Airflow Testing Report

Prepared for

Portland Public Schools

August 2021

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

PROJECT OVERVIEW

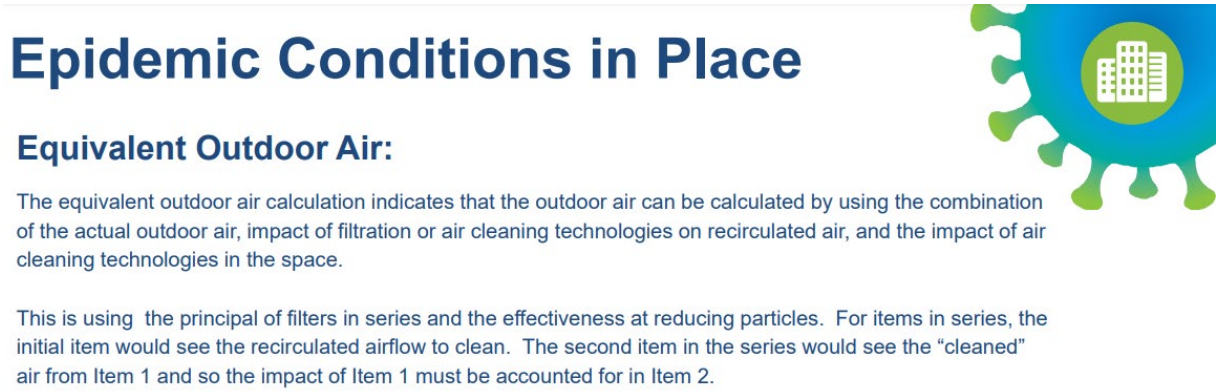
As part of the continuing process to ensure a safe return to in-person learning, Portland Public Schools has contracted with Ameresco to test the airflow and ventilation of all educational and office spaces in each school. The data is reviewed by both Ameresco and PPS personnel to identify any potential 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 CO_2 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:



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:

$$\mathrm{ACH_e} = \left(ACH_{oa} + ACH_f\right) * E_Z + ACH\_ir$$

where:

- $\mathrm{ACH_{oa}}$ = air changes per hour of outside air = outside airflow in cubic feet per minute * 60 minutes per hour / room volume in cubic feet
- $\mathrm{ACH_f}$ = 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.

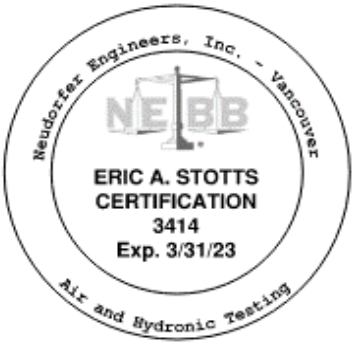
NEUDORFER ENGINEERS INC.

TEST REPORT TYPE:
SURVEY REPORT

Portland Public Schools Airflow Testing
Scott ES

Job Number: 2021-0297

Project Completion Date: **October 2021**
Revision Date: **-** **Revision Number:** **-**



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Portland Public Schools Airflow Testing
Scott ES
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REPORT TITLE

CERTIFIED TEST: SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Scott ES

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**

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
ACH	Air Changes per Hour
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
FSD	Fire Smoke 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 Absorbing
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 Handling Unit
MBH	1,000 BTUH
N/A	Not Applicable
OSA	Outside Air
OBD	Opposed Blade Damper
∆P	Pressure Drop.
PH	Phase
PSI	Pounds per Square Inch
RA	Return Air
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

Scott ES

Instrument Type	Air Data Meter with Flowhood	Instrument Serial #	**M97410**
Instrument Manufacturer	**Shortridge**	Calibration Date	**10/4/2021**
Instrument Model Number	**ADM 860**	Calibration Due	**10/4/2022**

Instrument Type	Differential Pressure Water Meter	Instrument Serial #	**W12178**
Instrument Manufacturer	**Shortridge**	Calibration Date	**10/4/2021**
Instrument Model Number	**HDM-250**	Calibration Due	**10/4/2022**

