. Staff Report. Available online at http://www.arb.ca.gov/research/aaqs/no2-rs/no2staff.pdf

6 U. S. Environmental Protection Agency. "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" Tyler Fox, Leader, March 1, 2011

Boiler Exhaust

For the proposed 5,000 MBH boilers operating on natural gas, the exhaust must be diluted by a factor of 50:1 to meet the short-term 188 μg/m³ NO_2 limit, which is applicable to continuously operating sources. This health-based dilution criterion was developed based on the low-NO_x (<20 ppm) emissions provided for the proposed boilers. This health-based dilution criterion was developed based on typical emissions of similarly sized boilers.

Diesel Generator Odor

To address odor from diesel generator exhaust, RWDI recommends designing to achieve an exhaust dilution of 3,000:1 at nearby receptors of concern (i.e., the exhaust is diluted 3,000 times before reaching the receptor location). This design target is based on odor panel testing conducted previously by RWDI using field samples from modern (post-2005) diesel generator exhausts operating on ultra-low sulfur diesel (ULSD) fuel.

The 3,000:1 target corresponds to a 50% detection level and also to a 20% recognition level (i.e., approximately 20% of the population will be able to recognize the diesel odor at this dilution level). Table A1 provides the approximate levels of response that could be expected at various levels of dilution for diesel odor based on the odor panel testing.

Table A1: Approximate Levels of Population Response to Diesel Odor

Level of Exhaust Dilution	Diesel Odor Detection Response (% of population)	Diesel Odor Recognition Response (% of population)
1,000:1	95%	60%
1,500:1	80%	50%
2,000:1	70%	30%
3,000:1	50%	20%
5,000:1	15%	<10%

For older, existing diesel generators, RWDI recommends designing to achieve an exhaust dilution of 4,000:1 at nearby receptors of concern (i.e., the exhaust is diluted 4,000 times before reaching the receptor location). This target differs from the design target RWDI applies to new diesel generators, as older engines do not typically burn as cleanly as newer ones. Table A2 below provides the approximate levels of response that could be expected at various levels of dilution for diesel odor based on odor panel testing.

Table A2: Approximate Levels of Population Response to Diesel Odor (Engines older than 2005)

Level of Exhaust Dilution	Diesel Odor Detection Response (% of population)	Diesel Odor Recognition Response (% of population)
1,000:1	95 %	90 %
2,000:1	85 %	60 %
4,000:1	50 %	20 %
8,000:1	15 %	< 5 %

The information in the above tables can be used to demonstrate the expected strength of diesel odors at various levels of exhaust dilution. Stronger odors elicit higher levels of response, while milder odors elicit lower levels of response. For example, with a dilution on the order of 1,000:1, nearly everyone exposed to the odor can be expected to detect it with 60% of people able to recognize it correctly as diesel. At this odor level, one might expect a strong correlation with odor-driven complaints. In general, very high levels of dilution are required in order to minimize the level of response to diesel odors.

Diesel Generator Odor Control Technology

The best available technology to reduce the strength of odor emissions from diesel generators is to implement a combined diesel particulate filter (DPF) and diesel oxidation catalyst (DOC). RWDI has conducted limited odor panel sampling for a generator installation with DPF/DOC technology. The results from the specific equipment installation indicates that a dilution level of 500:1 corresponds with a 50% odor detection response. It is noted that a specific minimum operating temperature is required for DOC equipment to function as designed; this minimum temperature and the minimum load to provide the required temperature should be confirmed with the manufacturer. It is also recommended that the equipment manufacturer be consulted to confirm that the unit does not increase the in-stack ratio of nitrogen dioxide (NO_2) above 10%. The same odor panel sampling testing indicated that, for a generator equipped with a DPF only, a dilution level of 1,000:1 may be sufficient to achieve a 50% odor detection response. However, RWDI cannot guarantee that these levels are applicable in all cases for all equipment.

APPENDIX B

APPENDIX B: DILUTION CRITERIA AND CHEMICAL HANDLING PROTOCOLS FOR LABORATORY FUME HOOD EXHAUST STACKS

Exhausts from laboratory fume hoods have been known to cause odors and adverse health effects if the exhausts are re-ingested back into a building with insufficient dilution. RWDI can predict the dilutions of exhausts with wind tunnel and numerical modelling. However, the modelling results must be compared to dilution criteria to determine whether an exhaust stack is well designed. This technical note discusses possible dilution criteria, makes suggestions on how to select the criteria and suggests a method of chemical assessment to demonstrate compliance with the chosen criteria.

RWDI has looked at the problem of dilution criteria from several perspectives: 1) exhaust stack dilution needed for various liquid chemical spills in the fume hood, 2) analogous dilution criteria for fume hood leakage tests, 3) the available literature, and 4) achievable dilutions for reasonable stack designs. Each of these perspectives is discussed below, along with a suggested procedure.

Examination of Liquid Spills

The best possible method of determining dilution requirements is to know exactly what chemicals are emitted and at what emission rates. Back-calculating a design dilution is then straightforward. For almost all laboratory situations, this emission information is not known in detail. To help determine representative emission information, RWDI has examined more than 300 commonly used liquid chemicals with known health limits and/or odor thresholds to determine what dilutions are necessary for various accidental spill sizes. Accidental spills are used since they would represent the upper end of possible emission rates from the many processes that may be performed, such as boiling liquids, acid digestion, and pouring and mixing of liquids.

Image b1 below presents the calculations of required dilution for spill scenarios of 362 liquid chemicals. This figure can be used by laboratory designers and operators to estimate required dilution for a chemical release scenario without detailed evaporation calculations. (Estimated evaporation rates for chemical spills in fume hoods are described in detail in another RWDI Technical Note). First, the value on the x-axis is determined for the scenario. The horizontal x-axis is a combination of parameters relating to the spill: namely vapor pressure of the liquid in kPa (1 mm Hg = 0.133 kPa), spill area in m^2 (1 m^2 = 10.77 ft^2), chemical exposure limit (mg/m^3), and fume hood volume flow rate in m^3/s (1 m^3/s = 2,119 cfm). The exposure limit can be an odor threshold or a health limit. For health limits, RWDI typically uses occupational health limits from the American Conference of Governmental Industrial Hygienists (ACGIH), specifically their 8-hour Time Weighted Averaged - Threshold Limit Values (TWA-TLV). After the point on the x-axis is determined, the corresponding required dilution is read from the y-axis where the x-axis value intersects the data points. The spread in the data points is due to variations in chemical properties, such as molecular weight and diffusivity.

APPENDIX B

For example, consider a spill of nitric acid (90%), with an odor threshold of 0.7 mg/m^3 (more restrictive than the ACGIH TWA - TLV of 5.2 mg/m^3) and a vapor pressure of 6.39 kPa (48 mmHg at 20°C). If the spill area is 0.81 m^2 (8.8 ft^2) corresponding roughly to a typical five-foot fume hood and the volume flow rate of the hood is 0.47 m^3/s (1,000 cfm), then the spill parameter on the horizontal x-axis is

$$\frac{6.39 \times 0.81}{0.7 \times 0.47} = 15.7$$

For nitric acid (90%), the corresponding required dilution on the vertical y-axis axis range from 500:1 to 2,000:1. A red trend line has been placed near the upper bounds of the data points to estimate a dilution target for a given chemical. For this example, a dilution target of approximately 1,900:1 would be selected based on the trend line. This methodology can be used to provide an approximation of the dilution criterion for chemicals not on RWDI's list of commonly used laboratory chemicals. Alternatively, an approximate dilution target can be estimated based on the following equation for the red trend line:

$$y = 125x$$

Where:

y = Approximate dilution target

x = Value of x-axis equation

For this example, given an x-axis value of 15.7, the dilution target estimate using the equation would be:

$$y = 125(15.7) \cong 1{,}900{:}\,1$$

Note that the trend line and equation are intended to provide a conservative estimate of a dilution target for a chemical that is not on RWDI's list of commonly used laboratory chemicals and should not be used to determine specific dilution targets for a chemical.

The boxed values inside Image B1 indicate the percentage of chemicals that will meet odor and health criteria for a given dilution value, assuming a 1,000 cfm fume hood flow rate, a spill area of 8.8 ft^2, health limits from ACGIH (TWA-TLV), and published odor thresholds. For example, dilutions between 3,000:1 and 5,000:1 are adequate for about 89 percent of the chemicals. If a 3,000:1 dilution criterion is specified for a stack, the other 11 percent of the chemicals on the list would require special handling procedures to reduce the risk of large spills and releases. In practice, many of these chemicals are already well known to need special handling, and large quantities are not typically used. If the list of chemicals analysed is considered representative of all chemicals used in fume hoods, then we can expect the 11 percent of the chemicals in any facility may require handling protocols.

Chemical Handling Protocols

If a chemical dilution target is greater than the minimum dilution level estimated for a given exhaust, the corresponding health limits and/or odor thresholds would not be met in all wind conditions. In order to meet these limits without stack modifications, handling protocols can be put in place for the chemicals that require dilution levels greater than that being achieved. This can be performed in one of two ways; limiting the volume of chemical in the fume hood or limiting the area that could be covered in the event of a chemical spill (typically done through the use of a spill tray). The maximum volumetric usage rate or spill area can be determined based on a ratio of the achieved dilution to the required dilution criterion.

From the above example for a spill of nitric acid (90%), the required dilution criterion of approximately 1,900:1 was determined based on the red trend line provided in Image B1. If, for example, your stack to receptor dilution is determined to be 1,000:1, then the ratio of the achieved dilution to required dilution level is:

$$\frac{1{,}000:1}{1{,}900:1} = 0.53$$

Restricting the spill area via a spill tray will reduce the surface area that is available for evaporation, thereby reducing the concentration of the chemical in the exhaust stack. Assuming a constant spill depth of 0.5 mm (0.02 in) a reduction in spill volume correlates directly into a reduction in evaporative area. Therefore, in order to achieve a 53% reduction in evaporative area, the spill area must be reduced by 53%.

$$8.8\ ft^2 \times 0.53 = 4.7\ ft^2$$

RWDI's spill scenario assumes a spill volume of 406 mL (a spill that covers the entire fume hood area of 8.8 ft^2 (0.8 m^2) and which is 0.5 mm (0.02 in) deep). In order to determine the maximum allowable volumetric usage rate, the original volume of 406 mL must be multiplied by the above calculated factor of 0.53.

$$406\ mL\ \times 0.53\ = 215\ mL$$

Therefore, if a chemical with a dilution target of 1,900:1 were to be used in a fume hood that was determined to be achieving a 1,000:1 stack to receptor dilution level then the chemical would need to be used either with a maximum of 215 mL at a time, or be used in a spill tray that is 4.7 ft^2 or smaller.

Adjustment of Dilution Criteria for Various Exhaust Flow Rates

Problems with fume hood exhausts typically arise from large or accidental releases from one fume hood at a time. Exhausts from other fume hoods can be considered relatively clean and will provide added dilution internal to the building before reaching the stack. This internal dilution should be taken into account. As internal dilution increases, less outdoor stack exhaust dilution is needed, and the dilution criterion can be adjusted accordingly. Therefore, several exhaust stacks with differing flow rates can have varying dilution criteria, which can create confusion during the design phase of a project.

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To account for varying flow rates of several stacks, RWDI usually references the dilution criterion to a 1,000 cfm flow rate. Then if the actual flow rate for a particular stack differs from 1,000 cfm, the criterion can be adjusted for that stack as needed. For example, a 3,000:1 dilution criterion referenced to a 1,000 cfm exhaust may be specified for a project. A particular stack with a 10,000 cfm exhaust, ten times the 1,000 cfm reference exhaust flow rate, would have a factor of 10 internal dilution since the fumes from the accidental spill from one fume hood would be internally diluted by exhausts from other fume hoods. The 10,000 cfm stack would have its criterion reduced from 3,000:1 to 300:1 to account for the internal dilution within that particular stack.

Fume Hood Performance

Fume hood manufacturers routinely test hoods using the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 110-1995 tracer gas test (ASHRAE, 1995). In the ASHRAE 110 test, a tracer gas is released in the fume hood at 4 litres per minute (0.14 cfm), and tracer gas concentration is measured at the breathing zone of a mannequin standing in front of the hood. A common acceptance criterion used by hood manufacturers for the ASHRAE 110 test is to have breathing zone concentrations less than 0.05 ppm (see for example the 2012 American Industrial Hygiene Association (AIHA) Z9.5 Standard on Laboratory Ventilation). A more lenient 0.10 ppm concentration is usually considered acceptable under field conditions. For the reference 1,000 cfm fume hood, the 0.05 ppm value corresponds to a 2,800:1 dilution between the fume hood and the mannequin, and the 0.10 ppm field criterion corresponds to 1,400:1. These dilutions at the face of the hood are analogous to the dilution provided by the stack since the release occurs in the fume hood for both dilutions. The only difference is the location of the exposed person, the mannequin at the hood versus the persons exposed to contaminated outside air.

