

QUEEN'S UNIVERSITY
LIGHTING MASTER PLAN REPORT

OCTOBER 1993

Gabriel/design

QUEEN'S UNIVERSITY

MASTER PLAN LIGHTING DESIGN REPORT

Design Criteria and Guidelines

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I INTRODUCTION

The Lighting Design Report provides an analysis of the role of exterior lighting on the Queen's University Campus. The report suggests a rationale for the establishment of lighting objectives that take into account both the practical and aesthetic goals of lighting at Queen's. The technical means to support these objectives are also detailed.

Throughout our research and analysis, an effort has been made to identify and discuss situations that are typical of the current exterior lighting conditions at Queen's. The general principles proposed here may later be applied to more site specific concerns. Graphic representations have also been included to support these general findings.

This report is intended to compliment the ongoing process of developmental planning currently underway at Queen's. To that end, all aspects of the exterior lighting concepts recommended here have been designed to work in conjunction with the planning, landscaping and improvement goals of the University.

II EXECUTIVE SUMMARY

The Lighting Design Report provides a detailed explanation of lighting design principles that are appropriate for application to the Queen's University Campus. The principles proposed in this report take into account the imperatives of personal safety as well as the many practical and aesthetic considerations of campus lighting.

BACKGROUND

The relationship of exterior lighting to the issue of personal safety was highlighted by a recent safety audit of the Queen's University campus. The audit identified numerous areas where the lack of light, or the poor quality of its design, resulted in a potential risk to night time occupants of the campus and, in the event of an incident, could leave the university open to accusations of negligence.

The following report further supports the initial findings of the safety audit. It examines in greater detail common lighting deficiencies throughout the campus that were felt to be significant enough to affect night time orientation, pedestrian and vehicular circulation, and safety.

In particular, visibility in many areas of the campus is impeded by the existence of a seemingly random assortment of overly bright lights. The extreme contrasts between lightness and darkness that result from the use of excessive wattage or inappropriately bright light sources can blind night time observers with their glare, obscuring the areas immediately adjacent to the light and creating forbidding "black holes".

BASIC LIGHTING CONCEPTS

The following concepts are those most frequently encountered in discussions of lighting design:

VISION - Vision is made possible by reflected light interspersed with the light emanating directly from the source. The eye perceives the effect of light, not the light energy. More specifically, it is the brightness and contrasts caused by the light sources and the reflecting surfaces that allow us to see, not the light energy that passes between them.

As light hits the eye, there are three visual ranges by which it is perceived: daytime, night time and darkness. The lighting design for Queen's University will be developed to accommodate the night time or "mesopic" vision in order to maximize its use for both safety and visibility.

EYE ADAPTATION - The eye requires time to adapt to varying degrees of light. If a bright light shines suddenly in the dark, as is the case at night when an oncoming car shines its high beams, the eye cannot adapt quickly to both levels of light. The result is a "blinding" effect that obscures all areas adjacent to that light. The varying degree of time required for the eye to adjust to changes in the level of light explains why bright lights on a night time scene can impair visibility rather than enhance it.

CONTRAST - Dimensions, shapes, textures and differences in materials are seen through a contrast of brightness and colour. It is this contrast, rather than the light itself, which permits vision.

The most effective lighting is that which allows the greatest contrasts between objects or elements in a space. Higher contrast allows you to identify trees in the forest; low contrast will reveal only the forest. The goal in night lighting is therefore to identify the most important elements of a view, i.e. doorways, paths, signage etc., and to deploy light and create contrast so as to establish the desired visual hierarchy.

GLARE - Glare is the term used to describe the result of the eye encountering light to which it has not yet adapted. It is the "glare" from the lights of an oncoming car that blind you to the road. The objective of lighting design is to limit this phenomenon in night time lighting in order to facilitate the greatest visibility.

