



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
Llewellyn ES
6301 SE 14th Ave, Portland, OR 97202
Job Number: 2021-0297**

Project Completion Date: September 2021

Revision Date:

-

Revision Number:

-



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Neudorfer Engineers, Inc.

Consulting Engineers Seattle, Washington - Portland, Oregon



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**Portland Public Schools Airflow Testing
Llewellyn ES**

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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
Llewellyn ES

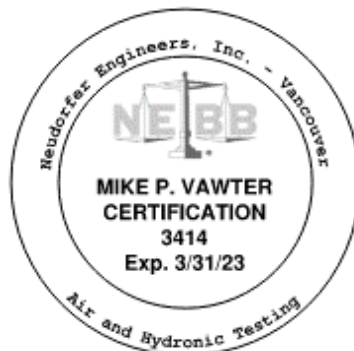
NEI Job#: 2021-0297

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**

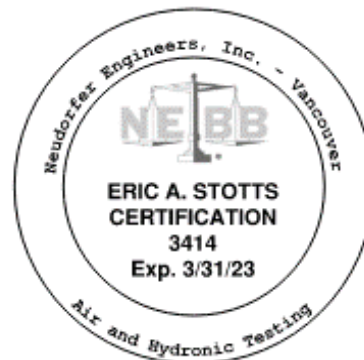
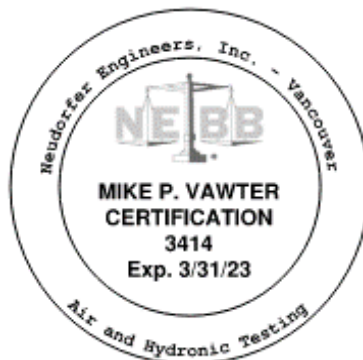
Expiration Date: **March 31, 2023**

Certification Date: **March 31, 2021**

(Date completed) Signed and Sealed by:

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

NEBB Supervisor: **Eric Stotts**





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	HEPA High Efficiency Particulate Arrestance
AH or AHU Air Handler or Air Handling Unit	HP Horsepower
AVG Average	HVAC Heating Ventilation and Air Conditioning
BHP Brake Horsepower	HWS Heating Water Supply
CAV Constant Air Volume	HWR Heating Water Return
CBV Calibrated Balancing Valve (Circuit Setter)	HX Heat Exchanger
CC Cooling Coil	HZ Hertz, cycle per second
CD Ceiling Diffuser	in. inches
CFM Cubic Feet per Minute	in.w.g. inches of water gauge
CH Chiller	Kfactor Correction factor to the free area need to calculate CFM.
CHWS Chilled Water Supply	KW Kilowatts
CHWR Chilled Water Return	LAT Leaving Air Temperature
CP Circulating Pump	LWG Low Wall Grille
CR Ceiling Register	LWR Low Wall Register
CRAC Computer Room Air Conditioner	LWT Leaving Water Temperature
CRU Computer Room Unit	MAU Make-up Air Hanging Unit
CT Cooling Tower	MBH 1,000 BTUH
CU Condenser Unit	N/A Not Applicable
CUH Cabinet Unit Heater	OSA Outside Air
CWS Condenser Water Supply	OBD Opposed Blade Damper
CWR Condenser Water Return	ΔP Pressure Drop.
DAT Discharge Air Temperature	PH Phase
DB Dyr Bulb	PSI Pounds per Square Inch
DD Direct Drive	RA Return Air
DDC Direct Digital Controls: EMS Control System for the HVAC	RAD Radiator
Des. Design	RAT Return Air Temperature
Dia. Diameter	RF Return Fan
Disch. Discharge	RH Relative Humidity
EA Exhaust Air	RHC Reheat Coil
EAT Entering Air Temperature	RPM Revolutions per Minute
Economizer Controls and components that allow an air handler to logically utilize outdoor air for cooling as opposed to the use of mechanical cooling.	RTU Roof Top Unit
EF Exhaust Fan	SA Supply Air
EG Exhaust Grille	SAT Supply Air Temperature
EMCS Energy Management Control System	S.F. Service Factor
ERU Energy Recovery Unit	SF Supply Fan
E.S.P. External Static Pressure	SFD Smoke/Fire Damper
HRC Heat Recovery Coil	SP Static Pressure
EWT Entering Water Temperature	sq.ft. square feet
FCU Fan Coil Unit	Suct. Suction
FD Fire Damper	SWG Sidewall Grille
FLA Full Load Amperage: Maximum amperage a motor can draw.	SWR Sidewall Register
Flow Hood Instrument that captures air and converts the reading to CFM.	TAB Test; Adjust; and Balance
FHT Fume Hood Test	TSP Total Static Pressure: Difference between the entering and leaving static pressure of a fan.
FPB Fan Powered Box	UH Unit Heater
FPM Feet per Minute	VAV Variable Air Volume; box that contains a motorized damper that modulates airflow.
FR Field Report	VD Volume Damper
FT Foot, Feet	VFD Variable Frequency Drive
FTU Fan Terminal Unit	Velgrid Instrument that reads used to read velocity in feet per minute.
GPM Gallons per Minute	VVT Variable Volume Terminal
HC Heating Coil	WC Water Column
TDH Pressure Difference across the entering and leaving side of a pump.	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	Llewellyn ES; 6301 SE 14th Ave, Portland, OR 97202