In RWDI's opinion, the stack dilution should be at least as large as that provided by the fume hood since the stack and fume hood are both safety devices dealing with the same emissions. The 2,800:1 dilution value from the ASHRAE 110 tests compares well with the 3,000:1 dilution that satisfies the requirements of approximately 90 percent of the chemicals in Image B1.

Literature Review

The only known published dilution criterion for design of laboratory fume hood exhausts is that of Halitsky (1988 annual meeting of the Air Pollution Control Association) that has been incorporated in the 2011 ASHRAE HVAC Applications Handbook. For an accidental release, Halitsky specifies that a 15 cfm vapor release should not have an outside air intake concentration exceeding 3 ppm. With a reference 1,000 cfm exhaust, this criterion corresponds to a 5,000:1 dilution, reasonably close to the analogous fume hood criteria (2,800:1) and the value at which 89 percent of chemicals are controlled in Image b1 (between 3,000:1 and 5,000:1).

Achievable Dilutions for Reasonable Stack Designs

It is difficult to quantify achievable dilutions since there are varying aesthetic values, building geometries, and budgets possible. However, RWDI can make some general comments. In our experience, achieving dilutions of 10,000:1 or greater (referenced to 1,000 cfm) is difficult and requires an aggressive stack design. For a stack exhausting a single fume hood, dilutions of 1,000:1 and greater are difficult. On the lower end of the dilution scale, dilutions of 10:1 or 100:1 will probably cause frequent odor complaints based on our experience with laboratory exhaust problem cases. RWDI has in the past used dilution criteria in the vicinity of 1,000:1 for numerous projects with very few problems reported.

Conclusion: A Suggested Dilution Procedure

RWDI does not specify firm dilution criteria for fume hood exhausts without review of emissions and consultation with the client. Based on the above discussion, RWDI suggests as a starting point a dilution criterion of 3,000:1 referenced to a 1,000 cfm fume hood exhaust stack. For stack exhaust flow rates differing from the reference 1,000 cfm flow rate, the required dilution can be adjusted as discussed above. The 3,000:1 dilution level avoids odors and occupational health effects for about 89 percent of spills on RWDI's chemical list, is consistent with ASHRAE 110 fume hood test criteria, is consistent with other published data, and has been found to be reasonably achievable. A more lenient criterion may be used if chemical usage is relatively mild. On the other hand, a more stringent criterion may be desirable if chemical usage is intense or if potentially exposed people are sensitive, such as at hospitals or schools. It is recommended that Image b1 be used by the client to evaluate required dilutions for chemicals to be used and that protocols be placed on chemical usage amounts or spill areas as described above. If the 3,000:1 dilution target is applied, consideration should also be given to applying handling protocols to chemicals requiring dilution levels above 3,000:1 (refer to Table B1).

References

ACGIH (American Conference of Governmental Industrial Hygienists). 1998 TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, Cincinnati, Ohio, 1998.

ANSI/AIHA (American National Standards Institute / American Industrial Hygiene Association). American National Standard for Laboratory Ventilation, Standard Z9.5-1992. Fairfax, Virginia, 2012.

ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers). Method of Testing Performance of Laboratory Fume Hoods. ASHRAE Standard 110-1995. Atlanta, GA. 1995.

ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers). Handbook -- HVAC Applications, Chapter 16. Atlanta, GA. 2011.

Halitsky, J. "Dispersion of laboratory exhaust gas by large jets." 81st Annual Meeting of the Air Pollution Control Association. Paper 88-75.1, Dallas, TX, 1988.

APPENDIX B

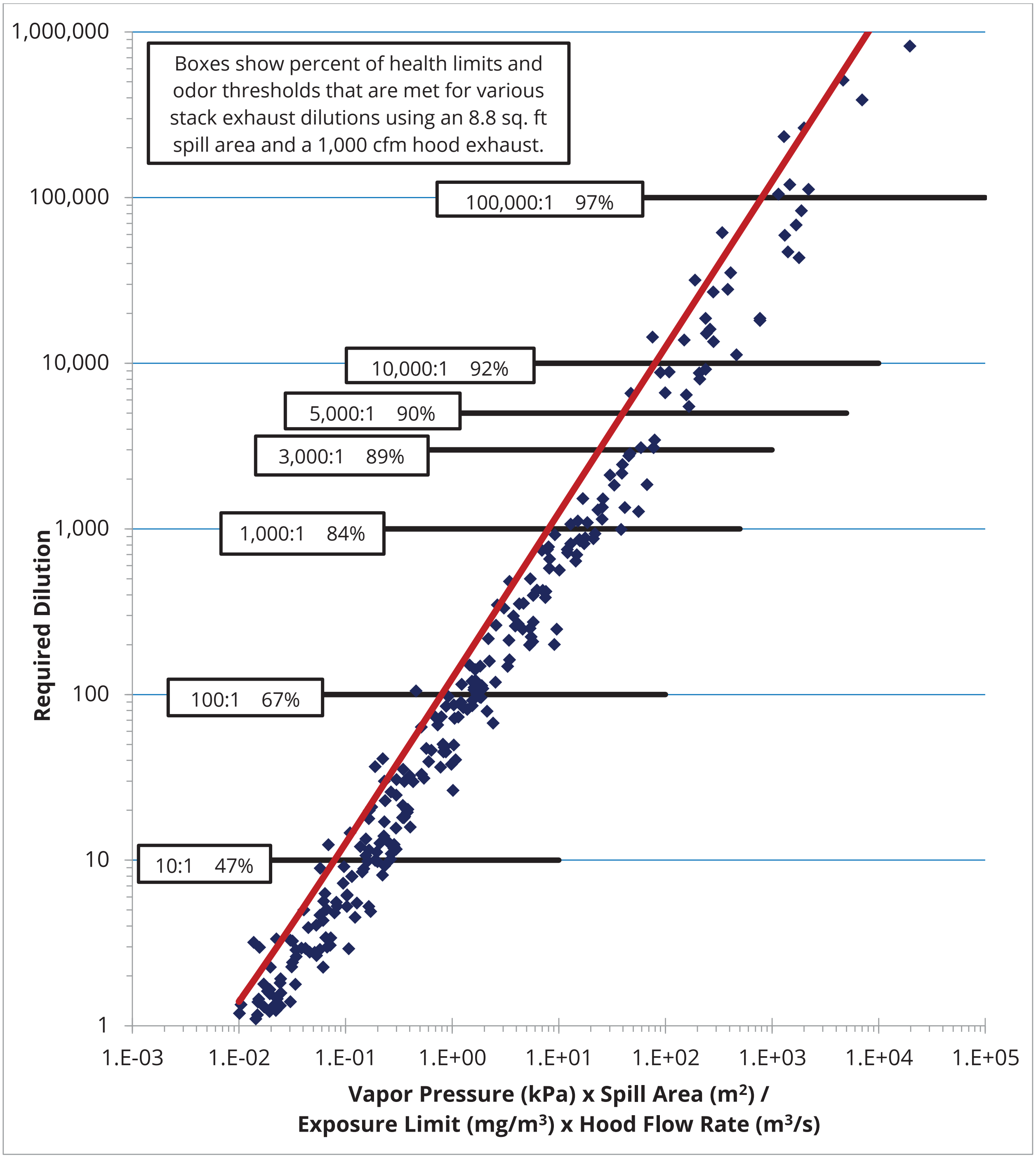

Image B1: Required Dilution Levels for 362 Chemicals to meet Health Limits and Odor Thresholds

<u>Notes:</u> i) Required dilution less than 1:1 not shown – indicates that a chemical meets its exposure limit within the exhaust stack.

ii) Face velocity of 100 fpm assured.

Table B1: Handling Limits for Liquid Chemicals on RWDI List for a Dilution Level of 3,000:1

Chemical Name	CAS Number	Volume Use Limit [mL]	Spill Area Limit [ft^2]
Propargyl alcohol	107-19-7	395	8.50
Ethyl ether	60-29-7	394	8.48
n-Butylamine	109-73-9	355	7.64
Ethylamine	75-04-7	223	4.79
1,1-Dimethylhydrazine	57-14-7	189	4.07
Tetranitromethane	509-14-8	185	3.98
Dimethyl disulfide	624-92-0	184	3.96
Acrolein	107-02-8	152	3.27
Isopropylamine	75-31-0	140	3.01
Bromine	7726-95-6	138	2.98
Bromine pentafluoride	7789-30-2	138	2.97
Propionaldehyde	123-38-6	133	2.85
Dimethylamine (25 %)	124-40-3	108	2.33
Diethylamine	109-89-7	90	1.94
sec-Amyl acetate	626-38-0	88	1.90
Tetramethyl lead	75-74-1	85	1.83
Methyl tert-butyl ether	1634-04-4	81	1.74
Methyl acrylate	96-33-3	76	1.64
Hydrofluoric acid (46 to 53%)	7664-39-3	67	1.45
Dimethylamine (40 %)	124-40-3	65	1.41
Benzenethiol (phenyl mercaptan)	108-98-5	65	1.41
Sulfur monochloride	10025-67-9	45	0.98
Isopropyl ether	108-20-3	44	0.94
1-2-Dibromo-3-chloropropane	96-12-8	38	0.83
Xylidine	1300-73-8	35	0.75
Dimethylamine (60 %)	124-40-3	28	0.61
Acetaldehyde	75-07-0	26	0.56
Pentaborane	19624-22-7	21	0.44
Osmium tetroxide	20816-12-0	20	0.43
Methyl isocyanate	624-83-9	18	0.38
Dimethyl sulfide	75-18-3	15	0.32
Arsenic trichloride	7784-34-1	12	0.25
n-Butyl mercaptan	109-79-5	11	0.23
bis-Chloromethyl ether	542-88-1	10	0.22
Sulfur pentafluoride	5714-22-7	5 [1]	0.11 [1]
Perchloromethyl mercaptan	594-42-3	5 [1]	0.10 [1]
Ethyl acrylate	140-88-5	3 [1]	0.07 [1]
Chromyl chloride	14977-61-8	2 [1]	0.05 [1]
Trimethylamine (40 %)	75-50-3	1 [1]	0.03 [1]
Nickel carbonyl	13463-39-3	1 [1]	0.02 [1]
Ethyl mercaptan	75-08-1	0.25 [1]	0.01 [1]

Note: [1] Handling limits may not be feasible. Store/use chemical in the smallest quantity possible and handle with extreme caution.

APPENDIX C

APPENDIX C: ESTIMATING CHEMICAL EMISSIONS FROM FUME HOODS

The proper design of chemical fume hood exhaust stacks requires an estimate of the concentrations of chemical vapors in the stack. The level of chemical vapors in the stack is dependent on many variables including the type of process being undertaken in the fume hood, the face velocity through the hood and the flow rate of the hood exhaust plus the physical state and the volatility of the chemical in question. The evaluation of acceptable levels of chemical fumes is also dependent on the toxicity or odor potential of the particular substance.

This document outlines the method used to estimate chemical emissions from both liquid and gaseous chemicals within a fume hood. The calculated emission rates are estimates only and are intended to provide a guideline for good engineering design of fume hood exhaust stacks. It is left to the owner or operator of the facility to determine whether the calculations are appropriate for their facility, or whether the list of chemicals presented herein is sufficiently comprehensive for a given application.

Determination of Evaporation Rate for Liquid Chemicals

The method described herein is a conservative estimate of liquid chemical emissions based on the principle of mass transfer from a flat plate. This method assumes a hypothetical worst-case spill of a chemical over the entire surface of a typical bench-top fume hood. This method ignores the effect of cooling on evaporation rates. For highly volatile liquids, the high initial evaporation rate cools the liquid, which lowers vapor pressure and evaporation rate.

Emissions of liquid chemicals and solutions from fume hoods are calculated by estimating the mass transfer rates (evaporation rates) of these substances. The mass transfer is driven by the chemical vapor density gradient and is expressed as follows:

$$q_B = h_m(\rho_{Bi} - \rho_\infty)A \qquad \textbf{(1)}$$

where q_B = the evaporation rate of the chemical (kg/s);

h_m = the mass transfer coefficient (m/s);

ρ_{Bi} = the chemical vapor density at the interface (kg/m^3);

ρ_∞ = the chemical vapor density at infinity or background (kg/m^3); and,

A = the exposed area of the chemical (m^2).

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Note that ρ_{Bi} is taken to be zero. The chemical vapor density at the film interface is calculated using the ideal gas law, assuming that the air is saturated with the chemical at this point. The relationship is given by[1]:

$$\rho_{Bi} = \frac{M_B p_{Bi}}{R_g T_i} \qquad \textbf{(2)}$$

where M_B = the molecular weight of the chemical (kg/mol);

ρ_{Bi} = the partial pressure of the vapor (i.e. vapor pressure) at 20ºC (kPa);

R_g = the molar gas constant (kPa·m^3/mol·K); and,

T_i = the temperature of the air in the fume hood (K).