Instrument Type	Psychrometer	Instrument Serial #	**181128924**
Instrument Manufacturer	**Extech**	Calibration Date	**10/1/2021**
Instrument Model Number	**RH390**	Calibration Due	**10/1/2022**

Instrument Type	Tachometer	Instrument Serial #	**B185B5022P**
Instrument Manufacturer	**Nidec**	Calibration Date	**10/1/2021**
Instrument Model Number	**MT-200**	Calibration Due	**10/1/2022**

Instrument Type	Amp Probe	Instrument Serial #	**33380179WS**
Instrument Manufacturer	**Fluke**	Calibration Date	**10/1/2021**
Instrument Model Number	**323 Clamp Meter**	Calibration Due	**10/1/2022**

Instrument Type	Digital Thermometer	Instrument Serial #	**45400509WS**
Instrument Manufacturer	**Fluke**	Calibration Date	**10/1/2021**
Instrument Model Number	**52 II**	Calibration Due	**10/1/2022**

Instrument Type	Manometer	Instrument Serial #	**M97410**
Instrument Manufacturer	**Shortridge**	Calibration Date	**10/4/2021**
Instrument Model Number	**ADM 860**	Calibration Due	**10/4/2022**

Instrument Type	Thermal Anemometer	Instrument Serial #	**AVM440808002**
Instrument Manufacturer	**Alnor Instruments**	Calibration Date	**9/22/2021**
Instrument Model Number	**AVM 440**	Calibration Due	**9/22/2022**

Instrument Type	Ultrasonic Flow Meter	Instrument Serial #	**N1F1823T**
Instrument Manufacturer	**Fuji**	Calibration Date	**9/20/2021**
Instrument Model Number	**Portaflow-C**	Calibration Due	**9/20/2022**

PROJECT Portland Public Schools Airflow Testing
LOCATION Scott ES; 6700 NE Prescott St, Portland, OR 97218

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: Scott ES; 6700 NE Prescott St, Portland, OR 97218
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	
Lower Level 1																
Cafeteria 02	Café AHU	AHU	56.2	54.1	3,424	9.0	30,816	2,310	2,310	100%	4.5	4.5	1	4.1	3.6	Non-rectangular room.
8	-	-	35.2	15.0	528	8.2	4,330	-	-	-	0	0	1	3.6	0.0	Ventilation provided by adjacent spaces.
9	-	-	5.0	7.9	40	7.0	277	-	-	-	0	0	0	N/A	0.0	Ventilation provided by adjacent spaces.
11	-	-	7.9	5.2	41	8.0	329	-	-	-	0	0	0	N/A	0.0	Ventilation provided by adjacent spaces.
13	Stage #2 FCU	FCU	14.2	20.6	293	7.8	2,282	100	100	100%	2.6	2.6	1	8.9	2.1	
Conf. Room 16	-	-	7.7	11.0	85	7.7	652	-	-	-	0	0	1	23.9	0.0	Ventilation provided by adjacent spaces.
First Floor																
Rm 406	Stage #1 FCU	FCU	35.4	24.6	871	10.0	8,708	887	887	100%	6.1	6.1	1	6.7	4.9	
Rm 405	Stage #1 FCU	FCU	36.9	24.0	886	9.9	8,767	690	690	100%	4.7	4.7	1	5.6	3.8	
Rm 404	Stage #1 FCU	FCU	26.3	24.3	639	10.6	6,774	806	806	100%	7.1	7.1	1	8.0	5.7	
Library 401	Stage #1 FCU	FCU	76.1	24.0	1,826	10.6	19,360	1,600	1,600	100%	5.0	5.0	1	4.8	4.0	
Rm 402	Stage #1 FCU	FCU	36.9	24.6	908	10.7	9,713	730	730	100%	4.5	4.5	1	5.2	3.6	
219	Stage #1 FCU	FCU	25.2	15.2	383	10.0	3,830	340	340	100%	5.3	5.3	1	8.3	4.3	
217E	Stage #1 FCU	FCU	18.6	14.7	273	7.5	2,051	160	160	100%	4.7	4.7	1	11.4	3.7	
217G	-	-	16.6	5.9	98	8.0	784	-	-	-	0	0	1	19.9	0.0	Ventilation provided by adjacent spaces.
Auditorium 217	Gym AHU	AHU	55.9	86.0	4,807	20.0	96,148	9,070	9,070	100%	5.0	5.0	1	4.2	4.0	
Stage 217C	-	-	20.4	34.5	704	17.6	12,387	-	-	-						Open and shared with Auditorium.
Rm 301	Gym AHU	AHU	37.0	23.9	884	10.7	9,462	950	950	100%	6.0	6.0	1	6.5	4.8	
Rm 302	Gym AHU	AHU	39.5	23.7	936	10.8	10,110	850	850	100%	5.0	5.0	1	5.6	4.0	
Rm 303	Gym AHU	AHU	37.0	24.0	888	10.6	9,413	775	775	100%	4.9	4.9	1	5.6	4.0	
Rm 304	Gym AHU	AHU	40.1	23.9	958	10.6	10,159	660	660	100%	3.9	3.9	1	4.7	3.1	
Rm 305	Gym AHU	AHU	36.9	23.7	875	10.7	9,357	785	785	100%	5.0	5.0	1	5.7	4.0	
Rm 306	Gym AHU	AHU	36.9	23.9	882	10.1	8,907	650	650	100%	4.4	4.4	1	5.3	3.5	
Rm 307	Gym AHU	AHU	36.9	24.0	886	10.1	8,945	630	630	100%	4.2	4.2	1	5.1	3.4	