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: Llewellyn ES; 6301 SE 14th Ave, Portland, OR 97202
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																
Rm 99A	AHU-1	AHU	31.9	28.4	906	14.50	13,136	1,917	1,917	100%	8.8	8.8	1	8.2	7.0	
Rm 99B	AHU-1	AHU	31.9	20.8	664	14.5	9,621	2,121	2,121	100%	13.2	13.2	1	12.2	10.6	
Rm 99C	-	-	-	-	-	-	-	-	-	-	0	0	0	N/A	0.0	Note #3
Rm 100	UV	UV	34.6	30.1	1,041	12.2	12,706	830	50	6%	3.9	0.2	1	3.1	1.8	
Rm 101	UV	UV	29.8	22.0	656	12.2	7,998	870	80	9%	6.5	0.6	1	5.1	3.1	
Rm 102	UV	UV	35.9	22.4	804	12.2	9,811	670	55	8%	4.1	0.3	1	3.5	1.9	
Rm 103	UV	UV	35.9	22.3	801	12.2	9,767	650	55	8%	4.0	0.3	1	3.5	1.9	
Conf Room 104	UV	UV	23.3	12.2	284	12.2	3,468	360	190	53%	6.2	3.3	1	8.4	3.9	
Rm 104A	-	-	9.7	9.2	89	12.2	1,089	-	-	-	0	0	1	14.3	0.0	Note #1
Rm 104B	-	-	14.0	10.0	161	12.2	1,963	-	-	-	0	0	1	7.9	0.0	Note #1, Note #2
Rm 106B	-	-	14.1	11.7	165	12.2	2,013	-	-	-	0	0	1	7.8	0.0	Note #1
Cafeteria 106	AHU-1	AHU	53.9	44.5	2,399	21.3	51,089	10,128	10,128	100%	11.9	11.9	1	9.8	9.5	
Stage 106A	-	-	30.9	15.7	485	26.9	13,050	-	-	-	0	0	1	1.2	0.0	Note #1
Gym 116	AHU-1	AHU	69.0	50.0	3,450	25.0	86,250	7,016	7,016	100%	4.9	4.9	1	4.1	3.9	
Rm 116A	-	-	10.5	9.5	100	12.2	1,217	-	-	-	0	0	1	12.8	0.0	Note #1
Rm 116B	-	-	10.0	9.6	96	10.4	998	-	-	-	0	0	1	15.6	0.0	Note #1
Rm 112	-	-	-	-	-	-	-	-	-	-	0	0	0	N/A	0.0	Note #3
Rm 106C	UV	UV	23.8	12.4	295	12.2	3,600	525	55	10%	8.7	0.9	1	8.5	4.2	
Rm 114	UV	UV	12.0	10.4	125	12.2	1,523	570	55	10%	22.5	2.2	1	21.0	10.8	
107B	-	-	8.0	26.9	215	12.3	2,647	-	-	-	0	0	1	5.9	0.0	Note #1
Rm 107	UV	UV	34.8	22.3	776	12.2	9,468	805	155	19%	5.1	1.0	1	4.3	2.6	
Rm 108	UV	UV	29.8	22.3	665	12.2	8,107	810	140	17%	6.0	1.0	1	5.0	3.0	
Rm 109	UV	UV	30.0	22.0	660	12.2	8,052	875	40	5%	6.5	0.3	1	4.9	3.0	
Rm 110	UV	UV	30.4	36.6	1,113	12.2	13,574	415	380	92%	1.8	1.7	1	2.6	1.4	

