



Airflow Testing Report

Prepared for

Portland Public Schools

August 2021





9700 SW Capitol Hwy, Suite 110
Portland, OR 97219
ameresco.com

PROJECT OVERVIEW

As part of the continuing process to ensure a safe return to in-person learning, Portland Public Schools has contracted with Ameresco to test the airflow and ventilation of all educational and office spaces in each school. The data is reviewed by both Ameresco and PPS personnel to identify any potential shortcomings in the airflow from the HVAC systems. To accomplish this task, Ameresco has partnered with a local NEBB certified Test-Adjust-Balance (TAB) firm, Neudorfer Engineers, who will measure the airflow to each zone with calibrated measurement equipment in accordance with current testing standards and procedures. As part of this effort, HVAC professionals will review the operation of the HVAC equipment serving every educational and office space in each school.

Ameresco is pleased to have partnered with PPS over the last decade as the district's Energy Services Company (ESCO) on six energy efficiency construction projects, four service projects, and numerous energy audits. Our partnership has resulted in reducing over 3,000 tons of CO₂ and other GHG emissions and over \$1,000,000 in utility cost savings per year. Ameresco appreciates this opportunity to play a small role in the safe reopening of schools.

About Ameresco, Inc.

Founded in 2000, Ameresco, Inc. (NYSE:AMRC) is a leading cleantech integrator and renewable energy asset developer, owner and operator. Our comprehensive portfolio includes energy efficiency, infrastructure upgrades, asset sustainability and renewable energy solutions delivered to clients throughout North America and the United Kingdom. Ameresco's sustainability services in support of clients' pursuit of Net Zero include upgrades to a facility's energy infrastructure and the development, construction, and operation of distributed energy resources. Ameresco has successfully completed energy saving, environmentally responsible projects with Federal, state and local governments, healthcare and educational institutions, housing authorities, and commercial and industrial customers. With its corporate headquarters in Framingham, MA, Ameresco has more than 1,000 employees providing local expertise in the United States, Canada, and the United Kingdom. For more information, visit www.ameresco.com.

Explanation of ASHRAE Total Effective Air Changes per Hour (ACH_e) Calculation

ASHRAE has been updating their Building Readiness document to reflect the most current understanding in the engineering community for how to operate and maintain buildings during the pandemic. Their update on 4/27/2021 provided an explanation of the impact air filters and air cleaning devices have on the air in buildings. They provided the methodology, formulas, and an Excel-based tool for determining the equivalent outside air a space is receiving by having a mix of outside air, filtered recirculated air, and additional air filtration or cleaning devices in the room. Here is the explanation from ASHRAE:

Epidemic Conditions in Place



Equivalent Outdoor Air:

The equivalent outdoor air calculation indicates that the outdoor air can be calculated by using the combination of the actual outdoor air, impact of filtration or air cleaning technologies on recirculated air, and the impact of air cleaning technologies in the space.

This is using the principal of filters in series and the effectiveness at reducing particles. For items in series, the initial item would see the recirculated airflow to clean. The second item in the series would see the “cleaned” air from Item 1 and so the impact of Item 1 must be accounted for in Item 2.

As part of the airflow testing project that Portland Public Schools has partnered with Ameresco to complete, we are including the calculation of the Total Effective Air Changes per Hour (ACH_e) to show the impact of the air filtration that is active in nearly all spaces in the PPS schools. The formula for doing so is:

$$ACH_e = (ACH_{oa} + ACH_f) * E_z + ACH_{ir}$$

where:

- ACH_{oa} = air changes per hour of outside air = outside airflow in cubic feet per minute * 60 minutes per hour / room volume in cubic feet
- ACH_f = air changes per hour of clean air from filtered recirculated air with filters of the specified MERV rating as determined by ASHRAE
- E_z = Zone Air Distribution Effectiveness = how effective the HVAC system is at circulating and mixing the air to distribute the clean air throughout the room
- ACH_{ir} = the air changes per hour of clean air from portable air filters in the room = number of filters * CADR * 60 minutes per hour / room volume in cubic feet
 - CADR = Clear Air Delivery Rate = the CFM of clean air as specified by the manufacturer of the air filter

In order to include these calculations in the airflow testing reports, Ameresco and PPS have made the following assumptions as not all the variables are known:

1. PPS is in process of upgrading the air filters in their HVAC systems to MERV 13 and plans to be complete with that project for the start of the '21-'22 school year. In this report and for the sake of the ACH_e calculation, we are using the filters that are in place at the time of the measurements, so some of them are still MERV 8.
2. ASHRAE has guidelines for what should be used for the Zone Air Distribution Effectiveness (E_z) based on the HVAC system configuration, but they do not provide a value for every HVAC system and room configuration. For the majority of PPS rooms, an E_z of 0.8 – 1.0 would be most appropriate, so we have made the conservative assumption of using 0.8 for every space as that yields the lower ACH_e.
3. The CADR for a given air filter is from manufacturer ratings and is based on certain conditions (fan speed, particulate size, filter cleanliness, etc.) that change with operating conditions.



