Plumbing & HVAC Assessment
Waterloo City Centre

For

THE CITY OF Waterloo

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1.0 Acknowledgement

DEI was retained by the City of Waterloo to review plumbing and HVAC systems at the Waterloo City Centre.

The general scope of the plumbing work involved mapping the existing sanitary and domestic water systems, providing comment on existing conditions, and proposing updates to address key issues.

The primary focus of the HVAC work involved a review of the ventilation effectiveness in identified meeting rooms and providing recommendations to improve effectiveness to meet an acceptable baseline. In addition, the HVAC work included a general review of the building system for heating, cooling, ventilation, and occupant comfort, with recommendations for improving general operation.

2.0 Information Obtained

Multiple site surveys were conducted during the investigation process. The information gathered in these investigations has been summarized and included in this report in tables and drawings. Some key items are identified directly in the body of this report. The owner also provided digital pdf documents of existing systems and equipment and building outlines.

3.0 Defined Acronyms

ACH – air changes per hour.

CCTV – closed circuit television.

DWV – drainage, waste, vent. This acronym is used for copper and plastic piping to indicate wall piping with wall thickness and composition intended for conducting sanitary sewage.

eACH – equivalent outdoor air changes per hour. This term is used for considering filtration effectiveness at removing viruses from air (i.e., COVID 19 reduction). This term is not applicable to code minimum outdoor air requirements (i.e., ASHRAE 62.1).

FDNE – Filter Droplet Nuclei Efficiency. This is a measure of the efficiency of removal of a specific virus based on the anticipated distribution of the virus in a range of droplet sizes, combined with filter efficiency at removing droplets of this size.

HEPA – high efficiency particulate air filters. HEPA rated filters remove more than 99.9% of particulates in the 0.3 micron range.

IAQ – indoor air quality – the definition of IAQ and use of IAQ for ventilation rates is defined in ASHRAE 62.1.

MERV – minimum efficiency reporting value. This is an established test method for reporting the efficiency of air filters.

OA – outdoor air. Fresh air direct from outside.

OAe – equivalent outdoor air. Equivalent outdoor air based on a combination of fresh outdoor air and filtered recirculation air. This is a

PVC – polyvinyl chloride. This is a type of plastic commonly used for construction of plastic pipe for use in plumbing systems.

UVGI – ultra-violet germicidal irradiation. This is the use of UV light, specifically UVC spectrum wavelengths, for killing of viruses.

XFR – trade-name used to indicate plenum rating for PVC pipe. Plenum rated pipe has low flame spread and smoke developed ratings.

4.0 Plumbing

4.1 System Investigation

Existing plumbing services were traced with a CCTV camera using a combination of site surveys and existing drawings. Where possible, existing routing was confirmed through site verification. Where existing systems are buried or concealed above gypsum ceilings, pipe routing was determined based on a combination of existing drawings, pipe scoping, and estimations.

Pipes smaller than 80Ø (3"Ø) were not scoped with CCTV due to equipment size limitations.

Drawings of the traced systems are included in the appendices of this report.

During the tracing and scoping of systems, notes were taken as to existing system quality and concerns. Comments regarding specific concerns are detailed in the following sections, along with recommendations for system improvements.

4.2 Water System Description

The domestic water system is primarily cold-water supply mains with distributed electric hot water tanks to serve individual fixtures or groups of fixtures. The hot and cold-water distribution piping is copper, and it appears to be in reasonable condition for most of the facility. Hot water heaters are not a significant portion of the building’s electrical load – there are very few showers, and most fixtures are lavatories which have low hot water demand.

Domestic cold water pipe runs are long. Pipe sizing is not generous based on length of piping runs, especially for a system that includes flush valve toilets and urinals. However, pipe sizing is acceptable based on fixture counts, and does not appear to be causing issues in high volume locations such as the central washroom stack.

Some fixtures on the 2nd floor of the William Street Wing have significant issues with 'sputtering' and low flow. These issues appear like signs of low water pressure or air in the pipework. However, building pressure is good and fixtures are relatively close to the building water entry, so building pressure is not likely the issue. And the issue does not decrease with use, so air in the line is also suspect. The sputtering is sometimes more noticeable on the hot water but is not isolated to the hot water system. Further diagnostics are required to determine the cause of the issue for these fixtures.

4.3 Sanitary Sewer and Storm Drain Description

The sanitary sewer main leaves the building below the ground floor at the south end of the building under the stack of central washrooms. The main size is 150mm diameter. Refer to plumbing drawings in Appendix D.

Four main sanitary sewer branches serve the building:

- A 100Ø sanitary stack serves the stack of central washrooms in the south of the building.
- A 100Ø sanitary main (approximately 1m deep below the parking structure) runs north in the central corridor of the Regina Street Wing to serve this wing.
- A 100Ø sanitary main runs north-east to serve William Street Wing. This main comes up from below grade near to gridline 14/F, adjacent to the underground parking, but is nowhere exposed in the parkade. Sanitary drains for fixtures on the 2nd and 3rd floors of the William Street Wing offset a long distance in the 1st and 2nd floor ceiling space to meet this connection.
- A 100Ø sanitary main picks up parkade drains and is routed to a sump pit. The sump pump discharges into the above grade sanitary main serving the ground floor.

The below ground sanitary mains appear to be in generally in good condition. Buried PVC pipe typically does not deteriorate and settling is usually the only issue that occurs after installation. Some smaller buried PVC branch piping at this site has been found to be problematic due to multiple changes in direction or other installation issues. Notable problematic underground branches are identified in this report.

Above ground sanitary mains are cast iron construction, some are in reasonable condition, and some are showing substantial wear. New branches to some of individual sinks are DWV copper pipe, and one main branch serving fixtures at the end of the William Street Wing is PVC. Below grade main branches and the sewer main leaving the building are PVC DWV.

The storm sewer main leaves south corner of the building below the ground floor slab beside the sanitary main. There is a long run of below grade storm up the Regina Street Wing and a shorter run along the William Street Wing following the general routing of the sanitary main branches. The rainwater leaders tend to drop close to HVAC trunk mains near each of the stairwells. Above ground storm mains are cast iron. Below ground mains are likely the same material as sanitary, though below ground storm mains were not camera scoped. There are no apparent active issues with the storm piping. It is not expected that the storm mains have deteriorated. Storm piping is generally maintenance free for 50 years.

4.4 Recommendation #1 – First Aid Washroom – 1st Floor Regina Street Wing

This two-piece washroom experiences frequent back-ups and is a regular maintenance issue. A scope with camera was used to survey the 80Ø branch sewer. The camera revealed a convoluted sewer routing with multiple bends/offsets and possibly routed through an abandoned floor drain trap. Review of the original drawings does not show this washroom, and the camera indicates perhaps poor planning at the time of installation. This washroom has frequent usage due to the adjacent wellness tenant and other city tenants.

Recommendation: Rework/replace the sanitary routing from the washroom to central sanitary main. This involves excavating/exposing the piping and providing new sanitary drain with minimal bends to connect existing washroom directly to existing sanitary main. Note: drawings were prepared to remedy this issue. Work was completed April 2022.

Opinion of probable cost: $20,000 (two fixture drains, excavation, and slab repair).

4.5 Recommendation #2 – Men's Washroom – 2nd Floor

There has been a re-occurring back-up in this washroom. The sanitary pipe plugs and waste backs up through the floor drain and has caused water damage to the space below. The camera revealed that a portion of the sanitary branch main serving this washroom is pitted and in poor condition. Roughness in sanitary pipework creates an opportunity for material to become trapped and start a blockage. The aged piping appears to be creating blockages in the branch piping before it connects to the vertical sanitary stack.

Urinals use less water than water closets and the high urine content is corrosive to metals. It is common to find accelerated wear of cast iron or copper waste pipes usually within 15m (50ft) downstream of urinals. The typical service life of metallic pipe in this accelerated corrosion zone is 20-30 years.

Also, in this washroom, the floor drain appears to connect to the main branch serving the water closets. For a washroom group that is experiencing issues with backups, it is best not to connect the drain between water closets.

Recommendation #2A: remove and replace the sanitary branch main from the water-closets to the vertical stack. Disconnect the floor drain and reconnect to the vertical stack as a second main.

Recommendation #2B: the sanitary branch from the urinals to the vertical main was not reviewed with camera, but it will be in poor condition due to the aggressive waste as discussed above. Remove and replace all sanitary waste piping serving this washroom, including the waste pipes from the urinals and lavatories.

Opinion of probable cost:

- Recommendation #2A: $25,000 (3 fixture drain rough-ins and fixtures (WCx2, FDx1), main branch, and drywall repair, trades will access primarily through one washroom)
- Recommendation #2B: $50,000 (9 fixture drain rough-ins and fixtures (WCx2, FDx1, URx3, LAVx3) and 3 domestic water reconnections at urinals, main branch, and drywall repair, trades will access plumbing through two washrooms)

4.6 Recommendation #3 – Women's Washroom – 1st Floor

The cast iron sanitary pipe serving the ground floor women's washroom appears to be badly pitted and in poor condition. Considering this item, and Plumbing Concern #2 above, the cast iron pipework serving this washroom appears to be at end of life.

Investigation from the adjacent men's washroom shows that the sanitary main leaving the building is PVC SDR and in relatively good shape. No changes are recommended for this portion of pipe.

Recommendation: replace the entire sanitary stack serving the central stack of washrooms, replace sanitary branch pipework serving all the fixtures in the central washroom core, and replace the sanitary branch pipework serving the 1st Floor central Women's Washroom.

Detailed coordination will be required between the user and the contractor to replace the central washroom stack. During portions of the replacement, all the washrooms in the central stack will be out of service.

Coordination to minimize downtime could look something like this:

1) Take ground floor washrooms out of service (multiple weeks) and replace the below ground piping.
2) Prepare access points in upper floor washrooms for removal, replacement of the central stack.
3) During a short, coordinated shutdown, replace the below grade sanitary main, remove and replace central stack, and reconnect existing branches on levels 2 and 3.
4) Patch up access points on upper floors and bring washrooms back into service.
5) Finish ground floor washroom below-grade work.
6) With ground floor washrooms still out of service, take 2nd floor washrooms out of service and replace drains.
7) Finish ceiling of ground floor washrooms and bring these washrooms back into service.

8) With 2nd floor washrooms still out of service, take 3rd floor washrooms out of service and replace drains.
9) Finish the ceiling of the 2nd floor washrooms and bring these washrooms back into service.
10) Finish the 3rd floor washrooms.

To facilitate ongoing operation of the building, washrooms could be taken out of service on one side of the central stack at a time. Proper sequencing could result in two washrooms being out of service at any one time, instead of 4 or 6. Regardless of coordination, shorter periods of temporary shutdown of the full stack will be required.

The opinion of probable cost is estimated for typical renovation work. Detailed coordination may double the cost of the installation.

Opinion of probable cost: $250,000.00 (45 drain rough-ins and new fixtures and domestic water reconnections, drywall repair, excavation, concrete repair). Opinion of probable cost with added coordination: $500,000.00.

4.7 Recommendation #4 – Washroom – 2nd Floor William Street Wing

The sanitary system serving the 2nd floor washroom at the north-east end of the William Street wing is a frequent maintenance item. This washroom is at the end of a very long run of horizontal cast iron pipe – more than 46m (150ft) – that picks up no other fixtures. A long horizontal run with very low usage can is problematic as waste solids are left behind by water flow and will often dry to pipe. Recently, a failure of a portion of this pipe created a leak and caused damage to the ground floor ceiling – this pipe and ceiling were repaired prior to the site investigation. This pipe is routed through structural I-beams for the entire length and does not appear to have sufficient downward slope.

Recommendations: replace 80Ø (3"Ø) cast iron pipe with 100Ø (4"Ø) PVC-XFR. Review inverts and possibility of routing with available ceiling space. By code 100Ø pipe can be run at a less 1% slope whereas 80Ø pipe requires minimum 2% slope. Cast iron will begin to corrode slowly after installation and the surface will become rougher whereas PVC pipe will maintain smooth inside surface for longer promoting fewer backups.

If this does not fully eliminate the issue, then a timed water valve could be installed to induce artificial flow in the pipe. The installation of a timed valve is not compliant with water savings directives of the code. It is a solution for problem fixtures like this one.

Opinion of probable cost: $17,500.00 (replace approximately 125 ft of pipe with 4"Ø PVC-XFR, make connections to existing, and repair some drywall).

Structural review and modification: Detailed measurements of pipe routing should be completed prior to proceeding with this item. Where 4"Ø pipe cannot fit through existing holes, larger holes may be required in I-beams. Structural review, and minor structural modifications may be required. Additional cost is estimated at $500.00 per beam for structural investigation and engineering design, and $500 to $1,000.00 per beam for structural work.

4.8 Recommendation #5 – Mayor's Washroom – 3rd Floor William Street Wing

The sanitary system serving the mayor's washroom is a frequent maintenance item. The branch serving the mayor's washroom is 80Ø (3") cast iron pipe that runs 20m (65 ft) horizontal at approximately 1% grade before connecting a larger 100Ø (4"Ø) main that picks up multiple other fixtures. The length of this pipe is routed through holes cut in the middle of structural I-beams. This pipe was investigated by camera, and the piping appears to be in good condition.

Two issues may be leading to the backups: (1) the slope is not sufficient – code minimum is 2% 80Ø sanitary pipe; (2) this is an isolated washroom at the end of a long branch, and flow frequency may not be sufficient.

Recommendations #1: replace cast iron pipe with fire rated PVC (PVC-XFR) and increase pipe size to 100Ø (4"Ø) which is allowed by code to be installed at 1%.

Recommendation #2: add the extra water flush (timed water valve) to the main as recommended for Plumbing Concern #4.

Opinion of probable cost: $10,000.00 (replace approximately 65 ft of pipe with 4"Ø PVC-XFR and make connections to existing)

Structural review and modification: Detailed measurements of pipe routing should be completed prior to proceeding with this item. Where 4"Ø pipe cannot fit through existing holes, larger holes may be required in I-beams. Structural review, and minor structural modifications may be required. Additional cost is estimated at $500 per beam for structural investigation and engineering design, and $500 to $1000 per beam for structural work.

4.9 Recommendation #6 – The Studio – 3rd Floor William Street Wing

There is some concern with washroom backups in "The Studio" (the third-floor fitness area). Sanitary pipework was investigated by camera. All the drainage piping serving The Studio fixtures is PVC-XFR for the first 10' (3.0m). Branches to multiple fixtures are typically 3"Ø and the central main branch serving this area is 4"Ø. The sanitary main transitions to cast iron downstream of The Studio. From camera inspection, the pipework appears in good condition, but the camera could not make it past consecutive 45° elbows at gridline 15 between J/K. These back-to-back 45° elbows meet minimum code requirements but may be a cause for some sewage backups.

Recommendation: revise piping to add a portion of straight pipe between the current back-to-back 45° elbows at gridline 15-J/K and install a line clean-out for assess to troublesome backups. If this does not fix the problem, replace cast iron piping with PVC-XFR which has a smoother inside surface, especially as the pipe ages.

Opinion of probable cost: $7,500.00 (replace approximately 35 ft of cast iron pipe with 4"Ø PVC-XFR in existing building, make connections to existing, add line clean-out).

4.10 Recommendation #7 – Kitchenette Sink – 3rd Floor Regina Street Wing

Sewer pipework from a kitchenette sink on the 3rd floor of the Regina Street Wing is showing water damage on the ceiling below and currently has a drip pan under the pipe. It is not certain whether the pipe is leaking, or whether this moisture is condensation from the drainage pipe in the ceiling space. Condensation on copper pipes is not always an issue but can occur on frequently used pipes with high cold water flows.

Recommendation: replace copper DWV pipe with PVC-XFR and insulate the full length of pipe until it turns vertical and drops in the wall cavity of the 2nd floor.

Opinion of probable cost: $3,500.00 (replace approximately 35 ft of copper pipe with 1.5"Ø PVC-XFR, in existing building, make connections to existing, and insulate)

Note that another leak was discovered above the municipal By Law office. The leak could not be found during site visits. However, if the leak re-occurs, similar treatment is recommended for this location – identify leaking or sweating pipe and replace with PVC-XFR

4.11 Opinion of Probable Cost – Plumbing

Opinions of probable costs for the HVAC Recommendations are summarized in the following table.

Table 1: Opinion of Probable Cost for Plumbing

	Recommendation	Opinion of Probable Cost	Notes
#1	First Aid Washroom – 1st Floor Regina St Wing	$20,000	This work already complete.
#2	Men's Washroom 2nd Floor – Partial Replacement Full Fixture Replacement	$25,000 $50,000	3 fixtures and drains, drywall, etc. 9 fixtures and drains, drywall, etc.
#3	Central Washroom Core – Sanitary Drain Replace Detailed Coordination to Maintain Facilities	$250,000 $500,000	40-45 fixtures, drains, drywall, etc. Overtime, multiple staging's, high level of coordination.
#4	Washroom 2nd Floor William St Wing	$17,500	125 ft 4"Ø PVC-XFR
#5	Mayor's Washroom – 3rd Floor William St Wing	$10,000	65 ft 4"Ø PVC-XFR
#6	The Studio – 3rd Floor William St Wing	$7,500	35 ft 4"Ø PVC-XFR
#7	Kitchenette Sink – 3rd Floor Regina St Wing	$3,500	35 ft 2"Ø PVC-XFR

5.0 Heating Ventilation and Air Conditioning (HVAC)

5.1 System Description

The building is served from four 60 ton rooftop custom built air handling units (AHU), two serving the Regina St Wing and two serving the William St Wing. One additional 20 ton rooftop AHU is dedicated to the serve the Council Chambers. Room sub-zoning or space sub-zoning for the 60 ton units is provided, primarily, by series configuration fan powered VAV Boxes. Some spaces are served by standard VAV boxes; some spaces are served by VVT style control dampers (no airflow sensing grid). No heat is provided in the central air handlers, or at the any of the VAV boxes. Stage one of the air conditioning system is free cooling using outdoor air. All AHUs are equipped with direct expansion cooling coils/compressors to provide mechanical cooling when necessary.