Date: 8/5/2021

Readings By: Zach Mayer



AIRFLOW SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Location: Llewellyn ES; 6301 SE 14th Ave, Portland, OR 97202
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																
111A	-	-	9.2	8.2	75	8.0	604	-	-	-	0	0	1	25.8	0.0	Note #1
Library 111	AHU-1	AHU	48.9	32.0	1,565	14.30	22,377	1,558	1,558	100%	4.2	4.2	1	4.0	3.3	
Conf Room 111C	-	-	12.3	7.5	92	14.1	1,301	-	-	-	0	0	1	12.0	0.0	Note #1
Z001	HP	HP	29	31.5	914	8.8	8,039	1,330	155	12%	9.9	1.2	1	1.9	0.0	
Z002	HP	HP	31.1	26.7	830	8.9	7,390	960	30	3%	7.8	0.2	1	5.7	3.6	
Z003	HP	HP	31.1	26.7	830	8.9	7,390	1,446	414	29%	11.7	3.4	1	8.5	6.4	
Second Floor																
Rm 200	UV	UV	22.0	30.0	660	12.3	8,118	880	475	54%	6.5	3.5	1	6.1	4.1	
Rm 201	UV	UV	22.0	30.0	660	12.3	8,118	760	510	67%	5.6	3.8	1	5.8	3.8	
RM 202	UV	UV	22.0	30.0	660	12.3	8,118	670	440	66%	5.0	3.3	1	5.3	3.4	
Rm 203	UV	UV	35.9	21.9	786	12.3	9,670	745	290	39%	4.6	1.8	1	4.3	2.7	
204	-	-	15.6	16.0	250	12.3	3,070	-	-	-	0	0	1	5.1	0.0	Note #1
Rm 205	UV	UV	22.0	31.9	702	12.3	8,632	895	415	46%	6.2	2.9	1	5.6	3.8	
Rm 206	UV	UV	22.0	31.9	702	12.3	8,632	860	510	59%	6.0	3.5	1	5.7	3.9	
207	UV	UV	22.5	15.7	353	12.3	4,345	405	245	60%	5.6	3.4	1	7.3	3.7	
Rm 208	UV	UV	35.4	21.5	761	12.3	9,362	735	560	76%	4.7	3.6	1	5.0	3.4	
Rm 209	UV	UV	29.9	22.0	658	12.3	8,091	790	510	65%	5.9	3.8	1	5.9	3.9	
Rm 210	UV	UV	32.5	22.0	715	12.3	8,795	985	525	53%	6.7	3.6	1	6.0	4.3	
Rm 211	UV	UV	29.8	22.3	665	12.3	8,174	1,010	0	0%	7.4	0.0	1	5.2	3.3	OSA intake clogged.