NEUDORFER ENGINEERS INC.

**TEST REPORT TYPE:
SURVEY REPORT**

**Portland Public Schools Airflow Testing
Laurelhurst K-8
840 NE 41st Ave, Portland, OR 97232**

Job Number: 2021-0297

Project Completion Date: 09/02/21

Revision Date:

-

Revision Number:

-



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Neudorfer Engineers, Inc.

Consulting Engineers Seattle, Washington - Portland, Oregon



www.NeudorferEngineers.com

**Portland Public Schools Airflow Testing
Laurelhurst K-8**

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Neudorfer Engineers, Inc.

Consulting Engineers Seattle, Washington - Portland, Oregon



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REPORT TITLE

CERTIFIED TEST: SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Laurelhurst K-8

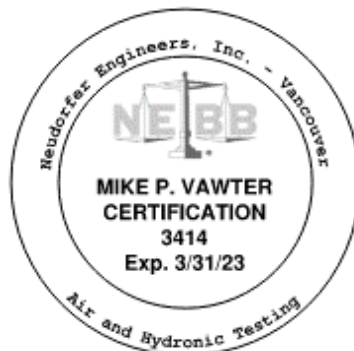
NEI Job#: 2021-0297

Mechanical Engineer: NA

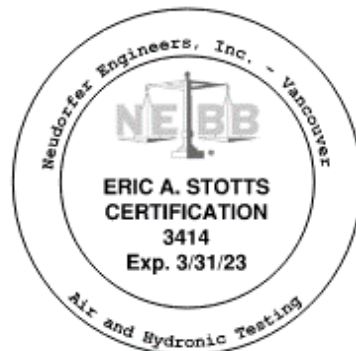
Architect: NA

HVAC Contractor: NA

TAB Firm: Neudorfer Engineers Inc
Test Engineer: Zach Mayer



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CERTIFICATION

Portland Public Schools Airflow Testing

The data presented in this report is a record of system measurements and final adjustments that have been obtained in accordance with the current edition of the NEBB Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems. Any variances from design quantities, which exceed NEBB tolerances, are noted in the Test-Adjust-Balance Report Project Summary.

Significant / Noteworthy Remarks are noted on the General Remarks and General Field Notes pages. Other remarks are noted on individual test sheets.

Noted deficiencies are not the TAB firms responsibility to repair. Prior to issuance of this report, Deficiency Reports are forwarded to our contracted agent.

Warranty is limited to one year from date of this report. Within that time, any discrepancies, ambiguities, or omissions found in this report will be retested, adjusted, or balanced as needed. A written notification will be required.

Submitted and Certified by:

NEBB TAB Firm: **Neudorfer Engineers Inc**

Certification No: **3414**

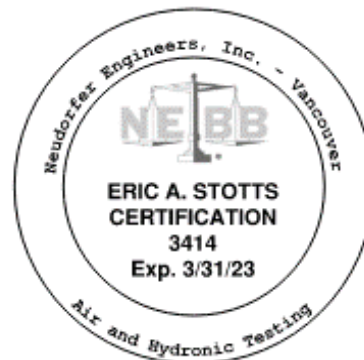
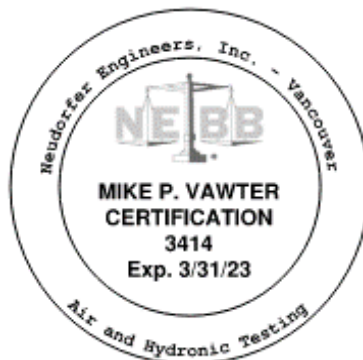
Expiration Date: **March 31, 2023**

Certification Date: **March 31, 2021**

(Date completed) **Signed and Sealed by:**

NEBB Supervisor: **Mike Vawter P.E.**

NEBB Supervisor: **Eric Stotts**





Neudorfer Engineers, Inc.

Consulting Engineers Seattle, Washington - Portland, Oregon



www.NeudorferEngineers.com

TERMS AND ABBREVIATIONS

Project: Portland Public Schools Airflow Testing

AC or ACU Air Conditioner or Air Conditioning Unit

AH or AHU Air Handler or Air Handling Unit

AVG Average

BHP Brake Horsepower

CAV Constant Air Volume

CBV Calibrated Balancing Valve
(Circuit Setter)

CC Cooling Coil

CD Ceiling Diffuser

CFM Cubic Feet per Minute

CH Chiller

CHWS Chilled Water Supply

CHWR Chilled Water Return

CP Circulating Pump

CR Ceiling Register

CRAC Computer Room Air Conditioner

CRU Computer Room Unit

CT Cooling Tower

CU Condenser Unit

CUH Cabinet Unit Heater

CWS Condenser Water Supply

CWR Condenser Water Return

DAT Discharge Air Temperature

DB Dry Bulb

DD Direct Drive

DDC Direct Digital Controls: EMS Control
System for the HVAC

Des. Design

Dia. Diameter

Disch. Discharge

EA Exhaust Air

EAT Entering Air Temperature

Economizer Controls and components that allow an air handler to logically utilize outdoor air for cooling as opposed to the use of mechanical cooling.

