NON-TECHNICAL SUMMARY

RWDI was retained to conduct simulations of the illuminance levels in the planned greenspace north of the Pier 27 Towers A & F (“Proposed Project”) to understand how light from the sky and reflected light from adjacent buildings may brighten the shadow cast by the Proposed Project.

RWDI conducted illuminance simulations at a single time and date when the shadow has been predicted to fall on the greenspace. These simulations were conducted at an accuracy level above typical industry best practices. Further details can be found in the *Methodology* and *Assumptions and Limitations* sections of this report.

When only direct sunlight was accounted for in the analysis, the shadowed region (approximately 30% of the total area) was predicted to have no illumination at all (i.e. 0 lux).

Once skylight was included, the shadowed region was substantially brightened. **The average illuminance in the shadowed region was predicted to be 22% of the average illuminance in the unshadowed region.** This highlights the importance of including skylight when investigating outdoor illuminance.

Surfaces reflect light in two ways. *Specular* reflectors (e.g. glass, polished metals) reflect light in a ‘mirror-like’ fashion. That is to say, the majority of the reflected light travels in the same direction.

This is in contrast to *diffuse* reflectors (e.g. drywall, or other matte finish surfaces) which scatter reflected light in all directions. Specular reflections often appear ‘brighter’ because of their directional nature even though they may reflect less light in total. For example white concrete reflects 70%-80% of incoming light, while most common glazing units are only 20%-30% reflective. The difference is that the reflections from concrete are highly diffuse and thus the light is scattered, whereas reflections from glass are highly specular so the glazing can project clear reflections further away which can be visually more impactful to an observer.

Industry standard practice is to model buildings outdoors as uniformly diffuse reflectors. They are simpler to represent in simulations and in the context of Toronto, is a conservative assumption.

Various diffuse reflectivity values (10%-30%) were tested to understand the sensitively of the results to the surrounds. **Accounting for diffuse reflections increased the average illuminance in the unshadowed area to 23%-26% of ambient illuminance.**

Assigning the specular reflectivity properties of a common glazing unit to the park facing facades of surrounding buildings increased the average shadowed illuminance to 34% of ambient.

REPORT

PIER 27

SHADOW ILLUMINANCE ANALYSIS

PROJECT #2004693

SUBMITTED TO

Pier 27 Toronto (Northeast) Inc.

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EXECUTIVE SUMMARY

RWDI was retained by Pier 27 Toronto (Northeast) Inc. to investigate the impact of diffuse sky light and light reflected from surrounding buildings on the illuminance in a greenspace shadowed by the proposed Pier 27 tower.

A single 'worst-case' date and time was studied to understand the effects of other sources of light across the greenspace. Lighting simulations were conducted comparing the illuminance in the park with and without the influence of diffuse and reflected light.

When only direct sunlight was accounted for in the analysis, the shadowed region (approximately 30% of the total area) was predicted to have no illumination at all (i.e. 0 lux).

When light from the sun and sky were considered (i.e. no reflected light) the average illuminance in the shadowed area was predicted to be over 16,000 lux (for reference, a typical interior office lighting target is 300 lux). This is approximately 22% as bright as the prediction of the unshadowed area and highlights the importance of diffuse sky light went discussing the impacts of shadowing on illuminance.

When generic diffuse reflectivity properties were applied to the surrounding buildings as well, the predicted average illuminance in the shadowed region increased to 23%-26% of the unshadowed region. The simulations also predicted a distinct pattern of brighter conditions on the north side of the greenspace, due to its closer proximity to the towers to the north.

The park facing facades of surrounding buildings were then assigned reflectivity properties consistent with a commonly used insulated glazing unit. The specular reflectivity resulted in a further increase in the predicted average illuminance in the shadowed area to 34% of the unshadowed region.

Overall, it is clear from the simulations that while the Proposed Project will create shadows on the planned greenspace, the park's openness to the sky and proximity to highly reflective buildings result in a significant amount of light that can still reach the shadowed area.

INTRODUCTION

RWDI was retained by Pier 27 Toronto (Northeast) Inc. to investigate the effects of shadows cast by the proposed Pier 27 tower (Proposed Project) on a nearby greenspace.