Date: 8/5/2021

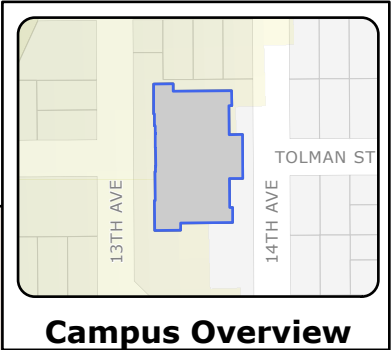
Readings By: Zach Mayer



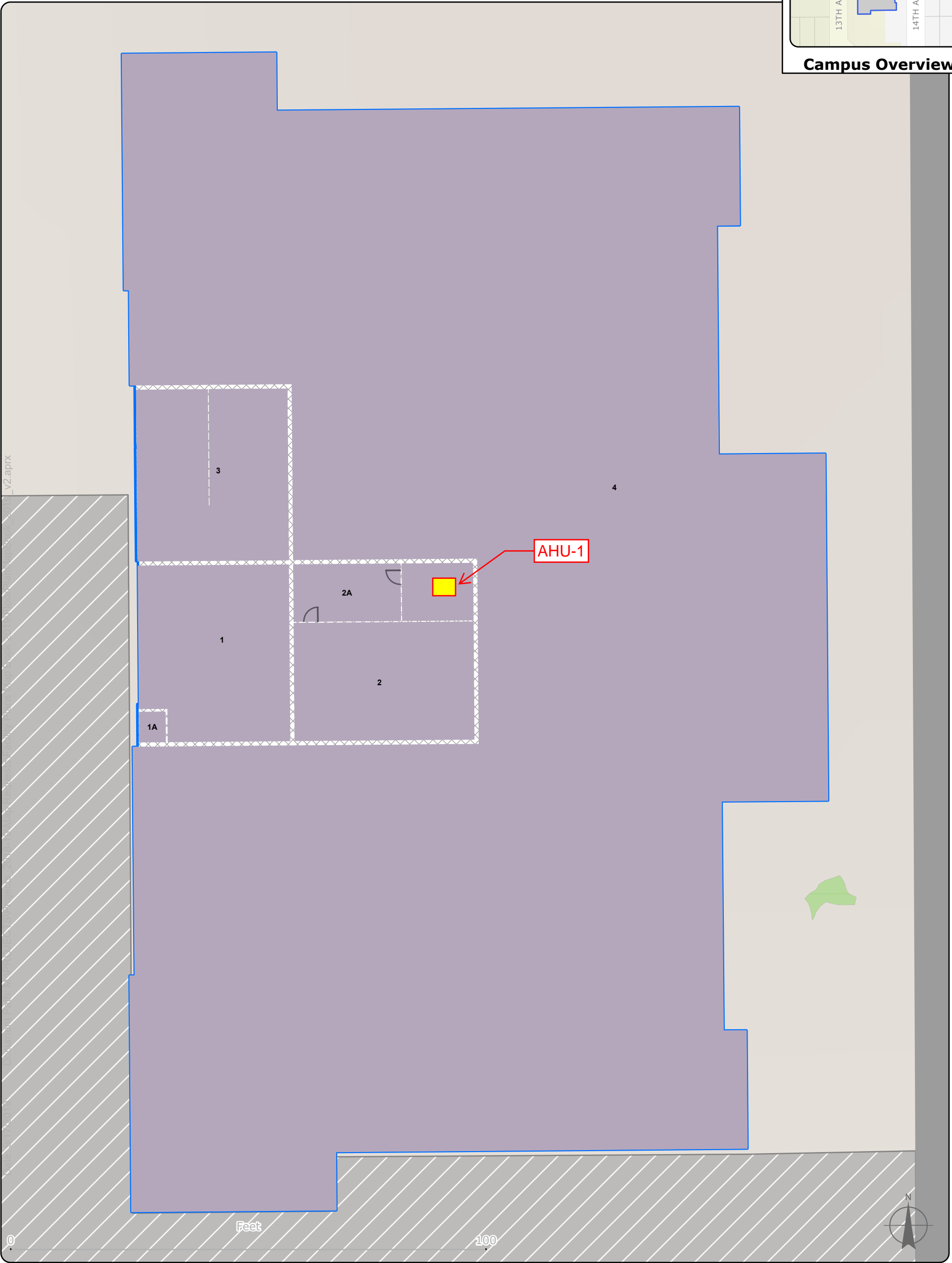
Location: Llewellyn ES; 6301 SE 14th Ave, Portland, OR 97202














