Les Terrasses de la Chaudière - Envelope Rehabilitation

Combined Pre-Design & Schematic Design Report

June 08, 2016

Canada

grc architects

TABLE OF CONTENTS

List of Appendices

1. EXECUTIVE SUMMARY

1.1. MANDATE & CONTEXT

GRC Architects has been engaged to provide Schematic Design services as part of the *Les Terrasses de la Chaudière* (LTDLC) Building Envelope Rehabilitation Project. This document brings together the project RS1 & RS2 deliverables into a single report. These components are: a Construction Options Analysis (Pre-Design) Report, a Schematic Design Report, and an Implementation Strategy Report. These deliverables are chapters 3, 4, & 5 of this report, respectively.

The purpose of the LTDLC Envelope Rehabilitation Project (the Project) is to address the health and safety risks associated with the deteriorating brick cladding through the provision of a new building envelope and to assist in developing a more functional and sustainable site in accordance with PSPC's vision for a contemporary workplace.

In addition, significant energy performance improvements, and improvements to the interior work environment are anticipated.

The objective of this report is to examine the project constraints and requirements, and to identify the preferred scenario for design and construction. This process included input from a variety of specialists (sub-consultants) and collaboration with project stakeholders. This document is intended to be a repository of the design and technical knowledge required to advance the project to the next stage: the procurement of a Prime Consultant to undertake the final design and execution of the envelope rehabilitation.

1.2. VISION & GOALS

This project presents an opportunity to re-imagine a major piece of urban fabric within the context of the National Capital region. *Les Terrasses de la Chaudière* is a highly visible landmark that houses a significant portion of the Canadian public service. It is crucial that the envelope rehabilitation phase be fully understood in the context of a larger intervention, and that all opportunities for coordination with planned future phases are taken advantage of.

In terms of design excellence, sustainability and performance, this project is expected to set a high standard for future government projects.

Developed by PSPC, the vision for the overall complex rehabilitation project is:

Les Terrasses de la Chaudière: Bridging People, Place and Communities

Furthermore, the mission statement is:

To move forward to a holistic approach to site + building design that reflects the values of an evolving Canadian identity and a modern public service

In general terms, the guiding principles, as presented to the NCC, for this phase of the project include:

1. Enhancing pedestrian experience:

    - Where people take priority; and
    - Human scale is the first priority for all site design solutions

2. Contributing to the economic vitality of the:

    - Broader National Capital Area;
    - City of Gatineau;
    - Surrounding neighbourhood; and
    - Surrounding streetscapes

3. Supporting sustainability and durability where:

    - Efficient systems reduce energy consumption in compliance with the *National Performance Standards for Office Buildings*;
    - The selection of high quality, long lasting materials;
    - The inclusion of flexible adaptable workplaces to support *Blueprint 2020* and *Workplace 2.0*; and
    - Designing to take advantage of the natural climatic conditions whenever possible

4. Creating an exciting work environment that is:

    - Healthy;
    - Collaborative;
    - Attracts the next generation of public servants in support of blueprint 2020; and
    - Supportive of the public service renewal directives as per Workplace 2.0

5. Promoting design excellence that is:

    - Innovative;
    - Exciting;
    - Culturally relevant;
    - Forward looking; and
    - Flexible and adaptable for the future life-cycle of Les Terrasses de la Chaudière

1.3. METHODOLOGY

The format of this report is representative of GRC's design and investigation process. In order to reach an overall preferred approach to the envelope rehabilitation, technical and design investigations were executed in the following order:

1. Based on the existing conditions, budget, schedule, and occupancy requirements, construction options for the fabrication and installation of an envelope system were analyzed;

2. Based on the performance requirements, Client vision, and site analysis, a preferred schematic design option was selected; and

3. Following the above, the project was re-examined in terms implementation requirements in order to select a preferred implementation scenario.

This process included: review of the existing documentation, site visits and investigations, preparation of a tender package for test panel removal and replacement, three (3) presentations to the National Capital Commission (NCC), preparation of reports, input from various specialists, and regular meetings with the Client and project stakeholders.

Ongoing research and collaboration between the Consultant Team, stakeholders, and the Client Team, has resulted in an approach to project deliverables that combines prescriptive project requirements with performance requirements and project strategies. This approach will provide a solid foundation to the future Prime Consultant in order to hit the ground running while still affording a high level of flexibility and adaptability to the implementation team.

1.4. CONSTRUCTION OPTIONS ANALYSIS SUMMARY

The construction options analysis component of this report examined the impacts and risks associated with different envelope construction approaches from previous reports developed by others. Options were evaluated based on: implementation risks, envelope performance, impacts to occupants, and cost. The following four (4) options were examined in detail:

Option 1: Retention of the existing pre-cast back-up panels with new exterior insulation and cladding;

Option 2: Steel stud slab infill (traditional construction);

Option 3: Prefabricated wall panels; and

Option 4: Curtain wall.

Options 3 and 4 both offer significant advantages to the schedule, tenant impacts, quality control and implementation compared to options 1 and 2. However, Option 3 offers greater design flexibility whereas the curtain wall approach (option 4) could offer expedited construction and cost savings

1.5. SCHEMATIC DESIGN SUMMARY

The goal of the Schematic Design component of this report is to define the overall design criteria, as well as examine design options for the new building envelope, including a preferred option. As such, it contains both prescriptive and performance criteria relating to the technical performance and the aesthetic vision for the project.

This report also follows a series of design review presentations to the National Capital Commission (NCC) review committee, after which the schematic design was granted concept approval. This level of approval requires that the eventual Prime Consultant return to the NCC to seek approval for the final design prior to beginning construction. In this regard, the preferred design is not to be considered as a final design, but rather as one potential aesthetic outcome of the vision, guidelines, and criteria outlined in this report. The evolution of the design during the next phases of the project is anticipated.

A key element for success will be the coordination between this project and two other adjacent planned projects: the Zibi Domtar development; and the Laurier Street planned municipal improvements. Another critical factor for success will be the integration of this phase with subsequent project phases to create a high-quality final product that is coherent and fulfils the vision of the Client.

A site analysis was performed, which highlighted the prominence of the complex on the skyline as well as the significant issues with the existing urban conditions and site design.

Overall, a design approach that included lighter, more transparent and reflective materials was established. Based on this, four (4) distinct façade themes were developed. Following the site analysis, the preferred option (Option 4) expresses the complex as a **family of three distinct buildings**. This option was the most successful at reducing the visual impact of the complex on the skyline, while offering a fresh, contemporary look for this important government asset.

Fig. 1: *Option 4 (view from Chaudière Bridge) – Three distinct buildings shown here with the option of a new atrium on the center building and a glazed base on 15-25 Eddy.*

1.6. IMPLEMENTATION STRATEGY SUMMARY

This component of the report defined the overall implementation requirements, analyzed implementation risks, and assessed the construction strategies for the new building envelope, including the selection of a preferred scenario.

The continued occupancy of the complex during construction is assessed as the principle risk-creating factor for the project. The critical importance of careful project planning and oversight as a risk mitigation factor cannot be understated. In order to accommodate the occupants, and deal with the associated phasing of work, a carefully orchestrated work sequence (panel removals, material handling, deliveries, move management, etc.) will be essential to avoid delays and cost-overruns.

The preferred implementation scenario proposes to begin the envelope rehabilitation with 1 Promenade du Portage, whose full complement of occupants can be temporarily relocated to swing space in designated areas of 25 Eddy. This “soft start” in an unoccupied, low rise building is a fundamental component of the risk mitigation strategy. It allows for the work sequence and technical challenges to be honed before beginning work in riskier areas. Subsequently, the other buildings will use a top-down construction method with occupants from 4 (four) sequential floors being phased in and out of the available swing space.

The perceived bottleneck to the schedule is the rate at which the existing panels can be removed from the building. This report assumes that an average of 50 linear feet of façade (two structural bays) can be removed daily. At this rate of construction, the envelope rehabilitation phase could be completed within a five (5) year period. This fundamental assumption regarding the removal process will need to re-validated at project start-up, as it is the basis for the project schedule.

The preferred implementation approach includes the following strategies:

- Swing space will be provided at designated areas in 25 Eddy with an approximate minimum area of 8,500m^2;
- Construction begins with 1 Promenade du Portage while fully unoccupied;
- Material handling is primarily by tower crane, supplemented by mobile cranes to speed construction;
- Once the construction is complete and tenants of 1 Promenade du Portage are back, occupants of other areas are relocated to swing space to vacate affected floor areas, with the capacity to relocate four (4) sequential floors at a time;
- Work begins at the top of buildings and progresses downwards;
- Existing panels are loaded directly onto trucks to avoid site storage and double-handling;
- Delivery of new façade system is a “just-in-time” method, potentially picked by crane directly off of a truck to minimize site storage and double handling.

In general, this is a highly complex project with significant challenges and risks in all implementation areas. The project management team will need to design and enforce a sophisticated communications, reporting and oversight plan in order to be proactive about identifying & mitigating project risk. A clear project charter and well defined individual responsibilities, as well as lines of communication for all stakeholders is critical at an early stage.

1.7. CONCLUSIONS AND RECOMMENDATIONS

Overall, PSPC's strategy for the basic envelope remediation is the total removal of the existing precast panel system, and its replacement with an all-new building envelope. This strategy was selected based on information presented in previous reports (Smith Carter, 2013), and in conjunction with the project goals of improved energy efficiency, user comfort, and providing a new look to a complex that is representative of a contemporary public service.

Based on the performed seismic analysis and structural assessment, the existing block 100's, 200's and 300's structural system could sustain a seismic event up to 70%, 90%, and 100%, respectively, which suggests all the existing blocks could pass the 60% Public Works Seismic Policy.

The complete construction, including all soft costs and the replacement of all roofing, is estimated between **178 to 195 million dollars**, take approximately **five and one half (5.5)** years to complete, and will yield increases to energy performance and workplace improvements.

This project is anticipated to reduce overall energy consumption of the LTDLC complex by approximately **8 to 16%**. Future upgrades to the building systems are expected to generate further efficiencies.

This phase of the overall complex rehabilitation is a critical step towards much-needed improvements to the workplace environment and urban condition. It is important that subsequent phases are well-conceived and properly coordinated with this phase to ensure best value and return on investment.

There are various elements which have been illustrated in the conceptual renderings in this report, including penthouse surrounds, strategies for ground level glazing, site work, new commercial spaces at grade, etc. The aspirations for improvements to the complex, as well as the clear opportunities to include items in the scope of the envelope rehabilitation have led to a variety of design add-ons and options. It is crucial that the full scope of the project be clearly defined at this stage in order to avoid scheduling and budgetary pitfalls. Given the scale of the project, there is an economy to including as many of these items as possible in the scope of this project, as opposed to pushing them to later phases.

The continuous presence of building occupants during construction creates a complex implementation scenario as well as risks to the schedule and budget. Planning and coordination with occupants will be a determining factor for the success of this project.

Properly executed, this project has the potential to set a high standard for future government projects. This highly visible project can contribute to a revitalized public service, particularly with regards to consideration for the local communities, healthy workplaces, and sustainable design.

2. PROJECT BACKGROUND

2.1. HISTORICAL SUMMARY

The LTDLC complex, designed by Arcop Associates of Montreal, was built by Campeau Corporation between 1976 and 1978. It is composed of four office towers linked at their first and second levels by an interconnected retail concourse, and at their basement levels by a tunnel system. The complex contains an 810-space underground parking garage (below the hotel building) and a central exterior courtyard accessible from all of the towers and from surrounding streets at five points. The office complex has a total rentable area of 142,353 m^2 accommodating over 6,400 staff, and is the second largest federal government complex in Canada. The complex also includes a hotel building which is owned by the Government of Canada, but which is leased and operated by third parties. (Note: The hotel building is not included in the scope of this project.)

2.2. PROJECT OBJECTIVES

The purpose of the LTDLC Envelope Rehabilitation Project (the Project) is to address the health and safety risks associated with the deteriorating brick cladding through the provision of a new building envelope.

The overall façade construction is a unitized precast concrete panel system complete with integrated windows, insulation and brick veneer. While the overall system performs well for a façade of that era, certain construction deficiencies (uncoated rebar, epoxy mortar) have led to the cracking and spalling of the brick veneer. This deterioration is accelerating, requiring rapid action for rehabilitation.

The location, scale, and use of the complex are all factors that illustrate the impact that this project will have on a wide array of stakeholders. As such, this project phase (in coordination with planned future phases) has the potential to improve the urban condition and work environment for many individuals.

Despite its fundamental purpose to mitigate health and safety risks, this project should take advantage of the opportunity to work with all stakeholders in order to implement a solution that creates tangible benefits for all.

2.3. REPORT OBJECTIVES

The objective of this report is to establish project guidelines and criteria in order to facilitate the procurement of a Prime Consultant to execute the project.

This report's main objectives are as follows:

- Analyze and summarize the existing building conditions;
- Update and analyze the construction approaches (including indicative cost estimate);
- Identify the preferred construction approach, including rationale;
- Identify the project vision and desired outcomes;
- Identify factors & criteria having an impact on envelope design;
- Perform site analysis and provide a conceptual urban design plan;
- Illustrate four (4) façade design concepts that exemplify the project vision and criteria (including indicative cost estimate and energy modelling analysis for the preferred option);
- Identify the anticipated project scope and limits of intervention;
- Identify project risks and propose mitigation strategies;
- Identify different options for project implementation, including a preferred scenario; and
- Create a project schedule based on the preferred scenario.

2.4. METHODOLOGY

The Consultant Team method taken to complete this project is as follows:

- Review of the existing documentation, site visits and visual investigations;
- Consultation with various specialists (sub-consultants);
- Development of a project vision and guiding principles in collaboration with PSPC;
- Development of reports including:
  - Analysis of construction techniques;
  - Materials research;
  - Site analysis;
  - Design investigations;
  - Implementation options;
  - Risk analysis;
  - Energy modeling;
  - Seismic Modeling;
  - Costing
- Preparation of a tender package and contract administration for a test panel removal and replacement;
- Three (3) presentations to the National Capital Commission (NCC); and
- Regular meetings with the Client and stakeholders.

Ongoing research and collaboration between the Consultant Team, stakeholders and PSPC, has resulted in an approach to project deliverables that combines prescriptive project requirements with performance requirements and project strategies. This approach will provide a solid foundation to the future Prime Consultant in order to “hit the ground running” while still affording a high level of flexibility and adaptability to the implementation team.

2.5. Related Projects

The envelope rehabilitation is the first phase of a larger rehabilitation of the LTDLC complex including the following future phases:

- Development of site master plan;
- Rehabilitation of landscaping and ground level including public and commercial spaces in accordance with site master plan;
- Rehabilitation of base building systems; and
- Rehabilitation of interior spaces to fit up WP2.0.

NOTE: Development of a master plan, including ground level program and landscaping plans should occur prior to finalizing the new envelope design. The envelope rehabilitation phase should include coordination with planned future phases.

2.6. Project Team

Client Team (PSPC):

- Major Crown Projects (MPC)

Consultant Team:

- John Cook; *Principal, GRC Architects*
- Chris Lance; *Project Lead, GRC Architects*
- Stefan Gingras; *GRC Architects*
- John Cooke; *Principal, John G. Cooke Associates*
- Marty Lockman; *Senior Structural Engineer, John G. Cooke Associates*
- Nick Jones; *Structural Engineer, John G. Cooke Associates*
- Yudi Sun; *Structural Engineer, John G. Cooke Associates*
- Steve Clark; *Senior Cost Estimator, Marshall Murray*
- Francois Laframboise; *Façade Energy Modeling & Engineering, Pageau Morel*
- Heath Baxa; *Façade Energy Modeling & Engineering, Pageau Morel*
- Mark van Dalen; *Envelope Specialist, PTVD*
- Graham Bird, *Constructability Consultant, GBA*
- Philip Belanger*, Constructability Consultant, GBA*

2.7. PROJECT STAKEHOLDERS

2.7.1. *NATIONAL CAPITAL COMMISSION (NCC)*

As part of their mandate, the NCC approval process for applicable projects in the National Capital Region includes presentations to the Advisory Committee on Planning, Design, and Realty (ACPDR). To date, three presentations to ACPDR have taken place; August 21, 2015; December 10, 2015 and; March 3, 2016. It is anticipated that a minimum of one more presentation will be required for NCC project approval.

2.7.2. *THE CITY OF GATINEAU*

As this construction project stands to have a major impact on the City of Gatineau both during and after construction, consultation is recommended throughout the project.

Impacts to transit infrastructure, pedestrian routes, roads, sewer infrastructure, traffic patterns, and cycling routes may all be affected by this project. Working in collaboration with the city will help to mitigate risks of delay, and minimize impacts on local communities, commuters, and building occupants.

2.7.3. *PSPC*

PSPC is the entity responsible for the project management and oversight of the project. As a result, PSPC is responsible for guiding the project in a manner that best meets with the desired project outcomes for all stakeholders.

2.7.4. *TENANT DEPARTMENTS (CTA, CRTC, INAC, PCH, PSPC, SSC, COMMERCIAL)*

The existing tenants and building occupants all stand to benefit from a renewed building complex. However, they will also be impacted by the activities of construction. Providing a safe and productive workplace for the duration of this phase if of the utmost importance. Consultation with tenants throughout the process will be fundamental to ensuring the success of the project.

2.7.5. *GOVERNMENT OF CANADA (GOC)*

The GoC is the Owner/Investor of the project. In addition (and in accordance with government initiatives such as Blueprint 2020), the GoC also has an interest in the vitality and productivity of a modern public service, including sustainable and contemporary workplaces.

2.8. HERITAGE CONSERVATION

The design process for this project has included input from both the Federal Heritage Buildings Review Office (FHBRO), the Heritage Conservation Directorate (HCD) branch of PSPC, and the National Capital Commission (NCC).

The LTDLC complex did not meet the criteria for heritage designation from FHBRO. Furthermore, a design approach which re-imagines the appearance and character of the complex has been encouraged by the NCC, as well as by PSPC.

The design of the new building envelope should not be constrained by the existing appearance and character of the building.

2.9. BIBLIOGRAPHY

This report included review of the following documents:

- Building Evaluation Record; Federal Heritage Buildings Review Office (FHBRO); March, 2015.
- Building Envelope Retrofit – Feasibility Study and Options Analysis; Smith Carter; April, 2013.
- *Les Terrasses De la Chaudière Architectural Conservation Guidelines*; Heritage Conservation Directorate & DFS Architects; June, 2011.
- *Les Terrasses De la Chaudière – Brick Façade Investigation*; John G. Cooke & Associates; February, 2010.
- *Les Terrasses De la Chaudière (Seismic Report),Tomes 1-3*; Dessau; May, 2011.
- *Exterior Cladding Panel Anchors Investigation and Report*; Robertson Martin Architects & John G. Cooke Associates; February, 2011.
- *Assessment of Masonry Inspection and Repair Program – Overhead Protection Measures*; PTVD Building Envelope Consultants; January, 2015.
- Original construction shop drawings by Beer Precast Concrete Ltd., and stamped by Adjeleian and Associates Consulting Engineers, 1976.
- *Creating a Vision: Les Terrasses de la Chaudière*; PSPC P&TS Centre of Expertise Gatineau; PWGSC; 2016.
- *LTDLC Urban Design/Landscape Integration Study*; IBI Group et al.; July 2011.

- *Designated Substances Report for LTDLC Building Envelope Rehabilitation – Panel Investigation Project…Summary Report*; PWGSC P&TS NCA Operations, Real Property Branch; October 2015.
- *LTDLC Options Analysis Report – Draft*; GRC Architects, 2015.
- *LTDLC Implementation Study*; GRC Architects, 2016.

3. CONSTRUCTION OPTIONS ANALYSIS

3.1. TECHNICAL BRIEF

3.1.1. *EXISTING PANEL DETERIORATION*

The overall envelope rehabilitation project results from the need to mitigate the health and safety risks associated with the brick failure of the precast panel system. Failure was first noted in 1997 when some debris fell into the exterior yard of the daycare facility housed in 10 Wellington.

A series of investigations and repair efforts have been ongoing since 1997. The rate of failure of the brick, as well as the subsequent failure of early repair efforts has confirmed the need for rehabilitation of the building façade – repair and protection measures have been deemed as inadequate long-term solutions.

As a result of the products used in the fabricatiom process (uncoated rebar & epoxy grout), the brick veneer has developed cracks and areas of spalling.

***Fig. 2 –** Brick cracking in a rowlock course at the bottom of a panel. New mortar from a recent repair can be seen on the left.*

The impermeable epoxy mortar is problematic for moisture management considering the porosity of brick veneer and the corrosion of the uncoated rebar which is experiencing rust jacking. According to the brick investigations completed by John G. Cooke & Associates Ltd., the most common form of brick failure is cracking within the standard running-bond bricks at the edges of the windows and panels – concurrent with the vertical location of the internal rebar structure of the brick veneer.

The overall assessment of the Smith Carter report is that there is no feasible way to remediate or stabilize the existing brick veneer – resulting in the requirement for an overall building skin replacement. The report also examined the possibility of providing long-term overhead protection measures as a means of risk mitigations, but concluded that this was neither feasible nor practical considering the rate of decay of the brick veneer.

In addition, slumping and warping of the panels has been observed, although it is unclear if this is a result of deterioration or a fabrication error.

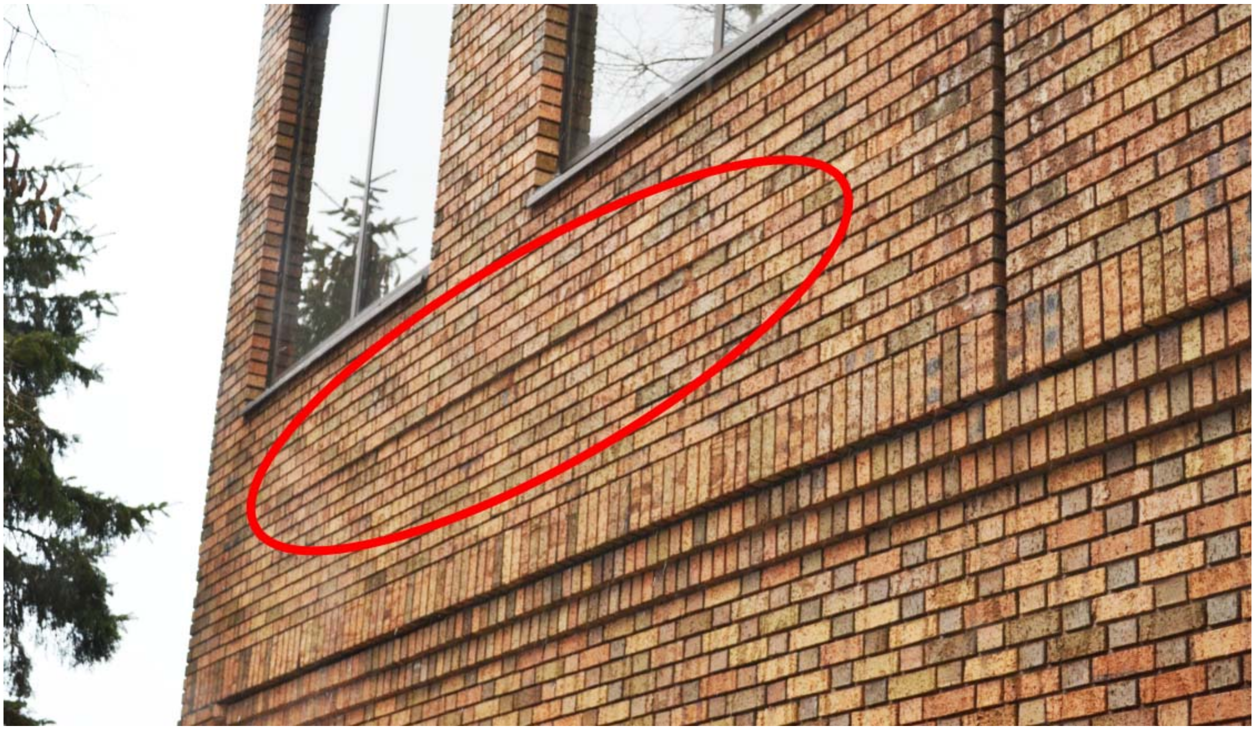


***Fig. 3 –** A clear shadow line can be seen where the precast panel above has warped in comparison to the traditional masonry wall below. View of the east side of 1 Promenade du Portage.*

3.1.2. <u>Existing Building Conditions</u>

NOTE: This section only examines those conditions affecting the exterior wall construction, and items related to panel removal and replacement.

3.1.2.1. Structure

The overall construction consists of a cast-in-place reinforced concrete structural system (column grid and slabs) with prefabricated concrete panels with integrated insulation and brick veneer as the exterior envelope system. The precast panels are top-hung from the slab edge, and are outboard of the floor slab and column structure. With some variation, there is a general 25 foot structural grid at the perimeter of the building, which has determined the two typical precast panel sizes (25’ and 12’-6”). The precast panel joints are coordinated with the structural grid, with joints either falling on the centre-line of columns or midway between structural bays.

Concrete floor slabs are typically 9 inches in thickness, with the roof slab also including an upturned perimeter beam.

Fig. 4 – *An historical photo of the complex during construction.*

3.1.2.2. Typical Panel Assembly

Based on the original 1976 shop drawings by Beer Precast Concrete Ltd., and validated in earlier investigations by Cooke & Associates, the panels have the following general wall assembly:

- Exterior brick veneer, including integrated rebar and epoxy mortar;
- 13mm airspace, likely created by strips of rigid insulation (see Fig 6);
- 50mm rigid insulation;
- 100mm reinforced concrete panel, including embedded expanded steel and steel angle brick supports; and
- 13mm gypsum board.

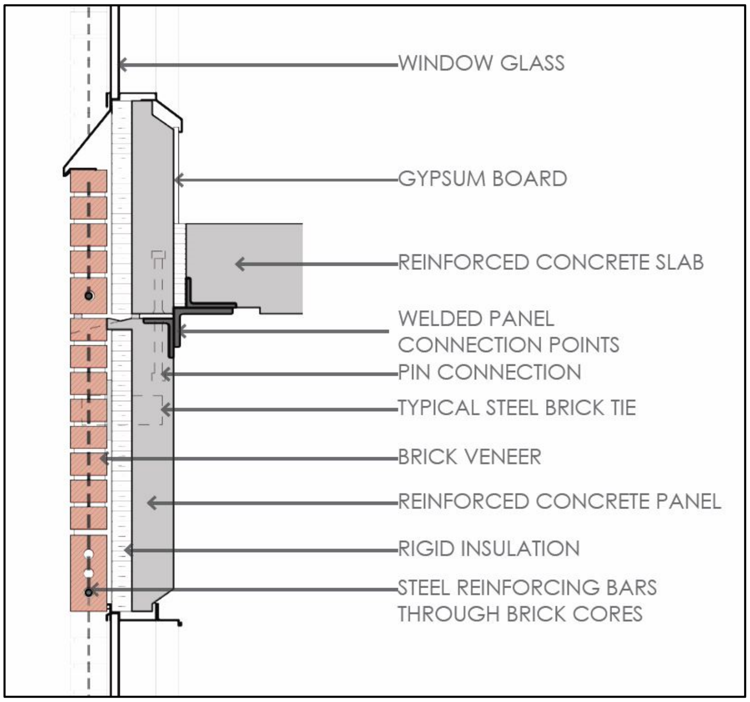


Fig. 5 - *Typical Panel Assembly*

There are two typical window panel types: a single window panel of 3.8m x 3.65m and a double window panel of 7.62m x 3.65m, weighing approximately 4500kg & 9000kg respectively. There are also a variety of opaque all-brick panels. Precast panels occur above the 2nd floor level across the complex (hotel not included). The masonry of the first two floors is of conventional site built construction and is not subject to the same deterioration as the precast panels.

The brick veneer contains continuous grouted rebar within the brick cores at all perimeter brick, as well as around the perimeter of the window frames. It was discovered that all brick cores, including those without rebar, are grouted solid. The bricks are supported by a grid of galvanized steel fins and tabs (see Figure 6) that were cast directly into the precast concrete panel, and which protrude into the mortar joints between individual bricks. This system does not include shelf angles to support the brick veneer; it instead relies on the internal rebar structure and epoxy grouted cores and brick voids to bind the brick into a rigid entity which is then supported by the protruding steel supports (in an approximate 600mm X 600mm grid).

Sealing between panels for building envelope continuity was designed with compressible gaskets at the perimeter of panels. During the panel removal investigation, it was observed that a common gasket width was likely used for the entire project where, due to site variances, some gaskets were under no compression while others were over-compressed and flattened. It should also be noted that the facility has experienced critters gaining access through these envelope deficiencies and making habitats within some ceiling plenums.

Fig. 6 – *Steel supports and grouted brick assembly over insulated precast substrate. Note the expanded steel shear fins which support the brick veneer and a strip of rigid insulation (just behind the fin) which creates the air space.*

3.1.2.3. Panel Connections

As outlined in the *Exterior Cladding Panel Anchors Investigation and Report* (Robertson Martin Architects & John G. Cooke Associates; February, 2011), and supported by the original 1976 shop drawings, there are multiple typical connection types. Each single window panel's gravity load is supported by a single top-hung welded connection to the slab edge; each double window panel includes two similar connections. Lateral connections occur at the corners of each panel with dowel connections that are slotted into the tops of panels and slotted into the panel above through a steel angle. During a panel removal, it was observed that these pins are not fixed to either panel but have negligible gaps in the slotted openings thereby creating a tight fit. The steel angles cast into the slab edges are not continuous, and occur only at the connection points.

Original hoisting points for the panels remain inconclusive based on the original 1976 shop drawings and in reviewing the removed panels. Steel inserts with threaded cores have been observed (see Figure 8) in the centre of the gravity plates which appear plausible connectors for screw-in type hoist anchors however, considering the weight of the panels, seems insufficient as a sole hoisting point.

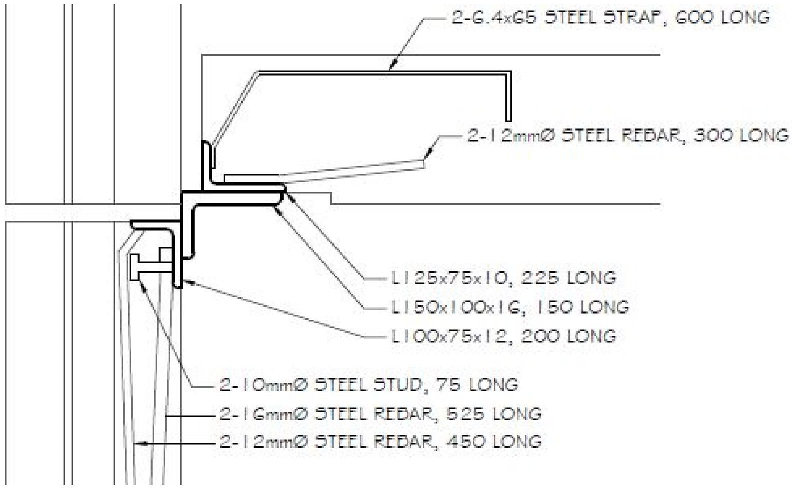


***Fig. 7 –** Detail of gravity connection, top-hung from the slab above. Detail from the Panel Anchor Investigation Report (RMA & Cooke, 2011)*

***Fig. 8** - Threaded sleeve observed at centre gravity connection plate*

The Dessau seismic report (2011) examines in detail the existing capacities of the panel connections and associated supports. The report's general findings indicate that the panel connections are adequate in terms of their gravity and lateral load capacities. However, in a seismic event, the report indicates that all connections are not capable of resisting the imposed seismic loads. As a result, any option which includes the retention of all or part of the existing precast system will require that all connections are upgraded.

Fig. 9 – *On the left is a double window panel gravity connection, top-hung from the slab above. On the right is a double window panel lateral connection. The white residue around the anchors are remnants of removed asbestos fireproofing. Photos from the Panel Anchor Investigation Report (RMA & Cooke, 2011).*

3.1.2.4. PARAPETS

The original drawings indicate that the parapet panels have a different connection strategy than typical window panels. The panel is supported from below; it rests on steel shims supported by the gravity connection of the panel below. Lateral stability is achieved through typical “pin” connections into the panel below and with additional lateral connections on the top of the concrete upstand along the roof perimeter. The original architectural drawings indicate that the parapet panels typically span a full structural bay (approx. 25’).

3.1.2.5. SKIRT PANELS

There is an additional precast panel at the transition between the typical brick construction of the bottom levels and the precast window panels above. Based on the original architectural drawings, these panels span between structural columns and provide an attachment for the ground level glazing and soffit. As these panels are subject to the typical construction and deterioration issues, they are included in the scope for panel removal.

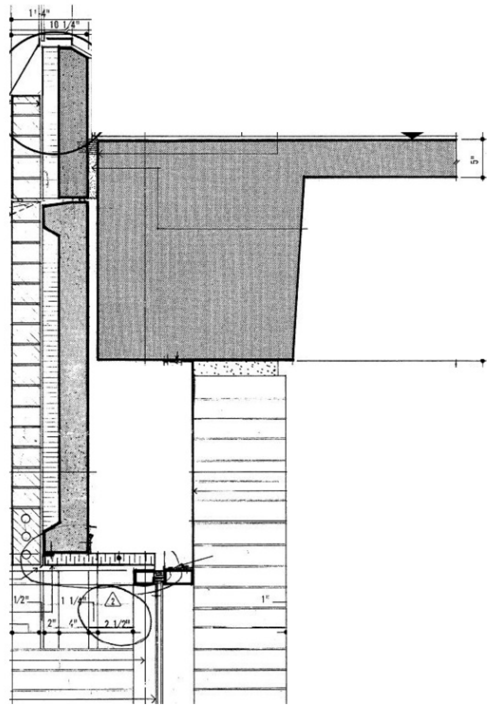


Fig. 10 – *A section illustrating the skirt panel construction at ground-floor glazing. Taken from the original architectural drawings (Arcop, 1977).*

3.1.2.6. WINDOW ASSEMBLIES

The existing documentation indicates that the window frames are cast directly into the precast concrete panels – which has been verified by the panel removal investigation. The interior aluminum flashing is removable. The existing window caulking is known to contain asbestos and will require appropriate work procedures.

Fig. 11 – *The window caulking throughout the complex is known to contain asbestos.*

3.1.2.7. Mechanical, Electrical & Communications

The need to protect (may include temporary removal and remediation) building systems is anticipated within the perimeter work zone that will be affected by the envelope replacement, including services within the existing drop ceiling and perimeter drywall bulkhead.

In general, the exterior walls are free from building services with the following known exceptions:

- Mechanical rooms located at the building perimeter have conduit, communications, and HVAC ductwork affixed to the building exterior (15^{th} floor of 25 Eddy and 11^{th} floor of 15 Eddy);
- Areas where louvers, intakes, and exhaust vents penetrate the exterior;
- Areas where services (such as electrical receptacles) are available on the building exterior; and
- Areas throughout 1 Promenade du Portage, which has different interior perimeter conditions than the other buildings, including specialized telecommunications equipment, and food service facilities.

In addition, the building may also include electrical conduit embedded in floor slabs. The presence of conduit should be verified before any drilling or cutting of slabs.

Fig. 12 – *A mechanical room on the 15^{th} floor of 25 Eddy, including electrical and communications infrastructure on the exterior precast concrete wall.*

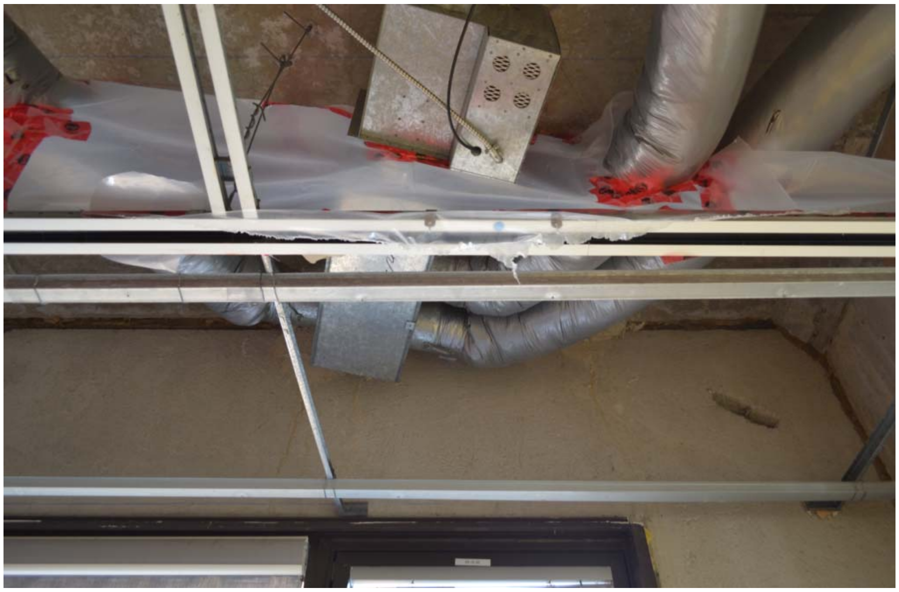


Fig. 13 – *A typical office interior with the ceiling and drywall removed. The ductwork is in proximity to the exterior wall but is not attached.*

Fig. 14 – *A wall cavity between the exterior louvres and the air handling unit. The hung mesh screen has been installed to catch debris, and may indicate that the louvers are undersized. Consideration should be given to increasing louver size on the new façade.*

3.1.2.8. Mechanical System Constraints

<u>Cooling Capacity</u>

The existing mechanical cooling system reportedly operates at maximum capacity during peak cooling events (should be confirmed by a Capacity Assessment Report). This has restricted the possibility of upgrading the majority of the building floorplate to the planned future Workplace 2.0 Fit-Up standard since a major upgrade of the mechanical cooling system would be required in order to do so. The Workplace 2.0 Fit-Up standard would result in an increase in occupancy from roughly 6400 to 9000 people.

The envelope rehabilitation solution should aim for an overall reduction in the cooling load.

Ideally, the new envelope would reduce the cooling load by at least the load that will be imposed on the cooling system once the building has been fully retrofitted to Workplace 2.0 Fit-Up standard.

<u>Heating Capacity</u>

The capacity of the existing mechanical heating system should be confirmed by a Capacity Assessment Report. It is assumed that there are currently no problems with the existing perimeter heating system (overhead forced-air).

The envelope rehabilitation solution must not impose a higher heating load than the existing envelope in order to keep in place the existing perimeter heating system.

Ideally, the new envelope will significantly reduce the heating energy consumption of the complex. This goal is supported by the applicable energy codes and standards.

3.1.2.9. Smoke Evacuation

Certain floor areas include a passive, user-operated smoke evacuation system. The system consists of operable windows which can be opened by building operators or the fire department to facilitate smoke evacuation.

NOTE: Investigations will be required to determine if the smoke evacuation openings are connected to the existing alarm and life safety systems.

The new building envelope will require a code analysis to determine the requirements for a smoke evacuation strategy should it be required.

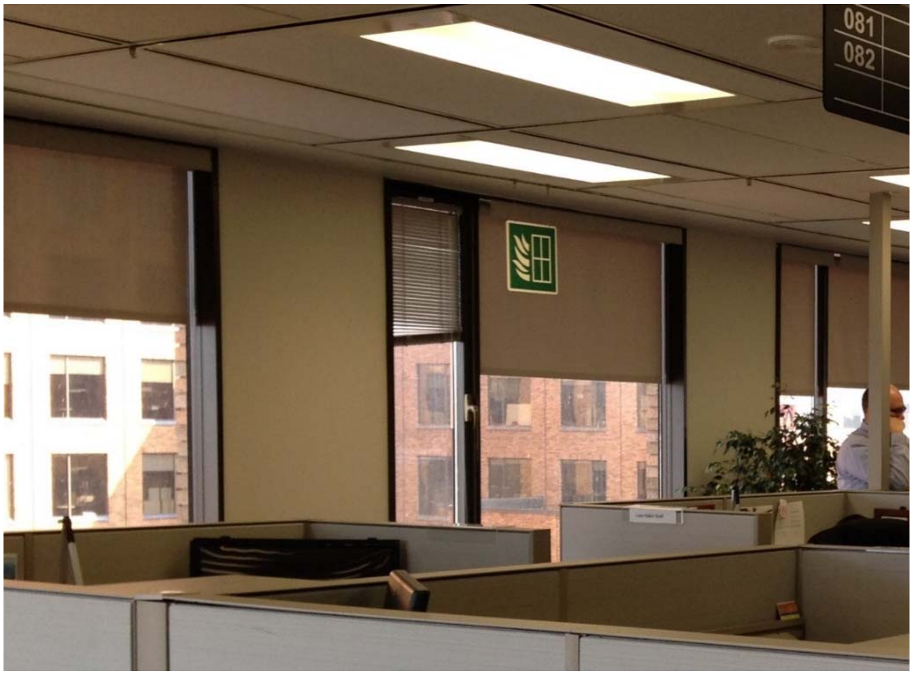


Fig. 15 – *A typical manually operated smoke evacuation opening including signage.*

3.2. CODES AND STANDARDS

3.2.1. *CODES & STANDARDS*

In order to provide schematic design options that meet the project criteria, various codes and standards were considered. The codes and standards that informed this phase of schematic design are:

- The National Building Code of Canada, 2015
- The National Performance Standards for Office Buildings (NPS) , PSPC, 2016
- The National Energy Code of Canada for Buildings, 2011
- Applicable Federal Legislature including Seismic Policy

Although not mandatory to Federal projects, consideration was also given to:

- The National Building Code of Canada modified – Quebec, 2010
- The Act respecting the conservation of energy in building (*Loi sur l'economie de l'energie*)– Quebec, 2016

3.3. OPTIONS ANALYSIS METHODOLOGY

GRC has built on the baseline established by Smith Carter (*Feasibility and Options Analysis*, 2013), and has updated the options based on four (4) different construction approaches, and their associated implementation requirements.

As the project has advanced, it has become clear that all feasible options will constitute a major aesthetic change for the complex – resulting from an overall material change from the existing brick masonry facade. This allows for the consideration of better performing wall systems, and greater variety of aesthetic options. This aesthetic change has been validated by the NCC ACPDR committee as an appropriate and desirable change. Maintaining the aesthetic continuity of the complex (brick cladding) is not a project constraint.

Each option has been evaluated based on the following factors:

1. Implementation risk mitigation;
2. Schedule risk mitigation;
3. Performance potential of envelope;
4. Implications for tenants; and
5. Cost (this report uses class “C” cost estimates, based on a uniform metal panel cladding system where applicable).

NOTE: Refer to Appendix B for comparison matrix.

3.4. OPTION 1 – RETENTION OF THE EXISTING PRE-CAST BACKUP PANEL

This option includes:

- The panel-by-panel removal of the brick veneer, insulation, rebar and steel fins;
- Removal and replacement of the existing cast-in-place window assemblies;
- Removal and replacement of the corner curtain wall bay-windows;
- The installation of a new insulated exterior cladding;
- The upgrade of all existing panel connections for seismic capacity; and
- Interior demolition and remediation as required.

<u>Implementation Risks</u>

The panel-by-panel removal of the brick veneer and other panel elements, as well as the installation of the replacement cladding system will require a lengthy and protracted process with many on-site trades. Chipping, removal and replacement of the window assemblies will add to the schedule risks.

The panel seismic connection upgrades will require the demolition and replacement of interior ceilings and finishes, as well as the use of welding equipment within the occupied spaces. As outlined in the Dessau seismic report (Tome 2, Vol. 1 – Section 5.5), the seismic upgrades alone would take approximately 2 ½ years, with an approximate cost of $13,000 per panel.

This option would require a substantial lay-down space for the site-built components and waste control. The constrained site may require the contractor to arrange additional space nearby.

The exterior work would have to coordinate with the existing exterior pedestrian circulation and fire access routes – a task complicated by the duration of the exterior construction and the quantity and coordination of on-site trades.

One significant benefit to this option is the elimination of lifting the existing panels off the face of the building – effectively eliminating one of the riskiest activities that is common to all the other options.

Another benefit to this option is overall reduction in waste, resulting from the retention of the precast panel.

This option presents a medium risk related to implementation and construction.

Rating: *Neutral*

Risk to Schedule

This option requires a protracted, labour intensive, and lengthy process which results from the complicated demolition process, the panel upgrades, and the fact that the new façade components must be constructed in place. In addition, delays caused by weather, occupant complaints, and lay-down space are likely.

This option presents a high risk of schedule slippage.

Rating: *Poor*

Performance Potential of Envelope

This option does offer the opportunity to provide thermal upgrades, depending on the proposed exterior wall assembly. However, the exterior wall assembly will be constrained by the need to reduce the weight of the system in light of retaining the concrete backup panels. It is presumed that modest upgrades to thermal performance could be achieved. In addition, this option will require the retention of the existing openings and window pattern throughout the complex, and will limit the amount of design choice and variability – making it more difficult to fulfill the Client's design vision for the complex.

Rating: *Neutral*

Implications for Tenants

Because this option does not require the full removal of the building envelope, it may reduce the need for tenant relocation; instead replacing it with protracted and lengthy disruptions within the occupied tenant space. However, the presence of asbestos in the windows and drywall joint compound generate significant risk of exposure in any scenario where occupants remain in-situ during the construction process.

Acoustically, tenants would be subjected to ongoing noise resulting from the panel seismic upgrades, the removal of the brick veneer, the cutting and grinding of the steel components, the window replacement, and the subsequent installation of the new exterior system. This ongoing acoustic and physical disruption is assessed as a major drawback and risk, and will create an unpleasant work environment for an extended period of time.

Rating: *Poor*

Summary

Pros	Cons
• Reduced landfill waste due to retention of precast back-up panels • No need to lift full panels off of the building	• Very high risk to schedule due to brick removal process, panel seismic upgrades, and exterior façade construction process (incl. winter construction) • Prolonged acoustic/physical disruptions for tenants • Winter work on exterior face of building • Requirement for large areas of lay-down space • Risk of exposure to hazardous substances

The combination of negative attributes creates a high-risk scenario that even in a best-case scenario will create many years of workplace disruptions.

3.5. Option 2 – Slab Infill (steel stud back-up)

This option consists of:

- Installation of an interior weather/protection wall;
- Interior demolition and remediation as required;
- The removal of the existing pre-cast panel system and curtain wall bay windows;
- Installation of an engineered steel stud back-up wall between slabs; and
- Installation of a site-built exterior insulation and cladding system.

Implementation Risks

This option will require the full removal of the precast concrete panels, either intact or in pieces. The height of the towers and the weight of the panels create a complex technical and logistical challenge for this aspect of the work. (This is common to options 2,3,4)

This option, will require the erection of interior insulated hoarding walls in order to close the building from the while providing a minimum of space at the perimeter of the building to execute the work. An estimated minimum perimeter of 3m (10 feet) will be required.

This option would require a substantial lay-down space for the site-built components and waste control. The constrained site may require the contractor to arrange additional space nearby.

The exterior work would have to coordinate with the existing exterior pedestrian circulation and fire access routes – a task complicated by the duration of the exterior construction and the quantity and coordination of on-site trades.

This option creates high levels of risk associated with the quantity of materials, workers, and equipment within a very constrained site.

Rating: *Poor*

Risk to Schedule

The overall schedule remains dependent on a large and well-coordinated labour force. Of all options this is the most labour intensive; it includes the risk associated with lifting the existing panels and also the drawbacks to a site-build approach. Furthermore, much of the assembly such as sheathing, A/V barriers, rigid insulation and cladding, require exterior installation from swing stage or scaffolding.

One benefit of this option is that it has greater flexibility and tolerances to accommodate unforeseen building conditions. The site built nature of the system, and the well-known construction technique will be less at risk of delays due to discrepancies between measured and actual site dimensions.

Nonetheless, the combination of panel removals, and the high volume of workers and materials on site present a high risk to the schedule due to coordination issues.

Rating: *Poor*

Performance of Envelope

The overall thermal performance of the envelope will depend on the selected wall assembly for the back-up wall, integrated fenestration and exterior cladding system. In this case, the envelope's energy performance will be a function of the assembly, products specified and quality of installation. Based on infinite design approaches, this system will be able to meet the energy code requirements.

This option does not offer the benefits of quality control monitoring that are achieved in a factory (pre-fabricated) scenario.

In addition, (as noted in the Smith Carter report) this system is susceptible to corrosion of the steel components due to their light-gauge construction. Unless a high-quality installation and perfect seal against water infiltration is achieved throughout the project, corrosion and longevity of the envelope is questionable.

Rating: *Neutral*

Implications for Tenants

Similar to all options requiring the full removal of the building envelope, this option requires the temporary relocation of tenants during construction activities. The move management and coordination of occupants is a fundamental project risk that is common to all options involving client relocation and the need for swing space.

This option would create a loss of floor in the tenant spaces in the range of 150-300mm at the perimeter of the building depending on the design of the back-up wall; an unavoidable outcome of the construction technique.