Date: 7/14/2021 Readings By: Mayer

AIRFLOW SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Location: Scott ES; 6700 NE Prescott St, Portland, OR 97218
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																
300	Fan #8	AHU	26.1	20.0	522	10.8	5,638	336	336	100%	3.6	3.6	1	5.6	2.9	
300A	-	-	5.9	6.5	38	7.6	291	-	-	-	0.0	0.0	0	N/A	0.0	This is a vestibule/interstitial.
300E	-	-	8.1	6.5	53	10.8	569	-	-	-	0.0	0.0	1	27.4	0.0	Ventilation provided by adjacent spaces.
300D	Fan #8	AHU	15.6	13.8	215	10.8	2,325	180	180	100%	4.6	4.6	1	10.4	3.7	
300C	Fan #8	AHU	19.9	8.1	161	8.0	1,290	125	125	100%	5.8	5.8	1	16.8	4.7	
300H	Fan #8	AHU	8.1	6.0	49	8.1	394	60	60	100%	9.1	9.1	1	46.9	7.3	
Main Office 214	Fan #8	AHU	12.3	15.5	191	8.0	1,525	180	180	100%	7.1	7.1	1	15.9	5.7	
216	Fan #8	AHU	15.5	12.5	194	10.8	2,093	185	185	100%	5.3	5.3	1	11.7	4.2	
210	Fan #8	AHU	12.1	26.8	324	10.8	3,502	85	85	100%	1.5	1.5	1	5.6	1.2	
Rm 208	Fan #7	AHU	36.0	24.4	878	10.5	9,223	1,220	1,220	100%	7.9	7.9	1	8.0	6.3	
Rm 207	Fan #7	AHU	36.8	24.4	898	10.5	9,428	810	810	100%	5.2	5.2	1	5.8	4.1	
Rm 206	Fan #7	AHU	36.0	24.0	864	10.5	9,072	1,190	1,190	100%	7.9	7.9	1	8.0	6.3	
Rm 205	Fan #7	AHU	36.9	24.0	886	10.5	9,299	1,135	1,135	100%	7.3	7.3	1	7.5	5.9	
Rm 204	Fan #7	AHU	36.9	24.1	889	10.5	9,338	960	960	100%	6.2	6.2	1	6.6	4.9	
Rm 203	Fan #7	AHU	36.9	24.1	889	10.5	9,338	1,110	1,110	100%	7.1	7.1	1	7.4	5.7	
Rm 202	Fan #7	AHU	48.4	25.0	1,210	10.0	12,100	1,035	1,035	100%	5.1	5.1	1	5.4	4.1	
Rm 201	Fan #7	AHU	36.9	24.0	886	10.0	8,856	640	640	100%	4.3	4.3	1	5.2	3.5	
Rm 101	Annex Fan	AHU	31.9	25.0	798	10.0	7,975	190	190	100%	1.4	1.4	1	3.1	1.1	
101C	Annex Fan	AHU	16.0	12.0	192	10.0	1,920	305	305	100%	9.5	9.5	1	15.8	7.6	
Rm 102	Annex Fan	AHU	31.9	25.1	801	10.0	8,007	770	770	100%	5.8	5.8	1	6.6	4.6	
Rm 103	Annex Fan	AHU	33.4	25.0	835	10.0	8,350	775	775	100%	5.6	5.6	1	6.3	4.5	
Rm 104	Annex Fan	AHU	31.1	25.0	0	10.0	0	665	665	100%	0.0	0.0	1	-	0.0	
Rm 105	Annex Fan	AHU	33.9	25.0	848	10.0	8,475	345	345	100%	2.4	2.4	1	3.8	2.0	
Rm 106	Annex Fan	AHU	34.0	24.9	847	9.9	8,381	700	700	100%	5.0	5.0	1	5.9	4.0	