LIGHTING AS PART OF A SYSTEM - All lighting subsystems includes a) a source of light energy such as a lightbulb, b) the means to control that light energy (lamp shades, "luminaires", and lenses); c) the surfaces that receive the light energy, reflect and absorb it; and d) the brain through the eye which is the ultimate receptor of both direct and reflected light. The proper manipulation of all these variables to create optimum visibility, safety and effect is the ultimate goal of all lighting design.

LIGHTING STRATEGY

The use of a comprehensive lighting design strategy represents the most cost effective means of illuminating the exterior spaces of the Queen's campus. The implementation of such a strategy ensures the maximum deterrence of persons contemplating mischief or assault. Well designed night lighting enhances the intellectual and emotional sense of safety on campus, encourages activity and facilitates the easy flow of both pedestrian and vehicular traffic.

GOALS AND OBJECTIVES OF LIGHTING DESIGN

SAFETY AND SECURITY - One of the primary goals of lighting is to provide enough illumination in a given space to enable distant vision, thus ensuring the ability of an individual to anticipate danger. Lights must not be so bright as to obscure one's vision by "blinding" the eye to areas adjacent to the immediate light source. Pedestrian activity, encouraged by the existence of adequate lighting, strongly contributes to a sense of personal safety and security.

SENSE OF PLACE AND CHARACTER - Organized patterns of light assist in the identification of objects and their components as part of an organized whole, i.e. the university premises as distinct from the adjoining streets. The use of closely spaced, pedestrian scale fixtures will project a sense of warmth and "neighbourhood" throughout the campus and will contrast strongly with the surrounding city environs. The use of white light sources on campus will further enhance this cohesive effect.

CLARITY OF CIRCULATION - One of the priorities of exterior lighting is to facilitate pedestrian orientation. Contrasts between buildings, paths and spatial areas should enable pedestrians to use the light fixtures as beacons to lead them from one zone to another.

Lighting gives motorists an awareness of place. Street borders and sidewalks must likewise be well lit to allow for pedestrian visibility. Lighting at entrances can be used to create a unique tone and character, as well as for orientation. Glare free fixtures in parking lots and vertically lit signage will also reinforce a sense of place and security.

IDENTIFICATION OF BUILDINGS AND MONUMENTS - Well designed lighting enhances the character and aids in the identification of buildings. Buildings provide night time orientation and create a backdrop for the silhouette of activity. Interior lighting provides a source of secondary illumination at night. Special features on buildings or monuments can be enhanced by the use of different or unique lighting.

ENHANCEMENT OF VIEWS - The use of glare free, low light levels at regular vantage points aid in long distance vision and enable pedestrians and drivers to see beyond their immediate position.

CONSIDERATIONS IN LIGHTING DESIGN

FIXTURE DESIGN - Light fixtures or "luminaires" give scale, rhythm, order, definition and focus to a space by day or night. Identifiable pedestrian scale fixtures should border all roads and major pathways. The design of the fixture should relate to the historical quality of the architecture. The unique character and lighting needs of specific buildings and areas require that many fixtures be selected to meet specific purposes.

ENERGY - Energy efficiency must be evaluated in terms of colour, glare and quality. Lighting should reinforce natural vision through the judicious application of light output. In accomodating night vision, where the problem is overbrightness, the solution is not simply to turn off lights but to reduce the overall level of light through a reduction in light energy or a modification of the type of light source.

COSTS - The total cost of lighting includes capital costs, energy costs, and maintenance costs. To achieve recommended goals, capital costs will be greater than they have been in the past. Shorter fixtures with more frequent spacing will double the usual budget in some areas. In other cases the total number of fixtures will be similar to previous orders, but different types will be required. Energy costs will be reduced or equivalent to the present system. Maintenance costs will be somewhat higher due to the increase in total number of fixtures. Long life lightbulbs will reduce frequency of re-lamping.

MAINTENANCE - No matter how effective the lighting design, it will fail to achieve its objectives without a good maintenance program.