Specifically, the intent of this analysis to provide predictions of the illuminance levels within the greenspace to contextualize the shadowing as it pertains to the level of 'brightness' a patron would experience.

Illuminance is the technical term for the quantity of light falling onto a surface. It is measured in unit of *lux.* For context, 300 lux is a common target for indoor illuminance levels in offices. On a sunny day illuminance values approaching 100,000 lux are not uncommon.

This report summarizes RWDI's methodology and findings of this analysis.

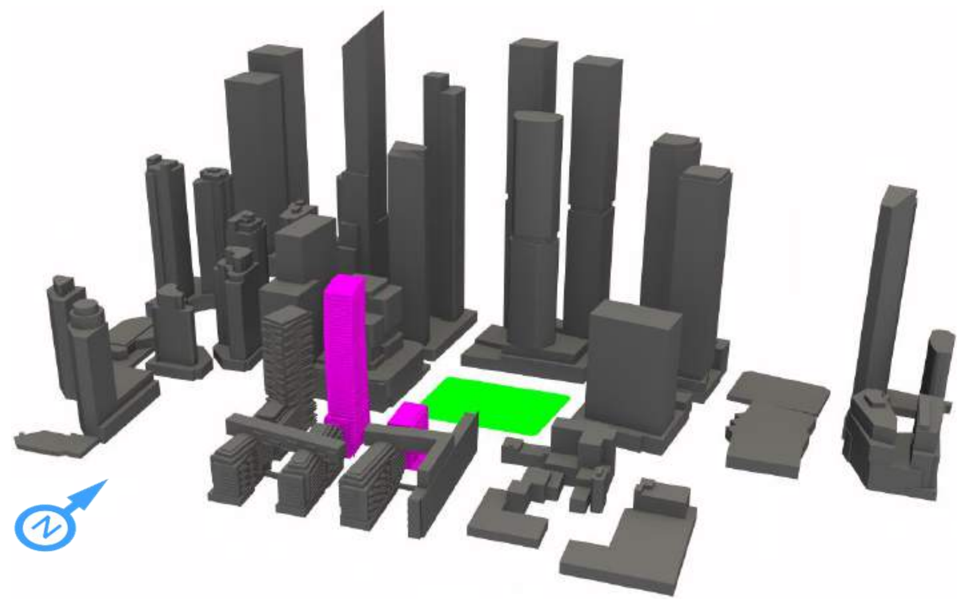


Figure 1: Rendering of 3D Model Used In This Study

Outdoor Illuminance and Shadows

When one is outdoors there are two primary sources of light:

Direct Illuminance (i.e. light rays which have travelled in a straight line from the sun to the viewer); and

Diffuse Illuminance (i.e. light which emanates from the entire sky dome due to sunlight being scattered in the atmosphere).

In urban environments there is also a third source of light which can play an important role in the overall brightness of a location: **Reflected Illuminance**. This is light which has reflected from surrounding buildings to the observer's location. Reflected light can occur due to specular reflections (e.g. from glass or polished metal) or diffuse reflections (e.g. light-colored concrete). Figure 2 presents a schematic of these sources of light.

The primary effect of a building on outdoor daylight access occurs when it obstructs the sun. This eliminates the direct illuminance which provides the bulk of the total illuminance. However, depending on sky conditions and surrounding buildings, the other components can still provide a significant amount of illuminance in a shadowed area which is typically not acknowledged in shadow studies.