Date: 7/14/2021 Readings By: Mayer

Neudorfer Engineers. Inc.
Consulting Engineers Seattle Portland
www.NeudorferEngineers.com

AIRFLOW SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Location: Scott ES; 6700 NE Prescott St, Portland, OR 97218
Filter Status: Not Upgraded

Room	Equipment Info		Room Dimensions					Airflow Measurements			Calculated ACH					Notes
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First Floor																
Rm 506	Ind. Arts FCU	FCU	38.7	19.2	743	14.9	11,071	630	630	100%	3.4	3.4	1	4.1	2.7	
Rm 501	Ind. Arts FCU	FCU	38.7	19.0	735	9.3	6,838	860	860	100%	7.5	7.5	1	8.3	6.0	
503	-	-	18.1	16.5	299	14.9	4,450	-	-	-	0	0	0	N/A	0.0	This area is a storage room.
Rm 8A	Bard HP	HP	31.5	26.9	847	8.0	6,779	610	30	5%	5.4	0.3	1	4.8	2.5	
Rm 8B	Bard HP	HP	31.5	26.9	847	8.0	6,779	563	25	4%	5.0	0.2	1	4.6	2.3	

Date: 7/14/2021 Readings By: Mayer

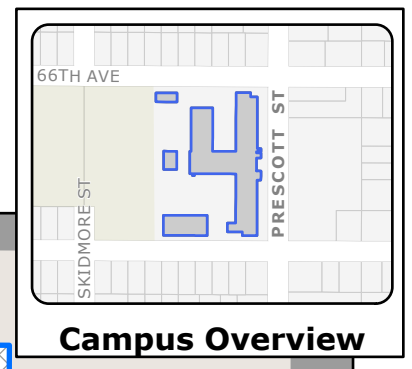
Project: Portland Public Schools Airflow Testing
Location: Scott ES; 6700 NE Prescott St, Portland, OR 97218