CONCLUSION

The judicious application of the lighting principles in this report will ensure that the Queen's University campus achieves its maximum potential for safety, visibility and aesthetic appeal.

III BACKGROUND

A. QUEEN'S SAFETY AUDIT

The role of adequate lighting in securing the personal safety and wellbeing of students, faculty and visitors to the Queen's campus was highlighted recently in a safety audit report compiled by the University. That report reflected a growing public awareness of the risk, particularly at night, experienced by those inhabiting university campuses across this county. In response to this concern, Queen's has undertaken to address the issue of personal safety in a positive, responsible and constructive manner. In so doing, the university ensures, to the greatest degree possible, the safety of its students and faculty. It protects itself from any claim of negligence in the event of an incident and enhances the reputation of the institution as a safe and appealing environment in which to live, work, and study.

B. ASSESSMENT OF EXISTING EXTERIOR LIGHTING

The existing exterior lighting conditions on the Queen's campus are not ideally suited to night time pathfinding, orientation, and safety. Past lighting problems or deficiencies appear to have been dealt with on an ad hoc basis. The result is a noticeable lack of cohesion and continuity in the overall lighting design that detracts from both its effectiveness and appearance. Such an approach to lighting can also result in great financial expenditure without any compensating improvement in visibility or personal safety.

There is a seemingly random assortment of excessively bright lights throughout the campus. The glare and extreme contrasts between light and dark that result from the use of excessive wattage or inappropriate light sources can "blind" night time observers. Areas immediately adjacent to these lights are obscured by the contrast, creating forbidding "black holes". Ironically, the use of these sparingly placed, glaring fixtures creates a sensation of more rather than fewer shadows, impairing night vision rather than enhancing it.

Other areas of the campus have been flooded with light, limiting visibility to the immediate area surrounding the fixture and "blacking out" the view beyond. Vistas are likewise obliterated by unshielded lamps, while entrances are often unlit and uninviting.

