Buidling 661 Annual Daylight Performance Modeling Studies

A Report for GPIC Task 2.2

Compiled by

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Introduction

This report contains some general findings of a series of daylight models that was conducted for Building 661 with its existing fenestration systems and with a few small modifications that were made to these systems. In this full scale renovation of Building 661, it is anticipated that some restrictions will be placed on the mounting of exterior devices onto this building due to the historical significance of the structure, so only glazing and interior shading devices were considered. These analyses were conducted using the Penn State version of the Daysim software, which applies the Radiance lighting software programs that were developed at the Lawrence Berkeley National Laboratory [1].

The ability to save energy is important, and is based primarily on daylight levels within a space. Since the proposed layout and intended use of these spaces was not available to consider in this study, this work considers primarily open work spaces and does not consider the impact of furniture, except in one of these spaces, the east-facing offices. The glazing apertures were studied as they currently exist, except for the south wall of the pool area, where glazing was added to study the effect of south-facing windows and the impact of the large warehouse-like structure that is immediately across the street (Kitty Hawk Ave.). While surrounding buildings were considered in this study, the trees that are located against the building on the east side were not. Daylight provided through the east-facing windows is likely to be significantly reduced due to presence of these deciduous trees, if they are retained, particularly during the warmer months when their branches contain leaves.

The Building 661 spaces that were considered in this study include the following:

1) A second-floor open office space facing east.
2) A first floor open area on the south-east corner of the building that has both south and east-facing windows.
3) An open area along the south-edge of the pool where a series of windows were added, and where the existing skylight configuration was retained.
4) The full-height pool and gymnasium with the existing skylight configuration and diffusing glass on the north wall of the gym. This space was considered with both diffusing skylights as well as clear skylights.
5) The sunlight shadow patterns presented by sunlight on the building at different times of the year due to neighboring structures.

Material properties were considered for the following surfaces within these spaces.

- Ceiling
- Walls
- Floor
- Windows
- Skylights
- Mullions
- Exterior Ground

- Adjacent Buildings
- Translucent Shades or Horizontal Blinds

In situations where clear vertical windows are present, translucent shades of diffuse transmittance and a 3% openness factor, or horizontal blinds with a 50% reflectance, were applied when interior illuminance conditions indicate that direct sunlight is penetrating the daylight aperture. It is difficult to exactly predict when these shading devices may be lowered in a real space, and it is very possible that this protocol may under- or over-estimate the amount of time that shades or blinds will be applied. In these models, the blinds or shades were considered to be lowered completely when interior daylight levels reached a threshold condition at a selected point. When exterior skies are overcast or when direct sunlight does not strike a façade, a setting was selected that would retract the blinds or shades to allow for maximum daylight penetration.

To address daylight conditions over the entire year, and their potential to provide energy savings, contours are provided for the daylight autonomy (DA) across the space[2]. Daylight autonomy is the fraction of hours per year, in this case considering an operating schedule from 8AM to 6PM daily, when daylight illuminance exceeds a specified criterion value at a uniform grid of points spread across the space. In this study, the criterion value was placed at both 300 and 500 lux for these contours. In addition, the spatial daylight autonomy ($sDA_{300\ lux,\ 50\%}$) [4] is reported for the entire space. This is the fraction of the space (based on all of the work plane analysis points across the space) that reaches 300 lux for 50% or more of the operating hours. A nominally acceptable daylit space should have a $sDA_{300,50\%}$ of approximately 50% or higher [3].

Another daylight metric that is shown for each of these spaces is the daylight factor. This is the fraction of the exterior illuminance under an overcast sky that is received at an interior point. Acceptable daylight factors under a sidelighting condition are generally recommended to be at least 2% (0.02). For skylights, lower daylight factors can be acceptable, particularly when a significant fraction of the year has clear or partly cloudy skies.

In addition to these Daysim models, a movie file was created that illustrates the expected shadowing of Building 661 from the adjacent buildings on the winter and summer solstices and at the equinox.

Images showing the rough exterior modeling geometry that was applied in these models is shown in figures X through X below.

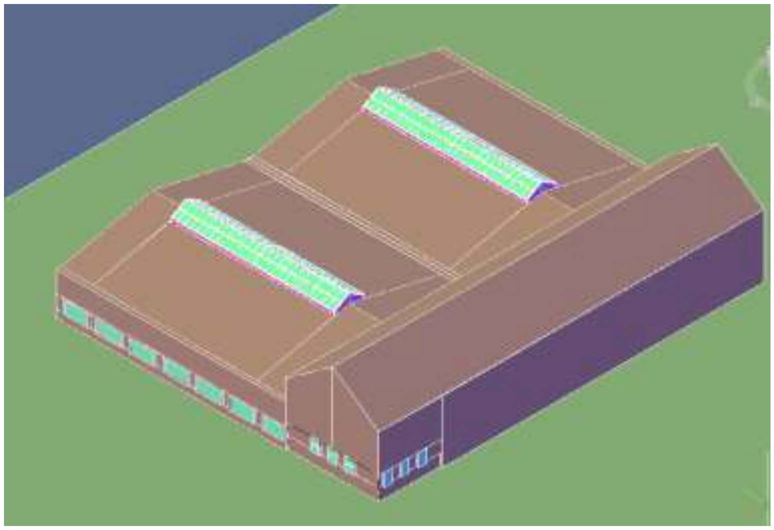


Figure 1. Southeast isometric of the Building 661 Model used in Daysim. The east-facing office space was modeled separately from this full Building 661 model. The windows that were added to the south wall of the pool were considered in one of the study cases.

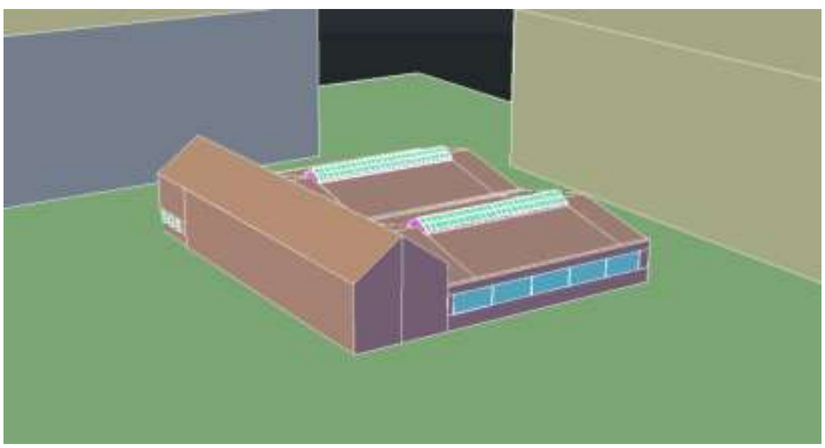


Figure 2. Northeast isometric of the Daysim Building 661 Model. The large shadowing buildings to the south and west are shown.

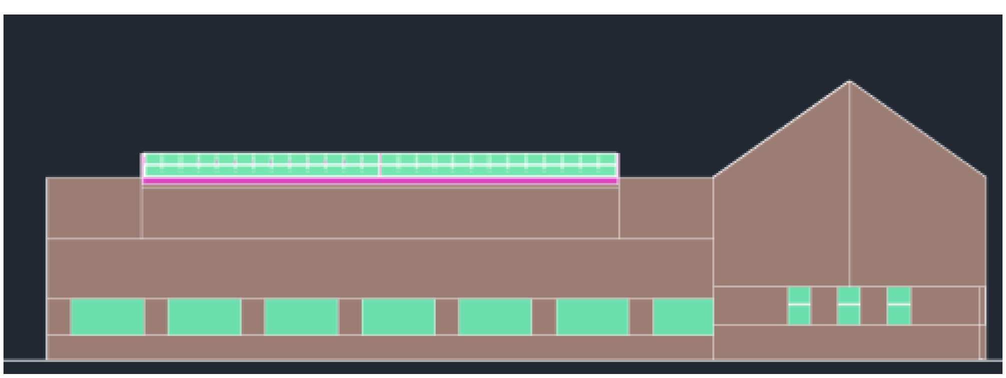


Figure 3. South elevation of Building 661 showing the south-facing windows that were added to the pool area for one of the modeling cases.