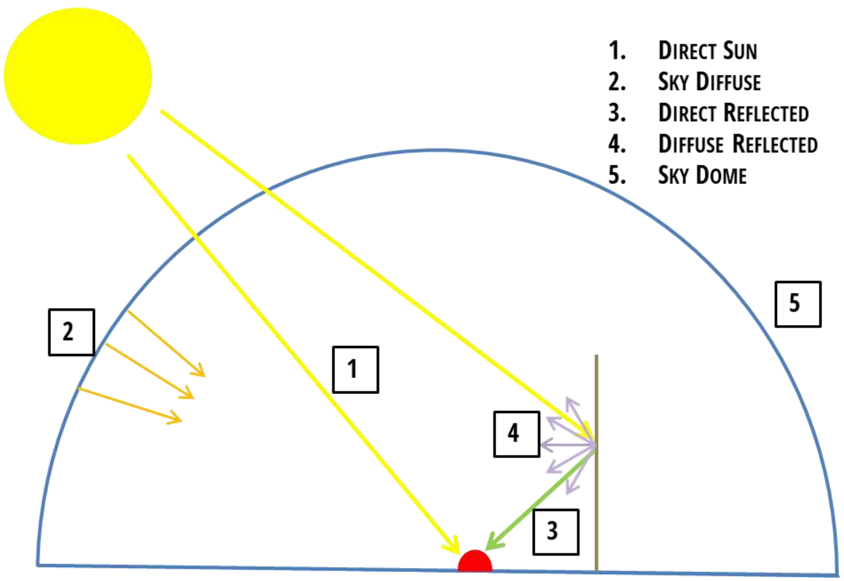


Figure 2: Schematic Illustrating Sources of Illuminance

Methodology

RWDI constructed a three-dimensional model of the greenspace, Proposed Project and other relevant surrounds that will exist at the time that the Proposed Project is constructed. This model was based on information provided by Architects Alliance up to November 3, 2020. Drawings were received in March 2021, after the study was completed, and were reviewed to ensure congruency with the results reported herein. The changes shown in the architectural drawings provided will not affect the presented results.

The greenspace was subdivided into a test grid of approximately 85,100 test points, each one representing 0.12m² of park area.

Ambient solar conditions were defined as 2:00 pm EDT on March 21 with a sunny sky in Toronto. This time and date were selected since this time was previously predicted to create a large shadow on the greenspace.

The illuminance level was then computed at each point using the industry standard software *Radiance* (v5.0).

Illuminance levels were predicted under various configurations of solar conditions and building properties as follows:

1. **Direct Illuminance Only** - No diffuse light from the sky, nor reflected light from the surrounding buildings is included.

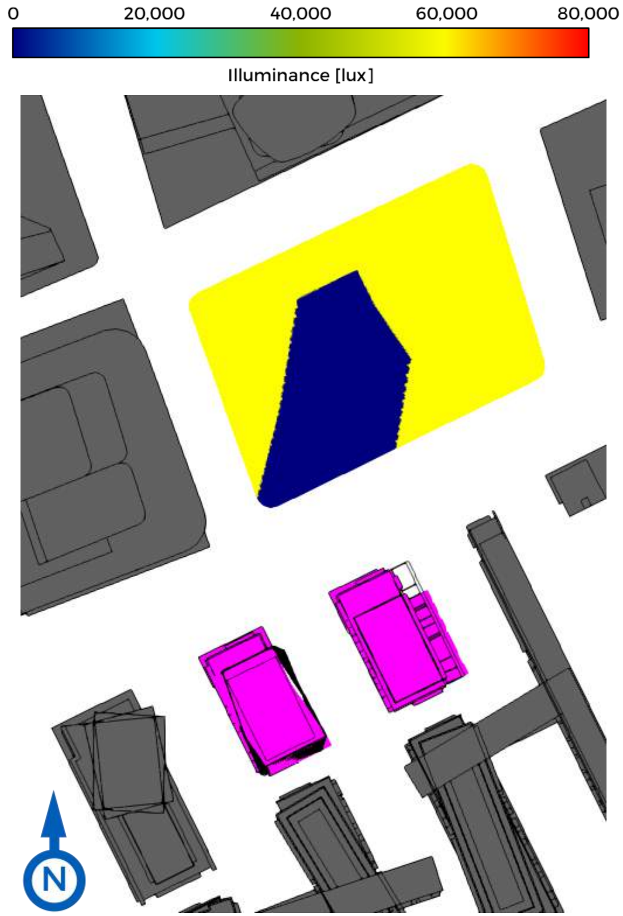
2. **Direct and Diffuse Sky Illuminance** - No reflected light from the surrounding buildings is included.

3. **Direct, Diffuse Sky and Diffuse Reflected Illuminance** – Generic diffuse reflectivity values (10%, 20% and 30%) are assigned to the facades of the buildings.

4. **Direct, Diffuse Sky and Specular Reflected Illuminance** – Select surrounding building facades are assigned properties of a common insulated glazing unit. This includes a 27% reflective component which is predominantly specular. All other surfaces remained at 30% diffuse reflectance.

The results of the above simulations are presented graphically on the following pages along with basic statistics of the distribution of illuminance levels.