Rating: *Poor*

Summary:

Pros	Cons
• Conventional construction techniques • Reduced crane use	• Very high risk to schedule due to all components being installed from the face of the building • Prolonged acoustic/physical disruptions for tenants • Winter work on exterior face of building • Requirement for large areas of lay-down space • Longer exposure to building interior • Loss of useable floor space

Although a conventional system, the prolonged schedule and acoustical disruptions, extended periods of exposure for building finishes and services as well as somehow ensuring superior quality control during installation, lends to an undesirable option.

3.6. Option 3 – New Prefabricated Panel

This option consists of:

- Installation of interior hoarding and protection measures;
- Interior demolition and remediation as needed;
- The removal of the existing pre-cast panel system and curtain wall bay windows; and
- The installation of new pre-fabricated wall panels.

Implementation Risks

As with options 2 & 4, this option will require removal of the concrete panels (either intact or in pieces) by crane. The height of the towers and the weight of the panels create a technical and logistical challenge for this aspect of the work.

This strategy reduces the need for lay-down spaces, as the installation of the pre-fabricated panels would be coordinated to minimize site storage (a “just-in-time” approach). This approach mitigates many risks associated with on-site construction and coordination, as well as the benefit of a reduced on-site labour force. The ability to transfer the panel assembly and site coordination off-site to a factory environment where work could proceed year-round is a fundamental benefit of this approach.

This option will require the erection of interior insulated hoarding walls in order to close the building from the while providing a minimum of space at the perimeter of the building to execute the work. An estimated minimum perimeter of 3m (10 feet) will be required.

Rating: *Good*

<u>Risk to Schedule</u>

This option is anticipated to reduce the on-site installation time and trade requirements when compared to a site-built system. The reduction of on-site coordination between multiple trades is a tangible benefit, given the occupied site.

One risk to the schedule is generated by lead-times for the panel components and assembly, and another is due to discrepancies between actual and anticipated site conditions. While still valid risk factors, both of these items can be mitigated with project management oversight (scheduling and quality control processes).

Rating: *Good*

<u>Performance of Envelope</u>

The overall thermal and energy performance of the envelope is readily achievable based on the design of the pre-fabricated panels, and the factory environment creates the opportunity to craft an innovative and high-performing system with strong quality control oversight.

The durability and service life of the envelope will benefit from quality-control processes in the factory, leading to a more reliable, higher quality product overall.

Rating: *Good*

<u>Implications for Tenants</u>

Similar to all options requiring the full removal of the building envelope, this option requires the temporary relocation of tenants during construction activities. The move management and coordination of occupants is a fundamental project risk that is common to all options involving client relocation and the need for swing space. In this option the estimated time for relocation is shorter compared to option 2. The prefabricated nature of the panels will speed installation.

This option offers favourable levels of acoustic disruption compared to site built options, as the fabrication takes place offsite, and there is a reduced need for chipping and cutting in situ.

This system would replicate the outboard construction of the existing panels, resulting in no loss of interior floor space.

Rating: *Good*

Summary

Pros	Cons
• Reduced coordination efforts between on-site trades • Year-round climate controlled fabrication environment • Good potential for thermal and user comfort improvements • New modular system coordinates well with the removal of the existing modular system • Reduced durations for on-site construction activities and occupant relocation	• Pre-fabrication is less forgiving for site conditions • Full removal panels is a challenging procedure • Large amounts of construction waste will need to be dealt with off site

This option mitigates risks through the use of off-site fabrication of the panelized wall system. It is less susceptible to delays caused by weather, and creates less overall disruption on-site due to the reduced presence of trades.

Compared to other options, this option offers a high degree of design flexibility, opportunities for improvements to envelope performance, and high-level quality control in a factory environment.

3.6.1. WALL PANEL ASSEMBLY CONCEPT FOR OPTION 3

The concept for the wall panel system is designed to use off-the-shelf materials and proven technologies that are available in the North American market.

The concept is based on the following criteria:

- It must meet the thermal performance code requirements and minimize thermal bridging;
- It should be constructed of readily available products of known durability and quality;
- It should be able to accommodate various cladding systems for design flexibility;
- It must be capable of being suspended outboard of the existing slab edge as loss of interior floor space is not acceptable.

The proposed solution uses an engineered stud back-up wall that is contained within a steel frame. Sheathing and the rain-screen drainage plane are on the outer surface, while a layer of continuous rigid or semi-rigid insulation can be installed on either the exterior or interior to minimise thermal bridging.

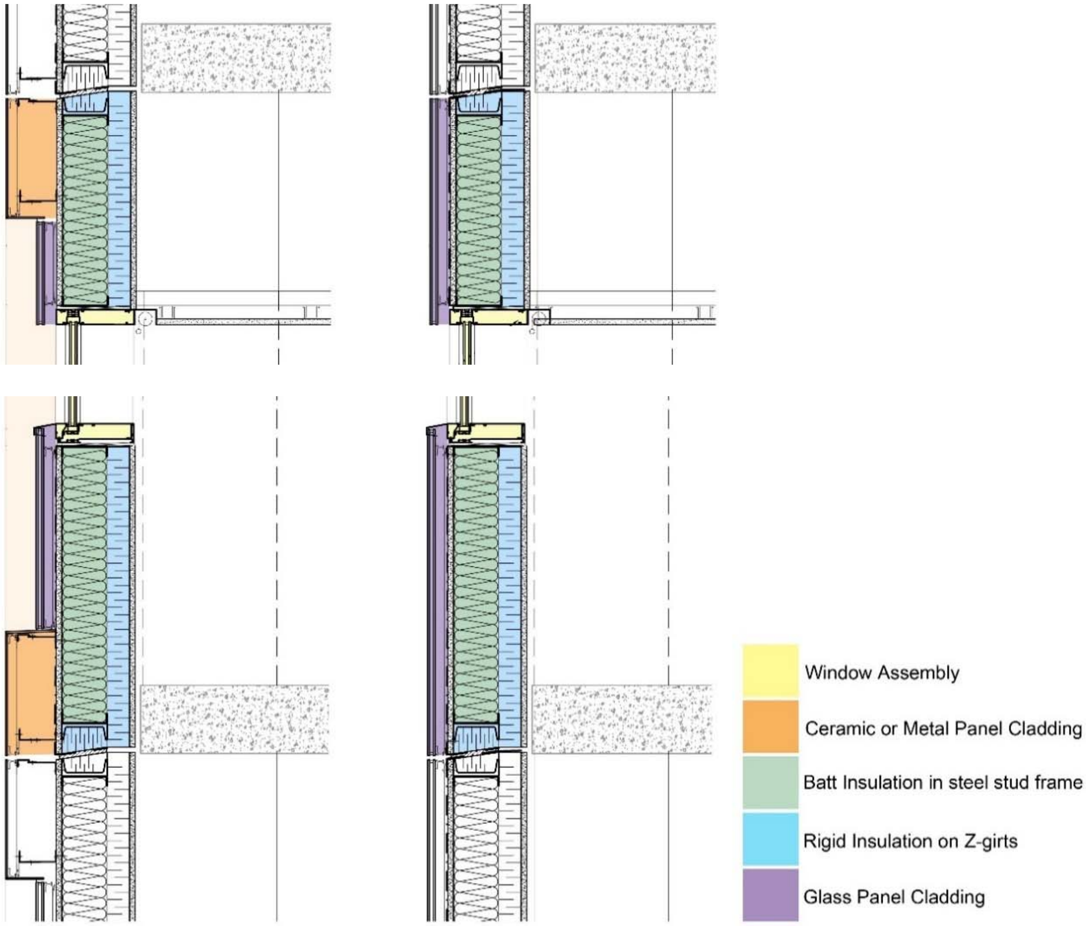


Fig. 16: *The two basic wall panel concept profiles. On the left is an expression of the framed grid, on the right is an all-glazed option. The vision glass plane has been recessed to avoid thermal bridging in the window frame.*

3.7. Option 4 – Unitized Curtain Wall

This option consists of:

- Interior demolition and remediation as required;
- Installation of interior hoarding and protection measures;
- The removal of the existing pre-cast panel system and curtain wall bay windows; and
- The installation of a new unitized curtain wall envelope.

Implementation Risks

This option has very similar implementation requirements to option 3. The principal difference resides in the fact that the full curtain wall system is provided by a single manufacturer, which standardizes and simplifies the installation process (typical and well-known construction method). The size of the individual units would also be smaller and lighter, simplifying the installation process.

This strategy minimizes the need for lay-down spaces, as the delivery and installation of the pre-fabricated panels can be coordinated to minimize site storage (a "just-in-time" approach). This approach mitigates many risks associated with on-site construction and coordination, as well as the benefit of a reduced on-site labour force. The ability to transfer the panel assembly and site coordination off-site to a factory environment where work could proceed year-round is a fundamental benefit of this approach.

This option will require the erection of interior insulated hoarding walls in order to close the building from the while providing a minimum of space at the perimeter of the building to execute the work. An estimated minimum perimeter of 3m (10 feet) will be required.

Rating: *Good*

Risk to Schedule

This option is anticipated to reduce the on-site installation time and trade requirements when compared to a site-built system. The reduction of on-site coordination between multiple trades is a tangible benefit, given the occupied site.

One risk to the schedule is generated by lead-times for the panel components and assembly, and another is due to discrepancies between actual and anticipated site conditions. While still valid risk factors, both of these items can be mitigated with project management oversight (scheduling and quality control processes).

Rating: *Good*

Performance of Envelope

Considering that high-end performing curtain wall systems (Appendix C) have been custom evaluated to the LTDLC design, the overall building thermal performance is comparable to Option 3.

Rating: *Good*

Implications for Tenants

Similar to all options requiring the full removal of the building envelope, this option requires the temporary relocation of tenants during construction activities. The move management and coordination of occupants is a fundamental project risk that is common to all options involving client relocation and the need for swing space. In this option the estimated time for relocation is shorter compared to option 2. The prefabricated nature of the panels will speed installation.

This option offers favourable levels of acoustic disruption compared to site built options, as the fabrication takes place offsite, and there is a reduced need for chipping and cutting in situ.

This system would replicate the outboard construction of the existing panels, resulting in no loss of interior floor space.

Rating: *Good*

<u>Summary</u>

Pros	Cons
• Reduced coordination Efforts between onsite trades • Single manufacturer system reduces lead time risk • New modular system coordinates well with the removal of the existing modular system • Greatly reduced façade weight (seismic benefit) • Reduced durations for on-site construction activities	• Challenging to meet thermal performance requirements • Full removal panels is a challenging procedure • Large amounts of construction waste will need to be dealt with off site

This option offers a solution which accommodates the site constraints and tenant requirements through the off-site fabrication of the panelized wall system. It is less susceptible to delays caused by weather, and creates less overall disruption on the site due to the presence of trades.

However, this option will require careful consideration to achieve comparable energy and thermal performance requirements to Option 3.

3.8. CONCLUSIONS

An examination of the risk analysis tables from the Smith Carter Report (2013) highlights the advantages of an overall strategy of complete panel replacement, including removal of the existing concrete back-up panels.

In particular, the risks related to cost variances, quality control, procurement control, and construction schedule, benefit the most from a strategy of complete removal of the existing panels.

In order to further mitigate these project risks (including project schedule and quality control), and to work within the tightly constrained project site, a general strategy of off-site prefabrication of engineered wall panels and/or curtainwall are the preferred construction approaches. Such approaches have the opportunity to make use of a variety of cladding solutions (aluminum panels, terra cotta systems, etc.) which will create an opportunity for greater design flexibility and the ability to better address the aesthetic and technical challenges of the project.

Option 1 is not considered a preferable construction approach based on several factors, but primarily for its inability to mitigate implementation risks and its prolonged construction schedule.

Option 2 is not considered a preferable construction approach due to prolonged schedule and acoustical disruptions as well as extended periods of exposure to building finishes and services.

Option 3 offers a range of risk mitigation benefits and the most versatile for design variations as well as speed of construction.

Option 4 offers similar benefits to option 3 in terms of off-site fabrication, scheduling and cost however has less design flexibility and requires careful thermal performance design.

Considering all factors, Option 3 and Option 4, used exclusively or in combination, are the preferred approaches. They offer the most comprehensive combination of risk-mitigation features and are better able to address the project constraints and requirements.

4. SCHEMATIC DESIGN

4.1. PROJECT FRAMEWORK

This project presents an opportunity to reimagine a major piece of urban fabric within the context of the National Capital. Les Terrasses de la Chaudière is a highly visible landmark that houses a significant portion of the Canadian public service. It is crucial that the envelope rehabilitation phase be fully understood in the context of a larger intervention, and that all opportunities for coordination with planned future phases are taken advantage of.

4.1.1. *PSPC PROJECT VISION*

Developed by PSPC, the vision for the overall complex rehabilitation project is:

Les Terrasses de la Chaudière: Bridging People, Place and Communities

The vision for this project captures the importance of bringing together the different “scales” of design (national identity, local context, building scale, and human scale) and to design with the needs of the associated stakeholders, communities and users of the complex in mind:

- It is a highly visible landmark in a landscape of national significance;
- It has the potential to be a symbol representative of a modern public service;
- It is a significant piece of urban fabric whose design impacts the adjacent communities;
- It is a workplace that affects the daily lives of more than 6400 individuals; and
- It falls within an area of the city that is rapidly densifying and changing the nature of the region in a significant way (other adjacent developments).

4.1.2. *PSPC MISSION STATEMENT*

Developed by PSPC, the mission statement for the overall complex rehabilitation is:

> ***To move forward to a holistic approach to site + building design that reflects the values of an evolving Canadian identity and a modern public service.***

4.1.3. *PROGRESSION OF SCHEMATIC DESIGN*

At the commencement of GRC's services, FBHRO had recently completed their evaluation on March 26, 2015 and had nearly designated the LTDLC complex as a recognized building. Initial design discussions involved the Heritage Conservation Directorate (HCD) while following the Architectural Conservation Guidelines published in June 2011.

Early design principles investigated included:

- Unified architectural language throughout complex
- Architecture of windows, to build on the existing grid of openings
- The existing subtle vertical emphasis should be maintained
- Contemporary cladding technologies and materials
- Lighter colours to increase the light in the courtyard and at street level
- Maintain appearance of glazing to wall ratio
- Fully transparent street level glazing
- New cladding compatibility with brick base and concourse if maintained.

Through continued schematic design, along with feedback from PSPC and the NCC ACPDR members, it was preferred that the Architectural Conservation Guidelines not be applied and that the design reflect the following principles:

4.1.4. *PSPC High-Level Design Principles*

The following five design principles were developed by PSPC to create a baseline of quality and design intent that will be applied to this and subsequent phases of the project.

Principle 1

Enhancing pedestrian experience:
- Where people take priority; and
- Human scale is the first priority for all site design solutions.

Principle 2

Contributing to the economic vitality of the:
- Broader National Capital Area;
- City of Gatineau;
- Surrounding neighbourhood; and
- Surrounding streetscapes.

Principle 3

Supporting economic viability through sustainability and durability:
- Efficient operational systems reduce energy consumption;
- The selection of high quality, long lasting materials;
- The inclusion of flexible adaptable workplaces to support Blueprint 2020 and Workplace 2.0; and
- Designing to take advantage of the natural climatic conditions whenever possible.

Principle 4

Creating an exciting work environment that is:

- Healthy;
- Collaborative;
- Attracts the next generation of public servants in support of Blueprint 2020; and
- Supportive of the public service renewal directives as per Workplace 2.0.

Principle 5

Promoting design excellence that is:

- Innovative;
- Exciting;
- Culturally relevant;
- Forward looking; and
- Flexible and adaptable for the future life-cycle of Les Terrasses de la Chaudière.

4.2. SCHEMATIC DESIGN CRITERIA

4.2.1. *SUSTAINABLE DESIGN STRATEGIES*

Due to the nature of the project (a major envelope rehabilitation), there are no specific sustainability requirements to follow (LEED, Living Building, etc.). However, sustainable strategies relating to product selection, carbon footprint, sourcing of materials, cradle-to-grave assessments and the use of recyclable materials should be considered.

In the broader context of sustainability, the mental and physical health of occupants, the economic vitality of the community, reducing energy consumption, and life-cycle waste strategies are all factors that should be included in the design of the new envelope.

Despite the lack of specific targets, this project is nonetheless expected to set a high standard for the inclusion of sustainable design for future government projects.

4.2.2. *Existing Building Envelope*

Based on an analysis of the existing wall assembly, the assessed performance baseline of the existing building envelope is as follows:

Existing Opaque Wall:

Layer Description	interior + exterior film	5/8" gypsum wallboard	4" thick concrete wall	2" rigid insulation angles at 24" o.c. to support brick.	1/2 " air space	3.5" masonry brick veneer	**Total R-Value**	**Total U-Value (Btu/ft^{2}F)**
Layer R-Value	0.85	0.56	0.25	5.63	0.82	0.96	**9.1**	**0.110**

Existing Vertical Fenestration:

	Glazing Only	**VLT**	**Assembly U-Value (Btu/ ft^{2}F)**	**SHGC**
Existing Window Assembly	Center of Glass U-0.47	**0.47**	**0.61**	**0.51**

The existing precast window panels (with some local variation) have a typical window to wall ratio (WWR) of 43%. The approximate total WWR for each block (including the curtainwall corners and ground level) are as follows:

- 10 Wellington (North Building): **47%**
- 1 Promenade du Portage (Centre Building): **53%**
- 15-25 Eddy (Jules Léger Building): **46%**

4.2.3. *New Envelope Design Criteria*

In general, exterior wall design should provide complete control of migration of heat, air, and moisture through the building enclosure. Minimizing risk of moisture-related damage to enclosure materials and of mould development should be a priority consideration in the design of the exterior wall.

4.2.3.1. Energy Performance

The combined envelope options modeled fall under two primary wall system categories: prefabricated panel and curtain wall. The purpose is to assist in determining which wall system has an overall lower life cycle cost.

These combined envelope options illustrate the energy performance of a variety of possible scenarios, not only to decide upon a wall system, but to help determine an appropriate window to wall ratio (WWR) for the building overall and for each facade. The two wall system categories (prefabricated panel and curtain wall) were modeled in parallel sets, with the same characteristics for the fenestration glass type and WWR per facade, so that the two systems can be easily compared for a variety of possible architectural design choices.

The envelope options modeled include variations of wall insulation, the fenestration characteristics, the WWR on different facades, and solar shading.

When ranked in order of potential to impact the annual energy cost these options are listed as follows in order from high to low priority:

1. Fenestration solar heat gain coefficient
2. Window to wall ratio overall and on each facade
3. Fenestration thermal transmittance, including the framing configuration
4. Wall insulation
5. Solar shading

In order to achieve the highest annual energy cost savings, the design could consist of prefabricated wall panel construction with triple pane fenestration having the following characteristics:

1. Fenestration with an assembly U-Value ≤ 0.20 Btu/(h·F·ft2), SHGC ≤ 0.30;
2. WWR not exceeding Code maximum of 36.3%. A lower WWR on south and west facades than on the north and east facades results in energy cost savings;
3. Wall U-Value at Code minimum of ≤ 0.044 Btu/(h·F·ft2)

4.2.3.2. Response to Solar Orientation

The response to solar orientation offers additional opportunity to control solar gain and make use of natural light.

Should external solar control be contemplated, the Prime Consultant will need to consider and demonstrate how snow and ice would affect horizontally oriented sun shade devices, particularly in the areas where the presence of pedestrians at grade may create a safety risk associated with falling compacted snow and ice.

Other solutions related to glazing technology and area of openings can be targeted to the seasonal and daily characteristics of the different elevations:

- The north and east elevations offer the opportunity for highly transparent glass (VLT of 70% or more) to make use of the natural diffuse light and low amounts of glare and direct sunlight during working hours;
- Reducing the percentage of vision glass on the south and west façades;
- The south and west elevations could include a lower SHGC glazing and/or ceramic frit in order to minimize solar heat gain; and
- The west elevation could include exterior vertical brises-soleil elements.

4.2.3.3. Window to Wall Ratio (WWR)

In accordance with the NECB and the *National Performance Standards for Office Buildings*, the new envelope is anticipated to have a vision area, excluding the ground floor podium glazing, of approximately 36% of the total facade area.

4.2.3.4. Maintenance

The design of the new envelope should include provisions for the attachment and use of swing stage equipment for the purposes of maintenance and cleaning (the existing façade includes concealed eye-hooks for swing stage attachment). The use of self-cleaning glazing and hydrophobic coatings are also encouraged to minimize routine maintenance.

NOTE: The eventual Prime Consultant should liaise with the building operator (BGIS) to verify requirements for maintenance.

4.2.3.5. Applicable Technologies

Based on the project requirements for durability, life-cycle costs, and envelope performance, the Consultant Team has determined that certain envelope technologies and materials are unlikely to meet the project requirements for durability and performance.

<u>The cladding systems assessed as viable for this project include:</u>

- Pressure equalized rain screen systems;
- Rear-ventilated rain screen systems;
- Unitized curtain wall (subject to thermal performance requirements);

<u>The materials assessed as viable for this project include</u>:

- Terra cotta tiles;
- Ceramic tiles;
- Metal panel systems (solid metal only; no composite);
- Stone veneer;
- Glass panels;
- Spandrel glass;
- Specialty glass, stone, and metal products.

<u>The cladding systems assessed as not viable for this project include:</u>

- Face sealed systems;
- Window wall systems;
- Any system with greater than 5% areas of thermal bridging;
- SIPS;
- Precast concrete panels (due to weight concerns for seismic performance).

The materials that are assessed as not viable for this project include:

- Metal composite panel cladding systems;
- EIFS;
- Wood;
- Cementitious fiber board.

4.3. USER COMFORT GOALS & CRITERIA

4.3.1. *SUMMARY OF STANDARDS*

Creating a thermally comfortable environment is critical for every project as it is a key component to occupant productivity and well-being. Programs and standards like LEED, the WELL standard, Green Globes, EN-15251, and ISO 7730 all address thermal comfort as a key element to producing high performing buildings.

This project should look to all the above standards for guidance on creating comfortable spaces, but it will ultimately be *ASHRAE Standard 55-2013: Thermal Environmental Conditions for Human Occupancy* that the project should demonstrate compliance with.

4.3.2. *DESIGN CONDITIONS*

ASHRAE 55 specifies a combination of personal and environmental factors that together can determine when a space will be deemed thermally comfortable. These factors include:

- Personal Factors
    - Metabolic rate: The energy generated from the human body
    - Clothing insulation: The amount of thermal insulation the person is wearing

- Environmental Factors
    - Air temperature: Temperature of the air surrounding the occupant
    - Relative humidity: Percentage of water vapor in the air
    - Radiant temperature: The weighted average of all the temperatures from surfaces surrounding an occupant
    - Air velocity: Rate of air movement

The envelope rehabilitation should be shown to meet ASHRAE 55's 80% comfort threshold using the most appropriate personal factors from Table 5.2.1.2 of ASHRAE 55-2013 for each space. An example of personal factors that would be appropriate for at least some spaces in this project's scope include:

- A 1.1 metabolic rate is used to represent an occupant that is sitting and typing;
- A 1.0 clothing insulation value is used to represent typical winter indoor clothing; and
- A 0.61 clothing insulation value is used to represent an occupant wearing pants and a long sleeve shirt.

For each occupant group type, the proponent should determine the most appropriate metabolic rate and clothing insulation value associated with their activities and attire. Use of averaged metabolic rates to represent occupants with dissimilar activities is not preferred.

4.3.3. DESIGN AND MONITORING STRATEGIES

Pre-Construction Strategies

- Pre-retrofit survey
  At the start of Design Development, a pre-retrofit survey is to be developed and distributed to existing building occupants. The results of this survey are to be analyzed to identify the location or reasons for any existing thermal comfort problems, and to help guide the proponent towards envelope solutions that could be implemented to address these problems.

- Establish minimum envelope parameters required to achieve comfort
  The appropriate clothing insulation values and metabolic rates for each type of occupant are to be combined with temperature, humidity, air velocity, and mean radiant temperatures in order to establish the comfort boundaries for each type of space.

- Comfort settings across different types of spaces
  It will be important during this stage to identify and clearly define any spaces that will require different thermal comfort settings. For example, divisions here are likely to include: occupancy type (i.e. regularly occupied spaces vs. transitional spaces vs. non-occupied storage spaces); and different occupant exertion areas (i.e. areas of sedentary activities vs. areas where physical exercise occurs).

- New envelope must achieve comfort with both existing and future HVAC systems
  Because the envelope rehabilitation phase of this project does not present the opportunity to modify the existing HVAC, it is important that the new envelope does not introduce any conditions that cannot be met by the existing system.

  As such, known comfort variables of ASHRAE 55 (e.g. clothing insulation, metabolic rate) are to be used in combination with derived variables (e.g. air and radiant temperature) to promote envelope solutions chosen that are able to maintain comfortable conditions for at least 80% of occupants (as determined through the Predicted Mean Vote method of ASHRAE 55-2013) with the existing HVAC systems in place.

- Outline plan to educate and inform
  The means by which occupants and building operators will be educated about the use of their environmental controls must also be defined at this stage. A written outline is to be provided along with a plan for eventually finalizing and disseminating this information.

Analysis of the Final Design

- Demonstrate compliance with ASHRAE 55-2013
  Compliance with ASHRAE 55-2013 using the Predicted Mean Vote (PMV) method

should be demonstrated on a room by room basis. Rooms with similar properties (e.g. same thermal block, same mechanical system, same orientation, similar envelope components, occupancy types, and window to-wall-ratios) can be grouped if deemed appropriate.

- <u>Mean radiant temperature</u>
  Operative and mean radiant temperatures should be calculated as described in ASHRAE 55-2013 Normative Appendix A. Any calculations required for the purposes of thermal comfort should be based on accepted calculation methodology followed by internationally recognized authorities (e.g. ASHRAE, ISO, EN).

- <u>Acceptable analysis tools</u>
  Tools like the CBE Thermal Comfort Tool (screenshot below) can provide assistance to minimize time efforts in developing compliance psychometric charts. Final thermal comfort documentation must also include all applicable requirements listed in Section 6.1.1 of ASHRAE 55-2013.

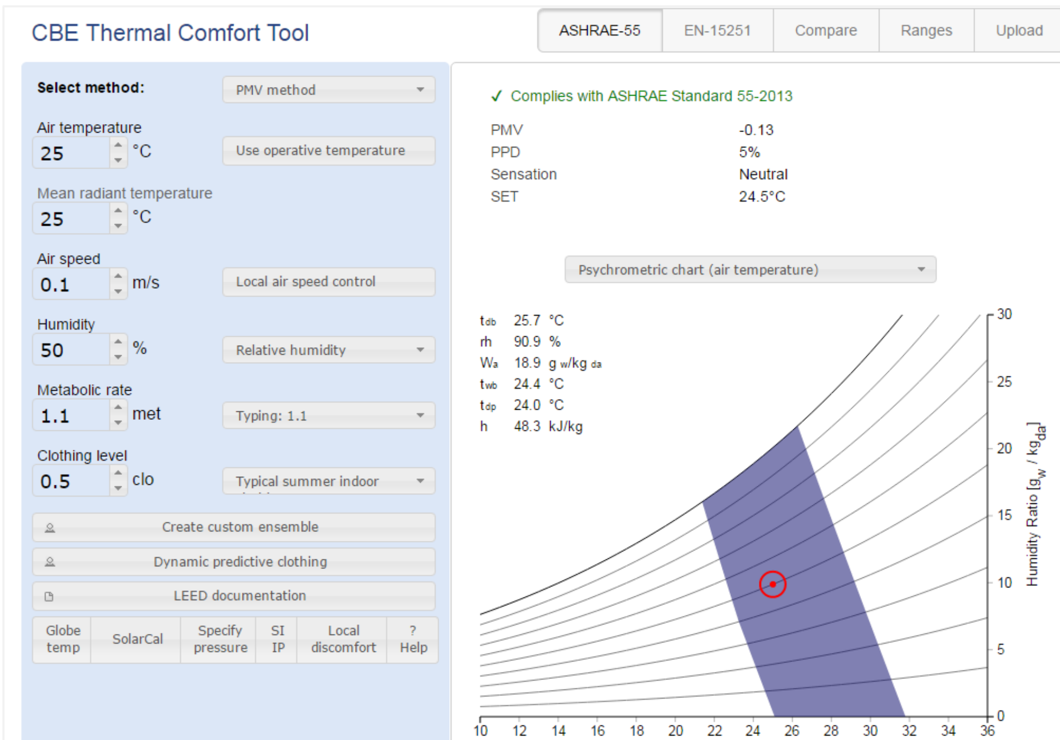


***Fig. 17 –** An example screenshot of a CBE analysis from the free online tool at: http://comfort.cbe.berkeley.edu/*

Commissioning & Verification Activities

- <u>Post-construction comfort surveys</u>
  Post-construction comfort surveys should be developed and distributed. These surveys must at a minimum: achieve a response rate of at least 30%; be from a sample that is representative of the project (e.g. different activities, different floors, perimeter / core locations, different orientations in perimeter zones); and follow ASHRAE 55-2013 Section 7.1's requirements and guidelines.

These surveys are to be distributed and analyzed at four month intervals in the first year of occupancy in order to help identify any issues that are seasonal.

If more than 20% of respondents report uncomfortable conditions in either of the surveys, a plan should be for corrective action.

4.3.4. NATURAL VENTILATION

Natural ventilation is a means of providing air into a space to achieve desired levels of indoor air quality and often in combination with other measures to control space temperature and thermal comfort. Wind pressure (effects governed by the wind speed and direction in combination with the building geometry and nearby building shapes and sizes), and buoyancy pressure (flow that arises from the temperature differences between air inside and outside of the building) are the two driving forces behind natural ventilation.

While a natural ventilation design will not operate with the same precision as a mechanical system there are a number of benefits associated with it, including:

- A sense of control over the conditions in the space by occupants through the use of operable elements;
- A connection to the outdoors for the occupants, resulting in a widening of the acceptable thermal comfort range; and
- A reduction in energy use when natural ventilation replaces a mechanical system.

Although there are numerous factors in favour for natural ventilation, careful consideration of building pressurization, particularly for the taller blocks of 10 Wellington and 15/25 Eddy, need to be identified and designed for.

Design Requirements for Natural Ventilation

While ASHRAE 55 has special requirements for naturally conditioned spaces, one of the stipulations is that no mechanical cooling system is to be installed (Section 5.4.1(a)). Given that the envelope rehabilitation does not involve mechanical system adjustments, these special requirements will not be applicable. As such, any proposed natural ventilation solutions should demonstrate compliance under both: ASHRAE 55-2013 using the Predicted Mean Vote method; and the ventilation requirements set forth in ASHRAE 62.1-2013.

In addition to the above, the following considerations should be addressed:

- Stack effect
  This whole building issue affects how air moves in the building through shafts and other vertically connected pathways. The driving force for stack effect is buoyancy due to temperature differences between the inside and outside. This is the same buoyancy force which is also used to generate natural ventilation. However, if the buoyancy force spans the entire height or part of the height of the building (through shafts or other vertical connections), then certain spaces may not receive ventilation air from the outdoors, but instead would receive stale air from the other parts of the building. Stack effect can also cause door operability issues or whistling of elevator shafts (under certain outdoor conditions). Any natural ventilation design must

account for stack effect, demonstrate adequate ventilation for all spaces, and demonstrate that there will not be whistling or door operability issues.

- Building pressurization
  Any proposed natural ventilation system must work with and not against the building pressurization.

- Fire and smoke exhaust
  Any natural ventilation system must comply with the requirements of the smoke and fire controls.

- Noise
  Natural ventilation systems provide additional pathways for noise and vibration. The design should demonstrate that those pathways will not adversely affect occupants

4.3.5. *Applicable Technologies*

Some guidance regarding technologies and strategies that may used to achieve thermal comfort are briefly outlined in this section. In general, innovative solutions and technologies will be viewed favourably by the Owner.

- External solar control
  Due to the local climate, the use of horizontally-oriented sun shade devices must be carefully considered to demonstrate that they will not accumulate snow or ice or pose a threat to pedestrians or property at grade.

- Interior solar control
  All interior solutions (e.g. light shelves, roller shades, venetian blinds, drapes, blackout screens, blinds within glazing unit) should be fully evaluated. The various shading materials and finishes, when matched to a glazing's visible light transmittance, should be optimized to control heat gain and mitigate glare, while still allowing some daylight penetration and a view to the outdoors.

- Opaque envelope components
  The performance of the opaque envelope systems used for this project will clearly play a critical role in achieving the thermal comfort requirements. Innovative solutions beyond the minimum requirements referenced in this document will be viewed favourably.

- Transparent and translucent envelope components

  Properly optimizing the glazing specifications based on the façade orientation (e.g. lower SHGCs on west and south facades) is critical to achieving the thermal comfort objectives.

  Innovative solutions beyond the minimum performance requirements referenced in this document will be viewed favourably. Some possibilities include:

  - Electrochromic glazing: these products can take advantage of solar gains when in heating mode, and reduce the gains when they would be detrimental to thermal comfort or energy usage (i.e. in the summer). Because these products have distinct advantages in balancing the project's thermal comfort, glare mitigation, can eliminate the need for blinds, and can even assist in meeting energy savings goals, they should be carefully evaluated.

- o Triple and quadruple glazing: three or more glazing layers with one low-e coating per gap and low-conductivity gas fills are the current state-of-the-art technology for high performance windows. While these products can have their drawbacks (e.g. costs, thickness, weight), proponents should weigh the advantages and drawbacks of new technologies to provide an optimized approach to retrofitting the building.
- o Frit patterns: frit patterns are not only bird friendly, they can help reduce long-wave radiation heat gains, particularly if they are placed on the interior surface of the exterior pane of an insulating glass unit. An opaque frit pattern can also help control glare.
- o Translucent glazing: translucent glazing products (e.g. Okalux, Solera, Kalwall) offer substantially higher thermal performance and lower SHGC. These products are also successful at bringing diffused daylight deeper into spaces while mitigating potential issues with glare. Because these products restrict views to the outdoors they are not ideal for every application, but should nonetheless be considered for certain applications.

- <u>Low infiltration</u>
  Minimizing air infiltration will be of the utmost importance for this envelope rehabilitation given its considerable effect on thermal comfort and energy use.

  For this project, a target maximum infiltration rate should established. It is anticipated that these will be based on the Maximum Allowable Leakage Requirement from the U.S. Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes, May 2012, which is 0.25 cfm/ft^2 of envelope at 0.3" WC.

  During commissioning, tests should be conducted to verify that these maximum leakage rates have not been exceeded.

- <u>Stack Effect</u>
  Regardless of whether a natural ventilation strategy is used for this building, the proponent will be required to demonstrate that the risks associated with stack effect have been properly and fully addressed. For example, infiltration losses are not to be greater on upper floors, and there shall be no whistling or door operability issues.

4.4. SITE ANALYSIS

4.4.1. *REGIONAL CONTEXT*

The site falls at a unique intersection between parkland to the west, Traditional Main Street retail to the east, low density residential and future development to the north, and planned mixed-use development and waterfront access to the south.

The site in its present state is an urban barrier that discourages movement through the site. This project presents the opportunity to change the nature of the complex into a link and to improve access for the community and building users.

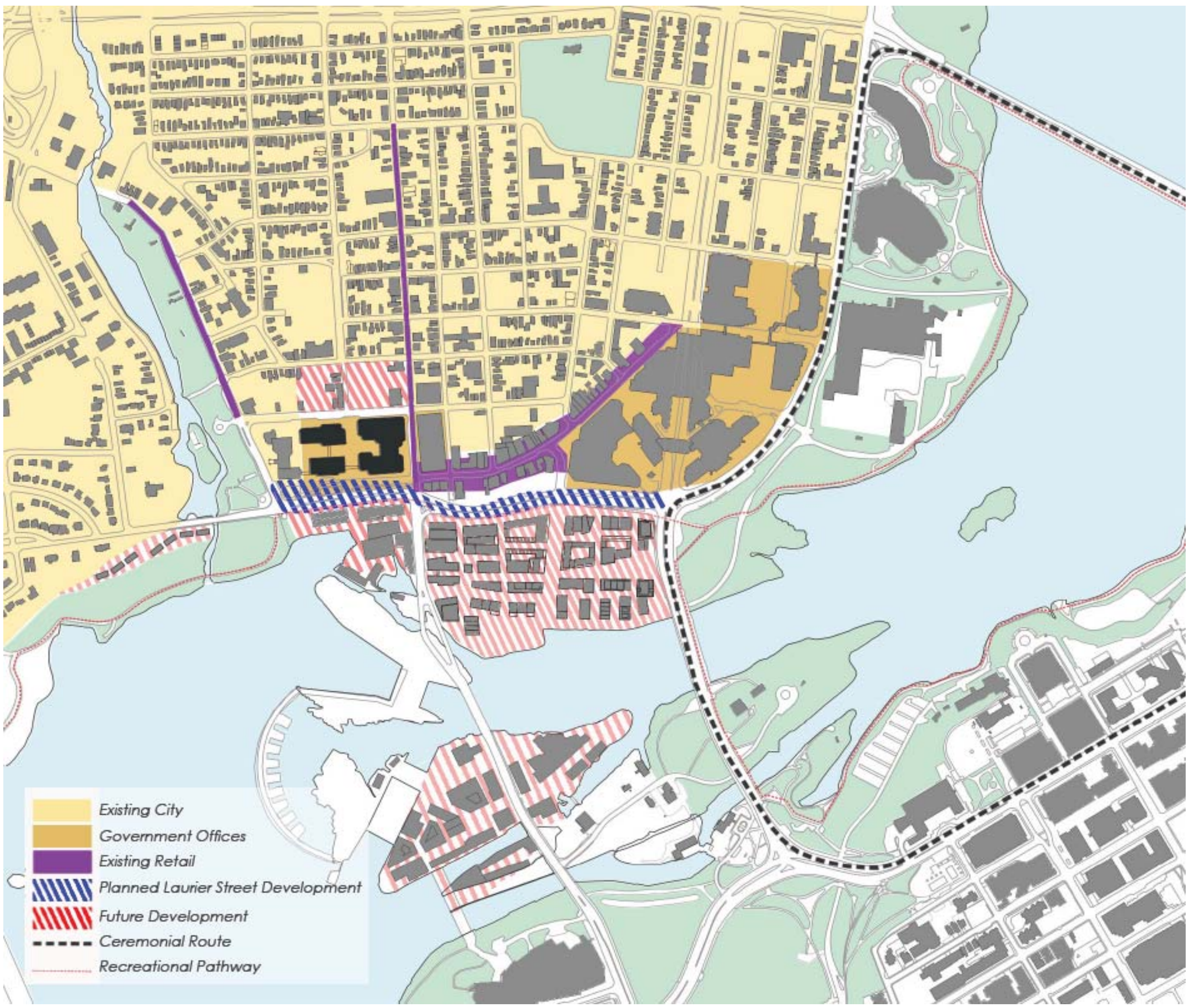


Fig. 18: *An illustration of the existing local context.*

In addition, Rue Laurier/Boul. Alexandre Taché (to the south of the complex) form part of an official *Capital Scenic Approach Route*, and is a direct connection to the ceremonial route of *Confederation Boulevard*. As a result, there is a strong rationale for urban design improvements, particularly on the south side of the complex.

The complex has a prominent position on the skyline, including a visual relationship with the Parliamentary Precinct. In addition, its appearance within the various protected views related to the ceremonial route (*Confederation Boulevard*) should be considered.

The skyline views illustrate the opportunity to reinforce the visual primacy of Parliament, while at the same time providing an updated, contemporary aesthetic for the complex. An analysis of the changing views of the complex from the surrounding areas have yielded the following:

- When viewed from east of the Supreme Court promontory, the surrounding buildings and landscape screen the bulk of the complex from view;
- Views from the west offer a picturesque river skyline with Parliament as the central focal point. (Note: This condition of national significance stands to be significantly altered by the planned Zibi development); and
- The skyline views from the west describe a city core in three distinct districts (public service, Parliamentary Precinct, and business / financial).

Fig. 19: *A comparison between eastern (top) and western (bottom) views of the complex.*

The view from the west (illustrated above) demonstrates the imposing scale of the complex on the skyline. As such, the overall objective is to re-scale the complex relative to its surroundings in order to promote the visual prominence of Parliament and the other national institutions.

Fig. 20: *Illustrations of various massing themes that were considered (view from Bate Island).*

A series of studies (selected themes shown above) were performed to examine various massing and material schemes. The preferred scheme expressed the complex as a **family of three distinct buildings**, and included an overall lightening in colour and inclusion of reflective materials.

4.4.2. LOCAL CONTEXT

The exterior areas of the site are a combination of pedestrian paths, non-accessible grade changes, concrete hard-scaping, vehicle areas, and public side-walks. Current access to the courtyard has been eliminated due to the safety risks associated with the existing façade. The prominent areas to the south of the building have been given over primarily to vehicle access, and there is a lack of amenity space throughout the exterior areas.

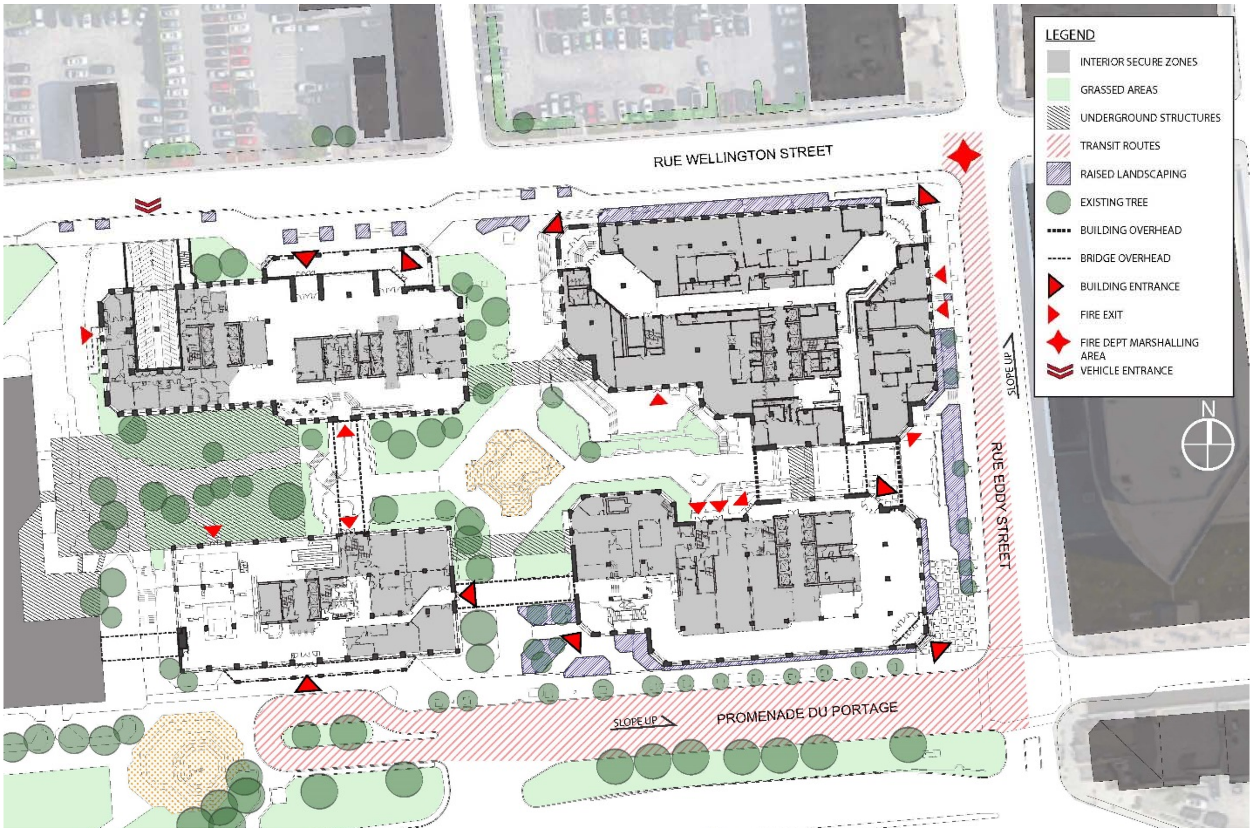


Fig. 21: *The existing site conditions.*

The land ownership also has important implications for the revitalization of the area. In many instances, the perimeter sidewalks as well as the areas to the south of the complex are City of Gatineau lands.

Understanding the seasonal and daily periods of direct sunlight across the façade is critical for the design of an envelope that responds to the technical requirements and user comfort issues.

There is a clear response to the solar orientation in the original design and massing of the complex; the smaller mass of the Centre Building is effective at allowing sunlight into the central courtyard during the hours and seasons when inhabitation is likely. The taller masses generally have excellent access to natural light and views throughout – a condition which has not benefited the building users fully due to the existing interior layout of perimeter offices.

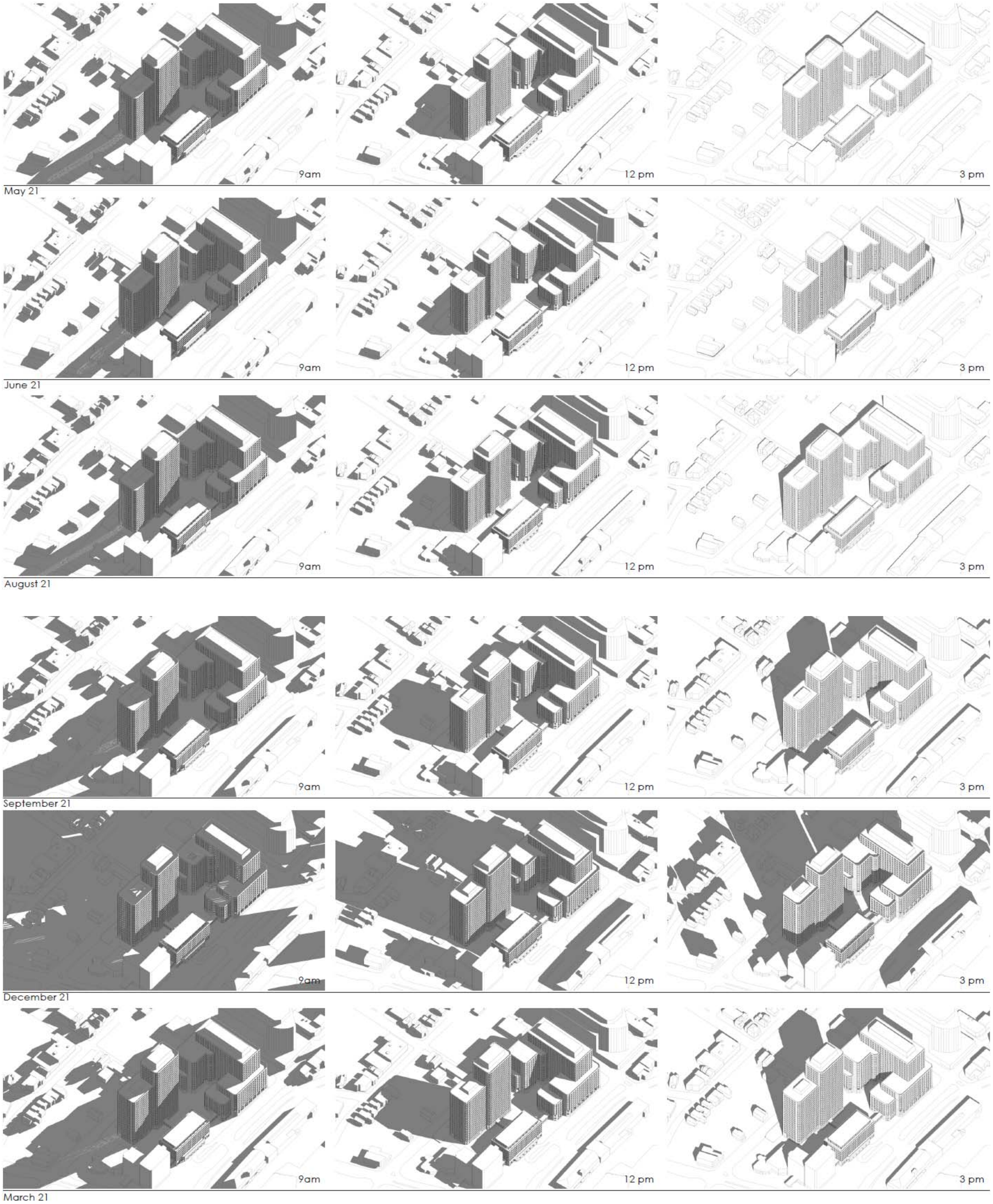


Fig. 22: *Daily and seasonal shadow studies.*

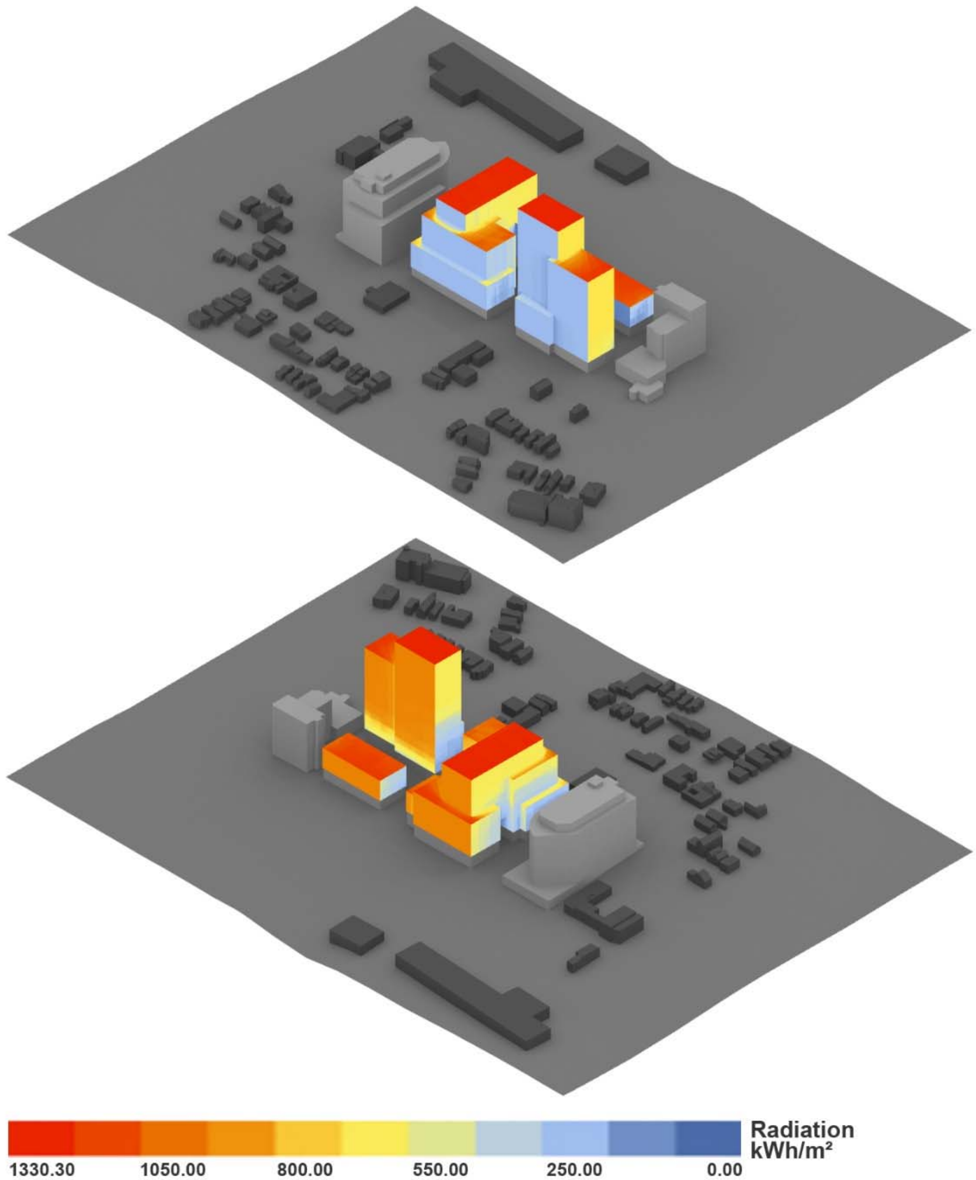


Fig. 23: *The average annual solar radiation mapped onto the façade - a useful tool for understanding the relative solar gain across façade areas. View from north-west is at top; view from south-east is at bottom.*

The above solar radiation studies offer a clear illustration of the façade areas that will require higher levels of solar gain control, as well as areas where more transparent glass or larger areas of glazing may be acceptable. One strategy to address this issue is to vary the vision glass performance across the façade in response to solar conditions.