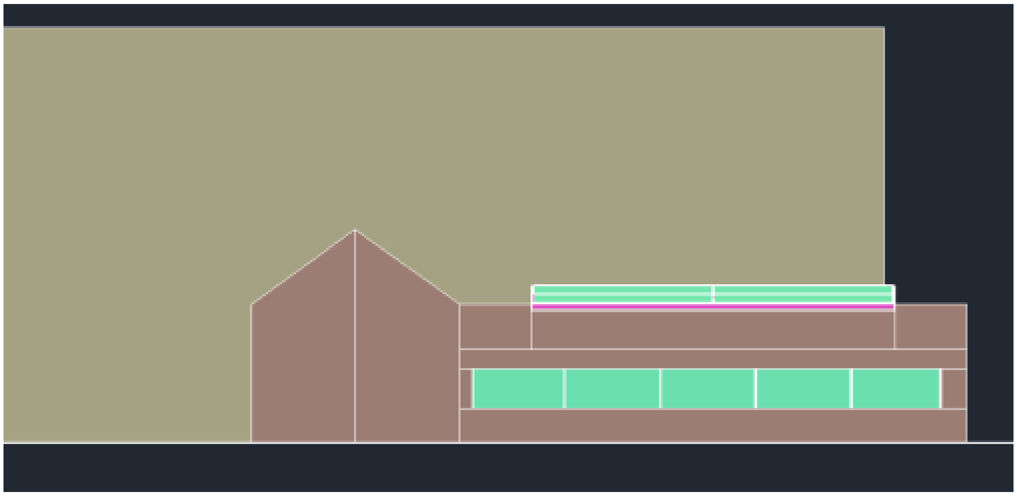


Figure 4. North elevation of Building 661 showing the diffusing glazing on the north-facing side of the gymnasium. The large warehouse structure located to the south of Building 661 is in the background.

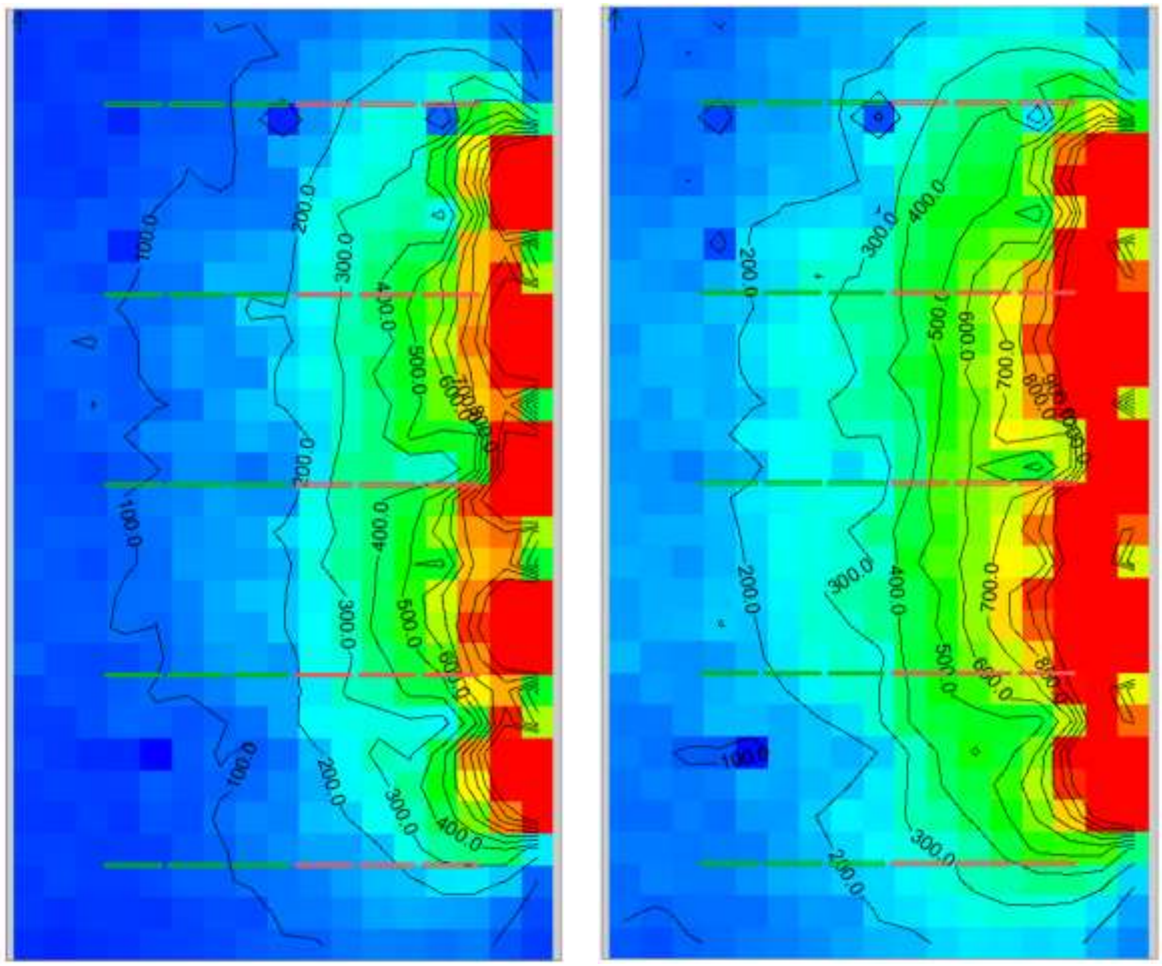
East-Facing Open Office Area

This space is a model of a hypothetical second-floor open office space in Building 661 that considers the existing punched windows. Interior furnishings are as shown in Figure 1. Material properties are as listed below.

- Ceiling Reflectance = 0.80
- Floor Reflectance = 0.30
- Wall Reflectance = 0.50
- Ground Reflectance = 0.20
- Glazing Transmittance = 0.60
- Blind Reflectance = 0.50
- Shade Transmittance (0.10 Total, 3% holes)

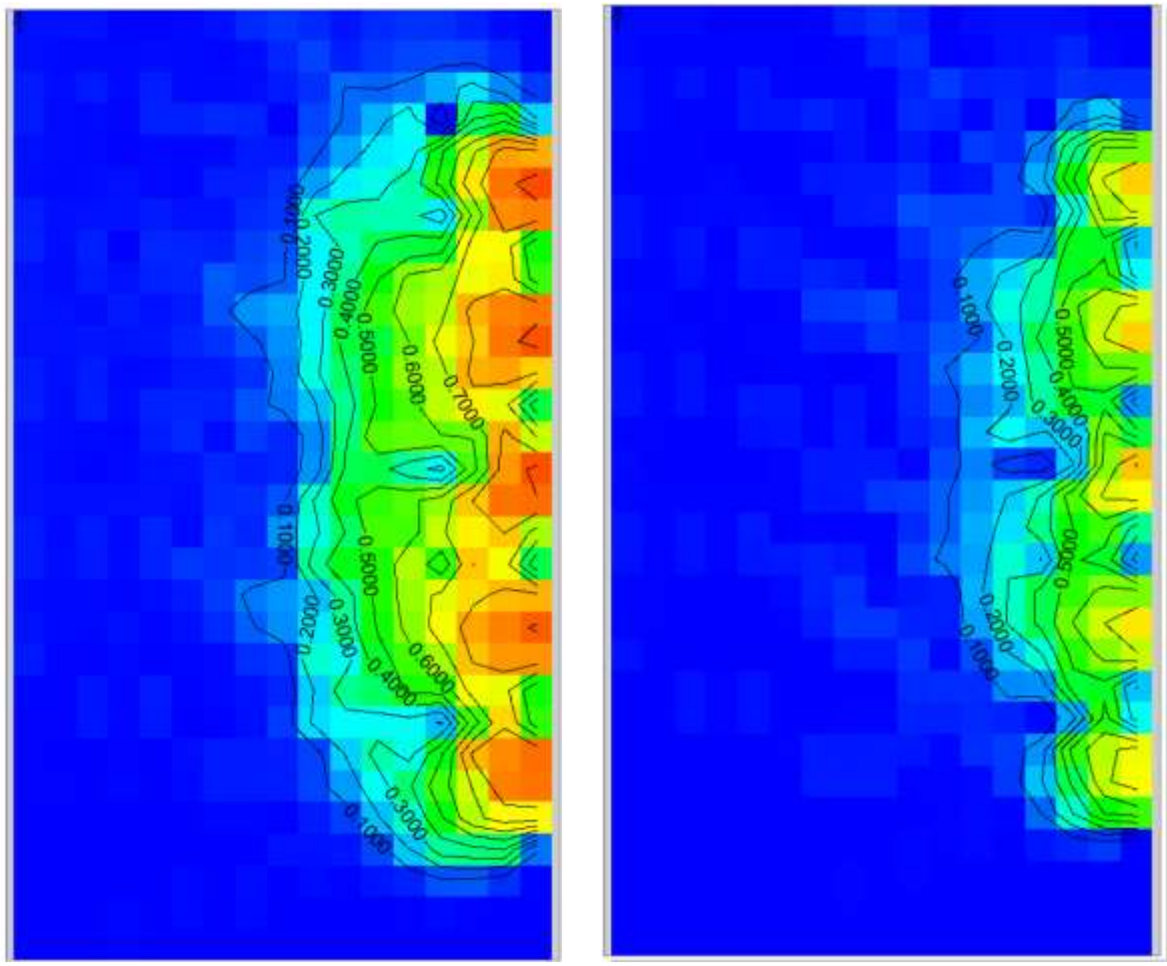
The space dimensions are 35 x 60 x 12 ft with the window opening at approximately 38.5 inches above the floor.