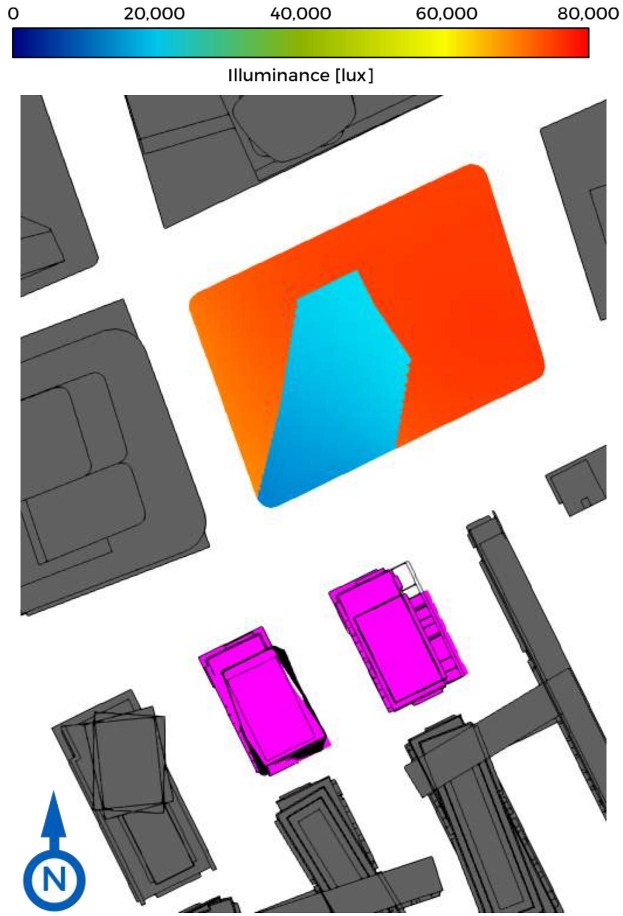
Configuration 1 – Direct Illuminance Only



	In Shadow	Out of Shadow
Average Illuminance [lux]	0	59,791
Average Illuminance [% of Ambient]	0%	-
Illuminance Range [lux]	0 – 0	59,791 - 59,791

Figure 3: Configuration 1 Illuminance Graphical Results (left) and Statistics (Right)

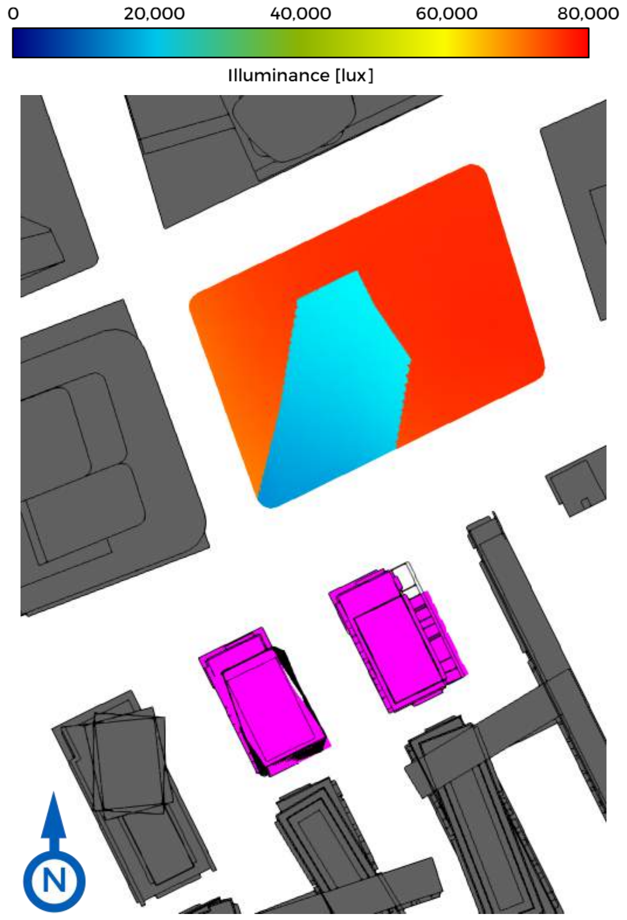
Configuration 2 – Direct and Diffuse Sky Illuminance