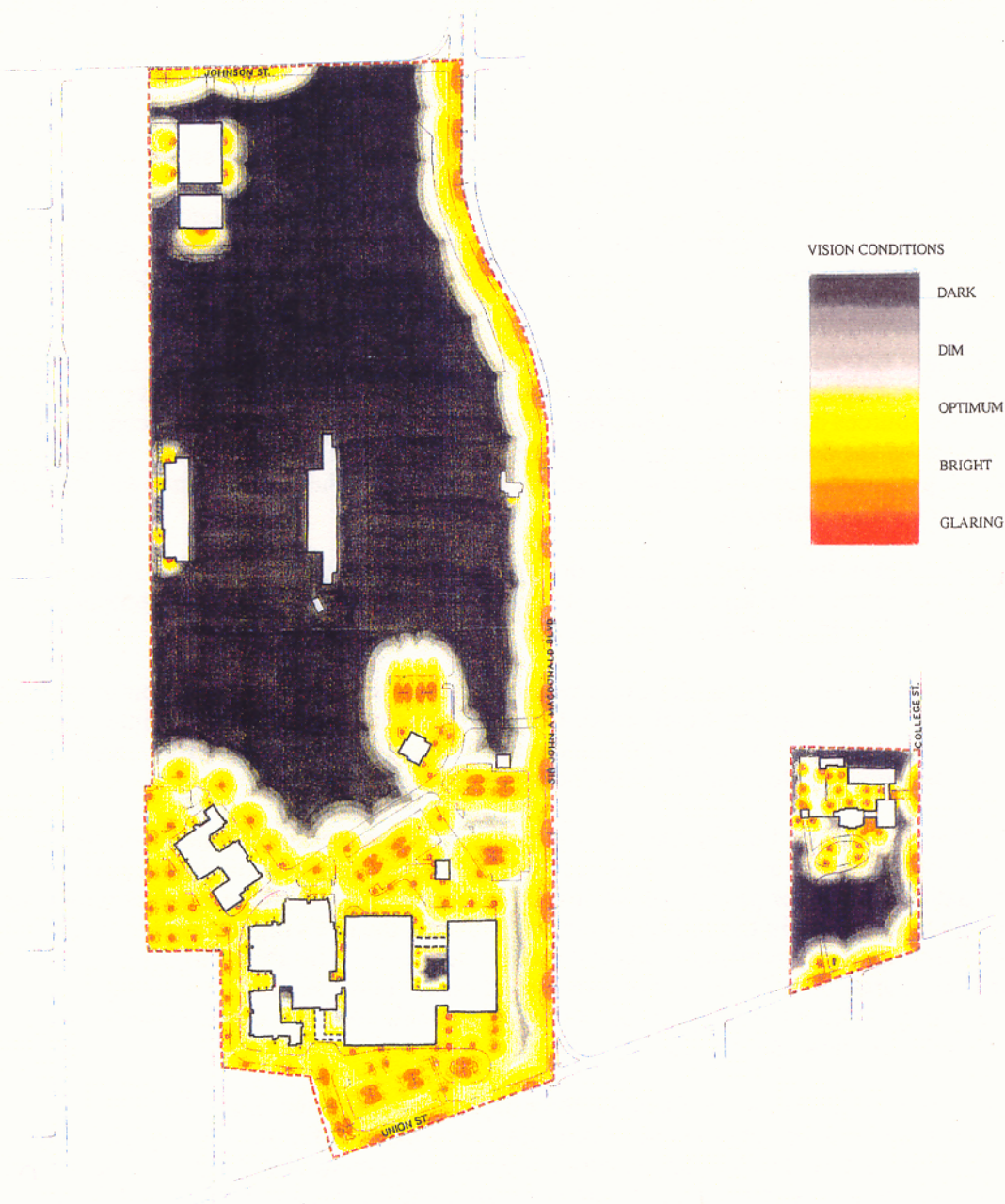
The lighting in courtyards throughout the campus ranges from forbidding and ominous to inviting and uplifting. The courtyards in the Mackintosh-Corry precinct have numerous low intensity incandescent sources that create a comfortable and sparkling quality while conversely, areas such as the courtyard between Gordon and Nicol Halls are forbiddingly dark.

The source or type of light used on the Queen's campus also influences night time visibility. The predominant use of high pressure sodium sources throughout the campus provides a light that is too monochromatic to allow for proper colour discrimination at night. Foliage appears brown and unnatural and the lack of blue in the sodium spectrum prevents the eye's night receptor system from properly adapting, compromising focus and motion detection. The ability to detect differences in colour after dark is a necessary element of object perception. Consequently, the use of these high pressure sodium lamps has a direct impact on one's ability to detect danger and should be assessed with these deficiencies in mind.

In addition to the type of lights used at Queen's, their haphazard placement makes the already confusing task of night time orientation and pathfinding even more difficult. The few pathway grids that do exist are distorted rather than reinforced by the placement of the lights. Proper night lighting should contribute to a sense of order and facilitate pathfinding, not confuse and disorient the observer.

A significant yet easily managed factor in the efficacy of night lighting at Queen's is the amount of foliage allowed to grow into the pedestrian's line of vision. Dark shadows, often close to the light fixtures, are created where this has happened, diminishing one's overall feeling of security. A proper pruning and maintenance program would ensure that vegetation does not become an impediment to night time safety.

As a final point, the style of fixtures used throughout the campus does little to compliment the richness of the architecture. There is no continuity between fixture types and many are of a modern, functionalist style that conflicts with, rather than enhances the character of the surrounding buildings. See Appendix "E" for existing fixture inventory.