Perimeter hydronic heat provides the heating for the building. The hot water loop is heated with gas fired boilers. Each boiler has an input capacity of 1,787 MBH and an output capacity of 1,501 MBH. The total plant output capacity is 3,002 MBH. Heat is delivered by two 300 GPM circ pumps.

Each 60 ton AHU includes MERV-8 pre-filters and MERV-13 final filters upstream of the cooling coil as indicated in shop drawings from 2011 system upgrade. The 20 ton Council Chambers AHU filter rack allows 2" throwaway filter as standard, and can accommodate up to a 4" filter. Based on available external static pressure, use of MERV-8 filters is possible. Factory consult would be required prior to using MERV 10 or MERV 13 filters.

The building HVAC system is fitted with electric humidification units that provide humidification directly to supply air ductwork downstream of the air handling units. The City of Waterloo has indicated that these humidifiers are operational but are currently turned off.

5.2 HVAC Review Scope and Summary of Findings

The scope of the report was to review/measure the exact ventilation rates and airflow for 9 meeting rooms and the council chambers to determine the quality of the ventilation to the spaces while considering the latest ASHRAE Epidemic Task Force guidelines and best practices for infection control in office environments.

A general review of the overall system was also to be conducted to determine the feasibility of increasing overall filtration or ventilation levels.

5.2.1 ASHRAE Epidemic Task Force – Viral Load Reduction and Filtration Analysis for Covid-19

To address concerns of Covid-19, the ASHRAE Epidemic Task Force prepared and documented several recommendations. The Building Readiness[1] document uses room flushing rates of outdoor air and indicates a reduction in viral load as the air change rate increases:

[1] ASHRAE Epidemic Task Force, 2022, Part 2 – Epidemic Conditions in Place, Page 25 – Flushing Air Changes Calculations for Well-Mixed Spaces, ASHRAE Epidemic Task Force: Building Readiness | Updated 5-17-2022 https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf

Table 2: Viral Load Reduction by Outdoor Air Changes

Outdoor Air Changes/Hour	Remaining Viral Load After 1 hr
1	37%
3	5%
5	1%
7	0.1%

Recirculation of air through a MERV rated filter decreases viral load and can be considered a partial outdoor air change. The effectiveness of removal for a specific virus depends on two factors: (1) prevalence of that virus in various droplet sizes; and (2) filter efficiency for each of those droplet sizes. The total combined efficiency is referred to as the Filter Droplet Nuclei Efficiency (FDNE). [2]

According to the ASHRAE Epidemic Tack Force, a MERV-13 filters provides 86% for Covid-19. Essentially, a MERV-13 filter removes 86% of airborne particles (droplets) carrying Covid-19.

Table 3: Covid-19 Filter Droplet Nuclei Efficiency (FDNE) of Various Filters

MERV Rating	FDNE (May 17, 2022 values) [3]
4	16%
7	36%
8	49%
10	67%
13	86%
HEPA	99.9%

Outdoor air is considered free of viral load, so when filtered return air is combined with outdoor air, the viral load is further reduced. For example, the following equation describes a system with a MERV-13 return air filter operating at 20% outdoor air and 80% return air. The net result is 88.8% equivalent outdoor air.

(20% OA) + (80% x 86% FDNE) = 88.8% equivalent outdoor air (OA) ratio in supply air

[2] ASHRAE Epidemic Task Force, 2022, Part 2 – Epidemic Conditions in Place, Page 44 – Filter Droplet Nuclei Efficiency / Particle Size Expectations, ASHRAE Epidemic Task Force: Building Readiness | Updated 5-17-2022 https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf

[3] A previous version of ASHRAE Epidemic Task Force: Building Readiness (April 27, 2021), used the Influenza A profile (Anticipated Distribution of Virus - 20% E1, 29% E2, 51% E3) as the model profile for Covid-19. An updated version of the document (May 17, 2022, pages 40-44) recommends a specific Covid-19 profile: 30% E1, 30% E2, 40% E3.

ASHRAE Epidemic Task Force guidelines suggest implementing pre and post occupancy purges of the spaces. In this purge mode the AHUs operate at higher outdoor air rates, potentially at the cost of space temperatures/humidity control. These purges flush the space of contaminants. It is important to stop the pre-occupancy purge to provide adequate time for the building systems perimeter heat, AHU air conditioning) to bring the space back to occupied temperatures for the start of the workday. Energy cost must be assessed before using purge mode operation.

ASHRAE guidelines suggest that the relative humidity be maintained at 40% to 60% to combat the spread of infections and virus and to maintain and occupant comfort. Existing humidifiers can maintain humidity in winter months when dry outdoor air will drop humidity levels below 40%; however, existing humidifiers are currently turned off.[4]

Research has shown UVC lamps to be effective at sterilizing or killing viruses. The addition of UVC lamps to the airstream can provide an additional layer of protection. ASHRAE has provided guidance on recommended irradiation rates. Peer reviewed COVID specific studies regarding optimal irradiation and UVC implementation continue to develop. While solutions exist for UVC disinfection of airstreams, this report is focused on modifications to the currently installed ventilation system.

5.2.2 Existing System Analysis and Evaluation Criteria

For the remainder of this report, ventilation effectiveness is analyzed based on equivalent outdoor air changes. Equivalent outdoor air changes are determined based on the equivalent outdoor air ratio of supply air, supply air distribution effectiveness, and air changes per hour in the space.

Equivalent outdoor air ratio is defined in the previous section. Distribution effectiveness is defined in ASHRAE 62.1 and described as 80% for spaces with ceiling supply and ceiling returns when supply temperature is relatively close to room temperature. Air changes per hour are defined as the number of times that supply air will fill the space volume in one hour (ACH = cfm*60/cubic ft).

The following sample equation would determine equivalent outdoor air changes for a space with 88.8% equivalent outdoor air ratio (OAe) in supply air, 80% distribution effectiveness, and 10 total air changes per hour.

(88.8% OAe) x (80% effectiveness) x (10 ACH) = 7.1 Equivalent Outdoor ACH (eACH)

A qualitative criterion is required to comment on the effectiveness ventilation. For this report the criterion will be based on the equivalent outdoor air changes and viral load reduction. These qualitative values of ‘ok’, ‘good’, and ‘great’ are not based on an established ASHRAE standard. These qualitative terms equate, respectively, to approximately 95%, 99%, and 99.9% viral load reduction.

[4] These humidifiers represent larger electric loads (H1 = 61.2 kW, H2 = 61.2 kW, H3 = 10.2 kW). Re-energization of these units is relatively simple provided the existing electrical infrastructure has not been modified or removed.

Table 4: Qualitative Criterion for Assessment of Ventilation Effectiveness

Equivalent Outdoor ACH	Remaining Viral Load After 1 hr	Qualitative Criterion
Less than 3 ACH	More than 5%	Poor
3 ACH or more	5% or less	Ok
5 ACH or more	1% or less	Good
7 ACH or more	0.1% or less	Great

5.2.3 Review of systems for practical operation (human comfort, system control, and efficiency)

While targeting outdoor air rates and equivalent outdoor air changes, the recommendations provided in this analysis also consider effects on occupant comfort, system controls, and overall building efficiency.

In our review of this building, we have come to the determination that it is not possible to increase outdoor air rates in this building for the following two reasons:

1. There is no heat in the AHUs and no reheat in the system VAV boxes. The inability to heat the outdoor air before supplying it to the building means that increasing the outdoor air rate beyond the current set point will result in cold spaces and drafts being felt by occupants of the building.[5] Typical VAV reheat applications use supply air to the reheat boxes at 12.8°C (55°F).
2. There is not enough air conditioning capacity in the AHUs to substantially increase the outdoor air rate in peak summer conditions summer without adversely affecting both space temperature and humidity. The result will be significant occupant complaints,[6] and increased power consumption.

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[5] Typical VAV reheat applications supply cool air to the VAV boxes somewhere between 12.8°C (55°F). The cool air provides cooling where required. In spaces with smaller cooling load the VAVs decrease the airflow, or in a VAV reheat system is added to heat the cool air. Direct supply of 55°F will feel like a cold draft in winter, especially in spaces with cold window surfaces 'radiating' cold.

Also, since this building has no direct heat for the supply air, the heating strategy relies on air mixing (pulling heat from the return air) to heat the supply air. Using 22°C return air temp and minimum 55°F supply air temperature, the current strategy can operate down to -8.8°C at 30% outdoor air damper position. As noted, this 55°F supply air will still feel cold in many spaces. At the design temperature of -21°C (-6°F) the roof-top AHUs are limited to maximum 21.5% outdoor air ratio. At a more moderate supply air temperature of 15.6°C (60°F) the outdoor air damper position is limited to maximum 30% at 0°C – below this temperature the damper position must decrease.

Hydronic perimeter and plenum heating are responsible for maintaining the return air temperature (indoor air temperature). The only way to increase supply air temperature is to increase the indoor air temperature. Increasing outdoor air rates in heating season will also increase the load on the central boilers.

[6] The existing cooling system is well suited to meet cooling load a standard outdoor air ratio, approximately 30% OA. In cooling season high temperature often aligns with high humidity and latent loads (dehumidification) will absorb a portion of the cooling capacity, approximately 30%. In Waterloo, summer design temperature is 29°C (84.2°F), but air temperatures on the roof, where fresh air intakes are located, can climb higher and systems typically use 35°C (95°F) intake are temperature. Based on 29°C to 35°C intake air temperature, the system is limited to between approximately 30% and 50% outdoor air ratio. Also, at higher outdoor air ratios the dehumidification effect (due to recirculating air across the cooling coil) decreases. Indoor air humidity will rise leading to decreased occupant comfort.

5.2.4 Fan Powered VAV System Findings

In a VAV system utilizing series fan powered VAV boxes (FPVAV) there are two airflows of importance:

1. Primary Airflow – The airflow from the AHU, which consists of both outdoor air and filtered recirculated air. In this building, the recirculated air is passed through a MERV 8 pre-filter followed by a MERV 13 filter.
2. Total Airflow – The airflow measured at the terminal devices/diffusers in the space. This airflow is the primary airflow, plus air that has been locally recirculated from the ceiling plenum. The recirculated air from the room is drawn through the FPVAV box by the fan that is part of the assembly. Typically, a filter attached to the FPVAV box provides some air cleaning. The filters on site appeared to be either non-MERV rated or possibly MERV 8. Existing filters are not higher than MERV 8 rated.

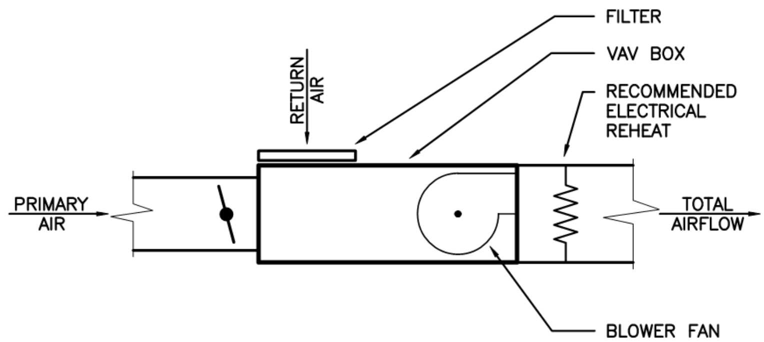

Figure 1 Fan Powered VAV Box

During the preliminary stage of airflow investigation, the filters in the series flow FPVAV boxes were found to be completely blocked. Based on the quantity of dust accumulated, it appears that the filters have not been changed for a substantial time – more than a year. When the dirty filters were removed, total airflow rates increased substantially (up to triple), and total airflow more closely approached design values.

This substantial increase in airflow indicates that the rooms were receiving only the primary airflow supply air from the AHU. Very little air was being locally recirculated airflow from the FPVAV boxes, and the primary air damper was partially closed at the time of initial investigation.

With primary air damper full open, and with dirty filters removed, the site investigation revealed that total airflow is close to primary airflow (+/- 20%). With clean filters and proper balancing, the total airflow should always match or exceed the primary airflow. Typically, primary airflow will be close to total airflow when the primary air damper full open.

5.2.5 Fan Powered VAV – Effects of Local Filter Upgrades

One option considered is the addition of higher rated filters to fan powered VAV boxes. Improving the FPVAV filters would increase the level of local air filtration when cooling demands are met and the FPVAV is operating with reduced primary air – for example, during periods of low occupancy.

All values in the FPVAV filtration tables are based on measured FPVAV recirculation rates measured with dirty filters removed. The Cafeteria FPVAV fan was not operable at the time of investigation, so primary airflow is used instead of recirculation airflow. Air changes are calculated based on room volume and an 80% distribution effectiveness.

Table 5: Equivalent OA Rates with FPVAV Filtration – 0% Primary Air, 100% FPVAV Recirc

Room Name	Measured Total Airflow (cfm)	Measured Total (ACH)	Equivalent Outdoor Air Changes MERV-7	Equivalent Outdoor Air Changes MERV-8	Equivalent Outdoor Air Changes MERV-10	Equivalent Outdoor Air Changes MERV-13
Cafeteria (L2)	600	8.2	2.4	3.2	4.4	5.6
Small Seagram MTG Rm (L2)	254	9.7	2.8	3.8	5.2	6.7
Hilliard MTG Rm (L2)	295	12.0	3.5	4.7	6.4	8.3
Neufeld MTG Rm (L2)	627	13.3	3.8	5.2	7.1	9.1
Large Seagram MTG Rm (L2)	703	11.1	3.2	4.4	6.0	7.6

The first FPVAV filtration table assumes 0% primary air for demonstration purposes. For FPVAV systems, the minimum primary air can go down to 0% while the fan provides 100% local recirculation. At the Waterloo City Centre, controls to not currently limit the minimum primary airflow rated for the FPVAVs.

Typical non-fan powered VAV system controls will limit the minimum primary air to 30%. This ensures that at least some outdoor air is being continuously introduced to the space. The following table represents the FPVAV system if primary air is limited to no less than 30%. Note that primary air includes MERV-13 filtration and outdoor air, so the introduction of cleaner primary air increases the equivalent outdoor air rate.

Table 6: Equivalent OA Rates with FPVAV Filtration – 30% Primary Air, 70% FPVAV Recirc

Room Name	Measured Total Airflow (cfm)	Measured Total (ACH)	Equivalent Outdoor Air Changes MERV-7	Equivalent Outdoor Air Changes MERV-8	Equivalent Outdoor Air Changes MERV-10	Equivalent Outdoor Air Changes MERV-13
Cafeteria (L2)	600	8.2	3.4	4.0	4.9	5.7
Small Seagram MTG Rm (L2)	254	9.7	4.1	4.8	5.8	6.8
Hilliard MTG Rm (L2)	295	12.0	5.0	5.9	7.1	8.4
Neufeld MTG Rm (L2)	627	13.3	5.6	6.5	7.9	9.3
Large Seagram MTG Rm (L2)	703	11.1	4.6	5.5	6.6	7.8

As can be seen in the table above, the existing FPVAV filters – MERV-7 or less – provide little filtration for Covid-19 viral load reduction. For the existing system, the FPVAVs with MERV-7 filtration and damper in 30% position will provide 'ok' ventilation. Plugged filters, or filters rated less then MERV-7 will provide poor equivalent outdoor air changes. In theory, the installation of a MERV-13 filters would provide great equivalent outdoor air changes; however, filter racks would have double in size to mitigate a substantial increase in static pressure loss. There is not room for such filter modifications, and the filtration gains are marginal. MERV-8 or MERV-10 filtration provides reasonable improvements to equivalent outdoor air change rates.

5.2.6 Detailed airflow investigation in nine meeting rooms – Outdoor Air ACH and eACH

Air Audit was retained by the City of Waterloo to perform airflow testing in nine meeting rooms. These results are summarized in the following tables and in Appendix A in full detail.

The second last column in the following table records measured primary air changes per hour. Primary air is equivalent to total air for VAV/VVT dampers without fan power – all primary air through the damper is delivered to the supply air diffusers. For FPVAV boxes with primary air damper in fully open position, the primary airflow rate will be equal to the total airflow, or in some cases it is somewhat less. Removal of dirty filters will affect the total airflow but should not affect primary airflow. Measurements for the following table were made with plugged filters removed.