	In Shadow	Out of Shadow
Average Illuminance [lux]	16,104	74,303
Average Illuminance [% of Ambient]	22%	-
Illuminance Range [lux]	12,300 – 18,326	69,080 – 76,027

Figure 4: Configuration 2 Illuminance Graphical Results (left) and Statistics (Right)

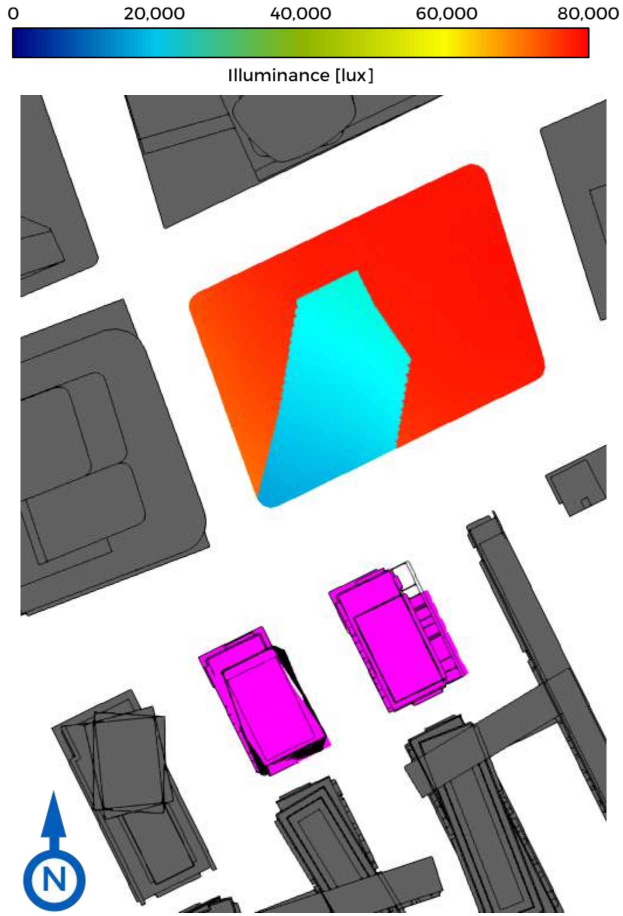
Configuration 3a – Direct, Diffuse and Reflected Illuminance (10% Diffuse Reflectivity)



	In Shadow	Out of Shadow
Average Illuminance [lux]	17,263	75,622
Average Illuminance [% of Ambient]	23%	-
Illuminance Range [lux]	13,256 – 19,645	70,033 – 77,217

Figure 5a: Configuration 3a Illuminance Graphical Results (left) and Statistics (Right)

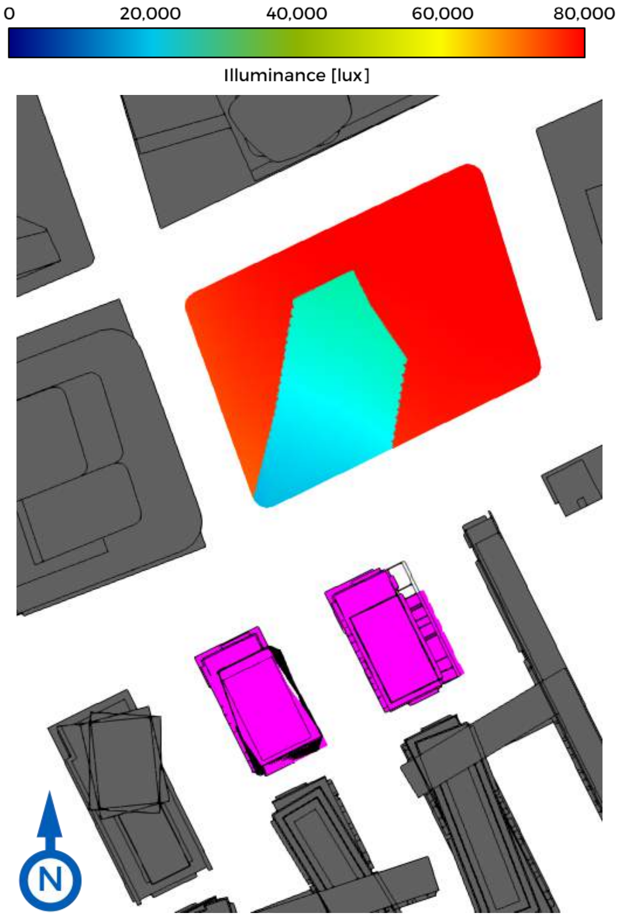
Configuration 3b – Direct, Diffuse Sky and Reflected Illuminance (20% Diffuse Reflectivity)