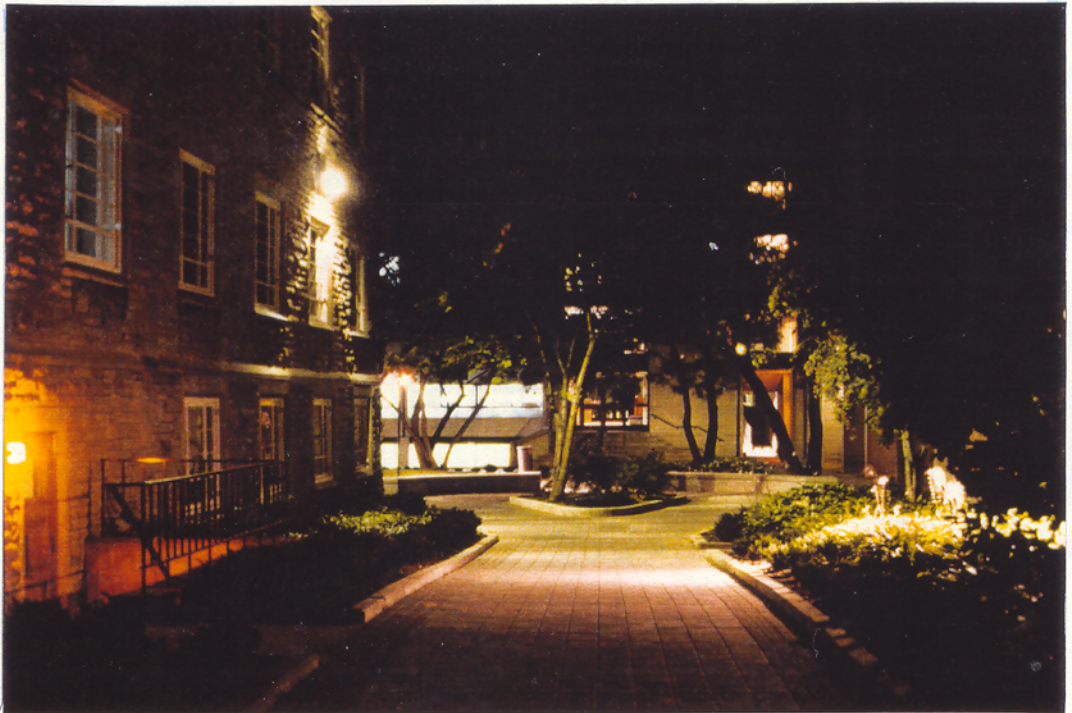
EXISTING CONDITIONS - NIGHT ANALYSIS - WEST CAMPUS



EXISTING CONDITIONS - NIGHT ANALYSIS - MAIN CAMPUS



UNIVERSITY AVE - Adequate light on street, but poor visibility into paths



MACKINTOSH-CORRY COURTYARD - Good general lighting & view into distance

IV BASIC LIGHTING CONCEPTS

A. VISION

Vision is made possible by reflected light interspersed with the light emanating directly from the source. The eye perceives the effect of light interacting with the environment, not the light energy itself. More specifically, it is the brightness and contrasts caused by the light sources and the reflecting surfaces that allow us to see, not the light energy that passes between them. It is critical to understand the brightness and contrasts caused by light sources and their reflectors which permit perception - not "footcandles."

Type of Vision:

As light hits the eye, there are three visual ranges by which it is perceived: daytime, night time and darkness. The lighting design for Queen's University will be developed to accommodate the night time or "mesopic" vision in order to maximize its use for both safety and visibility. A more detailed discussion of human vision can be found in Appendix B.

Eye Adaptation:

The eye requires time to adapt to low light levels. If exterior light levels are very bright the eye cannot quickly adapt to see objects in darkness. In order to see one's total night time surroundings, exterior lighting levels must not be too bright. Lighting levels from high pressure sodium lamps above streets may produce brightness in the daytime range of view. This level will be detrimental to effective night vision, if the eye is exposed to it for too long. Conversely, lowering the lighting levels in a rooftop restaurant allows a better night view through the windows. This same principle holds true in an exterior environment when looking from one area to another.