The mass transfer coefficient h_m from Equation (1) is calculated assuming the area of the chemical (e.g., area of a spill) is exposed to airflow over a flat plate. In such cases, the mass transfer coefficient is determined empirically using the Chilton-Colburn analogy[1], given as follows:

$$h_m = \frac{j_D u / P_{AM}}{(\mu/\rho D_{AB})^{2/3}} \qquad \textbf{(3)}$$

where j_D = the Chilton-Colburn j factor (dimensionless);

u = the mean free-stream velocity of air flow across the plate (m/s);

P_{AM} = the logarithmic mean density factor (dimensionless);

μ = the viscosity of air at 20ºC (kg/m·s);

ρ = the density of air at 20ºC (kg/m^3); and,

D_{AB} = the diffusivity of chemical vapor in the air (m^2/s).

The mean density factor is approximately equal to unity. For this application, we have assumed a mean free-stream velocity of 0.5 m/s (100 fpm). The Chilton-Colburn j factor is a function of the Reynolds number. For the assumed velocity of 0.5 m/s, the resulting value for the j factor is 0.0048.

Estimating the diffusivity of the chemical vapor in air is accomplished using the Fuller/Schettler/Giddings method[2] for binary mixtures at moderately low pressures (< 10 atm). This relationship is defined as follows:

$$D_{AB} = \frac{10^{-3} T^{1.75} [(M_A + M_B)/M_A M_B]^{1/2}}{P\left[(\Sigma v)_A^{1/3} + (\Sigma v)_B^{1/3}\right]^2} \qquad \textbf{(4)}$$

where T = the temperature of the mixture (K);

P = the pressure of the mixture (atm);

M_A = the molecular weight of the air (kg/mol);

M_B = the molecular weight of chemical (kg/mol);

Σv_A = the atomic diffusion volume of the air (dimensionless); and,

Σv_B = the atomic diffusion volume of chemical vapor (dimensionless).

Atomic diffusion volumes have been determined empirically from linear regression of experimental data[2] for various binary mixtures.

In many cases, the diffusivity for a chemical compound in air has been published. In these instances, the published value has been used in lieu of Equation (4).

Determination of Concentration in Exhaust Duct from Liquid Chemicals

Having determined the emission rate, the concentration of chemical vapors in the fume hood duct is calculated as follows:

$$C_{duct} = \frac{q}{Q} \qquad \textbf{(5)}$$

where C_{duct} = the concentration of vapor in the exhaust duct (kg/m^3);

q = the evaporation rate of the chemical (kg/s); and,

Q = the flow rate of air through the duct (m^3/s).

Determination of Emission Rate for Compressed Gases

The method described herein is a conservative estimate of chemical emissions from compressed gas bottles based on the ideal gas law. This method assumes a reasonable maximum volumetric gas flow rate of 4 liters per minute (0.000067 m^3/s) out of the cylinder.

The ideal gas law is used to calculate the gas density, in kg/m^3, as follows:

$$\rho = \frac{P_{atm}}{RT} \times MW \qquad \textbf{(6)}$$

where ρ = the gas density in (g/m^3);

P_{atm} = the atmospheric pressure (Pa);

APPENDIX C

R = the gas constant (8.314 J/mol K);

T = the gas temperature (K); and,

MW = the molecular weight (g/mol).

The mass emission rate is calculated from the gas density and the assumed gas flow rate through the following equation:

$$\dot{m} = \rho \times Q_{gas} \quad \textbf{(7)}$$

where $\dot{m}$ = the mass emission rate (g/s); and,

Q_{gas} = the gas flow rate out of the cylinder (m^3/s).

Alternatively, the cylinder characteristics can be applied to estimate the mass emission rate. When the valve of a pressurized gas bottle is left wide open, the peak-gas emission rate is dependent on physical properties of the gas, the size of the valve throat, and the gas pressure. This emission rate can be calculated through the following fluid mechanics relationship:

$$\dot{m} = k\sqrt{\frac{M_B d^4 P^2}{RT}} \quad \textbf{(8)}$$

where k = a gas specific constant (dimensionless);

P = the bottled gas pressure (kPa gauge);

M_B = the molecular weight of chemical (kg/mole);

R = the universal gas constant (J/mole/K);

T = the gas temperature (K); and,

d = the diameter of the gas bottle valve throat (m).

The above method of calculation results in a worst-case estimate of an emission rate. The results for many typical bottled gases indicate that with practical stack designs, an accidental release of this type will lead to excessive concentrations at nearby fresh air intakes. Therefore, special handling procedures should be adopted for bottled gases, including low risk ones, to guard against accidental releases. Most suppliers of bottled gases have documentation on the handling of bottled gases.

Determination of Concentration in Exhaust Duct from Gaseous Chemicals

Having used either of the above methods to determine the emission rate, the concentration of chemical vapors in the fume hood duct, resulting from gaseous chemicals, is calculated as follows:

$$C_{duct} = \frac{\dot{m}}{Q_{hood}} \quad \textbf{(9)}$$

where C_{duct} = the duct concentration (g/m^3);and,

Q_{hood} = the fume hood flow rate (m^3/s).

Determination of Dilution Requirement

The required dilution is determined as the ratio of the concentration of chemical vapors at the stack to the maximum desired concentration at the air intake (or other sensitive area). This is represented as follows:

$$D_{required} = \frac{C_{duct}}{C_{desired}} \quad \textbf{(10)}$$

where $D_{required}$ = the required dilution; and,

$C_{desired}$ = the desired concentration (e.g., exposure limit).

The desired concentration varies from one chemical to another. A variety of exposure limits may be used. In our calculations shown in the attached tables, we have used the following exposure limits as the desired concentrations:

- American Conference of Governmental Industrial Hygienists (ACGIH) Time-Weighted Average (TWA) and Short-Term Exposure (STEL) limits or Ceiling values[3].
- National Institute of Occupational Safety and Health (NIOSH), TWA, STEL, or Ceiling values[4]
- Occupational Safety and Health Administration (OSHA) TWA, STEL, or Ceiling values[5]
- AIHA 1989. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.[6]

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- Nagy, G.Z., 1991. The odor impact model. Journal of the Air Waste Management Association, p. 1360-1362.[7]
- Ruth, J.H., 1986. Odor thresholds and irritation levels of several chemicals: a review. Journal of the American Industrial Hygienists Association, 47:A-142-A-151.[8]
- 3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.[9]

RWDI has estimated emission rates and dilution requirements for more than 350 chemicals, based on the above methods. Emissions for liquid chemical spills were calculated using a typical 5-ft bench-top fume hood with an exhaust flow rate of 1,000 cfm and a spill area of 8.8ft^2. For gaseous chemicals, the assumed 4 liters per minute outlet flow rate was applied.

Attached Summary Tables

The two tables attached at the end of this technical note show predicted emission rates and dilution requirements for liquids and compressed gases. Health limits are based on occupational limits of ACGIH, NIOSH, or OSHA as described above. The table shows the most stringent 8-hour TWA and the most stringent STEL/Ceiling value from the three sources. Odor thresholds are based on several references also described above. The last column indicates the worst case (highest) of either health or odor, which is used for design purposes. If both the 8-hour TWA and STEL/Ceiling values exist for a chemical, the short term STEL/Ceiling health limit is used because the emission duration is assumed to be an hour or less.

References

American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE Handbook, 1993 Fundamentals, Chapter 5, "Mass Transfer", Atlanta, 1993.

Perry, R.H. and D. Green, Perry's Chemical Engineers' Handbook, 6th Edition, 1984.

American Conference of Government Industrial Hygienists, 2001 Guide to Occupational Exposure Values, Cincinnati, Ohio, 2001.

National Institute of Occupational Safety and Health (NIOSH), TWA, STEL, or Ceiling values.

Occupational Safety and Health Administration (OSHA) TWA, STEL, or Ceiling values.

AIHA 1989. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.

Nagy, G.Z., 1991. The Odor Impact Model. Journal of the Air Waste Management Association, p. 1360-1362.

Ruth, J.H., 1986. Odor Thresholds and Irritation Levels of Several Chemicals: A Review. Journal of the American Industrial Hygienists Association, 47:A-142-A-151.

3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.

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GASES

Pressure	**101325.00**	**Pa**
Temperature	**293.00**	**K**
Gas Constant	**8.31**	**J/mol*K**
Gas Flow Rate	**4.00**	**l/min**
Hood Flow Rate	**1000.00**	**cfm**

Chemical	CHEMICAL PROPERTIES					ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Density (kg/m^3)	Mass Emission Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health/Odor
Acetylene	74-86-2	26.04	1.08	72.20	152.87	510.00	2662.000	NV	510.000	none
Ammonia	7664-41-7	17.03	0.71	47.23	99.99	11.84	24.000	17.000	11.841	8
Arsine	7784-42-1	77.93	3.24	216.10	457.54	3.19	0.002	0.160	0.002	228768
Boron Trichloride	10294-34-5	117.17	4.87	324.91	687.91	NV	NV	NV	NV	N/A
2-Butene (beta-butylene)	107-01-7	56.11	2.33	155.58	329.41	NV	NV	NV	NV	N/A
Carbon Monoxide	630-08-0	28.01	1.17	77.67	164.45	114561.96	229.000	29.000	229.000	none
Chlorine	7782-50-5	70.91	2.95	196.62	416.30	0.23	1.450	1.500	0.232	1794
Chlorine Dioxide	10049-04-4	67.45	2.81	187.04	396.01	41.38	0.830	0.280	0.830	477
Chlorodifluoromethane (Freon 22)	75-45-6	86.47	3.60	239.78	507.68	NV	4375.000	3500.000	4375.000	none
Carbon Tetrafluoride	75-73-0	88.01	3.66	244.05	516.72	NV	NV	NV	NV	N/A
Cyanogen Chloride	506-77-4	61.48	2.56	170.48	360.96	2.00	0.060	NV	0.060	6016
Diborane	19287-45-7	27.67	1.15	76.72	162.44	2.84	NV	0.100	0.100	1624
Dichlorosilane	4109-96-0	101.01	4.20	280.09	593.03	NV	NV	NV	NV	N/A
Dichloro-1,1,2,2,-tetrafluoroethane, 1,2 (Freon 114)	76-14-2	170.92	7.11	473.96	1003.49	NV	NV	6990.000	6990.000	none
Difluorodichloromethane (Freon 12)	75-71-8	120.92	5.03	335.31	709.94	NV	NV	4950.000	4950.000	none
Ethylene (ethene)	74-85-1	28.05	1.17	77.79	164.71	309.79	NV	NV	309.794	none
Ethylene Oxide	75-21-8	44.05	1.83	122.15	258.62	756.69	9.000	0.180	9.000	29
Fluoroform (Carbon Trifluoride, trifluoromethane)	75-46-7	70.01	2.91	194.15	411.06	NV	NV	NV	NV	N/A
Fluorine	7782-41-4	37.99	1.58	105.35	223.04	6.00	3.100	0.200	3.100	72
Hexafluoropropane (hydrofluorocarbon)	690-39-1	152.00	6.32	421.49	892.41	NV	NV	NV	NV	N/A
Hydrogen Bromide	10035-10-6	80.91	3.37	224.37	475.04	6.67	9.900	10.000	6.667	71
Hydrogen Chloride	7647-01-0	36.46	1.52	101.11	214.07	2.39	7.000	NV	2.388	90
Hydrogen Fluoride	7664-39-3	20.01	0.83	55.48	117.46	0.03	2.300	2.455	0.033	3589
Hydrogen Sulfide	7783-06-4	34.08	1.42	94.49	200.06	0.01	15.000	7.000	0.013	15271
Methyl Bromide (Bromomethane)	74-83-9	94.94	3.95	263.26	557.40	565.69	80.000	3.900	80.000	7
Methyl Chloride	74-87-3	50.49	2.10	140.00	296.42	20.65	207.000	103.000	20.649	14
Methyl Mercaptan	74-93-1	48.11	2.00	133.41	282.46	0.00	1.000	0.980	0.001	265831
Methane	74-82-8	16.04	0.67	44.49	94.19	NV	NV	NV	NV	N/A
Nitrogen Trifluoride	7783-54-2	71.00	2.95	196.89	416.86	NV	NV	29.000	29.000	14
Nitric Oxide	10102-43-9	30.01	1.25	83.21	176.17	0.66	NV	30.000	0.657	268
Nitrogen Dioxide	10102-44-0	46.01	1.91	127.59	270.13	4.47	1.800	5.600	1.800	150

GASES

Pressure	**101325.00**	**Pa**
Temperature	**293.00**	**K**
Gas Constant	**8.31**	**J/mol*K**
Gas Flow Rate	**4.00**	**l/min**
Hood Flow Rate	**1000.00**	**cfm**

Chemical	CHEMICAL PROPERTIES					ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Density (kg/m^3)	Mass Emission Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health/Odor
Nitrous Oxide	10024-97-2	44.01	1.83	122.05	258.40	NV	NV	46.000	46.000	6
Ozone	10028-15-6	48.00	2.00	133.10	281.81	0.03	0.200	0.100	0.032	8824
Phosgene (carbonyl chloride)	75-44-5	98.92	4.11	274.29	580.75	3.35	0.800	0.400	0.800	726
Phosphine (hydrogen phosphide)	7803-51-2	34.00	1.41	94.27	199.60	0.19	1.000	0.400	0.195	1025
Sulfur Dioxide	7446-09-5	64.06	2.66	177.63	376.10	7.07	13.000	5.000	7.074	53
Sulfur hexafluoride	2551-62-4	146.05	6.07	404.99	857.48	NV	NV	5970.000	5970.000	none
Silane	7803-62-5	32.12	1.34	89.06	188.57	NV	NV	6.600	6.600	29
Silicon Tetrafluoride	7783-61-1	104.08	4.33	288.61	611.06	4.25	NV	NV	4.250	144
Trifluoroacetyl Chloride	354-32-5	132.47	5.51	367.34	777.74	NV	NV	NV	NV	N/A
Vinyl Chloride	75-01-4	62.50	2.60	173.31	366.94	36.15	12.900	2.600	12.900	28

Chemical Properties can be referenced to www.chemfinder.com

ACGIH, OSHA, NIOSH Health Limits taken from 2001 Guide to Occupational Exposure Values, compiled by ACGIH
NV indicates no value for air quality or odor standards
N/A indicates required dilution is not applicable.
"none" indicates criterion met at the source (i.e., no dilution required).