Table 7: Measured Primary and Total Airflows Meeting Rooms

Room Name	Zone Control Equipment	Measured Total Fan Assisted Airflow (cfm)	Design Primary Airflow (cfm)	Measured Primary Airflow (cfm)	Measured Primary Air Changes / Hr
Erb Meeting Rm (L3)	VVT (x3)	-	Not known	1,884	16.5
Connie Lounge (L3)	VVT (partial)	-	Not known	784	16.7
Meeting Rm (L3)	VVT (partial)	-	Not known	246	7.9
Cowan MTG Rm (L3)	Direct Connect	-	Not known	104	5.1
Cafeteria (L2)	Series FPVAV	Fan not working	816	424	5.8
Small Seagram Rm (L2)	Series FPVAV	254	254	233	8.9
Hilliard MTG Rm (L2)	Series FPVAV	295	197	212	8.6
Neufeld MTG Rm (L2)	Series FPVAV	627	572	551	11.7
Large Seagram Rm (L2)	Series FPVAV	703	600	585	9.2

Table Notes:

1. VVT (x3) indicates a system served by three separate VVT style dampers
2. VVT (partial) indicates a room that is served by a VVT style damper that also serves an adjacent space
3. VVT style dampers have read-only hot-wire airflow sensor with no accurate airflow sensing grid.
4. Direct connect indicates a zone that is directly connected to a supply main with no zone control
5. Series FPVAV is a series fan powered VAV box with sensing grid
6. Measured airflows are values verified on site April 7, 2022 by Air Audit. See Appendix A.

The total airflow is approximately 8 to 9 ACH for four of the meeting rooms. Two meeting rooms are slightly lower at 5 ACH, one is higher at almost 12 ACH, and two are higher than 16 ACH. However, these numbers are misrepresentative as the measured primary airflow is only achieved when the VAV damper is open to provide air conditioning to the room. When cooling is not required in FPVAV systems the primary airflow will be substantially lower, possibly none. For FPVAV systems, the bulk of the air changes will be locally recirculated from the ceiling plenum. No air is locally recirculated in VVT systems – total airflow equals primary airflow. When cooling is not required for in VVT systems, the damper is closed to minimum position, typically 30%.

The estimated equivalent outdoor air change rates for each of the meeting rooms are tabulated below using only the primary airflow values. Minimum and maximum primary air CFM rates are from the Building Automation System setpoints.

The outdoor air rate for the equivalent air-change analysis is 10% outdoor air. During summer, and during periods of moderate outdoor air temperatures, the outdoor air rate will be much higher than 10% as the air handler controls take advantage of free cooling. However, the rooftop HVAC units are fitted with a minimum outdoor air damper position of approximately 10% so this is used in the analysis. Note that due to the high degree of filtration, the outdoor air percentage actually has very little effect on equivalent outdoor air changes (eACH).

Table 8: Room Air Changes with VAV Dampers in Minimum Position

Room Name	Zone Control	Primary Air ACH	Equivalent Outdoor ACH*	Ventilation Quality	Equiv ACH with FPVAV Filter **	Ventilation Quality
Erb Meeting Rm (L3)	VAV Min Position	4.8	3.4	Ok	-	-
Connie Lounge (L3)	VAV Min Position	4.3	3.0	Ok	-	-
Meeting Rm (L3)	VAV Min Position	5.7	4.0	Ok	-	-
Cowan MTG Rm (L3)	None	5.1	3.6	Ok	-	-
Cafeteria (L2)	FPVAV Min Position	0	0	Poor	3.2	Ok
Small Seagram Rm (L2)	FPVAV Min Position	0	0	Poor	3.8	Ok
Hilliard MTG Rm (L2)	FPVAV Min Position	0	0	Poor	4.7	Ok
Neufeld MTG Rm (L2)	FPVAV Min Position	0	0	Poor	5.2	Good
Large Seagram Rm (L2)	FPVAV Min Position	0	0	Poor	4.4	Ok
*Equivalent Outdoor ACH assumes that outdoor air damper at rooftop HVAC unit is 10% open **Equivalent Outdoor ACH considering additional benefits of MERV-8 FPVAV filtration.						

For FPVAV controlled zones the minimum primary air damper position is 0%. Zero primary air provides zero equivalent outdoor air changes, and ventilation quality is poor. The last two columns in the table consider the additional benefit of air circulating through the FPVAV filter – minimum MERV-7 is considered in this table. With the added benefit of a MERV-8 filter on the FPVAV, air quality ranges from poor to ok.

The VVT style systems (Erb, Connie), and the standard fan-less VAV systems (L3 Meeting, Cowan), have pre-set non-zero minimum positions. The Cowan MTG room has no form of control, so air flow is constant. With VAV damper in minimum position, the air quality is ok, but not good or great for all meeting rooms without FPVAVs.

Table 9: Room Air Changes with VAV Dampers in 100% Open Position

Room Name	Zone Control	Primary Air ACH	Equivalent Outdoor ACH*	Ventilation Quality	Equiv ACH with FPVAV Filter **	Ventilation Quality
Erb Meeting Rm (L3)	VAV Min Position	16.5	11.5	Great	-	-
Connie Lounge (L3)	VAV Min Position	16.7	11.7	Great	-	-
Meeting Rm (L3)	VAV Min Position	7.8	5.5	Good	-	-
Cowan MTG Rm (L3)	None	5.1	3.6	Ok	-	-
Cafeteria (L2)	FPVAV Min Position	8.2	5.7	Good	8.9	Great
Small Seagram Rm (L2)	FPVAV Min Position	8.9	6.2	Good	9.4	Great
Hilliard MTG Rm (L2)	FPVAV Min Position	8.6	6.0	Good	9.0	Great
Neufeld MTG Rm (L2)	FPVAV Min Position	11.7	8.2	Great	12.3	Great
Large Seagram Rm (L2)	FPVAV Min Position	9.2	6.5	Good	9.7	Great
*Equivalent Outdoor ACH assumes that outdoor air damper at rooftop HVAC unit is 10% open. **Equivalent Outdoor ACH considering additional benefits of MERV-8 FPVAV filtration.						

With the VAV dampers in fully open position, the equivalent outdoor air rate for all VAV controlled zones is 'good' (above 5 ACH) or even 'great' (above 7 ACH). However, VAV dampers will rarely be in a fully open position unless there is significant heat load in the room.

Table 10: Room Air Changes with VAV Dampers in 50% Open Position

Room Name	Zone Control	Primary Air ACH	Equivalent Outdoor ACH*	Ventilation Quality	Equiv ACH with FPVAV Filter **	Ventilation Quality
Erb Meeting Rm (L3)	VAV Min Position	8.2	5.8	Good	-	-
Connie Lounge (L3)	VAV Min Position	8.4	5.8	Good	-	-
Meeting Rm (L3)	VAV Min Position	3.9	2.7	Poor	-	-
Cowan MTG Rm (L3)	None	5.1	3.6	Ok	-	-
Cafeteria (L2)	FPVAV Min Position	4.1	2.9	Poor	4.6	Ok
Small Seagram Rm (L2)	FPVAV Min Position	4.5	3.1	Ok	5.2	Good
Hilliard MTG Rm (L2)	FPVAV Min Position	4.3	3.0	Ok	5.7	Good
Neufeld MTG Rm (L2)	FPVAV Min Position	5.8	4.1	Ok	7.0	Good
Large Seagram Rm (L2)	FPVAV Min Position	4.6	3.2	Ok	5.7	Good
*Equivalent Outdoor ACH assumes that outdoor air damper at rooftop HVAC unit is 10% open **Equivalent Outdoor ACH considering additional benefits of MERV-8 FPVAV filtration.						

Finally, we consider the ventilation quality at a moderate VAV operating point – 50% open. With VAV damper in 50% open position, most of the non-FPVAV zones experience ventilation quality ranging from poor to good. Most FPVAV zones experience 'ok' ventilation quality with damper in minimum position – ventilation quality increases to 'good' for most FPVAV zones when the added benefits of a MERV-8 filter are considered.

The Cowan meeting room is currently served directly off the supply air main. There is no VAV control, so supply air is constant.

Based on the above analysis, ventilation quality in the meeting rooms is ok, but not good, when VAV dampers are in minimum position.[7] In zones with FPVAV boxes, ventilation quality is poor, and only moderately improves if upgrade to MERV-8 filtration on the FPVAV is considered. Ventilation quality is good, and even great, when VAV damper in fully open position, but this is not typical operation.

By increasing minimum damper position to 50%, the ventilation rates can be elevated to an 'ok' for most meeting rooms. Revising the minimum VAV damper position to 50% decreases space temperature control – this will result in overcooling at most times for all these rooms. Operationally, an 'occupied' setting could be added, and the VAV minimum position could be reset to 50% only when occupied. The room will still experience overcooling, but the effects will be lessened. Addition of electric reheat to the FPVAV boxes would permit the primary outdoor air damper position to be increased while maintaining control of room temperature.

Finally, increasing the quality of filters on the FPVAV VAV boxes does increase ventilation quality. However, the FPVAV boxes are not necessarily designed to operate at the increased static, the filter racks are too small to accept MERV-8 filters, and in two of the 5 cases, the existing filter racks are very difficult to access. Increasing to MERV-8 filters on the filter racks would require detailed design, and likely replacement of the FPVAV for models with higher static fans. Instead of modifying existing FPVAV boxes, a better option is to install new dedicated single room air purification systems. This option is discussed in HVAC Recommendation #7.

5.2.7 Detailed airflow investigation in nine meeting rooms – ASHRAE 62.1 Consideration

The table below tabulates the required ASHRAE 62.1 ventilation rate for the meeting rooms. The ventilation rate includes both VAV damper in minimum and in maximum position. With VAV damper in minimum position, none of the spaces meet ASHRAE 62.1 outdoor air requirements. The final column of the table indicates the minimum VAV position required to meet ASHRAE 62.1 when the room is occupied.

[7] A typical VAV system will often operate close to minimum position unless a there is a significant heat load in the room, such as a high occupancy.

Table 11: ASHRAE 62.1 Outdoor Airflow Analysis for Meeting Rooms

Room Name	ASHRAE 62.1 Min Required Outdoor Air (cfm)	OA Rate with VAV Damper in Min Position (cfm)	OA Rate with VAV Damper in Max Position (cfm)	Min VAV Damper Position to Meet ASHRAE 62.1
Erb Meeting Rm (L3)	184	78	565	33%
Connie Lounge (L3)	99	29	235	42%
Meeting Rm (L3)	66	25	74	90%
Cowan MTG Rm (L3)	61	31	31	N/A
Cafeteria (L2)	169	0	180	94%
Small Seagram Rm (L2)	63	0	70	91%
Hilliard MTG Rm (L2)	63	0	64	99%
Neufeld MTG Rm (L2)	87	0	165	53%
Large Seagram Rm (L2)	120	0	175	68%

Note that the values in the table assume that the AHU is operating at 30% outdoor air. The minimum outdoor air damper position currently set to approximately 10%. However, at 10% outdoor air, none of the meeting rooms will be close to meeting ASHRAE 62.1 outdoor air requirements. A minimum outdoor air position of 30% is somewhat high, but not unreasonable. This will provide more free cooling when free cooling is an issue but will also mean that more heat must be introduced into the system during cold outdoor temperatures.

Also, as discussed elsewhere, increasing the minimum VAV damper position will lead to overcooling of the space. Some form of zone reheat is recommended at the VAV box itself.

ASHRAE 62.1 does not currently include any simple credit for filtration quality.

ASHRAE 62.1 does have to methods for determining minimum outdoor air rates in a mechanically ventilated building. The Ventilation Rate Procedure is based on section 6.2 of ASHRAE 62.1. This more typical calculation method – used to create the table above – stipulates simple minimum outdoor airflow rates based on room area and number of occupants. The other method is called the Indoor Air Quality (IAQ) Procedure and is based on section 6.3 of ASHRAE 62.1. The IAQ Procedure is significantly more involved, and more subjective – it requires the identification of air contaminant sources as well as evaluation of contaminated air or subjective evaluation based on perceived occupant satisfaction. Based on the IAQ procedure, the outdoor air rate in the meeting rooms may meet ASHRAE 62.1, but this analysis is outside the scope of this report.

5.2.8 Demand Control Ventilation

Demand-controlled systems (systems capable of monitoring and controlling indoor air quality to suit occupancy) are permitted by ASHRAE 62.1 to drop below minimum outdoor air requirements, provided air quality is maintained. The addition of CO^2 sensors in each individual zone could be used to modulate primary airflow conserve energy and still meet ASHRAE 62.1. Occupancy sensors or Building Automation Scheduling schedule could be used in in addition to CO^2 sensors to provide higher outdoor air change rates when the space is occupied.

The current system includes CO^2 sensors in return air trunk mains to the RTUs. These CO^2 sensors modulate the outdoor air dampers based on return air quality averaged across the entire system. This data is not sufficiently localized for control of zone control dampers in meeting rooms. Additional CO^2 sensors are required (one per zone) to monitor and adjust to a demand-controlled airflow system. The cost for supply and install of room mounted CO^2 sensors, and programming for demand control ventilation is estimated at $1.5k to $2k per room.

5.2.9 Detailed airflow investigation of systems in the Council Chambers

Air Audit was retained by the City of Waterloo to perform airflow testing in the Council Chambers. These results are summarized in the following table. Due to the complex geometry of the room, the room volume is approximate.

Table 12: Evaluation of Council Chambers Ventilation

Room Status	RTU-5 Equip	Room Area (sq ft)	Avg Height (ft)	Room Volume (cu ft)	People	Min OA Damper Position	ASHRAE 62.1 Min Required OA (cfm)	Actual Outdoor Air (cfm)	Actual eACH
Occupied	7,200 cfm 20 ton	2,470	13.5	33,400	141	15%	1,067	1,080	7.3
Unoccupied					0	3%	185	216	6.5

The Council Chambers is served by a dedicated constant volume rooftop HVAC unit. The Council Chambers has over 12 ACH total airflow. The outdoor air damper position modulates based on return air CO2 concentration based on a duct mounted CO2 sensor.

Assuming an outdoor air damper position of 15% and MERV-8 filters, the outdoor air change rate is 1.9, and the equivalent outdoor air rate is 9.5 ACH. The equivalent outdoor air change rate in the Council Chambers is very good; and is great even when occupied.

Note that MERV-8 filtration is a minimum estimate based on equipment shop drawings. Actual equipment filter ratings should be confirmed. If existing equipment has low rated filters, then these should be upgraded to minimum MERV-8. Consult with equipment manufacturer prior to upgrading filters.

Note that the rooftop HVAC unit serving this area does have gas heat. The outdoor air ventilation rate could be further increased if desired. The maximum outdoor air rate should be limited to 40% in the winter months to ensure that the mixed air conditions at the gas fired burner stay above the manufacturer's recommended minimums. Most manufacturers recommend that the supply air entering the gas heater coil be not less than 40°F.

5.2.10 Summary tables and HVAC appendices

For further details, Appendix A contains detailed airflow balancing reports for the meeting rooms and the Council Chambers. Appendix B contains airflow analysis for the meeting room and Council Chambers based on available information. Appendix C shows the full building with HVAC areas of interest.

5.3 Recommendation #1 – Deficiency Items Requiring Immediate Attention

Several deficient conditions were found during the site airflow investigation.

1) The filters in all the series fan powered VAVs were very dirty and do not appear to have been changed for a very long time, by appearance, much more than one year. Manufacturers typically recommend filter replacements multiple times per year. Requirement: replace all filters in VAV boxes in the entire building. Add filter replacement for VAV boxes to the maintenance schedule.

2) In the Level 2 Cafeteria the fan for the series VAV box was not working. Requirement: service call to have this fan fixed.

3) In the Level 2 Seagram Room the primary air damper was stuck in a minimum position. The condition was temporarily remedied by disconnecting and reconnecting power. However, it is likely that this damper will fail again soon. Recommendation: replace all damaged parts.

4) The building is equipped with humidifiers that are not currently being used. Maintaining a minimum humidity setpoint has positive effects for occupant comfort and health. Recommendation: recommission humidifiers. Confirm that all system components are functional, and restart humidifiers according to manufacturers recommendations and industry best practice.[8]

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[8] The existing humidifiers use electric heat to create steam which is injected into supply air ductwork to provide humidification to the building. This process uses a substantial amount of electricity (four humidifiers at 60kW each – site confirmation of actual equipment is required). The City of Waterloo requested a discussion of alternative methods for humidification that use less electricity.

Adiabatic humidifiers are humidifiers that use evaporation or other methods to entrain room temperature water directly into air without heating to steam temperatures. Adiabatic humidifiers either pass air over wetted media or inject mist through nozzles directly into the air. Wetted media requires ductwork and would be very difficult (costly) to install and maintain in this building due to distribution to duct mains. High pressure nozzle applications can inject directly into the space volume but require high ceiling spaces for to permit entrainment. The large atrium at WCC may be suitable for high pressure spray application (note that the install would be very visible). The existing humidifiers, approximately 240 lb/hr total capacity, would maintain approximately 50% RH at approximately 25% outdoor air ratio on a design day. An equivalent high pressure water system equipment cost (with reverse osmosis water filtration) is estimated at $85k. The installed cost is estimated at $175k.

Note that while adiabatic humidifiers do not require the large direct heat energy input to create steam, the latent heat of evaporation removes an equivalent amount of heat from the airstream. Therefore, any energy that is not compensated by internal loads must be made up by the building heating system. Low humidity coincides with low outdoor air temperatures, so adiabatic humidification 'robs' heat during peak heating demand. A detailed review of the building heating system would need to be conducted, to determine whether it could support the added humidification load. Adiabatic systems do not necessarily provide a net energy efficiency gain over steam humidifiers.

5.4 Recommendation #2 – Electric Reheat at VAV Boxes

Standard operation for zones served by VAV boxes is for the VAV damper to remain in fully open position only as required for cooling. When cooling demand is low, the damper will move to minimum outdoor air position. This operation is the same for VVT, VAV, or FPVAV systems[9].