Figure 5. Rendered Radiance image of the east-facing open office space considered in this analysis



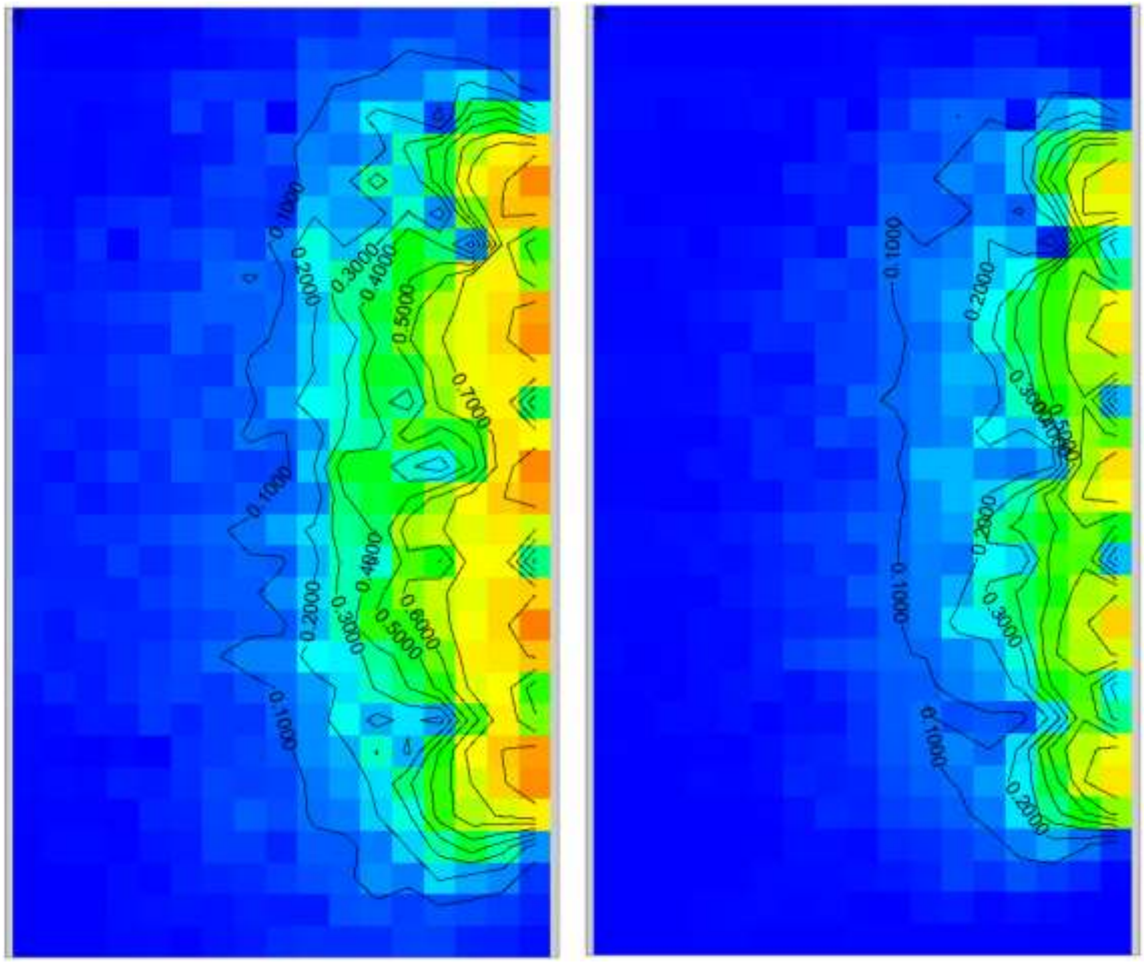
ILLUMINANCE (LUX)

Figure 6. Illuminance contours (measured in lux) in an east-facing open office area with furniture for January 8 (Overcast Sky) and June 1 at noon with no shading applied to the windows. Each square is a 2 ft x 2 ft area.



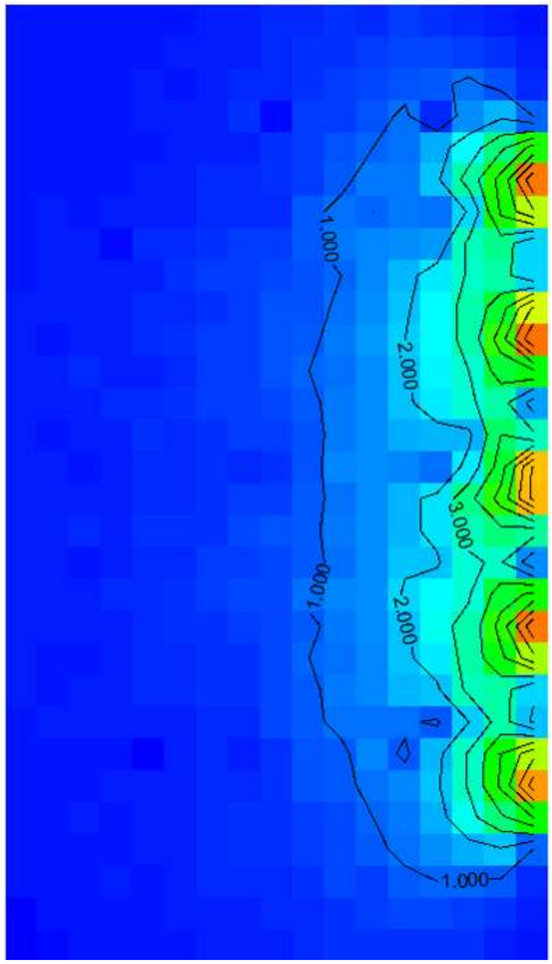
DAYLIGHT AUTONOMY (BLINDS ACTIVATED WHEN NECESSARY)

Figure 7. Daylight Autonomy Contours in an east-facing open office area with furniture for 300 lux (left) and 500 lux (right) at desk height (2.5 ft). Each square is a 2 ft x 2 ft area. Horizontal blinds are applied to the windows when direct sunlight penetration is a concern.



DAYLIGHT AUTONOMY (FABRIC SHADES ACTIVATED WHEN NECESSARY)

Figure 8. Daylight Autonomy Contours in an east-facing open office area with furniture for 300 lux (left) and 500 lux (right) at desk height (2.5 ft). Each square is a 2 ft x 2 ft area. Fabric shades are applied to the windows when direct sunlight penetration is a concern.