4.4.3. STREETSCAPE AND HUMAN SCALE

The perimeters of the complex at grade have an abrupt and hard-edged relationship with sidewalks and roads. There are also areas where the interior floor levels are raised above the exterior grade by several feet. Entrances are not welcoming or well-defined, and the glazing on the grade-level windows is dark and reflective. There is an overall fortress-like, unwelcoming feel to the complex along its perimeter edges. The inwards-focused commercial services and lack of wayfinding devices reinforce the insular nature of the complex. In addition, the complex as a whole has no discernible “front door” or clear entry point for visitors.

Fig. 24: *The termination of Promenade du Portage to the south of the complex. Despite large areas of glazing at grade level, the complex remains opaque and uninviting.*

When compared to the commercial zones of Promenade du Portage to the east, there is a lack of pedestrian-friendly infrastructure (planters, benches, crosswalks, wide sidewalks, etc.). A striking difference between the street edges of the complex and the surrounding commercial and residential areas is the difference in porosity (the quantity and quality of entrances and visual connection).

While the exisiting conditions are not ideal, they nonetheless highlight the potential of this project to make positive changes that will affect a wide variety of users.

Fig. 25: *Looking west along Promenade du Portage. The generous sidewalks, and human-scaled detail are both strategies that could be continued along the southern and eastern edges of the complex.*

Fig. 26: *Looking east along Wellington Street. The low-rise buildings on the left may be developed in the future.*

4.5. Design Strategies

Prior to beginning schematic design, four design strategies were developed. The purpose of these were to ensure that certain fundamental design “layers” were identified, and then to establish goals of design excellence that any design options would be required to meet. These strategies are itemized below.

4.5.1. *Cultural Landscape Strategy*

Within the context of the cultural landscape of the National Capital, the complex is a highly visible landmark that is emblematic of the public service and its relationship with the Parliamentary Precinct across the river.

In order to respond to this condition of national significance, the complex should present an exciting contemporary design that embodies the concepts of transparency, diversity, accountability and accessibility.

The goal is to create a distinct family of buildings that presents the image of an attractive employer and work environment.

4.5.2. *Massing Strategy*

The complex in its current form is an imposing and monolithic mass with an imposing appearance in the skyline – particularly from the west and south. This project presents an opportunity to rethink the role of the complex in the skyline, particularly its visual relationship with the Parliamentary Precinct. The strategy to respond to this condition is to create facades that will be lighter and more varied. The preferred approach is to express the complex as a family of three distinct buildings.

The goal is to reduce the imposing mass of the complex and re-scale the buildings more appropriately in their context. The continuity of the complex should be maintained at the street and human scale, with entrances, details, landscaping, glazing, and other elements designed to relate the buildings to each other.

4.5.3. *Strategy for Exterior Space*

The existing exterior spaces contain large expanses of paved area (particularly on the south) as well as pathways and landscaping that are not accessible and have deteriorated over time.

The new urban design should include green, inviting open spaces for gathering and circulation that connect the buildings to the community and to each other. New programme and amenities serving both public servants and the surrounding neighbourhoods should be introduced. An emphasis on accessibility, wayfinding, and connectivity is encouraged. Also of benefit is increasing the flow between interior/exterior spaces and increased transparency and visual connection at grade.

The goal is to create accessible, functional, and inviting exterior spaces.

4.5.4. *Strategy for Interior Space*

The complex has, for many years, been subject to a high rate of occupant complaints relating to air quality and temperature fluctuations. The existing office layouts generally include perimeter offices which block the natural light and views for the users of central workspaces.

This phase should take every opportunity to coordinate with future phases in order to contribute to a renewed high quality work environment for public servants, including improved access to natural light and thermal comfort.

Air quality is an issue that is not easily dealt without direct modification of the HVAC system. Nonetheless, opportunities to provide natural ventilation (ie operable windows or vents) in key areas should be explored.

The goal is a significant improvement in occupant health and wellness, as well as workplace productivity.

4.6. Urban Design Concept

The existing urban condition is problematic for various reasons where primarily it asserts the dominance of vehicles (particularly along the highly visible south elevation). It also fails to relate to the context of the neighbourhood, connect to the adjacent park and waterfront, or offer any tangible amenity to the adjacent communities.

In the context of increasing urban density, the site can be re imagined as an urban activator and a link between neighbourhoods and amenities (i.e. riverfront, transit hub, retail street, parks etc.).

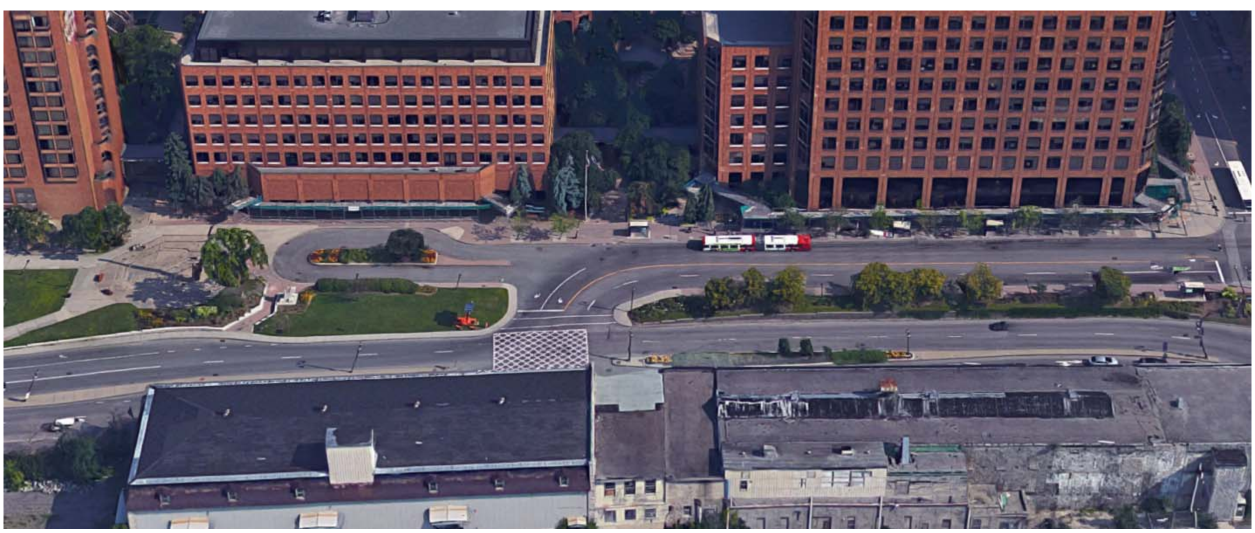


Fig. 27: *The existing areas to the south of the complex. (Google Earth)*

In order to achieve this, the use of new programmatic elements, improved pedestrian conditions, simplified circulation corridors, and an emphasis on context and views are proposed.

In addition, the urban design should coordinate with the planned Zibi development to the south – which offers the opportunity to create a continuous pedestrian corridor to the waterfront – as well as respond to the City of Gatineau's rehabilitation plan for the Laurier corridor. Collaboration between the parties responsible for these planned interventions holds an opportunity to dramatically improve this area of the city.

The goal of the new urban design concept is to transform the nature of the complex from an urban barrier into a linking element that better relates to its surroundings. The fundamental components of the concept are as follows:

- Create a forecourt to the south of the complex (in collaboration with the City of Gatineau);
- Reinforce the two main site axes with simplified, linear pedestrian corridors;
- Re-design the existing courtyard and peripheral spaces as an urban park to relate to the parkland to the west;
- Greater visual and physical connection between interior and exterior public spaces;
- Reinforce the primacy of pedestrians;
- Create urban anchors through the introduction of new exterior programme;
- Enhance the views and physical connection to the surroundings; and
- Improve bus transit serving the site (in collaboration with the City of Gatineau).

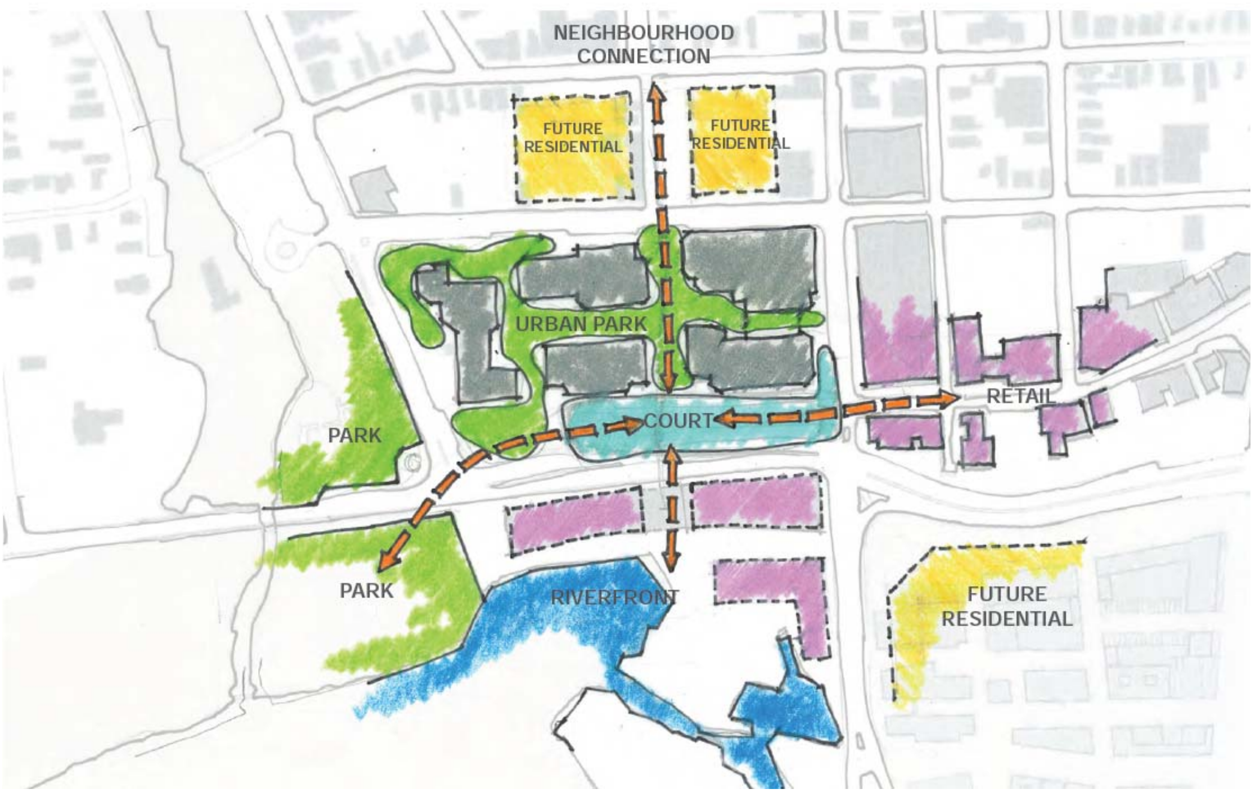


Fig. 28: *An illustration of the basic organizing principles of the urban design strategy.*

The concept as illustrated in the following images also includes the following design options:

- Introduction of canopies targeted to entrances and key areas;
- Simplified landscape features, particularly along Eddy Street;
- Introduction of new retail space along Eddy Street;
- Redesign of the bus zone as a primarily pedestrian area which is crossed by vehicles;
- A public amenity function on the south-west corner of the site;
- An new conference centre on the roof of the center building with new atrium;
- A new park and resting area connected to new commercial services in the center building; and
- A new landscape feature and meeting area at the intersection of the site axes.

Fig. 29: *A conceptual sketch based on the organizing principles of the urban design concept.*

Ample bicycle parking, as well as site infrastructure to encourage cycling as a commuting method should also be included in any design.

Fig. 30: *A conceptual sketch of the south-east corner of the complex.*

Fig. 31: *A conceptual sketch looking south through the courtyard.*

4.7. FAÇADE DESIGN OPTIONS

Based on the most successful themes explored in the skyline and massing investigations, and in response to the urban design strategy, a series of façade concepts were developed. Each option presents a unique theme.

4.7.1. *OPTION 1 – MONOLITHIC THEME 1*

The first option examines the possibility of retaining the existing continuity of the building facades and the expression of the existing underlying grid. The use of the structural grid is a natural outcome of the proposed strategy to pre-fabricate the new façade panels, as well as to provide uniform interior access to light and views. As this was the strategy used by the original designers, there is an obvious resemblance to the existing façade.

This strategy has been updated to include an increase in reflective materials through the use of spandrel glass at the top and bottom of each window opening.

Multiple materials and variations were explored to test the effect on the skyline, and to determine whether this option achieves the goals of reducing the visual impact of the complex on the skyline.

Fig. 32: *Option 1-A (South View) – A natural terra-cotta cladding gives a similar appearance to the existing façade.*

Despite the lightening of the façade and changes to the material, the use of natural terra-cotta (as a strategy to integrate with the existing brick throughout the complex) yielded results that did not sufficiently update the look and feel of the complex.

Fig. 33: *Option 1-B (South View) – a ceramic or metal panel option applied uniformly across the complex with an optional new coloured atrium on the center building.*

A material change to the same scheme created an improved look, but still retained a rather imposing and monolithic appearance that is not sufficiently distinct from the existing buildings.

4.7.2. *Option 2 – Monolithic Theme 2*

This option also proposes a uniformly applied façade across the complex, but with a system that is not based on the existing structural grid system. Instead, a variety of panel sizes are introduced to create a varied, contemporary look. In addition, the use of colour creates some distinction between the separate masses of the structures.

Fig. 34: *Option 2 (South View) – A uniformly applied paneled approach with coloured accents.*

This option, (and others like it) using a variety of panel strategies, created a new look for the complex but failed to integrate well with the landscape context. In addition, these investigations demonstrated that the sheer size of the complex is not conducive to irregular patterns or small grids – these designs become too busy and distracting when applied across such large areas.

4.7.3. OPTION 3 – PODIUM THEME

This option introduces two distinct façade strategies, and applies one to the lower volumes and the other to the taller volumes. The lower volumes retain some of the expression of the existing structural grid and a sense of solidity. Terra cotta or ceramic window jambs add a splash of colour that changes with the angle of the façade. The upper volumes are given a light glazed appearance with some variation of colour and reflectance to create a mottled and dynamic effect that minimizes horizontal banding.

Fig. 35: *Option 3 (South View) – Bases and towers expressed differently (shown with optional conference center and atrium on the Centre Building).*

The resulting effect is an overall improvement in the scale of the complex, and a clear strategy regarding the massing and volumes. This is a relatively successful theme, but there are design challenges relating to the volumes of the 15-25 Eddy building. The stepped massing and interior corners create many awkward material transitions.

4.7.4. *OPTION 4 – THREE DISTINCT BUILDINGS*

This option expresses the complex as a family of distinct (yet related) buildings. 15-25 Eddy and 2 Portage have retained a reference to the existing architectural grid, with some alteration of panels and opaque areas in order to bring some relief to the window pattern. They are separated by colour and material: a grey ceramic cladding for 2 portage, and light metal panel system for 15-25 Eddy.

10 Wellington has been given a light glazed appearance with some variation of colour and reflectance to create a mottled and dynamic effect that reduces the appearance horizontal banding.

Fig. 36: *Option 4 (South View) – Three distinct buildings shown here with the option of a new atrium on the center building and a glazed base on 15-25 Eddy. The chamfered corners on 15-25 Eddy have been squared off for a more contemporary look.*

This option best fulfills the project goals related to the appearance and scale of the complex on the skyline, as well as a new and contemporary look overall. It is the preferred option.

4.8. PREFERRED OPTION – THREE DISTINCT BUILDINGS

This option represents a synthesis of all of the project requirements and project vision. As illustrated, it is compatible with a pre-fabricated wall panel system that is sized according to the existing structural grid. It creates variety and breaks down the mass of the complex on the skyline. It creates the opportunity for a façade that is distinct in appearance from the existing complex.

Fig. 37: *A view of the area to the south of the complex with new site design and envelope. Options for continuous ground level glazing and a new atrium/conference center are included.*

All three buildings use a combination of a pre-fabricated panel system and/or curtain wall (construction options 3 & 4), but with changes to the exterior cladding materials, and size and expression of the windows. This concept is designed to speed the prefabrication and installation processes, as well as to simplify the detailing of the panels and sourcing of materials.

4.8.1. *1 Promenade du Portage & 15-25 Eddy Façade Strategy*

These two buildings can use a similar façade strategy: the expression of a grid (related to the existing structural grid), and the selected use of "opaque" panels to break up the monotony of the grid and add a contemporary look. The concept for the opaque panels is such that, while they appear opaque from the exterior, there may be a layer of perforated metal finished to match the surrounding frame located outboard of the vision glass. These lightweight perforated panels should be hinged or demountable in sections to facilitate maintenance and cleaning of the glazing behind.

1 Promenade du Portage (the Centre Building) could be clad with a grey fibre-reinforced ceramic tile rainscreen system including high-gloss white window jambs.

15-25 Eddy could be clad in a prefinished metal panel system with a satin white finish. Window jambs could be a coloured terra-cotta or ceramic tile – to provide colour that is compatible with the existing brick throughout the complex. 15-25 Eddy could also include corner bay windows of fully glazed unitized curtain-wall; essentially replicating the existing strategy to provide some accent materials that can help to unify this building's complex massing.

Both buildings aim to increase the apparent area of glazing by using a panelized opaque glass cladding, installed inside the "frame" component, above and below the vision glass.

Fig. 38: *View of Eddy Street looking north, including the option of new retail spaces at grade.*

4.8.2. *10 Wellington Façade Strategy*

10 Wellington can use the same back-up wall system as the other buildings, but instead of expressing a grid of windows, can use a glass panel cladding in order to achieve a glazed, reflective appearance.

The use of a variety of glass types (different tints, ceramic frits, opaque glass, frosted glass, etc.) can be used to break up the regularity of the façade and to vary the apparent spacing of the vision glass in each wall panel. Subtle horizontal banding in white glass can be introduced at every 2nd floor slab to provide some rhythm and scale to the façade.

The corner windows can be treated with the same panel system as the rest of the building, at a 45 degree angle that follows the edge of the existing floor slab.

4.9. ADDITIONAL DESIGN CONSIDERATIONS

4.9.1. *EXISTING BRICK AT GRADE*

The bottom two storeys, (which generally accommodates the public, commercial and gathering areas) are not constructed of pre-cast panels, but of a traditional rain-screen brick veneer. These areas are not experiencing the same erosion and failure as the existing precast panels above. As such, their removal is not mandatory as part of this phase however careful analysis to determine to what extent this brick can be retained should be performed. The precise scope of the envelope rehabilitation at grade levels should be determined as early as possible to avoid scope-creep related to unforeseen impacts of the panel removals.

There is the additional design challenge of the continuity and pervasiveness of the existing brick on the interior of the building, particularly in public spaces. The new façade must integrate with these interior/exterior elements; it is a transition that will be particularly visible at the glazed areas in the public concourses.

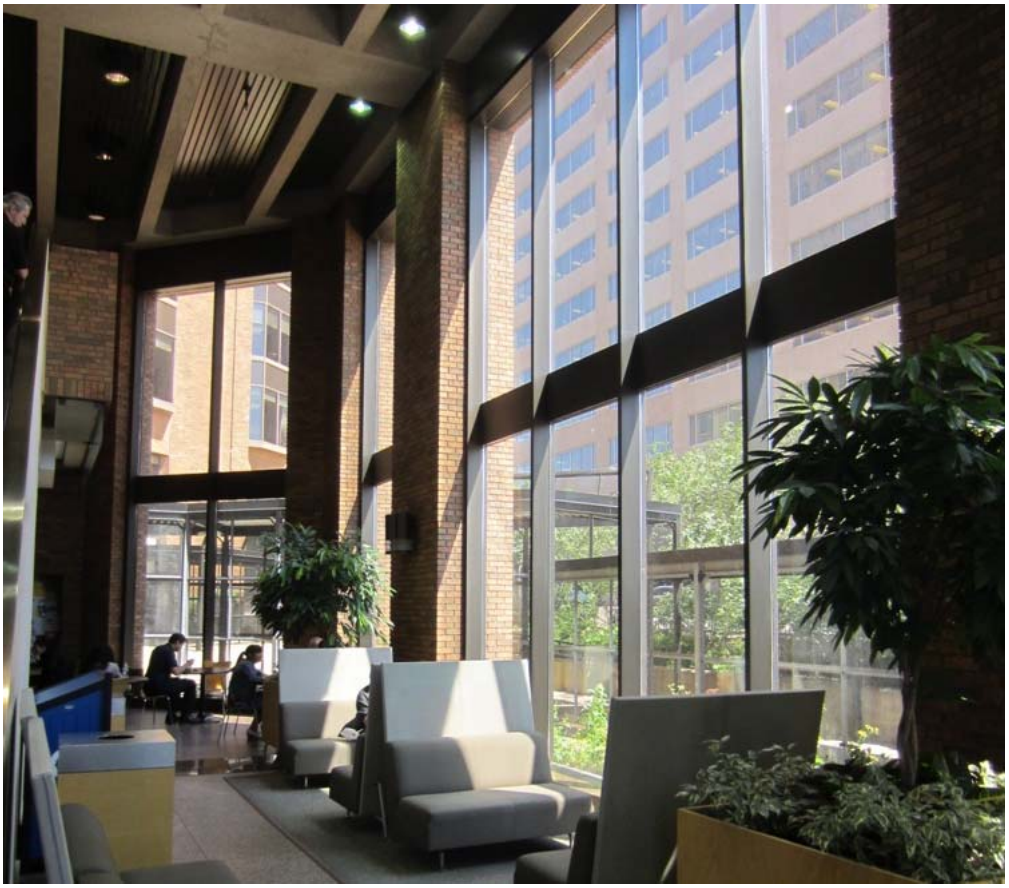


Fig. 39: *One of the many public areas where the interior/exterior continuity of brick is a key feature.*

4.9.2. <u>*EXISTING WINDOWS AT GRADE*</u>

The existing windows at grade are nearing the end of their expected service lifeand should be replaced for both performance and aesthetic reasons. Regardless of the eventual solution for the interior/exterior brick continuity, the window assembly should be replaced in order to have a compatible appearance with the glazing included in the new envelope on the upper storeys.

4.9.3. <u>*SNOW & ICE ACCUMULATION*</u>

The local climate (ice storms, snow accumulation, and the freeze-thaw cycle) creates a health and safety hazard due falling compacted snow and ice. This hazard is compounded by the proximity of the building perimeter to at-grade circulation areas.

Horizontal and low-slope surfaces should be carefully considered to mitigate health and safety risks to building occupants, the public and adjacent properties. This includes horizontal sun-shade devices, and deep window sills. Despite the performance benefits of these features, they present a risk in this context.

In addition, the high thermal performance of the new building envelope will limit heat loss through the wall and window assemblies, diminishing the effect of “controlled” melting that can mitigate the accumulation of snow and ice.

4.9.4. Vegetated & Inhabitable Roofs

The potential inclusion of vegetated roofs and terraces would bring a tangible benefit to project. The solar gain studies illustrated in this report highlight the potential of the roofs to reduce “heat island” effect. In addition, vegetated roofs can also provide additional benefits for storm water retention and peak flow rates.

The existing massing of the complex offers the opportunity for rooftop inhabitation. The inclusion of vegetated roofs at the envelope rehabilitation stage would create the opportunity for new public and private spaces that could be coordinated with the planned interior office upgrades.

4.9.5. Penthouses

The existing penthouses are to remain. In order to update the appearance of the building, the two most prominent penthouses (10 Wellington & 15-25 Eddy) have been previously illustrated screened with a new freestanding structure that incorporates translucent glass panels.

These structures could integrate LED lights, solar panels or projections, to allow the penthouse surrounds to act as themed beacons during national events and celebrations.

4.9.6. Canopies & Entrances

Many of the existing building entrances contain a covered transitional zone. The building entrances are generally problematic insofar as they are not adequately defined and there is no clear sense of a “front door” either to the complex as a whole and each building individually.

The envelope rehabilitation phase should include design elements related to the entrances in order to define a hierarchy of entrances and to orient the building to the street and city. In addition, weather protection would benefit users in targeted zones such as the bus waiting areas.

4.9.7. Public Space and Commercial Services

Both the public spaces (concourses, meeting areas, etc.) and the commercial enterprises in the complex provide valuable and well-used services for employees and the public. In conjunction with the future development of a master plan, the envelope rehabilitation phase should consider opportunities to improve these areas with a new envelope (greater visual connections, better natural lighting conditions, etc.).

4.9.8. *1 Promenade du Portage (Center Building) Proposed Conference Centre and Atrium*

The potential inclusion of a new conference centre on the roof of the Centre Building, as well as a connected atrium space have been included in selected images in this report. A key part of the preliminary urban design strategy was the identified need for new programmatic elements to bring new life to the complex. The conference centre and atrium as illustrated provide an opportunity for new program that has a distinctive architectural expression and could add a contemporary element to the massing of the complex. Its location would allow it to connect to the central (proposed) forecourt and to redefine the Centre Building as the urban “front door” of the complex. The use of a double-sided ceramic frit could bring a coloured or graphic element to the façade without affecting the interior quality.

In the context of the implementation of the envelope rehabilitation phase, these elements remain hypothetical. However, new programmatic elements and opportunities to re-imagine the massing and function of the complex should be explored as part of the planned future master plan.

4.10. Conclusions

Many design criteria and project requirements have come together to create a substantial design challenge. The opportunities for improvements (workplace, urban, skyline, energy performance, etc.) inherent in this project cannot be understated. Public servants, local communities, and even the cultural setting of the National Capital all stand to benefit from a well-executed, thoughtfully designed, and high quality project.

Conversely, a negative outcome (poor execution, poor design, or low quality) will be subject to a high level of scrutiny from many parties. The perceived existing negative image of this building complex from occupants and local communities (related to its appearance and quality of work environment) make a positive outcome all the more critical.

The full replacement of a building envelope while occupied, and on this scale, is an unprecedented undertaking in Canada. No examples or case studies for an equivalent endeavor could be found. As such, there is an additional opportunity to set a high standard for quality and execution with this project – a scenario which is likely to repeat itself, however unlikely at this scale, given the age and condition of many office buildings in Canada.

There are various elements which have been illustrated in the conceptual renderings in this report, including penthouse surrounds, strategies for ground level glazing, site work, new commercial spaces at grade, etc. The aspirations for improvements to the complex, as well as the clear opportunities to include items in the scope of the envelope rehabilitation have led to a variety of design add-ons and options. It is crucial that the full scope of the project be clearly defined in order to avoid scheduling and budgetary pitfalls. Given the scale of the project, there is an economy to including as many of these items as possible in the scope of this project, as opposed to pushing them to later phases.

While there is latitude for the look and feel of the individual buildings to change through future design investigations, there are many factors that have been identified in this report which should continue to inform design investigations.

The main factors and criteria are assessed as:

- The vision and aspirations of the Client;
- Cladding panelization and prefabrication;
- The energy performance and regulatory criteria;
- The interior office environment and user comfort;
- The appearance of the complex on the skyline, particularly its relationship to Parliament;
- Coordinating the design to adapt to the future project phases, both interior and exterior; and
- Coordinating the urban design with the adjacent Zibi development, as well as with the City of Gatineau.

This project is very much about the public realm: it is visually prominent, it is publicly (federally) owned and operated, it is located in a densifying area undergoing significant development, the site falls at a junction between different urban conditions used by different groups, etc.

As one of several prominent buildings in the area which houses government departments, the envelope rehabilitation of the LTDLC complex has the potential to be a catalyst for re-imagining the role and image of a contemporary public service – an opportunity that does not come often, and could help contribute to the vitality of the public service for decades to come.

5. IMPLEMENTATION STRATEGY

5.1. SCOPE OF WORK

5.1.1. *PLANNING*

The complexity of this project requires careful planning and monitoring in several areas, including:

- The development of a transit plan in conjunction with the City of Gatineau, the STO, and OC Transpo. This plan will examine the impacts of construction activities on the existing transit infrastructure and develop strategies for accommodation;
- The development of a phasing and move management plan in conjunction with tenants and building operators;
- The development of a life safety and protection plan, including relating the updated plans to all building occupants;
- The development of a detailed work plan, schedule, and material handling strategy; and
- A detailed construction waste management plan.

5.1.2. *LIFE SAFETY & SECURITY*

This project will require comprehensive protection measures for building occupants and separation of construction activities, particularly at grade. The opportunity to use the existing overhead protection in conjunction with new protection measures should be examined. Other measures may include key card systems, pre-programmable elevator floor access, and alteration of lock mechanisms in stairwells.

Throughout the duration of construction, the building will need to operate normally, including access to fire exits and life safety systems. Exit routes must be maintained, and may require additional exterior hoarding and protection measures. Life safety services may need to be altered/relocated to provide appropriate fire protection and monitoring during the rehabilitation work.

5.1.3. *ENVELOPE REPLACEMENT*

The full replacement of the building envelope is anticipated for:

- All roofing systems
- All precast concrete panels with brick veneer;

- All areas of existing curtain wall (corner bay windows); and
- All podium level window systems

NOTE: The approximate area of precast and curtain wall envelope to be replaced (not including ground level glazing or penthouses) is 48,000m^2.

5.1.4. STRUCTURAL

Block 100 is a 19 storey reinforced concrete structure with two levels of basement. Block 200 is a dual shear wall core construction; with half the building is 28 stories and the other half is 21 stories. Block 300 is a 7 storey reinforced concrete structure, with one level of basement. The podium slab is located between Blocks 200, 300 and the hotel, and is a concrete structure located at grade level.

Based on the performed seismic analysis and structural assessment, the existing block 100's, 200's and 300's structural system could sustain a seismic event up to 70%, 90%, and 100%, respectively, which suggests all the existing blocks could pass the 60% Public Works Seismic Policy.

Based on the performed dynamic analysis, the maximum displacement at roof level of the existing structure for block 100, 200 and 300 are 150 mm, 210 mm, and 60 mm, respectively. The overall displacement within the gap between block 200 and the podium is only 5 mm, much smaller than a 25mm expansion joint present between block 200 and the podium slab.

Although the precast cladding panel is not part of the lateral resisting system, the precast cladding panels would still have a potential to fall during an earthquake event, due to the limited displacement tolerance of the precast cladding panel anchorage system. Removing all the existing panels and replacing with a new wall system would be recommended. Alternatively, all the existing precast panel connections would need to be retrofitted. In addition, removing all the existing panels and replacing with a new lighter wall system would have a positive influence to the seismic response of the entire complex. Based on the additional seismic analysis of the structure with new lighter wall system, the total seismic load input would decrease 3%, 5%, and 3% for block 100, 200 and 300, respectively.

5.1.5. MECHANICAL & ELECTRICAL

The scope related to the existing M&E systems is limited to the work necessary for protection and reinstatement of the existing building systems. Typically, the precast concrete panels have no integrated or attached building system infrastructure. There are some known exceptions to this:

- Mechanical rooms located at the building perimeter have conduit, communications, and HVAC ductwork affixed to the building exterior;
- Areas where louvers, intakes, and exhaust vents penetrate the exterior.
- Areas where services (such as electrical receptacles) are available on the building exterior.

Decommissioning of systems, including relocation/cut-back to the weather wall (and subsequent remediation) will need to be coordinated with the removal of panels and installation of the new envelope.

The tuning of the existing HVAC system to accommodate the post-construction conditions is included in the scope.

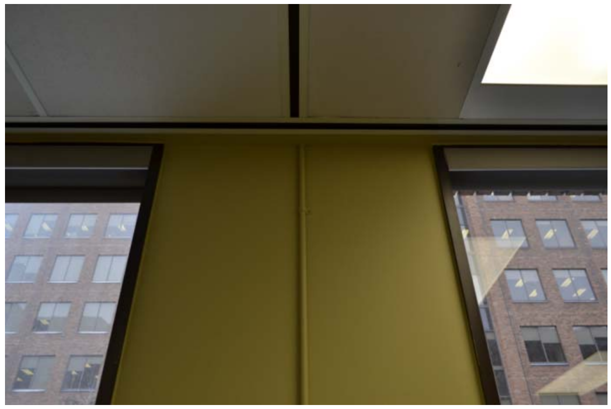
5.1.6. *1 Promenade du Portage – Unique Conditions*

1 Promenade du Portage (Center Building) differs from the other buildings in several important ways that will likely affect the construction process.

1. The interior ceiling condition is different at the perimeter of the building. There is no perimeter drywall bulkhead; the suspended ceiling and light fixtures run to the perimeter;

2. There are cable pulls in proximity to the perimeter;

3. Instances of electrical conduit installed on the exterior wall were observed;



4. There are high-security areas which contain sensitive testing equipment;

5. The building includes an inhabited penthouse with sloped perimeter glazing. The inclusion of this area in the envelope rehabilitation phase must be clarified;

6. There is a food service area whose electrical supply and exhaust equipment are on the exterior wall. This area is on the 2nd level, adjacent to the pedestrian bridge; its inclusion in the envelope rehabilitation must be clarified.

In general, there is an economy inherent in including as many of these items as possible in the scope of the envelope rehabilitation phase. In addition, any areas that are not in scope will have a significant impact on the appearance of the final project - where old meets new.

1 Promenade du Portage will require further investigation and clarification to define the limits of the proposed intervention.

5.1.7. *Interior Office Space*

Interior spaces should be protected during construction and remediated to their pre-construction conditions. This includes all drop ceilings, demising walls, flooring, bulkheads etc. The need for a weather wall to protect interior floor areas from perimeter work zones is anticipated.

In addition, temporary connections and trim should be provided to connect existing demising walls and partitions to the new interior envelope in select zones. These connections should be removable without creating the need for re-finishing the interior surfaces of the new envelope – in order to facilitate future office fit-up including the removal of perimeter offices.

The Client should clarify which office areas should be remediated in anticipation of future fit-ups, and which areas should be remediated to their existing conditions. For example, the Center Building has recently had interior upgrades and will require remediation to the existing conditions.

5.1.8. *Pedestrian Bridges*

There are 4 existing pedestrian bridges which link the circulation zones of the three office buildings and the hotel. The rehabilitation of these bridges is included in the envelope rehabilitation phase with the exception of the bridge linking to the hotel which cannot be impacted by this project. The rehabilitation of the bridges should include, at a minimum, the replacement of the glazing (to maintain aesthetic and performance continuity with the rest of the complex), and the associated replacement of exterior finishes and trim.

Due to site constraints, it is anticipated that one or more bridges may need to be removed during construction to allow site access for cranes and equipment. These bridges form an important part of the complex's interior circulation and will need to be replaced post-construction.

Fig. 40– *The interior of the existing pedestrian bridge linking 15 Eddy and 1 Promenade du Portage*

5.1.9. Site Work and Landscaping

This phase includes any necessary alterations or upgrades to the existing site services. For example, the use of tower cranes will certainly impact the courtyard landscaping and may require alteration of existing underground services to accommodate foundations.

The complex includes a network of underground service tunnels and a vehicle bay. The underground parking lot is below the hotel and should not be impacted by the envelope rehabilitation. However, many occupants make use of the parking garage; access and functionality will need to be maintained throughout construction. An assessment of these underground structures is required to determine the need for protection from construction equipment (i.e. grade beams or plates may be required to span above the tunnels for vehicle access.).

The existing stepped and terraced site conditions are not ideal for use as lay-down space; alteration and re-grading for construction use is anticipated. Any alteration to the site for construction purposes should be remediated in accordance with a new site master plan.

Based on the anticipated level of intervention, it is likely that the full site will require re-design and landscaping. It is important that this is coordinated with the future site master plan to ensure coherence with future phases.

5.1.10. Ground Floor Interventions

The brick construction at grade levels has not suffered the same deterioration as the precast concrete panels. Depending on the final design, the brick base may be retained in all or in part.

The replacement of all glazing and frames at grade is anticipated in the scope of the envelope rehabilitation.

NOTE: The requirements for this work need to be fully defined at an early stage in order avoid coordination issues and cost-overruns.

5.1.11. ROOFS

The existing roofs of the complex have been replaced in a piecemeal manner, with different areas having been replaced at different times. Due to the scale and impact of the envelope project, the replacement of all roof areas is anticipated. The existing roofs include a perimeter track and positioning anchors for swing stage equipment which should form part of the new roofing.

Additionally, early intervention on the roofs will be required for the installation of lifeline anchors. The existing roof anchors are designed for swing stage positioning only and are not suitable for lifeline attachment.

Fig. 41 – *The existing parapet of 25 Eddy with perimeter track and positioning anchors. The existing anchors are not suitable for life-line attachment.*

5.1.12. PENTHOUSES

The existing penthouses on 10 Wellington and 15-25 Eddy are to remain. The related scope for the envelope rehabilitation will be dependent on the final envelope design. The penthouse's appearance must be considered in order to maintain aesthetic continuity and meet the design vision as outlined in this report. The preferred approach is the erection of a new enclosing wall of frosted glass and painting of the existing penthouse structures.

The top level of 1 Promenade du Portage is an occupied penthouse. This level will require the replacement of glazing and frames, as well as the re-cladding of the exterior to maintain aesthetic continuity with the new envelope design.

5.1.13. *WASTE MANAGEMENT*

A full investigation by NRC will be performed in order to provide detailed information about the composition of the existing panels. There is an estimated 15,000 metric tonnes of material to be recycled and disposed of, which includes embedded steel rebar in both the precast and brick veneer.

Recycling and material diversion must be prioritized to limit the degree of material sent to landfill. Based on the degree of effort required to remove the vapour barrier and insulation from the face of precast, it is anticipated that the precast panels can be broken down by impacting to remove the rebar and salvage clean concrete for re-use. Window frames and glass are anticipated to be easily recycled.

Similar to concrete, the brick veneer could be separated from the rebar cores and mortar joints by impacting and sieve methods. A strategy for recycling the cleaned brick veneer must be resolved in advance. Currently, some initial approaches for recycling clean brick are:

- Supplemental aggregate for base courses in civil projects
- Clean fill not subject to structural compaction
- Exposed landscaping finishes

A detailed construction waste management strategy will be required. This plan could include relocation of the existing panels for off-site processing and materials reclamation/re-use.

5.2. Construction & Implementation Constraints

5.2.1. *Prefabricated Wall Panels or Curtain Wall*

The preferred approaches to the envelope replacement are by prefabricated wall panel and curtain wall - either used solely or in combination. The benefits to these include:

- Year-round, quality controlled fabrication;
- Reduced need for on-site trades & lay-down space;
- Reduced risk related to labour availability and schedule;
- Faster installation; and
- Reduced duration of tenant displacements.

5.2.2. *Existing Panel Weight and Connections*

The weight of the existing panels imposes constraints on the equipment that can be used for panel removals. Single window panels are generously estimated at 4,500kg and double window panels at 9,000 kg. Crane boom length, type, and need for crane bracing are all affected by the panel weight.

The original installation procedure for the precast panels was a bottom-up install which included pin connections between vertically stacked panels. These pin connections use the welded slab connections of the panel below to provide lateral stability to the panel above. As a result, it is a simpler procedure to remove the existing panels from the top-down.

The panel removal process must not allow the weight of any panel to bear down on, or to shock the panel below. The existing connections are loaded at approximately 87% capacity for single window panels and 79% for double window panels[1]

In addition, vertically cutting the double window panels in-situ is anticipated to meet the weight restrictions of tower cranes and facilitate removal.

5.2.3. *Building Occupancy*

The complex will remain occupied and operational during construction. This constitutes the biggest project risk, as it has serious implications for all aspects of project implementation, including schedule, health and safety, approach to construction and installation, phasing, etc.

Significant disruptions to the routines of occupants cannot be avoided. Nonetheless, users must be provided with a safe and functional workplace for the duration of the project.

[1] Exterior Cladding Panel Anchors Investigation; Cooke; 2011.

5.2.4. *HEALTH AND SAFETY*

The principal challenges to occupant health and safety are:

- The separation of occupants from the hazards of construction activities; and
- Maintaining the functionality of egress routes and life-safety systems during construction.

In addition, asbestos is present in certain instances (e.g. drywall joint compound, window caulking, and mechanical rooms) and will require appropriate work procedures to ensure protection of workers and occupants.

The mental health, productivity, and work environment of occupants are an important element for consideration in all aspects of the project. In this regard, construction strategies which maintain access to natural light, minimize acoustic disruptions and other workplace incursions must be given priority.

5.2.5. *ACOUSTIC DISRUPTION*

Acoustic disruptions (noise and vibration) can cause productivity problems for workplaces adjacent to construction zones. Collaboration with PSPC must establish clear guidelines for tolerances and monitoring of noise and vibration to permit occupancy of the complex.

Noise levels adjacent to construction zones should be monitored with a system in place to respond to tenant concerns and mitigate the effects of acoustic disruption.

Certain activities are likely to cause significant noise and vibration (drilling, cutting, and chipping of concrete to prepare the existing panels for removal). An implementation strategy which relocates occupants from floors (and adjacent floors) where disruptive work is taking place is recommended.

Activities which exceed the guidelines agreed upon with PSPC will need to take place during off-hours.

5.2.6. *EXISTING DAY-CARE CENTRE*

GRC recommends that the day care centre located in 10 Wellington be relocated off-site prior to any construction activities and remain off-site until project completion.

5.2.7. *MATERIALS HANDLING, STORAGE & LAY-DOWN SPACE*

The management of materials, both new and existing, poses a significant challenge on this constrained site. The size of the existing panels and the volume of removed materials will require a carefully orchestrated transportation and management strategy. Due to the occupied building and the incremental removal and replacement of panels there will be additional coordination needed between the removal process and the arrival and installation of new materials.

The following approaches should be considered:

- Pedestrian bridges between buildings, although not ideal, can be removed to allow courtyard access to vehicles and equipment;
- The interior courtyard can be re-graded, and services relocated in order to facilitate access and lay-down space;
- The opportunity to lease and use the parking lot(s) to the north of the complex as construction staging areas should be explored;
- Coordination with the City of Gatineau to use the areas to the south of the complex for staging should be explored; and
- The structural capacity of the tunnels and underground structures should be determined and protected accordingly.

Material handling is generally anticipated by traditional tower cranes, at a minimum of two concurrent locations throughout the course of the project. It is expected that these may need to be supplemented by an additional tower crane or combination of mobile cranes and tower cranes to facilitate the work. Careful selection of tower cranes need to be considered should intermediate support struts require anchoring to the building slab edge.

Roof-mounted cranes or derricks are not anticipated however may be a possible alternative to tower cranes.

5.2.8. *Vertical Transportation*

In order to minimize impacts to occupants, strategies to reduce the use of existing building vertical circulation should be employed. Use of the existing vertical circulation should be limited to movement of personnel, transportation of small tools and materials and minor waste.

The use of a man-hoist installed on the building façade undergoing renovation should be explored as a primary method of access.

5.2.9. *Site Limitations*

NOTE: Refer to Appendix F for site plan.

The site is bounded by Wellington Street, Eddy Street, Promenade du Portage and Alexandre-Taché Boulevard. The courtyard within the complex includes a variety of landscaping, curbs, varying grade changes, underground parking garage, and below grade utilities. Existing fire routes and necessary interior circulation will need to be taken into account. Achieving an efficient work yard will be paramount; space allocated for laydown, site offices, and access points will need to be carefully considered.

A Crowne Plaza hotel is also located at the most western end of the complex requiring additional considerations when accessing this portion of the site, particularly during off-hours and weekend work when the rest of the complex is much less occupied. The pedestrian bridge between 1 Promenade de Portage and the hotel must remain operational at all times.

Collaboration with transit agencies and the City of Gatineau is anticipated to establish appropriate points of entry and lay-by areas. Layout and site access may vary depending on time of day (rush hour).

5.2.10. *UNDERGROUND UTILITIES AND INFRASTRUCTURE*

An updated site survey should be completed including potential on-site investigation to ensure all utilities, tunnels and landscape elements are documented.

5.2.11. *SEASONAL CONSIDERATIONS*

There are a number of seasonal issues which should be considered when scheduling work:

- Weather: Winter temperatures below -20C will significantly reduce productivity, and work on platform lifts would likely be suspended due to safety concerns. Wind will need to be closely monitored, in particular when work is taking place on the upper floors. During the spring, half-load time periods for trucking panels to and from the site will need to be taken into account.
- Holidays: As the Government of Canada is the main tenant for the LTDLC complex, opportunities for increased work capacity during these times should be investigated. This analysis should consider times during the year which are sensitive periods for the government (major deadlines, budget time, elections) which may pose potential delays or impacts of site works.
- Construction Holiday: Being located in Quebec, there will be a significant impact of the construction schedule with work shutdown in late July and early August each year.

The above factors reduce annual working time to an estimated 10 months.

5.3. IMPLEMENTATION APPROACHES

Within the context of a continuously occupied building, three (3) basic approaches to the envelope replacement have been considered: a façade-by-façade approach; a floor-by-floor in-situ approach; and a floor-by-floor unoccupied approach.

In each case, the limiting factors for speed and ease of construction is always the presence of occupants, the availability of swing space, and the rate at which the existing panels can be removed.

5.3.1. *REMOVAL ANCHORING*

Regardless of the implementation strategy, existing panel removals should ideally have hoist connections incorporated into the precast panel edges as opposed to through-anchor approaches. A through anchor approach was utilized for the panel investigation project, which created significant noise and vibration while coring of the precast and brick veneer. Coring was provided to permit a horizontal HSS anchor point through the panel assembly while avoiding any applied pressure to the brick veneer. This process was lengthy, difficult, disruptive and not deemed to be a feasible implementation approach for the actual project.