EF Exhaust Fan

EG Exhaust Grille

EMCS Energy Management Control System

ERU Energy Recovery Unit

E.S.P. External Static Pressure

HRC Heat Recovery Coil

EWT Entering Water Temperature

FCU Fan Coil Unit

FD Fire Damper

FLA Full Load Amperage: Maximum
amperage a motor can draw.

Flow Hood Instrument that captures air and
converts the reading to CFM.

FHT Fume Hood Test

FPB Fan Powered Box

FPM Feet per Minute

FR Field Report

FT Foot, Feet

FTU Fan Terminal Unit

GPM Gallons per Minute

HC Heating Coil

TDH Pressure Difference across the entering
and leaving side of a pump.

HEPA High Efficiency Particulate Arrestance

HP Horsepower

HVAC Heating Ventilation and Air Conditioning

HWS Heating Water Supply

HWR Heating Water Return

HX Heat Exchanger

HZ Hertz, cycle per second

in. inches

in.w.g. inches of water gauge

Kfactor Correction factor to the free area need to
calculate CFM.

KW Kilowatts

LAT Leaving Air Temperature

LWG Low Wall Grille

LWR Low Wall Register

LWT Leaving Water Temperature

MAU Make-up Air Hanging Unit

MBH 1,000 BTUH

N/A Not Applicable

OSA Outside Air

OBD Opposed Blade Damper

ΔP Pressure Drop.

PH Phase

PSI Pounds per Square Inch

RA Return Air

RAD Radiator

RAT Return Air Temperature

RF Return Fan

RH Relative Humidity

RHC Reheat Coil

RPM Revolutions per Minute

RTU Roof Top Unit

SA Supply Air

SAT Supply Air Temperature

S.F. Service Factor

SF Supply Fan

SFD Smoke/Fire Damper

SP Static Pressure

sq.ft. square feet

Suct. Suction

SWG Sidewall Grille

SWR Sidewall Register

TAB Test; Adjust; and Balance

TSP Total Static Pressure: Difference
between the entering and leaving
static pressure of a fan.

UH Unit Heater

VAV Variable Air Volume; box that
contains a motorized damper that
modulates airflow.

VD Volume Damper

VFD Variable Frequency Drive

Velgrid Instrument that reads used to read
velocity in feet per minute.

VVT Variable Volume Terminal

WC Water Column

W.G. Water Gauge

WB Wet Bulb

INSTRUMENT CALIBRATIONS

Portland Public Schools Airflow Testing

Instrument Type	Air Data Meter with Flowhood	Instrument Serial #	M00475
Instrument Manufacturer	Shortridge	Calibration Date	11/4/2020
Instrument Model Number	ADM 870	Calibration Due	11/4/2021
Instrument Type	Differential Pressure Water Meter	Instrument Serial #	W14090
Instrument Manufacturer	Shortridge	Calibration Date	10/16/2020
Instrument Model Number	HDM-250	Calibration Due	10/16/2021
Instrument Type	Psychrometer	Instrument Serial #	8084305
Instrument Manufacturer	Extech	Calibration Date	10/13/2020
Instrument Model Number	RH390	Calibration Due	10/13/2021
Instrument Type	Tachometer	Instrument Serial #	B185B5022P
Instrument Manufacturer	Nidec	Calibration Date	10/11/2020
Instrument Model Number	MT-200	Calibration Due	10/11/2021
Instrument Type	Amp Probe	Instrument Serial #	33380179WS
Instrument Manufacturer	Fluke	Calibration Date	10/9/2020
Instrument Model Number	323 Clamp Meter	Calibration Due	10/9/2021
Instrument Type	Digital Thermometer	Instrument Serial #	45400509WS
Instrument Manufacturer	Fluke	Calibration Date	10/9/2020
Instrument Model Number	52 II	Calibration Due	10/9/2021
Instrument Type	Manometer	Instrument Serial #	M00475
Instrument Manufacturer	Shortridge	Calibration Date	11/4/2020
Instrument Model Number	ADM 870	Calibration Due	11/4/2021
Instrument Type	Thermal Anemometer	Instrument Serial #	AVM440742003
Instrument Manufacturer	Alnor Instruments	Calibration Date	11/9/2020
Instrument Model Number	AVM 440	Calibration Due	11/9/2021
Instrument Type	Ultrasonic Flow Meter	Instrument Serial #	N5K1435T
Instrument Manufacturer	Fuji	Calibration Date	10/14/2020
Instrument Model Number	Portaflow-C	Calibration Due	10/14/2021



PROJECT	Portland Public Schools Airflow Testing
LOCATION	Laurelhurst K-8; 840 NE 41st Ave, Portland, OR 97232

REPORT SUMMARY

This project has been surveyed per plans and specifications using the National Environmental Balancing Bureau (NEBB) standards and procedures.