Odor Threshold Values taken from the following five sources (listed in priority):
1) American Industrial Hygiene Association. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, OH. 1989.
2) Nagy, George Z. The Odor Impact Model. J. Air Waste Manage. Assoc., October 1991. Volume 41, No. 10, pp 1360-1362.
3) Same as source 1)
4) Ruth, Jon H. Odor Thresholds and Irritation Levels of Several Chemicals: A Review. American Industrial Hygiene Association (47). March, 1986. pp A142-A151.
5) 3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.

Maximum Required Dilution based on:
1) Minimum of STEL or C of ACGIH, OSHA, and NIOSH limits (short-term health);
2) Minimum of TWA of ACGIH, OSHA, and NIOSH limits (long-term health);
3) Odor threshold based on priority of resource used.
The minimum value out of the health and the odor values was used with the short term health limit taking precedence over the long-term health limit.

APPENDIX C

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Acetaldehyde	75-07-0	44.05	99.00	1.79E+00	0.11	1.84E-03	2683.46	5685.94	0.12	45.00	360.00	0.12	47104
Acetic acid	64-19-7	60.05	1.52	3.75E-02	0.11	1.80E-03	54.88	116.28	0.18	37.00	25.00	0.18	640
Acetic anhydride	108-24-7	102.10	0.47	1.97E-02	0.07	1.40E-03	22.45	47.58	0.58	20.00	20.00	0.58	81
Acetone	67-64-1	58.08	24.40	5.82E-01	0.11	1.83E-03	865.85	1834.64	147.28	1782.00	590.00	147.28	12
Acetone cyanohydrin	75-86-5	85.10	0.11	3.74E-03	0.10	1.73E-03	5.25	11.13	10.44	4.00	NV	4.00	3
Acetonitrile	75-05-8	41.05	9.70	1.63E-01	0.11	1.88E-03	250.06	529.86	1947.57	101.00	34.00	101.00	5
Acetophenone	98-86-2	120.15	0.13	6.41E-03	0.06	1.21E-03	6.29	13.32	1.57	NV	49.00	1.57	8
Acetyl acetone	123-54-6	100.12	0.93	3.82E-02	0.07	1.35E-03	41.86	88.70	0.04	NV	NV	0.04	2169
Acetyl chloride	75-36-5	78.50	33.20	1.07E+00	0.07	1.37E-03	1195.27	2532.63	NV	NV	NV	NV	N/A
Acetylene tetrabromide	79-27-6	346.00	0.02	2.84E-03	0.05	1.12E-03	2.58	5.46	NV	NV	14.00	14.00	none
Acrolein	107-02-8	56.06	28.10	6.47E-01	0.09	1.65E-03	869.84	1843.08	4.13	0.23	0.25	0.23	8013
Acrylamide	79-06-1	71.00	0.001	2.9E-05	0.10	1.73E-03	0.04	0.09	NV	NV	0.03	0.03	3
Acrylic acid	79-10-7	72.06	0.40	1.18E-02	0.09	1.58E-03	15.16	32.13	0.27	NV	5.90	0.27	118
Acrylonitrile	107-13-1	53.06	11.50	2.50E-01	0.10	1.68E-03	341.65	723.91	3.47	22.00	2.20	3.47	208
Allyl alcohol	107-18-6	58.08	2.30	5.48E-02	0.09	1.62E-03	72.29	153.18	4.04	10.00	1.19	4.04	38
Allyl chloride	107-05-1	76.53	45.00	1.41E+00	0.08	1.51E-03	1734.62	3675.46	5.27	6.00	3.00	5.27	698
Allyl glycidyl ether	106-92-3	114.00	0.27	1.26E-02	0.06	1.27E-03	13.05	27.66	44.00	44.00	4.70	44.00	none
Amitrole	61-82-5	84.00	1.00E-06	3.45E-08	0.09	1.58E-03	4.44E-05	9.41E-05	NV	NV	0.20	0.20	none
Ammonium chloride	12125-02-9	53.00	0.13	2.89E-03	0.10	1.73E-03	4.07	8.62	NV	20.00	10.00	20.00	none
Ammonium hydroxide sol'n (10%), as NH4	1336-21-6	35.00	15.00	2.16E-01	0.19	2.61E-03	457.20	968.74	24.34	24.00	17.00	24.00	40
Ammonium hydroxide sol'n (20%), as NH4	1336-21-6	35.00	29.50	4.24E-01	0.19	2.61E-03	897.60	1901.90	24.34	24.00	17.00	24.00	79
Ammonium hydroxide sol'n (30%), as NH4	1336-21-6	35.00	74.20	1.07E+00	0.19	2.61E-03	2257.68	4783.76	24.34	24.00	17.00	24.00	199
n-Amyl acetate	628-63-7	130.18	0.67	3.58E-02	0.06	1.20E-03	34.88	73.90	0.28	532.00	266.00	0.28	267
sec-Amyl acetate	626-38-0	130.18	0.93	4.97E-02	0.10	1.73E-03	69.84	147.98	0.01	532.00	266.00	0.01	13830
n-Amyl alcohol	71-41-0	88.15	0.22	7.89E-03	0.06	1.23E-03	7.89	16.71	5.59	NV	NV	5.59	3
t-Amyl alcohol	75-85-4	88.15	1.60	5.79E-02	0.06	1.23E-03	57.88	122.64	0.83	NV	NV	0.83	148
Aniline	62-53-3	93.12	0.04	1.53E-03	0.06	1.24E-03	1.55	3.27	9.14	NV	7.60	7.60	none
2-Anisidine	90-04-0	123.15	0.01	6.57E-04	0.10	1.73E-03	0.92	1.96	NV	NV	0.50	0.50	4
Anisole	100-66-3	108.14	1.30	5.77E-02	0.06	1.26E-03	58.93	124.86	0.22	NV	NV	0.22	565
Arsenic trichloride	7784-34-1	181.00	1.33	9.90E-02	0.06	1.23E-03	98.93	209.61	NV	0.002	0.01	0.002	104806
Azinphos methyl	86-50-0	317.00	8.00E-08	1.04E-08	0.04	9.89E-04	8.37E-06	1.77E-05	NV	NV	0.20	0.20	none
Benzaldehyde	100-52-7	106.13	0.13	5.66E-03	0.07	1.35E-03	6.23	13.20	0.01	NV	NV	0.01	1093
Benzene	71-43-2	78.11	10.00	3.21E-01	0.08	1.45E-03	378.54	802.08	194.88	3.20	0.32	3.20	251
Benzenethiol (phenyl mercaptan)	108-98-5	110.18	0.19	8.46E-03	0.10	1.73E-03	11.89	25.18	0.00	0.50	2.30	0.001	18629
Benzoic Acid	65-85-0	122.00	0.13	6.66E-03	0.10	1.73E-03	9.36	19.83	NV	NV	NV	NV	N/A

APPENDIX C

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odor Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odor
Benzothiazole	95-16-9	135.00	4.50	2.49E-01	0.10	1.73E-03	350.45	742.56	0.99	NV	NV	0.99	751
Benzoyl chloride	98-88-4	140.60	0.05	2.94E-03	0.10	1.73E-03	4.14	8.76	0.04	2.80	NV	0.04	218
Benzyl Alcohol	100-51-6	108.13	0.02	8.88E-04	0.10	1.73E-03	1.25	2.64	24.54	NV	NV	24.54	none
Benzyl chloride	100-44-7	126.58	0.13	6.75E-03	0.07	1.31E-03	7.20	15.25	0.21	5.00	5.00	0.21	72
Benzylamine	100-46-9	107.16	13.30	5.85E-01	0.07	1.31E-03	622.63	1319.29	NV	NV	NV	NV	N/A
Biphenyl	92-52-4	154.00	0.001	8.22E-05	0.10	1.73E-03	0.12	0.24	0.00	NV	1.00	0.003	74
Boron tribromide	10294-33-4	251.00	5.33	5.49E-01	0.05	1.03E-03	459.89	974.45	NV	10.00	NV	10.00	97
Bromine	7726-95-6	159.83	23.00	1.51E+00	0.08	1.50E-03	1834.75	3887.61	0.44	1.30	0.66	0.44	8813
Bromine pentafluoride	7789-30-2	175.00	44.00	3.16E+00	0.05	1.14E-03	2923.32	6194.17	NV	NV	0.70	0.70	8849
Bromobenzene	108-86-1	157.02	0.54	3.48E-02	0.06	1.27E-03	35.88	76.02	NV	NV	NV	NV	N/A
1-Bromobutane	109-65-9	137.03	5.35	3.01E-01	0.06	1.30E-03	317.08	671.86	NV	NV	NV	NV	N/A
2-Bromobutane	78-76-2	137.03	9.33	5.25E-01	0.06	1.30E-03	552.96	1171.67	NV	NV	NV	NV	N/A
1-Bromopropane	106-94-5	122.90	16.00	8.07E-01	0.07	1.38E-03	902.72	1912.75	NV	NV	NV	NV	N/A
Bromoform	75-25-2	252.77	0.67	6.95E-02	0.06	1.25E-03	70.74	149.90	17.45	NV	5.00	5.00	30
1-Butoxy-2-propanol	5131-66-8	132.00	0.19	1.01E-02	0.10	1.73E-03	14.24	30.17	NV	NV	NV	NV	N/A
n-Butyl acetate	123-86-4	116.16	1.33	6.34E-02	0.06	1.24E-03	64.10	135.82	1.47	950.00	710.00	1.47	92
sec-Butyl acetate	105-46-4	116.16	1.30	6.20E-02	0.06	1.24E-03	62.66	132.76	21.76	NV	950.00	21.76	6
n-Butyl acrylate	141-32-2	128.00	0.50	2.63E-02	0.10	1.73E-03	36.92	78.23	0.05	NV	11.00	0.05	1525
Isobutyl alcohol	78-83-1	74.00	1.20	3.65E-02	0.10	1.73E-03	51.23	108.54	10.90	NV	150.00	10.90	10
n-Butyl alcohol	71-36-3	74.00	0.60	1.82E-02	0.07	1.40E-03	20.77	44.00	3.63	150.00	61.00	3.63	12
tert-Butyl alcohol	75-65-0	74.00	4.10	1.25E-01	0.07	1.36E-03	137.98	292.37	2905.52	450.00	300.00	450.00	none
sec-Butyl alcohol	78-92-2	74.00	1.60	4.86E-02	0.07	1.36E-03	53.85	114.10	9.69	455.00	300.00	9.69	12
n-Butylamine	109-73-9	73.00	11.00	3.30E-01	0.08	1.45E-03	387.43	820.92	0.24	15.00	NV	0.24	3437
Butyl Cellosolve (2-butoxyethanol)	111-76-2	118.17	0.10	4.85E-03	0.10	1.73E-03	6.82	14.44	0.48	NV	24.00	0.48	30
n-Butyl ether	142-96-1	130.23	0.64	3.42E-02	0.06	1.20E-03	33.32	70.61	0.97	NV	NV	0.97	73
n-Butyl glycidyl ether (BGE)	2426-08-6	130.00	0.43	2.29E-02	0.06	1.20E-03	22.35	47.36	NV	30.00	133.00	30.00	2
n-Butyl lactate	138-22-7	146.20	0.05	3.00E-03	0.06	1.21E-03	2.95	6.25	35.00	NV	25.00	25.00	none
n-Butyl mercaptan	109-79-5	90.00	4.70	1.74E-01	0.07	1.38E-03	195.11	413.41	0.00	1.80	1.80	0.004	112310
o-sec-Butylphenol	89-72-5	150.00	0.004	2.46E-04	0.06	1.19E-03	0.24	0.50	NV	NV	30.00	30.00	none
p-tert-Butyl toluene	98-51-1	148.00	0.10	6.08E-03	0.05	1.08E-03	5.33	11.30	30.00	120.00	6.10	30.00	none
n-Butyric acid	107-92-6	88.11	0.06	2.06E-03	0.07	1.32E-03	2.22	4.70	0.09	NV	NV	0.09	50
n-Butyronitrile	109-74-0	69.10	2.55	7.23E-02	0.10	1.73E-03	101.65	215.38	NV	NV	22.00	22.00	10
Carbon disulfide	75-15-0	76.00	40.00	1.25E+00	0.09	1.60E-03	1625.02	3443.23	3.90	30.00	3.00	3.90	883
Carbon tetrachloride	56-23-5	154.00	12.00	7.59E-01	0.07	1.37E-03	842.18	1784.49	1587.24	12.60	31.00	12.60	142
Chloroacetaldehyde	107-20-0	79.00	13.00	4.22E-01	0.09	1.59E-03	545.33	1155.48	3.00	3.00	NV	3.00	385
Chloroacetone	78-95-5	92.50	2.80	1.06E-01	0.10	1.73E-03	149.41	316.58	NV	3.80	NV	3.80	83