DAYLIGHT FACTOR (NO BLINDS OR SHADES)

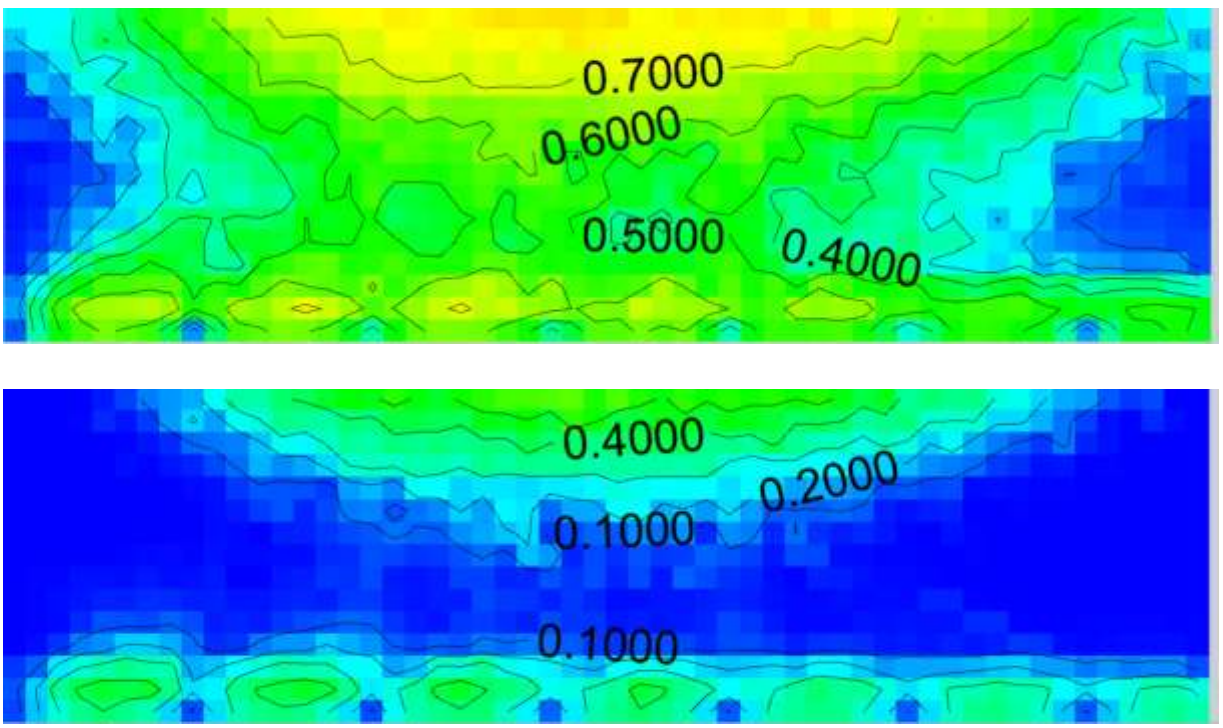
Figure 9. Daylight Factor contours in an east-facing open office area with furniture. No shading is considered on the windows. Each square is a 2 ft x 2 ft area

South-Facing Pool Area

This space is a model of a hypothetical open office space in Building 661 that considers the addition of large windows in the south-facing wall. The first 30 feet from the wall are considered in the results. Material properties are as listed below.

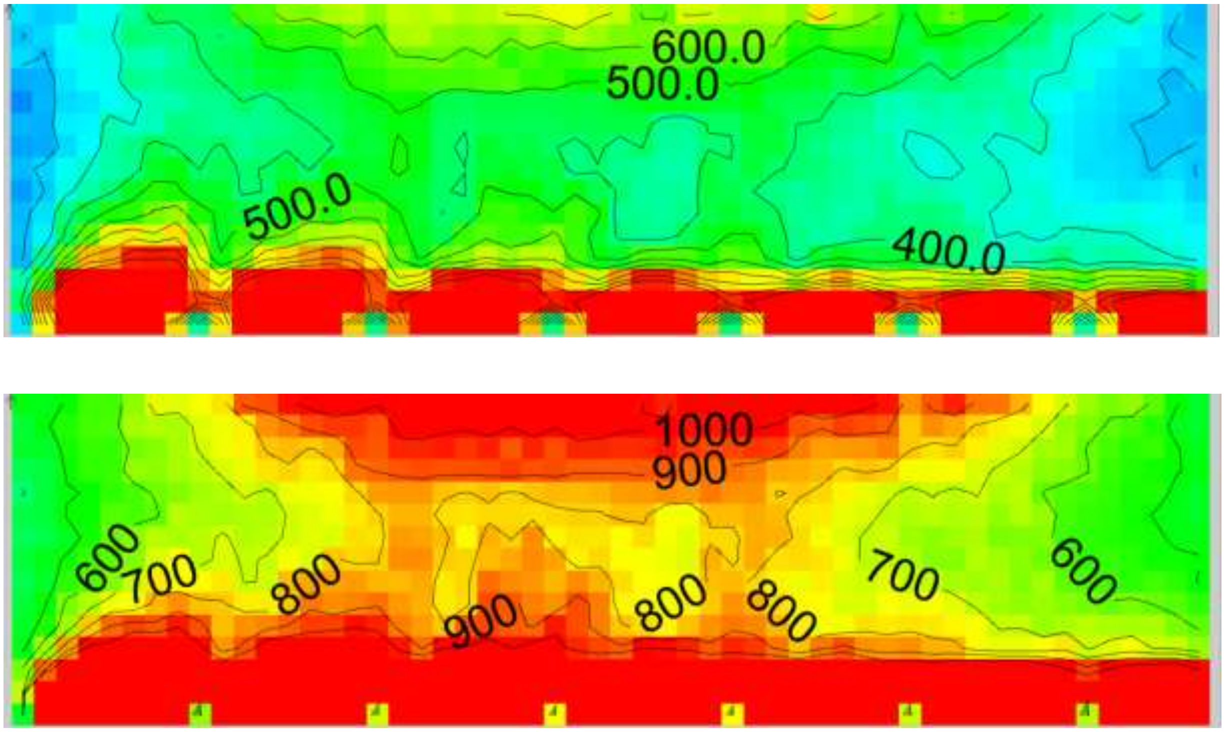
- Ceiling Reflectance = 0.80
- Floor Reflectance = 0.25
- Wall Reflectance = 0.60
- Ground Reflectance = 0.20
- Glazing Transmittance = 0.46 (which includes mullion losses)
- Shade Transmittance (0.10 Total, 3% holes)

The space dimensions are 30 x 110 ft with rough window openings that are 12 ft wide by 6 ft high with a sill height of 48 inches above finished floor.



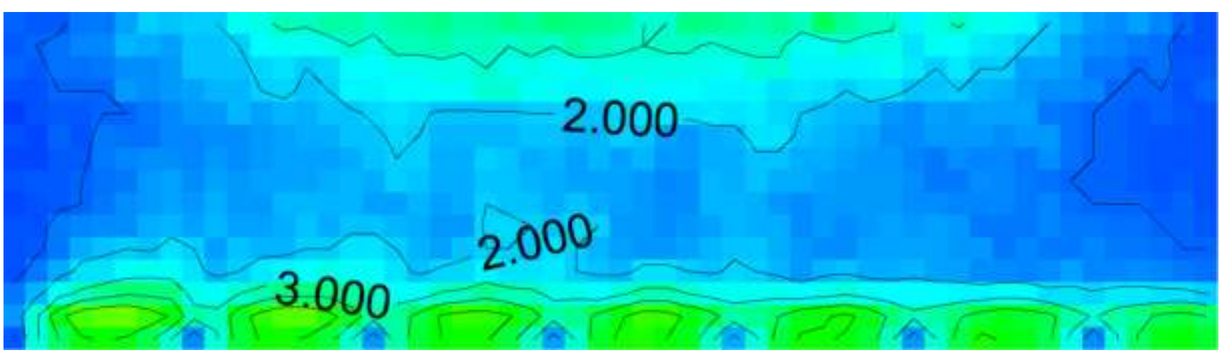
DAYLIGHT AUTONOMY (FABRIC SHADES ACTIVATED WHEN NECESSARY)

Figure 10. Daylight Autonomy Contours in a south-facing open office area for 300 lux (top) and 500 lux (bottom) at desk height (2.5 ft). Each square is a 2 ft x 2 ft area.