The scope of work for this project was to assess the current airflows for each classroom, office, and special purpose space. Air changes per hour were calculated along with the % of OSA for the spaces and any deficiencies found for each piece of equipment has been noted in the following report.

All ventilation equipment was commanded to run by the BMS system. Ventilation units were measured with a flowhood on the supply outlets. Outside air was recorded with a flowhood on the OSA louvre where accessible. AK factors were calculated from flowhood readings. The remaining OSA values were recorded with a velgrid. AHU supply air was recorded by a summation of the outlets as recorded by flowhood or velgrid when appropriate. Outside air was recorded with a velgrid or airfoil and calculated by the free area method.

The measured airflows in this report represent the performance of the equipment at the time of measurement, which vary over time based on operating conditions. There are factors outside the control of Neudorfer that impact airflow, and variance in those factors is expected and normal. One significant factor is the MERV rating and condition of the air filters on the equipment. During the summer of 2021, PPS began upgrading the filters on all their fan systems to MERV 13. Those upgraded filters are more effective at capturing particles but also impact the amount of airflow from the equipment. These filter changes were occurring while the airflow measurement project was happening, so some schools had the new filters, and some had the old filters at the time of measurement. On the data page included this report, there is a line stating whether or not the upgraded filters were in place at the time of measurement.



AIRFLOW SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Location: Laurelhurst K-8; 840 NE 41st Ave, Portland, OR 97232
Filter Status: Not Upgraded

Room	Equipment Info		Room Dimensions					Airflow Measurements			Calculated ACH						Notes
	Served By	Equipment Type	Room Length	Room Width	Room Area	Room Height	Room Volume	Total CFM Supply	OA CFM Supply	OA %	Air Changes per Hour (supply)	Air Changes per Hour (OA)	# of Portable Filters	Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter		
Annex First Floor																	
Rm 111	AHU-5	AHU	34.0	25.0	850	11.1	9,418	505	505	100%	3.2	3.2	1	4.2	2.6		
Rm 112	AHU-5	AHU	34.0	25.0	850	11.1	9,418	380	380	100%	2.4	2.4	1	3.6	1.9		
Rm 113	AHU-5	AHU	36.0	25.0	900	11.1	9,972	422	422	100%	2.5	2.5	1	3.6	2.0		
Rm 114	AHU-5	AHU	36.0	25.0	900	11.1	9,972	720	720	100%	4.3	4.3	1	5.0	3.5		
Rm 115	RTU	RTU	30.2	30.2	910	8.9	8,119	1,230	110	9%	9.1	0.8	1	6.3	4.3		
Rm 116	RTU	RTU	30.2	30.2	910	8.9	8,119	1,290	130	10%	9.5	1.0	1	6.5	4.6		
Rm 117	FCU	FCU	31.4	26.9	846	8.0	6,767	770	50	6%	6.8	0.4	1	5.5	3.2		
Rm 118	FCU	FCU	31.4	26.9	846	8.0	6,767	625	0	0%	5.5	0.0	1	4.8	2.5	Note #1	
First Floor																	
Rm 1	AHU-2	AHU	28.9	23.7	685	12.4	8,502	830	830	100%	5.9	5.9	1	6.5	4.7		
Rm 2	AHU-2	AHU	28.9	23.7	685	12.4	8,502	1,040	1,040	100%	7.3	7.3	1	7.7	5.9		
Rm 3	AHU-2	AHU	28.9	23.7	685	12.4	8,502	690	690	100%	4.9	4.9	1	5.7	3.9		
Rm 4	AHU-2	AHU	28.9	23.7	685	12.4	8,502	1,475	1,475	100%	10.4	10.4	1	10.2	8.3		
Rm 5	AHU-2	AHU	29.3	24.7	724	12.4	8,987	950	950	100%	6.3	6.3	1	6.8	5.1		
Rm 6	AHU-2	AHU	29.3	24.7	724	12.4	8,987	790	790	100%	5.3	5.3	1	6.0	4.2		
Rm 7	AHU-2	AHU	28.8	21.9	630	12.4	7,827	475	475	100%	3.6	3.6	1	4.9	2.9		
Rm 8	AHU-2	AHU	29.9	21.9	656	12.4	8,146	660	660	100%	4.9	4.9	1	5.8	3.9		
Rm 9	AHU-2	AHU	29.9	21.9	656	12.4	8,146	730	730	100%	5.4	5.4	1	6.2	4.3		
Rm 10	AHU-2	AHU	30.3	21.9	766	12.4	9,514	845	845	100%	5.3	5.3	1	5.9	4.3		
Rm 23	AHU-1	AHU	33.0	22.8	751	12.0	9,009	685	459	67%	4.6	3.1	1	4.8	3.1		
Rm 25	AHU-1	AHU	29.8	35.6	1,061	13.8	14,678	320	214	67%	1.3	0.9	1	2.0	0.9		
Office 18D	-	-	16.3	7.9	129	12.5	1,609	-	-	-	0.0	0.0	1	9.7	0.0	Room is ventilated from room 18	
Conf Rm 18	-	-	18.6	16.8	313	12.5	3,910	-	-	-	0.0	0.0	1	4.0	0.0	Room is ventilated by windows	
Office 18A	-	-	14.1	9.8	139	12.5	1,736	-	-	-	0.0	0.0	1	9.0	0.0	Room is ventilated from room 18	

Date: 4/22/2021

Readings By: Kevin E.