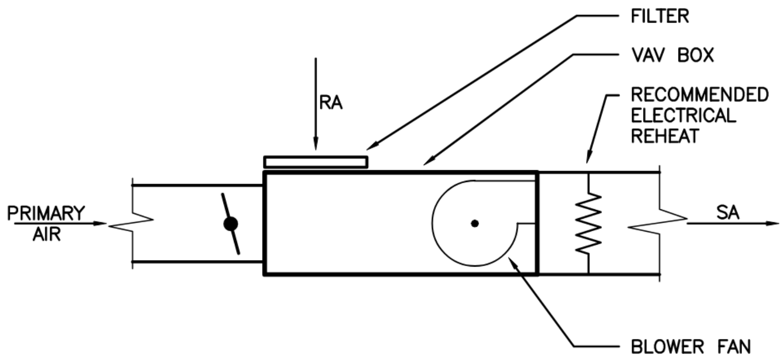

Figure 2 Fan Powered VAV Box

To achieve higher primary air and outdoor air changes, the minimum VAV damper position can be increased. Increasing the minimum damper position and primary airflow rate also increases space cooling. Increasing the minimum damper position decreases temperature control and leads to overcooling. The typical method to mitigate overcooling is to add reheat to the VAV box. Electric reheat is recommended because it is available all year round and is not dependent on seasonal gas boiler operation.

Note that the Connie Lounge and 3rd Floor MTG room are both served by VAV boxes that also serve portions of the adjacent Legislative Services space. Installing additional VAV boxes (one per room) while adding the electric reheat would greatly increase thermal comfort in these areas.

Note that the Erb Room uses three separate variable volume dampers instead of a single dedicated VAV box. This room will require three separate electric duct heaters.

Recommendation: add electric reheat to zones where delivery of sufficient outdoor air requires higher primary rates. Add approximately 1 kW of electric reheat for every 100 cfm primary airflow.

[9] In FPVAV systems the fan will operate continuously during occupied hours, recirculating room air to deliver constant airflow at the diffusers. Primary air fluctuates to meet space cooling demand. In VVT systems and standard VAV systems there is no air recirculated at the VAV box. All air through the box is primary air; when the damper position decreases, the airflow at the diffusers decreases.

5.5 Recommendation #3 – CO2 Sensors in Meeting Rooms

In rooms with intermittent high occupancy the addition of a CO^2 sensor is recommended. Measuring CO^2 level does not provide a direct indication of occupancy, but it does provide a reasonable indication of air quality and can be roughly corelated to high or low occupancy. This correlation allows ventilation to increase when there are many people in the room but will not necessarily increase ventilation for few occupants. This is one strategy for demand control ventilation. Demand control ventilation permits the system to lower the primary air usage during low occupancy and decreases total system energy use. Note that if demand control is used, then reheat should also be installed so that space temperature can be properly maintained.

Recommendation: Add a CO^2 sensor to the space served by the VAV. Locate the CO^2 sensor beside the thermostat. During occupied hours, use the CO^2 sensor to modulate the VAV damper position to increase primary airflow (which increases outdoor air rate). Increase minimum VAV damper position. Add a duct heater downstream of the VAV box to maintain space temperature at the temperature setpoint.

5.6 Recommendation #4 – Cowan MTG Room

The Cowan Meeting Room is currently served by a branch connected directly to the supply air main. The supply air branch includes a balance damper but is not connected to a VAV box for zone control. The supply air will vary marginally depending on pressure in the supply air main, but there is no zone control to meet achieve temperature setpoints. Also, the room does not have a proper supply air diffuser. Supply air is connected to a plenum behind a light fixture. These slots are typically intended for return air use only.

Recommendation: install a VAV box complete with duct heater to serve this space. Install a CO^2 sensor and implement a control strategy zones with VAV control. Install a proper supply air diffuser.

5.7 Recommendation #5 – Council Chambers

The Council Chambers already has sufficient total airflow, appears to have adequate outdoor air rates (ASHRAE 62.1), and appear to have adequate eACH for Covid recommendations. The air handler for this space sized to provide a relatively high rate of total air changes, with relatively low outdoor air ratio to ensure good air movement which is important for high occupancy. However, due to the intermittent high occupancy of this room, the room could benefit from higher outdoor air rates while Covid-19 remains a concern. The air handler has a high recirculation rate, and air filtration quality is lower than the other air handlers on the building.

Recommendation: add occupancy sensor to the room. Revise control logic to modulate outdoor air damper keeping the damper open as wide as possible (or to a reasonable maximum position) during occupied periods. Outdoor air damper can have different minimum positions based on outdoor air temperature. The existing unit has two outdoor air dampers positions. A minimum outdoor air damper position is set for occupied periods, and beyond this minimum setpoint the damper modulates for free-cooling economizer mode. The minimum occupied outdoor air damper should be open 100% whenever the building is occupied; this recommendation is regarding the economizer outdoor air modulation.

5.8 Recommendation #6 – Central Air Handler Heat

There is currently no heat provided by the central air handling units (RTUs), the only heat in the building is perimeter radiant heat and 3rd floor ceiling plenum heat. The building heating strategy relies entirely on this heat. This limits the amount of outside air that can enter the building for ventilation air. This method of keeping the building warm is reducing the amount of cold outside ventilation air that enters the building through the RTUs. This method goes against the COVID recommended procedures to increase outdoor air rates.

Roof top units without reheat can also create uncomfortably cool drafts on occupants. For example, on a mild winter day, if 70% return air at 21°C (70°F) mixes with 30%[10] outdoor air at -5°C (23°F), this creates a mixed supply air temperature of 13.2°C (56°F). This supply air temperature feels cool to occupants. When occupants feel uncomfortable, nothing can be done except cheat on outdoor air. The reduced outdoor air ventilation rate is below ASHRAE 62.1 requirements.

Outdoor ventilation air rates cannot be significantly increased to meet ASHRAE 62.1 if there is no heat in the VAV boxes or the central air handler.

Recommendation: install heat in the central air handling units to raise supply air temperature or install heat in VAV boxes so that primary air damper can remain in a more open position to maintain outdoor air rates at higher level. The air handlers are very compactly built, and do not currently have room for installation of heat (gas, electric, or heat pump). Addition of heat to the supply air system in this building would require either new air handlers, substantially reconfigured air handlers, or installation of heat supply air duct mains. Installation of heat at unit VAV units – a previous recommendation – is likely more practical in this building.

[10] Existing equipment appears to be operating at approximately 10% minimum outdoor air ratio. Due to substantial mixing of return air, and considering the entire building, this low outdoor air ratio likely provides reasonable IAQ, and may meet ASHRAE 62.1 IAQ requirements. However, higher outdoor air rates are required to meet ASHRAE 62.1 prescriptive requirements within the meeting rooms in this analysis. A 30% outdoor air ratio is a relatively common baseline setpoint and is used here for discussion purposes.

5.9 Recommendation #7 – Revision to BAS Logic at AHUs and VAV Boxes

A “pandemic mode” could be added to the unit that offers the following options:

1. In Winter Season: Open OA damper as far as possible while maintaining supply air above a low limit setpoint (suggested to be between 55°F and 65°F initially).
2. In Cooling Season: Open OA damper as far as possible while maintaining the supply air temperature at setpoint. While this is energy intensive, it will improve ventilation rates in the building.
3. Implement pre and post occupancy purge. This operating mode sees the unit operate at very high outdoor air rates before and after the working day to flush contaminants out. The pre-occupancy purge will need to be stopped early enough that the perimeter heat in the building has time to bring the spaces back to temperature before the workday begins.

ASHRAE Task Force for Covid-19 building readiness recommends minimum 3 equivalent complete air volume changes between occupancies. Three equivalent air volume changes is considered to reduce viral load by 95%.

5.10 Recommendation #8 – UVGI or HEPA Options for Meeting Rooms

Recirculation of local air through a high efficiency filter or other air purifying device is an effective means of decreasing viral load in the air. Recirculation does not introduce outdoor air, does not increase the level of oxygen in the air, and does not meet ASHRAE 62.1 prescriptive requirements. However, when reduction of viral load is the target, then local recirculation through a purifier is effective. The practicality of recirculation technologies increases when considering localized HVAC zones with intermittent periods of high occupancy.

Two recirculation methods that have proved effective at reducing viral load are high-efficiently filtration to remove virus-carrying droplets, or UVGI light to sterilize or kill viruses. HEPA filters remove more than 99.9% of particles in a single pass. For UVGI installed in ductwork, the lamp intensity can be varied as required to increase effectiveness and can achieve single pass kill rates that exceed 99%. Ventilation units are available that combine both HEPA filtration and UVGI and can be installed with ductwork, or portable units may simply be rolled into the room and plugged in.

UVGI can be installed in what is called an ‘upper room’ implementation. Upper room UVGI blankets the top of the room with a thin layer of UVC light that is distributed in a thin layer above the occupied zone. UVC light installed in an upper room configuration should not contact occupants – it requires ceiling fans or similar ventilation to circulate room air into the upper room area for disinfection.

Upper room UVGI is not recommended. Upper room UVGI provides most effective advantages in spaces with poor ventilation not meeting code minimums, or spaces with no ventilation. It is recommended that the ventilation be improved where it is deficient instead of using the stop-gap measure of UVGI. Also, item it may be difficult to implement upper room UVGI due to congested ceiling space and the presence of acoustic ceiling tile. Also, more widespread implementation of upper room UVGI is relatively recent, and the writer of this report will not be recommending without more familiarity with the proven benefits of the technology.

Note that ventilation solutions do not immediately kill local viruses immediately – the intent is to reduce viral load and reduce risk of infection. This is most effective for future users of the space. Current space users will always be at higher risk of infection from infected person in the room at the same time.

Recommendation: install air purification ventilation unit with HEPA filtration and UVGI lamps designed for 99% single pass kill rate. Ensure equipment is sufficiently sized to provide minimum 3 total air changes per hour. Equipment can be installed above ceiling and provided with dedicated supply air diffusers and return air grille – ensure grill and diffuser are located at opposite corners of room to maximize air mixing.

5.11 Opinion of Probable Cost - HVAC

Opinions of probable costs for the HVAC Recommendations are summarized in the following table.

Table 13: Opinion of Probable Cost for HVAC Recommendations

	Recommendation	Opinion of Probable Cost	Notes
#1	VAV Box Filters and Service Calls	$5,000	Ongoing Service Contract Costs not included.
#2	VAV Reheat (Electric)	$750,000	Additional CO2 sensors part of cost estimate
#3	VAV Reheat (Hydronic)	$1,500,000	New Boilers/pumps/hydronic loop required. Additional CO2 sensors part of cost estimate
#4	Cowan Meeting Room Upgrades	$15,000	
#5	Council Chamber BAS Revisions	$5,000	
#6	Central AHU Heat	$500,000+	This would entail complete replacement of existing air handlers, or installation of heat in all supply air main trunks.
#7	Pandemic Mode AHU Logic Upgrades	$25,000	
#8	UVGI & HEPA packaged ventilation unit - 1 room Multiple rooms (9 meeting rooms)	$5,000 to $7,500 $67,500	Installed cost / rm up to 1000 sq ft. Estimated cost for 9 meeting rooms.

6.0 Conclusion

A review of the drainage system and ventilation systems in the building was completed. The sanitary drainage system appears to be a mixture of original construction and various renovations. Several areas of renovation work were poorly installed and subject to backups and poor performance. Areas of original construction are showing signs of wear and are reaching end of life. The primary recommendation for the sanitary drainage system is to reinstall or rework areas that are becoming a maintenance burden.

The ventilation systems were reviewed from the existing drawings, and field calculations were completed for 10 meeting rooms. It was found that the fan powered VAV boxes are not being regularly maintained with many plugged filters and severely reduced airflows. VAV box primary airflows were reviewed and found to not meet ASHRAE 62.1 guidelines. Significant capital investment will be required in the ventilation system to allow for an increase in outdoor air rates.

Appendix A – Airflow Investigation – Meeting Rooms and Council Chambers

CERTIFIED TEST, ADJUST AND BALANCE REPORT

PREPARED ON: APRIL 19/2022 BY:

AIR AUDIT INC. *Since 1987*

110 TURNBULL COURT, UNIT 11 CAMBRIDGE, ONTARIO N1T 1K6

PH(519)740-0871 FAX(519)740-1312

PROJECT: WATERLOO CITY HALL

LOCATION: 100 REGINA STREET SOUTH WATERLOO, ONTARIO

CONTENTS: AIRFLOW MEASUREMENTS/AIR CHANGES PER HOUR

NEBB CERTIFICATION

PROJECT: WATERLOO CITY HALL

LOCATION: 100 REGINA STREET SOUTH WATERLOO, ONTARIO

DATE: APRIL 19/2022

The data presented in this report is an exact record of system(s) performance and was obtained in accordance with the National Environmental Balancing Bureau Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems.

Any variances from the design quantities which do not meet the specifiers tolerances are noted throughout the report.

SUBMITTED AND CERTIFIED BY NEBB CERTIFIED BALANCING CONTRACTOR

AIR AUDIT INC.
110 TURNBULL COURT, UNIT 11 CAMBRIDGE, ONTARIO
N1T 1K6
PH # (519)740-0871
FAX # (519)740-1312

NEBB REGISTRATION # *2779*

TAB SUPERVISOR *BRENT LIPSIT*

Air Audit Inc.
NEBB
BRENT D. LIPSIT
CERTIFICATION
2779
Exp. 3/31/22
Air and Hydronic Testing

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

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SYSTEM AIR CHANGES PER HOUR

Submitted by Air Audit Inc. - Cambridge, Ont. www.airaudit.ca

PROJECT: WATERLOO CITY HALL

DATE: APRIL 7/2022

ROOM	LENGTH IN FEET	WIDTH IN FEET	HEIGHT IN FEET	PLUS or MIN IN FEET	ROOM VOLUME IN CUBIC FEET	RM. SUPPLY AIR IN L/S	RM. RETURN AIR IN L/S	RM. AC/H SUPPLY	RM. AC/H RETURN
ROUND ROOM -	56.80	56.80	13.52	-876	33401	3401		12.94	
COUNCIL CHAMBERS									
ERB ROOM	27.79	24.07	8.73	+1018	6858	889		16.48	
CONNIE LOUNGE	22.10	14.39	8.71	+43	2813	370		16.72	
MEETING ROOM	14.76	14.85	8.72	-30	1881	116		7.85	
COWAN ROOM	11.80	11.97	8.62	-9	1218	49		5.11	
CAFETERIA	24.17	20.94	8.72	-25	4388	200		5.79	
SEAGRAM ROOM	13.82	13.02	8.71	0	1567	110		8.92	
HILLARD ROOM	13.82	13.09	8.74	-109	1472	100		8.64	
NEUFELD ROOM	13.90	24.17	8.74	-103	2833	260		11.67	
SEAGRAM 2	29.48	14.62	8.83	-7	3799	276		9.24	

NOTE- room volumes based on an empty room
- room volumes with a minus figure are equipment chases or irregularities in room size

REMARKS:
- AIRFLOW WAS MEASURED IN L/S (PRINTS PROVIDED ARE METRIC).

AIR OUTLET TEST REPORT

Submitted by Air Audit Inc-Cambridge Ont.

PROJECT: **WATERLOO CITY HALL** **SYSTEM: EX RTU-5**

TEST INSTRUMENT: **ALNOR RVA 801** **DATE: APRIL 7/2022**

AREA SERVED	OUTLET DATA				DESIGN		TEST	TEST	TEST	FINAL	
	#	TYPE	SIZE	AK	VEL	L/S	# 1	# 2	# 3	VEL	L/S
COUNCIL CHAMBER	1	GRILLE	1200 X 150	1.40	395	261	488			488	322
COUNCIL CHAMBER	2	GRILLE	1200 X 150	1.40	395	261	506			506	334
COUNCIL CHAMBER	3	GRILLE	1200 X 150	1.40	395	261	353			353	233
COUNCIL CHAMBER	4	GRILLE	1200 X 150	1.40	395	261	440			440	291
COUNCIL CHAMBER	5	GRILLE	1200 X 150	1.40	395	261	409			409	270
COUNCIL CHAMBER	6	GRILLE	1200 X 150	1.40	395	261	410			410	271
COUNCIL CHAMBER	7	GRILLE	1200 X 150	1.40	395	261	420			420	278
COUNCIL CHAMBER	8	GRILLE	1200 X 150	1.40	395	261	528			528	349
COUNCIL CHAMBER	9	GRILLE	1200 X 150	1.40	395	261	281			281	186
COUNCIL CHAMBER	10	GRILLE	1200 X 150	1.40	395	261	186			186	123
COUNCIL CHAMBER	11	GRILLE	1200 X 150	1.40	395	261	358			358	237
COUNCIL CHAMBER	12	GRILLE	1200 X 150	1.40	395	261	371			371	245
COUNCIL CHAMBER	13	GRILLE	900 X 150	1.05	527	261	528			528	262
										TOTAL = 3401	

REMARKS-

- UNIT IS RATED FOR 3393 L/S.