DAYLIGHT ILLUMINANCE

Figure 11. Illuminance contours (measured in lux) in a south-facing open office area for January 8 (Overcast Sky) and June 1 at noon with no shading applied to the windows. Each square is a 2 ft x 2 ft area.



DAYLIGHT FACTOR (NO SHADES)

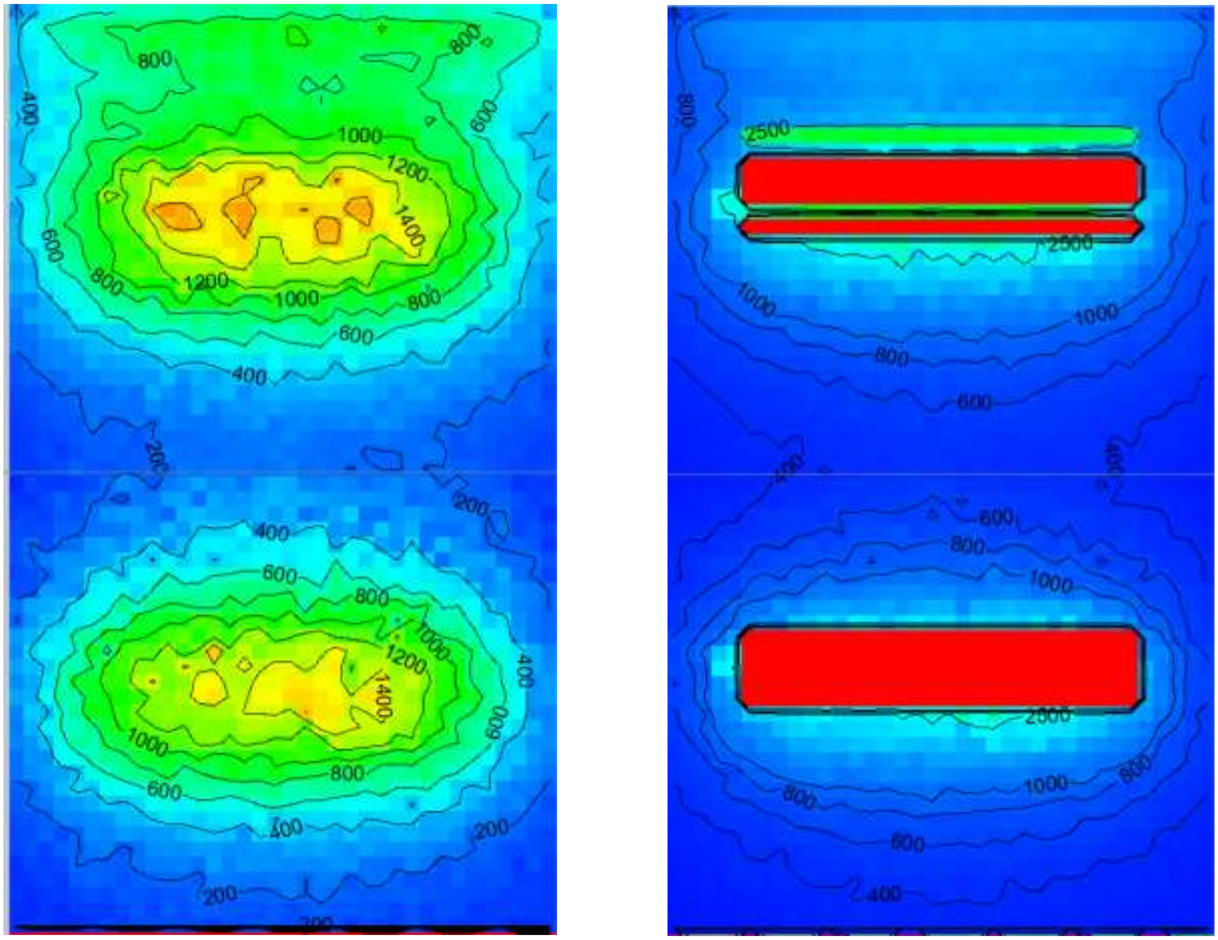
Figure 12. Daylight Factor contours in a south-facing open office area. No shading is considered on the windows. Each square is a 2 ft x 2 ft area.

Gymnasium and Pool Skylighting

The gymnasium and pool areas each have a continuous run of skylights along the peak of the roof, and, in addition, the gym has a diffusing glass block wall on its north wall. These spaces were modeled with both clear and diffuse glazing. If this space is to be a work area, a diffuse glazing material would be a logical retrofit for the skylights to avoid direct sunlight in the area below. This should also help to diffuse daylight across a wider area beneath the skylights. These space models consider the deep mullions that are currently in place between the existing skylight panels. Material properties are as listed below.

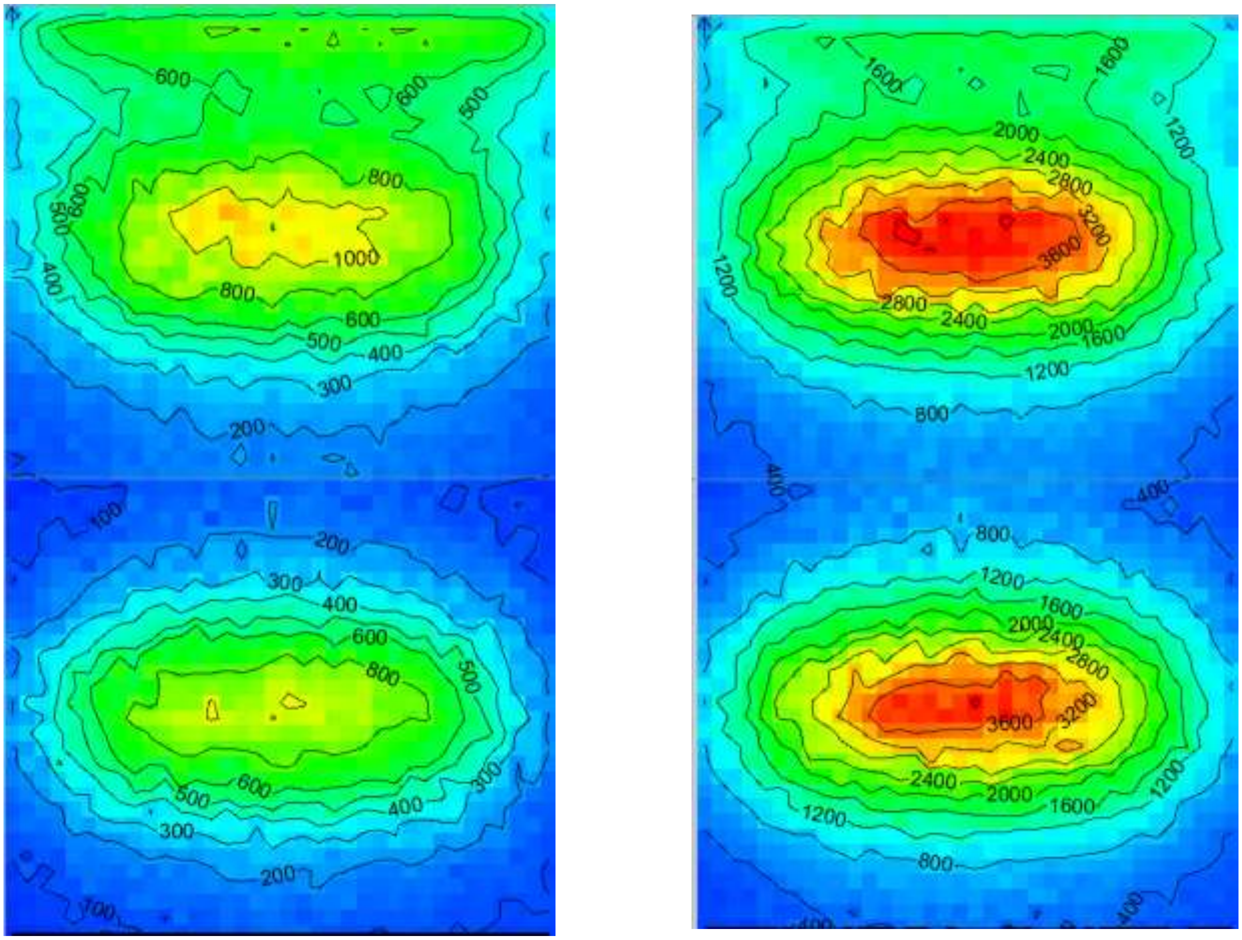
- Ceiling Reflectance = 0.80
- Floor Reflectance = 0.25
- Wall Reflectance = 0.60
- Ground Reflectance = 0.20
- Clear Glazing=0.60
- Diffuse Glazing=0.40

The results for these analyses are presented below. While the diffuse skylights provide less illuminance under a perfectly overcast sky, which can be seen in the daylight factor contours, it is surprising that the daylight autonomy values turn out much closer to each other. Under both scenarios, the space receives significantly more light directly under the skylights than near the walls and the corners. With no additional daylight apertures, the lighting equipment around the perimeter of the space should be zoned separately from that in the center of the space if lighting is being controlled in an attempt to gain energy savings.