AIRFLOW SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Location: Laurelhurst K-8; 840 NE 41st Ave, Portland, OR 97232
Filter Status: Not Upgraded

Room	Equipment Info		Room Dimensions					Airflow Measurements			Calculated ACH						Notes
	Served By	Equipment Type	Room Length	Room Width	Room Area	Room Height	Room Volume	Total CFM Supply	OA CFM Supply	OA %	Air Changes per Hour (supply)	Air Changes per Hour (OA)	# of Portable Filters	Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter		
First Floor																	
Office 18B	-	-	16.3	10.3	167	12.5	2,092	-	-	-	0.0	0.0	1	7.5	0.0	Room is ventilated by windows	
Office 18C	-	-	9.8	8.1	80	12.8	1,025	-	-	-	0.0	0.0	1	15.2	0.0	Room is ventilated by room 18	
Conf Rm 20B	-	-	14.5	7.3	106	12.8	1,355	-	-	-	0.0	0.0	1	11.5	0.0	Room is ventilated by cafeteria	
Conf Rm 24A	AHU-01	AHU	14.0	11.9	139	10.0	1,388	200	134	67%	8.6	5.8	1	17.1	5.9		
Office 24B	AHU-01	AHU	15.0	12.3	185	10.0	1,850	200	134	67%	6.5	4.3	1	12.9	4.4		
Conf Rm 26A	Exhaust Fan	Exhaust Fan	11.5	5.8	66	7.5	496	0	0	0%	0.0	0.0	0	N/A	0.0	This is a storage room.	
Gym 11	AHU-01	AHU	92.8	41.0	3,806	20.6	78,328	1,215	814	67%	0.9	0.6	1	0.8	0.6		
11A	-	-	26.2	10.1	264	20.6	5,429	-	-	-	0.0	0.0	1	2.9	0.0	Room is ventilated by gym	
12	-	-	22.5	7.6	171	18.2	3,099	-	-	-	0.0	0.0	1	5.0	0.0	Room is ventilated by gym	
19	AHU-02	AHU	18.4	10.0	184	10.5	1,934	45	45	100%	1.4	1.4	1	9.2	1.1		
Cafeteria 20	AHU-02	AHU	62.7	45.3	2,841	19.2	54,459	5,345	5,345	100%	5.9	5.9	1	5.0	4.7		
20A	-	-	29.8	14.3	426	172.0	73,327	-	-	-	0.0	0.0	1	0.2	0.0	Room is ventilated by cafeteria	
20C	-	-	14.5	7.3	106	12.8	1,355	-	-	-	0.0	0.0	1	11.5	0.0	Room is ventilated by cafeteria	
21	AHU-02	AHU	26.0	13.0	338	10.5	3,549	660	660	100%	11.2	11.2	1	13.3	8.9		
23A	AHU-01	AHU	19.8	9.8	195	21.4	4,175	160	107	67%	2.3	1.5	1	5.3	1.6		
Library 24	AHU-01	AHU	57.5	40.0	2,300	12.5	28,750	1,730	1,159	67%	3.6	2.4	1	3.0	2.5		
Second Floor																	
Rm 211	AHU-03	AHU	29.2	23.8	693	12.4	8,604	285	171	60%	2.0	1.2	1	3.1	1.3		
Rm 212	AHU-03	AHU	29.2	23.8	693	12.4	8,604	245	147	60%	1.7	1.0	1	2.9	1.1		
Rm 213	AHU-03	AHU	29.2	23.8	693	12.4	8,604	265	159	60%	1.8	1.1	1	3.0	1.2		
Rm 214	AHU-03	AHU	29.2	23.8	693	12.4	8,604	320	192	60%	2.2	1.3	1	3.3	1.5		
Rm 215	AHU-02	AHU	35.0	28.6	1,112	12.4	13,810	855	855	100%	3.7	3.7	1	4.1	3.0		
Rm 216	AHU-02	AHU	29.4	27.8	816	12.4	10,140	320	320	100%	1.9	1.9	1	3.1	1.5		
Rm 217	AHU-02	AHU	32.9	22.3	735	12.4	9,130	740	740	100%	4.9	4.9	1	5.6	3.9		

Date: 4/22/2021

Readings By: Kevin E.