APPENDIX C

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Chloroacetyl chloride	79-04-9	112.94	2.50	1.16E-01	0.08	1.48E-03	139.20	294.95	NV	0.69	0.20	0.69	427
Chlorobenzene	108-90-7	112.60	1.20	5.55E-02	0.07	1.34E-03	60.41	128.01	5.99	NV	46.00	5.99	21
Chlorobromomethane	74-97-5	129.00	15.00	7.94E-01	0.08	1.48E-03	954.04	2021.50	2100.00	NV	1050.00	1050.00	2
1-Chlorobutane	109-69-3	92.57	10.80	4.10E-01	0.07	1.38E-03	459.47	973.55	NV	NV	NV	NV	N/A
2-Chlorobenzaldehyde	89-98-5	140.60	0.13	7.50E-03	0.06	1.21E-03	7.41	15.70	NV	NV	NV	NV	N/A
Chlorodiphenyl (42% free chlorine)	53469-21-9	258.00	1.30E-04	1.38E-05	0.10	1.73E-03	0.02	0.04	NV	NV	0.001	0.001	41
Chlorodiphenyl (54% free chlorine)	11097-69-1	326.00	8.00E-06	1.07E-06	0.10	1.73E-03	0.002	0.003	NV	NV	0.001	0.001	3
Chloroform	67-66-3	119.38	21.30	1.04E+00	0.09	1.62E-03	1377.47	2918.69	937.46	9.78	49.00	9.78	298
bis-Chloromethyl ether	542-88-1	115.00	4.01	1.89E-01	0.10	1.73E-03	266.02	563.67	NV	NV	0.00	0.005	119930
1-Chloro-1-nitropropane	600-25-9	123.60	0.80	4.06E-02	0.10	1.73E-03	57.04	120.86	NV	NV	10.00	10.00	12
Chloropicrin	76-06-2	164.00	2.70	1.82E-01	0.09	1.59E-03	234.57	497.03	6.48	NV	0.67	0.67	742
beta-Chloroprene	126-99-8	88.54	27.10	9.85E-01	0.10	1.73E-03	1384.16	2932.86	14.11	3.60	36.00	3.60	815
Chlorosulfonic acid	7790-94-5	116.53	0.13	6.22E-03	0.09	1.61E-03	8.12	17.20	NV	NV	NV	NV	N/A
Ortho-Chlorotoluene	95-49-8	126.58	0.48	2.49E-02	0.10	1.73E-03	35.05	74.27	1.13	375.00	250.00	1.13	66
Chromic acid	1333-82-0	100.00	0.13	5.34E-03	0.10	1.73E-03	7.50	15.89	NV	0.10	0.001	0.10	159
Chromyl chloride	14977-61-8	154.90	2.70	1.72E-01	0.10	1.73E-03	241.26	511.21	NV	NV	0.001	0.001	511209
Cresol (o, m, & p-isomers)	1319-77-3	108.15	0.04	1.78E-03	0.07	1.32E-03	1.90	4.02	0.003	NV	10.00	0.003	1516
Crotonaldehyde	4170-30-3	70.00	4.00	1.15E-01	0.08	1.49E-03	139.09	294.73	0.31	0.86	6.00	0.31	936
Cumene (isopropyl benzene)	98-82-8	120.00	1.10	5.42E-02	0.06	1.21E-03	53.27	112.87	0.16	NV	245.00	0.16	719
Cyanogen bromide	506-68-3	105.90	12.30	5.35E-01	0.07	1.37E-03	594.69	1260.08	NV	NV	NV	NV	N/A
Cyclohexane	110-82-7	84.00	10.27	3.54E-01	0.09	1.56E-03	450.05	953.60	2679.75	NV	344.00	344.00	3
Cyclohexanol	108-93-0	100.00	0.13	5.34E-03	0.06	1.29E-03	5.58	11.83	0.65	NV	200.00	0.65	18
Cyclohexanone	108-94-1	98.00	0.53	2.13E-02	0.07	1.30E-03	22.55	47.77	14.03	NV	100.00	14.03	3
Cyclohexene	110-83-8	82.15	8.93	3.01E-01	0.07	1.34E-03	327.27	693.44	0.60	NV	1010.00	0.60	1147
Cyclohexylamine	108-91-8	99.00	1.43	5.81E-02	0.10	1.73E-03	81.67	173.04	217.92	NV	40.00	40.00	4
Cyclopentadiene	542-92-7	66.10	49.00	1.33E+00	0.10	1.73E-03	1868.42	3958.95	4.87	NV	200.00	4.87	814
Cyclopentane	287-92-3	70.10	53.33	1.53E+00	0.10	1.73E-03	2156.58	4569.54	NV	NV	1720.00	1720.00	3
Cyclopentanone	120-92-3	84.12	1.52	5.25E-02	0.08	1.47E-03	62.81	133.09	NV	NV	NV	NV	N/A
Decaborane	17702-41-9	122.00	0.03	1.35E-03	0.10	1.73E-03	1.90	4.03	0.30	0.75	0.25	0.30	13
1-Decene	872-05-9	140.00	0.23	1.30E-02	0.10	1.73E-03	18.33	38.85	NV	NV	NV	NV	N/A
n-Decyl alcohol	112-30-1	158.28	0.13	8.45E-03	0.05	1.07E-03	7.37	15.62	NV	NV	NV	NV	N/A
Diacetone alcohol	123-42-2	116.00	0.11	5.24E-03	0.06	1.26E-03	5.36	11.35	1.28	NV	238.00	1.28	9
Diazinon	333-41-5	304.00	1.90E-05	2.37E-06	0.10	1.73E-03	0.003	0.01	NV	NV	0.10	0.10	none
1-2-Dibromo-3-chloropropane	96-12-8	236.40	0.11	1.07E-02	0.10	1.73E-03	15.00	31.79	0.17	NV	0.001	0.001	31785
Dibutyl phosphate	107-66-4	210.20	0.13	1.12E-02	0.10	1.73E-03	15.76	33.40	NV	10.00	5.00	10.00	3
Dibutyl phthalate	84-74-2	278.40	1.30E-07	1.49E-08	0.04	9.17E-04	1.11E-05	2.35E-05	NV	NV	5.00	5.00	none

LIQUIDS

Face Velocity	100	fpm	0.51	m/s
Total Spill Area	8.8	ft²	0.813	m²
Sing Fume Hood	1000	cfm	0.472	m3/s
Reynolds Number	30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
o-Dichlorobenzene	95-50-1	147.00	0.13	7.84E-03	0.06	1.26E-03	8.05	17.06	4.21	300.00	150.00	4.21	4
p-Dichlorobenzene	106-46-7	147.00	0.17	1.03E-02	0.06	1.26E-03	10.53	22.31	0.72	NV	60.00	0.72	31
1,1-Dichloroethylene	75-35-4	96.94	67.00	2.67E+00	0.10	1.73E-03	3746.74	7938.91	NV	NV	20.00	20.00	397
1,2-Dichloroethylene (sym)	540-59-0	96.94	24.00	9.55E-01	0.10	1.73E-03	1342.12	2843.79	25.75	NV	790.00	25.75	110
trans-1,2-Dichloroethylene	156-60-5	97.00	71.00	2.83E+00	0.10	1.73E-03	3972.89	8418.08	NV	NV	790.00	790.00	11
Dichloroethyl ether	111-44-4	143.00	0.09	5.46E-03	0.06	1.26E-03	5.60	11.88	440.91	58.00	29.00	58.00	none
1,2-Dichloroethane	107-06-2	99.00	8.80	3.58E-01	0.08	1.47E-03	427.64	906.12	105.28	8.00	4.00	8.00	113
1,1-Dichloro-1-nitroethane	594-72-9	144.00	2.00	1.18E-01	0.07	1.37E-03	131.69	279.04	NV	60.00	10.00	60.00	5
1,1-Dichloroethane	75-34-3	99.00	24.00	9.75E-01	0.08	1.47E-03	1166.30	2471.24	1044.87	NV	400.00	400.00	6
1,3-Dichloropropene	542-75-6	111.00	4.00	1.82E-01	0.10	1.73E-03	256.13	542.71	NV	NV	4.50	4.50	121
1,2-Dichloropropane	78-87-5	113.00	5.73	2.66E-01	0.10	1.73E-03	373.52	791.44	NV	508.00	347.00	508.00	2
Dichlorvos	62-73-7	221.00	0.001	1.18E-04	0.10	1.73E-03	0.17	0.35	NV	NV	0.90	0.90	none
Dicrotophos	141-66-2	237.00	1.00E-05	9.73E-07	0.10	1.73E-03	0.001	0.00	NV	NV	0.25	0.25	none
Dicyclopentadiene	77-73-6	132.21	0.19	1.01E-02	0.10	1.70E-03	14.03	29.73	0.06	NV	27.00	0.06	500
Diethylamine	109-89-7	73.00	26.00	7.79E-01	0.09	1.59E-03	1008.50	2136.88	0.16	45.00	15.00	0.16	13504
2-Diethylaminoethanol	100-37-8	117.00	0.13	6.24E-03	0.10	1.73E-03	8.77	18.59	0.05	NV	9.60	0.05	353
Diethylene glycol	111-46-6	106.12	0.001	5.66E-05	0.07	1.37E-03	0.06	0.13	NV	NV	NV	NV	N/A
Diethylene glycol monoethyl ether	111-90-0	134.00	0.02	1.03E-03	0.10	1.73E-03	1.45	3.06	3.88	NV	NV	3.88	none
Diethylene glycol monomethyl ether	111-77-3	120.00	0.02	1.18E-03	0.10	1.73E-03	1.66	3.52	NV	NV	NV	NV	N/A
Diethyl ketone	96-22-0	86.10	4.70	1.66E-01	0.10	1.73E-03	233.44	494.63	9.86	1057.00	705.00	9.86	50
Diethyl phthalate	84-66-2	222.00	2.20E-04	2.00E-05	0.10	1.73E-03	0.03	0.06	NV	NV	5.00	5.00	none
Diglycidyl ether (DGE)	2238-07-5	130.20	0.01	5.34E-04	0.10	1.73E-03	0.75	1.59	25.00	2.80	0.50	2.80	none
Diisobutyl ketone	108-83-8	142.00	0.23	1.32E-02	0.06	1.20E-03	12.85	27.23	9.30	NV	145.00	9.30	3
Diisopropylamine	108-18-9	101.19	8.00	3.32E-01	0.06	1.27E-03	342.84	726.44	0.54	NV	20.00	0.54	1350
N,N-Dimethyl acetamide	127-19-5	87.00	0.20	7.14E-03	0.07	1.42E-03	8.23	17.43	162.39	NV	35.00	35.00	none
N,N-Dimethylaniline	121-69-7	121.20	0.07	3.43E-03	0.06	1.19E-03	3.33	7.05	0.07	50.00	25.00	0.07	101
Dimethylamine (25 %)	124-40-3	45.10	17.33	3.21E-01	0.07	1.31E-03	341.42	723.42	0.06	27.60	9.20	0.06	11247
Dimethylamine (40 %)	124-40-3	45.00	28.67	5.30E-01	0.07	1.31E-03	564.17	1195.42	0.06	27.60	9.20	0.06	18626
Dimethylamine (60 %)	124-40-3	45.00	66.67	1.23E+00	0.07	1.31E-03	1311.94	2779.85	0.06	27.60	9.20	0.06	43313
n,n-Dimethyl-1,3-diaminopropane	109-55-7	102.00	0.80	3.35E-02	0.10	1.73E-03	47.07	99.74	NV	NV	NV	NV	N/A
Dimethyl disulfide	624-92-0	94.00	3.81	1.47E-01	0.10	1.73E-03	206.60	437.76	0.07	NV	NV	0.07	6633
Dimethylformamide	68-12-2	73.00	0.36	1.08E-02	0.08	1.54E-03	13.49	28.59	20.47	NV	30.00	20.47	1
1,1-Dimethylhydrazine	57-14-7	60.00	13.70	3.37E-01	0.09	1.66E-03	456.45	967.16	22.58	0.15	0.03	0.15	6448
Dimethylphthalate	131-11-3	194.00	0.001	1.04E-04	0.10	1.73E-03	0.15	0.31	NV	NV	5.00	5.00	none
Dimethylsulfate	77-78-1	126.00	0.07	3.47E-03	0.08	1.43E-03	4.02	8.52	NV	NV	0.50	0.50	17
Dimethyl sulfide	75-18-3	62.00	56.00	1.43E+00	0.10	1.73E-03	2002.88	4243.88	0.05	NV	NV	0.05	83213