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LLEWELLYN: Lower Level 1



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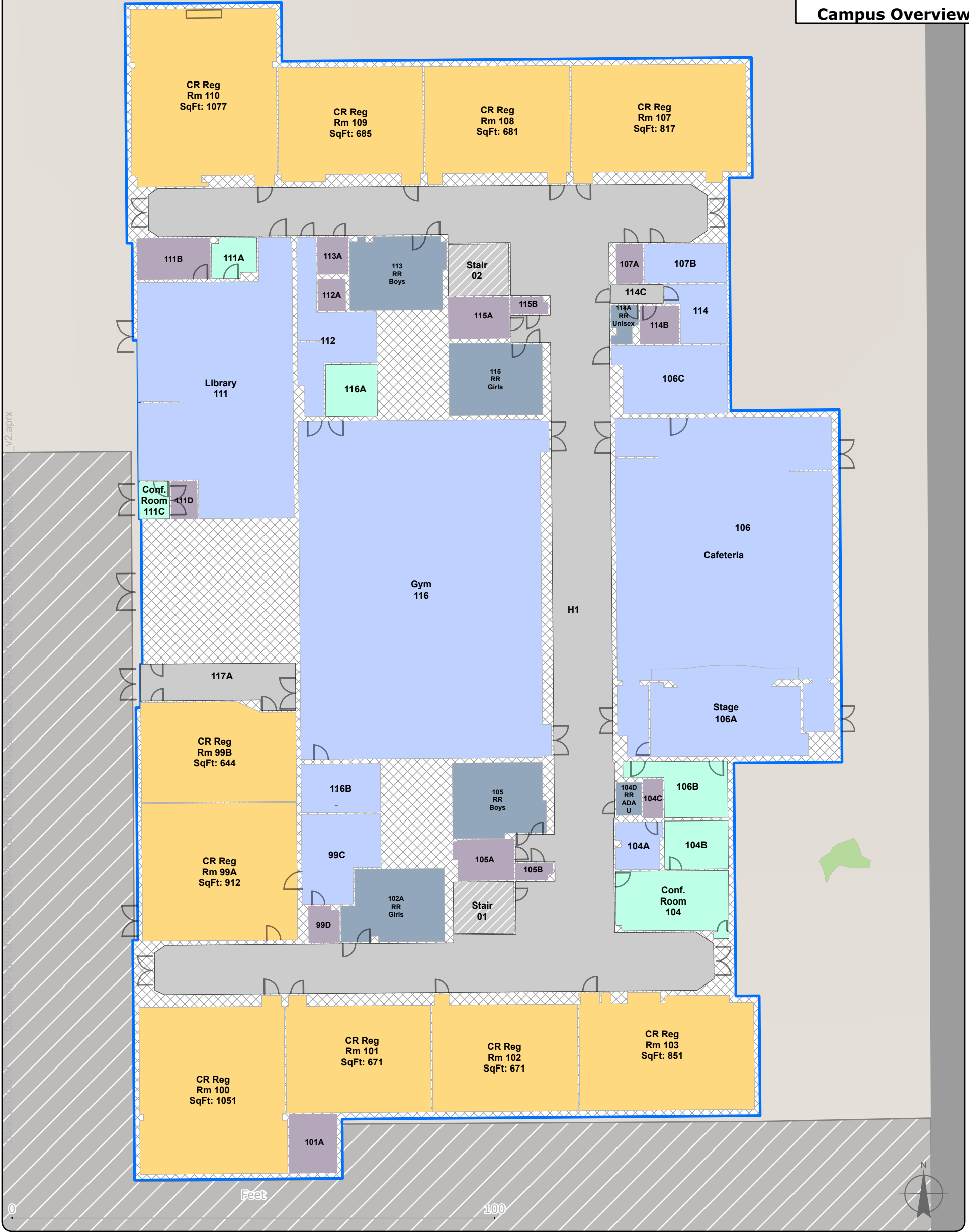
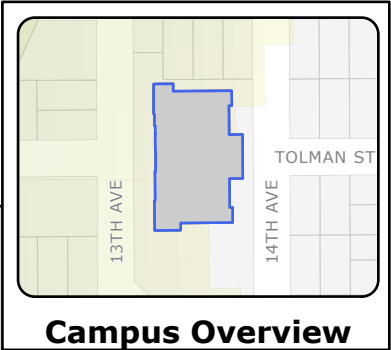


Space Use		School Grounds	
	Classroom		Campus Footprints
	Office		Athletic Field
	Rest Room		Playground: Paved
	Special Purpose		Playground: Unpaved
	Corridor		Streets
	Other		Doors
	Stairs/Elevator		