Project:	Portland Public Schools Airflow Testing
Location:	Laurelhurst K-8; 840 NE 41st Ave, Portland, OR 97232
Filter Status:	Not Upgraded

[illegible]

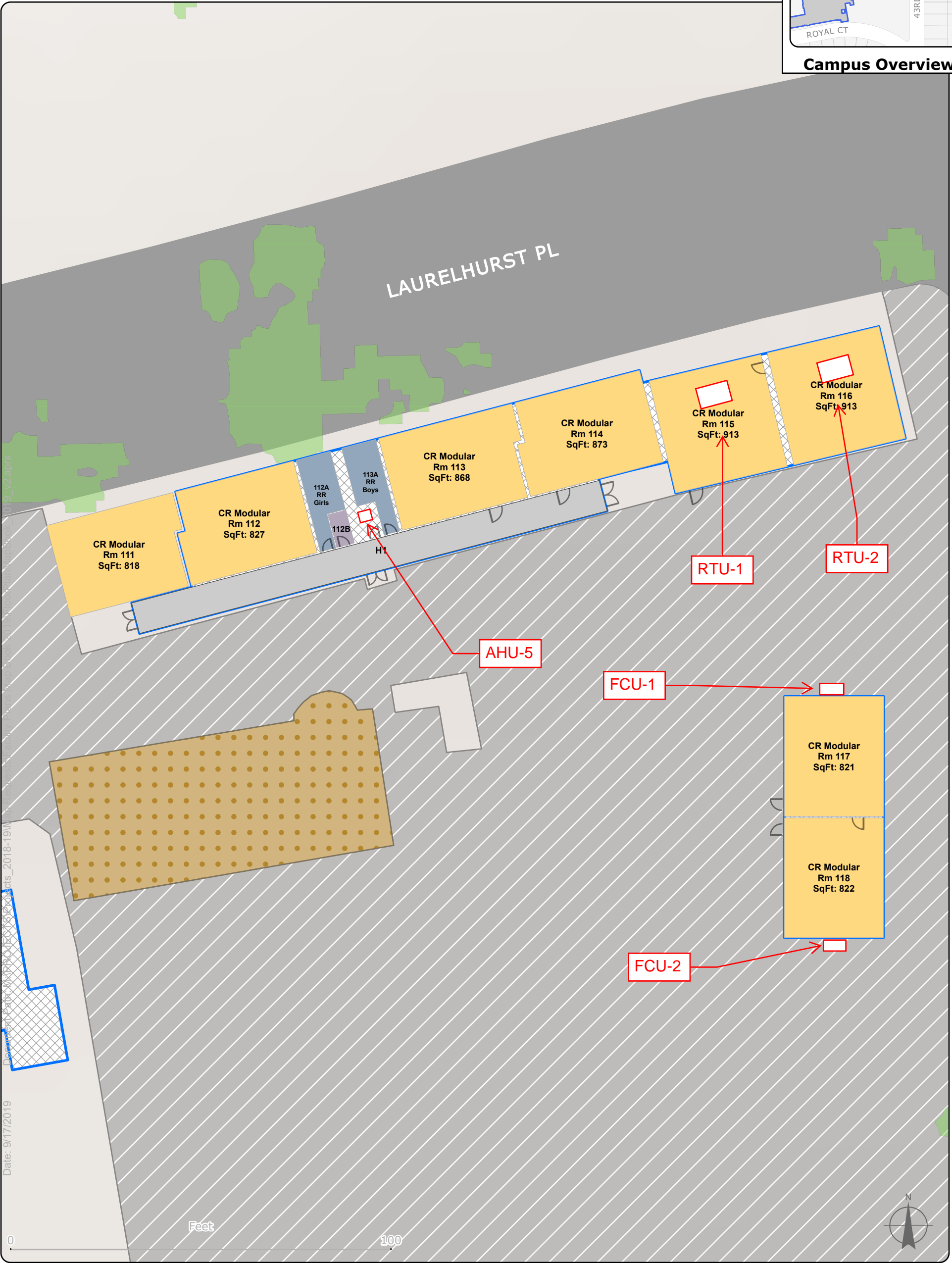
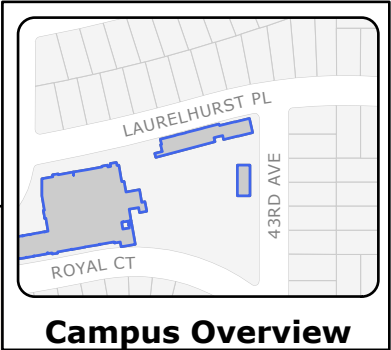
Date: 4/21/2021



Project: Portland Public Schools Airflow Testing
Location: Laurelhurst K-8; 840 NE 41st Ave, Portland, OR 97232

NOTE #	NOTE DESCRIPTION
1	OSA damper was found closed.