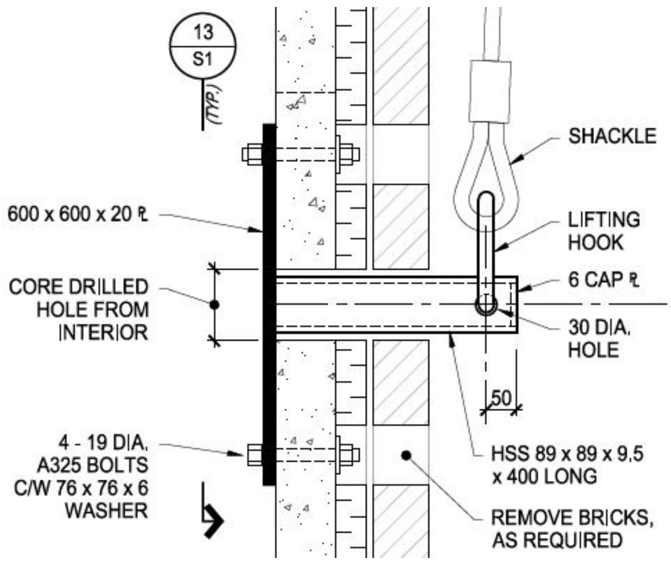


Fig. 42 *- Hoisting detail from panel removal investigation project*

Although a threaded sleeve was observed during the panel removal, it is unlikely this connector would sufficiently accommodate the weight of the panel for removals. Ideally cored openings at the panel edges could be provided to accept structurally adhered hoisting points, possibly bent rebar or other means, in order to sufficiently bear the weight of the panel for removal and handling.

5.3.2. *FAÇADE-BY-FAÇADE APPROACH*

This approach includes the establishment of a construction zone across large multi-storey areas of façade. The full façade could be removed from the top-down, and then replaced from the bottom-up. Once complete, the process begins again on a new façade area. Impacted occupants would either be accommodated on their floor, or relocated to swing space.

The advantages of this approach include:

- Ability to remove panels without risk to adjacent new construction;
- Top-down removal of the existing panels is the preferred approach;
- Bottom-up installation of new panels is simpler (typical method) than top-down;
- Simplified platform lift requirements.

The disadvantages to this approach include:

- Large areas of the façade (with occupied spaces behind) will be exposed to weather and will need extensive protection to maintain the integrity of the work environment;
- Occupants of building perimeter zones from different departments and groups may need to be relocated simultaneously, creating privacy and security issues related to swing space layout;
- Upgrades to weather wall / hoarding system will need to provide acoustical dampening for adjacent occupied spaces;
- Increased security requirements and coordination is needed to maintain separation of workers and tenants;
- Overall increased risk to schedule and budget;
- Demolition of existing designated substances poses additional risks to occupants who remain; and
- Potential increased insurance costs due to occupants remaining on the floor.

This approach is assessed as not viable due to the ongoing and lengthy disruptions to tenants and the lack of efficiency of the process.

5.3.3. *FLOOR-BY-FLOOR – OCCUPANTS IN-SITU*

This approach would undertake the rehabilitation work on a floor-by-floor basis, but allow for tenants to remain in-situ in the existing work space behind a perimeter separating wall. A platform lift system on each façade is the preferred approach, completing all facades of a floor at a time. This approach would require a weather wall for the perimeter of the building with additional acoustical barrier to minimize noise disruption as much as possible for the remaining occupants.

The advantages of this approach include:

- Most occupants can remain in-situ, reducing the need to relocate to temporary work space; and
- Reduces costs associated with temporary work stations.

The disadvantages to this approach include:

- Upgrades to weather wall / hoarding system will need to provide additional acoustical dampening;
- Increased security requirements and coordination is needed to maintain separation of workers and tenants;
- Overall increased schedule and costs associated with rehabilitation work;
- Potential for designated substances poses additional risks to occupants; and
- Potential increased insurance costs due to occupants remaining on the floor.

In general, the modest benefits associated with swing space and move management which could be obtained by an in-situ approach are far outweighed by the risks to schedule and level of tenant disruption.

5.3.4. FLOOR-BY-FLOOR – DEDICATED SPACE (OCCUPANTS RELOCATED)

This approach requires that all occupants of a given floor plate are relocated to swing space; the furniture remains and is pushed aside temporarily, and the entire area is given over to construction activities. Interior partitions (other than a perimeter weather wall) are not anticipated; occupants would need to clean desks and secure any sensitive material prior to relocation.

In this approach, panels are removed one floor at a time, and subsequently replaced with the new envelope as the entire work zone "crawls" vertically (top-to-bottom) across the façade of the building.

In order for this approach to work, the swing space must be able to accommodate a minimum of three (3) full floors of occupants at any given time. An additional 4th floor is preferred. It would allow for more flexibility of move management, increase efficiency, and remove bottlenecks related to construction.

The advantages of this approach include:

- Greatly reduces conflicts between construction work and occupants (security & life safety concerns);
- One-time move for occupants (as opposed to multiple times for other approaches);
- Increases efficiency, with overall benefits to schedule and cost;
- Simpler weather wall construction;
- Better acoustic separation between work zones and users; and
- Work groups and departments can be kept together during relocation to swing space.

The disadvantages to this approach include:

- Requires temporary relocation of tenants on affected floors; and
- On-going coordination and management of swing space.

Clearing floors of occupants is the preferred approach for undertaking the building envelope rehabilitation work. It will expedite the work being completed and allow for the shortest amount of time that the tenant will need to endure disruption to their work, as well as mitigate risks associated with life safety and security.

5.3.5. PREFERRED APPROACH & OVERVIEW

The preferred implementation approach is the floor-by-floor unoccupied scenario.

In addition, a top-to-bottom work sequence will also ease the removal of the existing panels (based on the existing connections) as well as prevent damage due to falling debris that would be a risk in a bottom-up removal and installation sequence.

Although existing tenants will need to relocate to swing space, they will only need to undertake this once resulting in minimal disruption to tenants compared to other options (which involve ongoing disruptions). In this scenario, the move itself is the primary disruption, as opposed to ongoing exposure to noise and construction activities in the other two scenarios.

Having entire floors cleared allow for increased efficiency, allowing work to proceed unhindered. While three (3) unoccupied floors is the minimum required for this approach to function, it will introduce constraints and create bottlenecks related to move management: Four (4) floors or more is required for a steady workflow. Also, by including a buffer of several sequential unoccupied floors, particularly noisy cutting work can take place throughout the day with minimal disruption occupants.

This implementation approach significantly reduces health & safety and security risks by separating the construction zones from occupied zones on a floor-by-floor basis.

Note: One of the future related projects includes interior office upgrades to WP2.0 standards. The possibility of performing these upgrades in tandem with the envelope rehabilitation should be examined in order to minimize the long-term impacts on occupants.

5.3.6. EXAMPLES OF APPLICABLE EQUIPMENT

Implementation of the preferred approach could include the use of the following equipment:

- Fraco Hydraulic mast-climbing work platform system (ACT-8)
- Manitowoc’s Potain MD-1600 (440ft free standing height. The top of the existing penthouse of 10 Wellington is approximately 380ft from grade.)
- Peiner SK-415 Tower Crane
- Pecco PC 1400 Tower Crane
- Mobile Cranes as required

5.4. PANEL REMOVAL & REPLACEMENT PROCEDURE

Due to the existing deterioration and poor condition of the brick veneer, panels should be inspected as they are prepared for removal to ensure there is sufficient capacity of the panel to facilitate the removal. The possibility to vertically cut the double window panels in-situ to facilitate the lift process could be examined.

The panel removal process is anticipated to include the following sequence:

1. Demolition of demising walls and finishes as needed, relocation and decommissioning of interior services, and cutting and capping as required;
2. Temporary lighting/electrical put in place for exterior work area;
3. Construction of an interior weather wall;

4. Removal of glass thermal panes;

5. Existing precast panels are provided with temporary connections and bracing for removal procedure (note that panels prepared for removal cannot transfer any load to the panels below as existing connectors are already near capacity);

6. Existing precast panels are prepared to allow for crane slings to be put in place;

7. Double-window panels cut vertically (if needed), panels are prepared for removal (chipping, bracing etc.);

8. Top weld connections cut, and panel is removed by crane;

9. Slab edge undergoes preparation for new wall system, anchoring or other work as required;

10. New panels are lowered into place, in sequence following the panel removal operation.

11. Interior and exterior detailing, flashing, finishing etc.;

12. Office space remediation.

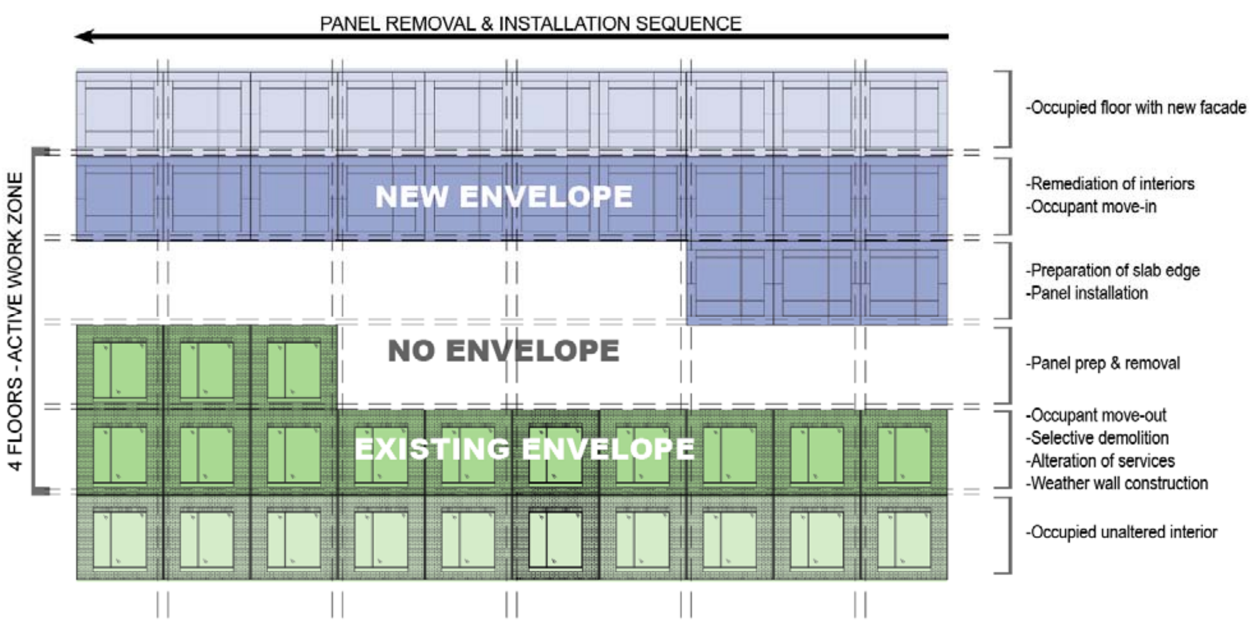


Fig. 43 – *An elevation of sample façade with concept work sequence indicated. There is always a one storey minimum separation between panel removal and new panel installation (the “no envelope” area). The two storey “no envelope” area shown in the diagram will likely span more distance than the two structural bays shown here – operational conflicts between the teams responsible for panel removal and panel installation should be avoided.*

5.5. Swing Space & Move Management

5.5.1. *Analysis & Rationale of Requirements*

Location of Swing Space

One critical factor to consider is that, at some point during construction process, the façade of the swing space itself will need to be replaced, rendering the swing space uninhabitable. This fact suggests constraints for the swing space:

1. ***The swing space should ideally be a unified block of areas (sequential floors).*** A scenario where the available swing space is separated into multiple smaller areas scattered throughout the complex will result in delays, coordination issues, and a need for more swing space overall.

2. ***The swing space should fall either at the beginning, or the end of the construction process.*** Replacing the façade of a unified block of swing space, which is either first or last in the overall construction sequence will reduce the risk of delays.

The Panel Removal & Installation Process

As panels are removed and replaced, there will always need to be an empty floor between the panels going on and the panels coming off (refer to Fig. 43). **This sequence of three (3) affected floors is the minimum requirement for the construction process** (panel lifting, preparation of the slab edge etc.).

However, the minimum of three (3) floors is not ideal for the project schedule or budget. Relocating only three floors at once will introduce significant coordination issues relating to tenant moving, which will result in delays.

For example, in order to begin construction on a new floor, that floor must first be emptied of occupants. In order for the occupants to be relocated, there must be swing space to accept them. In order for the swing space to accept them, the tenants currently in the swing space must be returned to their offices, but in order for this to happen construction must be fully completed and the space be remediated. Therein lies the scheduling conflict; every time a floor is completed, construction will come to a standstill while the occupants swap spaces. Use of the minimum requirements for swing space (three floors) will result in significant construction delays.

In addition, not all floors areas in the complex house an equal number of occupants. Consider a situation where 100 people are moving back into their offices, but the new floor being relocated includes 180 people requiring accommodation. There is an additional conflict created by the lack of a buffer of additional workstations.

Instead, the ability to relocate four (4) floors (or more) offers substantial risk mitigation and benefit to the schedule. In this scenario, there is always a floor relocated in advance of the construction sequence. This will allow for the continuous movement of tenants, as well as continuous construction activities.

The Number of Occupants on Affected Sequential Floors

Based on the minimum requirements of the construction process, and integrating the known occupancies of the floor areas, it is possible to ascertain the minimum number of occupants that will need to be relocated at any given time.

Based on information provided by the Client at the time of writing, this minimum number of occupants requiring relocation at any given time is:

- **For three (3) floors relocated: approximately 550 persons** (an average of 150 persons per floor with a 100 person buffer for variances)

- **For four (4) floors relocated: approximately 700 persons** (an average of 150 persons per floor with a 100 person buffer for variances)

<u>Layout and Assumed Density of Swing Space Fit-Up</u>

Based on fit-up guidelines provided by PSPC, the assumed area requirement for new swing space is:

- **For three (3) floors relocated: 6,600m^2 to 7,900m^2**

- **For four (4) floors relocated: 8,500m^2 to 10,000m^2**

In addition to the area requirements, the swing space should allow for a spatial layout of five (5) or more distinct, separated zones: three or four zones to act as the primary workspace for relocated tenants, and one or two zones to act as buffer zones to accommodate the overflow of particularly large floors, or for use by groups with particular security or privacy requirements.

5.5.2. *OCCUPANT COORDINATION*

At the time of finalizing this report, the following constraints and occupant swing space coordination issues have been identified:

- 1 Promenade du Portage requires as much notice as possible for relocation. It is advised that the Prime Consultant immediately address the anticipated timing of this relocation at the commencement of their mandate
- CRTC 2nd and 3rd floor personnel must be relocated to common swing space areas
- Substantial I/T and computer equipment will need additional move management time and setup
- Additional protection and monitoring of the 2nd floor server rooms at 1 Promenade du Portage while construction is underway. It is anticipated that these server rooms will remain operational and will be remotely accessed from the swing stage space
- Hearing rooms at the 7th floor of 1 Promenade du Portage and the 15th floor of 15 Eddy St will require advance notice of any disruptive work activities.

5.5.3. *SCHEDULE IMPLICATIONS*

The schedule implications relating to three versus four floors of swing space are significant.

Assuming that only the minimum floor area is provided, and considering not all floor areas have similar occupancies; there may still be some instances where four or more floors will be able to be relocated at once.

Factoring this in, and assuming a two week delay (one week for one tenant to move out, one week for the other tenant to move in) for all areas where only three floors will be able to be relocated at once, there will be an approximate schedule impact of **62 weeks**. There may also be additional delays caused by the stop-and-start nature of the construction work.

Once seasonal delays are included, selecting only the minimum swing space required for construction activities could potentially delay the overall project by eighteen (18) months or more.

Regardless of the quantity of swing space required, the management and coordination of occupant relocation is a major risk factor, and will require careful planning and should include a dedicated team to manage the process for the duration of the project.

Issues arising with move management and coordination will cause construction delays, particularly in a scenario where there is a minimum amount of swing space, or insufficient buffer space to accommodate unforeseen issues.

5.5.4. *Preferred Scenario*

At the time of writing, there is no single vacant space capable of meeting the area requirements of the proposed swing space.

In order to meet the preceding requirements (unified space, construction order, area), the currently proposed area for swing space is in 25 Eddy.

This proposed space is a mix of vacant and occupied space, with the distinct benefit that the construction phasing can be arranged in order to replace this area of façade at the very end of construction.

Ultimately, coordination with the existing tenants in this area will be required. The possibility of relocating the existing tenants in this area should be explored in order to provide a unified block of swing space.

5.6. Preferred Phasing Approach and Schedule

5.6.1. *Assumptions*

The phasing approach and schedule are based on some key assumptions regarding the construction process:

1. That the primary impact to the schedule and the construction process will be the rate at which the existing panels can be removed. The assumed rate of removal of façade is roughly 15 linear metres per day. This equates approximately to 4 single window panels

(primarily at 15-25 Eddy) or 2 double window panels (everywhere else). This assumption also implies that the rate of interior demolition, fabrication, installation of new envelope, and interior remediation will all be determined by the rate of panel removal.

2. There will be only one work zone happening at any given time. The construction will be linear, with the buildings being rehabilitated in sequence (not concurrently).

3. That structural alteration to the slab edge will not be required. This assessment assumes that the existing slab edge will be capable of accepting the new connections required for panel installation.

4. That the location of swing space will be capable of accommodating four (4) floors of relocated occupants at a time.

5. The schedule assumes that weekends are working days, and that eight (8) weeks will be lost to inclement weather and the construction holiday.

5.6.2. PHASING SEQUENCE

The phasing sequence of work is based on two (2) risk mitigation strategies:

1. Mitigate overall project risk by beginning construction in an unoccupied, easy to access area. This will allow the contractor to work out any kinks and hone the removal and installation strategy before moving on to riskier areas.

2. Subsequently target the high-priority areas (related to brick failure and spalling), in order to mitigate the health & safety risks as quickly as possible.

In order to address these strategies, construction is proposed to begin with a fully unoccupied building at 1 Promenade du Portage. The proposed area for swing space at approximately 8,400m^2 should be sufficient to accommodate all the building occupants. This will be considered a “soft start” to construction, and will allow the construction sequence to be refined without the risks associated with an occupied building. Subsequently, work will move to 10 Wellington, and shift to a floor-by-floor and top-down approach. The swing space, located in 25 Eddy will be remediated last, allowing for tenants to be moved back to their permanent spaces and avoiding moving conflicts.

The summarized proposed phasing sequence is as follows:

1. Pre-construction activities & site prep work;

2. Swing space fit-up;

3. Move all building occupants from 1 Promenade du Portage to swing space;

4. Full-building envelope rehabilitation of 1 Promenade du Portage while unoccupied (low-risk, “soft start” scenario with an unoccupied space);

5. Floor-by-floor envelope rehabilitation of 10 Wellington (highest risk areas);

6. Floor-by-floor envelope rehabilitation of 15 Eddy;
7. Floor-by-floor envelope rehabilitation of 25 Eddy; and
8. Site remediation.

This general sequence treats 15-25 Eddy as two separate buildings, otherwise the affected floor plates would be too large to accommodate in swings space. The exact limits between each “building” will need to be determined at the project outset.

*NOTE: Refer to **Appendix F** for the crane layout and phasing concept.*

5.6.3. Construction Schedule Summary

Based on the above phasing scenario, the construction phase requires an estimated **1400 working days**.

Based on the design phase schedule provided by PSPC, and allowing for seasonal and weather work stoppages, and assuming weekends are working days, **the estimated completion date is June 2023.**

*NOTE: Refer to **Appendix G** for the project schedule.*

5.7. Risk Analysis

The following risk analysis is based on the original analysis presented in the *Smith Carter Feasibility Study and Options Analysis (2013)*, and has been updated to reflect the project status and recent investigations.

D=Design phase impacts, T= Tender phase impacts, C= Construction phase impacts

Item	Risk Description	D	T	C	Prob	Impact	Risk	Notes/ Mitigation Strategies
A	**Scope Management**							
A.1	Accuracy of scope definition	X			Med	High	High	The precise project scope (particularly relating to the landscaping, penthouses, and ground plane) needs to be collaboratively revalidated at project start-up. The sustainability and waste management strategies should be further developed before tender.
A.2	Scope variance due to site conditions	X			Med	Med	Med	The panel composition and overall existing construction have been well defined in the background documents. Risk related to site conditions is primarily related to the impact on the building

								systems and the level of required intervention and remediation. Complete site investigations should be performed at project start-up to identify any problem areas.
A.3	Scope variance due to budget constraints		X		Low	High	Med	The scale of the project and quantity of materials involved mean that small changes to the panel design could have large impacts on the budget. Costing should be re-validated at project start-up to identify any potential gaps.
B	**Schedule Management**							
B.1	Schedule Slippage due to scope creep and redefinition	X			High	High	Crit	Certain areas of the scope will need to be further defined at project start-up (penthouse surrounds, ground level interventions, M/E impacts, landscaping etc.). A well-defined scope will mitigate slippage risks and allow for the creation of a realistic project schedule early on.
B.2	Schedule slippage due to approvals delays (NCC & City of Gatineau etc.)	X			Low	Low	Low	Collaboration with the NCC to resolve design issues and clarify project scope should be continued. The approvals requirements of the project should be included in a detailed project schedule
B.3	Schedule slippage due to materials availability and lead time			X	Low	Med	Med	The large quantity of materials required for this project, and the fabrication of envelope components will need strong oversight and coordination of supply chains.
B.4	Schedule slippage due to move management and swing space availability			X	High	High	Crit	Complications relating to move management of occupants is likely. Close collaboration with occupants at project start-up to manage expectations and identify potential issues is crucial. A comprehensive move management schedule and phasing plan should be developed as early as possible.
B.5	Schedule slippage due to construction delays			X	Med	High	High	The requirement of a realistic and reliable contractor's CPM timeline is fundamental. Factory prefabrication of components will mitigate risks associated with labour availability and weather conditions. It will also assist with a "just in time" delivery

								method of supplies and planning for weather variances.
B.6	Schedule slippage due to equipment availability			X	Low	High	Med	The need for specialized equipment (cranes, hoisting equipment etc.) should be examined at project start-up to determine availability and lead times.
C	**Cost Management**							
C.1	Cost variance due to marketplace fluctuations		X		High	High	Crit	Strategies should include thorough elemental cost modeling, continuous marketplace research and auditing through “what if?” modeling, and strategic alternatives visioning. The design of the prefabricated panels should make use of readily available products and offer design flexibility in order to maximize competitive tendering.
C.2	Cost variance due to labour rates		X		Med	Med	Med	Mitigation will require continuous monitoring of strike risk and contingency planning. The use of factory prefabrication offers the opportunity to mitigate the quantity of required specialists and labour availability.
C.3	Cost variance due to unknown site conditions			X	Low	High	Med	Panel removal and replacement investigations to mitigate the risk of unknowns have already been performed. Further site investigations to identify potential issues (particularly relating to M&E and ground floor glazing conditions) should be performed at project start-up to further mitigate unknowns.
D	**Quality Management**							
D.1	Quality variability arising from construction contract interpretation and site issues			X	Low	High	Med	Factory fabrication of the wall panels and simplicity of the installation procedure both mitigate the probability of this risk. Mock ups, including testing and analysis of the panel joint design should be performed as part of the quality control procedures.
D.2	Quality variability arising from factory fabrication issues			X	Low	Low	Low	Oversight and inspection procedures will be required to maintain a high-level of fabrication quality.
E	**Project Implementation**							
E.1	Procurement control issues (fair, open, and competitive bidding)		X	X	Low	Low	Low	As a mitigation strategy, the proposed design includes a standard wall assembly made of industry standard components,

								and a flexible cladding system that could accept a wide range of products.
E.2	Project impact on building access and tenant operations			**X**	High	High	Crit	The phased work will require the relocation of occupants, as well as the temporary closure of exits and public areas to accommodate construction. Managing tenant expectations from an early stage, as well as a thorough an open consultation with user groups is recommended for move management and complaint reduction.
E.3	Project impact on building systems and maintenance operations			**X**	High	Med	High	An analysis of the building systems, and coordination with the building operators will be required to maintain user comfort and identify any impacts to the interior environment.
E.4	Impact on public safety due to large-scale construction activities			**X**	Med	High	High	The removal of the existing panels poses the greatest challenge to public safety. Given the weight of the panels, a failure during hoisting would result in catastrophe. Traffic and pedestrian control is crucial to mitigate the risk. An impact study should be performed to analyze the risk posed by a panel falling onto a lower adjacent roof.
E.5	Risk of exposure to hazardous materials			**X**	Low	High	Med	Asbestos is known to be present in certain façade and partition components. Appropriate work measures are required. The temporary relocation of occupants during should be performed on a floor-by-floor basis in order to minimize the risk of exposure to building occupants during construction.

5.8. CONCLUSIONS

The preferred implementation scenario includes the following strategies:

- Swing space provided in 15/25 Eddy with an approximate minimum area of 8,500m^2;
- Construction begins with 1 Promenade du Portage while fully unoccupied;
- Material handling is primarily by tower crane, supplemented by mobile cranes to speed construction;
- Once the first building is complete, other occupants are relocated to swing space to fully vacate affected floor areas, with the capacity to relocate four (4) floors at a time;
- Work sequence is a top-to-bottom method;
- Existing panels are loaded directly onto trucks to avoid site storage and double-handling;
- Delivery of the new façade is a "just-in-time" method, preferably picked by crane directly off of a truck to avoid site storage and double handling.

The single biggest risk factor for this project is the occupied complex. The relocation of all building occupants to another site during construction would mitigate risks associated with health & safety, scheduling, delays, and budget. The occupied buildings create the need for constant vigilance in many areas, and increase the complexity of the project.

A second high-level risk factor is the need to fully define the scope of certain work packages (landscaping, ground level interventions & glazing, penthouse surrounds, etc.). These items will need to be carefully considered during the tender stage, and again at project start-up in order to identify the expected levels of intervention and the strategies to execute the work in an occupied setting.

In general, this is a highly complex project with significant challenges and risks in all implementation areas. The project management team will need to design and enforce a sophisticated communications, reporting and oversight plan in order to be proactive about identifying & mitigating project risk. A clear project charter and well defined individual responsibilities, as well as lines of communication for all stakeholders are critical at an early stage.

6. COST ESTIMATES

6.1. CONSTRUCTION COST ESTIMATE SUMMARY

NOTE: Refer to Appendix A for the full class "C" construction cost estimate

	Building Complex	Option 1	Option 2	Option 3	Option 4
1	Block 100 - Jules Léger Building (North & South)	$44,449,000	$42,204,000	$48,785,000	$46,316,000
2	Block 200 - North Building	$34,677,000	$34,585,000	$43,812,000	$37,726,000
3	Block 300 - Central Building	$6,021,000	$5,235,000	$6,300,000	$5,840,000
4	**Sub Total**	**$85,147,000**	**$82,024,000**	**$98,897,000**	**$89,882,000**
5	General Requirements, Overheads and Profit	$8,515,000	$8,202,000	$9,890,000	$8,988,000
6	Sub Total	$93,662,000	$90,226,000	$108,787,000	$98,870,000
7	Design & Pricing Contingency	$14,049,000	$13,534,000	$16,318,000	$14,831,000
8	Sub Total	$107,711,000	$103,760,000	$125,105,000	$113,701,000
9	Phasing Premium	$10,771,000	$10,376,000	$12,511,000	$11,370,000
10	**Sub Total**	**$118,482,000**	**$114,136,000**	**$137,616,000**	**$125,071,000**
11	Construction Contingency Allowance	$11,848,000	$11,414,000	$13,762,000	$12,507,000
12	Escalation from 2016 to 2017	$6,484,000	$6,247,000	$7,532,000	$6,845,000
13	**TOTAL ESTIMATE ($CY)**	**$136,814,000**	**$131,797,000**	**$158,910,000**	**$144,423,000**
	Common Scope Options				
14	Courtyard - Landscaping, grading, site works	$1,635,000	$1,635,000	$1,635,000	$1,635,000
15	Roofing Replacement - All Blocks	$4,784,000	$4,784,000	$4,784,000	$4,784,000
16	Penthouse Recladding and Glazed Surrounds - All Blocks	$4,841,000	$4,841,000	$4,841,000	$4,841,000
17	New Window Blinds	$2,596,000	$2,596,000	$2,596,000	None
18	Ground Level Upgrades	$5,387,000	$5,387,000	$5,387,000	$5,387,000
19	**TOTAL ESTIMATE w/ All Common Scope Options ($CY)**	**$156,057,000**	**$151,040,000**	**$178,153,000**	**$161,070,000**

Fig. 44 *– The class "C" cost estimate summary of the four construction options. Refer to Appendix A for the full cost estimate.*

The construction costs for each of the construction options analyzed in section 3 of this report were estimated at a class "C" level. Between the two preferred options (options 3 and 4) there is a delta of approximately $17M.

6.2. SOFT COST ESTIMATE SUMMARY

In addition to the construction cost estimates, a number of 'soft' costs will be need to be considered for the complete project delivery. Below are anticipated soft costs where percentage based costs have been applied against the complete project scope inclusive of the identified additional efforts:

- Prime Consultant team: $12,000,000 (based on 7% of a nominal $170M construction budget)
  Includes all disciplines and services required by the Terms of Reference This figure is based on minimal services from M, E and S but requires extensive design, presentation, planning, move management and environmental studies.

- Construction Manager services: $7,000,000 (based on 4% of a nominal $170M construction budget)

- Underground tunnel protection: $200,000 for excavation, reinforcing and making good at project completion

- Site security / access control: $1,500,000 includes rental costs of $20K / month for 66 months plus labour for relocations for phasing.

- Street/sidewalk encroachments and public transit: $2,000,000 which includes anticipated encroachment fees for North and South of the complex along with fees for relocating transit stops.

- Pedestrian Bridges: $3,000,000 which is comprised of $1.5M for the removal and construction of 2 new pedestrian bridges. It is anticipated that bridge replacement will be required between 1 Promenade du Portage and 10 Wellington as well as between 1 Promenade du Portage and 15 Eddy.

- M&E rooms and miscellaneous abatement: $2,000,000 for miscellaneous abatement as well as isolated instances of building services attached to the panels requiring temporary relocation.

- Move Management and swing space coordination: $600,000 based on 30 grouped staff moves and considering relocating to the swing space and relocating back to completed floors. This amount is based on the preferred implementation approach of 1 Promenade du Portage as an entire move stage and upgrading 4 floors at a time for the remaining buildings.

- Waste & recycling: $250,000 which includes a nominal $5 / tonne for precast and, assuming a worst case scenario of brick disposal, $26.50 / tonne for brick as waste. Costs for shipping and handling of these materials have been included in the construction cost estimate.

In total, the identified soft costs for this project are anticipated to be: $28,550,000

6.3. LIFE CYCLE COST ESTIMATE SUMMARY

Life cycle costing for this project has been considered with respect to the maintenance, replacement and operational costs of new envelope systems as well as the energy savings compared to the capital cost difference for each preferred option.

Maintenance, replacement and operational cost for the envelope are anticipated at $14.00 per m2 of gross floor area. Considering that both a prefabricated wall assembly and curtainwall framing system have a similar expected performance life of 50 years, no savings or cost difference is anticipated from a maintenance and replacement perspective.

Analysis between energy cost savings (Appendix D) and capital costs (Appendix A) have been considered for each preferred option with design differences as identified in Appendix D:

- Prefab 1 / Curtain 1: 50mm rigid insulation for Prefab, reduced glazing on different facades for a cumulative complex window to wall ratio of 32.4%
- Prefab 2 / Curtain 2: 75mm rigid insulation for Prefab, increased glazing throughout the complex for an average window to wall ratio of 47.4%

Two life cycle periods have been considered for this analysis: 25 years based on the anticipated half-life of the envelope and; 50 years based on the complete anticipated service life when either full replacement or major rehabilitation will be required. Energy cost savings have been compounded with a 3% annual inflation rate.

Energy cost saving analysis

Savings	Option 3		Option 4	
	Prefab 1	Prefab 2	Curtain 1	Curtain 2
Annually	$204,729	$150,138	$145,265	$93,019
25 years	$7,464,269	$5,473,921	$5,296,255	$3,391,404
50 years	$23,092,790	$16,935,096	$16,385,437	$10,492,252

Based on the energy cost saving analysis, a new cladding system will yield annual energy cost savings between $93,000 to over $200,000 compared to the existing modeled assembly.

Considering the half-life and full service life energy cost savings, the capital cost premium between options 3 and 4 becomes negligible between 5 - 8%.

Appendix A - Cost Estimate

Canada

grc architects

Les Terrasses de la Chaudiere
Gatineau, Quebec

Building Envelope Rehabilitation
Class C Estimate

prepared for

grc architects

prepared by

MARSHALL & MURRAY INCORPORATED

Marshall & Murray Incorporated
Quantity Surveyors & Cost Consultants
1379 Bank Street, Suite 301
Ottawa, Ontario
K1H 8N3

Issued:
April 29, 2016

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Basis of the Estimates

General Building Description

a. The project is located in Gatineau, Quebec.
b. The office complex comprises three office towers identified as Block 100, Block 200, and Block 300, each with a gross exterior cladding surface area of 22,871sm, 21,228sm, and 3,593sm respectively.
c. The building is currently occupied and may remain operational during the delivery of this project
d. The scope of work excludes all masonry at the ground floor level

Estimating Methodology

a. Quantities were measured and appropriate unit rates were applied where possible.
b. Lump sum costs were included where quantities or full descriptions were unavailable.
c. The Design & Pricing Allowance is to cover variations such as design detailing & material selection.
d. The project will be delivered under a construction management (CM) form of contract.

Exclusions

The following items are excluded from the cost estimate:

a. Consultant fees
b. Project management fees
c. Building and road closure permits
d. Project Risks
e. Separate investigative work
f. Security requirements
g. Furniture and office equipment moving/relocation
h. Swing space fit-up costs
i. Fit-up of existing floors following building envelope rehabilitation
j. Shoring work to existing tunnel below courtyard
k. Asbestos abatement to M&E during roofing replacement
l. Harmonised Sales Tax (HST)

Documentation

The following documentation was used in the preparation of the Estimate:

a. Les Terrasses De la Chaudière Building Envelope Rehabilitation, Options Analysis Update, 66% Draft Report, Date: October 23, 2015, by grc architects
b. Email notes, drawings and images as provided by grc architects February 22, 2016
c. Les Terraces de la Chaudiere Building Envelope Rehabilitation, Construction Implementation Strategies, Final Draft report, Date: March 7, 2016, by GBA Development and Project Management
d. Email notes, drawings, and review comments as provided by grc architects March 14, 2016

Assumptions and Cost Base

a. Construction bids will be by a minimum of four pre-qualified general contractors
b. $CY costs represent March 2016 dollars.
c. Work will be carried out on a floor-by-floor basis, requiring a minimum of three floors at a time
d. Working areas are not occupied during construction
e. Construction work will be undertaken during normal hours, all year round
f. Work will be carried out during the winter months
g. The project will be phased by Block over sixty-two months or approximately five years

Escalation

a. Escalation up to start of construction in 2017 has been included in the estimate at a rate of 2.7% p.a.

Contingencies

A 15% Design and Pricing Allowance has been included to provide for the following:

a. Unknown details in design and construction
b. Design layout variations
c. Material selections
d. Final design variations
e. This contingency does not allow for scope creep.

A 10% Construction Contingency Allowance has been included to cover extra costs incurred during construction due to existing conditions

A 10% Phasing Contingency Allowance has been included to cover additional costs incurred as a result of the CM project delivery method

Unit Rates

a. Unit rates used in this estimate include labour, equipment, materials and sub trade overhead and profit.
b. General requirements (10%) are included

Taxes

Harmonised Sales Tax (HST) is not included in this estimate.

Statement of Probable Costs

This estimate represents a professional opinion of the probable costs for this project. Marshall & Murray cannot guarantee that the actual cost will not vary from this opinion.

Ongoing Cost Control

We recommend that the estimate contained herein be reviewed thoroughly by the project team. Any comments or suggestions should be forwarded to the undersigned as soon as possible. We also recommend that further cost estimates be prepared once a firm design has been established.

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Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Options Analysis - Summary

	Building Complex	Option 1	Option 2	Option 3	Option 4
1	Block 100 - Jules Léger Building (North & South)	$44,449,000	$42,204,000	$48,785,000	$46,316,000
2	Block 200 - North Building	$34,677,000	$34,585,000	$43,812,000	$37,726,000
3	Block 300 - Central Building	$6,021,000	$5,235,000	$6,300,000	$5,840,000
4	**Sub Total**	**$85,147,000**	**$82,024,000**	**$98,897,000**	**$89,882,000**
5	General Requirements, Overheads and Profit	$8,515,000	$8,202,000	$9,890,000	$8,988,000
6	Sub Total	$93,662,000	$90,226,000	$108,787,000	$98,870,000
7	Design & Pricing Contingency	$14,049,000	$13,534,000	$16,318,000	$14,831,000
8	Sub Total	$107,711,000	$103,760,000	$125,105,000	$113,701,000
9	Phasing Premium	$10,771,000	$10,376,000	$12,511,000	$11,370,000
10	**Sub Total**	**$118,482,000**	**$114,136,000**	**$137,616,000**	**$125,071,000**
11	Construction Contingency Allowance	$11,848,000	$11,414,000	$13,762,000	$12,507,000
12	Escalation from 2016 to 2017	$6,484,000	$6,247,000	$7,532,000	$6,845,000
13	**TOTAL ESTIMATE ($CY)**	**$136,814,000**	**$131,797,000**	**$158,910,000**	**$144,423,000**

Common Scope Options

14	Courtyard - Landscaping, grading, site works	$1,635,000	$1,635,000	$1,635,000	$1,635,000
15	Roofing Replacement - All Blocks	$4,784,000	$4,784,000	$4,784,000	$4,784,000
16	Penthouse Recladding and Glazed Surrounds - All Blocks	$4,841,000	$4,841,000	$4,841,000	$4,841,000
17	New Window Blinds	$2,596,000	$2,596,000	$2,596,000	None
18	Ground Level Upgrades	$5,387,000	$5,387,000	$5,387,000	$5,387,000

19	**TOTAL ESTIMATE w/ All Common Scope Options ($CY)**	**$156,057,000**	**$151,040,000**	**$178,153,000**	**$161,070,000**

General notes relating to estimates:

Option 1 - Retention of the Existing Pre-cast Backup Panel
Panel-by-panel removal of the brick veneer;
Removal and replacement of the existing window thermal panes;
Removal and replacement of the corner curtain wall bay-windows;
Installation of a new exterior cladding;
The upgrade of all existing panel connections for seismic capacity;

Option 2 - Slab Infill (Steel Stud Back-Up)
Removal of the existing pre-cast panel system;
Installation of a steel stud back-up wall between slabs;
Installation of an exterior membrane and rain screen cladding system;

Option 3 - New Prefabricated Panel
Removal of the existing pre-cast panel system;
Installation of new pre-fabricated panels w/ integrated window and cladding;

Option 4 - Unitized Curtain Wall
Removal of the existing pre-cast panel system;
Installation of a new unitized curtain wall system;

Les Terrasses de la Chaudiere

Building Envelope Rehabilitation

Class C Estimate

Option 1 - Retention of the Existing Pre-Cast Backup Panels

	Description	Estimate
	Architectural & Structural	
	BLOCK 100	***$44,448,733***
	Exterior Works	***$16,980,423***
1	Remove existing parapet cap flashing	$20,363
2	Remove brick veneer cladding from existing precast panels, incl. steel brick supports	$3,383,505
3	Remove existing insulation and dispose	$143,979
4	Remove existing glazed thermal pane windows	$981,600
5	Remove existing corner glazed curtain wall bay-windows	$517,714
6	Allow for isolated repairs to precast panels	$613,500
7	Install new prefinished metal panel cladding system on existing precast panel	$4,607,326
8	Install new glazed windows	$5,429,475
9	Install new corner glazed curtain wall	$1,257,305
10	Install new prefinished metal parapet flashing	$25,657
	Interior Works	***$16,555,530***
11	Remove existing window blinds	$306,750
12	Remove existing suspended gypsum bulkhead ceiling	$123,086
13	Remove existing suspended acoustic ceiling for reuse	$189,277
14	Remove existing carpet flooring and reinstate after construction	$526,257
15	Remove perimeter heating cabinets and units	$214,725
16	Remove existing fire resistant foam at panel connections	$736,200
17	Remove interior gypsum furring wall w/ACM	$834,122
18	Setup temporary weather resistant hoarding enclosure, w/door access per floor	$730,440
19	Setup temporary corridors c/w doors at each floor	$288,000
20	Upgrade of all existing panel connections for seismic capacity, per panel	$6,380,400
21	Install new gypsum furring wall - (16gwb, 92mm steel stud)	$352,898
22	Install 100mm rubber baseboard	$35,084
23	Paint finish to new wall	$190,856

	Description	Estimate
24	Install new suspended gypsum ceiling w/paint finish	$615,428
25	Install acoustic tile ceiling removed for construction	$252,369
26	Install perimeter ribbon wall for heating systems	$409,311
27	Reinstate perimeter heating cabinets and units	$368,100
28	Additional M&E to working space - HVAC, fire protection, lighting	$3,759,906
29	Remove temporary weather resistant hoarding enclosure after construction work	$162,320
30	Remove temporary corridors and doors at each floor	$80,000
	Miscellaneous	***$10,912,780***
31	Mobile crane rental	$105,000
32	Elevated platform lift system	$3,742,000
33	Man lift system	$839,000
34	Scaffolding system	$4,979,520
35	Temporary shoring of roof structure to support scaffolding and construction work	$569,160
36	Winter heat	$462,100
37	Waste disposal/management	$216,000

	BLOCK 200	***$34,677,164***
	Exterior Works	***$16,231,556***
1	Remove existing parapet cap flashing	$7,583
2	Remove brick veneer cladding from existing precast panels, incl. steel brick supports	$2,726,760
3	Remove existing insulation and dispose	$116,032
4	Remove existing glazed thermal pane windows	$1,135,200
5	Remove existing corner glazed curtain wall bay-windows	$537,780
6	Allow for isolated repairs to precast panels	$400,500
7	Install new prefinished metal panel cladding system on existing precast panel	$3,713,034
8	Install new glazed windows	$6,279,075
9	Install new corner glazed curtain walls	$1,306,038
10	Install new prefinished metal parapet flashing	$9,554

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 1 - Retention of the Existing Pre-Cast Backup Panels

	Description	Estimate
	Interior Works	***$13,642,268***
11	Remove existing window blinds	$354,750
12	Remove existing suspended gypsum bulkhead ceiling	$117,408
13	Remove existing suspended acoustic ceiling for reuse	$180,547
14	Remove existing carpet flooring and reinstate after construction	$501,984
15	Remove perimeter heating cabinets and units	$248,325
16	Remove existing fire resistant foam at panel connections	$480,600
17	Remove interior gypsum furring wall w/ACM	$861,065
18	Setup temporary weather resistant hoarding enclosure, w/door access per floor	$200,790
19	Setup temporary corridors c/w doors at each floor	$486,000
20	Upgrade of all existing panel connections for seismic capacity, per panel	$4,165,200
21	Install new gypsum furring wall - (16gwb, 92mm steel stud)	$364,297
22	Install 100mm rubber baseboard	$33,466
23	Paint finish to new wall	$182,053
24	Install new suspended gypsum ceiling w/paint finish	$587,042
25	Install acoustic tile ceiling removed for construction	$240,729
26	Install perimeter ribbon wall for heating systems	$446,208
27	Reinstate perimeter heating cabinets and units	$425,700
28	Additional M&E to working space - HVAC, fire protection, lighting	$3,586,485
29	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
30	Remove temporary corridors and doors at each floor	$135,000
	Miscellaneous	***$4,803,340***
31	Mobile crane rental	$121,000
32	Elevated platform lift system	$1,721,000
33	Man lift system	$968,000
34	Scaffolding system	$1,176,000
35	Temporary shoring of roof structure to support scaffolding and construction work	$218,040
36	Winter heat	$425,300
37	Waste disposal/management	$174,000

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 1 - Retention of the Existing Pre-Cast Backup Panels

	Description	Estimate
	BLOCK 300	***$6,020,839***
	Exterior Works	***$2,696,544***
1	Remove existing parapet cap flashing	$4,553
2	Remove brick veneer cladding from existing precast panels, incl. steel brick supports	$455,861
3	Remove existing insulation and dispose	$19,398
4	Remove existing glazed thermal pane windows	$232,000
5	Remove existing corner glazed curtain wall bay-windows	None
6	Allow for isolated repairs to precast panels	$75,000
7	Install new prefinished metal panel cladding system on existing precast panel	$620,747
8	Install new glazed windows	$1,283,250
9	Install new corner glazed curtain walls	None
10	Install new prefinished metal parapet flashing	$5,736
	Interior Works	***$3,012,115***
11	Remove existing window blinds	$72,500
12	Remove existing suspended gypsum bulkhead ceiling	$19,166
13	Remove existing suspended acoustic ceiling for reuse	$29,473
14	Remove existing carpet flooring and reinstate after construction	$81,945
15	Remove perimeter heating cabinets and units	$50,750
16	Remove existing fire resistant foam at panel connections	$90,000
17	Remove interior gypsum furring wall w/ACM	$173,679
18	Setup temporary weather resistant hoarding enclosure, w/door access per floor	$200,790
19	Setup temporary corridors c/w doors at each floor	$72,000
20	Upgrade of all existing panel connections for seismic capacity, per panel	$780,000
21	Install new gypsum furring wall - (16gwb, 92mm steel stud)	$73,480
22	Install 100mm rubber baseboard	$33,466
23	Paint finish to new wall	$29,719
24	Install new suspended gypsum ceiling w/paint finish	$95,830
25	Install acoustic tile ceiling removed for construction	$39,297

	Description	Estimate
26	Install perimeter ribbon wall for heating systems	$427,935
27	Reinstate perimeter heating cabinets and units	$87,000
28	Additional M&E to working space - HVAC, fire protection, lighting	$585,466
29	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
30	Remove temporary corridors and doors at each floor	$25,000
	Miscellaneous	***$312,180***
31	Mobile crane rental	$25,000
32	Elevated platform lift system	NA
33	Man lift system	NA
34	Scaffolding system	$245,280
35	Temporary shoring of roof structure to support scaffolding and construction work	NA
36	Winter heat	$12,900
37	Waste disposal/management	$29,000

ESTIMATED CONSTRUCTION COST	**$85,146,736**

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 2 - Slab Infill (Steel Stud Back-Up)

	Description	Estimate
	Architectural & Structural	
	BLOCK 100	***$42,204,223***
	Exterior Works	***$17,639,313***
1	Remove existing parapet cap flashing	$20,363
2	Remove existing roof assembly as needed for access to existing panel connections	$81,450
3	Remove existing vertical joint between panels	$124,663
4	Remove existing sill flashing	$92,000
5	Remove existing precast panels as a single entity w/bricks and integrated window	$2,208,600
6	Remove existing corner glazed curtain wall bay-windows	$517,714
7	Allow for cutting double window precast panels in-situ prior to removal	None
8	Install new prefinished metal panel cladding system on steel stud back-up wall	$7,846,852
9	Install new glazed windows	$5,429,475
10	Install new corner glazed curtain wall	$1,257,305
11	Install new parapet framing	$35,235
12	Install new prefinished metal parapet flashing	$25,657
	Interior Works	***$10,175,130***
13	Remove existing window blinds	$306,750
14	Remove existing suspended gypsum bulkhead ceiling	$123,086
15	Remove existing suspended acoustic ceiling for reuse	$189,277
16	Remove existing carpet flooring and reinstate after construction	$526,257
17	Remove perimeter heating cabinets and units	$214,725
18	Remove existing fire resistant foam at panel connections	$736,200
19	Remove interior gypsum furring wall w/ACM	$834,122
20	Setup temporary weather resistant hoarding enclosure, w/door access per floor	$730,440
21	Setup temporary corridors c/w doors at each floor	$288,000
22	Install new gypsum furring wall - (16gwb, 92mm steel stud)	$352,898
23	Install 100mm rubber baseboard	$35,084

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 2 - Slab Infill (Steel Stud Back-Up)

	Description	Estimate
24	Paint finish to new wall	$190,856
25	Install new suspended gypsum ceiling w/paint finish	$615,428
26	Install acoustic tile ceiling removed for construction	$252,369
27	Install perimeter ribbon wall for heating systems	$409,311
28	Reinstate perimeter heating cabinets and units	$368,100
29	Additional M&E to working space - HVAC, fire protection, lighting	$3,759,906
30	Remove temporary weather resistant hoarding enclosure after construction work	$162,320
31	Remove temporary corridors and doors at each floor	$80,000
	Miscellaneous	***$14,389,780***
32	Tower crane rental	$3,582,000
33	Elevated platform lift system	$3,742,000
34	Man lift system	$839,000
35	Scaffolding system	$4,979,520
36	Temporary shoring of roof structure to support scaffolding and construction work	$569,160
37	Winter heat	$462,100
38	Waste disposal/management	$216,000