APPENDIX C

LIQUIDS

Face Velocity	100	fpm	0.51	m/s
Total Spill Area	8.8	ft²	0.813	m²
Sing Fume Hood	1000	cfm	0.472	m3/s
Reynolds Number	30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Dimethyl sulfoxide	67-68-5	78.00	0.06	1.92E-03	0.10	1.73E-03	2.70	5.72	NV	NV	NV	NV	N/A
1,4-Dioxane	123-91-1	88.00	3.90	1.41E-01	0.07	1.42E-03	163.19	345.79	43.19	3.60	72.00	3.60	96
1,3-Dioxolane	646-06-0	74.00	10.53	3.20E-01	0.10	1.73E-03	449.51	952.45	122.22	NV	61.00	61.00	16
Dipropylene glycol methyl ether	34590-94-8	148.20	0.05	3.04E-03	0.10	1.73E-03	4.27	9.06	1122.50	900.00	600.00	900.00	none
Dipropyl ketone	123-19-3	114.00	0.16	7.49E-03	0.10	1.73E-03	10.52	22.30	NV	NV	233.00	233.00	none
Di-sec-octyl phthalate	117-81-7	391.00	0.00	2.09E-04	0.10	1.73E-03	0.29	0.62	NV	10.00	5.00	10.00	none
Epichlorohydrin	106-89-8	93.00	1.70	6.49E-02	0.08	1.46E-03	76.83	162.80	3.73	NV	1.90	1.90	86
Ethanolamine	141-43-5	61.00	0.05	1.33E-03	0.10	1.67E-03	1.81	3.83	7.54	15.00	6.00	7.54	none
Enflurane	13838-16-9	184.00	23.30	1.76E+00	0.10	1.73E-03	2473.15	5240.31	NV	15.10	566.00	15.10	347
2-Ethoxyethanol (EGEE)	110-80-5	90.12	0.54	2.00E-02	0.10	1.73E-03	28.07	59.48	9.95	NV	1.80	1.80	33
2-Ethoxyethylacetate	111-15-9	132.00	0.30	1.63E-02	0.06	1.23E-03	16.30	34.54	0.32	NV	2.70	0.32	107
Ethyl acetate	141-78-6	88.00	9.60	3.47E-01	0.07	1.38E-03	389.67	825.67	64.79	NV	1400.00	64.79	13
Ethyl acrylate	140-88-5	100.00	4.00	1.64E-01	0.07	1.35E-03	179.85	381.08	0.00	61.00	20.00	0.001	388223
Ethyl alcohol	64-17-5	46.00	5.90	1.11E-01	0.01	3.77E-04	34.18	72.42	338.65	NV	1880.00	338.65	none
Ethyl benzene	100-41-4	106.00	0.93	4.05E-02	0.07	1.31E-03	43.02	91.16	1.90	543.00	434.00	1.90	48
Ethyl bromide	74-96-4	109.00	50.00	2.24E+00	0.08	1.48E-03	2688.30	5696.20	890.00	NV	22.00	22.00	259
Ethyl butyl ketone	106-35-4	114.00	0.53	2.48E-02	0.06	1.22E-03	24.63	52.18	4.66	350.00	230.00	4.66	11
Ethyl ether	60-29-7	74.14	59.00	1.80E+00	0.10	1.72E-03	2515.91	5330.91	1.72	1520.00	1200.00	1.72	3093
Ethyl-3-ethoxy propionate	763-69-9	146.00	0.09	5.57E-03	0.10	1.73E-03	7.83	16.60	0.11	NV	NV	0.11	151
Ethyl formate	109-94-4	74.00	26.00	7.90E-01	0.08	1.54E-03	988.10	2093.67	57.43	NV	300.00	57.43	36
2-Ethyl hexanol	104-76-7	130.00	0.01	3.74E-04	0.10	1.73E-03	0.52	1.11	0.80	NV	NV	0.80	1
Ethyl iodide	75-03-6	155.97	18.30	1.17E+00	0.07	1.41E-03	1347.30	2854.77	NV	NV	NV	NV	N/A
Ethyl mercaptan	75-08-1	62.13	59.00	1.50E+00	0.09	1.64E-03	2010.22	4259.41	0.00	1.30	1.30	0.001	4789159
Ethyl silicate	78-10-4	208.00	0.13	1.14E-02	0.05	1.07E-03	9.87	20.91	30.63	NV	85.00	30.63	none
Ethylamine	75-04-7	45.00	48.00	8.87E-01	0.10	1.78E-03	1285.09	2722.96	0.50	27.60	9.20	0.50	5480
Ethylene chlorohydrin	107-07-3	80.50	0.67	2.21E-02	0.09	1.56E-03	28.12	59.59	1.32	3.00	16.00	1.32	45
Ethylene dibromide	106-93-4	188.00	1.50	1.16E-01	0.07	1.32E-03	123.85	262.43	76.80	1.00	0.35	1.00	263
Ethylene glycol	107-21-1	62.00	0.01	1.69E-04	0.10	1.73E-03	0.24	0.50	13.00	100.00	NV	13.00	none
Ethylene glycol dinitrate	628-96-6	152.10	0.01	5.99E-04	0.10	1.73E-03	0.84	1.78	NV	0.10	0.31	0.10	18
Ethylene glycol monobutyl ether acetate	112-07-2	160.00	0.04	2.63E-03	0.10	1.73E-03	3.69	7.82	NV	NV	33.00	33.00	none
Ethylenediamine	107-15-3	60.00	1.30	3.20E-02	0.09	1.66E-03	43.23	91.61	8.37	NV	25.00	8.37	11
Ethyleneimine	151-56-4	43.00	21.30	3.76E-01	0.11	1.83E-03	559.00	1184.46	2.05	NV	0.88	0.88	1346
Formaldehyde solution (37 %)	50-00-0	30.03	0.173	2.1E-03	0.15	2.25E-03	3.89	8.25	2.20	0.12	0.02	0.12	67
Formamide	75-12-7	45.04	0.01	2.40E-04	0.10	1.73E-03	0.34	0.72	150.00	NV	15.00	15.00	none
Formic acid	64-18-6	46.00	4.47	8.44E-02	0.13	2.07E-03	141.87	300.60	43.88	19.00	9.00	19.00	16
Furan	110-00-9	68.08	65.96	1.84E+00	0.09	1.65E-03	2477.23	5248.96	NV	NV	NV	NV	N/A

LIQUIDS

Face Velocity	100	fpm	0.51	m/s
Total Spill Area	8.8	ft²	0.813	m²
Sing Fume Hood	1000	cfm	0.472	m3/s
Reynolds Number	30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Furfural	98-01-1	96.08	0.13	5.25E-03	0.10	1.73E-03	7.37	15.62	2.80	NV	7.90	2.80	6
Furfuryl alcohol	98-00-0	98.00	0.13	5.23E-03	0.07	1.36E-03	5.80	12.28	32.07	60.00	40.00	32.07	none
Glutaraldehyde (100 %)	111-30-8	100.00	2.10	8.62E-02	0.07	1.36E-03	95.51	202.36	0.16	0.20	NV	0.16	1302
Glutaraldehyde (50 %)	111-30-8	100.00	0.002	8.21E-05	0.07	1.36E-03	0.09	0.19	0.16	0.20	NV	0.16	1
Glycerin	56-81-5	92.00	3.30E-04	1.25E-05	0.10	1.73E-03	0.02	0.04	NV	NV	5.00	5.00	none
Glycidol	556-52-5	74.00	0.12	3.65E-03	0.10	1.73E-03	5.12	10.85	NV	NV	6.10	6.10	2
Halothane	151-67-7	197.00	32.40	2.62E+00	0.10	1.73E-03	3682.03	7801.79	265.89	16.20	404.00	16.20	482
n-Heptane	142-82-5	100.00	5.30	2.18E-01	0.10	1.73E-03	305.74	647.83	940.70	1800.00	350.00	940.70	none
Hexachlorocyclopentadiene	77-47-4	273.00	0.01	1.23E-03	0.10	1.73E-03	1.73	3.67	2.22	NV	0.10	0.10	37
Hexamethyldisilazane	999-97-3	161.00	2.67	1.76E-01	0.10	1.73E-03	247.61	524.65	NV	NV	NV	NV	N/A
Hexamethylene diisocyanate	822-06-0	168.00	0.01	4.83E-04	0.10	1.73E-03	0.68	1.44	0.07	0.14	0.03	0.07	21
Hexamethylene diisocyanate biuret	4035-89-6	479.00	1.00E-05	1.97E-06	0.10	1.73E-03	0.00	0.01	NV	NV	NV	NV	N/A
1,6-Hexane diamine	124-09-4	116.00	0.40	1.90E-02	0.10	1.73E-03	26.77	56.72	NV	NV	2.30	2.30	25
n-Hexane	110-54-3	86.00	16.53	5.84E-01	0.10	1.73E-03	820.06	1737.62	446.58	NV	176.00	176.00	10
Hexanoic acid	142-62-1	116.16	0.03	1.29E-03	0.07	1.36E-03	1.43	3.03	NV	NV	NV	NV	N/A
2-Hexanone	591-78-6	100.00	1.47	6.03E-02	0.10	1.73E-03	84.80	179.68	0.31	40.00	4.00	0.31	578
sec-Hexyl acetate	108-84-9	144.00	0.40	2.36E-02	0.10	1.73E-03	33.23	70.41	2.30	NV	295.00	2.30	31
Hexylene glycol	107-41-5	118.00	0.01	3.20E-04	0.10	1.73E-03	0.45	0.95	19.00	121.00	NV	19.00	none
Hydrazine	302-01-2	32.00	1.30	1.71E-02	0.10	1.73E-03	24.00	50.85	4.84	0.04	0.01	0.04	1271
Hydrobromic acid	10035-10-6	80.91	2.10	6.97E-02	0.10	1.73E-03	98.02	207.69	6.66	9.90	10.00	6.66	31
Hydrochloric acid (10 %)	7647-01-0	36.47	0.001	7.89E-06	0.15	2.28E-03	0.01	0.03	2.39	7.00	NV	2.39	none
Hydrochloric acid (20 %)	7647-01-0	36.47	0.03	4.09E-04	0.10	1.73E-03	0.57	1.22	2.39	7.00	NV	2.39	none
Hydrochloric acid (30 %)	7647-01-0	36.47	1.41	2.12E-02	0.10	1.73E-03	29.73	63.00	2.39	7.00	NV	2.39	26
Hydrochloric acid (35 %)	7647-01-0	36.47	13.30	1.99E-01	0.10	1.73E-03	279.81	592.88	2.39	7.00	NV	2.39	248
Hydrochloric acid (40 %)	7647-01-0	36.47	53.20	7.96E-01	0.10	1.73E-03	1119.15	2371.34	2.39	7.00	NV	2.39	993
Hydrofluoric acid (46 to 53%)	7664-39-3	20.00	14.67	1.20E-01	0.21	2.86E-03	279.80	592.87	0.03	2.30	2.46	0.03	18120
Hydrogen Cyanide (liquid at <26C)	74-90-8	27.00	82.70	9.17E-01	0.17	2.49E-03	1856.28	3933.23	2.12	5.00	11.00	2.12	1854
Hydrogen peroxide (35 %)	7722-84-1	34.00	0.05	6.98E-04	0.19	2.63E-03	1.49	3.17	NV	NV	1.40	1.40	2
Hydrogen peroxide (50 %)	7722-84-1	34.00	0.05	6.98E-04	0.19	2.63E-03	1.49	3.17	NV	NV	1.40	1.40	2
Hydrogen peroxide (70 %)	7722-84-1	34.00	0.10	1.40E-03	0.19	2.63E-03	2.99	6.33	NV	NV	1.40	1.40	5
Hydrogen peroxide (90 %)	7722-84-1	34.00	0.18	2.51E-03	0.19	2.63E-03	5.38	11.39	NV	NV	1.40	1.40	8
Indene	95-13-6	116.15	0.15	7.15E-03	0.10	1.73E-03	10.05	21.30	0.02	NV	45.00	0.02	1067
Isoamyl acetate	123-92-2	130.20	0.54	2.89E-02	0.10	1.73E-03	40.56	85.94	1.17	532.00	266.00	1.17	73
Isoamyl alcohol	123-51-3	88.20	0.32	1.16E-02	0.10	1.73E-03	16.28	34.50	0.16	450.00	360.00	0.16	213
Isobutyl acetate	110-19-0	116.20	1.74	8.30E-02	0.10	1.73E-03	116.64	247.14	5.23	NV	700.00	5.23	47
Isophorone	78-59-1	138.00	0.04	2.27E-03	0.10	1.73E-03	3.18	6.75	1.07	28.00	23.00	1.07	6