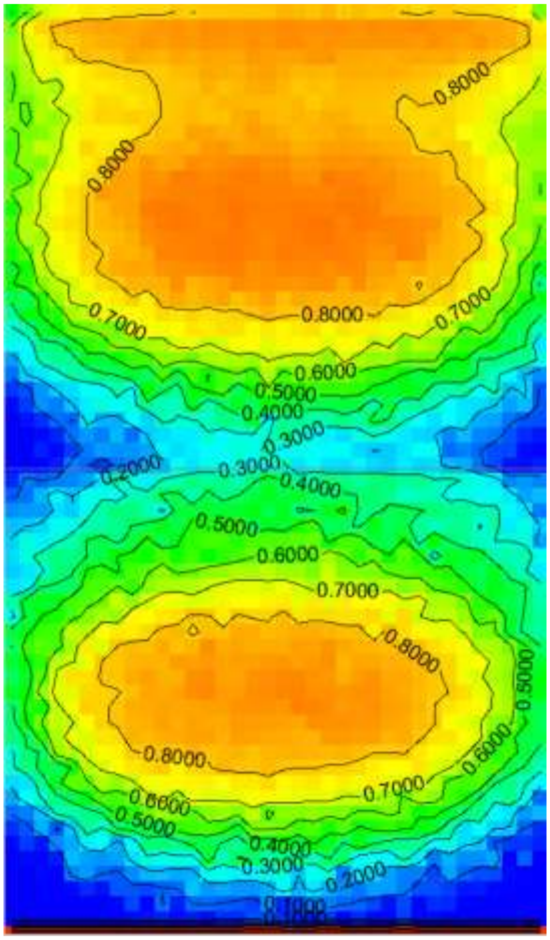
DAYLIGHT ILLUMINANCE WITH CLEAR GLAZING

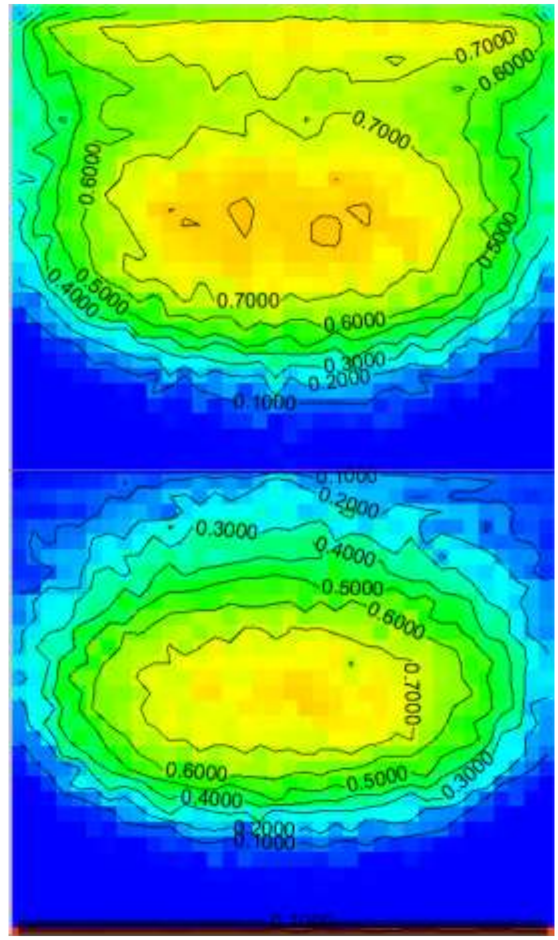
Figure 13. Illuminance contours (measured in lux) in a gymnasium/pool area with clear glazing for January 8 (left image) and June 1 (right) for a mostly overcast sky at noon with no shading applied to the windows. Each square is a 3 ft x 3 ft area.



DAYLIGHT ILLUMINANCE WITH DIFFUSE GLAZING

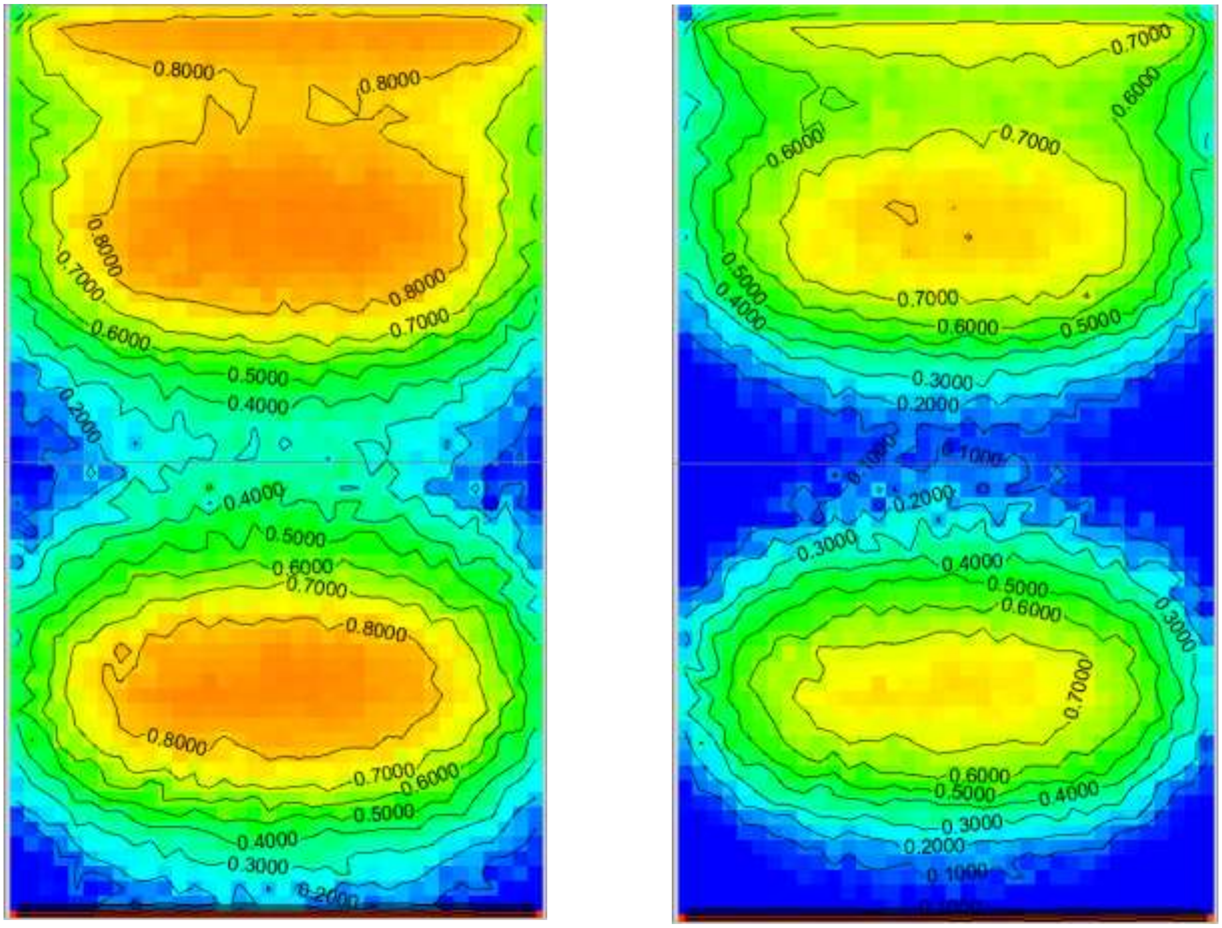
Figure 14. Illuminance contours (measured in lux) in a gymnasium/pool area with diffuse glazing for January 8 (left image) and June 1 (right) for a mostly overcast sky at noon with no shading applied to the windows. Each square is a 3 ft x 3 ft area.