Psychological and physical needs require that people will be able to see as much of their surroundings as possible at night without being temporarily blinded by brightness. This temporary blindness, or impairment of visual acuity, is often caused by glare. Extreme contrasts of brightness and darkness can also produce a similar effect. As a result an environment with several large bright areas is actually less safe than one which has lower brightness, where light is more carefully distributed and allows the eye to comfortably adapt and see into shadows.

Contrasts and Brightness:

Dimensions, shapes, textures and differences in materials are seen through contrasts in brightness and colour. Contrast assists our perception of relative space, distance, dimension, orientation and shape. These contrasts are revealed by differences in lighting sources as well as by differences in the colour, shape, texture, and orientation of surfaces that are lit. Contrast is created by the nature of the light and by the type of surface on which it is reflected.

Every side of a three dimensional object lit from a single source is illuminated with a different intensity of light, depending on it's orientation and it's distance from the source. These differences allow for contrast in the reflected brightness. In addition, the character of the surfaces such as shiny metal or wet, smooth pavement can be mirror-like, reflecting a nearly exact visual image of the source. Rough building materials, or uneven surfaces, typical of foliage, will be much less perfect reflectors. Their unevenness and shadowing may direct very little light toward the viewer.

In order to easily see any given space, it should be lit so that distinct elements can be distinguished from each other through the contrasting intensities of their reflections. This is best accomplished by direct lighting, illuminating surfaces with different levels of intensity, and using light sources which contain all the visible light wavelengths that surfaces can reflect. As a general principle, the lesser the contrast, the more difficult the visual task of identifying separate objects will become. For example, the greater the contrast, the more easy it is to see individual trees in a forest; the lesser the contrast, the more the forest appears as a mass without character. The goal of lighting design is to understand what is visually important and to deploy light accordingly.

Contrast in Colour:

Surfaces are only thought to be "coloured". In actual fact, it results from some surfaces reflecting differing light wavelengths more efficiently than others. Not all light sources emit the entire spectrum of wavelengths. Surfaces can only reflect those wavelengths that are emitted by a particular source. When a light source which is rich in red and has little green energy - such as high pressure sodium - shines on a dark green leaf, the leaf takes on a dirty brown appearance. This colour will be due to the slight reddish tinge of the green, while the true green will absorb most energy and reflect almost none. When viewing objects under monochromatic light, differences can be detected only by contrasts in brightness, not colour.

Thus, a full spectrum light source such as an incandescent lamp requires less wattage to reveal differences between objects than the monochromatic light typical of high pressure sodium sources. Even great intensities of monochromatically biased high pressure sodium light will reveal little difference between objects. In terms of visibility, therefore, high pressure sodium lighting may prove to be less efficient than full spectrum source alternatives.

Glare:

Glare is produced by brightness within the field of vision that is sufficiently greater than the level of the light to which the eyes are adapted. Glare can cause annoyance, discomfort, or loss of visibility. "Direct" glare is caused by light sources, such as head lights, in the line of vision. "Reflected" or specular glare is caused by reflections of high brightness from polished or glossy surfaces like building glass, polished metal, or wet pavement that are reflected toward the eye.

Illumination vs. Brightness:

Illumination is the quantity of light falling on an object, and has been the primary criteria for designing lighting systems. However, people do not see the illumination. Instead, one sees objects by virtue of the light reflecting from the object to the eye, which is often referred to as the "brightness" of the object. The technical term for this is "luminance". Contrasts in luminance (or brightness) is how the eye sees objects. Luminance contrasts may vary while illumination may remain fixed. Luminance is affected by the light reflectance value of the object moderating the illumination. Luminance is measured in candelas per square meter, and simply put, is a product of lux times the reflectance. The night time design composition must be carefully arranged to provide maximum impact in terms of relative brightness and colour.