LAURELHURST ANNEX: Annex First Floor

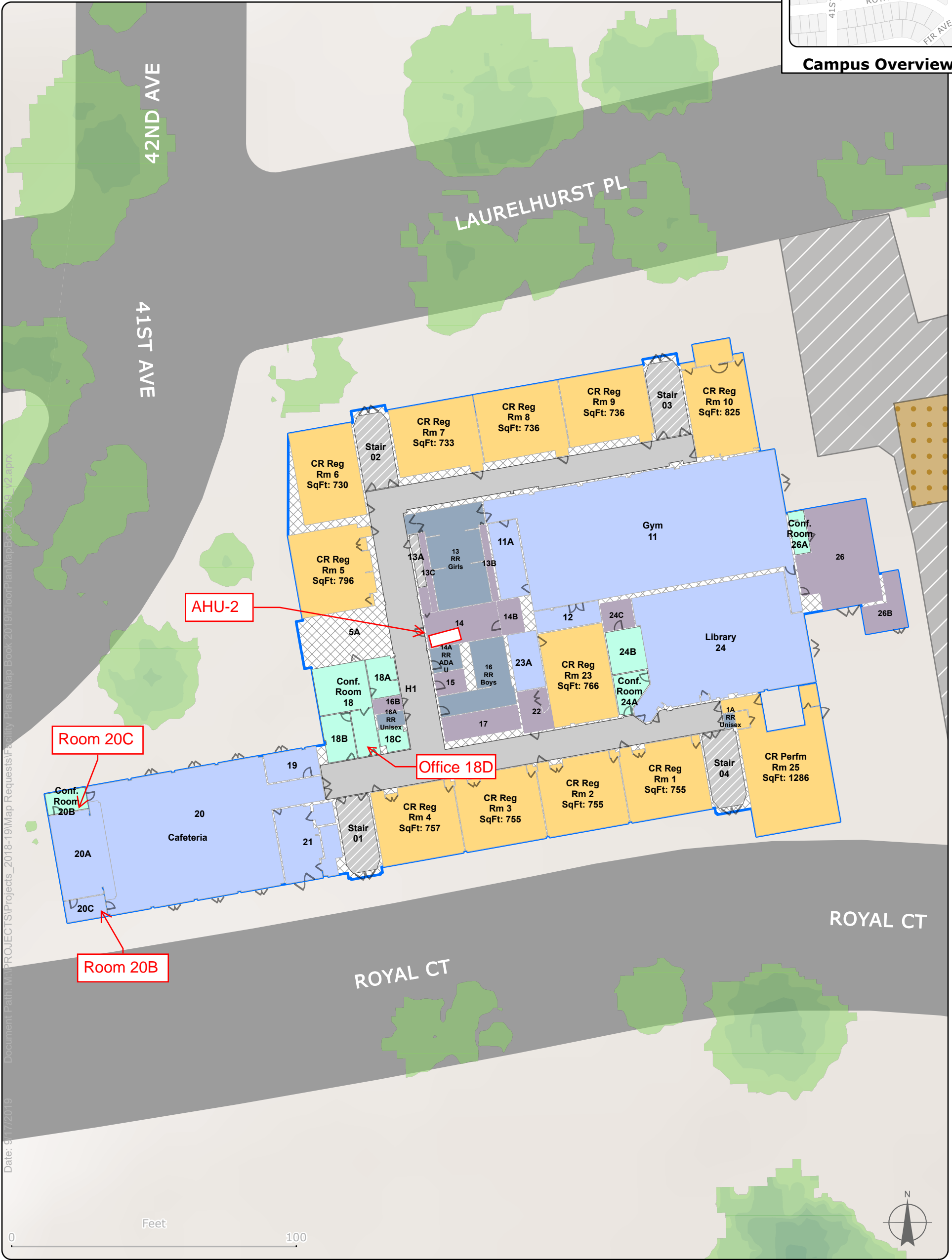
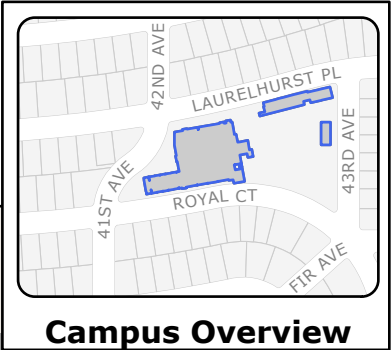


Space Use		School Grounds	
	Classroom		Campus Footprints
	Office		Athletic Field
	Rest Room		Playground: Paved
	Special Purpose		Playground: Unpaved
	Corridor		Streets
	Other		Doors
	Stairs/Elevator		