WATERLOO CITY HALL
EX. RTU-5 - THIRD FLOOR - HVAC LAYOUT

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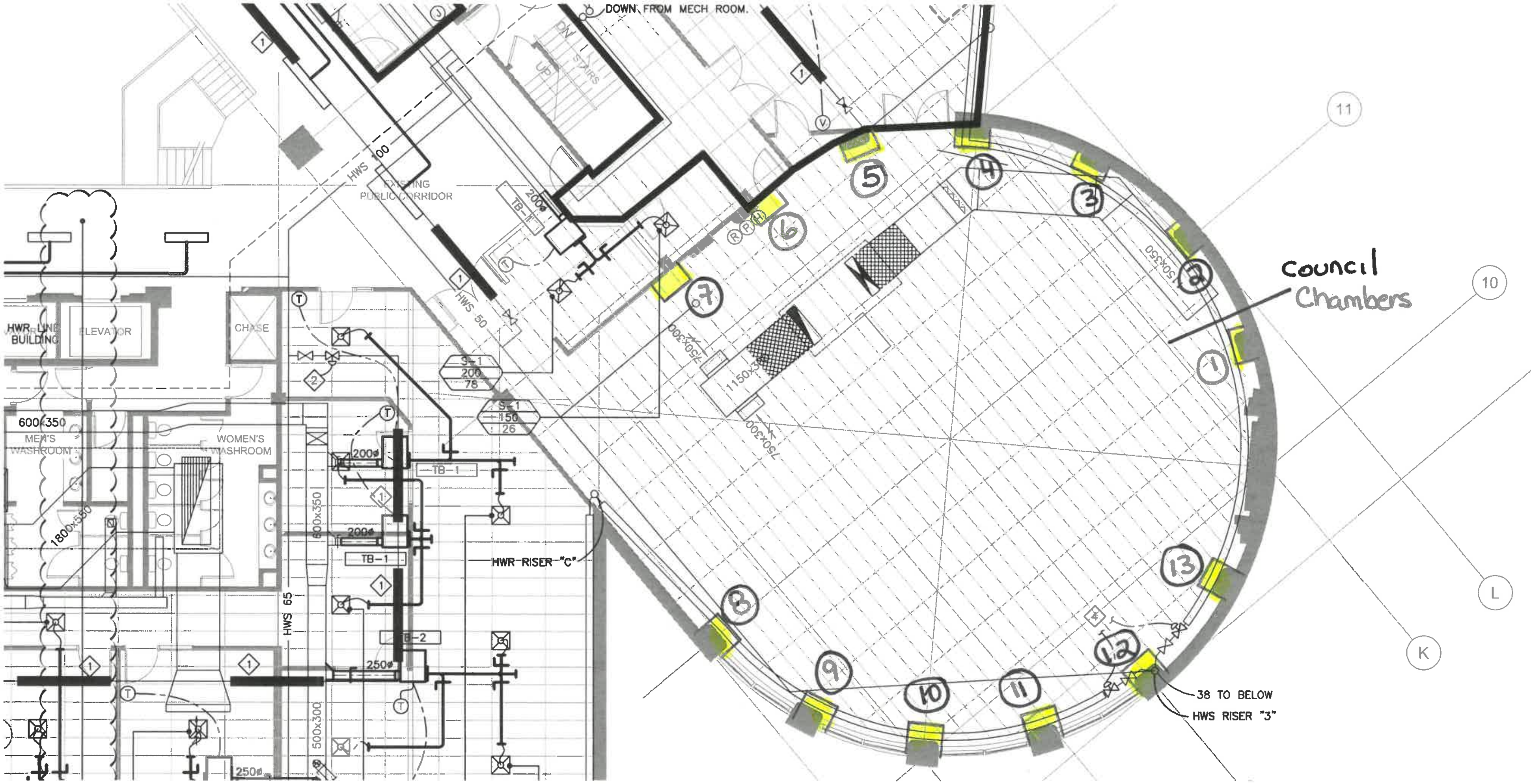

AIR OUTLET TEST REPORT

Submitted by Air Audit Inc-Cambridge Ont.

PROJECT: **WATERLOO CITY HALL** **SYSTEM: EX PART RTU-2**

TEST INSTRUMENT: **ADM 860 W/AIRFOIL** **DATE: APRIL 7/2022**

AREA	OUTLET DATA				DESIGN		TEST	TEST	TEST	FINAL	
SERVED	#	TYPE	SIZE	AK	VEL	L/S	# 1	# 2	# 3	VEL	L/S
3RD FLOOR											
COWAN ROOM	1	PIPE	200	0.35	NA	NA	297			297	49

REMARKS-

- COWAN ROOM OUTLET COMES OFF OF THE MAIN DUCT.

WATERLOO CITY HALL

EX. PART RTU-2 - THIRD FLOOR - HVAC LAYOUT

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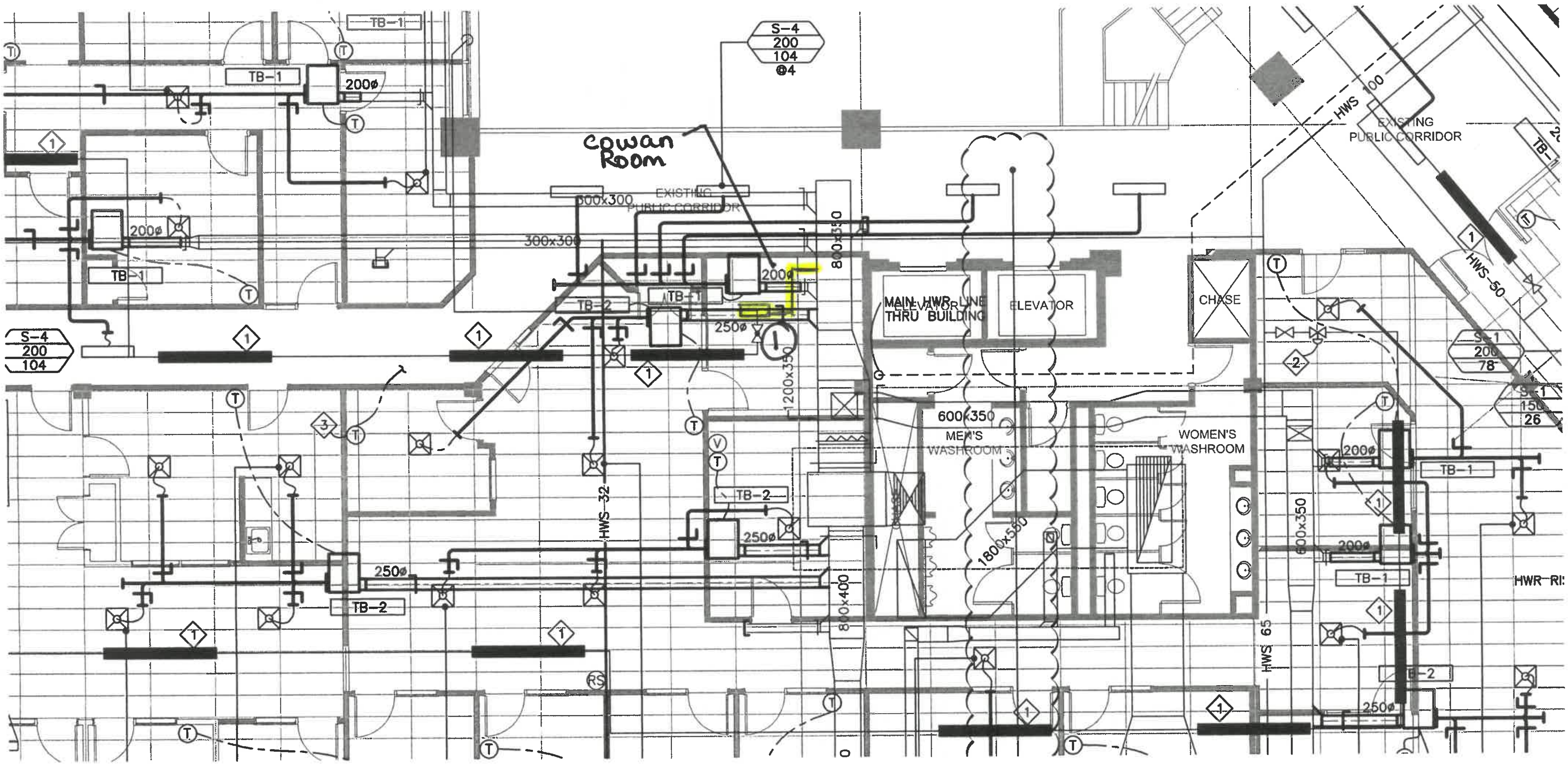

AIR OUTLET TEST REPORT

Submitted by Air Audit Inc-Cambridge Ont.

PROJECT: WATERLOO CITY HALL **SYSTEM:** EX PART RTU-3

TEST INSTRUMENT: ALNOR RVA 801 **DATE:** APRIL 7/2022

AREA	OUTLET DATA				DESIGN L/S		TEST	BOX	FLOW	FINAL L/S	
SERVED	#	TYPE	SIZE	AK	MIN	MAX	# 1	SIZE	COEFF	MIN	MAX
3RD FLOOR											
VVT-1											
ERB ROOM	1	DIFF	250		NA	NA	85	250	2.0	24	85
ERB ROOM	2	DIFF	250		NA	NA	110			33	110
ERB ROOM	3	DIFF	250		NA	NA	129			42	129
VVT-2											
ERB ROOM	1	DIFF	250		NA	NA	110	250	1.50	30	110
ERB ROOM	2	DIFF	250		NA	NA	137			46	137
VVT-3											
ERB ROOM	1	DIFF	250		NA	NA	92	250	1.40	34	92
ERB ROOM	2	DIFF	250		NA	NA	106			26	106
ERB ROOM	3	DIFF	250		NA	NA	120			26	120
VVT-30 PART											
CONNIE LOUNGE	1	DIFF	250		NA	NA	86	300	1.30	22	86
CONNIE LOUNGE	2	DIFF	250		NA	NA	89			22	89
CONNIE LOUNGE	3	DIFF	250		NA	NA	94			28	94
CONNIE LOUNGE	4	DIFF	250		NA	NA	101			23	101
VAV-26											
MEETING RM.	1	DIFF	200		NA	NA	49	300	0.63	35	49
MEETING RM.	2	DIFF	200		NA	NA	67			49	67
OPEN OFFICE	3	DIFF	200		NA	NA	72			46	72
OPEN OFFICE	4	DIFF	200		NA	NA	58			26	58
OPEN OFFICE	5	DIFF	200		NA	NA	49			43	49
OFFICE	6	DIFF	200		NA	NA	45			34	45
OFFICE	7	DIFF	200		NA	NA	46			34	46

REMARKS-

- VVT-1,2,3,30 ARE NOT VAV'S. THEY HAVE A HOT WIRE THAT READS VELOCITY AND IS CONVERTED TO CFM.
- MAX : 100% DAMPER POSITION / MIN : 15% DAMPER POSITION.
- VVT 30 : VVT SERVES ANOTHER AREA OTHER THAN CONNIE LOUNGE.

WATERLOO CITY HALL

EX. PART RTU-3 - THIRD FLOOR - HVAC LAYOUT

P6.8

4. NEW CONTROL VALVE ARE TO BE PROVIDED. UTILIZE EXISTING "RELIABLE" CONTROLLER.
5. EXISTING CONTROLS IN THIS AREA ARE TO BE REPLACED WITH NEW. TO MATCH NEW BUILDING STANDARD CONTROL TYPE.
6. NEW HYDRONIC ZONE TO BE TIED INTO EXISTING HYDRONIC SYSTEM AS SHOWN. SEE DETAIL 5 ON M6.01 FOR ADDITIONAL INFORMATION.

FAN POWERED TERMINAL UNIT TEST REPORT

Submitted by Air Audit Inc. - Cambridge Ont. PH 519-740-0871 Fax 519-740-1312

PROJECT: WATERLOO CITY HALL

LOCATION: 100 REGINA STREET S. WATERLOO, ONTARIO

FAN BOX # / BAS # : FPVAV-15

DATE: APRIL 7/2022

FAN BOX SIZE: 200

INSTRUMENT USED: ADM 860 W/FLOWHOOD / AIRFOIL

	DESIGN	*ACTUAL*
TOTAL L/S	93	139
MIN. PRIM. L/S & V.P.	0	0
MAX. PRIM. L/S & V.P.	93	100
FLOW COEFF.		1.00
AIR FILTERS CONDITION	VERY DIRTY I X I I I I I I I I VERY CLEAN	

COMMENTS

-PRIMARY AIR DETERMINED BY A PIPE TRAVERSE (T), USING THE ADM 860 W/AIRFOIL.

-TOTAL L/S DETERMINED BY THE SUM OF THE OUTLETS WITH FAN RUNNING.

-V.P. = VELOCITY PRESSURE "W.C.

-FAN SPEED SET AND MARKED WHERE APPLICABLE.

AIR OUTLET TEST REPORT

OUTLET #	ROOM(S) SERVED	DESIGN L/S	PRELIM-TEST	FINAL L/S
1	HILLIARD ROOM	NA	63	63
2	HILLIARD ROOM	NA	76	76

-See the floor plans for the air outlet layout plan.

FAN POWERED TERMINAL UNIT TEST REPORT

Submitted by Air Audit Inc. - Cambridge Ont. PH 519-740-0871 Fax 519-740-1312

PROJECT: WATERLOO CITY HALL

LOCATION: 100 REGINA STREET S. WATERLOO, ONTARIO

FAN BOX # / BAS # : FPVAV-16

DATE: APRIL 7/2022

FAN BOX SIZE: 200

INSTRUMENT USED: ADM 860 W/FLOWHOOD / AIRFOIL

	DESIGN	*ACTUAL*
TOTAL L/S	120	120
MIN. PRIM. L/S & V.P.	0	0
MAX. PRIM. L/S & V.P.	120	110
FLOW COEFF.		1.42
AIR FILTERS CONDITION	VERY DIRTY I X I I I I I I I I VERY CLEAN	

COMMENTS

-PRIMARY AIR DETERMINED BY A PIPE TRAVERSE (T), USING THE ADM 860 W/AIRFOIL.

-TOTAL L/S DETERMINED BY THE SUM OF THE OUTLETS WITH FAN RUNNING.

-V.P. = VELOCITY PRESSURE "W.C.

-FAN SPEED SET AND MARKED WHERE APPLICABLE.

AIR OUTLET TEST REPORT

OUTLET #	ROOM(S) SERVED	DESIGN L/S	PRELIM-TEST	FINAL L/S
1	SEAGRAM ROOM	NA	61	61
2	SEAGRAM ROOM	NA	59	59

-See the floor plans for the air outlet layout plan.

FAN POWERED TERMINAL UNIT TEST REPORT

Submitted by Air Audit Inc. - Cambridge Ont. PH 519-740-0871 Fax 519-740-1312

PROJECT: WATERLOO CITY HALL

LOCATION: 100 REGINA STREET S. WATERLOO, ONTARIO

FAN BOX # / BAS # : FPVAV-17

DATE: APRIL 7/2022

FAN BOX SIZE: 250

INSTRUMENT USED: ADM 860 W/FLOWHOOD / AIRFOIL

	DESIGN	*ACTUAL*
TOTAL L/S	385	NA
MIN. PRIM. L/S & V.P.	0	0
MAX. PRIM. L/S & V.P.	385	283
FLOW COEFF.		1.00
AIR FILTERS CONDITION	VERY DIRTY I X I I I I I I I I VERY CLEAN	

COMMENTS

-PRIMARY AIR DETERMINED BY A PIPE TRAVERSE (T), USING THE ADM 860 W/AIRFOIL.

-TOTAL L/S DETERMINED BY THE SUM OF THE OUTLETS WITH FAN RUNNING.

-V.P. = VELOCITY PRESSURE "W.C.

-FAN SPEED SET AND MARKED WHERE APPLICABLE.

-FPVAV-17 REQUIRES SERVICE. FAN DOES NOT RUN. AIRFLOW TO DIFFUSERS IS LEAKAGE FROM PRIMARY AIR. THE REMAINDER OF THE PRIMARY AIR IS DISCHARGED THROUGH RETURN.

AIR OUTLET TEST REPORT

OUTLET #	ROOM(S) SERVED	DESIGN L/S	PRELIM-TEST	FINAL L/S
1	CAFETERIA	NA	45	45
2	CAFETERIA	NA	50	50
3	CAFETERIA	NA	51	51
4	CAFETERIA	NA	54	54

-See the floor plans for the air outlet layout plan.

FAN POWERED TERMINAL UNIT TEST REPORT

Submitted by Air Audit Inc. - Cambridge Ont. PH 519-740-0871 Fax 519-740-1312

PROJECT: WATERLOO CITY HALL

LOCATION: 100 REGINA STREET S. WATERLOO, ONTARIO

FAN BOX # / BAS # : FPVAV-20

DATE: APRIL 7/2022

FAN BOX SIZE: 200

INSTRUMENT USED: ADM 860 W/FLOWHOOD / AIRFOIL

	DESIGN	***ACTUAL***
TOTAL L/S	270	296
MIN. PRIM. L/S & V.P.	0	0
MAX. PRIM. L/S & V.P.	270	260
FLOW COEFF.		0.80
AIR FILTERS CONDITION	VERY DIRTY I X I I I I I I I I VERY CLEAN	

COMMENTS

-PRIMARY AIR DETERMINED BY A PIPE TRAVERSE (T), USING THE ADM 860 W/AIRFOIL.

-TOTAL L/S DETERMINED BY THE SUM OF THE OUTLETS WITH FAN RUNNING.

-V.P. = VELOCITY PRESSURE "W.C.

-FAN SPEED SET AND MARKED WHERE APPLICABLE.