	BLOCK 200	***$34,584,732***
	Exterior Works	***$16,291,323***
1	Remove existing parapet cap flashing	$7,583
2	Remove existing roof assembly as needed for access to existing panel connections	$30,330
3	Remove existing vertical joint between panels	$81,382
4	Remove existing sill flashing	$106,400
5	Remove existing precast panels as a single entity w/bricks and integrated window	$1,441,800
6	Remove existing corner glazed curtain wall bay-windows	$537,780
7	Allow for cutting double window precast panels in-situ prior to removal	$154,500
8	Install new prefinished metal panel cladding system on steel stud back-up wall	$6,323,761
9	Install new glazed windows	$6,279,075

	Description	Estimate
10	Install new corner glazed curtain wall	$1,306,038
11	Install new parapet framing	$13,121
12	Install new prefinished metal parapet flashing	$9,554
	Interior Works	***$9,477,068***
13	Remove existing window blinds	$354,750
14	Remove existing suspended gypsum bulkhead ceiling	$117,408
15	Remove existing suspended acoustic ceiling for reuse	$180,547
16	Remove existing carpet flooring and reinstate after construction	$501,984
17	Remove perimeter heating cabinets and units	$248,325
18	Remove existing fire resistant foam at panel connections	$480,600
19	Remove interior gypsum furring wall w/ACM	$861,065
20	Setup temporary weather resistant hoarding enclosure, w/door access per floor	$200,790
21	Setup temporary corridors c/w doors at each floor	$486,000
22	Install new gypsum furring wall (16gwb, 92mm steel stud)	$364,297
23	Install 100mm rubber baseboard	$33,466
24	Paint finish to new wall	$182,053
25	Install new suspended gypsum ceiling w/paint finish	$587,042
26	Install acoustic tile ceiling removed for construction	$240,729
27	Install perimeter ribbon wall for heating systems	$446,208
28	Reinstate perimeter heating cabinets and units	$425,700
29	Additional M&E to working space - HVAC, fire protection, lighting	$3,586,485
30	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
31	Remove temporary corridors and doors at each floor	$135,000
	Miscellaneous	***$8,816,340***
32	Tower crane rental	$4,134,000
33	Elevated platform lift system	$1,721,000
34	Man lift system	$968,000
35	Scaffolding system	$1,176,000

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 2 - Slab Infill (Steel Stud Back-Up)

	Description	Estimate
36	Temporary shoring of roof structure to support scaffolding and construction work	$218,040
37	Winter heat	$425,300
38	Waste disposal/management	$174,000
	BLOCK 300	***$5,235,168***
	Exterior Works	***$2,718,875***
1	Remove existing parapet cap flashing	$4,553
2	Remove existing roof assembly as needed for access to existing panel connections	$18,210
3	Remove existing vertical joint between panels	$15,240
4	Remove existing sill flashing	$21,800
5	Remove existing precast panels as a single entity w/bricks and integrated window	$270,000
6	Remove existing corner glazed curtain wall bay-windows	None
7	Allow for cutting double window precast panels in-situ prior to removal	$35,000
8	Install new prefinished metal panel cladding system on steel stud back-up wall	$1,057,209
9	Install new glazed windows	$1,283,250
10	Install new corner glazed curtain wall	None
11	Install new parapet framing	$7,878
12	Install new prefinished metal parapet flashing	$5,736
	Interior Works	***$2,204,112***
13	Remove existing window blinds	$72,500
14	Remove existing suspended gypsum bulkhead ceiling	$19,166
15	Remove existing suspended acoustic ceiling for reuse	$29,473
16	Remove existing carpet flooring and reinstate after construction	$81,945
17	Remove perimeter heating cabinets and units	$50,750
18	Remove existing fire resistant foam at panel connections	$90,000
19	Remove interior gypsum furring wall w/ACM	$173,679
20	Setup temporary weather resistant hoarding enclosure, w/door access per floor	$200,790

	Description	Estimate
21	Setup temporary corridors c/w doors at each floor	$72,000
22	Install new gypsum furring wall (16gwb, 92mm steel stud)	$73,480
23	Install 100mm rubber baseboard	$5,463
24	Paint finish to new wall	$29,719
25	Install new suspended gypsum ceiling w/paint finish	$95,830
26	Install acoustic tile ceiling removed for construction	$39,297
27	Install perimeter ribbon wall for heating systems	$427,935
28	Reinstate perimeter heating cabinets and units	$87,000
29	Additional M&E to working space - HVAC, fire protection, lighting	$585,466
30	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
31	Remove temporary corridors and doors at each floor	$25,000
	Miscellaneous	***$312,180***
32	Mobile crane rental	$25,000
33	Elevated platform lift system	NA
34	Man lift system	NA
35	Scaffolding system	$245,280
36	Temporary shoring of roof structure to support scaffolding and construction work	NA
37	Winter heat	$12,900
38	Waste disposal/management	$29,000

	ESTIMATED CONSTRUCTION COST	**$82,024,123**

Les Terrasses de la Chaudiere

Building Envelope Rehabilitation

Class C Estimate

Option 3 - New Prefabricated Panels

	Description	Estimate
	Architectural & Structural	
	BLOCK 100	***$48,784,947***
	Exterior Works	***$24,436,037***
1	Remove existing parapet cap flashing	$20,363
2	Remove existing roof assembly as needed for access to existing panel connections	$81,450
3	Remove existing vertical joint between panels	$124,663
4	Remove existing sill flashing	$92,000
5	Remove existing precast panels as a single entity w/bricks and integrated window	$2,208,600
6	Remove existing corner glazed curtain wall bay-windows	$517,714
7	Allow for cutting double window precast panels in-situ prior to removal	None
8	Install new prefabricated panels w/aluminum and glass panels and integrated window	$20,108,286
9	Install new glazed windows	Integrated
10	Install new corner glazed curtain wall	$1,257,305
11	Install new prefinished metal parapet flashing	$25,657
	Interior Works	***$9,959,130***
12	Remove existing window blinds	$306,750
13	Remove existing suspended gypsum bulkhead ceiling	$123,086
14	Remove existing suspended acoustic ceiling for reuse	$189,277
15	Remove existing carpet flooring and reinstate after construction	$526,257
16	Remove perimeter heating cabinets and units	$214,725
17	Remove existing fire resistant foam at panel connections	$736,200
18	Remove interior gypsum furring wall w/ACM	$834,122
19	Setup temporary weather resistant hoarding enclosure, w/door access per 2 floors	$730,440
20	Setup temporary corridors c/w doors at each floor	$72,000
21	Install new gypsum furring wall - (16gwb, 92mm steel stud)	$352,898
22	Install 100mm rubber baseboard	$35,084
23	Paint finish to new wall	$190,856

	Description	Estimate
24	Install new suspended gypsum ceiling w/paint finish	$615,428
25	Install acoustic tile ceiling removed for construction	$252,369
26	Install perimeter ribbon wall for heating systems	$409,311
27	Reinstate perimeter heating cabinets and units	$368,100
28	Additional M&E to working space - HVAC, fire protection, lighting	$3,759,906
29	Remove temporary weather resistant hoarding enclosure after construction work	$162,320
30	Remove temporary corridors and doors at each floor	$80,000
	Miscellaneous	***$14,389,780***
31	Tower crane rental	$3,582,000
32	Elevated platform lift system	$3,742,000
33	Man lift system	$839,000
34	Scaffolding system	$4,979,520
35	Temporary shoring of roof structure to support scaffolding and construction work	$569,160
36	Winter heat	$462,100
37	Waste disposal/management	$216,000

	BLOCK 200	***$43,811,869***
	Exterior Works	***$25,932,460***
1	Remove existing parapet cap flashing	$7,583
2	Remove existing roof assembly as needed for access to existing panel connections	$30,330
3	Remove existing vertical joint between panels	$81,382
4	Remove existing sill flashing	$106,400
5	Remove existing precast panels as a single entity w/bricks and integrated window	$1,441,800
6	Remove existing corner glazed curtain wall bay-windows	$537,780
7	Allow for cutting double window precast panels in-situ prior to removal	$154,500
8	Install new prefabricated panels w/glass panel cladding and integrated window	$23,563,132
9	Install new glazed windows	Integrated
10	Install new corner glazed curtain wall	None

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 3 - New Prefabricated Panels

	Description	Estimate
11	Install new prefinished metal parapet flashing	$9,554
	Interior Works	***$9,063,068***
12	Remove existing window blinds	$354,750
13	Remove existing suspended gypsum bulkhead ceiling	$117,408
14	Remove existing suspended acoustic ceiling for reuse	$180,547
15	Remove existing carpet flooring and reinstate after construction	$501,984
16	Remove perimeter heating cabinets and units	$248,325
17	Remove existing fire resistant foam at panel connections	$480,600
18	Remove interior gypsum furring wall w/ACM	$861,065
19	Setup temporary weather resistant hoarding enclosure, w/door access per 2 floors	$200,790
20	Setup temporary corridors c/w doors at each floor	$72,000
21	Install new gypsum furring wall - (16gwb, 92mm steel stud)	$364,297
22	Install 100mm rubber baseboard	$33,466
23	Paint finish to new wall	$182,053
24	Install new suspended gypsum ceiling w/paint finish	$587,042
25	Install acoustic tile ceiling removed for construction	$240,729
26	Install perimeter ribbon wall for heating systems	$446,208
27	Reinstate perimeter heating cabinets and units	$425,700
28	Additional M&E to working space - HVAC, fire protection, lighting	$3,586,485
29	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
30	Remove temporary corridors and doors at each floor	$135,000
	Miscellaneous	***$8,816,340***
31	Tower crane rental	$4,134,000
32	Elevated platform lift system	$1,721,000
33	Man lift system	$968,000
34	Scaffolding system	$1,176,000
35	Temporary shoring of roof structure to support scaffolding and construction work	$218,040
36	Winter heat	$425,300

	Description	Estimate
37	Waste disposal/management	$174,000

	BLOCK 300	***$6,300,022***
	Exterior Works	***$3,783,730***
1	Remove existing parapet cap flashing	$4,553
2	Remove existing roof assembly as needed for access to existing panel connections	$18,210
3	Remove existing vertical joint between panels	$15,240
4	Remove existing sill flashing	$21,800
5	Remove existing precast panels as a single entity w/bricks and integrated window	$270,000
6	Remove existing corner glazed curtain wall bay-windows	None
7	Allow for cutting double window precast panels in-situ prior to removal	$35,000
8	Install new prefabricated panels w/aluminum and glass panels and integrated window	$3,413,191
9	Install new glazed windows	Integrated
10	Install new corner glazed curtain wall	None
11	Install new prefinished metal parapet flashing	$5,736
	Interior Works	***$2,204,112***
12	Remove existing window blinds	$72,500
13	Remove existing suspended gypsum bulkhead ceiling	$19,166
14	Remove existing suspended acoustic ceiling for reuse	$29,473
15	Remove existing carpet flooring and reinstate after construction	$81,945
16	Remove perimeter heating cabinets and units	$50,750
17	Remove existing fire resistant foam at panel connections	$90,000
18	Remove interior gypsum furring wall w/ACM	$173,679
19	Setup temporary weather resistant hoarding enclosure, w/door access per 2 floors	$200,790
20	Setup temporary corridors c/w doors at each floor	$72,000
21	Install new gypsum furring wall - (16gwb, 92mm steel stud)	$73,480
22	Install 100mm rubber baseboard	$5,463

	Description	Estimate
23	Paint finish to new wall	$29,719
24	Install new suspended gypsum ceiling w/paint finish	$95,830
25	Install acoustic tile ceiling removed for construction	$39,297
26	Install perimeter ribbon wall for heating systems	$427,935
27	Reinstate perimeter heating cabinets and units	$87,000
28	Additional M&E to working space - HVAC, fire protection, lighting	$585,466
29	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
30	Remove temporary corridors and doors at each floor	$25,000
	Miscellaneous	***$312,180***
31	Mobile crane rental	$25,000
32	Elevated platform lift system	NA
33	Man lift system	NA
34	Scaffolding system	$245,280
35	Temporary shoring of roof structure to support scaffolding and construction work	NA
36	Winter heat	$12,900
37	Waste disposal/management	$29,000
	ESTIMATED CONSTRUCTION COST	**$98,896,838**

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 4 - Unitized Curtain Wall

	Description	Estimate
	Architectural & Structural	
	BLOCK 100	***$46,316,083***
	Exterior Works	***$22,546,011***
1	Remove existing parapet cap flashing	$20,363
2	Remove existing roof assembly as needed for access to existing panel connections	$81,450
3	Remove existing vertical joint between panels	$124,663
4	Remove existing sill flashing	$92,000
5	Remove existing precast panels as a single entity w/bricks and integrated window	$2,208,600
6	Remove existing corner glazed curtain wall bay-windows	$517,714
7	Allow for cutting double window precast panels in-situ prior to removal	None
8	Install new unitized curtain wall system	$18,183,025
9	Install new glazed windows	None
10	Install new corner glazed curtain wall	$1,257,305
11	Install new parapet framing	$35,235
12	Install new prefinished metal parapet flashing	$25,657
	Interior Works	***$9,380,292***
13	Remove existing window blinds	$306,750
14	Remove existing suspended gypsum bulkhead ceiling	$123,086
15	Remove existing suspended acoustic ceiling for reuse	$189,277
16	Remove existing carpet flooring and reinstate after construction	$526,257
17	Remove perimeter heating cabinets and units	$214,725
18	Remove existing fire resistant foam at panel connections	$736,200
19	Remove interior gypsum furring wall w/ACM	$834,122
20	Setup temporary weather resistant hoarding enclosure, w/door access per 2 floors	$730,440
21	Setup temporary corridors c/w doors at each floor	$72,000
22	Install new suspended gypsum ceiling w/paint finish	$615,428
23	Install acoustic tile ceiling removed for construction	$252,369

	Description	Estimate
24	Install perimeter ribbon wall for heating systems	$409,311
25	Reinstate perimeter heating cabinets and units	$368,100
26	Additional M&E to working space - HVAC, fire protection, lighting	$3,759,906
27	Remove temporary weather resistant hoarding enclosure after construction work	$162,320
28	Remove temporary corridors and doors at each floor	$80,000
	Miscellaneous	***$14,389,780***
29	Tower crane rental	$3,582,000
30	Elevated platform lift system	$3,742,000
31	Man lift system	$839,000
32	Scaffolding system	$4,979,520
33	Temporary shoring of roof structure to support scaffolding and construction work	$569,160
34	Winter heat	$462,100
35	Waste disposal/management	$216,000

	BLOCK 200	***$37,725,882***
	Exterior Works	***$20,426,289***
1	Remove existing parapet cap flashing	$7,583
2	Remove existing roof assembly as needed for access to existing panel connections	$30,330
3	Remove existing vertical joint between panels	$81,382
4	Remove existing sill flashing	$106,400
5	Remove existing precast panels as a single entity w/bricks and integrated window	$1,441,800
6	Remove existing corner glazed curtain wall bay-windows	$537,780
7	Allow for cutting double window precast panels in-situ prior to removal	$154,500
8	Install new unitized curtain wall system	$16,737,802
9	Install new glazed windows	None
10	Install new corner glazed curtain wall	$1,306,038
11	Install new parapet framing	$13,121
12	Install new prefinished metal parapet flashing	$9,554
	Interior Works	***$8,483,253***
13	Remove existing window blinds	$354,750
14	Remove existing suspended gypsum bulkhead ceiling	$117,408

	Description	Estimate
15	Remove existing suspended acoustic ceiling for reuse	$180,547
16	Remove existing carpet flooring and reinstate after construction	$501,984
17	Remove perimeter heating cabinets and units	$248,325
18	Remove existing fire resistant foam at panel connections	$480,600
19	Remove interior gypsum furring wall w/ACM	$861,065
20	Setup temporary weather resistant hoarding enclosure, w/door access per 2 floors	$200,790
21	Setup temporary corridors c/w doors at each floor	$72,000
22	Install new suspended gypsum ceiling w/paint finish	$587,042
23	Install acoustic tile ceiling removed for construction	$240,729
24	Install perimeter ribbon wall for heating systems	$446,208
25	Reinstate perimeter heating cabinets and units	$425,700
26	Additional M&E to working space - HVAC, fire protection, lighting	$3,586,485
27	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
28	Remove temporary corridors and doors at each floor	$135,000
	Miscellaneous	***$8,816,340***
29	Tower crane rental	$4,134,000
30	Elevated platform lift system	$1,721,000
31	Man lift system	$968,000
32	Scaffolding system	$1,176,000
33	Temporary shoring of roof structure to support scaffolding and construction work	$218,040
34	Winter heat	$425,300
35	Waste disposal/management	$174,000

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 4 - Unitized Curtain Wall

	Description	Estimate
	BLOCK 300	***$5,839,955***
	Exterior Works	***$3,432,324***
1	Remove existing parapet cap flashing	$4,553
2	Remove existing roof assembly as needed for access to existing panel connections	$18,210
3	Remove existing vertical joint between panels	$15,240
4	Remove existing sill flashing	$21,800
5	Remove existing precast panels as a single entity w/bricks and integrated window	$270,000
6	Remove existing corner glazed curtain wall bay-windows	None
7	Allow for cutting double window precast panels in-situ prior to removal	$35,000
8	Install new unitized curtain wall system	$3,053,908
9	Install new glazed windows	None
10	Install new corner glazed unitized curtain wall system	Included
11	Install new parapet framing	$7,878
12	Install new prefinished metal parapet flashing	$5,736
	Interior Works	***$2,095,451***
13	Remove existing window blinds	$72,500
14	Remove existing suspended gypsum bulkhead ceiling	$19,166
15	Remove existing suspended acoustic ceiling for reuse	$29,473
16	Remove existing carpet flooring and reinstate after construction	$81,945
17	Remove perimeter heating cabinets and units	$50,750
18	Remove existing fire resistant foam at panel connections	$90,000
19	Remove interior gypsum furring wall w/ACM	$173,679
20	Setup temporary weather resistant hoarding enclosure, w/door access per 2 floors	$200,790
21	Setup temporary corridors c/w doors at each floor	$72,000
22	Install new suspended gypsum ceiling w/paint finish	$95,830
23	Install acoustic tile ceiling removed for construction	$39,297
24	Install perimeter ribbon wall for heating systems	$427,935

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Option 4 - Unitized Curtain Wall

	Description	Estimate
25	Reinstate perimeter heating cabinets and units	$87,000
26	Additional M&E to working space - HVAC, fire protection, lighting	$585,466
27	Remove temporary weather resistant hoarding enclosure after construction work	$44,620
28	Remove temporary corridors and doors at each floor	$25,000
	Miscellaneous	***$312,180***
29	Mobile crane rental	$25,000
30	Elevated platform lift system	NA
31	Man lift system	NA
32	Scaffolding system	$245,280
33	Temporary shoring of roof structure to support scaffolding and construction work	NA
34	Winter heat	$12,900
35	Waste disposal/management	$29,000
	ESTIMATED CONSTRUCTION COST	**$89,881,921**

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Courtyard Site Development

	Description	Estimate
	Architectural & Structural	
	Courtyard Works	***$1,016,818***
	Overhead Pedestrian Bridge - Block 100 to 300	***$125,919***
1	Remove existing curtain walls	$39,304
2	Remove existing floor finishes	$619
3	Remove existing ceiling finishes	$990
4	Remove existing roof covering	$1,856
5	Remove miscellaneous exterior items, detatch from existing buildings	$10,000
6	Remove structural steel frame - bridge, secure for reinstallation after construction	$25,000
7	Exterior wall infill panels to Block 100 and Block 300	$13,150
8	Mechanical	$15,000
9	Electrical	$20,000
	Courtyard - Site Development	***$808,858***
10	Remove existing trees	$45,000
11	Remove existing shrubs and grass	$35,907
12	Remove existing concrete planter walls, including foundations	$255,140
13	Remove existing concrete walkways and steps	$56,994
14	Grade area for construction and staging, compacted granular base	$234,818
15	Excavate footings for base of tower cranes, stock pile on site	$10,000
16	Mechanical Site - allow	$76,000
17	Electrical Site	$95,000
	Promenade du Portage - Site access and staging	***$82,041***
18	Remove existing bus stop shelter, secure for reinstallation	$2,500
19	Remove existing flag pole, secure for reinstallation	$500
20	Remove existing bollards	$2,500
21	Remove existing bicycle racks	$1,000
22	Remove existing miscellaneous landscaping items	$20,000
23	Remove existing stone pavers from sidewalk and stock pile for reinstallation	$17,060
24	Compacted granular base for vehicular access to courtyard	$18,481
25	Mechanical Site - rework mechanical as required	$10,000

	Description	Estimate
26	Electrical Site - rework electrical as required	$10,000
27	**ESTIMATED CONSTRUCTION COST**	**$1,016,818**

MARSHALL & MURRAY INCORPORATED

	Description	Estimate
	Architectural & Structural	
	Roofing Replacement	***$2,976,992***
	Block 100	***$1,677,248***
1	Remove existing roof accessories	$10,000
2	Remove all built-up wood curbs and dividers from all roof levels	$28,000
3	Remove existing flashing from all roof levels	$42,591
4	Remove existing roofing membrane down to concrete slab	$144,159
5	Allow for isloated repairs to concrete roof slab	$51,885
6	New 2-ply Mod-Bit roofing system c/w insulation and self-adhered a/v membrane	$864,951
7	New built-up wood curbs and dividers from all roof levels	$40,000
8	New flashing for all roof levels	$85,181
9	Allow for rubber mat walkways	$32,000
10	Mechanical	$307,500
11	Electrical	$70,981
	Block 200	***$779,048***
12	Remove existing roof accessories	$2,500
13	Remove all built-up wood curbs and dividers from all roof levels	$10,000
14	Remove existing flashing from all roof levels	$17,631
15	Remove existing roofing membrane down to concrete slab	$56,206
16	Allow for isloated repairs to concrete roof slab	$20,250
17	New 2-ply Mod-Bit roofing system c/w insulation and self-adhered a/v membrane	$337,238
18	New built-up wood curbs and dividers from all roof levels	$15,000
19	New flashing for all roof levels	$35,263
20	Allow for rubber mat walkways	$12,000
21	Mechanical	$220,000
22	Electrical	$52,960
	Block 300	***$520,696***
23	Remove existing roof accessories	$2,500
24	Remove all built-up wood curbs and dividers from all roof levels	$6,000
25	Remove existing flashing from all roof levels	$17,416
26	Remove existing roofing membrane down to concrete slab	$39,629

Roofing Replacement

	Description	Estimate
27	Allow for isloated repairs to concrete roof slab	$14,265
28	New 2-ply Mod-Bit roofing system c/w insulation and self-adhered a/v membrane	$237,771
29	New built-up wood curbs and dividers from all roof levels	$9,000
30	New flashing for all roof levels	$34,831
31	Allow for rubber mat walkways	$7,000
32	Mechanical	$95,000
33	Electrical	$57,285
34	**ESTIMATED CONSTRUCTION COST**	**$2,976,992**

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Penthouse Enclosure Replacement

	Description	Estimate
	Architectural & Structural	
	Penthouse Enclosure	***$3,014,287***
	Block 100	***$1,900,117***
1	Remove existing prefinished flashing, waterproofing membrane, plywood, insulation	$5,440
2	Remove existing pre-finished metal panel surrounds, including frame	$105,818
3	Remove existing insulated backup stud wall assembly	$25,800
4	Repair and retrofit existing structural framing for new structural outboard	$62,000
5	New insulated backup stud wall assembly	$96,749
6	New prefinished aluminum panel cladding	$451,495
7	New structural outboard frame	$304,445
8	New acid etched (frosted) glass surrounds	$799,045
9	New prefinished metal flashing	$9,325
10	Mechanical	$30,000
11	Electrical	$10,000
	Block 200	***$1,095,267***
	Large Mechanical Room	
12	Remove existing prefinished flashing, waterproofing membrane, plywood, insulation	$2,871
13	Remove existing pre-finished metal panel surrounds, including frame	$57,447
14	Remove existing insulated backup stud wall assembly	$13,238
15	Repair and retrofit existing structural framing for new panel cladding	$32,000
16	New insulated backup stud wall assembly	$49,643
17	New prefinished aluminum panel cladding	$231,665
18	New structural outboard frame	$163,798
19	New acid etched (frosted) glass surrounds	$446,785
20	New prefinished metal flashing	$4,921
	Small Mechanical Room	
21	Remove existing prefinished flashing, waterproofing membrane, plywood, insulation	$1,071
22	Remove existing pre-finished metal panel surrounds	$4,775
23	Remove existing insulated backup stud wall assembly	$2,302
24	Repair and retrofit existing structural framing for new panel cladding	$6,000
25	New insulated backup stud wall assembly	$8,632

	Description	Estimate
26	New prefinished aluminum panel cladding	$40,283
27	New prefinished metal flashing	$1,837
28	Mechanical Site	$20,000
29	Electrical Site	$8,000
	Block 300	***$18,903***
30	Remove existing prefinished flashing, waterproofing membrane, plywood, insulation	$829
31	Remove existing insulated prefinished metal panels, including backup wall assembly	$2,060
32	New insulated backup stud wall assembly	$2,575
33	New prefinished aluminum panel cladding	$12,018
34	New prefinished metal flashing	$1,421
35	Mechanical Site	nil
36	Electrical Site	nil
37	**ESTIMATED CONSTRUCTION COST**	**$3,014,287**

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Penthouse Enclosure Replacement

	Description	Estimate
	Architectural & Structural	
	Penthouse Enclosure	***$1,614,800***
	Block 100	***$674,850***
1	Install new window blinds	$674,850
	Block 200	***$780,450***
2	Install new window blinds	$780,450
	Block 300	***$159,500***
3	Install new window blinds	$159,500
4	**ESTIMATED CONSTRUCTION COST**	**$1,614,800**

Les Terrasses de la Chaudiere
Building Envelope Rehabilitation
Class C Estimate
Roofing Replacement

MARSHALL & MURRAY INCORPORATED

	Description	Estimate
	Architectural & Structural	
	Roofing Replacement	***$3,352,563***
	Block 100	***$1,785,965***
1	Remove existing ground floor windows and frames	$632,217
2	Remove existing entry doors at ground floor level	$7,200
3	Install new thermally broken storefront glazing in aluminum frames	$1,011,548
4	Install new entry doors at ground floor level	$135,000
	Block 200	***$937,980***
5	Remove existing ground floor windows and frames	$347,089
6	Remove existing entry doors at ground floor level	$1,800
7	Install new thermally broken storefront glazing in aluminum frames	$555,342
8	Install new entry doors at ground floor level	$33,750
	Block 300	***$628,618***
9	Remove existing ground floor windows and frames	$225,064
10	Remove existing entry doors at ground floor level	$2,200
11	Install new thermally broken storefront glazing in aluminum frames	$360,103
12	Install new entry doors at ground floor level	$41,250
13	**ESTIMATED CONSTRUCTION COST**	**$3,352,563**

Appendix B - Construction Options Comparison Matrix

Canada

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Constructions Options Comparison Matrix

Evaluation Criteria	Option 1 - Retain the Concrete Back-up Panel	Option 2 - Traditional Construction (Slab Infill)	Option 3 - Prefabricated Wall Assembly	Option 4 - Unitized Curtain Wall
Implementation Risks	• Substantial lay-down space, on site fabrication, and extensive scaffolding required; • Extensive ongoing acoustic and physical disruptions • Avoids risk associated with full-panel lifts **Rating:** ***Neutral***	• Substantial lay-down space, on site fabrication, and extensive scaffolding required; • Extended widespread disruption to grade-level circulation • Majority of work suspended from building face • Technical challenges of existing panel removal **Rating:** ***Poor***	• Challenge of lifting existing panels • Year-round factory fabrication • Hoist-in of new modular elements • Lay-Down space is reduced due to off-site fabrication **Rating:** ***Good***	• Challenge of lifting existing panels • Year-round factory fabrication • Hoist-in of new modular elements • Lay-Down space is reduced due to off-site fabrication **Rating:** ***Good***
Risk To Schedule	• Very high risk to schedule due to by-hand demolition and installation processes • Weather-related work stoppages anticipated • Lengthy panel modification process **Rating:** ***Poor***	• High risk to schedule • On-site winter construction delays • Extensive coordination of trades **Rating:** ***Poor***	• Factory fabrication reduces impact of weather • Simplified on-site coordination of trades • Reduction of overall site activities in favour of off-site fabrication **Rating:** ***Good***	• Factory fabrication reduces impact of weather • Simplified on-site coordination of trades • Reduction of overall site activities in favour of off-site fabrication **Rating:** ***Good***
Envelope Performance & Design	• Opportunity for performance upgrades are restricted by weight and existing panel configuration • Façade design is restricted due to existing panel design **Rating:** ***Poor***	• Able to meet energy code requirements •dependent on quality of on-site installation •susceptible to corrosion **Rating:** ***Neutral***	• Factory quality oversight of modular components • Able to meet prescriptive energy code requirements • Easily adaptable for different cladding materials & design vision **Rating:** ***Good***	• Only high end systems can be considered to meet energy performance targets • Potential cost saving **Rating:** ***Good***
Impact on Occupants	• Ongoing acoustic disruptions (years of by-hand demolition) • Increased risk of exposure to hazardous material due to in-situ demolition **Rating:** ***Poor***	• This option will lead to an unnacceptable loss in perimeter floor space **Rating:** ***Poor***	• Less acoustic disruption than Options 1 & 2 • Phased temporary relocation to on-site swing space **Rating:** ***Good***	• Less acoustic disruption than Options 1 & 2 • Phased temporary relocation to on-site swing space **Rating:** ***Good***
Overall Assessment	This option presents an elevated risk to the schedule, in addition to long duration impacts to tenants and offers the opportunity for only modest thermal improvements.	This option is overall a poor approach due to the number of trades involved, the work mainly performed from scaffolding or swingstage and the time to complete a wall assembly	This option offers the best opportunity to mitigate project risks and to meet the envelope performance requirements. **This is a preferred option.**	This option offers the same fundamental approach as option 3, but is more challenging to meet envelope performance targets. **Although a viable option, careful analysis to performance and implications for the HVAC system need to be considered. This is also a preferred option.**
Overall Evaluation:	**Poor**	**Poor**	**Good**	**Good**

Common elements between all options
•All options require a plan for the disposal and/or reuse of demolition waste (thousands of tonnes) • Options 2-4 will require custom equipment and a complex solution for the removal of the existing panels
•All options involve some level of tenant disruption •All options require interior hoarding walls at the perimeter of tenant spaces - although duration, and phasing differs by option.

Appendix C - Curtain Wall Performance Investigation

Canada

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PTVD
BUILDING ENVELOPE CONSULTANTS
MEMBER OF CLEB

Issued by e-mail
clance@grcarchitects.com

May 3, 2016

GRC Architects Inc.
47 Clarence Street, Suite 401
Ottawa, ON K1N 9K1

Attn: Mr. Chris Lance

Re: **Les Terrasses de la Chaudière**
Building Envelope Concept Design Consultation

O/file: O-0396-A

Dear Mr. Lance:

In the context of your own mandate where you are preparing the concept design for the recladding of Les Terrasses de la Chaudière complex on behalf of Public Works and Government Services Canada (PWGSC), Patenaude Trempe Van Dalen Inc. (PTVD) was retained to provide consultation on the thermal aspects of the building envelope concept design. Our office is intimately familiar with the situation surrounding the condition and performance of the panels that currently clad the complex, and therefore well aware of the intent of PWGSC to replace the exterior wall system.

The concept design that you are preparing contemplates the use of metal and glass curtain wall assemblies in two different scenarios. One scenario under consideration is using curtain wall framing to fabricate punched openings in a new cladding system that mimics the layout of the original exterior wall. A second scenario being considered would be a conventional configuration of alternating horizontal bands of vision and spandrel glass in a curtain wall system that is continuous over the height of the towers.

In both scenarios, your objective is for the wall assembly to provide superior overall thermal performance. As a minimum, you would like the overall performance to meet the prescriptive requirements outlined in current codes. However, you have correctly identified that your objectives will be challenging to achieve with products that are readily available in the market.

To support your concept design options, we were asked to prepare documentation that outlines the realistic thermal performance that could be achieved with practically available curtain wall assemblies used in the two different scenarios.

Scope of Services

To develop the documentation that you requested, we proposed to undertake the following tasks:

1. Meet with you and your team to review and discuss the general parameters of the project.
2. Research and explore the availability and performance of advanced insulating glass unit (IGU) compositions.
3. Research and explore the availability of curtain wall assemblies with thermal performance characteristics that exceed those of the systems currently common within the industry. Note that we have based our offer on the use of thermal performance data that is published and available from manufacturers.
4. Based on the product selection in task 4, prepare an estimate of the overall thermal transmittance of the new exterior wall on the typical floors, based on the option of punched window openings that mimic the layout of the current exterior wall. You have directed that the area of the punched openings would be 40% of the gross wall area in this scenario.
5. Based on the product selection in task 5, prepare an estimate of the overall thermal transmittance of the new exterior wall on the typical floors, based on the option of alternating horizontal bands of vision and spandrel glass in a curtain wall system that is continuous over the height of the towers. You have directed that the area of the vision bands would also be 40% of the gross wall area in this scenario.
6. Prepare a draft report that describes the results of our research, outlines the thermal characteristics of the glass units and wall systems recommended, and provides the estimated overall thermal transmittance of the recommended product applied in your two design options.
7. Meet with you to present our draft report and to discuss refinements for presentation to PWGSC.

Insulating Glass Unit (IGU) Compositions

The first phase of our work focussed strictly on the thermal performance of insulating glass unit (IGU) compositions fabricated with high performance components currently available in the market.

Assessment of thermal performance of IGU compositions involves consideration of the heat transmission and solar energy transfer through the unit. The visible light transmittance of the unit is also usually included in the assessment, as there is a direct correlation between the thermal and light transmittance characteristics, and because desired natural light levels will often define constraints on the thermal characteristics that can be obtained. These characteristics can be defined as follows:

> Heat Transmission (U-value): a measure of the rate of heat flow through the IGU (in W/m^2K) due to a temperature difference between inside and outside. The lower the U-value the better the thermal insulating performance. Note that this characteristic is not orientation related.

Solar Energy Transfer (Solar Heat Gain Coefficient – SHGC): the fraction of solar energy incident on the glazing that is transferred indoors both directly and indirectly through the IGU. The lower the SHGC, the more efficient the IGU is in blocking the transfer of solar energy into the building. This characteristic is orientation related.

Visible Light Transmittance (V_{LT}): the percentage of visible light at normal incidence to the glass (90 to surface) that is transmitted through the IGU to the inside of the building. This characteristic is orientation related.

We researched the high performance IGU products available in the market place from most of the major suppliers, including Saint-Gobain, Cardinal, Guardian, PPG and Viracon. We also obtained other performance data from web sites and by simulation using Window 7.4 software from LBNL (Lawrence Berkeley National Laboratory).

This research revealed that there is a considerable range of performance available in advanced glazing compositions. To achieve the highest practicable performance the use of argon gas fill between glass layers and multi-layer, silver low emissivity coatings was deemed mandatory. The following tables show the data we collected for high performance double and triple glazed insulated units.

Double IGU							
Manufacturer	Ext. Lite	Gas	Int. Lite	U-Value Winter Btu/(hr-ft2-°F)	Visible Light Transmittance %	SHGC	Notes
Cardinal/Prelco	6 mm clear + Low-E 272 (2)	13.5 mm argon	6 mm clear	0.25	69	0.40	Double Silver Low-e
Saint-Gobain	6 mm Diamant + Cool-Lite Extreme 70-33 II (2)	12 mm argon 90 %	6 mm Diamant	0.24	71	0.30	Triple Silver Low-e
PPG	6 mm Starphire + Solarban 70XL (2)	12.7 mm argon 90 %	6 mm clear	0.24	64	0.27	Triple Silver Low-e
Cardinal/Prelco	6 mm clear + Low-E 366 (2)	13.5 mm argon	6 mm clear	0.24	62	0.27	Triple Silver Low-e
Guardian/Trulite	6 mm ultraclear + Sungard AG 50 (2)	12.7 mm argon 90 %	6 mm ultraclear + Sungard IS (4)	0.21	50	0.34	Single Silver Low-e + Room side Low-e
Guardian/Trulite	6 mm ultraclear + Sungard SN 68 (2)	12.7 mm argon 90 %	6 mm ultraclear + Sungard IS (4)	0.20	67	0.37	Double Silver Low-e + Room side Low-e
Cardinal/Prelco	6 mm clear + Low-E 272 (2)	13.5 mm argon	6 mm clear + I89 (4)	0.20	68.2	0.39	Double Silver Low-e + Room side Low-e
Viracon	6 mm clear + Low-E VUE-50 (2)	13.2 mm argon	6 mm clear + Room side Low-E (4)	0.20	48	0.24	Double Silver Low-e + Room side Low-e
Cardinal/Prelco	6 mm clear + Low-E 366 (2)	13.5 mm argon	6 mm clear + I89 (4)	0.19	61.3	0.30	Triple Silver Low-e + Room side Low-e
Guardian/Trulite	6 mm ultraclear + Sungard SNX 62/27 (2)	12.7 mm argon 90 %	6 mm ultraclear + Sungard IS (4)	0.19	61	0.25	Triple Silver Low-e + Room side Low-e

Table 1

Triple IGU									
Manufacturer	Ext. Lite	Gas	Mid. Lite	Gas	Int. Lite	U-Value Winter Btu/(hr-ft2-°F)	Visible light Transmittance %	SHGC	Notes
Heat Mirror	6 mm clair + Low-E 366 (2)	6.35 mm argon 90 %	HM 88	6.35 mm argon 90 %	6 mm clear	0.2	55	0.25	Triple Silver Low-e (2) + Heat Mirror Film
Guardian/ Trulite	6 mm clair + Sungard AG 50 (2)	12.7 mm argon 90 %	6 mm clear	12.7 mm argon 90%	6 mm clear	0.19	45	0.31	Single Silver Low-e (2)
Guardian/ Trulite	6 mm clair + Sungard SN 68 (2)	12.7 mm argon 90%	6 mm clear	12.7 mm argon 90 %	6 mm clear	0.18	61	0.34	Double Silver Low-e (2)
Guardian/Trulite	6 mm clair + Sungard SNX 62/27 (2)	12.7 mm argon 90 %	6 mm clear	12.7 mm argon 90 %	6 mm clear	0.18	56	0.24	Triple Silver Low-e (2)
Viracon	6 mm clear + Low-E VUE-50 (2)	13.2 mm argon	6 mm clear	13.2 mm argon	6 mm clear	0.18	43	0.22	Double Silver Low-e (2)
Cardinal/Prelco	6 mm clair + Low-E 366 (2)	13.5 mm argon	6 mm clear	13.5 mm argon	6 mm clear + I89 (6)	0.15	55.2	0.24	Triple Silver Low-e (2) + Room side Low-e
Cardinal/Prelco	6 mm Low Iron	13.5 mm argon	6 mm clear + Low-E 366 (4)	13.5 mm argon	6 mm clear + I89 (6)	0.14	56.4	0.29	Triple Silver Low-e (4) + Room side Low-e
Saint-Gobain	6 mm Diamant + Cool-Lite Extreme 70-33 II (2)	14 mm argon 90 %	6 mm Diamant	14 mm argon 90 %	6 mm Diamant + Planitherm XN II (5)	0.12	65	0.28	Triple Silver Low-e (2) + Room side Low-e
Cardinal/Prelco	6 mm clair + Low-E 366 (2)	13.5 mm argon	6 mm clear + Low-E 366 (4)	13.5 mm argon	6 mm clear + I89 (6)	0.1	43.4	0.2	Triple Silver Low-e (2 + 4) + Room side Low-e

Table 2

As is illustrated in the tables above, high performance IGUs can achieve heat transmission performance (U-value) ranging from 0.19 to 0.25 for double IGU and 0.10 to 0.20 for triple IGU. Note that the performance at the low end of these ranges is achieved with the use of room side Low-e (face 4 or 6 of IGU) that actually results in lower interior glass temperatures. This could create problems with cold downdrafts (comfort issue) and condensation, which would need to be carefully assessed in the design process.

The high performance IGUs achieve visible light transmission ranging from 43% to 71%. They can also achieve control of solar energy transfer with SHGC as low as 0.24 for double IGU and 0.20 for triple IGU.

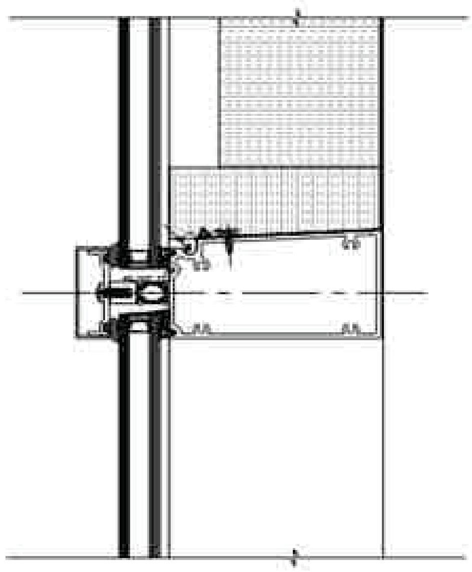
Curtain Wall Assemblies

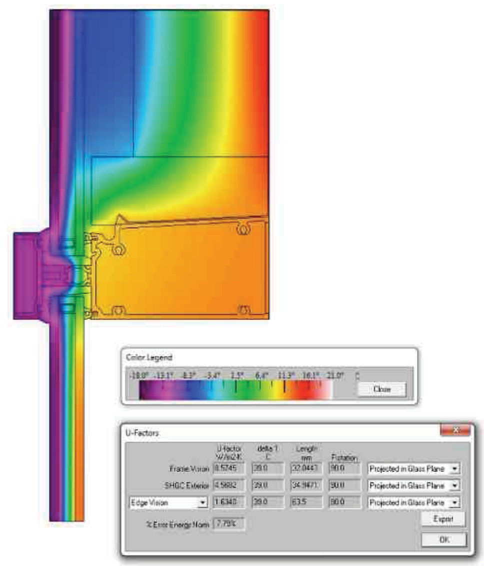
Performance data for high performance curtain wall assemblies available from various manufacturers was obtained from different sources and in different formats, as explained in the following table.

Curtain Wall Performance Data		
Manufacturers	Data format	Availability
Gamma	Therm report with spreadsheet calculation tool.	Prepared specifically for our work by Gamma technical department
Schuco	AAMA 507-12 Thermal performance report	Supplied by Schuco technical department
Alumico	NFRC Simulation report according to ANSI/NFRC 100, ANSI/NFRC 200 and NFRC 500 Guidelines	Supplied by Alumico technical department
Kawneer	AAMA 507-12 Thermal performance report + Catalogue data from Kawneer web site	Supplied by Kawneer technical department, web site
Flynn	Brochures	Supplied by Flynn technical department

Table 3

The following are examples of the different formats used by the manufacturers to report the performance of their assemblies.





Valeur U pour la partie spandrel (S)

Largeur (mm)	Hauteur(mm)	Apf
1500	1706	2559000

		Dim.pf	A_f	Dim.rive	A_e	U_f	U_e	$A_f \times U_f$	$A_e \times U_e$
Tête(D1_S)	1500	97,0	142396	63,5	87154	2,0157	0,9649	287028	84095
Jamb Gauche(D4_S_L)	1706	32,0	52340	63,5	95360	4,8075	0,9682	251624	92328
Jamb.Droite(D4_S_R)	1706	32,0	52340	63,5	95360	4,8109	0,9711	251802	92605
Seuil(D2_S)	1500	43,8	64240	63,5	87154	1,7888	0,7849	114912	68407
Totals			311315		365028			905365	337434

Centre-du-spandrel	A_c = 1882656,2	U_c =	0,203	W/m²·K	
			0,0357	Btu/hr·ft²·°F	28,00 R

U_{ft} = 2,9082 W/m²·K
U_{et} = 0,9244 W/m²·K

UtS = 0,63 W/m²·K	**0,112 Btu/hr·ft²·°F**

Table 4: Example of Therm Output Data & Associated Spreadsheet Calculation

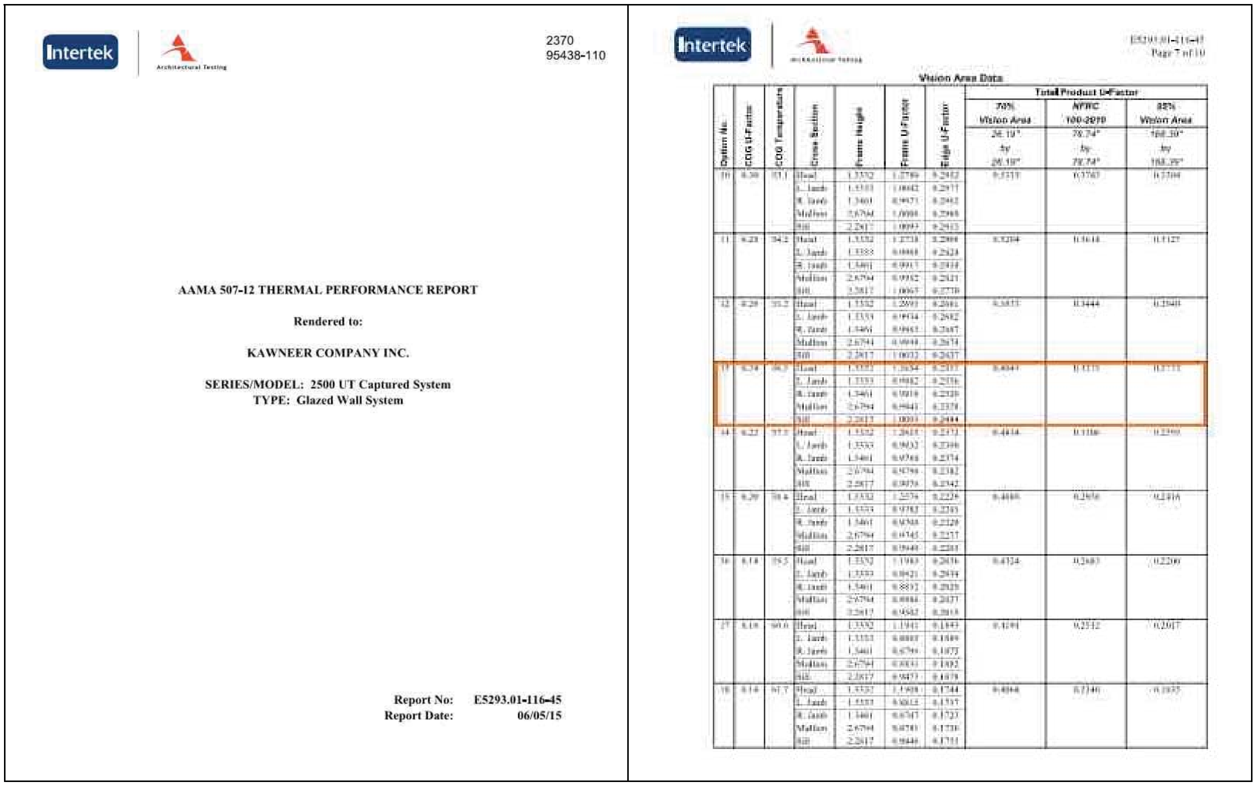
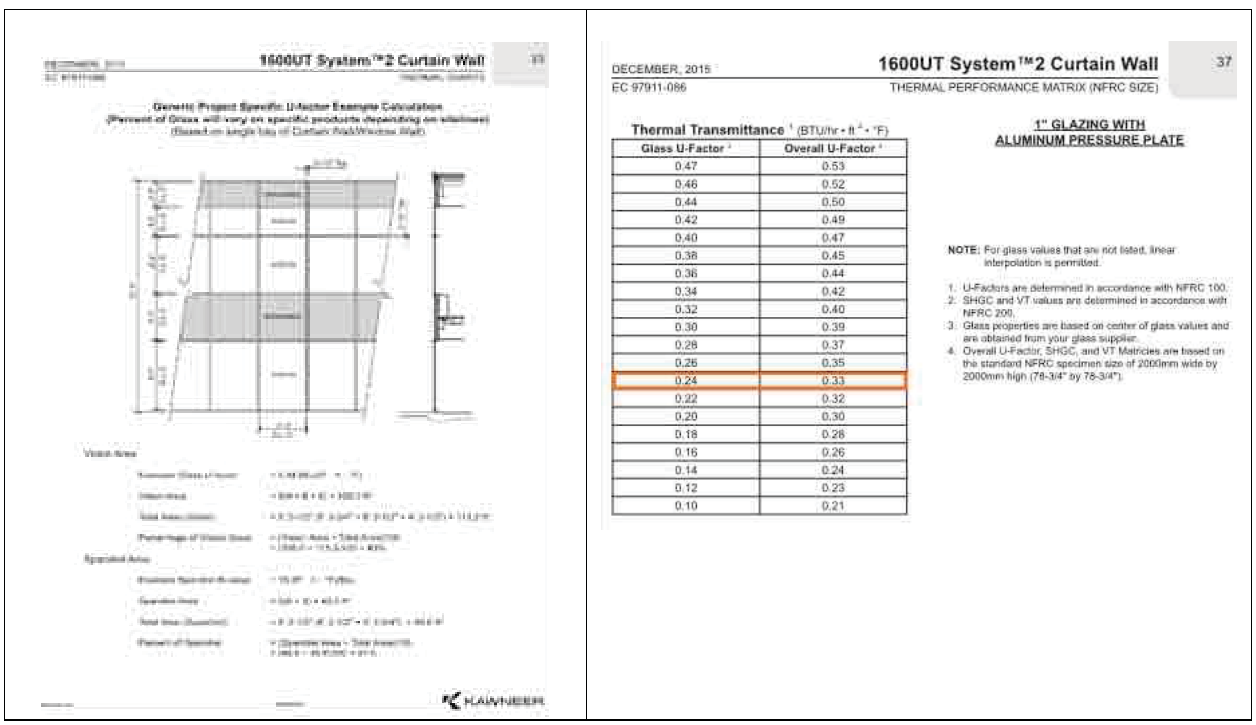


Table 5: Example of Data extracted from AAMA 507-12 Report (see enlarged documents in appendix 1)



Glass U-Factor [3]	Overall U-Factor [4]
0.47	0.53
0.46	0.52
0.44	0.50
0.42	0.49
0.40	0.47
0.38	0.45
0.36	0.44
0.34	0.42
0.32	0.40
0.30	0.39
0.28	0.37
0.26	0.35
0.24	0.33
0.22	0.32
0.20	0.30
0.18	0.28
0.16	0.26
0.14	0.24
0.12	0.23
0.10	0.21

Table 6: Example of Data Extracted from Published Catalogue (see enlarged documents in appendix 2)

NFRC SIMULATION ACCORDING TO THE
ANSI/NFRC 100, ANSI/NFRC 200 and NFRC 500 GUIDELINES
Mur rideau - Série 6800HP

AIR-INS	Submitted to :	Reissued To:
Report No.: AT-00444 Reissued Report No.: N/A	Alumico Architectural Inc. 4343 Hochelaga Street Montréal QC, Canada H1V 1C2 Mr. Christian Bérubé (514) 255-4343	N/A

Operation Type:	GWCW	Product Line ID Number:	N/A
Series/Model:	Mur rideau - Série 6800HP	Report Type:	N/A
Report Date:	2015-10-15	Simulation Date :	2015-10-15
Revision Date:	N/A	Number of Pages:	5

Reissue Information

Model:	N/A	Date of Reissue:	N/A
Reason for submittal:	N/A	Revision Date:	N/A
Product Line ID Number:	N/A		

Simulated by:

Ingrid Volbert
Simulator
Thermal Evaluation Department

Approved by:

Dave Deshaies Mc Mahon, Eng.
NFRC Certified Simulator
Person-in-Responsible Charge

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AIR-INS

Simulation Report No: AT-00444, Reissued Report: N/A — Mur rideau - Série 6800HP

Table 2: Overall fenestration products results

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	[illegible]	[illegible]

Table 7: Example of Data Extracted from ANSI/NFRC 100 Report (see enlarged documents in appendix 3)

Once the data was collected, it was necessary to convert the data to a common basis for use in our comparative calculations. For example, in AAMA 503-12 and ANSI/NFRC 100 reports the overall U-Value is published for a standard size vision frame unit measuring 1000 mm c/c x 2000 mm c/c. To be applicable to our exercise, it was necessary for us to convert the published data to represent the characteristic of vision frame units and punched windows with dimensions selected for this project.