NOTE #	NOTE DESCRIPTION

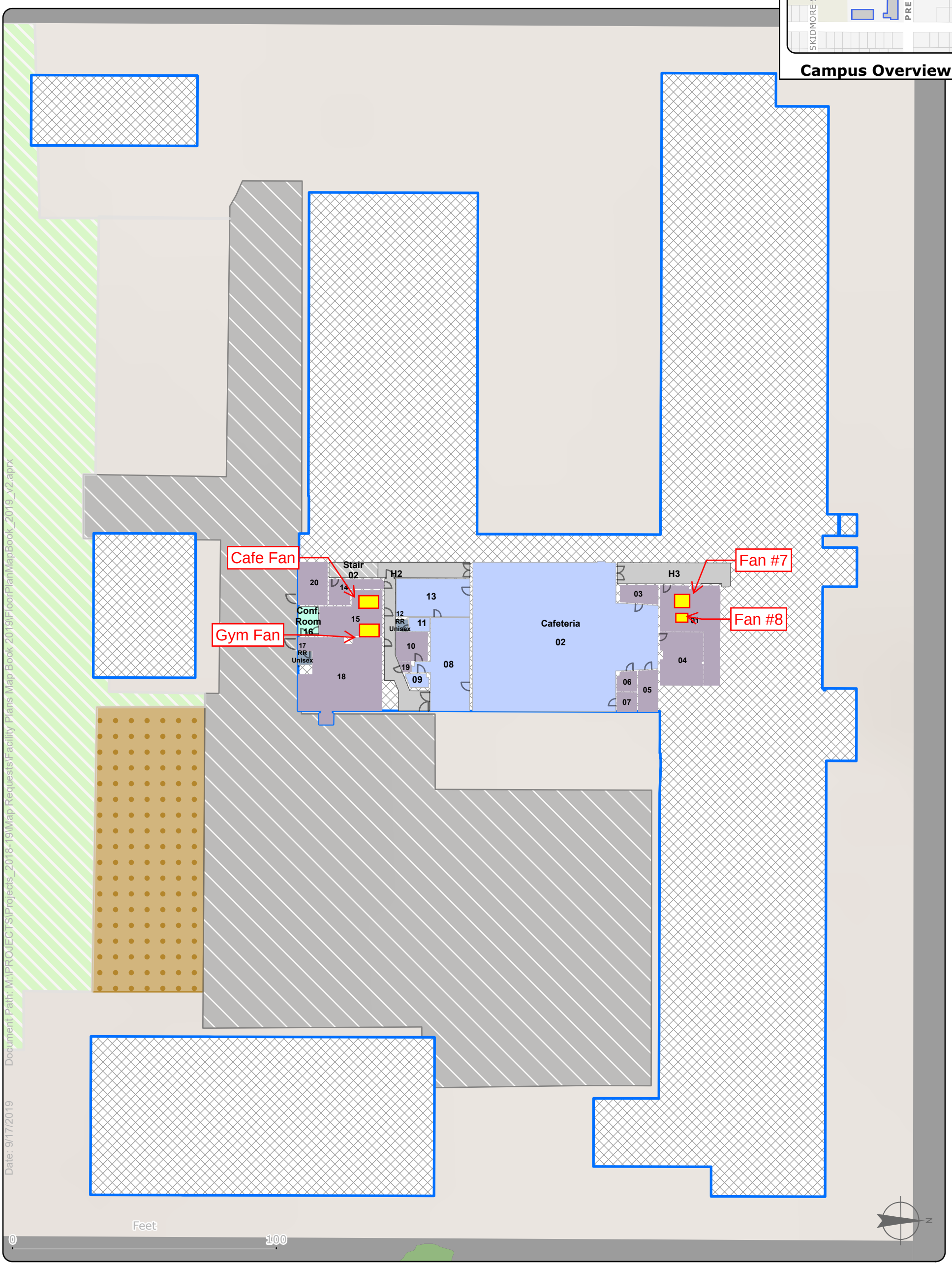
FOR INTERNAL USE ONLY

DO NOT DISTRIBUTE

SCOTT: Lower Level 1



Campus Overview



Space Use

- Classroom
- Office
- Rest Room
- Special Purpose
- Corridor
- Other
- Stairs/Elevator

School Grounds

- Campus Footprints
- Athletic Field
- Playground: Paved
- Playground: Unpaved
- Streets
- Doors