APPENDIX C

LIQUIDS

Face Velocity	100	fpm	0.51	m/s
Total Spill Area	8.8	ft²	0.813	m²
Sing Fume Hood	1000	cfm	0.472	m3/s
Reynolds Number	30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Isopropyl acetate	108-21-4	102.20	6.33	2.66E-01	0.10	1.73E-03	373.19	790.75	17.14	836.00	418.00	17.14	46
Isopropyl alcohol	67-63-0	60.00	4.41	1.09E-01	0.10	1.73E-03	152.64	323.42	105.52	984.00	491.00	105.52	3
Isopropyl ether	108-20-3	102.20	15.90	6.67E-01	0.10	1.73E-03	937.40	1986.24	0.07	1300.00	1040.00	0.07	27952
Isopropyl glycidyl ether	4016-14-2	116.20	1.26	6.01E-02	0.10	1.73E-03	84.46	178.96	1440.00	240.00	238.00	240.00	none
Isopropylamine	75-31-0	59.10	61.30	1.49E+00	0.10	1.73E-03	2089.89	4428.24	0.51	24.00	12.00	0.51	8724
Iodine	7553-56-2	253.80	0.04	4.17E-03	0.10	1.73E-03	5.86	12.41	9.00	1.00	NV	1.00	12
Kerosene	8008-20-6	175.00	1.40	1.01E-01	0.10	1.73E-03	141.33	299.47	4.70	NV	100.00	4.70	64
Malathion	121-75-5	330.00	5.40E-06	7.32E-07	0.10	1.73E-03	0.001	0.002	13.50	NV	10.00	10.00	none
2-Mercaptoethanol	60-24-2	78.13	8.00	2.57E-01	0.10	1.73E-03	360.57	764.00	0.88	NV	NV	0.88	864
Mercury	7439-97-6	201.00	2.70E-05	2.23E-06	0.11	1.86E-03	0.003	0.01	NV	0.10	0.03	0.10	none
Mesityl oxide	141-79-7	98.20	1.20	4.84E-02	0.10	1.73E-03	67.98	144.04	0.07	100.00	40.00	0.07	2110
Methacrylic acid	79-41-4	86.00	0.09	3.07E-03	0.10	1.73E-03	4.32	9.15	1.90	NV	70.00	1.90	5
Methyl acetate	79-20-9	74.00	23.00	6.99E-01	0.08	1.54E-03	874.09	1852.09	544.79	757.00	606.00	544.79	3
Methyl acrylate	96-33-3	86.00	9.30	3.28E-01	0.10	1.73E-03	461.38	977.61	0.06	NV	7.00	0.06	16026
Methyl alcohol	67-56-1	32.00	13.00	1.71E-01	0.13	2.08E-03	288.77	611.87	209.41	325.00	260.00	209.41	3
Methyl n-amyl ketone	110-43-0	114.00	0.20	9.36E-03	0.10	1.73E-03	13.15	27.87	0.86	NV	233.00	0.86	32
Methyl tert-butyl ether	1634-04-4	88.00	26.80	9.68E-01	0.10	1.73E-03	1360.48	2882.71	0.19	NV	180.00	0.19	15112
Methyl cellosolve	109-86-4	76.09	0.80	2.50E-02	0.10	1.73E-03	35.12	74.40	7.47	NV	0.30	0.30	248
Methyl cellosolve acetate	110-49-6	118.13	0.30	1.45E-02	0.10	1.73E-03	20.44	43.32	1.59	NV	0.50	0.50	87
Methyl ethyl ketone	78-93-3	72.00	10.40	3.07E-01	0.10	1.73E-03	431.96	915.27	47.12	885.00	590.00	47.12	19
N-Methyl aniline	100-61-8	107.15	0.04	1.76E-03	0.10	1.73E-03	2.47	5.24	7.84	NV	2.00	2.00	3
Methyl formate	107-31-3	60.00	64.00	1.58E+00	0.09	1.58E-03	2021.86	4284.09	4907.98	368.00	246.00	368.00	12
5-Methyl-2-hexanone (methy isoamyl ketone)	110-12-3	114.00	0.67	3.14E-02	0.10	1.73E-03	44.06	93.36	0.63	NV	234.00	0.63	148
Methyl iodide	74-88-4	142.00	53.20	3.10E+00	0.10	1.73E-03	4357.89	9233.85	NV	NV	10.00	10.00	923
Methyl isobutyl carbinol	108-11-2	102.18	0.37	1.55E-02	0.10	1.73E-03	21.81	46.21	20.40	165.00	100.00	20.40	2
Methyl isobutyl ketone (MIBK)	108-10-1	100.00	0.80	3.28E-02	0.06	1.29E-03	34.37	72.82	3.60	300.00	205.00	3.60	20
Methyl isocyanate	624-83-9	57.05	46.00	1.08E+00	0.10	1.73E-03	1513.87	3207.72	4.90	NV	0.05	0.05	68249
Methyl methacrylate	80-62-6	100.13	3.87	1.59E-01	0.07	1.35E-03	174.21	369.14	0.20	410.00	205.00	0.20	1840
Methyl propyl ketone	107-87-9	86.17	3.60	1.27E-01	0.10	1.73E-03	178.95	379.18	27.14	881.00	530.00	27.14	14
n-Methyl-2-pyrrolidinone	872-50-4	99.15	0.04	1.59E-03	0.10	1.73E-03	2.23	4.73	41.00	NV	NV	41.00	none
Methyl salicylate	119-36-8	152.00	0.01	8.11E-04	0.10	1.73E-03	1.14	2.42	0.74	NV	NV	0.74	3
Methylcyclohexane	108-87-2	98.00	4.90	1.97E-01	0.10	1.73E-03	277.01	586.96	2000.00	NV	NV	2000.00	none
Methylcyclohexanol	25639-42-3	114.20	0.27	1.27E-02	0.10	1.73E-03	17.79	37.69	2350.00	NV	NV	2350.00	none
o-Methylcyclohexanone	583-60-8	112.20	0.13	5.99E-03	0.10	1.73E-03	8.41	17.83	NV	NV	NV	NV	N/A
Methylcyclopentadienyl manganese tricarbonyl	12108-13-3	218.00	0.01	6.00E-04	0.10	1.73E-03	0.84	1.79	NV	NV	0.20	0.20	9
Methylacrylonitrile	126-98-7	67.09	9.00	2.48E-01	0.10	1.73E-03	348.32	738.05	15.87	NV	2.70	2.70	273

LIQUIDS

Face Velocity	100	fpm	0.51	m/s
Total Spill Area	8.8	ft²	0.813	m²
Sing Fume Hood	1000	cfm	0.472	m3/s
Reynolds Number	30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Methylal	109-87-5	76.10	44.10	1.38E+00	0.10	1.73E-03	1935.97	4102.10	NV	NV	3100.00	3100.00	1
Methylene bisphenyl isocyanate	101-68-8	250.00	1.86E-05	1.91E-06	0.10	1.73E-03	0.003	0.01	3.99	0.20	0.05	0.20	none
Methylene chloride	75-09-2	85.00	53.00	1.85E+00	0.10	1.73E-03	2598.79	5506.53	556.24	435.00	87.00	435.00	13
Methylene iodide	75-11-6	268.00	0.09	9.98E-03	0.10	1.73E-03	14.02	29.71	NV	NV	10.00	10.00	3
N-Methylimidazole	616-47-7	82.11	0.05	1.80E-03	0.10	1.73E-03	2.52	5.35	NV	NV	NV	NV	N/A
N-Methylmorpholine	109-02-4	101.00	0.67	2.76E-02	0.10	1.73E-03	38.84	82.29	NV	NV	NV	NV	N/A
alpha-Methyl styrene	98-83-9	118.20	0.31	1.49E-02	0.10	1.73E-03	20.93	44.35	15.48	480.00	240.00	15.48	3
Methylamine (40 %)	74-89-5	31.00	31.50	4.01E-01	0.10	1.73E-03	563.31	1193.59	5.96	19.00	6.40	5.96	200
Morpholine	110-91-8	87.12	0.90	3.22E-02	0.10	1.73E-03	45.23	95.84	0.04	105.00	70.00	0.04	2445
Naphtha (coal tar)	8030-30-6	110.00	3.47	1.57E-01	0.10	1.73E-03	219.94	466.02	420.00	NV	400.00	400.00	1
Naphthalene	91-20-3	128.00	0.01	3.78E-04	0.10	1.73E-03	0.53	1.13	0.20	75.00	50.00	0.20	6
1-Naphthol	90-15-3	144.00	0.13	7.86E-03	0.10	1.73E-03	11.05	23.41	NV	NV	NV	NV	N/A
Nickel carbonyl	13463-39-3	171.00	43.00	3.02E+00	0.10	1.73E-03	4241.71	8987.68	8.57	NV	0.01	0.01	1283954
Nicotine	54-11-5	162.00	0.01	3.79E-04	0.10	1.73E-03	0.53	1.13	NV	NV	0.50	0.50	2
Nitric acid (70 %)	7697-37-2	63.02	0.73	1.89E-02	0.13	2.07E-03	31.77	67.31	0.70	10.00	5.00	0.70	97
Nitric acid (90 %)	7697-37-2	63.02	6.39	1.65E-01	0.13	2.07E-03	278.06	589.17	0.70	10.00	5.00	0.70	847
Nitrobenzene	98-95-3	123.11	0.02	1.01E-03	0.10	1.73E-03	1.42	3.01	1.86	NV	5.00	1.86	2
Nitroethane	79-24-3	75.00	2.08	6.40E-02	0.10	1.73E-03	89.99	190.68	620.00	NV	307.00	307.00	none
Nitroglycerin	55-63-0	227.00	3.46E-05	3.22E-06	0.10	1.73E-03	0.00	0.01	NV	0.10	0.46	0.10	none
Nitromethane	75-52-5	61.00	3.70	9.26E-02	0.10	1.73E-03	130.20	275.88	124.00	NV	50.00	50.00	6
1-Nitropropane	108-03-2	89.09	1.01	3.69E-02	0.10	1.73E-03	51.91	109.98	510.13	NV	90.00	90.00	1
2-Nitropropane	79-46-9	89.09	1.74	6.36E-02	0.10	1.73E-03	89.42	189.48	556.53	NV	36.00	36.00	5
Nitrotoluene (m isomers)	99-08-1	137.10	0.01	7.32E-04	0.10	1.73E-03	1.03	2.18	0.10	NV	11.00	0.10	23
Nitrotoluene (o isomers)	88-72-2	137.00	0.01	8.27E-04	0.10	1.73E-03	1.16	2.46	0.10	NV	11.00	0.10	26
Nitrotoluene (p isomers)	99-99-0	137.00	0.01	7.31E-04	0.10	1.73E-03	1.03	2.18	0.10	NV	11.00	0.10	23
Octane	111-65-9	114.22	1.39	6.52E-02	0.05	1.10E-03	58.46	123.88	700.74	1800.00	350.00	700.74	none
1-Octanol	111-87-5	130.20	0.01	4.65E-04	0.05	1.16E-03	0.44	0.93	0.69	NV	NV	0.69	1
2-Octanol	123-96-6	130.20	0.13	7.12E-03	0.05	1.16E-03	6.71	14.21	NV	NV	NV	NV	N/A
Oleic Acid	112-80-1	282.47	7.28E-08	8.44E-09	0.07	1.34E-03	0.00	0.00	44.00	NV	NV	44.00	none
Osmium tetroxide	20816-12-0	254.00	0.93	9.70E-02	0.10	1.73E-03	136.27	288.74	0.02	0.005	0.002	0.005	61433
Oxalic acid	144-62-7	126.00	1.30E-04	6.72E-06	0.10	1.73E-03	0.01	0.02	NV	2.00	1.00	2.00	none
Oxo-heptyl acetate	90438-79-2	158.00	0.11	6.92E-03	0.10	1.73E-03	9.73	20.61	NV	NV	NV	NV	N/A
Oxo-hexyl acetate	88230-35-7	144.00	0.19	1.10E-02	0.10	1.73E-03	15.51	32.86	0.93	NV	NV	0.93	35
Pentaborane	19624-22-7	63.17	23.00	5.96E-01	0.10	1.73E-03	838.14	1775.91	2.51	0.03	0.01	0.03	59197
Pentachlorophenol	87-86-5	266.00	1.50E-05	1.64E-06	0.10	1.73E-03	0.002	0.005	NV	NV	0.50	0.50	none
Pentane	109-66-0	72.00	65.00	1.92E+00	0.10	1.73E-03	2699.74	5720.43	1087.95	1800.00	350.00	1087.95	5