	In Shadow	Out of Shadow
Average Illuminance [lux]	18,649	77,191
Average Illuminance [% of Ambient]	24%	-
Illuminance Range [lux]	14,396 – 21,289	71,241 – 78,785

Figure 5b: Configuration 3b Illuminance Graphical Results (left) and Statistics (Right)

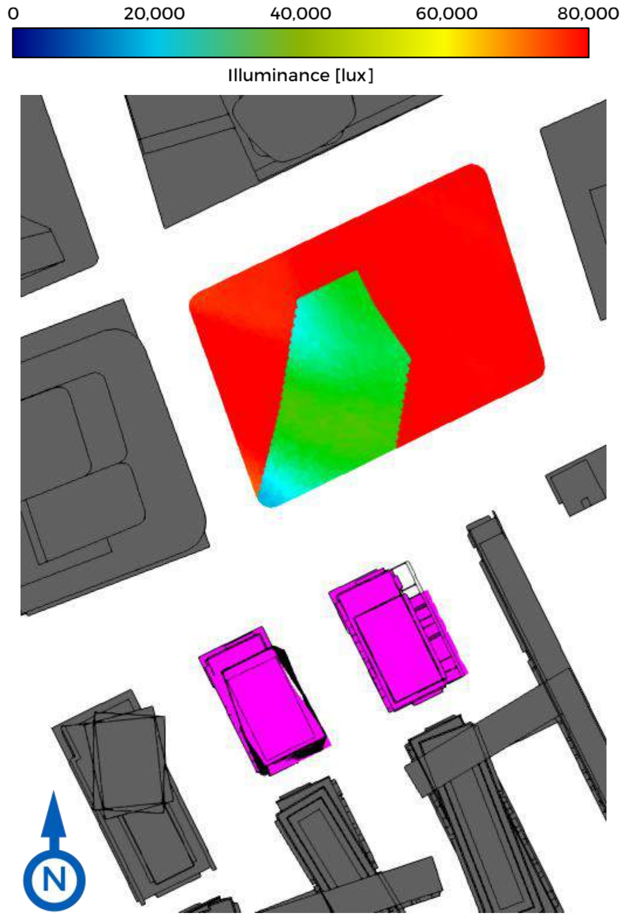
Configuration 3c – Direct, Diffuse Sky and Reflected Illuminance (30% Diffuse Reflectivity)



	In Shadow	Out of Shadow
Average Illuminance [lux]	20,173	78,898
Average Illuminance [% of Ambient]	26%	-
Illuminance Range [lux]	15,684 – 23,039	72,613 – 80,770

Figure 5c: Configuration 3c Illuminance Graphical Results (left) and Statistics (Right)

Configuration 4 – Direct, Diffuse Sky and Reflected Illuminance (27% Specular Reflectivity)



	In Shadow	Out of Shadow
Average Illuminance [lux]	27,657	81,968
Average Illuminance [% of Ambient]	34%	-
Illuminance Range [lux]	15,189 – 34,586	71,835 – 92,487

Figure 6: Configuration 4 Illuminance Graphical Results (left) and Statistics (Right)

OBSERVATIONS & CONCLUSIONS

1. At 2:00 pm EDT on March 21, approximately 30% of the greenspace was predicted to be shadowed by the Proposed Project.

2. Considering only direct sunlight resulted in predictions of 0 lux (total darkness) within the shadowed region. Common sense tells us that being in a shadow outdoors does not result in complete darkness, which highlights the issue with oversimplifying shadowing.

3. When diffuse light from the sky was also included, the shadowed area was still not predicted to be as bright as the rest of the greenspace. However, the level of brightness was predicted to increase significantly. On average the shadowed region was 22% as bright as the average illuminance outside of the shadow (16,104 lux). This emphasizes the importance of including diffuse skylight in any discussion about the impact of shadows.