Total Number Of Rooms By Classification

Classrooms: 8	Special Purpose: 0
Office Spaces: 0	Storage: 1

LAURELHURST: First Floor

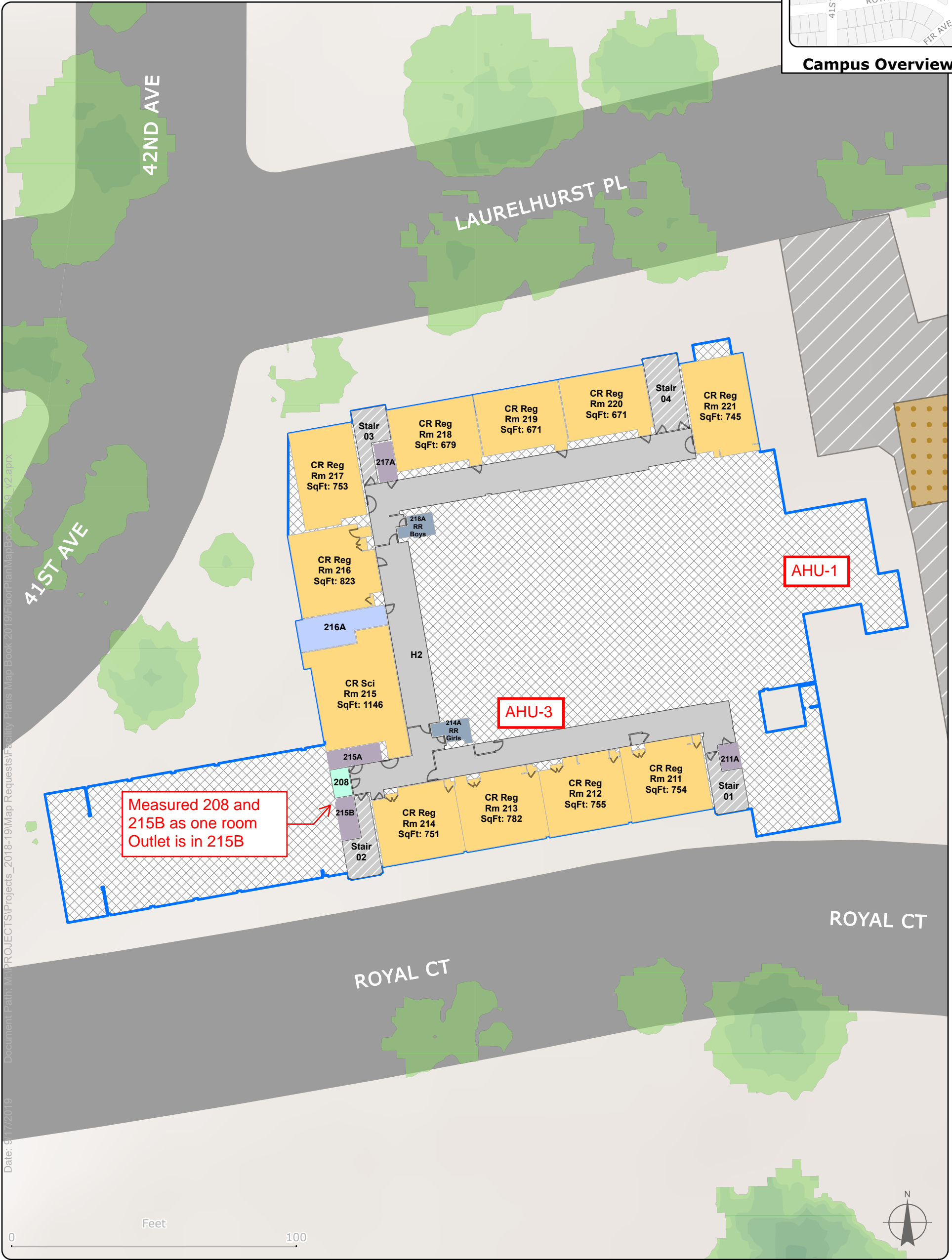
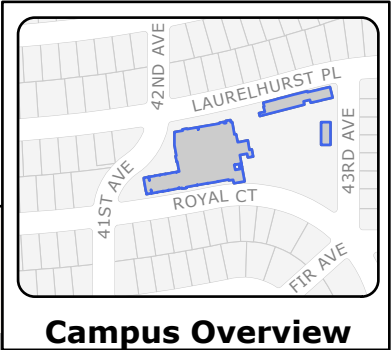















Space Use		School Grounds	
	Classroom		Campus Footprints
	Office		Athletic Field
	Rest Room		Playground: Paved
	Special Purpose		Playground: Unpaved
	Corridor		Streets
	Other		Doors
	Stairs/Elevator		

Total Number Of Rooms By Classification

Classrooms: 12	Special Purpose: 10
Office Spaces: 8	Storage: 6

LAURELHURST: Second Floor



Space Use		School Grounds	
	Classroom		Campus Footprints
	Office		Athletic Field
	Rest Room		Playground: Paved
	Special Purpose		Playground: Unpaved
	Corridor		Streets
	Other		Doors
	Stairs/Elevator		

Total Number Of Rooms By Classification

Classrooms: 11	Special Purpose: 1
Office Spaces: 1	Storage: 4