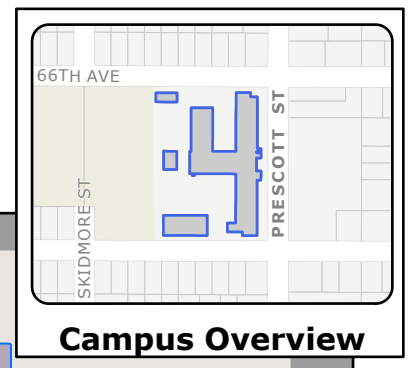
Total Number Of Rooms By Classification

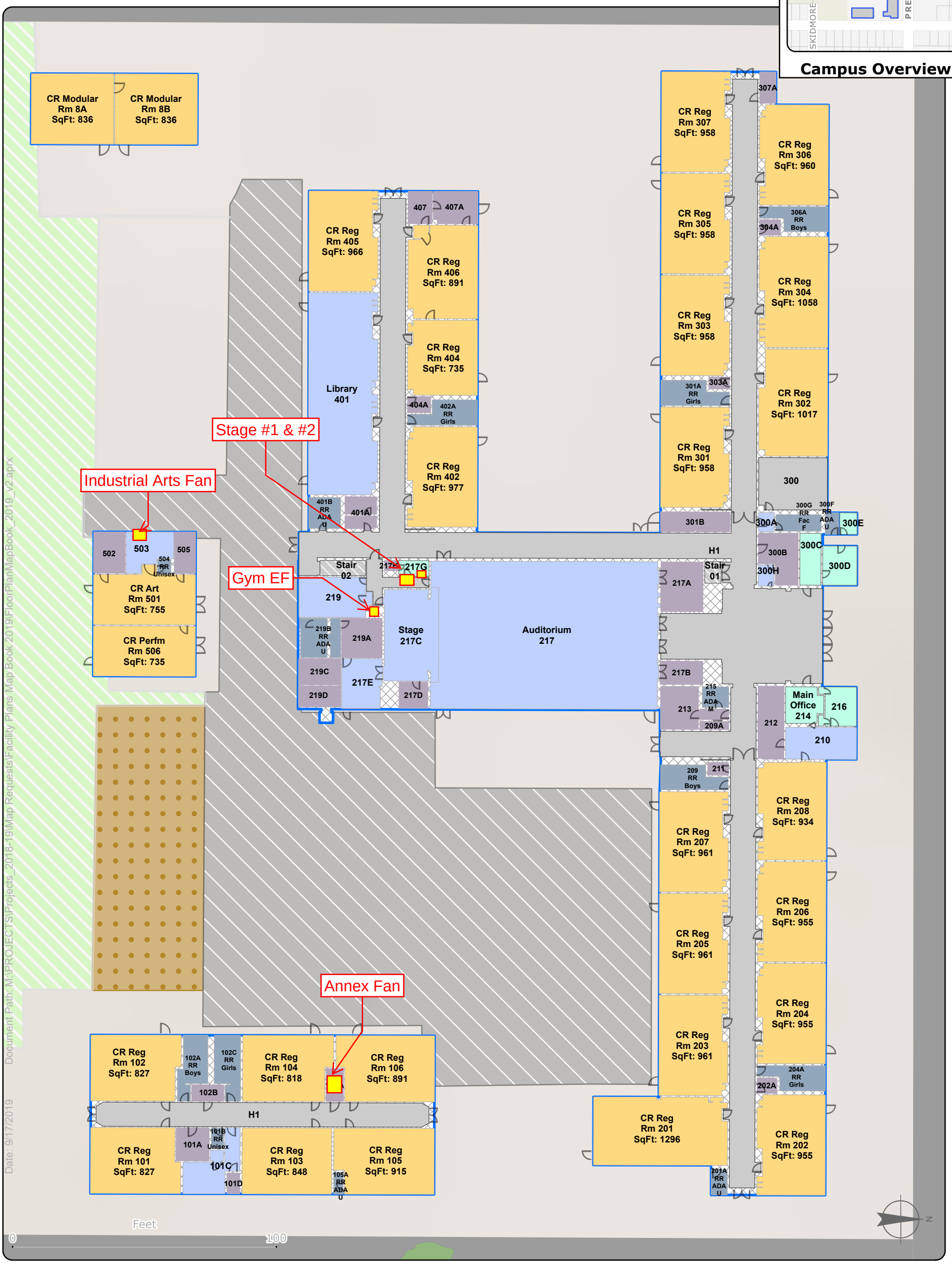
Classrooms: 0	Special Purpose: 5
Office Spaces: 1	Storage: 7

FOR INTERNAL USE ONLY

DO NOT DISTRIBUTE

SCOTT: First Floor





Space Use

- Classroom
- Office
- Rest Room
- Special Purpose
- Corridor
- Other
- Stairs/Elevator

School Grounds

- Campus Footprints
- Athletic Field
- Playground: Paved
- Playground: Unpaved
- Streets
- Doors

Total Number Of Rooms By Classification

Classrooms: 27	Special Purpose: 10
Office Spaces: 6	Storage: 21