AIR OUTLET TEST REPORT

OUTLET #	ROOM(S) SERVED	DESIGN L/S	PRELIM-TEST	FINAL L/S
1	NEUFELD ROOM	NA	149	149
2	NEUFELD ROOM	NA	147	147

-See the floor plans for the air outlet layout plan.

FAN POWERED TERMINAL UNIT TEST REPORT

Submitted by Air Audit Inc. - Cambridge Ont. PH 519-740-0871 Fax 519-740-1312

PROJECT: WATERLOO CITY HALL

LOCATION: 100 REGINA STREET S. WATERLOO, ONTARIO

FAN BOX # / BAS # : FPVAV-21

DATE: APRIL 7/2022

FAN BOX SIZE: 250

INSTRUMENT USED: ADM 860 W/FLOWHOOD / AIRFOIL

	DESIGN	*ACTUAL*
TOTAL L/S	283	332
MIN. PRIM. L/S & V.P.	0	0
MAX. PRIM. L/S & V.P.	283	276
FLOW COEFF.		0.51
AIR FILTERS CONDITION	VERY DIRTY I X I I I I I I I I VERY CLEAN	

COMMENTS

-PRIMARY AIR DETERMINED BY A PIPE TRAVERSE (T), USING THE ADM 860 W/AIRFOIL.

-TOTAL L/S DETERMINED BY THE SUM OF THE OUTLETS WITH FAN RUNNING.

-V.P. = VELOCITY PRESSURE "W.C.

-FAN SPEED SET AND MARKED WHERE APPLICABLE.

AIR OUTLET TEST REPORT

OUTLET #	ROOM(S) SERVED	DESIGN L/S	PRELIM-TEST	FINAL L/S
1	SEAGRAM 2	NA	79	79
2	SEAGRAM 2	NA	85	85
3	SEAGRAM 2	NA	84	84
4	SEAGRAM 2	NA	84	84

-See the floor plans for the air outlet layout plan.

WATERLOO CITY HALL
FPVAV UNITS LAYOUT - SECOND FLOOR - HVAC LAYOUT

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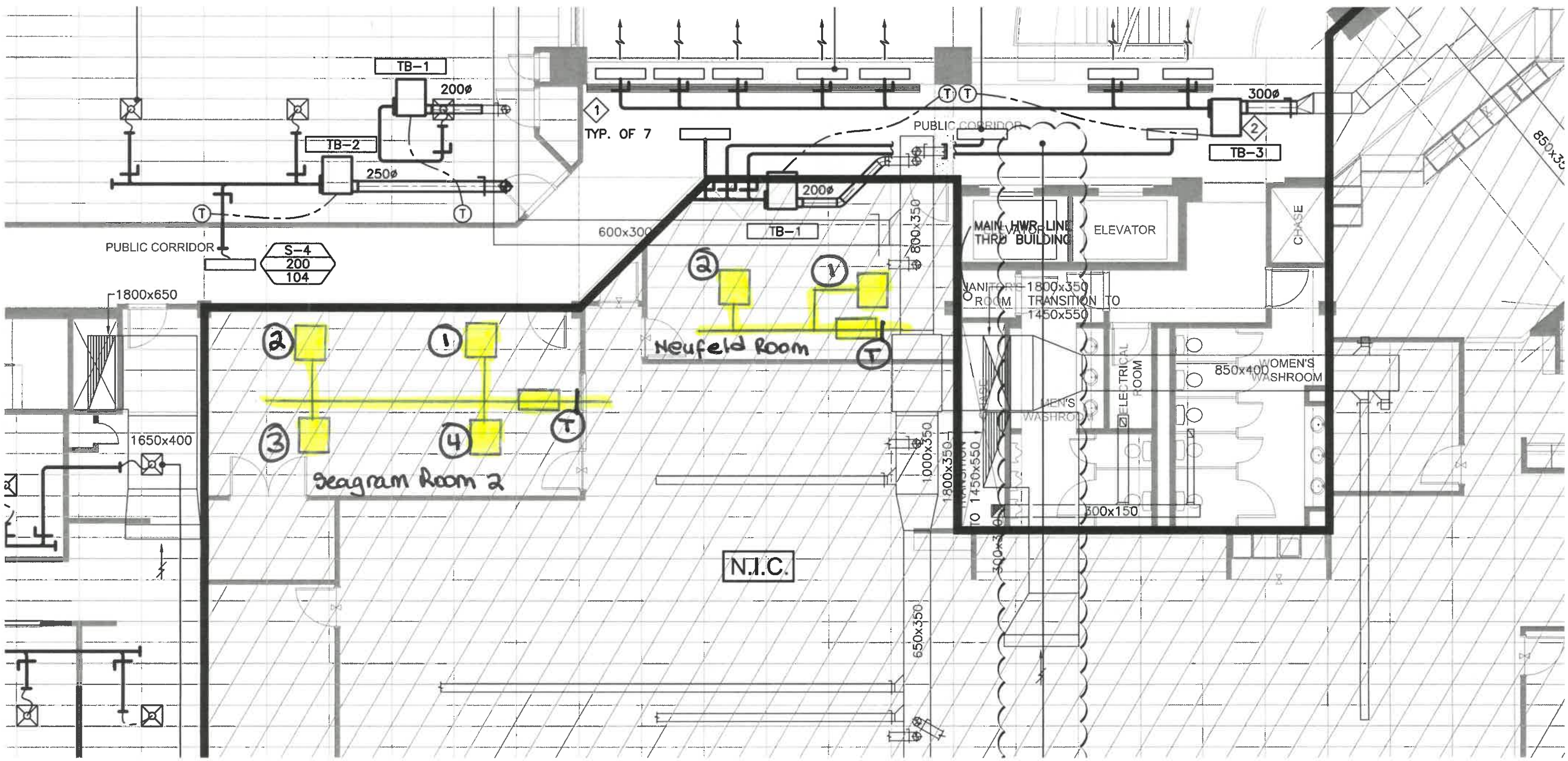
WATERLOO CITY HALL

FPVAV UNITS LAYOUT - SECOND FLOOR - HVAC LAYOUT

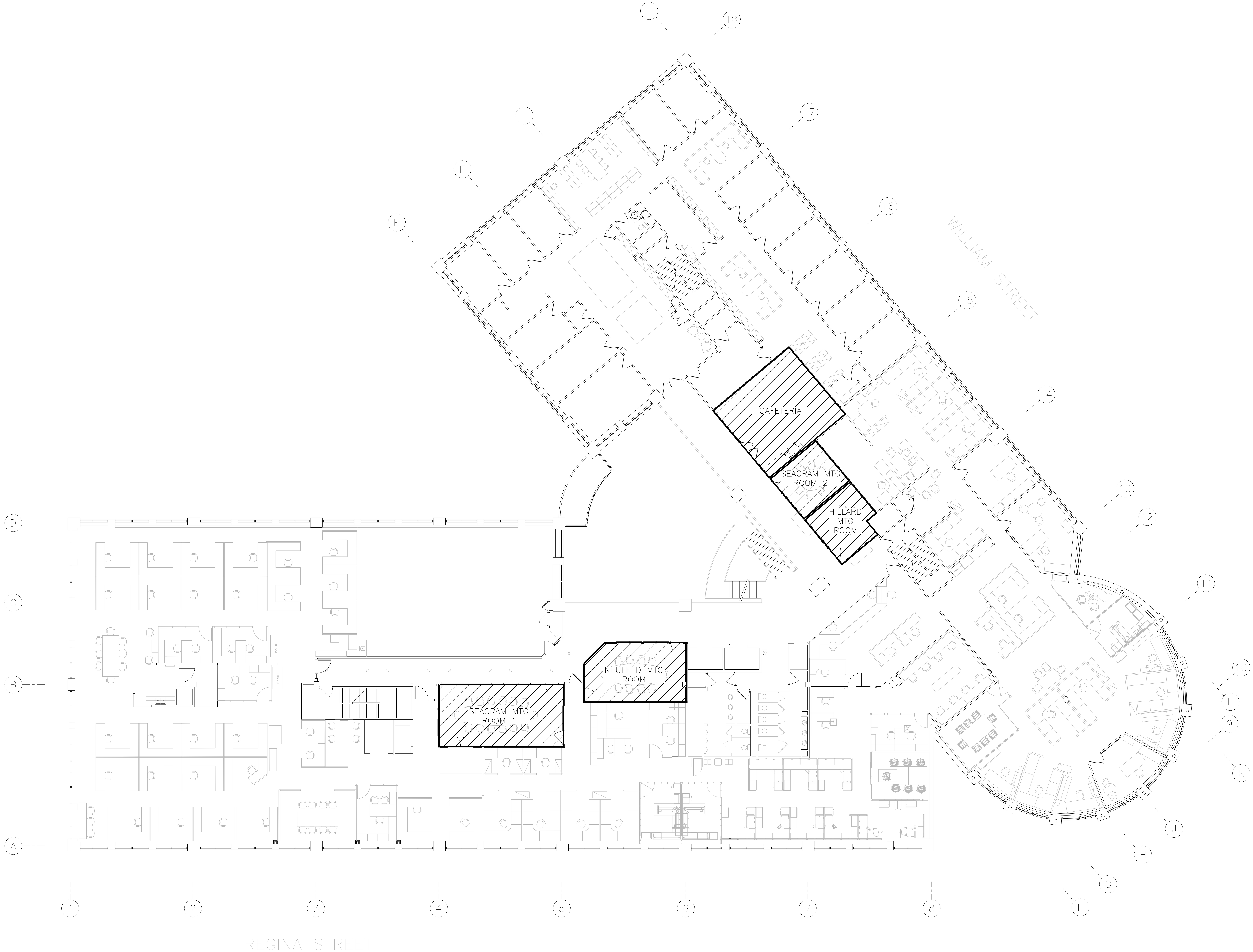


Appendix B – Airflow Analysis Summary

Appendix B - Table B.1 - Current minimum VAV/VVT position																		
Space Name	Area Site (sq ft)	Height (ft)	Volume (cu ft)	ASHRAE Occupancy Category Table 6-1	ASHRAE Recomm-ended Pz	Actual Design Pop. Pz	Outdoor Air flow/ person (cfm/per)	Outdoor Air flow/ area (cfm/sqft)	Required Breathing Zone OA (cfm)	Ventilation Effective-ness (%)	ASHRAE Required OA Empty Room	Occupied (cfm)	Measured Air VAV/VVT in Minimum Position (cfm)	Minimum VAV/VVT Position per BAS	Outdoor Air Damper Position	Outdoor Air After VAV/VVT Damper	ASHRAE Occupied Room OA Requirement	ASHRAE Unoccupied Room OA Requirement
Erb Meeting Rm (L3)	786	8.73	6,858	Office space	4	20	5	0.06	147.1	80%	59	184	553	"15%"	30%	166	(18 cfm SHORT)	(107 cfm surplus)
Connie Lounge (L3)	323	8.71	2,813	Office space	2	12	5	0.06	79.4	80%	24	99	201	"15%"	30%	60	(39 cfm SHORT)	(36 cfm surplus)
Meeting Rm (L3)	216	8.72	1,881	Office space	2	8	5	0.06	52.9	80%	16	66	178	"15%"	30%	53	(13 cfm SHORT)	(37 cfm surplus)
Cowan MTG Rm (L3)	141	8.62	1,218	Office space	1	8	5	0.06	48.5	80%	11	61	104	N/A	30%	31	(29 cfm SHORT)	(21 cfm surplus)
Cafeteria (L2)	503	8.72	4,388	Breakrooms (Office)	26	15	5	0.12	135.4	80%	75	169	0	"0%"	30%	0	(169 cfm SHORT)	(75 cfm SHORT)
Small Seagram Rm (L2)	180	8.71	1,567	Office space	1	8	5	0.06	50.8	80%	13	63	0	"0%"	30%	0	(63 cfm SHORT)	(13 cfm SHORT)
Hilliard MTG Rm (L2)	168	8.74	1,472	Office space	1	8	5	0.06	50.1	80%	13	63	0	"0%"	30%	0	(63 cfm SHORT)	(13 cfm SHORT)
Neufeld MTG Rm (L2)	324	8.74	2,833	Office space	2	10	5	0.06	69.4	80%	24	87	0	"0%"	30%	0	(87 cfm SHORT)	(24 cfm SHORT)
Large Seagram Rm (L2)	430	8.83	3,799	Office space	3	14	5	0.06	95.8	80%	32	120	0	"0%"	30%	0	(120 cfm SHORT)	(32 cfm SHORT)

Appendix B - Table B.2 - Revised minimum VAV/VVT position to suite ASHRAE 62.1																		
Space Name	Area Site (sq ft)	Height (ft)	Volume (cu ft)	ASHRAE Occupancy Category Table 6-1	ASHRAE Recomm-ended Pz	Actual Design Pop. Pz	Outdoor Air flow/ person (cfm/per)	Outdoor Air flow/ area (cfm/sqft)	Required Breathing Zone OA (cfm)	Ventilation Effective-ness (%)	ASHRAE Required OA Empty Room	Occupied (cfm)	Measured Primary Max Airflow (cfm)	Minimum Permitted VAV/VVT Position	Total Air After VAV/VVT Damper	Outdoor Air Damper Position	Outdoor Air After VAV/VVT in Min Position	Min Damper Meets ASHRAE OA Requirement
Council Chambers	2,470	13.52	33,401	Office space	13	141	5	0.06	853.2	80%	185	1,067	7,206	N/A	7,206	15%	1,067	(0 cfm surplus)
Erb Meeting Rm (L3)	786	8.73	6,858	Office space	4	20	5	0.06	147.1	80%	59	184	1,884	33%	613	30%	184	(0 cfm surplus)
Connie Lounge (L3)	323	8.71	2,813	Office space	2	12	5	0.06	79.4	80%	24	99	784	42%	331	30%	99	(0 cfm surplus)
Meeting Rm (L3)	216	8.72	1,881	Office space	2	8	5	0.06	52.9	80%	16	66	246	90%	221	30%	66	(0 cfm surplus)
Cowan MTG Rm (L3)	141	8.62	1,218	Office space	1	8	5	0.06	48.5	80%	11	61	104	N/A	104	30%	31	(29 cfm SHORT)
Cowan Rm Revised	141	8.62	1,218	Office space	1	8	5	0.06	48.5	80%	11	61	**205**	N/A	205	30%	61	(0 cfm surplus)
Cafeteria (L2)	503	8.72	4,388	Breakrooms (Office)	26	15	5	0.12	135.4	80%	75	169	600	94%	564	30%	169	(0 cfm surplus)
Small Seagram Rm (L2)	180	8.71	1,567	Office space	1	8	5	0.06	50.8	80%	13	63	233	91%	212	30%	63	(0 cfm surplus)
Hilliard MTG Rm (L2)	168	8.74	1,472	Office space	1	8	5	0.06	50.1	80%	13	63	212	99%	209	30%	63	(0 cfm surplus)
Neufeld MTG Rm (L2)	324	8.74	2,833	Office space	2	10	5	0.06	69.4	80%	24	87	551	53%	289	30%	87	(0 cfm surplus)
Large Seagram Rm (L2)	430	8.83	3,799	Office space	3	14	5	0.06	95.8	80%	32	120	585	68%	399	30%	120	(0 cfm surplus)

Appendix C.1 – Meeting Rooms for Detailed Airflow Investigation



SECOND FLOOR – HVAC ANALYSIS
SCALE: 1:100

ISSUANCES

No	DATE YY.MM.DD	DESCRIPTION	BY
1	22.05.03	EXISTING CONDITIONS	JA
1	22.11.21	EXISTING CONDITIONS	JA

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HVAC & PLUMBING
ASSESSMENT
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Sheet Title
LEVEL 2 PLAN
HVAC
(APPENDIX C.1)