Summary of Basic Visual Response Criteria:

The exterior lighting design for this project will deal primarily with luminance, (the amount of light entering the eye from a surface or object), because of the true physical nature of visual perception. The design will adjust brightness, as far as practical, to favour "night vision" conditions. Lighting within the night time vision range allows maximum night visual

perception, both in terms of intensity, contrast and colour differentiation, and hence safety and comfort. Problems of eye adaptation will be minimized by maintaining uniform light levels in the night time range, both for visibility when moving into darker areas, and for visibility when coming from a brighter environment. In addition, other visual conditions such as brightness contrasts, adaptation time, movement, and glare will be carefully controlled by the fixture design to allow optimum visual discrimination.

The lighting design will aim for an above average standard of visibility for safety and comfort, with a level of energy conservation compatible with the University Master Plan. Proper lighting will add a sense of completion and permanence to the existing university environment, conveying the sense that it is a well organized, comfortable, and aesthetically pleasing place to live and learn.

B. LIGHTING AS PART OF A SYSTEM

Lighting may be regarded as part of a system, or subsystem, just as the Queen's University Campus is part of the larger Kingston community. The lighting subsystem includes the sources of light energy (the light bulbs) and means to control and direct the light energy (luminaires or shades); surfaces that receive the energy, reflect and absorb it, such as buildings, pathways, foliage, and the ultimate receptor of both direct and reflected light energy: the brain via the eye.

The lighting subsystem has an important visual impact both by day and night. By daylight the fixtures, which are made up of sources, luminaires, standards and bases, are seen as objects in a larger visual environment. As individual objects, the light fixtures will be more or less visible depending upon their position within a given view. When several objects, such as light standards, share identifiable or similar visible features, they can be perceived as a group. If objects are seen as a group, they can have a single visual personality, and provide less clutter. The group relates to the larger visual context in a much more positive way than do single objects.

Light fixtures can help to give scale, rhythm, definition, and focus to a space by day. If the fixtures used in separate parts of the campus have a visual connection, one can still perceive a continuity between the spaces. To minimize clutter and, at the same time, to use the lighting fixtures as groups of objects, a limited number of repeated fixture types is most effective. A hierarchy of light sources aid in establishing orientation and navigation throughout the university.

At night, the luminaires will be one of the most important parts of the visual picture, exhibiting all of their daytime characteristics, but more powerfully and actively. Lighting fixtures are a dominant feature of the night scene. To have an appropriate significance, they must be designed and located so as to interact positively with their setting. Their height and location must be arranged in an integrated and dynamic way that strengthens the design goals of the setting.

A discussion of the characteristics of sources and luminaires as they relate to this project can be found in Appendix C. Topics include lamp and luminaire efficiency, life, colour, distribution and energy conservation.



MACKINTOSH-CORRY COURT - By day



Same view at night. Good visibility & character

V LIGHTING STRATEGY

A comprehensive lighting strategy ensures that the buildings, streets, walkways and greenspaces of the Queen's campus are perceived by the eye as a coherent whole. This will create a memorable visual experience by day and an easily discernable and inviting vista by night. While proper selection and placement of lighting fixtures will enhance the overall effect, it is the quality of the light, the balance, the contrast, and the focus of the light in the night environment that will reveal the full richness and character of the Queen's campus.

The imposition of exterior lighting on a university campus must provide sufficient illumination to deter those who would use the cover of darkness for mischief or assault and thus provide the inhabitants of the campus with an intellectual and emotional sense of safety and personal security. It also must be accomplished with a human scale in mind and must exude a warmth sufficient to raise the spirits of the students, faculty and visitors.

The lighting strategy is intended to compliment the objectives of the Master Plan. In so doing, it is designed to accommodate the issue of personal safety while at the same time fulfilling the aesthetic and practical objectives of exterior lighting.

VI GOALS AND OBJECTIVES OF LIGHTING DESIGN

A. GENERAL GOALS

A fundamental goal of the lighting design on Queen's University Campus is to contribute in a positive way to the character of each area of the campus and assist in clarifying and strengthening their interrelationships.