APPENDIX C

LIQUIDS

Face Velocity	100	fpm	0.51	m/s
Total Spill Area	8.8	ft²	0.813	m²
Sing Fume Hood	1000	cfm	0.472	m3/s
Reynolds Number	30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odor Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odor
2-Pentanol	6032-29-7	88.20	1.33	4.82E-02	0.07	1.35E-03	52.94	112.17	NV	NV	NV	NV	N/A
3-Pentanol	584-02-1	88.20	0.27	9.67E-03	0.07	1.35E-03	10.63	22.52	NV	NV	NV	NV	N/A
Pentyl mercaptan	110-66-7	104.20	18.40	7.87E-01	0.10	1.73E-03	1106.02	2343.52	NV	2.10	NV	2.10	1116
Perchloromethyl mercaptan	594-42-3	186.00	8.70	6.64E-01	0.10	1.73E-03	933.49	1977.95	0.01	NV	0.76	0.01	263727
Phenol	108-95-2	94.00	0.05	1.93E-03	0.07	1.40E-03	2.20	4.66	0.23	60.00	19.00	0.23	20
Phenyl ether	101-84-8	170.20	0.003	1.89E-04	0.05	1.09E-03	0.17	0.35	0.07	14.00	7.00	0.07	5
Phenyl glycidyl ether	122-60-1	150.00	0.001	6.16E-05	0.10	1.73E-03	0.09	0.18	NV	6.00	0.60	6.00	none
Phenyl isocyanate	103-71-9	119.12	0.20	9.78E-03	0.08	1.44E-03	11.41	24.18	NV	NV	NV	NV	N/A
Phenylhydrazine	100-63-0	108.00	0.01	2.22E-04	0.10	1.73E-03	0.31	0.66	NV	0.60	0.44	0.60	1
Phosphoric acid (75 %)	7664-38-2	98.00	0.75	3.02E-02	0.10	1.72E-03	42.12	89.24	NV	3.00	1.00	3.00	30
Phosphoric acid (85 %)	7664-38-2	98.00	0.29	1.17E-02	0.10	1.72E-03	16.32	34.59	NV	3.00	1.00	3.00	12
Phosphorus oxychloride	10025-87-3	153.30	5.32	3.35E-01	0.10	1.73E-03	470.47	996.87	NV	3.00	0.60	3.00	332
Phosphorus trichloride	7719-12-2	137.00	13.00	7.31E-01	0.10	1.73E-03	1027.40	2176.94	NV	2.80	1.10	2.80	777
Phthalic acid	88-99-3	166.14	0.13	8.87E-03	0.06	1.18E-03	8.49	17.99	NV	NV	NV	NV	N/A
Piperidine	110-89-4	85.00	5.30	1.85E-01	0.10	1.73E-03	259.88	550.65	1.29	NV	NV	1.29	426
Potassium Hydroxide	1310-58-3	56.00	0.27	6.21E-03	0.10	1.73E-03	8.72	18.48	NV	2.00	2.00	2.00	9
Propargyl alcohol	107-19-7	56.00	1.55	3.56E-02	0.10	1.73E-03	50.07	106.10	0.03	NV	2.00	0.03	3088
Propionaldehyde	123-38-6	58.08	29.00	6.91E-01	0.09	1.62E-03	911.22	1930.78	0.21	NV	48.00	0.21	9194
beta-Propiolacetone	57-57-8	72.10	0.31	9.09E-03	0.10	1.73E-03	12.77	27.06	NV	NV	1.50	1.50	18
Propionic acid	79-09-4	74.10	0.40	1.22E-02	0.08	1.55E-03	15.32	32.46	0.20	45.00	30.00	0.20	162
n-Propyl acetate	109-60-4	102.13	3.30	1.38E-01	0.07	1.32E-03	148.87	315.43	0.75	1040.00	835.00	0.75	420
n-Propyl alcohol	71-23-8	60.09	2.00	4.93E-02	0.09	1.55E-03	62.21	131.81	13.03	614.00	492.00	13.03	10
n-Propyl nitrate	627-13-4	105.00	2.40	1.03E-01	0.10	1.73E-03	145.37	308.02	210.00	170.00	105.00	170.00	2
Propylene Dichloride	78-87-5	113.00	5.73	2.66E-01	0.10	1.73E-03	373.52	791.44	1.20	508.00	347.00	1.20	659
Propylene glycol	57-55-6	76.10	0.13	4.17E-03	0.08	1.52E-03	5.16	10.92	16.00	NV	NV	16.00	none
Propylene glycol 1-methyl ether	107-98-2	90.00	1.60	5.91E-02	0.10	1.73E-03	83.07	176.01	121.00	540.00	360.00	121.00	1
Propylene glycol-1-methyl ether-2-acetate	108-65-6	132.00	0.50	2.71E-02	0.10	1.73E-03	38.07	80.67	0.70	NV	NV	0.70	115
Propylene imine	75-55-8	57.10	15.00	3.52E-01	0.10	1.73E-03	494.09	1046.91	NV	NV	4.70	4.70	223
Propylene oxide	75-56-9	58.00	59.00	1.40E+00	0.10	1.73E-03	1974.04	4182.76	106.75	NV	4.80	4.80	871
Pyridine	110-86-1	79.10	2.40	7.79E-02	0.10	1.73E-03	109.51	232.04	2.14	NV	15.00	2.14	109
Quinone	106-51-4	108.00	0.02	9.75E-04	0.10	1.73E-03	1.37	2.90	0.40	NV	0.40	0.40	7
Sodium Hydroxide (50%)	1310-73-2	40.01	0.20	3.28E-03	0.10	1.73E-03	4.62	9.78	NV	NV	2.00	2.00	5
Stoddard solvent (Mineral spirits)	8052-41-3	144.00	0.53	3.13E-02	0.10	1.73E-03	44.03	93.29	28.76	1800.00	350.00	28.76	3
Styrene, monomer	100-42-5	104.00	0.57	2.43E-02	0.10	1.73E-03	34.20	72.46	0.60	170.00	85.00	0.60	122
Sulfamic acid	5329-14-6	97.10	0.01	5.18E-04	0.09	1.57E-03	0.66	1.40	NV	NV	NV	NV	N/A
Sulfur monochloride	10025-67-9	135.00	0.90	4.99E-02	0.10	1.73E-03	70.09	148.51	0.01	5.50	6.00	0.01	26897

APPENDIX C

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Sulfur pentafluoride	5714-22-7	254.10	75.10	7.83E+00	0.10	1.73E-03	11008.31	23325.31	NV	0.10	0.25	0.10	233253
Sulfuric acid (100 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (98 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (93 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (78 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
1,1,2,2-Tetrachloroethane	79-34-5	167.90	0.67	4.62E-02	0.10	1.73E-03	64.89	137.50	50.13	NV	6.90	6.90	20
Tetrachloroethylene	127-18-4	166.00	1.87	1.27E-01	0.10	1.73E-03	179.07	379.43	319.10	685.00	170.00	319.10	1
Tetraethyl lead	78-00-2	323.00	0.02	2.65E-03	0.10	1.73E-03	3.73	7.90	NV	NV	0.08	0.08	105
Tetrahydrofuran	109-99-9	72.10	19.00	5.62E-01	0.10	1.73E-03	790.25	1674.45	91.42	735.00	590.00	91.42	18
Tetramethyl lead	75-74-1	267.30	3.30	3.62E-01	0.10	1.73E-03	508.85	1078.19	NV	NV	0.08	0.08	14376
Tetranitromethane	509-14-8	196.00	1.10	8.85E-02	0.10	1.73E-03	124.37	263.53	NV	NV	0.04	0.04	6588
Thioglycolic acid	68-11-1	92.10	1.33	5.03E-02	0.10	1.73E-03	70.66	149.72	NV	NV	3.80	3.80	39
Thionyl chloride	7719-09-7	118.90	13.30	6.49E-01	0.09	1.56E-03	822.00	1741.73	NV	4.90	NV	4.90	355
Toluene	108-88-3	92.00	2.90	1.10E-01	0.08	1.44E-03	128.18	271.59	6.02	560.00	188.00	6.02	45
Toluene-2,4-diisocyanate	584-84-9	174.00	0.003	2.36E-04	0.10	1.73E-03	0.33	0.70	7.40	0.14	0.04	0.14	5
m-Toluidine	108-44-1	107.20	0.13	5.85E-03	0.10	1.73E-03	8.22	17.43	7.22	NV	8.80	7.22	2
o-Toluidine	95-53-4	107.20	0.04	1.76E-03	0.10	1.73E-03	2.47	5.24	1.78	NV	8.80	1.78	3
Tributyl phosphate	126-73-8	266.30	0.001	5.79E-05	0.10	1.73E-03	0.08	0.17	NV	NV	2.20	2.20	none
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	187.40	37.80	2.91E+00	0.10	1.73E-03	4086.37	8658.53	592.36	9500.00	7600.00	592.36	15
1,2,4-Trichlorobenzene	120-82-1	181.46	0.13	9.91E-03	0.10	1.73E-03	13.92	29.50	21.97	37.00	NV	21.97	1
1,1,1-Trichloroethane	71-55-6	133.42	17.00	9.31E-01	0.10	1.73E-03	1308.42	2772.38	2128.17	1910.00	1900.00	1910.00	1
1,1,2-Trichloroethane	79-00-5	133.00	2.53	1.38E-01	0.10	1.73E-03	194.11	411.30	NV	NV	45.00	45.00	9
Trichloroethylene	79-01-6	131.40	7.70	4.15E-01	0.07	1.38E-03	466.65	988.78	440.69	11.00	134.00	11.00	90
Trichlorofluoromethane	75-69-4	137.00	92.00	5.17E+00	0.10	1.73E-03	7270.84	15406.05	181.03	5600.00	5600.00	181.03	85
1,2,3-Trichloropropane	96-18-4	147.40	0.40	2.42E-02	0.10	1.73E-03	34.01	72.07	40.31	NV	60.00	40.31	2
Triethanolamine	102-71-6	149.00	0.005	2.87E-04	0.10	1.73E-03	0.40	0.86	61.00	NV	5.00	5.00	none
Triethylamine	121-44-8	101.00	7.20	2.99E-01	0.08	1.51E-03	365.54	774.54	1.03	12.40	4.10	1.03	750
Triethylene glycol	112-27-6	150.20	0.0001	8.02E-06	0.08	1.47E-03	0.01	0.02	NV	NV	NV	NV	N/A
Trifluoroacetic acid	76-05-1	114.00	14.30	6.69E-01	0.08	1.49E-03	812.45	1721.48	NV	NV	NV	NV	N/A
Trimethylamine (40 %)	75-50-3	59.00	67.30	1.63E+00	0.10	1.73E-03	2290.57	4853.44	0.01	36.00	12.00	0.01	822618
1,2,4-Trimethylbenzene (as mixed isomers)	95-63-6	120.00	0.13	6.55E-03	0.10	1.73E-03	9.21	19.51	11.78	NV	123.00	11.78	2
2,2,4-Trimethylpentane	540-84-1	114.30	5.50	2.58E-01	0.08	1.49E-03	313.25	663.73	NV	1800.00	350.00	1800.00	none
2,4,6-Trimethylpyridine	108-75-8	121.20	0.27	1.33E-02	0.08	1.49E-03	16.06	34.03	NV	NV	NV	NV	N/A
Turpentine	8006-64-2	136.00	0.70	3.91E-02	0.10	1.73E-03	54.92	116.36	791.96	NV	556.00	556.00	none
n-Valeraldehyde	110-62-3	86.00	6.70	2.37E-01	0.10	1.73E-03	332.39	704.30	0.25	NV	175.00	0.25	2855
Vinyl acetate	108-05-4	86.00	11.10	3.92E-01	0.10	1.73E-03	550.68	1166.82	0.42	15.00	35.00	0.42	2764

APPENDIX C

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health / Odor
Vinyl toluene	25013-15-4	118.00	0.15	7.12E-03	0.10	1.73E-03	10.01	21.20	240.00	483.00	242.00	240.00	none
Xylene (o,m, p-isomers)	1330-20-7	106.16	0.87	3.79E-02	0.10	1.73E-03	53.28	112.89	86.84	651.00	434.00	86.84	1
Xylidine	1300-73-8	121.20	20.00	9.95E-01	0.10	1.73E-03	1398.33	2962.89	0.08	NV	2.50	0.08	35160

All chemical properties can be referenced to Canadian Centre for Occupational Health and Safety www.ccohs.ca

TWA is typically for an 8-hour averaging period.
STEL is typically for a 15-minute averaging period.
Ceiling limit (C) was used if there was no STEL.
NV indicates no value for air quality or odor standards
N/A indicates required dilution is not applicable.
"none" indicates criterion met at the source (i.e., no dilution required).

References for Odor Thresholds:

1) AIHA, 1989. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.
2) Nagy, G.Z., 1991. The odor impact model. Journal of the Air Waste Management Association, p. 1360-1362.
3) Ruth, J.H., 1986. Odor thresholds and irritation levels of several chemicals: a review. Journal of the American Industrial Hygienists Association, 47:A-142-A-151.
4) 3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.

Maximum Required Dilution is based on:
1) Minimum of STEL or C of ACGIH, OSHA, and NIOSH limits(short-term health);
2) Minimum of TWA of ACGIH, OSHA, and NIOSH limits(long-term health);
3) Odor threshold based on priority of resource used.
The minimum value out of the health and the odor values was used with the short term health limit taking precedence over the long-term health limit.

EXHAUST DISPERSION & DESIGN
125 CAMBRIDGEPARK DRIVE

RWDI #2100989
November 12, 2021

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