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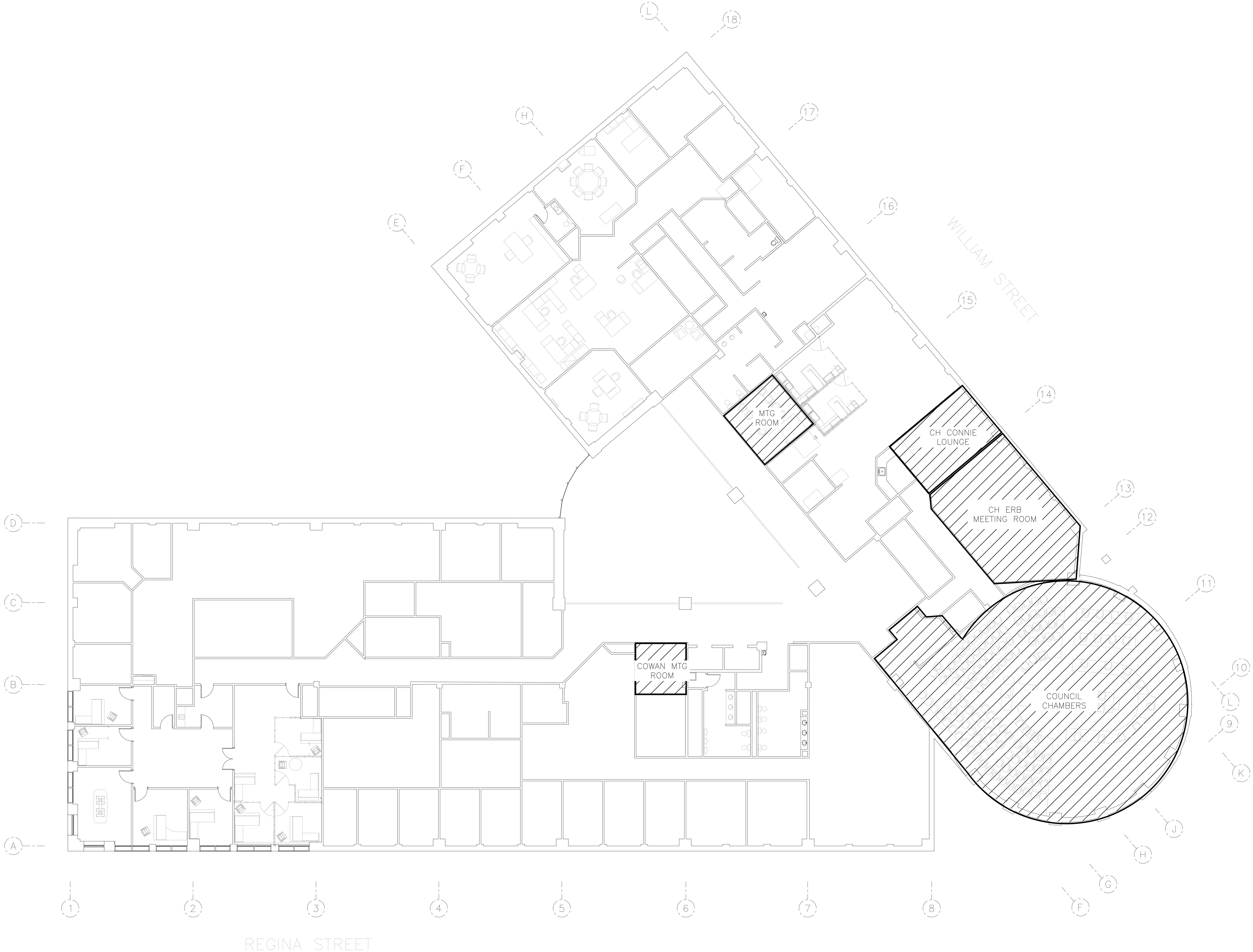
21410	M101



THIRD FLOOR – HVAC ANALYSIS
SCALE: 1:100

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1	22.11.21	EXISTING CONDITIONS	JA

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WATERLOO CITY CENTRE
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ASSESSMENT
100 REGINA ST S, WATERLOO, ON N2J 4P9

Sheet Title
LEVEL 3 PLAN
HVAC
(APPENDIX C.1)

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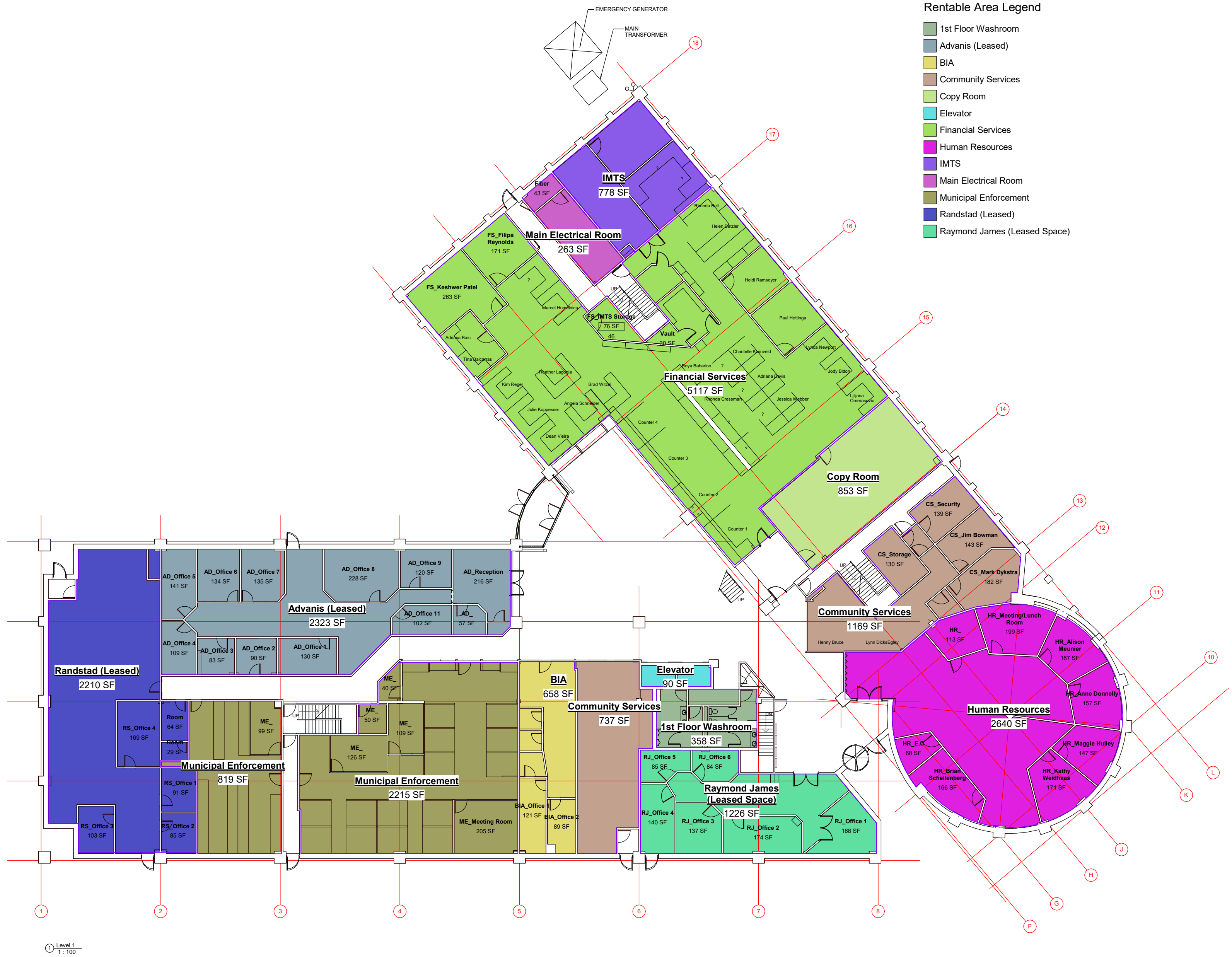
Project No.	Drawing No.
21410	M102

Appendix C.2 – Space Breakdown for Full-Building Airflow Summary

The content of Appendix C.2 was created by the consulting firm that created the I-Guide building model. The content of Appendix C.2 is not created by DEI. This was provided to DEI by the City of Waterloo as reference material, and is included in this Appendix for reference.



Rentable Area Legend

- 1st Floor Washroom
- Advanis (Leased)
- BIA
- Community Services
- Copy Room
- Elevator
- Financial Services
- Human Resources
- IMTS
- Main Electrical Room
- Municipal Enforcement
- Randstad (Leased)
- Raymond James (Leased Space)

THE CITY OF Waterloo

No.	Description	Date

CITY OF WATERLOO

CITY HALL RENOVATION (DRAFT)

1st Floor - Existing

Project Number	Project Number
Date	Issue Date
Drawn By	Author
Checked By	Checker

A101

Scale

2019-11-28 8:53:57 AM

THE CITY OF Waterloo

No.	Description	Date

CITY OF WATERLOO

CITY HALL RENOVATION (DRAFT)

2nd Floor - Existing

Project Number	Project Number
Date	Issue Date
Drawn By	Author
Checked By	Checker

A102

Scale

2019-11-28 8:54:16 AM

Rentable Area Legend

- 3rd Floor Washroom
- Communications
- Council Chambers
- Cowan MTG Room
- Economic Development
- Elected Officials (Mayor & CAO)
- Elevator
- ERB Room
- Fitness
- Legal
- Legislative Services
- MP-Chagger
- MTG Room
- Sapphire (Leased)
- Security
- SHAD (Leased)

THE CITY OF Waterloo

No.	Description	Date

CITY OF WATERLOO

CITY HALL RENOVATION (DRAFT)

3rd Floor - Existing

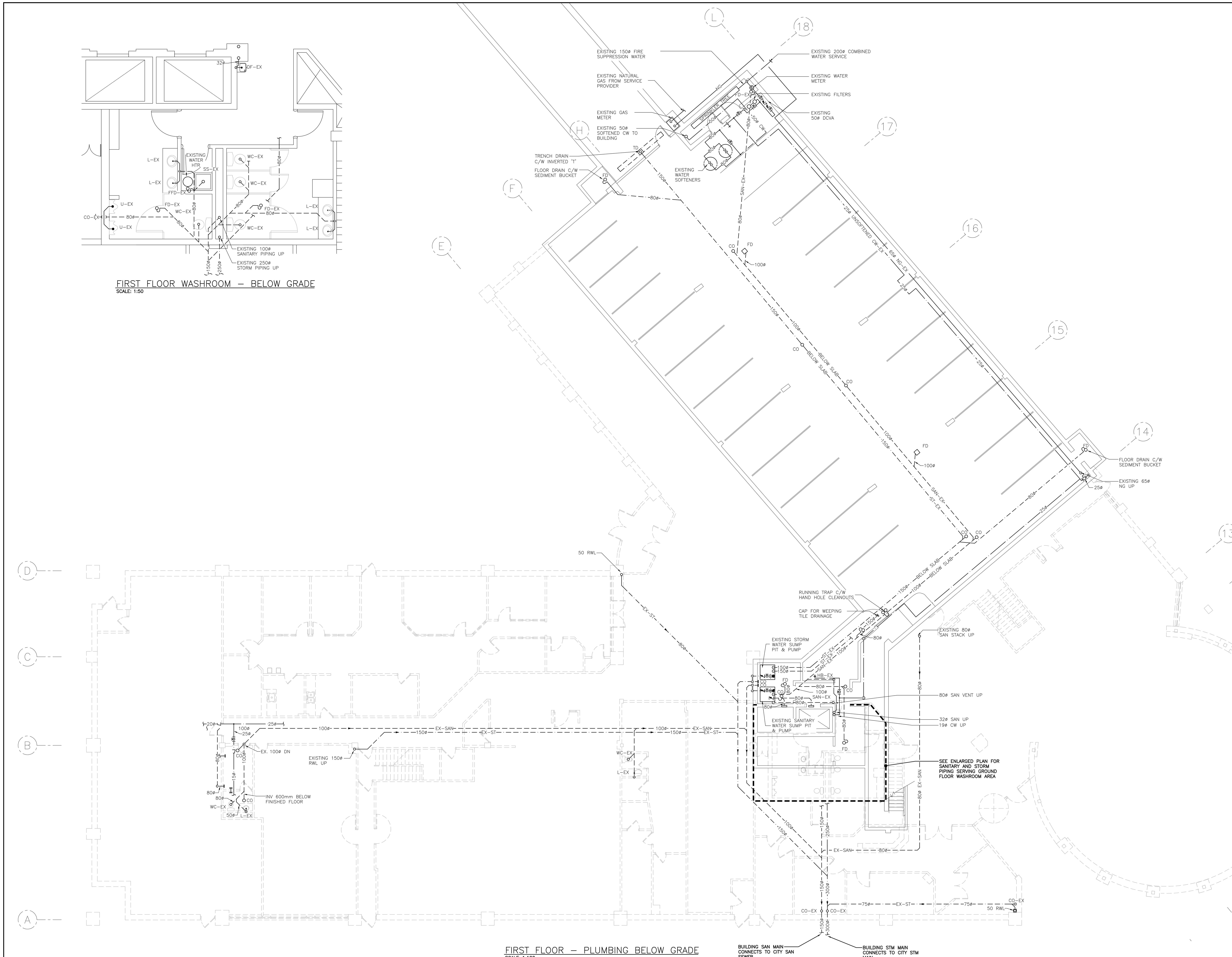
Project Number	Project Number
Date	Issue Date
Drawn By	Author
Checked By	Checker

A103

Scale

2019-11-28 8:54:33 AM

Appendix D – Plumbing Drawings



FIRST FLOOR – WASHROOM – BELOW GRADE
SCALE: 1:50

FIRST FLOOR – PLUMBING BELOW GRADE
SCALE: 1:100

PLUMBING PROBLEM AREAS

Item	Description
#1	FIRST AID WASHROOM SANITARY DRAIN 1ST FLOOR REGINA STREET WING (BELOW GRADE)
#2	MENS WASHROOM SANITARY DRAIN 2ND FLOOR SOUTHEAST CORNER OF BUILDING
#3	WOMENS WASHROOM & FULL WASHROOM STACK 1ST FLOOR SOUTHEAST CORNER OF BUILDING
#4	WASHROOM (BELOW MAYOR'S WASHROOM) 2ND FLOOR WILLIAM STREET WING (1ST FLOOR CEILING)
#5	MAYOR'S WASHROOM SANITARY DRAIN 3RD FLOOR WILLIAM STREET WING (2ND FLOOR CEILING)
#6	THE STUDIO WASHROOM SANITARY DRAIN 3RD FLOOR WILLIAM STREET WING (2ND FLOOR CEILING)
#7	SAPPHIRE KITCHENNETTE SANITARY DRAIN 3RD FLOOR REGINA STREET WING (2ND FLOOR CEILING)
#8	HOT WATER SPUTTERING 2ND FLOOR WILLIAM STREET WING
#9	COLD WATER DISTRIBUTION MAIN FROM WATER ENTRY TO CENTRAL WASHROOMS

Refer to report for full description of problem areas and recommended solutions.

MECHANICAL LEGEND

Item	Description
	POTABLE COLD WATER
SWS	POTABLE SOFT COLD WATER
SAN-EX	EXISTING SAN ABOVE FLOOR
SAN-EX	EXISTING SAN BELOW FLOOR
SAN	SANITARY ABOVE FLOOR
SAN	SANITARY BELOW FLOOR
STM-EX	EXISTING STM ABOVE FLOOR
STM-EX	EXISTING STM BELOW FLOOR
STM	STORM ABOVE FLOOR
STM	STORM BELOW FLOOR
V	VENT
	CATCH BASIN
FD	FLOOR DRAIN
	TRAP PRIMER
	TEE CONNECTION
	PIPE DOWN
	PIPE UP
	SCREWED OR WELDED PIPE CAP
	BALL VALVE
CO	FLOOR CLEANOUT

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Do not scale this drawing.

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No	DATE YY.MM.DD	DESCRIPTION	BY
1	22.05.03	EXISTING CONDITIONS	JA
1	22.11.21	EXISTING CONDITIONS	JA

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Sheet Title
BASEMENT & BELOW
GRADE PLAN PLUMBING
(APPENDIX D)

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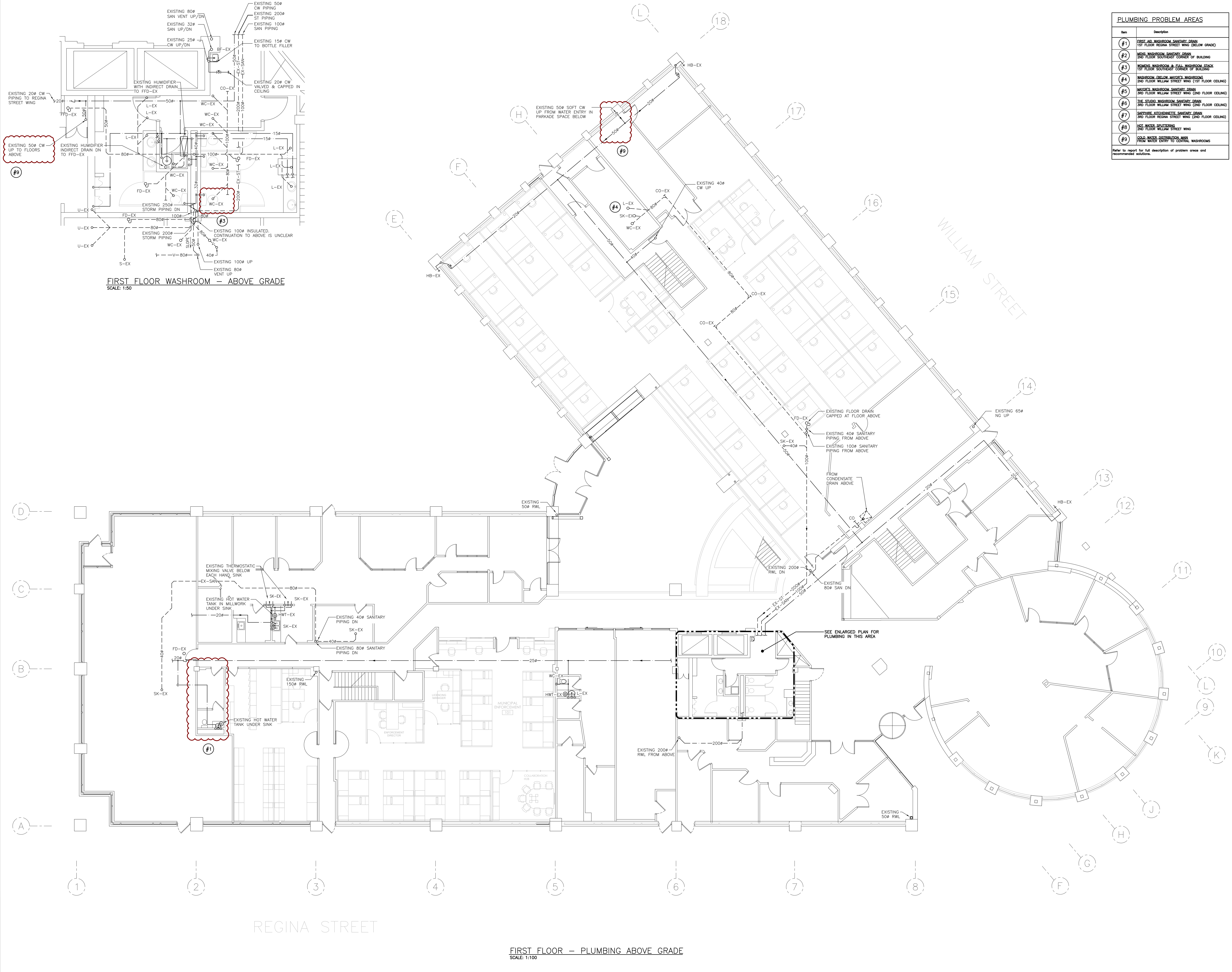
Project No.	Drawing No.
21410	M201