4. When diffusely reflected light from surrounding buildings was acknowledged, the predicted brightness increased again, particularly at the north end of the greenspace which is in closer proximity to the towers to the north.

5. Depending on the assumed level of diffuse reflectivity, the average illuminance in the shadowed region was predicted to increase to 23%-26% of the unshadowed illuminance.

6. The Illuminating Engineering Society of North America recommends an assumption of 30% reflective surrounds when conducting daylight simulations for programs such as LEED. However, this assumption may be less appropriate in this context where we understand the surrounding building facades to be predominantly glass as opposed to diffuse materials such as concrete.

7. When selected facades were assigned glass-like material properties with a 27% reflectivity (which in RWDI's experience is common in many urban centers) the average illuminance increased to 34%. The effects of the light being redirected by the specular reflections also created areas of higher illuminance further from the buildings in the south end of the park.

8. Overall, it is clear from the simulations that while the Proposed Project will create shadows on the greenspace, it's openness to the sky and proximity to reflective buildings results in a significant amount of light that can still reach the shadowed area.

ASSUMPTIONS AND LIMITATIONS

1. This study's intended use was to understand the extent to which sky light and light reflected from surrounding buildings illuminate the shadow cast by the current design of the Proposed Project. These findings are not generally applicable to other building geometries or locations.

2. Illuminance simulations were conducted using a standard above and beyond the minimum requirements outlined in the Illuminating Engineering Society of North America's LM-83 standard for internal daylighting studies. The parameters used in this assessment are noted in Appendix A.

3. The surrounding buildings and topography were modeled to a standard level of fidelity and only generic material properties were applied. In the case of the Configuration 4 simulation, all park facing facades were treated as glazed.

4. Glazing properties were defined based on the Viracon VRE1-65 glazing unit. Based on RWDI's experience, this is a typical glazing unit common in many urban centers. These properties were applied using a bi-directional scattering function (BDSF) file generated in WINDOW v7.6. The manufacturer's specification sheet for this glazing is included as Appendix B.

5. Only a single 'worst-case' time and date was simulated under a sunny sky condition. No annualized simulations or simulations which include the effects of cloud cover have been conducted.

APPENDIX A

SIMULATION PARAMETERS

RADIANCE Simulation Settings

Parameter	Value
Test Point Spacing	0.5 m (approx.)
Ambient Accuracy	0.1
Ambient Bounces (ab)	7 (Configurations 2-4); 0 (Configuration 1)
Ambient Divisions (ad)	4096
Ambient Resolution (ar)	512
Ambient Super-samples (as)	1024
Direct Relays (dr)	2
Source Sub-structuring (ds)	0.2
Limit Reflection (lr)	12
Limit Weight (lw)	0.001
Direct Certainty (dc)	0.75
Direct Pretest Density (dp)	2048
Direct Thresholding (dt)	0.05
Specular Threshold (st)	0.01

APPENDIX B

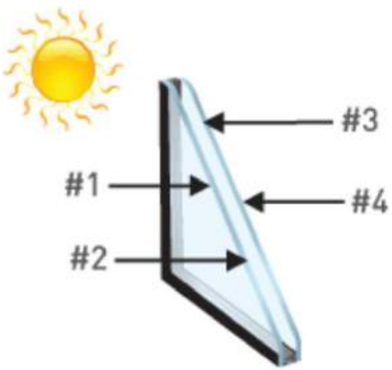
GLAZING SPECIFICATION SHEET

Viracon VRE1-65 Specification Sheet

1" (25mm) Insulating VRE1-65

1/4" (6mm) clear with VRE-65 #2
1/2" (13.2mm) space - air filled
1/4" (6mm) clear

Reflected Color   Transmitted Color



Performance Data

SHOW DATA AS:

METRIC IMPERIAL

Transmittance	
Visible Light	59%
Solar Energy	31%
UV	16%
Reflectance	
Visible Light-Exterior	27%
Visible Light-Interior	20%
Solar Energy	34%
NRFC U-Value	
Winter	1.70W/(M2 x °K)
Summer	1.48W/(M2 x °K)

Shading Coefficient	0.43
Relative Heat Gain	280.76W/M2
Solar Heat Gain Coefficient (SHGC)	0.37
LSG	1.59