In addition, in order to compare characteristics of different manufacturers, we had to assume the use of the same vision glass in each calculation. For this purpose, we used a value of 0.24 Btu/(hr-ft^2-°F) as a very common center of glass (COG) U-value for double IGU used in current office building construction.

The following table provides the published U-Values that we received for the various assemblies that were analysed. For the assemblies manufactured by Gamma, published U-values for a standard vision frame dimension of 1000 mm c/c x 2000 mm c/c were not available, so we have calculated this value to be able to report all information received from the manufacturers with the same reference.

Curtain Wall System				
Manufacturer	Series Label	Type	COG U-value	Published U-Value
Gamma	system 1	L'avenue H.Captured ,V. SSG	0.24	0.333
Gamma	system 2	Roccabella SSG	0.24	0.329
Gamma	system 3	Altoria Captured	0.24	0.389
Schuco	FW 60+.si	Captured	0.24	0.306
Schuco	FW 60+SG.si	SSG	0.24	0.351
Schuco	FW 50+.si	Captured	0.24	0.307
Schuco	FW 50+SG.si	SSG Verre triple	0.24	0.350
Alumico	6800HP	Captured	0.24	0.324
Kawneer	2500UT	Captured	0.24	0.340
Kawneer	2500UT	Captured	0.24	0.340
Kawneer	2500UT	SSG	0.24	0.340
Kawneer	1600UT	Captured alum pp 1"	0.24	0.350
Kawneer	1600UT	Captured fiber g pp 1"	0.24	0.340
Kawneer	1600UT	Captured alum pp 1.75"	0.24	0.350
Kawneer	1600UT	Captured fiber g pp 1.75"	0.24	0.340
Kawneer	1600UT	SSG vert alum pp 1"	0.24	0.330
Kawneer	1600UT	SSG vert fiber g pp 1"	0.24	0.330
Kawneer	1600UT	SSG vert alum pp 1.75"	0.24	0.320
Kawneer	1600UT	SSG vert fiber g pp 1.75"	0.24	0.320
Kawneer	FG201T	Window wall	0.24	0.390
Kawneer	451UT	Trifab	0.24	0.380
Flynn	6450UCW	Captured	0.24	0.340

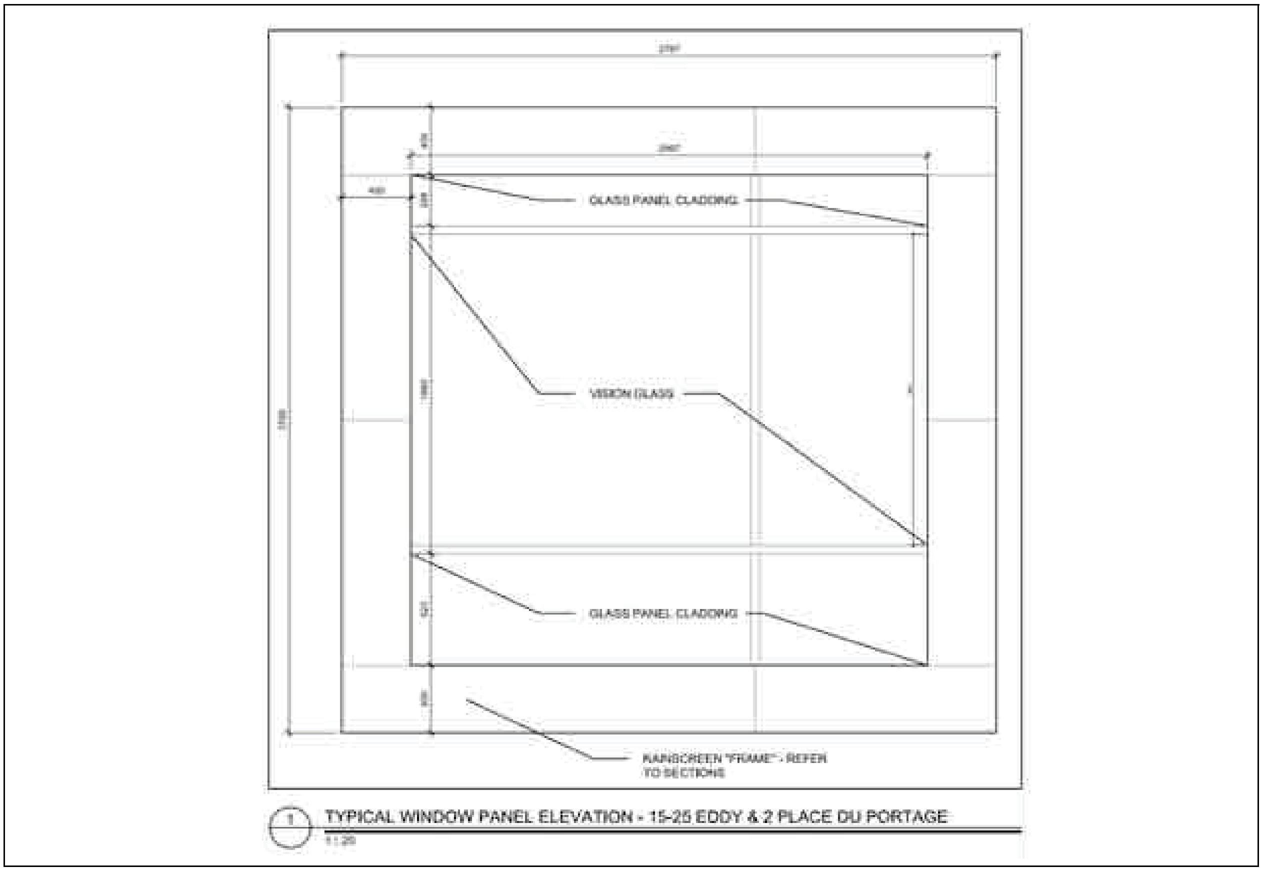
Table 8

From table 8, it is clear that Schuco captured assemblies achieve the best performance for a standard vision frame dimension of 1000 mm c/c x 2000 mm c/c.

Assessment of Potential Wall Configurations

As described previously, you advised that you are contemplating the use of metal and glass curtain wall assemblies in two different scenarios. We therefore assessed two potential wall configurations according to your design concepts.

The first configuration that we assessed is the use of curtain wall framing to fabricate punched openings within a unitized, insulated wall panel that would mimic the layout of the original exterior wall. In this configuration the area of vision glass represents 42% of the total wall area. You provided the sketch below to describe the proposed layout of the unitized wall panels.



The second configuration that we assessed is alternating bands of vision and spandrel glass in a curtain wall system that is continuous over the height of the towers. To optimise both fabrication cost and overall U-Value, we assumed a horizontal centre-to-centre dimension for the vertical mullions of 1.5 m. In order to be directly comparable to the contemplated punched window configuration, we assigned the height of the vision glass to be 1.56 m (and the height of the spandrel glass to be 2.14 m) so that the area of vision glass would match the contemplated punched window configuration as 42% of the total wall area.

We assumed a double glazed IGU with a U-value of 0.24 Btu/(hr-ft^2-°F) for all of our overall U-Value calculations to compare the various assemblies in both contemplated wall configurations. This was consistent with the calculations we made to normalize the published performance data from the manufacturers.

Finally, all of our calculations were undertaken using the parallel path method whereby the performance of each individual component in the wall is combined using area weighting to arrive at an overall performance value for the complete system.

Punched Window Configuration

Using the typical window panel dimensions that you provided, we calculated project specific U-Values of a punched window fabricated using each of the assemblies listed above, and obtained a range of U-Values from 0.36 to 0.57 with a mean of 0.43 Btu/(hr-ft^2-°F). As was the case with the normalized published data, we found that the best performance was achieved with a captured system.

For the opaque wall system surrounding the punched window we used the U-Value of 0.047 Btu/(hr-ft^2-°F) that was provided by your office. When we combined the results for punched windows with the characteristic of the opaque wall, we obtained overall U-Values ranging from 0.18 to 0.25 with a mean 0.21 Btu/(hr-ft^2-°F).

In order to demonstrate the influence of the glass performance on the overall U-Value, we selected one of the Gamma assemblies (System 1) as representative of the mean value of all the assemblies evaluated. We then repeated the set of calculations based on the use of IGUs with center of glass (COG) U-Values of 0.20 Btu/(hr-ft^2-°F) and 0.14 Btu/(hr-ft^2-°F). The following table shows the influence of the IGU thermal performance on the overall thermal performance of the wall.

Punched Window Option			
COG	Overall U-Value	Overall R-Value	% of improvement
0.240	0.201	4.98	0%
0.200	0.193	5.18	4%
0.140	0.180	5.56	12%

Continuous Curtain Wall Configuration

Using the module framing dimensions described above (to yield a vision glass area that matches the punched windows) we calculated project specific U-Values of vision and spandrel modules fabricated using each of the assemblies listed above. For the spandrel U-Value calculation we used a center of spandrel (COS) U-Value of 0.0454 Btu/(hr-ft^2-°F) which is equivalent to four (4) inches of Roxul CurtainRock 40 insulation with an double glazed spandrel panel with a centre of glass U-Value of 0.24 Btu/(hr-ft^2-°F). Note that the characteristics of the spandrel modules were provided by only one manufacturer and we used those characteristics for calculating the overall spandrel U-Value for the assemblies of the other manufacturers.

When we combined the results for vision and spandrel modules we obtained overall U-Values ranging from 0.20 to 0.22 with a mean of 0.21 Btu/(hr-ft^2-°F). As was the case with the normalized published data, we found that the best performance was achieved with a captured system.

In order to demonstrate the influence of the glass performance and spandrel insulation levels on the overall U-Value, we selected one of the assemblies as representative of the mean value of all the assemblies evaluated. We then repeated the set of calculations based on the use of IGUs with center of glass (COG) U-Values of 0.20 Btu/(hr-ft^2-°F) and 0.14 Btu/(hr-ft^2-°F), as well as with increased insulation thickness. The following table shows the influence of the IGU thermal performance and spandrel insulation thickness on the overall thermal performance of the wall.

Continuous Curtain Wall				
		42 % vision ratio		
COG	COS	Overall U-Value	Overall R-Value	% of improvement
0.24	0.045	0.205	4.88	0%
0.20	0.044	0.191	5.24	7%
0.20	0.037	0.188	5.32	9%
0.14	0.037	0.170	5.88	21%

*: 4 inches of insulation
**: 5 inches of insulation

Conclusions

The following table compares the overall thermal performance of the contemplated punched window and continuous curtain wall configurations, for different COG U-values.

Punched Window vs Continuous Curtain Wall						
		Continuous Curtain Wall		Punched Window		
		42% vision ratio		42% vision ratio		
COG	COS	Overall U-Value	Overall R-Value	Overall U-Value	Overall R-Value	% of diff. 42%
0.24	0.0454*	0.205	4.88	0.201	4.975	2%
0.20	0.0439*	0.191	5.24	0.193	5.181	-1%
0.20	0.037**	0.188	5.32	0.193	5.181	-3%
0.14	0.037**	0.170	5.88	0.180	5.556	-6%

*: 4 inches of insulation
**: 5 inches of insulation

As can be seen in the table above, for the same area of vision glass there is no significant difference in overall thermal performance of the wall between the two configurations under consideration. These results reflect the fact that significantly superior thermal performance planned for the opaque wall surrounding the punched windows is substantially offset by the increased area of relatively poor performance framing in the punched window configuration. In the continuous curtain wall configuration, the spandrel modules do not match the thermal performance of the planned opaque wall in the punched window option, but there is less framing area in the vision areas so the overall thermal performance for the wall is very similar to the punched window configuration. This emphasizes the reality that the overall thermal performance of the wall is dominated by the thermal performance of the weakest component in the system.

This governing principle can then be used to guide decisions regarding the wall design from a thermal perspective. The priority should always be to focus on improving and minimizing the total area of the weakest part of the system, in order of importance the framing members and the IGU. Unfortunately, currently available framing products are limited in terms of thermal performance so that, practically speaking, reducing the area of framing (minimizing framing), reducing the total area of vision glass and improving IGU performance is the easiest way to improve the overall thermal performance.

For the two configurations under consideration with the area of vision glass approximately 40% of the total wall area, the overall thermal transmittance of the exterior wall will be essentially the same, and in the order of 0.2 Btu/(hr-ft^2-°F) for the range of double IGU likely to be used on the project. As the designed total area of vision glass is reduced below approximately 40%, the punched window configuration will increasingly outperform the continuous curtain wall configuration.

Improvement of the overall thermal transmittance can be achieved with the use of glass compositions with COG U-Values below the standard range of high performance double glazed IGU, but the maximum level of improvement will only be in the order of 10% for the punched window configuration.

In summary, the best strategy to adopt for optimized thermal transmittance of the new exterior wall system is to utilize a frame member with the lowest possible U-Value and to limit the overall size of the punched windows to the smallest acceptable dimensions. To minimize cooling loads and thermal discomfort in the building, it would be prudent to combine the above strategy with the use of glass compositions with the lowest SHGC that accompanies the lowest acceptable V_{LT}) on the south and west elevations.

An overall energy simulation model for the building that includes thermal transmittance, solar control and air leakage characteristics for the exterior wall is required to obtain an accurate evaluation of the payback of the different wall component options.

We trust that this provides you with valuable information regarding the realistic thermal performance that could be achieved with practically available curtain wall assemblies used in the two different wall configurations contemplated in your design concepts.

Please do not hesitate to contact us if you have any questions.

Yours truly,

PATENAUDE TREMPE VAN DALEN INC.

2016-05-03

Loui
Project Director

Mark Van Dalen, P. Eng.
Vice-President

Appendix 1 – Example of Data extracted from AAMA 507-12 Report

Intertek | Architectural Testing

2370
95438-110

AAMA 507-12 THERMAL PERFORMANCE REPORT

Rendered to:

KAWNEER COMPANY INC.

SERIES/MODEL: 2500 UT Captured System
TYPE: Glazed Wall System

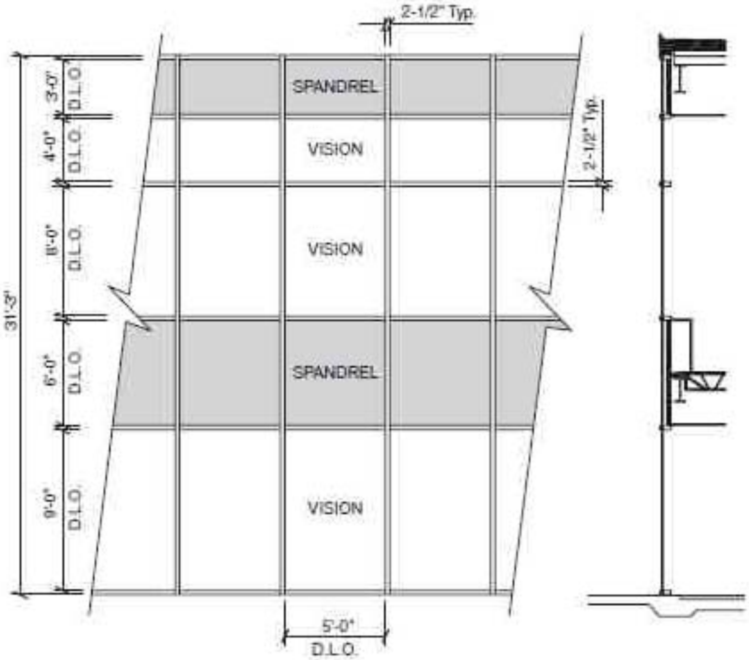
Report No: E5293.01-116-45
Report Date: 06/05/15

Vision Area Data

Option No.	COG U-Factor	COG Temperature	Cross Section	Frame Height	Frame U-Factor	Edge U-Factor	Total Product U-Factor: 70% Vision Area 26.19" by 26.19"	Total Product U-Factor: NFRC 100-2010 78.74" by 78.74"	Total Product U-Factor: 95% Vision Area 168.39" by 168.39"
10	0.30	53.1	Head	1.3332	1.2780	0.2952	0.5335	0.3783	0.3304
			L. Jamb	1.3333	1.0042	0.2977			
			R. Jamb	1.3461	0.9971	0.2962			
			Mullion	2.6794	1.0006	0.2969			
			Sill	2.2817	1.0093	0.2915			
11	0.28	54.2	Head	1.3332	1.2738	0.2806	0.5204	0.3614	0.3127
			L. Jamb	1.3333	0.9988	0.2828			
			R. Jamb	1.3461	0.9917	0.2814			
			Mullion	2.6794	0.9952	0.2821			
			Sill	2.2817	1.0063	0.2770			
12	0.26	55.2	Head	1.3332	1.2695	0.2661	0.5073	0.3444	0.2949
			L. Jamb	1.3333	0.9934	0.2682			
			R. Jamb	1.3461	0.9862	0.2667			
			Mullion	2.6794	0.9898	0.2674			
			Sill	2.2817	1.0032	0.2627			
13	0.24	56.3	Head	1.3332	1.2654	0.2517	0.4943	0.3275	0.2772
			L. Jamb	1.3333	0.9882	0.2536			
			R. Jamb	1.3461	0.9810	0.2520			
			Mullion	2.6794	0.9845	0.2528			
			Sill	2.2817	1.0003	0.2484			
14	0.22	57.3	Head	1.3332	1.2615	0.2372	0.4814	0.3106	0.2595
			L. Jamb	1.3333	0.9832	0.2390			
			R. Jamb	1.3461	0.9760	0.2374			
			Mullion	2.6794	0.9796	0.2382			
			Sill	2.2817	0.9976	0.2342			
15	0.20	58.4	Head	1.3332	1.2576	0.2229	0.4686	0.2936	0.2416
			L. Jamb	1.3333	0.9782	0.2245			
			R. Jamb	1.3461	0.9709	0.2229			
			Mullion	2.6794	0.9745	0.2237			
			Sill	2.2817	0.9949	0.2201			
16	0.18	59.5	Head	1.3332	1.1983	0.2036	0.4324	0.2683	0.2200
			L. Jamb	1.3333	0.8921	0.2034			
			R. Jamb	1.3461	0.8852	0.2020			
			Mullion	2.6794	0.8886	0.2027			
			Sill	2.2817	0.9502	0.2019			
17	0.16	60.6	Head	1.3332	1.1941	0.1893	0.4194	0.2512	0.2017
			L. Jamb	1.3333	0.8865	0.1889			
			R. Jamb	1.3461	0.8796	0.1875			
			Mullion	2.6794	0.8831	0.1882			
			Sill	2.2817	0.9473	0.1878			
18	0.14	61.7	Head	1.3332	1.1908	0.1744	0.4064	0.2340	0.1835
			L. Jamb	1.3333	0.8815	0.1737			
			R. Jamb	1.3461	0.8747	0.1723			
			Mullion	2.6794	0.8781	0.1730			
			Sill	2.2817	0.9446	0.1731			

Appendix 2 – Example of Data Extracted from Published Catalogue

Generic Project Specific U-factor Example Calculation
(Percent of Glass will vary on specific products depending on sitelines)
(Based on single bay of Curtain Wall/Window Wall)



Vision Area

Example Glass U-factor	= 0.48 Btu/(ft² · h · °F)
Vision Area	= 5(9 + 8 + 4) = 105.0 ft²
Total Area (Vision)	= 5' 2-1/2" (9' 3-3/4" + 8' 2-1/2" + 4' 2-1/2") = 113.2 ft²
Percentage of Vision Glass	= (Vision Area ÷ Total Area)100 = (105.0 ÷ 113.2)100 = 93%

Spandrel Area

Example Spandrel R-value	= 15 (ft² · h · °F)/Btu
Spandrel Area	= 5(6 + 3) = 45.0 ft²
Total Area (Spandrel)	= 5' 2-1/2" (6' 2-1/2" + 3' 3-3/4") = 49.6 ft²
Percent of Spandrel	= (Spandrel Area ÷ Total Area)100 = (45.0 ÷ 49.6)100 = 91%

Thermal Transmittance [1] (BTU/hr • ft² • °F)

Glass U-Factor [3]	Overall U-Factor [4]
0.47	0.53
0.46	0.52
0.44	0.50
0.42	0.49
0.40	0.47
0.38	0.45
0.36	0.44
0.34	0.42
0.32	0.40
0.30	0.39
0.28	0.37
0.26	0.35
0.24	0.33
0.22	0.32
0.20	0.30
0.18	0.28
0.16	0.26
0.14	0.24
0.12	0.23
0.10	0.21

1" GLAZING WITH ALUMINUM PRESSURE PLATE

NOTE: For glass values that are not listed, linear interpolation is permitted.

1. U-Factors are determined in accordance with NFRC 100.
2. SHGC and VT values are determined in accordance with NFRC 200.
3. Glass properties are based on center of glass values and are obtained from your glass supplier.
4. Overall U-Factor, SHGC, and VT Matricies are based on the standard NFRC specimen size of 2000mm wide by 2000mm high (78-3/4" by 78-3/4").

SHGC Matrix [2]

Glass SHGC [3]	Overall SHGC [4]
0.75	0.72
0.70	0.68
0.65	0.63
0.60	0.59
0.55	0.54
0.50	0.50
0.45	0.45
0.40	0.41
0.35	0.36
0.30	0.32
0.25	0.27
0.20	0.23
0.15	0.18
0.10	0.14
0.05	0.09

Visible Transmittance [2]

Glass VT [3]	Overall VT [4]
0.75	0.68
0.70	0.63
0.65	0.59
0.60	0.54
0.55	0.50
0.50	0.45
0.45	0.41
0.40	0.36
0.35	0.32
0.30	0.27
0.25	0.23
0.20	0.18
0.15	0.14
0.10	0.09
0.05	0.05

Appendix 3 – Example of Data Extracted from ANSI/NFRC 100 Report

NFRC SIMULATION ACCORDING TO THE
ANSI/NFRC 100, ANSI/NFRC 200 and NFRC 500 GUIDELINES
Mur rideau - Série 6800HP

AIR-INS	Submitted to :	Reissued To:
Report No.: AT-00444 Reissued Report No.: N/A	Alumico Architectural inc. 4343 Hochelaga Street Montréal QC, Canada H1V 1C2 Mr. Christian Bérubé (514) 255-4343	N/A

Operation Type:	GWCW	**Product Line ID Number:**	N/A
Series/Model:	Mur rideau - Série 6800HP	**Report Type:**	N/A
Report Date:	2015-10-15	**Simulation Date :**	2015-10-15
Revision Date:	N/A	**Number of Pages:**	5
		Reissue Information	
Model:	N/A	**Date of Reissue:**	N/A
Reason for submittal:	N/A	**Revision Date:**	N/A
Product Line ID Number:	N/A		

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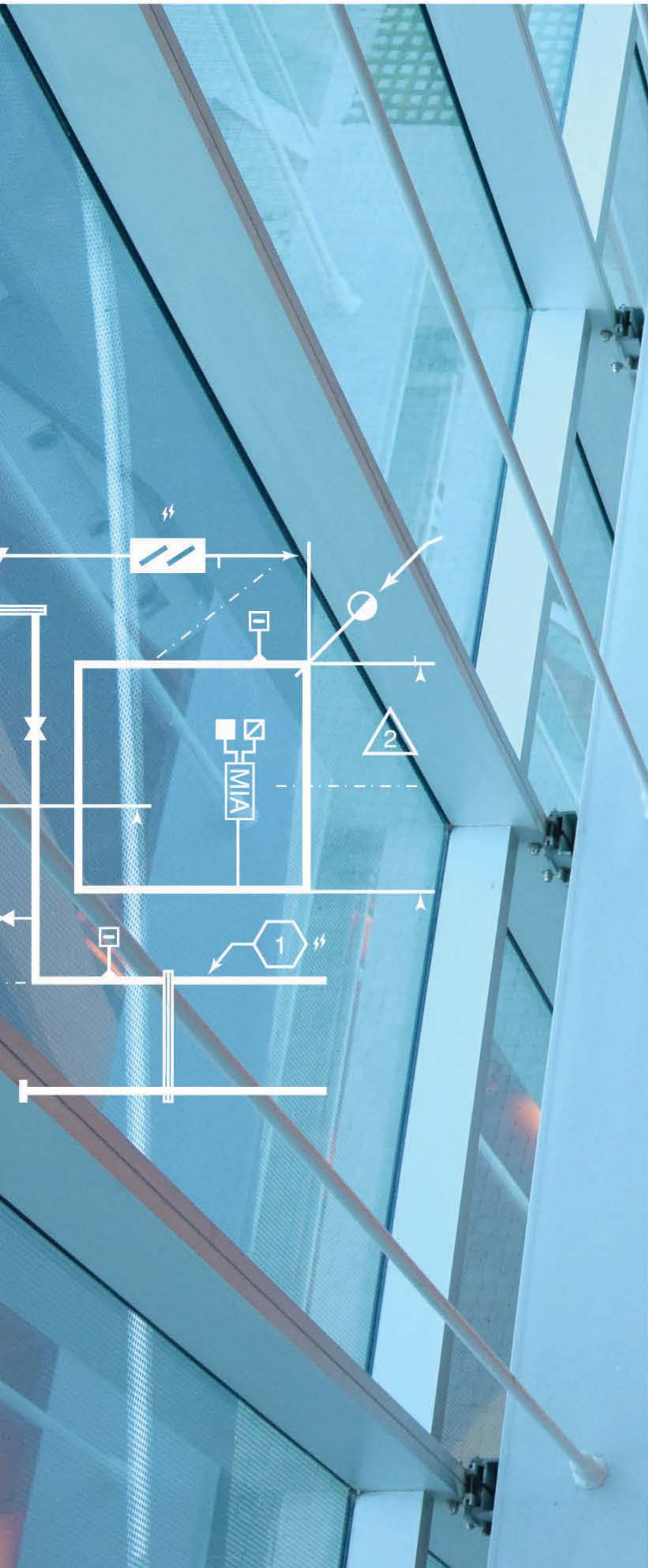
Table 2: Overall fenestration products results

ID	Option Name	Insulating Glass Unit								Overall Product			
		Glass 1		Gap 1				Glass 2		U Factor		SHGC	VT
		Type	mm	mm	Gas	Spacer	Grid	Type	mm	W/m2-K	Btu/hr-ft2-F		
1	RM-SNX62-27#2-Arg85-ClrGuard	Climaguard 62/27	5.6	12.26	Arg 85%	TS-D	None	Clear, Guardian	5.6	1.97	0.35	0.24	0.54

Appendix D - Energy Modeling

Canada

grc architects



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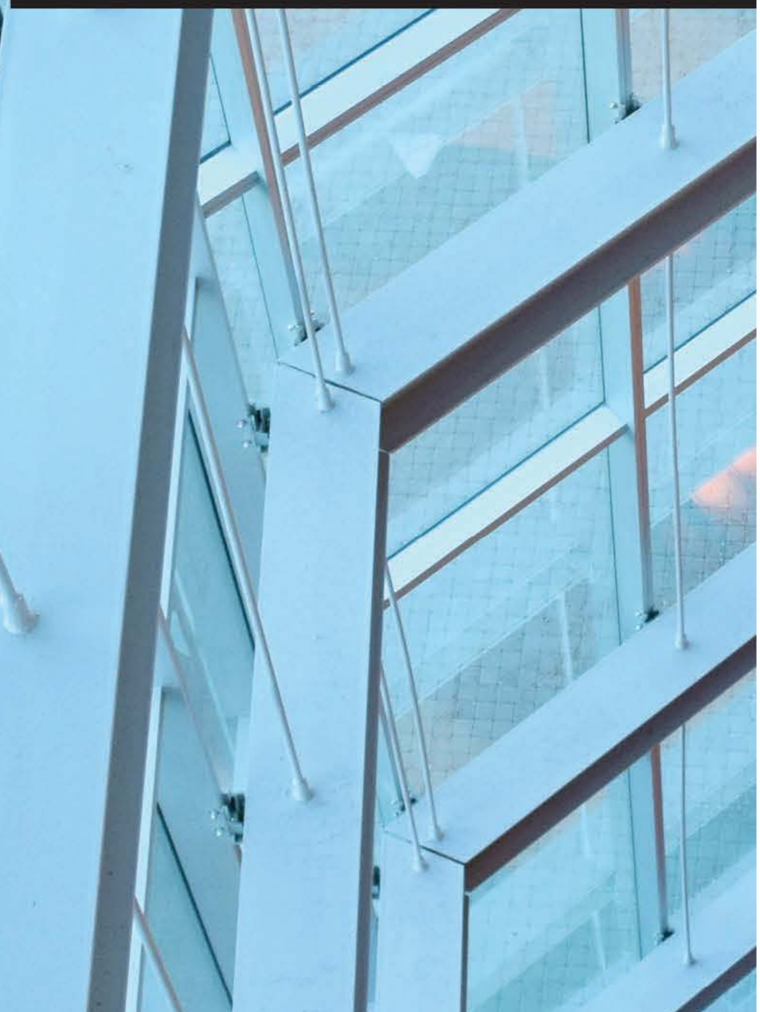

Les Terrasses de la Chaudière

Envelope Rehabilitation Development
PWGSC Project N° R.068114.018

Energy Analysis Report – 100%

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June 8, 2016 7232-005-00

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Table of contents

1 Executive Summary

This report summarizes the results for the Les Terrasses de la Chaudière Building Envelope Rehabilitation project energy analysis of design options. Multiple simulations were performed of wall construction and fenestration options in order to assist in optimizing the energy performance of the building envelope. These options were first modelled in isolation, and then in combination.

The envelope options modelled in isolation include variations of wall insulation, the fenestration characteristics, the WWR on different facades, and solar shading.

The combined envelope options modeled fall under two primary wall system categories: prefabricated panel and curtain wall. The purpose is to assist in determining which wall system has an overall lower life cycle cost.

These combined envelope options illustrate the energy performance of a variety of possible scenarios, not only to decide upon a wall system, but to help determine an appropriate window to wall ratio (WWR) for the building overall and for each facade. The two wall system categories (prefabricated panel and curtain wall) were modelled in parallel sets, with the same characteristics for the fenestration glass type and WWR per facade, so that the two systems can be easily compared for a variety of possible architectural design choices.

The results of the energy analysis indicate a clear ranking of priorities in order of potential to impact the annual energy cost. The envelope options are listed as follows in order from high to low priority.

.1 Fenestration solar heat gain coefficient

.2 Window to wall ratio overall and on each facade

.3 Fenestration thermal transmittance, including the framing configuration

.4 Wall insulation

.5 Solar shading

The results also show that the option with the highest annual energy cost savings consists of prefabricated wall panel construction with triple pane fenestration having the following characteristics:

.1 Fenestration with an assembly U-Value ≤ 0.20 Btu/(h·F·ft^2), SHGC ≤ 0.30;

.2 WWR not exceeding Code maximum of 36.3%. A lower WWR on south and west facades than on the north and east facades results in energy cost savings;

.3 Wall U-Value at Code minimum of ≤ 0.044 Btu/(h·F·ft^2).

The key findings that resulted from this energy analysis are summarized in the table below.

Table 1-1: Key Findings

Component	Potential Energy Cost Savings	Notes
Wall Insulation	3%	Increased wall insulation has a minor overall impact, with a potential for roughly 3% annual energy cost savings.
Fenestration	10%	Fenestration performance in general has a high impact, with a potential for roughly 10% annual energy cost savings.
		Solar heat gain coefficient (SHGC) has a high impact. For example, reducing the SHGC from 0.65 to 0.42 achieves approximately 6% energy cost savings.
		As supported by the envelope consultation report by PTVD, the framing members play a significant role in affecting the overall U-Value of the fenestration assembly. An optimized design would reduce the amount of framing members as much as possible.
Window to Wall Ratio	4%	The existing building at 43% WWR exceeds the Code maximum WWR of 36%.
		Decreasing the WWR to 36% has a potential for roughly 4% annual energy cost savings.
		The proposed design has a WWR of 47%, which results in 6% higher energy cost than a design with 36% WWR.
		The concentration of the fenestration on the facade orientations has a higher influence than overall building WWR. The same area of glass distributed differently on the building results in wide variations in energy use. This is also influenced by the fenestration performance
Solar Shading	0%	Vertical solar shading on the west facade results in marginal energy cost savings.
Combined Effects	8-16%	When modeled in combination, these measures have the potential for roughly 16% energy cost savings with prefab wall panel construction, and roughly 8% energy cost savings for curtain wall construction.
		On average, the prefab wall panel construction results in an annual energy cost savings of approximately $90,000 higher than curtain wall construction.

2 Introduction

Pageau Morel has been engaged to provide an energy analysis of the schematic design options for the Les Terrasses de la Chaudière Building Envelope Rehabilitation project. This analysis will help to determine which envelope options provide the best overall value to the Crown.

The energy analysis process for this project can be broken down into the following steps:

.1 Establish the energy performance of the existing building envelope;

.2 Establish the minimum Code energy performance criteria;

.3 Assist in optimizing the energy performance of the proposed envelope options;

.4 Provide energy cost data for the life cycle costing exercise.

The purpose of this energy analysis is not to make recommendations on a new envelope system for the building.

For all simulations, the annual energy cost is used for comparison. Only the areas of the building under consideration for envelope rehabilitation were simulated. The lower commercial levels (podium), parking garage, and site lighting are excluded. For this reason, the existing building energy simulation is not representative of the actual total energy use for the building. This energy simulation is also not intended to be used to predict actual energy bills.

Below are two renderings created by the energy simulation program which represents the existing building geometry as it was simulated. It is important to capture the building's unique geometry and relation between the office towers in order to accurately simulate solar patterns and building self-shading.

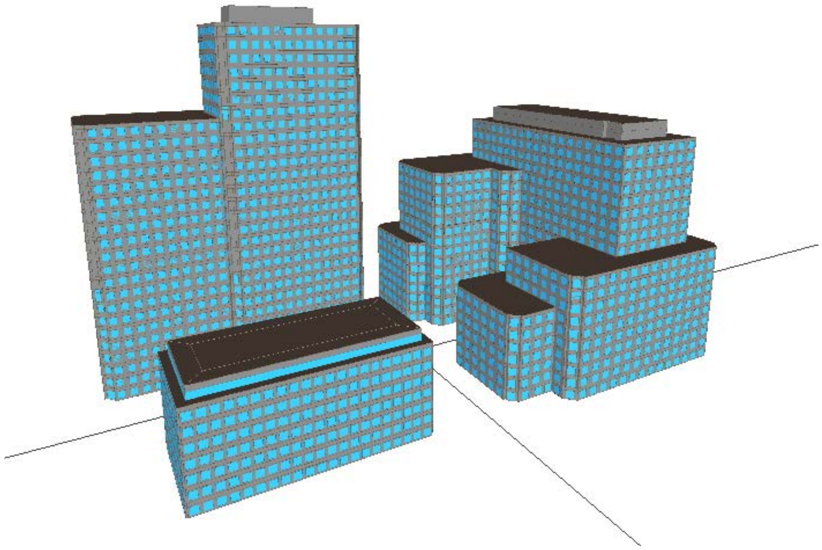


Figure 1 – View from south

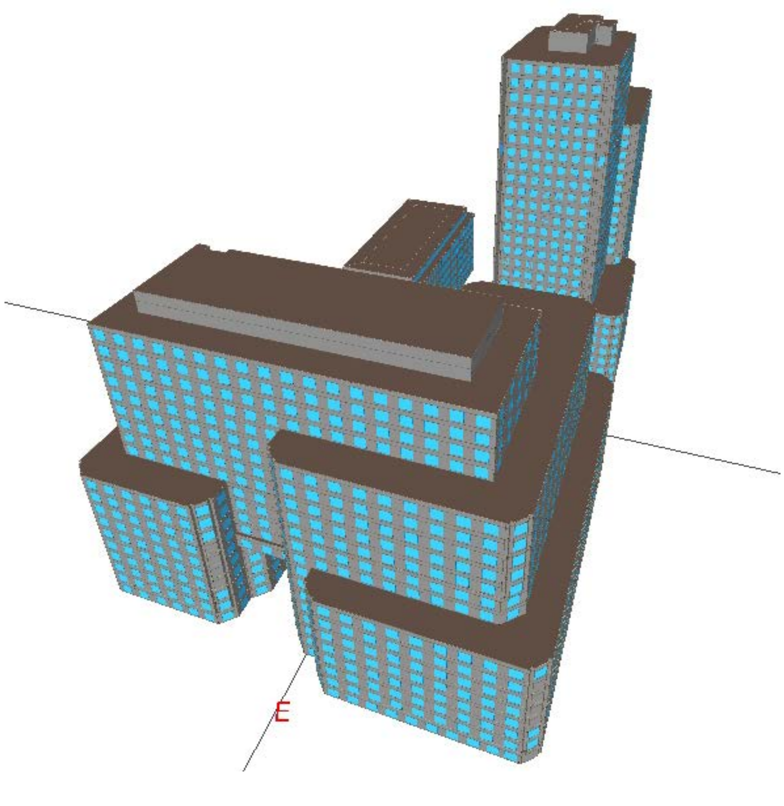


Figure 2 - View from east

3 Base Case Inputs

The energy simulation for the building was constructed based on the criteria below. These criteria are common to all of the simulations.

3.1 Simulation Software

3.1.1 The eQUEST (DOE-2.2) energy simulation software was used to create the computer simulation model. This software is sophisticated and allows for a high level of user inputs. The software calculates for all 8,760 hours of the year.

3.2 Building Geometry

3.2.1 The building geometry based on the existing architectural drawings was used for the energy simulation. All three office towers that comprise the facility were modeled. Although a high level of effort was required to do this, it was determined important for this building to capture its unique geometry and relation between the office towers. This resulted in accurate simulation of the solar patterns and building self-shading.

3.2.2 As mentioned, only the areas of the building which are under consideration for façade rehabilitation were simulated. The lower commercial levels, parking garage, and exterior lighting were excluded.

3.3 Building Code

3.3.1 To establish minimum Code performance, the building was simulated with an envelope that meets the minimum requirements of the *2011 National Energy Code of Canada for Buildings (NECB 2011)*. This represents a typical minimum level of construction and is mandatory for the construction of new federal buildings.

3.4 Utility Data

3.4.1 The electric utility rates used for the energy simulation are indicated in the table below. The building is serviced electricity by Hydro Québec and natural gas by Gazifère.

Table 2-2: Utility Rates

Energy Source	Cost
Electricity	**Hydro Quebec Rate M** **Base Service Charge** \$0.00 per Billing Period **Energy Charge** 4.93¢ per kWh for first 210,000 kWh per Billing Period 3.66¢ per kWh for balance kWh per Billing Period **Demand Charge** \$14.37 per kW
Natural Gas	**Gazifère Rate 1 – General Service** **Monthly Fixed Charge** \$17.13 **Delivery Charge** 21.53¢/m3 for the first 100 m3 20.39¢/m3 for the next 220 m3 19.28¢/m3 for the next 680 m3 **Transportation Charge** 6.09¢/m3 for all volumes sold **Supply Charge** 14.90¢/m3 for all volumes sold

3.5 Schedules

3.5.1 A typical office building schedule was used to simulate the building occupancy, lighting, miscellaneous loads, and HVAC systems. The schedules are identical between all of the simulations.

3.6 Occupants

3.6.1 The existing building has an occupant load of approximately 6,000 people. It is estimated that the total building occupant load following Workplace 2.0 renovations will increase to approximately 9,000 people. This load was assumed to be relatively uniform throughout the building.

3.6.2 The vast majority building has not been renovated to meet the Workplace 2.0 Fit-Up Standard. These renovations, however, may coincide or follow shortly thereafter, the envelope rehabilitation project. This represents an average cooling load increase of approximately 0.22 W/ft^2 in the office areas of the building.

3.7 HVAC Systems

3.7.1 The central heating and cooling plant equipment were modelled as a close approximation to the existing equipment. In order to simplify the energy model and the work involved in investigating the slight variances between floors, it was assumed that the same air distribution equipment types are installed on each floor of the building. Each floor was simulated with two variable air volume air handling units, one for the perimeter zones and one for the interior zones. Each air handling unit has two or more zone coils, each of which feeds multiple terminal variable air volume boxes. The variable air volume terminal boxes were modelled with reheat coils. For the perimeter air handling unit, there is generally a zone coil for each building facade orientation.

3.8 Lighting and Miscellaneous Loads

3.8.1 The lighting and miscellaneous office equipment loads were also modelled. In order to simplify the model, it was assumed that the same loads would apply to each specific space type on each floor of the building. These loads are summarized below for each space type.

Table 2-3: Lighting and Miscellaneous Loads

	Lighting (W/ft^2)	Miscellaneous (W/ft^2)
Office	0.8	1.0
Corridor	0.5	0.0
Lobby	1.3	0.2
Storage	0.8	0.0
Washrooms	0.9	0.1
Mechanical/Electrical	1.0	0.1

3.8.2 It is estimated that the existing lighting loads are approximately 1.1 W/ft^2. With improvements in lighting technology, and more stringent Code maximum lighting power density, the lighting loads are estimated to decrease by approximately 0.3 W/ft^2 in the office areas following the Workplace 2.0 Fit-up renovations. This would result in a lighting power density of approximately 0.8 W/ft^2 in the office areas.

4 Envelope Variances Simulated

A number of envelope variances were simulated individually in order to understand the impact of each individual variance. This helps to evaluate which measures have the highest impact. These variances are then combined into envelope packages in the following section of this report.

4.1 Wall Assemblies

4.1.1 Various wall assemblies were analyzed, including the existing wall and a wall representing Code prescriptive minimum insulation levels. In addition, a prefabricated wall assembly with various thickness of rigid insulation, as well as a high performance curtain wall were analyzed.

Table 3-1: Wall Assemblies

Type	Description	R-Value (h·F·ft²)/Btu	U-Value Btu/(h·F·ft²)
Existing	Existing Wall Layers from interior to exterior: 5/8" gypsum wallboard, 4" concrete wall, 2" rigid insulation, ½" air space, 3.5" masonry brick veneer.	9.1	0.110
W0	Code Minimum As per NECB 2011, the building is located in Hull, Quebec, which has 4550 Heating Degree Days (< 18C / 64F). This falls within Zone 6 (Heating Degree-Days from 4000 to 4999), which according to Table 3.2.2.2 in the NECB 2011, requires a maximum effective thermal transmittance of 0.247 W/(m^2·K), or 0.044 Btu/(h·F·ft^2).	22.7	0.044
W1	Prefab Wall Panel with 50mm Rigid Insulation Layers from interior to exterior: 5/8" gypsum wallboard, 2" rigid insulation, 6" steel stud with rock wool insulation, ¾" sheathing, ½" air space, rainscreen.	19.7	0.051
W2	Prefab Wall Panel with 75mm Rigid Insulation Layers from interior to exterior: 5/8" gypsum wallboard, 3" rigid insulation, 6" steel stud with rock wool insulation, ¾" sheathing, ½" air space, rainscreen.	24.7	0.041

Type	Description	R-Value (h·F·ft^2)/Btu	U-Value Btu/(h·F·ft^2)
W3	Prefab Wall Panel with 100mm Rigid Insulation Layers from interior to exterior: 5/8” gypsum wallboard, 4” rigid insulation, 6” steel stud with rock wool insulation, ¾” sheathing, ½” air space, rainscreen.	29.7	0.034
W4	Curtain wall – Spandrel Panel This is for a center of spandrel thermal transmittance of U-0.045.	7.1	0.140

4.1.2 It should be noted that two of the options, W1 and W4, do not meet the Code prescriptive assembly thermal transmittance. In order to demonstrate compliance with the National Energy Code of Canada for Buildings (NECB 2011) in either of these two scenarios, the Trade-off Path approach must be used as per Section 3.3 Trade-Off Path in the Code. This approach allows for trade-off of the thermal transmittance between components that do not meet Code prescriptive values and those that exceed them, according to the following equation:

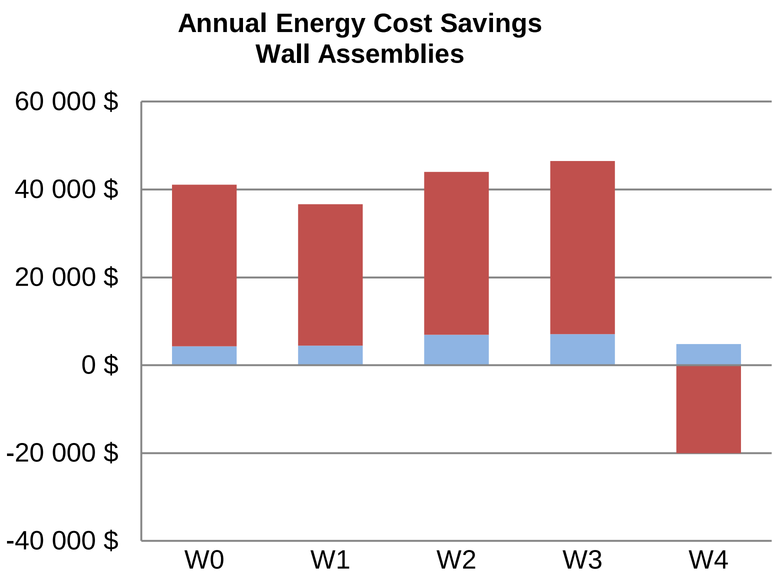
$$\sum_{i=1}^{n} U_{ip}A_{ip} \leq \sum_{i=1}^{n} U_{ir}A_{ir}$$

Where:
n = total number of above-ground assemblies;
U_{ip} = *overall thermal transmittance* of assembly i of the proposed *building*;
A_{ip} = area of assembly i of the proposed *building*;
U_{ir} = *overall thermal transmittance* of assembly i of the reference *building*, and;
A_{ir} = area of assembly i of the reference *building*.