Total Number Of Rooms By Classification

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

LLEWELLYN: First Floor

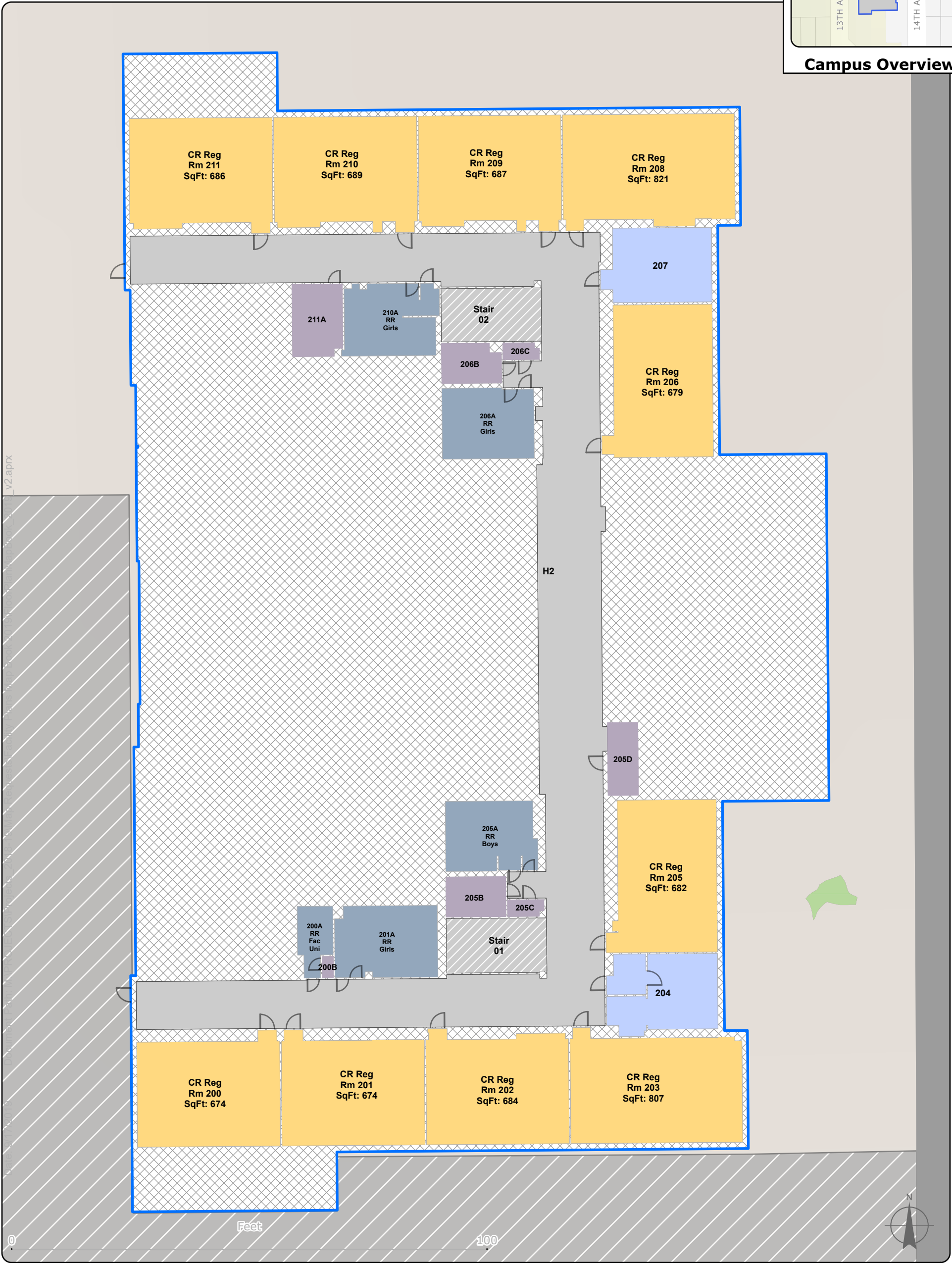
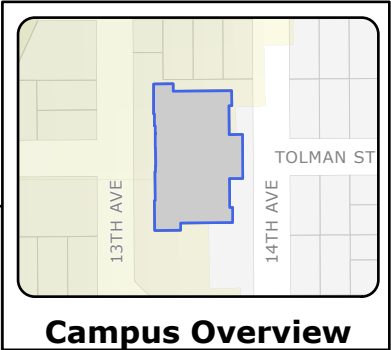















Space Use		School Grounds	
	Classroom		Campus Footprints
	Office		Athletic Field
	Rest Room		Playground: Paved
	Special Purpose		Playground: Unpaved
	Corridor		Streets
	Other		Doors
	Stairs/Elevator		

Total Number Of Rooms By Classification

Classrooms: 10	Special Purpose: 11
Office Spaces: 6	Storage: 12

LLEWELLYN: 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	

<u>Total Number Of Rooms By Classification</u>	
Classrooms: 10	Special Purpose: 2
Office Spaces: 0	Storage: 6