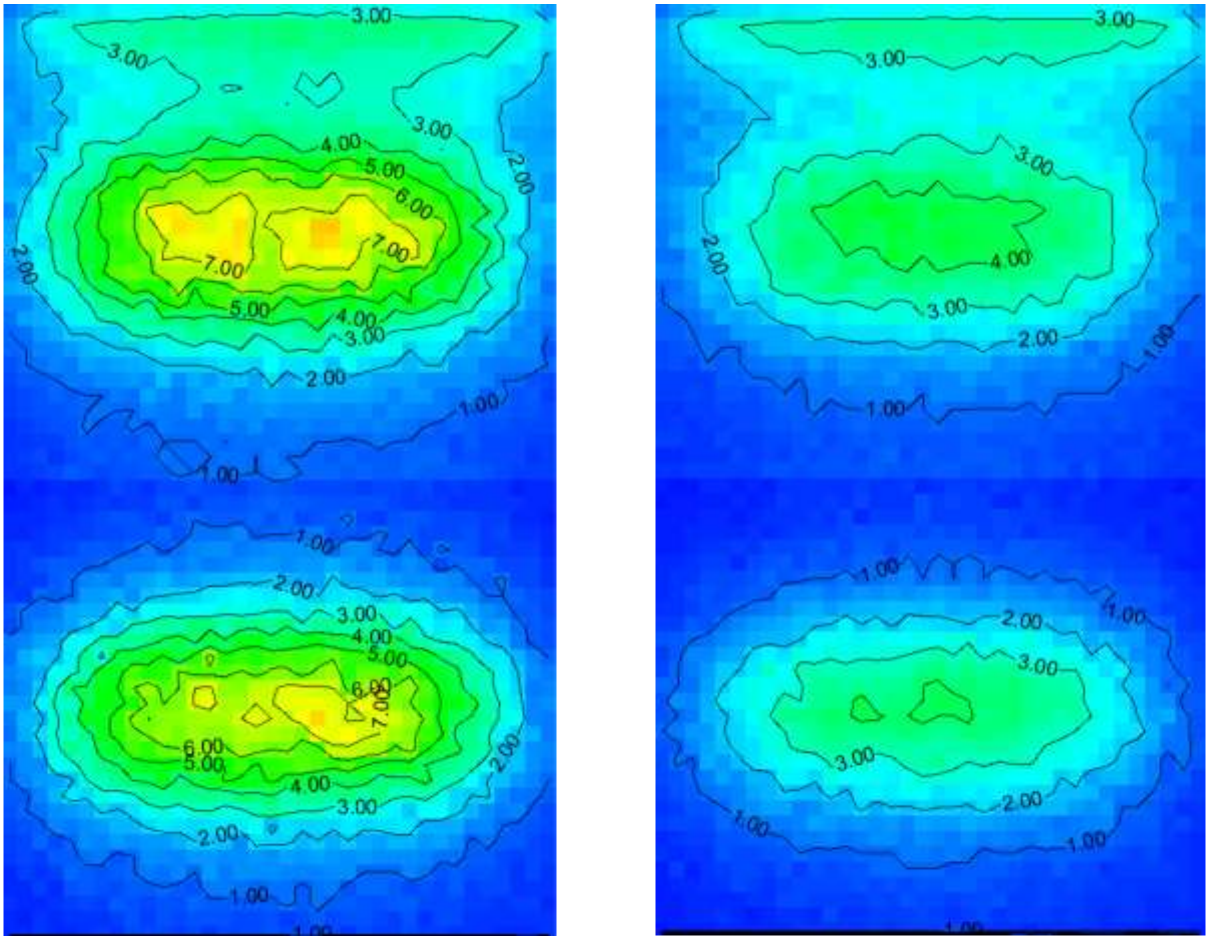
DAYLIGHT AUTONOMY WITH CLEAR GLAZING

Figure 15. Daylight Autonomy Contours in a gymnasium/pool area with clear glazing for 300 lux (left) and 500 lux (right) at desk/table height (2.5 ft above finished floor). Each square is a 3 ft x 3 ft area.



DAYLIGHT AUTONOMY WITH DIFFUSE GLAZING

Figure 16. Daylight Autonomy Contours in a gymnasium/pool area with diffuse glazing for 300 lux (left) and 500 lux (right) at desk/table height (2.5 ft above finished floor). Each square is a 3 ft x 3 ft area.



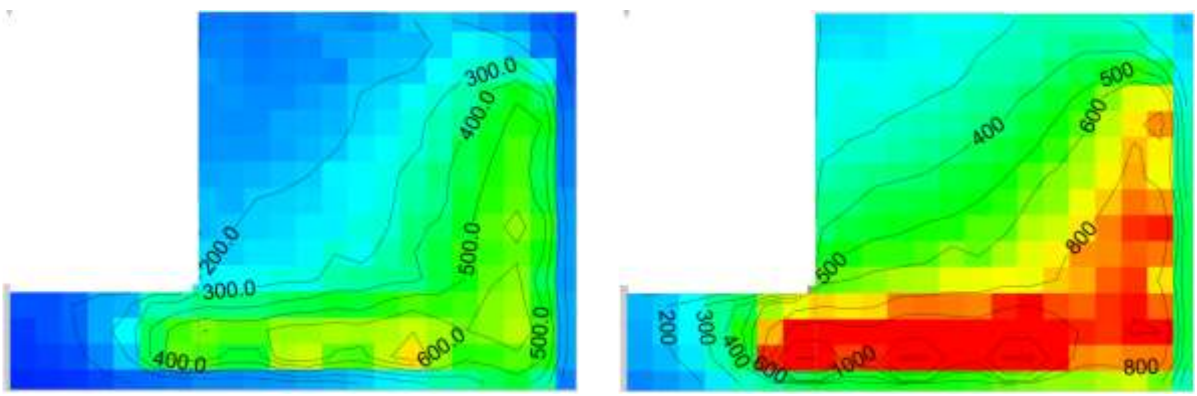
DAYLIGHT FACTOR

Figure 17. Daylight Factor Contours in a gymnasium/pool area with clear glazing (left) and diffuse glazing (right). Each square is a 3 ft x 3 ft area.

Southeast Corner Office with Lightshelves on South Windows

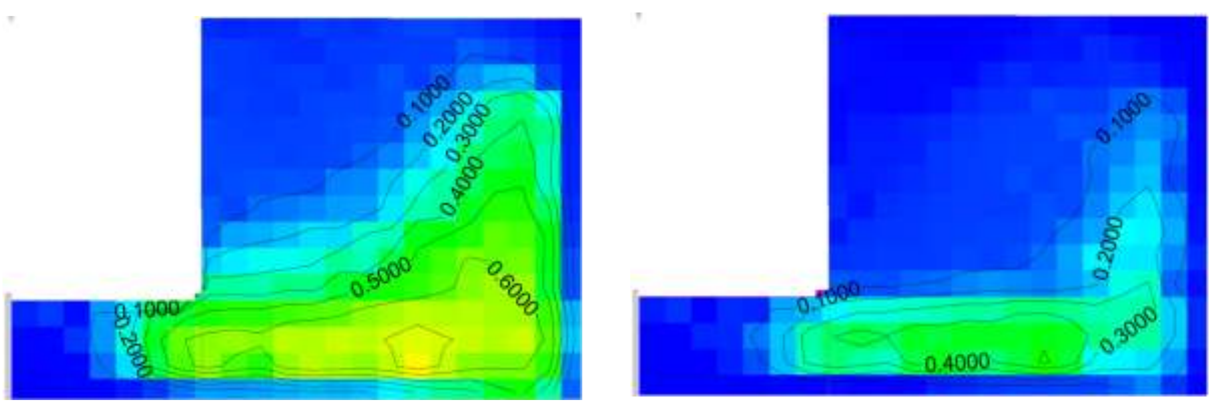
The southeast corner of the building contains a large space that has windows on both the east and the south-facing walls. This space was considered with translucent fabric shades on the east -facing windows and a light shelf on the interior of the south-facing windows with fabric shades capable of being applied only to the window beneath the shelf. The windows span from 5.75 to 12 feet vertically with a thin shelf mounted at a 9-foot height that is 3 feet deep. The shelf depth was set at a point where the window will be shaded by the warehouse building across the street at when times when the solar profile angle would allow direct sunlight to penetrate into the space above the lightshelf. There are some early morning sun positions during the wintertime where the adjacent building does not block the sun because the sun is to the east of that building's angular extents.