FIRST FLOOR WASHROOM – ABOVE GRADE
SCALE: 1:50

FIRST FLOOR – PLUMBING ABOVE GRADE
SCALE: 1:100

PLUMBING PROBLEM AREAS

Item	Description
#1	FIRST AID WASHROOM SANITARY DRAIN 1ST FLOOR REGINA STREET WING (BELOW GRADE)
#2	MENS WASHROOM SANITARY DRAIN 2ND FLOOR SOUTHEAST CORNER OF BUILDING
#3	WOMENS WASHROOM & FULL WASHROOM STACK 1ST FLOOR SOUTHEAST CORNER OF BUILDING
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#7	SAPPHIRE KITCHENNETTE SANITARY DRAIN 3RD FLOOR REGINA STREET WING (2ND FLOOR CEILING)
#8	HOT WATER SPUTTERING 2ND FLOOR WILLIAM STREET WING
#9	COLD WATER DISTRIBUTION MAIN FROM WATER ENTRY TO CENTRAL WASHROOMS

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1	22.11.21	EXISTING CONDITIONS	JA

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HVAC & PLUMBING
ASSESSMENT
100 REGINA ST S, WATERLOO, ON N2J 4P9

Sheet Title
LEVEL 1 PLAN
ABOVE GRADE PLUMBING
(APPENDIX D)

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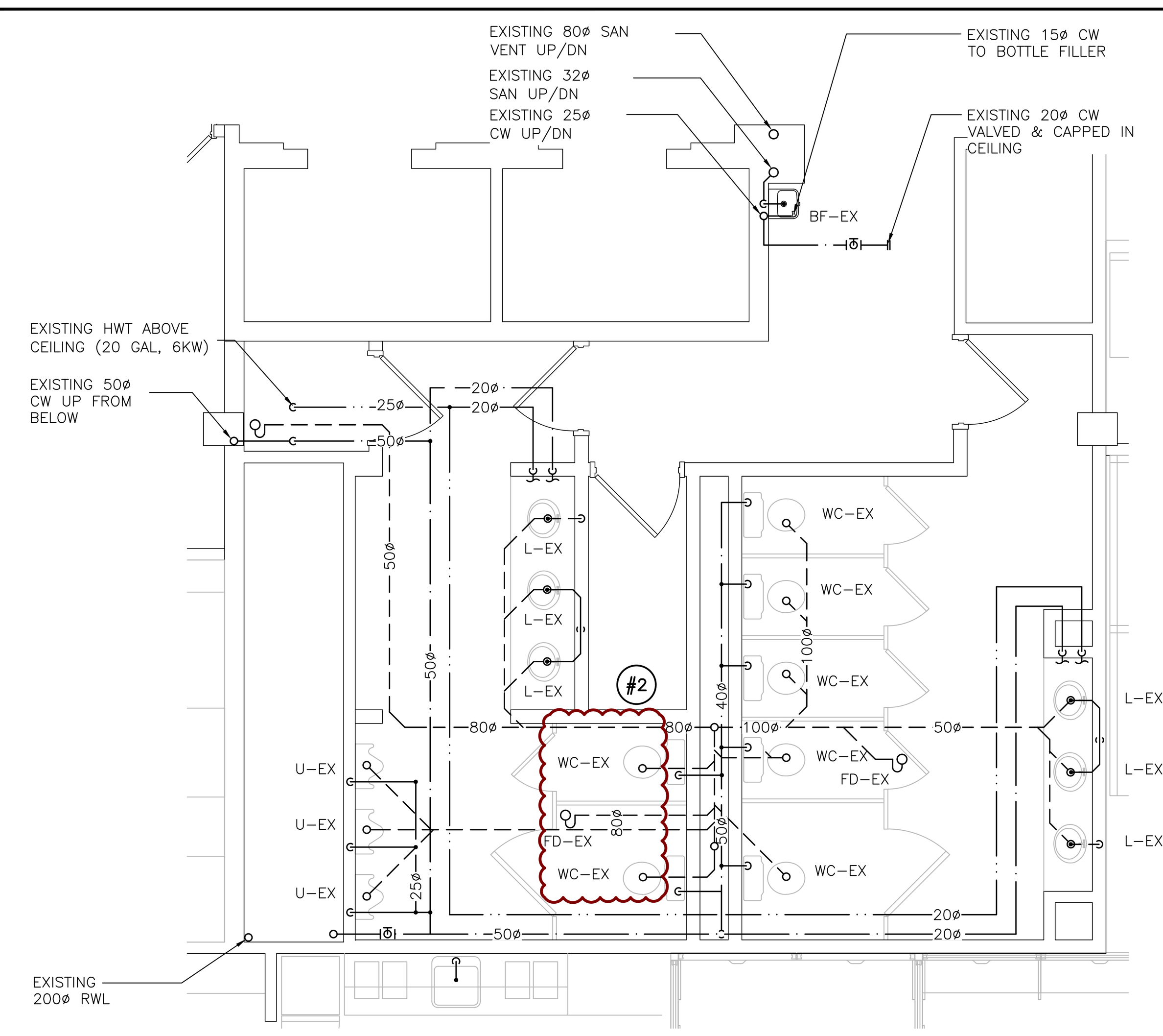
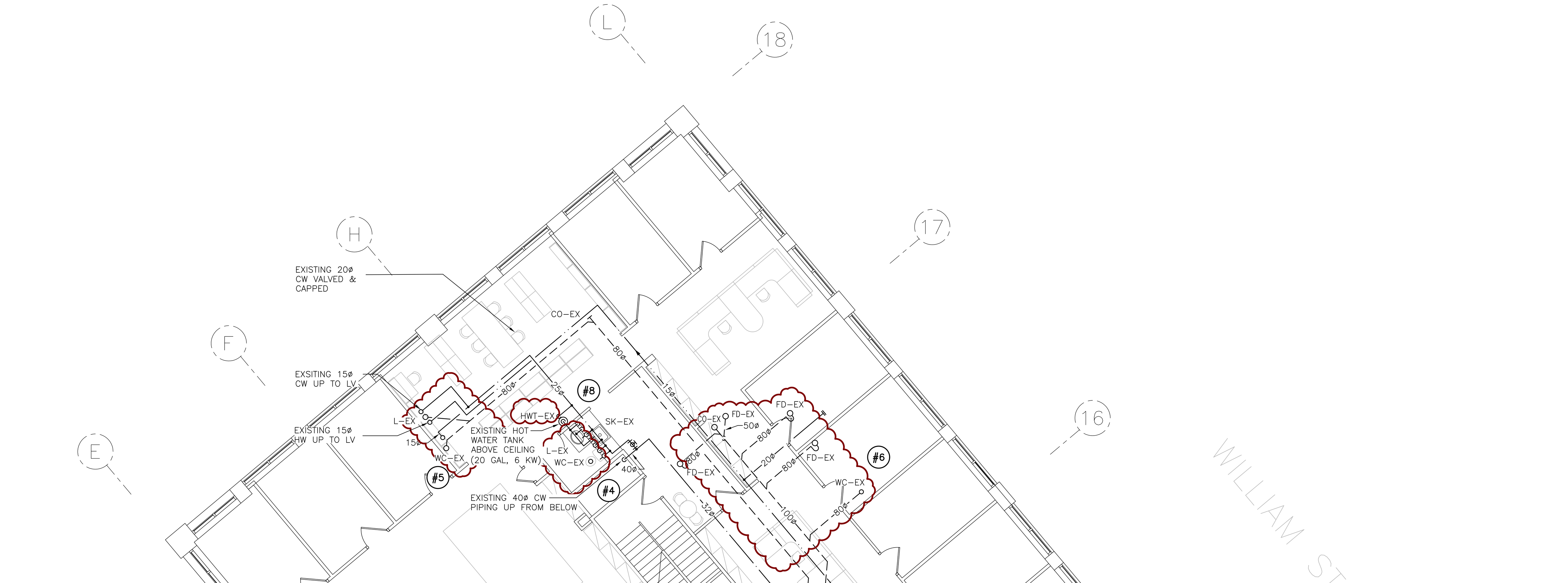
AS NOTED	NOV 2022	NOV 2022

Project No. 21410
Drawing No. M202



SECOND FLOOR WASHROOM – ABOVE GRADE
SCALE: 1:50




SECOND FLOOR – PLUMBING
SCALE: 1:100

PLUMBING PROBLEM AREAS

Item	Description
#1	FIRST AID WASHROOM SANITARY DRAIN 1ST FLOOR REGINA STREET WING (BELOW GRADE)
#2	MENS WASHROOM SANITARY DRAIN 2ND FLOOR SOUTHEAST CORNER OF BUILDING
#3	WOMENS WASHROOM & FULL WASHROOM STACK 1ST FLOOR SOUTHEAST CORNER OF BUILDING
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#8	HOT WATER SPUTTERING 2ND FLOOR WILLIAM STREET WING
#9	COLD WATER DISTRIBUTION MAIN FROM WATER ENTRY TO CENTRAL WASHROOMS

Refer to report for full description of problem areas and recommended solutions.

ISSUANCES

No	DATE YY.MM.DD	DESCRIPTION	BY
1	22.05.03	EXISTING CONDITIONS	JA
1	22.11.21	EXISTING CONDITIONS	JA

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Project
WATERLOO CITY CENTRE HVAC & PLUMBING ASSESSMENT
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Sheet Title
LEVEL 2 PLAN PLUMBING (APPENDIX D)

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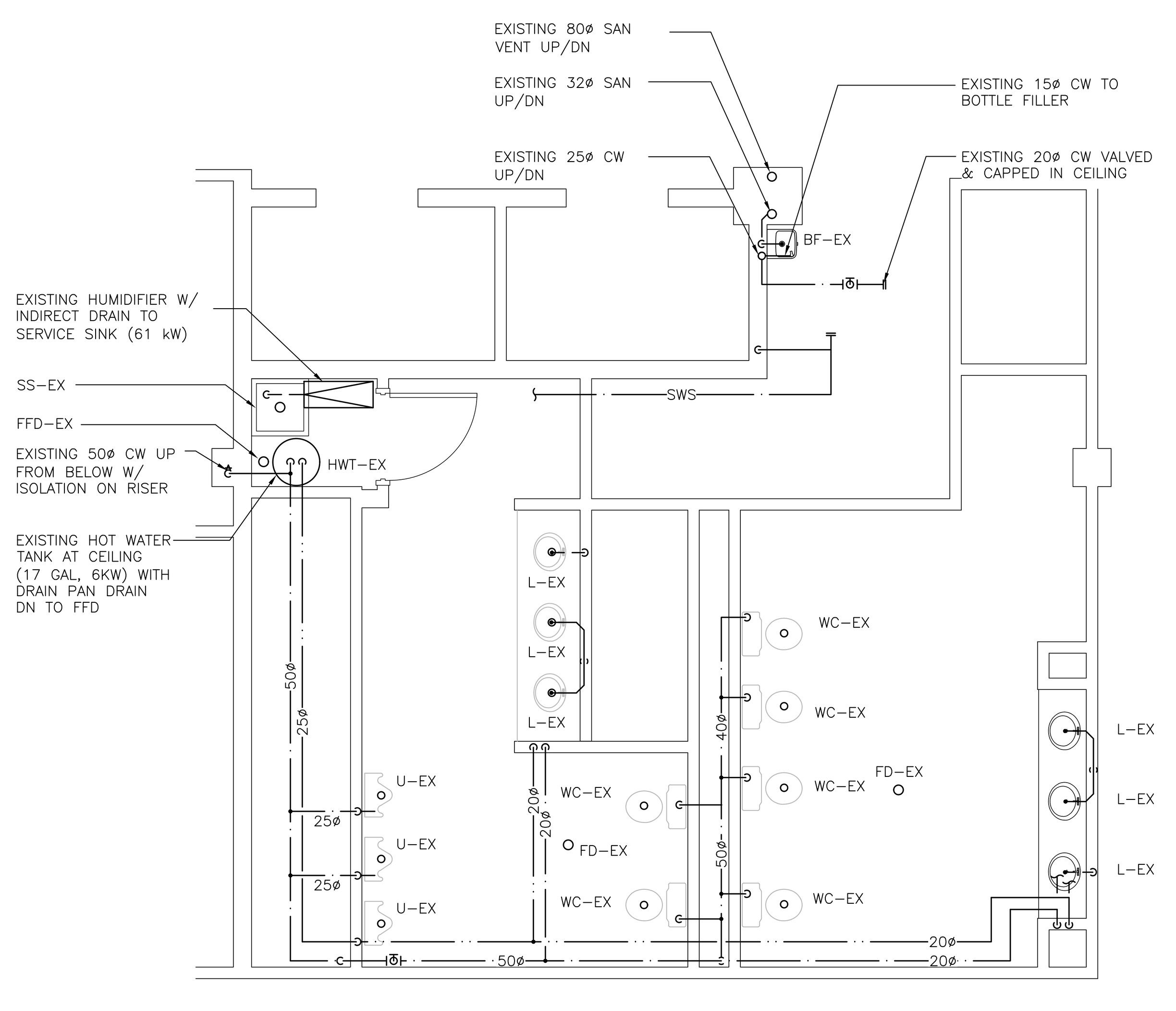
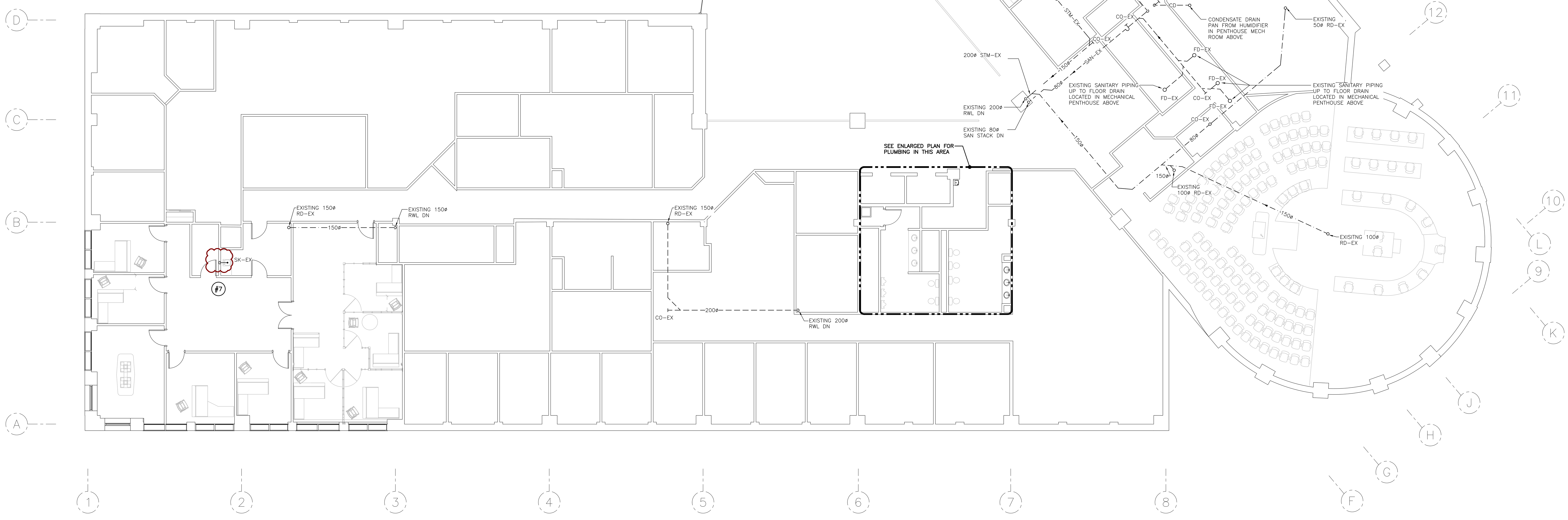
Project No.	Drawing No.	
21410	M203	



THIRD FLOOR WASHROOM – ABOVE GRADE
SCALE: 1:50

THIRD FLOOR – PLUMBING
SCALE: 1:100

PLUMBING PROBLEM AREAS

Item	Description
#1	FIRST AID WASHROOM SANITARY DRAIN 1ST FLOOR REGINA STREET WING (BELOW GRADE)
#2	MENS WASHROOM SANITARY DRAIN 2ND FLOOR SOUTHEAST CORNER OF BUILDING
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100 REGINA ST S, WATERLOO, ON N2J 4P9

Sheet Title
LEVEL 3 PLAN PLUMBING (APPENDIX D)

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Project No.	Drawing No.	
21410	M204	