4.2 Results of Wall Assembly Simulations

4.2.1 The results of the wall assembly simulations are below. For each assembly, the annual energy cost savings relative to the adjusted existing building is presented.

4.2.2 Increasing the wall insulation to Code minimum provides roughly 3% annual energy cost savings. Significantly exceeding this value such as assembly W3 provides marginal energy cost savings. The curtain wall assembly W4 performs slightly worse than the existing wall assembly, with roughly 1% higher annual energy cost.



	W0	W1	W2	W3	W4
Total	41 065 $	36 618 $	43 976 $	46 456 $	-15 247 $
Natural Gas	36 796 $	32 139 $	37 049 $	39 385 $	-20 054 $
Electricity	4 269 $	4 479 $	6 927 $	7 071 $	4 807 $

4.3 Fenestration Assemblies

4.3.1 Various fenestration assemblies were analyzed, including the existing fenestration and a fenestration representing Code minimum. Note that the Code does not stipulate a maximum solar heat gain coefficient (SHGC), so this value was assumed. It is understood that at a minimum, a high quality low-e double glazed insulated glazing unit (IGU) will be recommended due to the high impact of fenestration to the overall thermal performance of the envelope. For this reason, lower quality IGUs were not evaluated.

4.3.2 The options below include a few variances in SHGC in order to evaluate the impact of SHGC on energy performance and to optimize the fenestration selection. Selection of IGUs with a visible light transmittance (VLT) of at least 0.55 will be important for daylighting strategies, although daylighting controls were not simulated. It is possible to achieve a low SHGC with a higher VLT, but this requires a low iron glass and/or specialty coatings.

4.3.3 For all of the fenestration assemblies, except where indicated, the published NFRC U-Values were used. This value is essentially an average of the center of glass and frame for the test standard window size, and is typically the value that is used in order to demonstrate Code compliance.

Table 3-2: Fenestration Assemblies

Type	Description	CoG U-Value Btu/(h·F·ft^2)	Assembly U-Value Btu/(h·F·ft^2)	SHGC	VLT
Existing	Existing Fenestration	0.47	0.61	0.51	0.47
G0	Code Minimum	-	0.39	0.55	-
G1	Low-e Double, High SHGC	0.26	0.30	0.65	0.77
G2	Low-e Double, Low SHGC	0.23	0.26	0.42	0.68
G3	Low-e Double, Very Low SHGC	0.23	0.26	0.27	0.55
G4	High Performance Low-e Double, Very Low SHGC	0.20	0.24	0.27	0.55
G5	Low-e Triple, High SHGC	0.19	0.24	0.58	0.70
G6	Low-e Triple, Very Low SHGC	0.14	0.18	0.27	0.55

4.4 Results of Fenestration Assembly Simulations

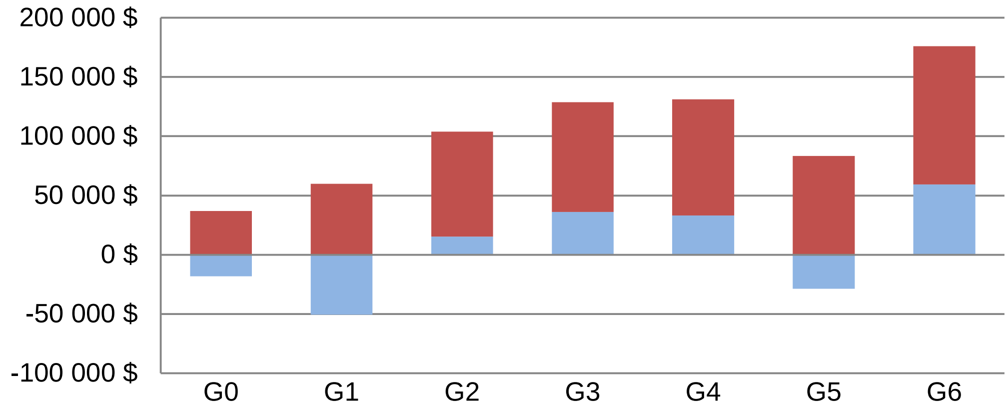
4.4.1 The results of the fenestration assembly simulations are below. For each assembly, the annual energy cost savings relative to the adjusted existing building is presented.

4.4.2 It is clear that the fenestration has a major impact on the overall building energy savings, with a potential for 10% annual energy cost savings.

4.4.3 SHGC has a high impact. The general trend observed is that for the same U-Value, the lower the SHGC, the higher the energy savings. It can also be observed that replacing the existing fenestration with fenestration type G1 results in marginal energy cost savings. This is due to the higher SHGC of the type G1 glass. However, for fenestration type G3 which has a much lower SHGC the savings are significant.

4.4.4 The triple pane fenestration type G6 provides by far the highest energy cost savings. This is due to its combination of both low U-Value and low SHGC. The triple pane type G5 which has a higher SHGC results in less energy cost savings than a double pane fenestration with a lower SHGC, such as types G3, G3 and G4.

Annual Energy Cost Savings
Fenestration Assemblies



	G0	G1	G2	G3	G4	G5	G6
Total	18 673 $	9 092 $	103 801	128 806	131 245	54 787 $	176 057
Natural Gas	36 926 $	59 773 $	88 539 $	92 744 $	98 248 $	83 441 $	116 635
Electricity	-18 253	-50 681	15 262 $	36 062 $	32 997 $	-28 654	59 422 $

4.5 Fenestration Percentage

4.5.1 The impact of varying the window to wall ratio (WWR) on each of the facades was also simulated. Understanding that there are many factors involved in the final decision for window size, this analysis was performed to illustrate the impact that WWR has on the building energy performance. Ultimately the energy performance, as well as Code requirements, will be weighed against other factors such as the aesthetic design of the building facade and interiors.

4.5.2 Furthermore, the goal of this exercise is also to explore the impact of significantly reducing the WWR on various facades, as detailed further below, in order to comply with Code.

4.6 Code Limitations to Window to Wall Ratio

4.6.1 The NECB 2011, article 3.2.1.4 limits the maximum allowable total vertical fenestration and door area to gross wall area ratio (FDWR) to:

.1 FDWR ≤ (2000 – 0.2 · HDD) / 3000 (for 4000 ≤ HDD ≤ 7000)

Where HDD is the heating degree-days of the location of the building. The building is located in Zone 6 (HDD (< 18C / 64F) = 4550. Therefore:

.2 FDWR ≤ (2000 – 0.2 · 4550) / 3000 ;

.3 FDWR ≤ 0.363

4.6.2 Therefore, the maximum allowable total vertical fenestration and door area to gross wall area ratio is 0.363, or 36.3%.

4.6.3 It will need to be decided very early in the design process whether or not the new facade design is to conform to this section of the NECB.

4.7 Existing Window to Wall Ratio

4.7.1 The existing wall panels are configured as follows:

Table 3-3: Existing Wall Panel Configuration

Building	Window Size (mm)	Window Area (m^2)	Panel Size (m^2)	Panel Window to Wall Ratio (%)
15-25 Eddy	2337 x 2591	6.06	14.07	43.0 %
2 Place du Portage	2184 x 2184	4.77	14.07	33.9 %
10 Wellington	2184 x 2184	4.77	14.07	33.9 %

4.7.2 When taking into account that there are some panels on the building corners that do not have windows, and the corner bay windows, the overall WWR for the floors analyzed is indicated in the table below. Overall for the three buildings, the WWR is 42.6%.

Table 3-4: Existing Building Window to Wall Ratio

Building	Total Window Area (m^2)	Total Wall Area (m^2)	Window to Wall Ratio (%)
15-25 Eddy	8,501	23,417	42.5 %
2 Place du Portage	1,450	3,585	40.4 %
10 Wellington	9,013	20,996	42.9 %

4.8 Window to Wall Ratio Options

4.8.1 Several options for WWR were analyzed, as indicated in the table below. The first option, WWR1, represents the proposed design as per GRC Architects' report. Options WWR2 to WWR 5 represent a reduction of overall building WWR to achieve Code compliance. These options explore the energy cost savings that result from concentrating the fenestration on various facade orientations, as is generally considered good design practice for passive solar strategies. Although this was complicated and timely to simulate, the intent is to help understand how this would impact annual energy cost.

Table 3-5: Window to Wall Ratio Options

Type	Description	Orientation	Window Area	WWR	Overall WWR
WWR1	Window to Wall Ratio 47.4%	North	+11%	47.4%	47.4%
		South			
		East			
		West			

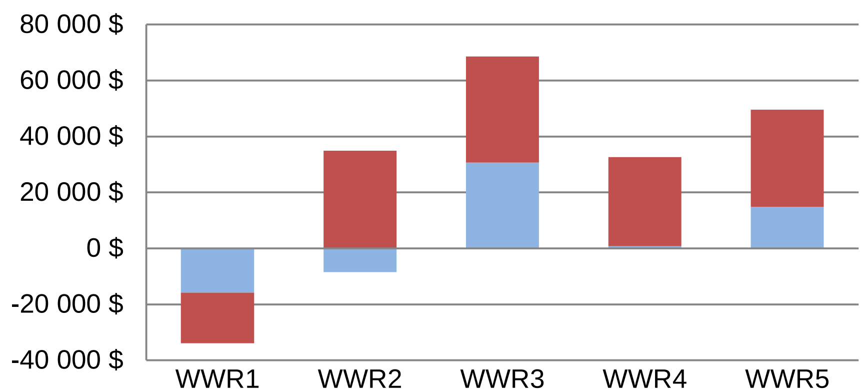
Type	Description	Orientation	Window Area	WWR	Overall WWR
WWR2	Window to Wall Ratio 36.3%	North	-15%	36.3%	36.3%
		South			
		East			
		West			
WWR3	Window to Wall Ratio 26.4% on S and 31.5% on N, E and W	North	-17%	34.9%	32.4%
		South	-40%	26.4%	
		East	-17%	34.9%	
		West	-17%	34.9%	
WWR4	Window to Wall Ratio 26.5% on N, E and W	North	-30%	26.5%	33.6%
		South	0%	42.6%	
		East	-30%	26.5%	
		West	-30%	26.5%	
WWR5	Window to Wall Ratio 20.0% on E and W	North	0%	42.6%	34.0%
		South	0%	42.6%	
		East	-50%	20.0%	
		West	-50%	20.0%	

4.9 Results of Fenestration Area Simulations

4.9.1 The results of the fenestration percentage simulations are below. For each option, the annual energy cost savings relative to the adjusted existing building is presented.

4.9.2 The WWR has a high impact on energy savings, with a potential for roughly 4% energy cost savings. While reducing the window sizes may not be desirable for various reasons, it is clear that there is a potential for high energy cost savings. The results also indicate that there is a high variance in energy savings between the four options with reduced WWR. If reducing the WWR to a Code-compliant level is required, the design should be optimized by varying the WWR between the facade orientations. This analysis indicates that the highest savings are achieved by limiting the south facing and west facing fenestration.

Annual Energy Cost Savings
Window to Wall Ratio



	WWR1	WWR2	WWR3	WWR4	WWR5
Total	-33 956 $	26 367 $	68 544 $	32 671 $	49 526 $
Natural Gas	-18 121 $	34 880 $	37 886 $	31 899 $	34 674 $
Electricity	-15 835 $	-8 513 $	30 658 $	772 $	14 852 $

4.10 Fenestration Shading

4.10.1 The existing building does not have any external shading on the office levels, besides the natural self shading of the building itself. The energy model does take into account self shading. As a potentially viable option, vertical fins were added to the west facade of the 10 Wellington building. In addition to improving the energy performance, vertical fins on the west facade will help to control low angle solar glare and direct solar radiation which are often problematic on west facades. The peak cooling load for the building, according to the energy simulation, occurs on September 1st, at 4:00 pm, when the sun is at a low angle.

Table 3-6: Fenestration Shading Options

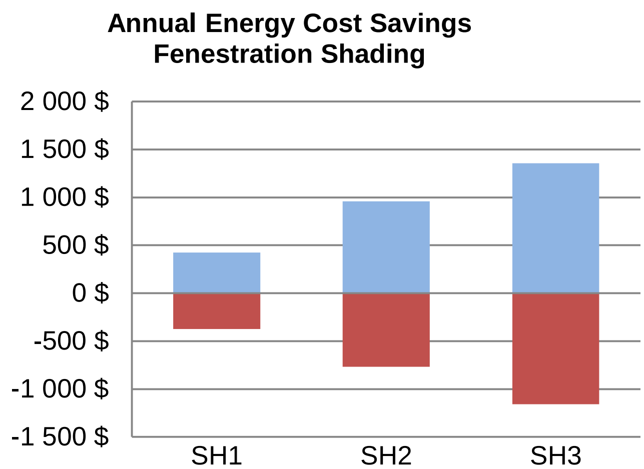
Type	Description
SH1	300 mm Fins on 10 Wellington West Facade All of the windows on the west facade were simulated with continuous vertical fins projecting 300 mm from the window face, and offset 150 mm horizontally from the window frame.
SH2	600 mm Fins on 10 Wellington West Facade All of the windows on the west facade were simulated with continuous vertical fins projecting 600 mm from the window face, and offset 150 mm horizontally from the window frame.
SH3	900 mm Fins on 10 Wellington West Facade All of the windows on the west facade were simulated with continuous vertical fins projecting 900 mm from the window face, and offset 150 mm horizontally from the window frame. Although this may not be practically feasible or aesthetically desirable, this simulation was run in order to understand the upper threshold of this measure.

4.11 Results of Fenestration Shading Simulations

4.11.1 The results of the fenestration shading simulations are below. For each option, the annual energy cost savings relative to the adjusted existing building is presented.

4.11.2 Nominal energy savings is achieved for each of the three options. This may be partly due to the fact that the existing fenestration has a low SHGC. For higher SHGC fenestration, the impact of shading will be higher.

4.11.3 The energy simulation does not take into account local thermal comfort effects. While it is recognized that direct solar radiation can be problematic at perimeter offices, and that this can be effectively mitigated with fenestration shading, it should also be considered that once this building is renovated to the Workplace 2.0 Fit-up Standards, locating enclosed offices at the perimeter will generally be avoided.



	SH1	SH2	SH3
Total	51 $	191 $	198 $
Natural Gas	-375 $	-769 $	-1 158 $
Electricity	426 $	960 $	1 356 $

5 Envelope Packages Simulated

Various combinations of the above options for wall assemblies, fenestration assemblies, and fenestration percentage were combined into envelope packages in order to evaluate the energy performance of each. It should be noted that the total savings of each option is not equal to the sum of the individual component savings. It should also be noted here that some of the envelope packages below may not be desirable or feasible, but are presented in order to understand their energy impact.

5.1 Options Simulated

5.1.1 Because there are two basic wall constructions under consideration, prefabricated wall panel and curtain wall, the envelope packages are presented in pairs. The two constructions are compared side-by-side with their representative wall insulation. The fenestration type and WWR are the same for each option.

Table 4-1: Option 1

Construction	Type	Component	Description	U-Value Btu/(h·F·ft^2)	SHGC
(Prefab Panels) PREFAB-1	W1	Wall	Prefab Wall Panel with 50mm Rigid Insulation	0.051	-
	G3	Fenestration	Low-e Double Glazing, Very Low SHGC	0.26	0.27
	WWR3	WWR	Window to Wall Ratio 26.4% on S and 31.5% on N, E and W	-	-
(Curtain Wall) CURTAIN-1	W4	Wall	Curtain Wall Spandrel Panel	0.140	-
	G3	Fenestration	Low-e Double Glazing, Very Low SHGC	0.26	0.27
	WWR3	WWR	Window to Wall Ratio 26.4% on S and 31.5% on N, E and W	-	-

Table 4-2: Option 2

Construction	Type	Component	Description	U-Value Btu/(h·F·ft^2)	SHGC
(Prefab Panels) PREFAB-2	W2	Wall	Prefab Wall Panel with 75mm Rigid Insulation	0.041	-
	G3	Fenestration	Low-e Double Glazing, Very Low SHGC	0.26	0.27
	WWR1	WWR	Window to Wall Ratio 47.4%	-	-
(Curtain Wall) CURTAIN-2	W4	Wall	Curtain Wall Spandrel Panel	0.140	-
	G3	Fenestration	Low-e Double Glazing, Very Low SHGC	0.26	0.27
	WWR1	WWR	Window to Wall Ratio 47.4%	-	-

Table 4-3: Option 3

Construction	Type	Component	Description	U-Value Btu/(h·F·ft^2)	SHGC
(Prefab Panels) PREFAB-3	W1	Wall	Prefab Wall Panel with 50mm Rigid Insulation	0.051	-
	G3	Fenestration	Low-e Double Glazing, Very Low SHGC	0.26	0.27
	WWR4	WWR	Window to Wall Ratio 26.5% on N, E and W	-	-
(Curtain Wall) CURTAIN-3	W4	Wall	Curtain Wall Spandrel Panel	0.140	-
	G3	Fenestration	Low-e Double Glazing, Very Low SHGC	0.26	0.27
	WWR4	WWR	Window to Wall Ratio 26.5% on N, E and W	-	-

Table 4-4: Option 4

Construction	Type	Component	Description	U-Value Btu/(h·F·ft^2)	SHGC
(Prefab Panels) PREFAB-4	W1	Wall	Prefab Wall Panel with 50mm Rigid Insulation	0.051	-
	G4	Fenestration	High Performance Low-e Double Glazing, Very Low SHGC	0.24	0.27
	WWR4	WWR	Window to Wall Ratio 26.5% on N, E and W	-	-
(Curtain Wall) CURTAIN-4	W4	Wall	Curtain Wall Spandrel Panel	0.140	-
	G4	Fenestration	High Performance Low-e Double Glazing, Very Low SHGC	0.24	0.27
	WWR4	WWR	Window to Wall Ratio 26.5% on N, E and W	-	-

Table 4-5: Option 5

Construction	Type	Component	Description	U-Value Btu/(h·F·ft^2)	SHGC
(Prefab Panels) PREFAB-5	W1	Wall	Prefab Wall Panel with 50mm Rigid Insulation	0.051	-
	G6	Fenestration	Low-e Triple Glazing, Very Low SHGC	0.18	0.27
	WWR4	WWR	Window to Wall Ratio 26.5% on N, E and W	-	-
(Curtain Wall) CURTAIN-5	W4	Wall	Curtain Wall Spandrel Panel	0.140	-
	G6	Fenestration	Low-e Triple Glazing, Very Low SHGC	0.18	0.27
	WWR4	WWR	Window to Wall Ratio 26.5% on N, E and W	-	-

5.2 Results of Envelope Package Simulations

5.2.1 The results of the envelope package simulations are below. For each option, the annual energy cost savings relative to the adjusted existing building is presented.

5.2.2 Option 2 represents the recommended option in GRC Architects' report. This option includes an increase in WWR above existing. All other options include a reduction in WWR to Code compliant levels. Options 1 to 4 have double pane fenestration, while Option 5 has triple pane fenestration. As can be observed, the highest performing option includes both a reduction in WWR and triple pane fenestration, and the lowest performing options include an increase in WWR.

5.2.3 It can also be observed, as indicated in the report by PTVD, that the higher the WWR, the less impact a lower U-Value of the wall will have. For a higher WWR, as in Option 2, the prefabricated panel wall construction provides less energy cost savings relative to the curtain wall construction.

5.2.4 The difference between the highest performing option (Prefab 5) and the option that is likely to be the most cost effective (Curtain 2) represents a difference in energy cost savings of roughly 9%, which is significant.

5.2.5 Among Options 1 to 4, the double pane fenestration options, the difference between the highest and lowest performing options (Prefab 3 and Curtain 2) represents a difference in energy cost savings of roughly 7%.

5.2.6 On average, the prefabricated wall panel construction results in an annual energy cost savings of approximately $90,000 higher than curtain wall construction. This difference varies, however.

5.2.7 The most energy efficient option, Prefab 5, provides roughly 16% energy cost savings, or roughly $237,000 annually.

Annual Energy Cost Savings
Envelope Packages

	Prefab 1	Curtain 1	Prefab 2	Curtain 2	Prefab 3	Curtain 3	Prefab 4	Curtain 4	Prefab 5	Curtain 5
Total	211 118	152 423	180 410	106 892	219 402	115 581	211 796	123 105	237 342	104 368
Natural Gas	143 963	79 342	118 392	66 041	143 033	77 488	146 145	83 190	162 482	95 097
Electricity	67 155	73 081	62 018	40 851	76 369	38 093	65 651	39 915	74 860	9 271

5.3 Results of Envelope Package Simulations (With Adjusted Window U-Values)

5.3.1 All of the windows in the project have been simulated according to the NFRC assembly U-Value. This U-Value often does not represent the actual installed window assembly U-Value. The NFRC U-Value is calculated based on a window size of 1200 x 1500 mm for fixed windows and 1000 x 2000 mm for curtain wall, but depending on the actual window size and the quantity of mullions, the actual U-Value could be lower or higher. This type of research is often not done for every project, but has been done for this project. Please refer to the report by PTVD, the building envelope consultants for this project, for detailed information.

5.3.2 To illustrate the magnitude of impact, each of the envelope packages was simulated a second time with the fenestration U-Values adjusted to a more realistic (Adjusted) assembly U-Value based upon the actual window configuration.

5.3.3 Note that the impact to the U-Value for the windows installed in the prefabricated panels is significantly higher than that in the curtain wall. This is due to a number of factors, which are described in the PTVD report.

Table 4-6: Fenestration Assemblies (Adjusted)

Type	Description	Wall Type	CoGU-Value Btu/(h·F·ft²)	(Adjusted) Assembly U-Value Btu/(h·F·ft²)	SHGC	VLT
G1	Low-e Double, High SHGC	Prefab Panel	0.26	0.39	0.65	0.77
		Curtain Wall		0.29		
G2	Low-e Double, Low SHGC	Prefab Panel	0.23	0.35	0.42	0.68
		Curtain Wall		0.26		
G3	Low-e Double, Very Low SHGC	Prefab Panel	0.23	0.35	0.27	0.55
		Curtain Wall		0.26		
G4	High Performance Low-e Double, Very Low SHGC	Prefab Panel	0.20	0.30	0.27	0.55
		Curtain Wall		0.23		
G5	Low-e Triple, High SHGC	Prefab Panel	0.19	0.29	0.58	0.70
		Curtain Wall		0.21		
G6	Low-e Triple, Very Low SHGC	Prefab Panel	0.14	0.21	0.27	0.55
		Curtain Wall		0.18		

5.3.4 The results of the adjusted envelope package simulations are below. For each option, the annual energy cost savings relative to the adjusted existing building is presented.

5.3.5 The same general trends can be observed with the adjusted fenestration U-Values as were previously seen with the non-adjusted fenestration U-Values.

5.3.6 Annual energy cost savings are slightly lower in all options.

5.3.7 The higher the WWR, the less impact a lower U-Value of the wall will have.

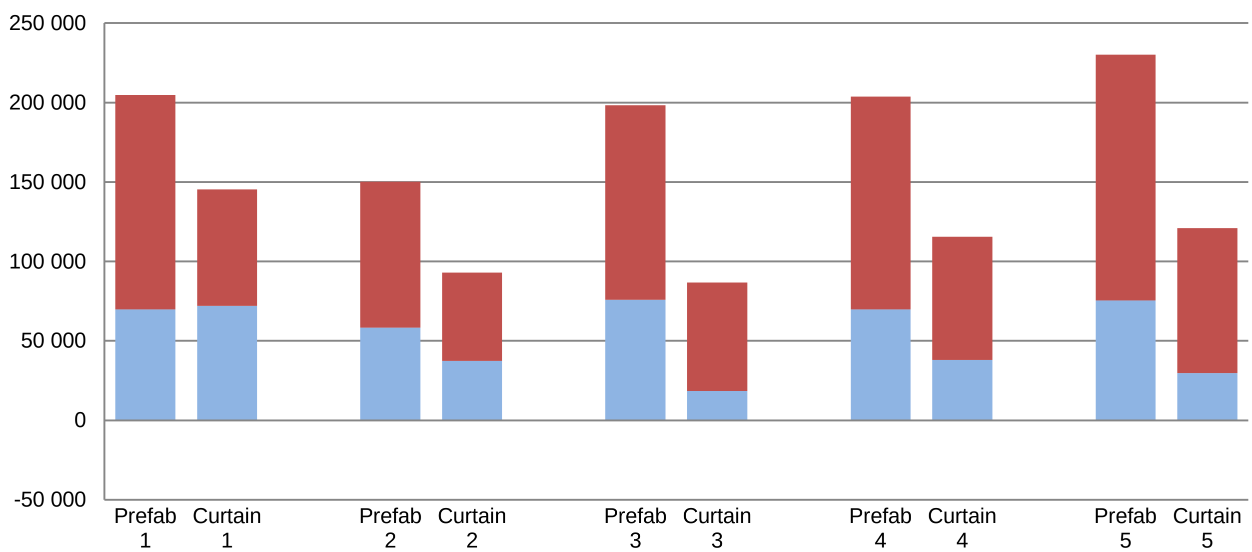
5.3.8 The difference between the highest performing option (Prefab 5) and the option that is likely to be the most cost effective (Curtain 2) represents a difference in energy cost savings of roughly 9%, which is significant.

5.3.9 Among Options 1 to 4, the double pane fenestration options, the difference between the highest and lowest performing options (Prefab 1 and Curtain 2) represents a difference in energy cost savings of roughly 7%.

5.3.10 On average, the prefabricated wall panel construction results in an annual energy cost savings of approximately $90,000 higher than curtain wall construction. This difference varies, however.

5.3.11 The most energy efficient option, Prefab 5, provides roughly 15% energy cost savings, or roughly $230,000 annually.

Annual Energy Cost Savings
Envelope Packages (Adjusted)



	Prefab 1	Curtain 1	Prefab 2	Curtain 2	Prefab 3	Curtain 3	Prefab 4	Curtain 4	Prefab 5	Curtain 5
Total	204 729	145 265	150 138	93 019	198 335	86 725	203 686	115 581	230 082	121 001
Natural Gas	134 828	73 302	91 825	55 528	122 460	68 240	133 860	77 488	154 619	91 249
Electricity	69 901	71 963	58 313	37 491	75 875	18 485	69 826	38 093	75 463	29 752

6 Conclusion

To assist in optimizing the energy performance of the envelope, multiple simulations were performed of wall construction and fenestration options. These options were first modelled in isolation, and then in combination.

The envelope options modelled in isolation include variations of wall insulation, the fenestration characteristics, the WWR on different facades, and solar shading.

The combined envelope options modeled fall under two primary wall system categories: prefabricated wall panel and curtain wall. The intent was to assist in determining which wall system has an overall lower life cycle cost.

These combined envelope options illustrate the energy performance of a variety of possible scenarios, not only to decide upon a wall system, but to help determine an appropriate window to wall ratio (WWR) for the building overall and for each facade. The two wall system categories (prefabricated panel and curtain wall) were modelled in parallel sets, with the same characteristics for the fenestration glass type and WWR per facade, so that the two systems can be easily compared for a variety of possible architectural design choices.

The results of the energy analysis indicate a clear ranking of priorities in order of potential to impact the annual energy cost. The envelope options are listed as follows in order from high to low priority.

.1 Fenestration SHGC;

.2 WWR overall and on each façade;

.3 Fenestration U-Value, including the framing configuration;

.4 Wall U-Value;

.5 Solar shading.

The results also show that the option with thehighest annual energy cost savings consists of prefabricated wall panel construction with triple pane fenestration having the following characteristics:

.1 Fenestration with an assembly U-Value ≤ 0.20 Btu/(h·F·ft2), SHGC ≤ 0.30;

.2 WWR not exceeding Code maximum of 36.3%. A lower WWR on south and west facades than on the north and east facades results in energy cost savings;

.3 Wall U-Value at Code minimum of ≤ 0.044 Btu/(h·F·ft2).

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Appendix E - Seismic Model

Canada

grc architects

LES TERRASSES DE LA CHAUDIERE
SEISMIC EVALUATION
GATINEAU, QUEBEC

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May 2016

Table of Contents

Appendices

APPENDIX A: **Precast Cladding Panel Anchorage Details**

1 EXECUTIVE SUMMARY

John G. Cooke & Associates Ltd. (JCAL) was contracted by GRC Architects Inc. to perform a seismic evaluation of the existing structural system of Les Terrasses de la Chaudière complex in Gatineau, Quebec. Each of the Blocks (100, 200 and 300) were analyzed separately using the ETABS analysis package by Computers and Structures Inc. The models were built, based on the original architectural and structural construction drawings.

The mandate of this report is to provide a detailed structural seismic analysis and assess the performance of the building's structural systems that establishes the adequacy of the overall structure to resist seismic loading under present conditions. The podium slab was reviewed for lateral deflection in relation with the adjacent blocks.

Block 100 is a 19 storey reinforced concrete structure with two levels of basement. Block 200 is a dual shear wall core construction; with half the building is 28 stories and the other half is 21 stories. Block 300 is a 7 storey reinforced concrete structure, with one level of basement. The podium slab is located between Blocks 200, 300 and the hotel, and is a concrete structure located at grade level.

Based on the performed seismic analysis and structural assessment, the existing block 100's, 200's and 300's structural system could sustain a seismic event up to 70%, 90%, and 100%, respectively, which suggests all the existing blocks could pass the 60% Public Works Seismic Policy.

Based on the performed dynamic analysis, the maximum displacement at roof level of the existing structure for block 100, 200 and 300 are 150 mm, 210 mm, and 60 mm, respectively. The overall displacement within the gap between block 200 and the podium is only 5 mm, much smaller than a 25mm expansion joint present between block 200 and the podium slab.

Although the precast cladding panel is not part of the lateral resisting system, the precast cladding panels would still have a potential to fall during an earthquake event, due to the limited displacement tolerance of the precast cladding panel anchorage system. Removing all the existing panels and replacing with a new wall system would be recommended. Alternatively, all the existing precast panel connections would need to be retrofitted. In addition, removing all the existing panels and replacing with a new lighter wall system would have a positive influence to the seismic response of the entire complex. Based on the additional seismic analysis of the structure with new lighter wall system, the total seismic load input would decrease 3%, 5%, and 3% for block 100, 200 and 300, respectively.

2 AVAILABLE INFORMATION

2.1 Drawings

The following drawings were made available to JCAL:

Les Terrassess de la Chaudiere Block 100 Architectural drawings – CAMPEAU CORPORATION. - 1976
Les Terrassess de la Chaudiere Block 200 Architectural drawings – CAMPEAU CORPORATION. - 1976
Les Terrassess de la Chaudiere Block 300 Architectural drawings – CAMPEAU CORPORATION. - 1976
Les Terrassess de la Chaudiere Block 400 Architectural drawings – CAMPEAU CORPORATION. - 1976
Les Terrassess de la Chaudiere Block 100 Structural drawings – CAMPEAU CORPORATION. - 1976
Les Terrassess de la Chaudiere Block 200 Structural drawings – CAMPEAU CORPORATION. - 1976
Les Terrassess de la Chaudiere Block 300 Structural drawings – CAMPEAU CORPORATION. - 1976
Les Terrassess de la Chaudiere Block 400 Structural drawings – CAMPEAU CORPORATION. - 1976
Precast panels shop drawings – BEER PRECAST CONCRETE LTD. - 1976

2.2 Previous Reports

The following previous seismic analysis reports were made available to JCAL:

'PWGSC LES TERRASSES DE LA CHAUDIERE Executive Summary Report – Tome 1 of Volume 1' prepared by DESSAU, May 2011

'PWGSC LES TERRASSES DE LA CHAUDIERE Seismic Assessment of Exterior Façade Anchorages Report – Tome 1 of Volume I' prepared by DESSAU, April 2012

3 INTRODUCTION

3.1 Building Description

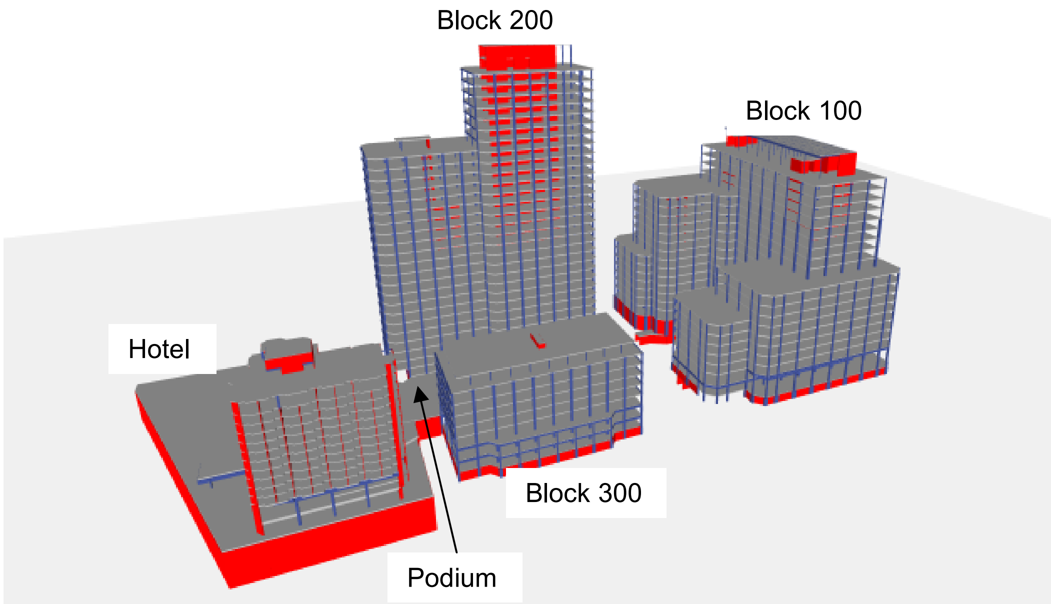

Fig.1 Overview

3.1.1 General

Les Terrasses de la Chaudiere (LTDLC) was built by the Campeau Corporation between 1976 and 1978. The complex was designed by Arcop Associates and is composed of three office towers located in downtown Gatineau, between Promenade du Portage, Eddy, Wellington and Montcalm streets. The west side the complex is bordered by the Crown Plaza Hotel, with an underground parking garage. The towers are 7, 19 and 28 stories high and are linked at their first and second levels by a retail concourse. The basement levels are connected by a tunnel system.

The total rentable area is 142,353 square meters, accommodating over 6,000 people, including retail and storage space. It is the single largest federal office complex in Canada, containing the administrative headquarters of Environment Canada, Aboriginal Affairs and Northern Development Canada, Canadian Heritage, the Canadian Radio and Telecommunications Commission and the Canadian Transportation Agency.

Within the complex, the outdoor areas around the buildings are used extensively by employees, as well as the general public. Uses include many paved walkways, seating areas, gardens and fountains, a play area attached to the daycare on the south side of block 200, and major bus stops on the south side of Block 100 for both STO and OC Transpo. Following the 2009 brick façade inspection, overhead protection was installed above the majority of the surrounding sidewalks. Also, the courtyard space between the buildings has been closed to public access.

3.1.2 Structure

3.1.2.1 Block 100

Block 100 is a 19 storey reinforced concrete structure, with two levels of basement. The building has two civic addresses: 15 Eddy Street and 25 Eddy Street. The ground floor of 15 and 25 Eddy are separate up to the fourth floor, except for a pedestrian bridge at the mezzanine level of 15 Eddy and ground floor level of 25 Eddy. Block 100 has four distinct shear wall cores. At the second floor level and below, the floor structure consists of concrete beams and slabs. Above the second floor, the floor structure is a two-way slab without beams. The 19 storey structure has numerous structural setbacks at the eighth, ninth, eleventh and sixteenth floors. There is no expansion joint separating 15 Eddy and 25 Eddy, therefore block 100 is to be considered as one building.

3.1.2.2 Block 200

Block 200 is dual shear wall core structure. Half of the building has 28 stories and half has 21 stories. Block 200 has one level of basement. A portion of the building protrudes to the north of the 28 storey section. That portion has 8 stories. At the second floor level and below, the floor structure comprises concrete beams and slabs. Above the second floor, the floor structure is a two-way slab without beams.

3.1.2.3 Block 300

Block 300 is a 7 storey reinforced concrete structure, with one level of basement. This building has a single shear wall core. At the second floor level and below, the floor structure consists of concrete beams and slabs. Above the second floor, the floor structure is a two-way slab without beams.

Block 300 is linked to Blocks 100 and 200 with pedestrian bridges and underground service tunnels. A 25mm wide expansion joint at the tunnel structurally separates the buildings.

3.1.2.4 Podium Slab

Between a portion of Blocks 200, 300 and the hotel, there is a podium slab, which is situated above the loading dock area of the complex. The podium is structurally separated from blocks 200, 300 and the hotel with a 25mm wide expansion joint. The podium is a reinforced concrete structure.

3.1.2.5 Hotel and Underground Parking

The hotel is a 13 storey reinforced concrete structure, with four levels of underground parking. The hotel has a shear wall core, with a series of concrete shear walls between the rooms. This structure was not included in the scope of the seismic analysis.

3.1.3 Cladding

3.1.3.1 Block 100, 200 and 300

For all the blocks, the typical construction of a wall, from interior to exterior, is a sheet of drywall, 100mm reinforced concrete back-up panel, 50mm insulation, 12mm void and precast brick panel façade or fenestration. The walls were erected in prefabricated panels, which included the concrete back-up, insulation, and brick façade or fenestration. The panels are attached to the structure at slab levels.

The brick façade is attached to the concrete back-up panels by shear ties, evenly spaced on a 400mm by 400mm grid. The mortar in between the bricks is very hard, more similar to concrete than a typical mortar, and likely having strength near 40 MPa.

The construction of the three blocks are each slightly different. In general, Block 100 is built with single brick-panels (one window per panel). Block 200 and 300 are built with double brick-panels (two windows per panel). About 5% of the panels of Block 100 consists of panels without windows. The windows are 2.35m wide and 2.60m high. Single brick-panels measure 3.80m wide and 3.70m high. Double brick-panels measure 7.60m wide and 3.70m high. Single brick-panels are constructed from approximately 625 bricks and double brick-panels from about 1250 bricks. A typical full brick measures 200mm long, 92mm wide and 57mm high and the joint width is typically 9.5mm.

Single brick-panels and double brick-panels are essentially constructed the same way. The bottom row of each panel is a course of rowlock (half brick on its side) with an horizontal reinforcing bar passing through. Above the window, the first row is a soldier course (full brick standing up) with an horizontal reinforcing bar passing through the center hole of the bricks. The remaining construction of the panel follows the standard running bond pattern, with vertical reinforcing bars at the edges of the panel and beside the window(s). There are also vertical rebars spaced within the panels.

The typical layout of an elevation from top to bottom is as follows: A panel with no window approximately 1.00m high at roof level, a series of single (or double) brick-panels, another panel with no windows approximately 0.60m high at the 2nd floor level and a brick masonry built pier between the 2nd floor and ground level. All panels are vertically separated by 12mm expansion joints (one expansion joint at every floor). For elevation sections without windows, there are two expansion joints per floor, evenly spaced. Generally, brick work between the 2nd floor and ground level is masonry, as opposed to precast brick panels.

Refer to Appendix A, for details showing the anchorage of the cladding to the building structure.

3.1.3.1 Hotel

The cladding system of the hotel is conventional brick masonry.

3.2 Scope of Work / Terms of Reference

John G. Cooke & Associates Ltd. (JCAL) was contracted by GRC Architects Inc. to carry out a seismic evaluation of Les Terrasses de la Chaudière complex in Gatineau, Quebec. The evaluation was completed by modeling the complex on ETABS, based on the information noted on the original architectural and structural construction drawings.

The hotel building is excluded from the seismic evaluation.

4 PROJECT OBJECTIVES AND METHODOLOGY

4.1 Objectives

The primary project objective is to determine the seismic performance of each of the three buildings (Blocks 100, 200 & 300) in relation to the 2015 National Building Code (NBC), under the existing conditions. The hotel is excluded from the analysis.

The secondary objective is to determine the seismic performance of the three buildings with the proposed new cladding system. The proposed new cladding system is lighter than the existing precast brick cladding, therefore reducing the seismic forces on the buildings. For the purpose of this report a glass curtain wall system was assumed for the new cladding system.

The third objective is to determine, in the event that the precast panels are contributing to the lateral seismic resistance of the building, if the anchorage of the panels is adequate to resist the imposed seismic forces.

4.2 Method of Analysis

An ETABS model of the entire complex, including hotel and underground parking garage was completed. This model is for the sole purpose of presentation. The buildings are separated with expansion joints at the underground tunnels and at the podium structure. ETABS is not intended to be used to analyze multiple independent structures within one model, therefore it is of no benefit to carry out an analysis this way.

Each of the Blocks (100, 200 and 300) were analyzed separately. The models were built, based on the original architectural and structural construction drawings. A detailed site investigation was not carried out to confirm the validity of the drawings.

The latest update for ETABS includes the 2010 National Building Code (NBC). The 2015 NBC has just been released. Hand calculations were performed to convert 2010 NBC values to those of the 2015 NBC, for modelling input purposes and analysis.

When LTDLC was constructed, detailing for shear wall ductility was not yet common practice and was not included in concrete construction standards. As such, we believe the manner in which the towers were designed and constructed, is most similar to "Conventional Construction", and so for each scenario, the modelling was carried out using Rd and Ro of 1.5 and 1.3 respectively.

4.3 Modelling Assumptions

When the building was constructed, the 1975 NBC had no sub-categories for the configuration or type of concrete shear walls. The lack of stringent steel reinforcing detailing suggests that the construction would be roughly equivalent to today's “Conventional” concrete shear wall construction.

The 2010 NBC did not permit use of ”conventional” construction for new structures, for towers at the height of LTDLC. The highest tower is 107 meters tall and the limit in the 2010 NBC was 40 meters, for new building constructed using shear walls in Ottawa. As a minimum, “moderately ductile” construction was required. Changes in the new 2015 NBC have re-introduced the use of “conventional” construction for buildings as tall as LTDLC.

A major benefit of moderately ductile versus conventional construction, is an increase in the Rd and Ro factors, which results in lower seismic forces. The factors are 1.5 and 1.3 respectively for conventional construction versus 2.0 and 1.4 for moderately ductile. This represents a force reduction of approximately 30%.

For towers with the height of LTDLC, the seismic analysis could not be limited to a static analysis. According to the 2010 NBC, a dynamic analysis would be required. A dynamic procedure is the default method in the 2015 NBC and is highly suggested for tall and complicated buildings, just like LTDLC.

In the absence of site specific geotechnical information, JCAL is proceeding assuming a Site Class of “A” to determine seismic values. This class appears to be justified, based on the founding of the building directly on rock. Rock in the area is typically found to be hard rock. JCAL is also setting the seismic base of the building at foundation level. This assumes that the contribution from surrounding soil pressure in resisting lateral loads is negligible.

Additional, design assumptions are as follows:

- The contribution of the concrete spandrel to the lateral stiffness is considered for block 100 and 200 but not considered for block 300, because diagonal rebars are only found on the drawings of block 100 and 200.
- Considering the shear cores have adequate flexural capacity, no stiffness reduction modifier is applied to all the concrete shear walls, according to the concrete code CSA A23.3-14. With this zero reduction modifier, a relatively more conservative result can be reached.
- A stiffness modifier of 0.6 is applied to all the columns according to the concrete code CSA A23.3-14.
- Stiffness of the basement retaining wall is released for the purpose of getting more accurate lateral capacity.

5 ANALYSIS OF EXISTING CONDITIONS

Underground parking/podium structures, tunnels, and pedestrian bridge links connect all the towers of the complex. Joints are noted to be present within the underground structures, separating them at the interface of the towers. Their presence was confirmed with a site investigation. According to the drawings, the reinforcing steel is discontinued at the joints. On site, fibreboard appeared to be present within the joints inspected.

We believe that due to the lack of continuous reinforcing steel across them, the joints act as seismic separations, dividing the base structure between the towers. This assumption will be validated as part of the seismic analysis, based on the lateral drifts of the structures. It should be noted that any non-compressible material may need to eventually be removed from these joints, to allow for free movement of the joint. A compression-only connection such as a solid butt joint with no reinforcing for tension would behave non-linearly, and may transmit forces unaccounted for in the analysis, such as those from pounding.

The analysis was performed considering the stiffness of the columns. Releasing the shear stiffness at the columns resulted in instability problems in the analysis software. Being considerably more flexible than the shear wall, the shear forces in the columns are very small and the columns can easily resist the forces.

When calculating the seismic resistance of the walls, the walls can either be considered as individual elements, or each core can be considered a wall group. The calculations were carried out with each core as a wall group, which is the realistic scenario. Back when the building was designed, each wall was likely considered as an individual element as there was no computer modelling at the time. Considering each core as a wall group provides a higher resistance than individual elements. This higher resistance offsets a certain amount of the seismic load increase between the 1975 NBC and 2015 NBC.

We found that many shear reinforcement in shear wall shown on the original drawings does not meet the minimum requirement of shear reinforcement ratio, which is stated in the current code.

We found some similar shear wall capacity behavior in block 100 & 200. The shear wall failure mode is mostly shear modes. Considering all the shear cores will act as wall groups while earthquake is occurring, so with these wall group behavior, the total moment of inertia would be very large, which indicates a significantly high flexural capacity. Whereas only 'web' walls will resist the shear forces generated from the earthquake. Ultimately most wall groups would have shear failure rather than a flexural failure; a brittle failure rather than a ductile failure.

As additional information that could be relevant when comparing the seismic performance of the towers with the previous report, the following changes between the previous NBC 2010 (and 2005) and the current NBC 2015 are of importance. These changes had an impact on the seismic analysis results.

- **Spectral Accelerations changed.**
  Seismic hazard values are changed based on the latest NBC 2015. The acceleration decreases significantly in the short period range, but increases on a minor scale in the long period range.

- **Site factors changed.**
  The previous Fa, Fv, values are removed, and a new F(T) value was used.

- **Higher Mode factor M_v changed.**
  This change applies to all the options with wall resisting systems. The higher mode factor remains the same for short period buildings, but significantly increased compared to the value in NBC 2010 for the long period buildings.

  For those long period buildings, as the fundamental acceleration decreased and on the other hand the higher mode factor increased, the final earthquake load input did not change so much.

Based on the NBC 2015, two methods can be used for the analysis for the earthquake actions. One is Equivalent Static Force Procedure (ESFP) and the other is Dynamic Analysis Procedure (DAP). The dynamic procedure would only be applicable with the technique of computer modeling. However the shear distributions between diaphragms obtained from these methods are quite different, especially for tall and irregular buildings. Also the NBC 2015 recommends the default method for earthquake analysis is the dynamic procedure. In addition, the commentary for NBC 2010 4.1.8.7(1) pointed out that the ESFP is accurate only in certain well defined circumstances, for example, when the structure is uniform along its height and has relatively short fundamental period.

LTDLC, block 100 and 200 are relatively tall, and not uniform along their heights We analyzed both methods. By looking into the ESFP distribution, it would apply a concentrated load at the top of the building and then use an upside down triangular distribution for the rest of the loads, which can turn out to be an approximate 3000 kN ($0.07T_aV$) concentrated load applied at the top of block 200 and cause a huge displacement. Obviously, this force distribution is not realistic. While in the DAP distribution, most of the load is applied to the lower level, and deflection is significantly smaller than the value obtained from the ESFP method. We believe the DAP method is the only suitable method for LTDLC, and this is the method that was used to calculate and report on the building's performance levels..

5.1 Block 100

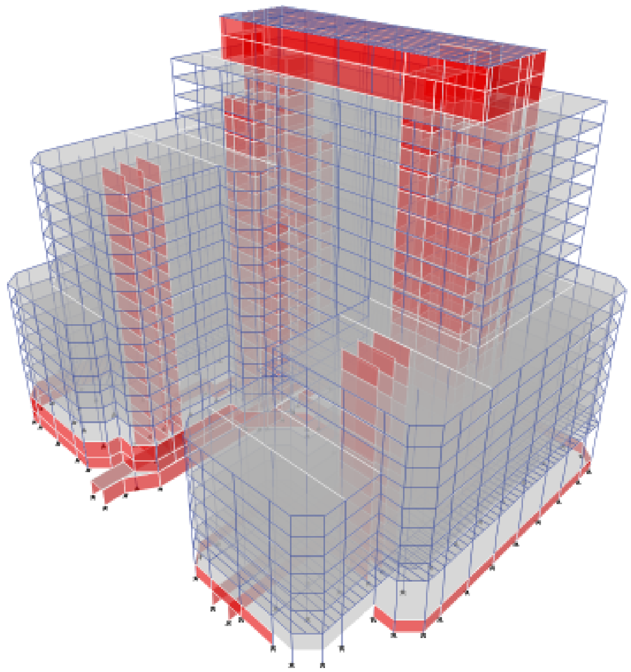

Fig.2 Block 100

Block 100 has four distinct cores. The preliminary calculation completed to date indicates that the two cores on the west side of the building are adequate to resist 100% of the seismic forces. However, the one wall in each of the two cores on the east side are not adequate. Their capacity is approximately 70% of the 2015 NBC. These inadequate walls all fail in shear resistance due to the lack of horizontal reinforcement. The most critical shear wall is the shear core located in the northeast corner. This core took more shear than any other shear wall because the center of mass is closest to this shear core. The two east cores are the main cores for the building. These cores have shear walls running north-south and east-west. The two west cores are secondary cores and only have shear walls running north-south.