This space achieves a spatial daylight autonomy ($sDA_{300,50\%}$) of aapproximately 40%.



DAYLIGHT ILLUMINANCE

Figure 18. Illuminance contours (measured in lux) in a south-east open office area for January 8 (left image) and June 1 (right) for a mostly overcast sky at noon with no shading applied to the windows. Each square is a 2 ft x 2 ft area.

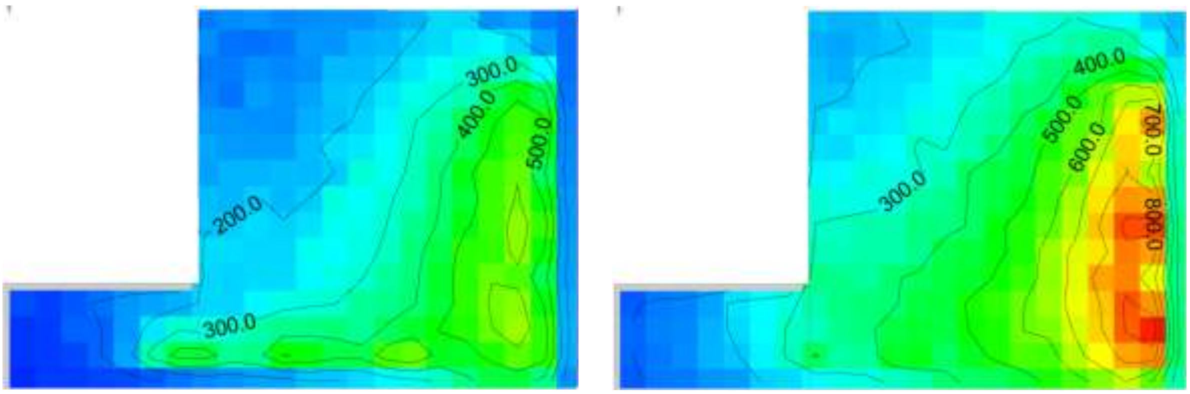


DAYLIGHT AUTONOMY (FABRIC SHADES ACTIVATED WHEN NECESSARY)

Figure 19. Daylight Autonomy Contours in a south east facing open office area for 300 lux (left) and 500 lux (right) at desk height (2.5 ft above finished floor). Each square is a 2 ft x 2 ft area.

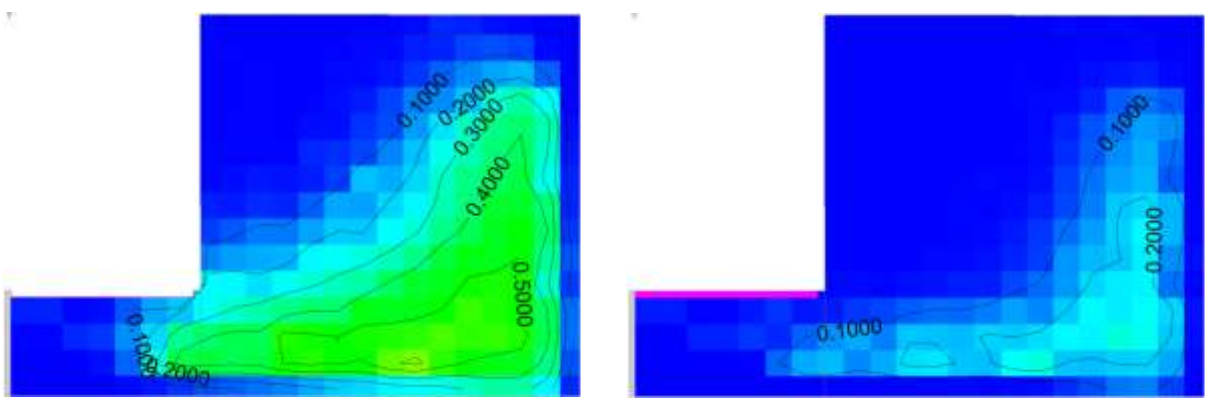
Figu ACTOR WITH LIGHTSHELVES (NO SHADES)

Southeast Corner Office with Existing Windows (No lightshelves)



DAYLIGHT ILLUMINANCE

Figure 21. Illuminance contours (measured in lux) in a south-east open office area for January 8 (left image) and June 1 (right) for a mostly overcast sky at noon with no shading applied to the windows. Each square is a 2 ft x 2 ft area.



DAYLIGHT AUTONOMY (FABRIC SHADES ACTIVATED WHEN NECESSARY)

Figure 22. Daylight Autonomy Contours in a south east facing open office area for 300 lux (left) and 500 lux (right) at desk height (2.5 ft above finished floor). Each square is a 2 ft x 2 ft area.

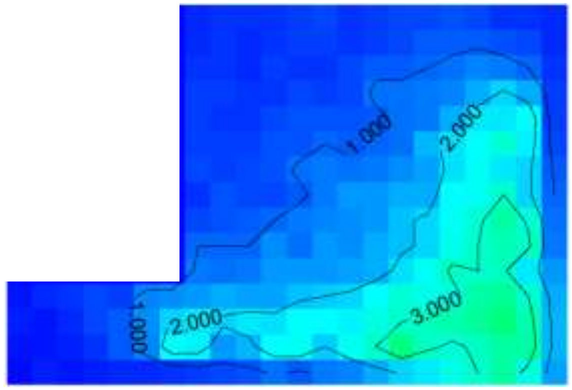


Figure 23. DAYLIGHT FACTOR (NO SHADES)

Conclusions

These studies illustrate that Building 661, as currently configured, has the potential for daylight harvesting along the perimeter of the building where the relatively large punched windows are present in the exterior masonry walls. In addition, a large portion of the gym and pool areas can zoned to dim or switch off with the available daylighting. The perimeter and corners should be on a separately controlled lighting zone.

Given the height of the windows, it may be beneficial to apply an interior lightshelf to these windows to eliminate the need for occupants to lower the shades or blinds under certain daylight conditions. This should help to maintain higher daylight levels within the space.

On the south side of Building 661, there is significant wintertime shading of the direct sunlight by the adjacent building to the south, preventing the sun's rays from striking the windows on the south side of the building for most of the day (particularly on the first floor). This occurs for a number of months and will likely eliminate the need for shading devices, except perhaps at early morning hours when the sun will be positioned to the east of that building.

Given the current conditions and the limitations provided by the heavy masonry exterior walls and steeply pitched room on the main section of the building, it will be challenging to efficienty daylight a large portion of the main building's interior area. In the gymnasium and pool, it should be possible to fine tune a design to provide adequate, high quality daylighting over nearly those entire spaces.

Annual simulations, such as those performed here, should be conducted to quantify daylighting performance. A tool, such as Daysim, can also be used to assist in the layout of lighting control zones, and to assess the potential energy savings in these interior areas for these lighting control zones.

References

1. Radiance Website. Lawrence Berkeley National Laboratory. http://radsite.lbl.gov. [Last accessed on January 23, 2012].
2. Research Project Discussions with Lisa Heschong of the Heschong-Mahone Group. 2011. Not yet in print.
3. Reinhart CF, Mardaljevic J, Rogers Z. 2006. Dynamic Daylight Performance Metrics for Sustainable Building Design. Leukos, 3(1):7-31.
4. DiLaura D, Houser K, Mistrick R, Steffy G. 2011. *IES Lighting Handbook (10th Edition)*. New York : Illuminating Engineering Society of North America, p. 14.47.