During the preliminary analysis of block 100, we found the shear core barely takes any load at three basement levels, and the force distribution between the cores is unrealistic. The reason behind this is that the slab is acting as a rigid diaphragm and the foundation wall is relatively much stiffer than the shear cores, leading most of the earthquake load to the foundation wall instead of the shear core.

Since the foundation wall is not reinforced as shear walls, also considering in reality the floor slab would not be as rigid as a rigid diaphragm. We release the stiffness of the foundation perimeter walls, then all the earthquake would be taken by the shear cores.

5.2 Block 200

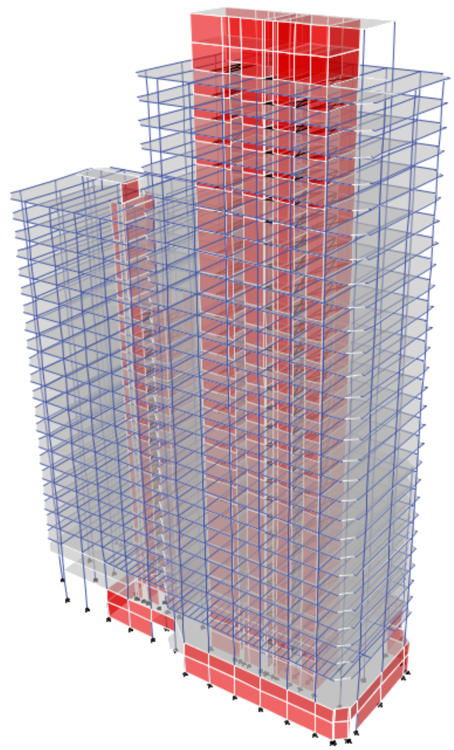

Fig.3 Block 200

Block 200 has two distinct cores. The east core is taller and is inadequate to resist the 100% of 2015 NBC seismic forces. The analysis indicates that the capacity of the east core is approximately 90% of the 2015 NBC. A major change in the 2015 NBC compared to the 2010 NBC, is the increase in the upper limit for higher mode factor from 1.2 to 1.7, which represents a 40% increase, however the fundamental earthquake acceleration decreased accordingly in the 2015 NBC compared to the 2010 NBC, ultimately the seismic force did not change significantly.

5.3 Block 300

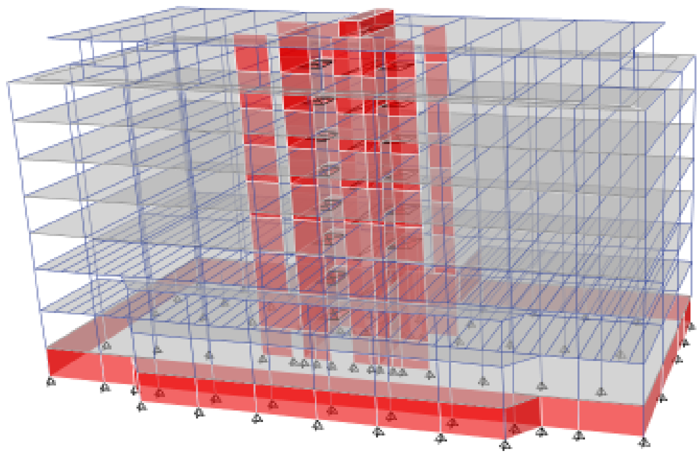

Fig.3 Block 300

Block 300 has one central core. The core is adequate to resist 100% of the 2015 NBC seismic forces.

5.4 Base Shear Comparison: Original Design and NBC 2015

The following is the base shear comparison between the original values (as noted on the structural drawings) and analyzed value based on the current NBC 2015.

The current seismic load increased differently in each block compared to the original design loads.

	Building height (m)	Historical Code Base shear (kN)	Current Code Base Shear (kN)
Block 100	87.1	$F_{x\,(E\text{-}W)}$ = 21333	$F_{x\,(E\text{-}W)}$ = 29200
		$F_{y\,(N\text{-}S)}$ = 26987	$F_{y\,(N\text{-}S)}$ = 32100
Block 200	123.5	$F_{x\,(E\text{-}W)}$ = 10178	$F_{x\,(E\text{-}W)}$ = 16200
		$F_{y\,(N\text{-}S)}$ = 8947	$F_{y\,(N\text{-}S)}$ = 13600
Block 300	35.5	$F_{x\,(E\text{-}W)}$ = 4196	$F_{x\,(E\text{-}W)}$ = 6400
		$F_{y\,(N\text{-}S)}$ = 4240	$F_{y\,(N\text{-}S)}$ = 8900

5.5 Lateral Displacement

All the deflection results from DAP are below the current code limitation. The maximum displacement of block 100 is 150 mm, block 200 has a maximum displacement of 210 mm, while the maximum displacement of block 300 is only 60 mm.

The overall displacement within the gap between block 200 and the podium is only 5 mm, much smaller than a 25mm expansion joint present between block 200 and the podium slab.

A site survey was performed to inspect the expansion joints shown on the drawings; there appears to be fiber boards in the gap between the podium and block 200. Removing the existing fiber boards would be recommended to create a movement free gap between block 200 and the podium to ensure the expansion joint would function as a seismic separation during an earthquake event.

6 ANALYSIS WITH PROPOSED NEW CLADDING

A proposed new cladding system for the complex is glass paneling. This cladding system would be significantly lighter than the existing precast and brick panels.

The analysis for each tower was redone replacing the existing precast/brick panels with a glass paneling system.

The approximate weight of a single window panel is between 36 kN and 44 kN (8,000 lbs and 10,000 lbs). The approximate weight of a glass panel of the same dimension would be approximately 14 kN (3,150 lbs.).

6.1 Block 100

On Block 100, the existing precast/brick cladding consists of 5% of the total weight of the building. The proposed cladding would reduce the weight of the building by 3%. This would reduce the seismic forces on the building by 3%. Therefore the seismic resistance would increase from 70% to 73%.

6.2 Block 200

On Block 200, the existing precast/brick cladding consists of 8% of the total weight of the building. The proposed cladding would reduce the weight of the building by 5%. This would reduce the seismic forces on the building by 5%. Therefore the seismic resistance would increase from 90% to 95%.

6.3 Block 300

On Block 300, the existing precast/brick cladding consists of 8% of the total weight of the building. The proposed cladding would reduce the weight of the building by 5%. This would reduce the seismic forces on the building by 3%. The seismic resistance of the building is already at 100% with the existing precast/brick cladding.

7 ANALYSIS OF PRECAST CLADDING PANELS

When LTDLC was constructed, the design intent was that the precast brick panels would be strictly a cladding system, and not part of the lateral resisting system of the buildings.

7.1 PRECAST CLADDING PANEL ANCHORAGE DESCRIPTION

The precast brick panels on block 100 are single-window panels. On blocks 200 and 300, the panels are double-window panels. The description below is based on the original shop drawings. Shop drawings for blocks 100 and 200 were found; no information was found for block 300, but was assumed to be similar to block 200. See Appendix A for precast cladding panel anchorage details.

Typical: Single-Window Panel (SWP)

The typical single-window panel anchorage is as follows:

- One gravity connection (for panel self-weight) is provided at the top centre of the panel, see sketches S-01 and SWP1.
- Two lateral connections (for wind and seismic) are provided at the top corners of the panel, see sketches S-01 and SWP2. These lateral connections also restrain the bottom corners of the panel above using dowels.

Typical: Double-Window Panel (DWP)

There are two distinct types of typical double-window panel anchorage. The anchorage of the panels on the north and south elevations of block 200 is different from the anchorage of the panels on the east and west elevations of the building. The difference is due to the location of the building columns. On the north and south elevations, the columns are located at the middle of the panels. On the east and west elevations, the columns are located at the joint between two panels.

Typical: Double-Window Panel (DWP) Type 1

The typical double-window panel anchorage on the north and south elevations (typical double-window panel Type 1) is as follows:

- Two gravity connections are provided at the top of the panel, as shown on sketches S-01 and DWP1. These connections are roughly lined up with the middle of the windows.
- Two laterals connections are provided at the top corners of the panel, as shown on sketches S-01 and DWP2. These lateral connections also restrain the bottom corners of the panel above using a dowel.
- At the top centre of the panel, a dowel is provided to laterally restrain the bottom centre of the panel above. This dowel is not secured back to the building. See sketches S-01 and DWP3.

Typical: Double-Window Panel (DWP) Type 2

The typical double-window panel anchorage on the east and west elevations (typical double-window panel Type 2) is as follows:

- Two gravity connections are provided at the top of the panel. These connections are roughly lined up with the middle of the windows. See sketches S-01 and DWP1.
- One lateral connection is provided at the top centre of the panel. This lateral connection also restrains the bottom centre of the panel above using a dowel. See sketches S-01 and DWP2.
- At the top corners of the panel, dowels are provided to laterally restrain the bottom corners of the panel above. These dowels are not secured back to the building. See sketches S-01 and DWP3.

A typical panel was removed on Block 100. The anchoring of this panel was essentially as detailed on sketches SWP1 and SWP2. The removal of the panel revealed that the L90x90x10 angle shown on SWP2 was notched and the 65x65x6.4 plate was welded on site after the bottom panel was in place. The hole in the plate is snug around the dowel, basically eliminating any play with the connection.

7.2 ANALYSIS

In 2011 JCAL carried out an analysis of the precast cladding panel anchorage. For the purpose of this report, an update of this analysis for the 2015 NBC was carried out. The following was noted:

- The lateral connections for the single-window panels are adequate to resist the wind and seismic forces from the 2015 NBC. The lateral connector has spare capacity of 30 kN per panel.
- The lateral connections for the double-window panels type 1 and 2 are inadequate to resist wind and seismic forces, without using the lateral resistance of the of the gravity anchors.

The analysis above ignores any effect of lateral interstorey drift, which would increase the loading on the anchorage. The magnitude of lateral interstorey drift which can occur before the precast panels are engaged, cannot be accurately determined. The bottom connection of the precast panel is doweled from the top of the panel below. As noted above, the dowel fits snug in a plate welded to an angle, which is welded to another angle cast into the building structure (see sketch SWP2). The clearance around the dowel is almost nil at the plate, which is restricting the rotation of the dowel. Therefore the lateral displacement that can occur before panels are engaged is very limited.

For single-window panels, the spare capacity is only 30 kN. The stiffness contribution of a panel would result in lateral loads exceeding 30 kN, and would cause failure of the connections.

For double-window panels, the lateral connections are already inadequate on their own and must rely on the lateral resistance of the gravity connectors, to resist the seismic forces without the additional loading from interstorey drifting. Therefore, the lateral connectors are inadequate to resist any additional seismic loads from lateral interstorey drifting.

Based on the above, the anchorage of the precast cladding panel would be inadequate to resist any additional seismic forces from the building, which would be in addition to the seismic loads generated by the self-weight of the panels.

Retrofitting of the existing anchors at all precast panels would be required. The retrofitting would consist of replacing the existing anchoring system with a new system that would not engage the panels.

8 CONCLUSION

The current conditions of the Les Terrasses de la Chaudiere blocks 100, 200 and 300 are believed to have sufficient capacity to resist 60% of the earthquake load based on the NBC 2015. However, block 100 and 200 are believed to pose a risk to occupants in the event of an important seismic event, since their seismic resistance is less than 100% seismic load based on the NBC 2015.

The existing precast cladding panel is another major source of the risks. The precast cladding panels would still have the potential to fall from the building during an earthquake event, due to the limited displacement tolerance of the precast cladding panel anchorage system. Removing all the existing panels and replacing with new wall system would be recommended. Alternatively, all the existing precast panel connections would need to be retrofitted.

Going forward, it is the recommendation of this report that the assumptions made during the design analysis be verified on site. For example, a thorough geotechnical report to confirm the site class for the complex, localized scanning of the shearwalls/slabs to confirm actually constructed vs original drawing accuracy.

9 DISCLAIMER AND LIMITATIONS

This report is based on and limited to our knowledge of this building complex, gained from our experience with various projects there over the past 15 years, and by the review of the original architectural and structural construction drawings. Only those items that are capable of being observed and are reasonably obvious to John G. Cooke & Associates Ltd. or have been identified by other parties and detailed during this investigation can be reported.

The work reflects the Consultant's best judgment in light of the information reviewed by them at the time of preparation. There is no warranty expressed or implied by John G. Cooke & Associates Ltd. that this investigation will uncover all potential deficiencies and risks of liabilities associated with the subject property. John G. Cooke & Associates Ltd. believes, however, that the level of detail carried out in this investigation is appropriate to meet the objectives as outlined in the Terms of Reference. We cannot guarantee the completeness or accuracy of information supplied by any third party.

John G. Cooke & Associates Ltd. is not investigating or providing advice about pollutants, contaminants or hazardous materials.

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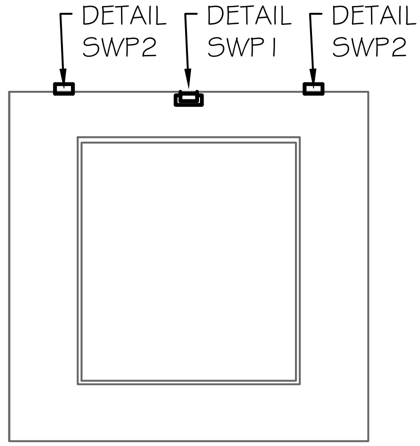
We trust that this report covers the scope of work as outlined in our Terms of Reference. Should there be any questions regarding this report, or if we can be of any further assistance to you, please contact the undersigned.

JOHN G. COOKE & ASSOCIATES LTD.

Marty Lockman, P. Eng, ing

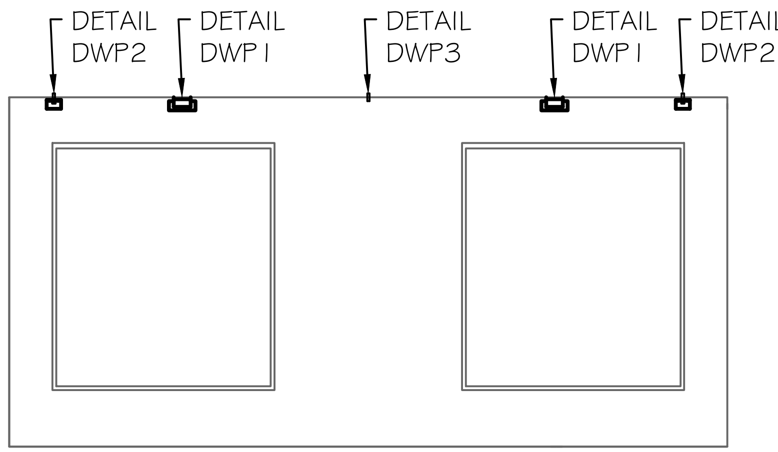
APPENDIX A: Precast Cladding Panel Anchorage Details

TYPICAL SINGLE-WINDOW PANEL



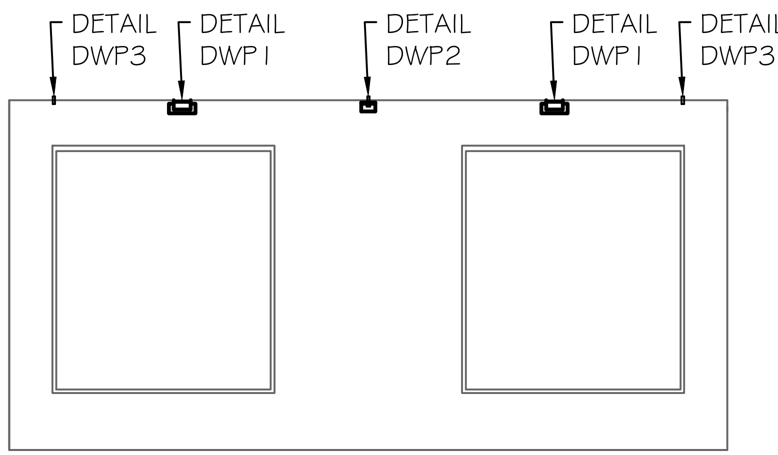
TYPICAL DOUBLE-WINDOW PANEL
TYPE 1

TYPICAL PANEL FOR NORTH AND SOUTH ELEVATIONS OF 10 WELLINGTON



TYPICAL DOUBLE-WINDOW PANEL
TYPE 2

TYPICAL PANEL FOR EAST AND WEST ELEVATIONS OF 10 WELLINGTON



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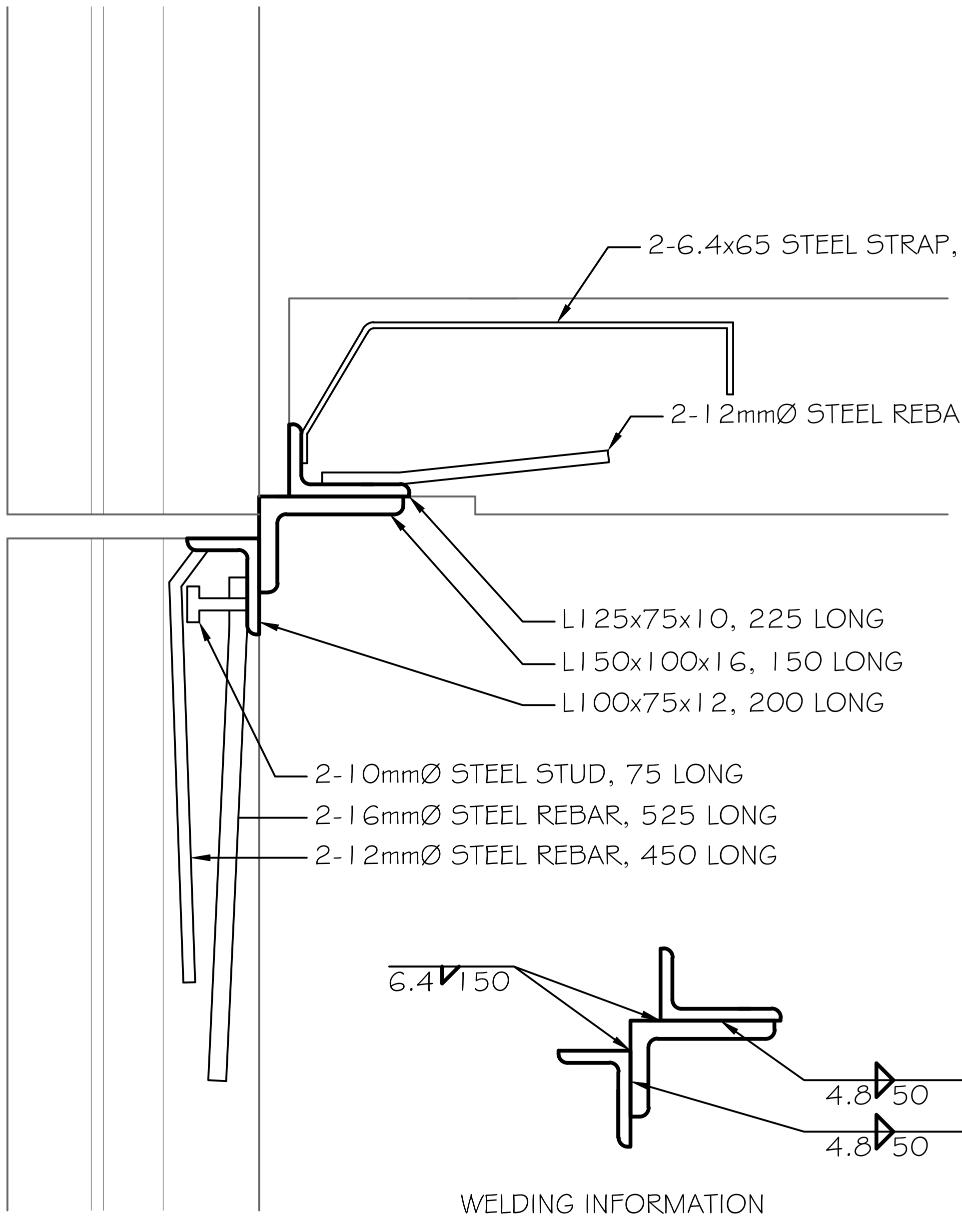
Project: LTDLC SEISMIC EVALUATION

Client: GRC ARCHITECTS INC.

Drawing: TYPICAL PANEL REFERENCE DRAWING

drawn	scale	date	project no.	dwg. no.
M.L.	N.T.S.	11-MAY-2016	15120	S-01



WELDING INFORMATION

THE ABOVE SKETCH IS BASED ON THE INFORMATION SHOWN ON THE ORIGINAL CONSTRUCTION SHOP DRAWINGS AND THE SITE INVESTIGATION. THE CAST-IN AND HIDDEN ELEMENTS SUCH AS STUDS, STEEL REBARS, PINS AND WELDS COULD NOT BE CONFIRMED ON SITE.

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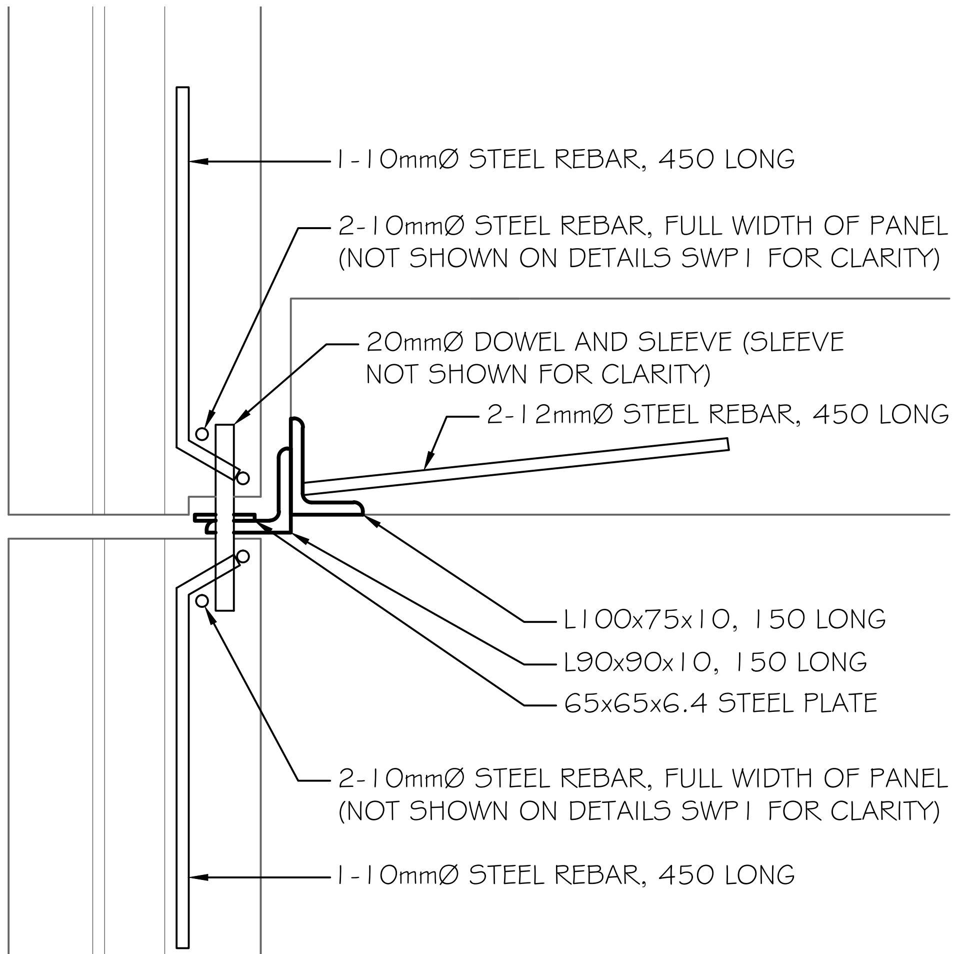
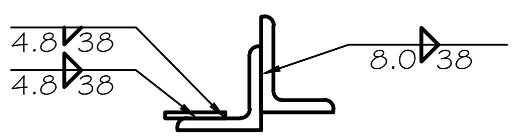
Project	LTDLC SEISMIC EVALUATION
Client	GRC ARCHITECTS INC.
Drawing	DETAIL SWP1
dwg. no.	SWP1
drawn	M.L.
scale	N.T.S.
date	11-MAY-2016
project no.	15120





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Project	LTDLC SEISMIC EVALUATION
Client	GRC ARCHITECTS INC.
Drawing	DETAIL SWP2
dwg. no.	SWP2

drawn	scale	date	project no.
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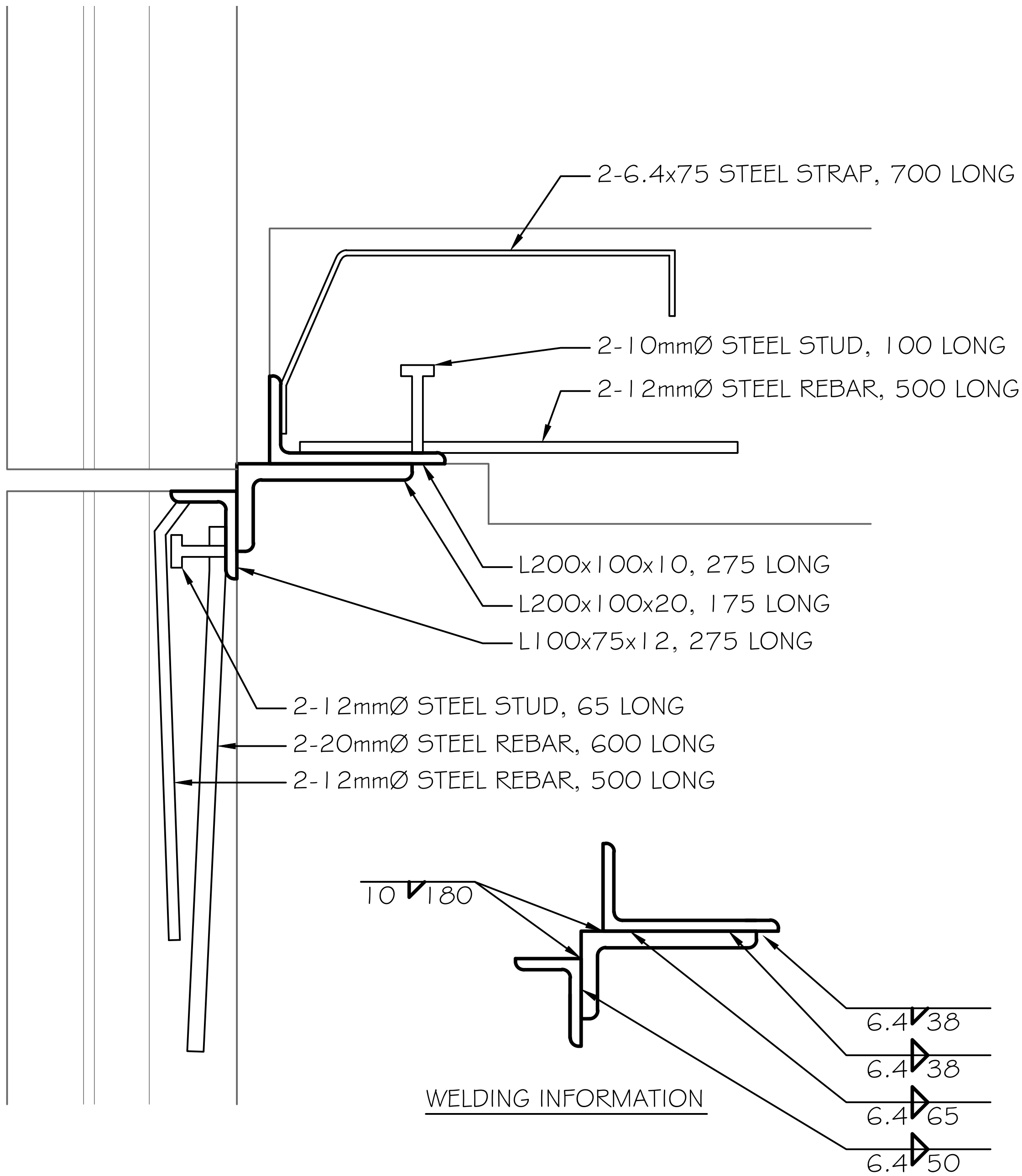

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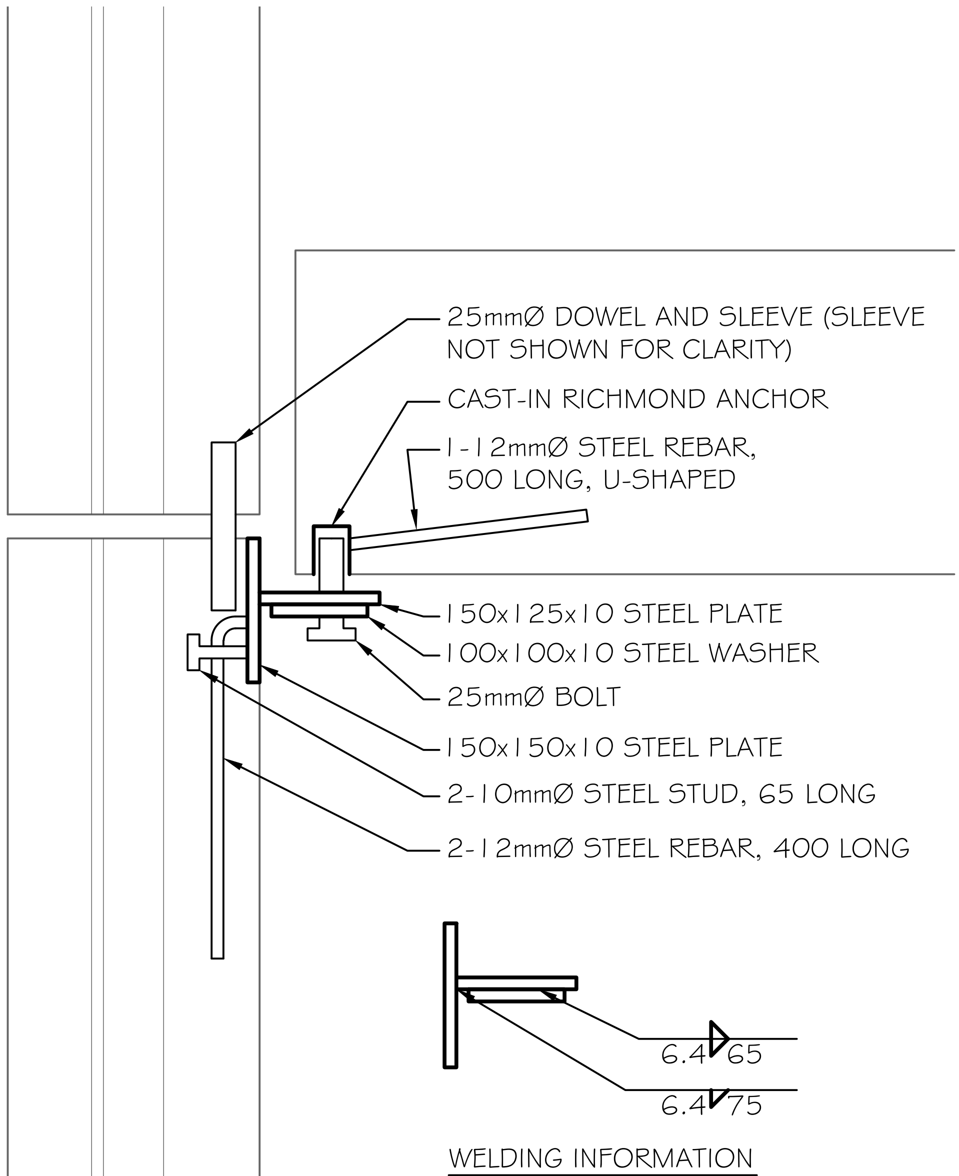
Project	LTDLC SEISMIC EVALUATION
Client	GRC ARCHITECTS INC.
Drawing	DETAIL DWP1
dwg. no.	DWP1

drawn	scale	date	project no.
M.L.	N.T.S.	11-MAY-2016	15120



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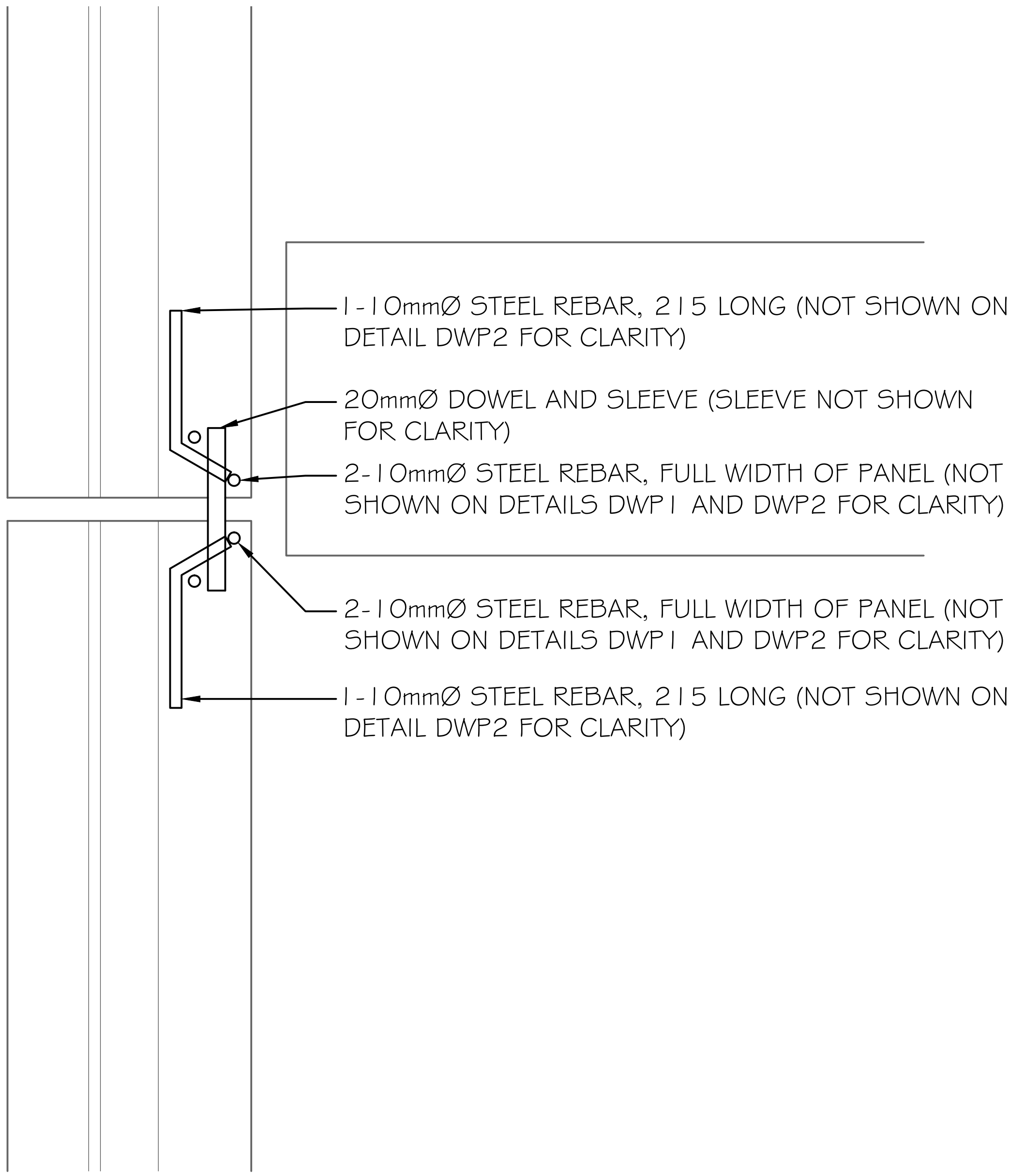
Project	LTDLC SEISMIC EVALUATION
Client	GRC ARCHITECTS INC.
Drawing	DETAIL DWP2
dwg. no.	DWP2

drawn	scale	date	project no.
M.L.	N.T.S.	11-MAY-2016	15120



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Project: LTDLC SEISMIC EVALUATION

Client: GRC ARCHITECTS INC.

Drawing: DETAIL DWP3

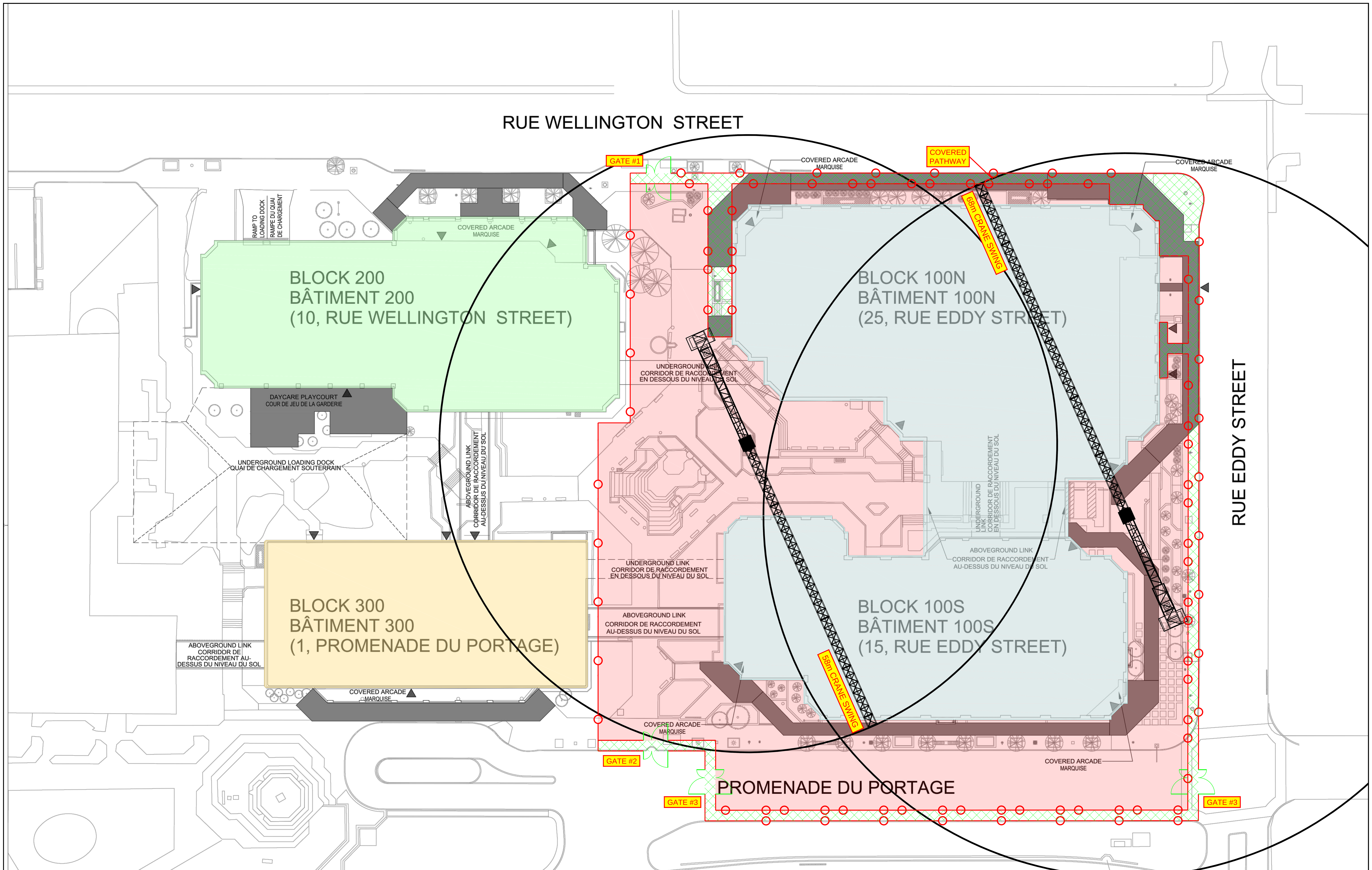
dwg. no. DWP3

drawn	scale	date	project no.
M.L.	N.T.S.	11-MAY-2016	15120

Appendix F - Crane Layout and Phasing Concept

PHASE 1 - BLOCK 300
(1 PROMENADE DU PORTAGE)

PHASE 2 - BLOCK 200
(10 RUE WELLINGTON)



PHASE 3 - BLOCK 100N & BLOCK 100S
(25 RUE EDDY & 15 RUE EDDY)

Appendix G - Construction Schedule

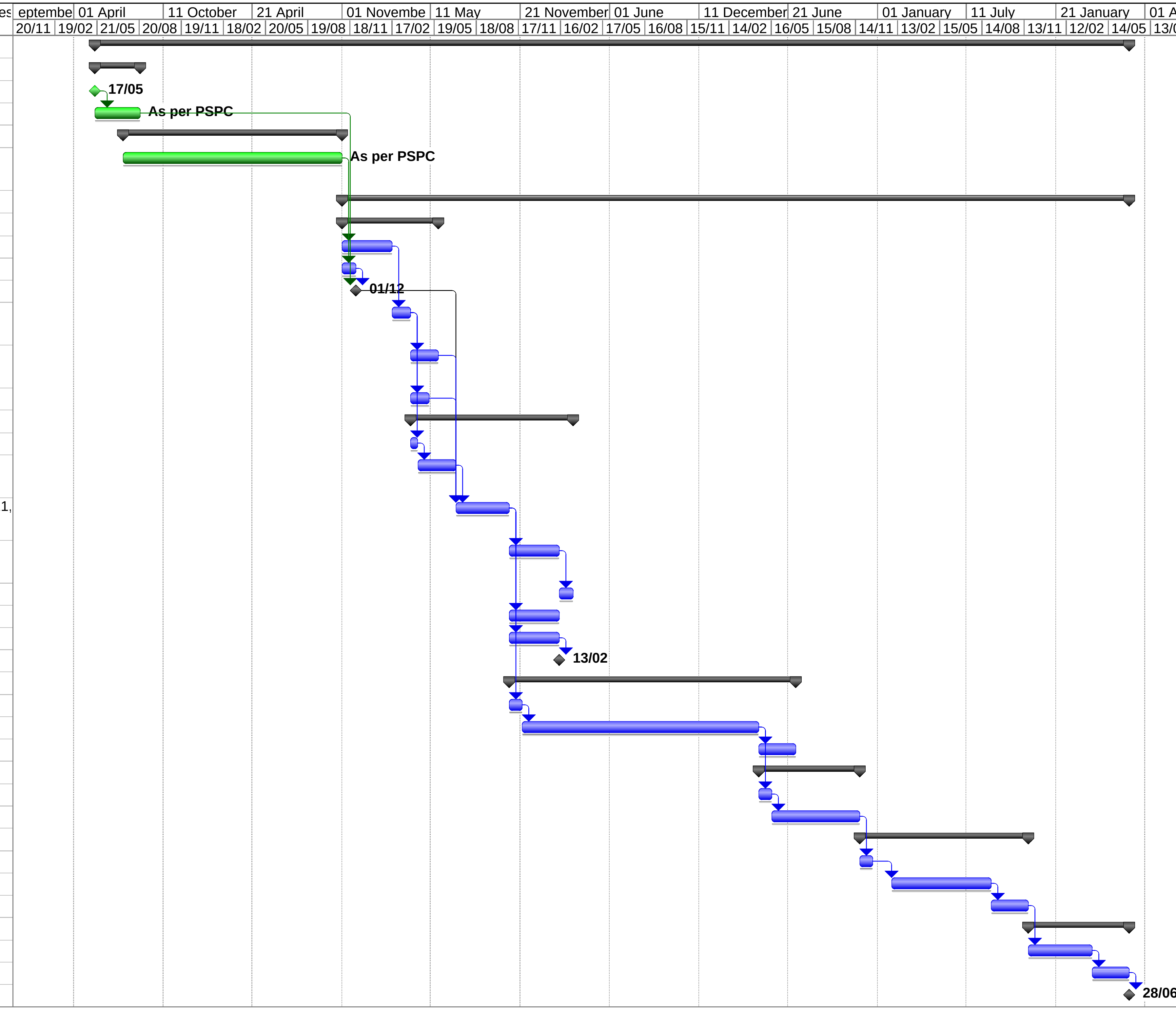
Canada

grc architects

LTDLC Envelope Rehabilitation
Concept Construction Schedule

May 19, 2016

ID	Task Name	Duration	Start	Finish	Predeces
1	**LTDLC IMPLEMENTATION PHASE**	**1596 days?**	**Wed 17/05/17**	**Wed 28/06/23**	
2	**Construction Documents Phase**	**70 days**	**Wed 17/05/17**	**Tue 22/08/17**	
3	PSPC Implementation Start-Up	0 days	Wed 17/05/17	Wed 17/05/17	
4	Envelope Construction Documents	70 days	Wed 17/05/17	Tue 22/08/17	3
5	**Procure Construction Management Services**	**339 days?**	**Mon 17/07/17**	**Thu 01/11/18**	
6	Procure Construction Management Services	339 days?	Mon 17/07/17	Thu 01/11/18	
7	**Construction Administration Process**	**1400 days**	**Fri 02/11/18**	**Wed 28/06/23**	
8	**Preparatory Work**	**148 days**	**Fri 02/11/18**	**Tue 28/05/19**	
9	Site Demolition and Staging Areas	60 days	Fri 02/11/18	Sun 17/02/19	6
10	Fabricate and Install Mock-ups	30 days	Fri 02/11/18	Sat 01/12/18	6
11	Factory Fabrication Begins	0 days	Sat 01/12/18	Sat 01/12/18	10,4
12	Site Hoarding and Protection Construction	40 days	Mon 18/02/19	Fri 29/03/19	9
13	Relocation of Services and Bridge Removals	60 days	Sat 30/03/19	Tue 28/05/19	12
14	Crane Erection	40 days	Sat 30/03/19	Wed 08/05/19	12
15	**Centre Building Envelope**	**288 days**	**Sat 30/03/19**	**Sat 14/03/20**	
16	Move all occupants to swing space	15 days	Sat 30/03/19	Sat 13/04/19	12
17	Interior protection and demolition incl. sensitive equipment	60 days	Mon 15/04/19	Fri 05/07/19	16
18	Envelope Replacement incl. Ground Floor Glazing	100 days	Sat 06/07/19	Mon 28/10/19	13,17,11,
19	Centre Building Occupied Penthouse Exterior Rehabilitation	60 days	Tue 29/10/19	Thu 13/02/20	18
20	Roofing	30 days	Fri 14/02/20	Sat 14/03/20	19
21	Exterior Detailing & Trim	60 days	Tue 29/10/19	Thu 13/02/20	18
22	Interior Remediation & Clean-Up	60 days	Tue 29/10/19	Thu 13/02/20	18
23	Occupants Return	0 days	Thu 13/02/20	Thu 13/02/20	22
24	**10 Wellington Envelope**	**508 days**	**Tue 29/10/19**	**Thu 08/07/21**	
25	Crane Relocation	20 days	Tue 29/10/19	Mon 25/11/19	18
26	Phased Envelope Replacement	400 days	Tue 26/11/19	Mon 19/04/21	25
27	Roofing & Penthouse Surround	80 days	Tue 20/04/21	Thu 08/07/21	26
28	**15 Eddy Envelope**	**203 days**	**Tue 20/04/21**	**Tue 23/11/21**	
29	Crane Relocation	20 days	Tue 20/04/21	Mon 17/05/21	26
30	Phased Envelope Replacement	175 days	Tue 18/05/21	Tue 23/11/21	29
31	**25 Eddy Envelope**	**301 days**	**Wed 24/11/21**	**Tue 22/11/22**	
32	Crane Relocation	20 days	Wed 24/11/21	Tue 21/12/21	30
33	Phased Envelope Replacement	200 days	Tue 01/02/22	Sat 03/09/22	32
34	Roofing & Penthouse Surround	80 days	Sun 04/09/22	Tue 22/11/22	33
35	**Site Remediation**	**156 days**	**Wed 23/11/22**	**Wed 28/06/23**	
36	Replace Pedestrian Bridges	90 days	Wed 23/11/22	Sun 09/04/23	34
37	Landscaping & Remediation	80 days	Mon 10/04/23	Wed 28/06/23	36
38	Construction Completion	0 days	Wed 28/06/23	Wed 28/06/23	37



Project: LDTLC Concept Schedule_R2
Date: Thu 19/05/16

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			