Lighting can assist urban and landscape planning goals as well as provide functional help for the movement of people in an otherwise dark environment. Night lighting can passively illuminate the developed landscape and reinforce its character merely by allowing it to be seen or be an active, visual component of the landscape picture both by day and night.

A priority for the lighting plan at Queen's is to improve the quality of the night environment for the university pedestrian. It should identify spaces giving them their own importance as exterior "rooms" surrounded by the walls of the adjacent buildings. By so doing, lighting can offer a sense of order and hierarchy among the spaces on the Queen's University campus.

Arising from the static concept of spaces as rooms or "places" is the idea of their dynamic relationship to each other and to one's movement through a space, or from one space to another. This is the idea of vitality. It refers not only to the life of spaces as entities in their own right, but to the pedestrian as an active participant in these spacial experiences and their sequence. Lighting must encourage activity and invite the presence of people by helping to show the connections and relationships among spaces, and by encouraging movement through, between, and into spaces.

As part of the University Master Plan, the lighting fixtures can help to achieve these visual objectives by creating order, character, and rhythms of their own. The fixtures are the most noticeable objects in the night landscape, forming a sympathetic, strategic design resource by providing an ordered network in the overall composition.



ARCH STREET - Poor street lighting, surrounded by darkness



FLEMING HALL : JEMMET WING - Poor use of "security" lights, glare and surrounding darkness

B. SAFETY AND SECURITY

An important goal of lighting is to ensure that the streets and public spaces of the campus provide a sense of security. The lighting must allow a level of visibility which deters crime and promotes pedestrian activity. The ability to see one's environment well enough to sense danger helps to give one the feeling of security. At the same time one must be able to see a potential attack in order to avoid it. Because an attacker may approach or wait on a pathway, areas adjacent to walks must also be visible in all directions. This does not mean that uniform lighting intensities are required everywhere or in all directions, but that the lighting must be organized in such a way as to ensure the minimum level of visibility necessary to permit safe passage.

Lighting can make us feel safer. Indeed, the psychological aspects of security may be as important a reason for providing security lighting as the practical ones. Lighted places suggest activity. They imply that we will be able to see danger in time to react and that others can see us if we are in trouble.

To ensure security, lighting must be adequate at a sufficient distance to allow recognition and time for evasive action. Spill lighting which extends away from the sides of walkways is necessary, and should not be considered lost. If there is no other background lighting, lighting must be added to allow silhouette vision. Lighting sources must never be so bright in contrast to their surroundings that vision is obscured beyond the source. Light levels must be controlled so that the viewer is not blinded by the sources. Low overall contrasts ensure safety; there should be no "black holes" or danger zones. Other people, objects and vehicles must be easily recognizable.

Psychologically, pedestrians must sense that illumination is more than adequate for them to perceive and avoid danger. Lighting levels should be no higher than necessary to achieve these goals and they must allow the character of each area of the campus to be apparent.

Motion provides another dimension. Objects in motion are easier to detect than still ones but do not always require front-lighting to be perceived. Humans can be distinguished very well in silhouette. Thus, an attacker might be in an unlit area but seen easily if in sharp contrast to a lit surface.

Security for one's person and property comes through an appropriately lighted environment. Yet, it also stands to reason that in both human attack and property crime, the lighting alone cannot provide security. If there are no witnesses to physically assist in crime prevention, security will be threatened regardless of the lighting system. Night lighting improves security which in turn encourages pedestrian activity. Safety is thereby enhanced through an increase in the numbers of people present. This activity strongly contributes to one's sense of security and should be encouraged through the development of evening activities (restaurants, shops, entertainment) along major pedestrian routes.

The ability to identify potential hazardous situations comes from visibility. At this point it is important to reiterate that additional quantities of light do not necessarily improve visibility. The glare of many street lights impairs good vision as do their spectrally biased colour. Bright lights do not necessarily provide good vision. By using full colour sources of low brightness, placing them carefully and, if necessary, using glare shields, the proposed lighting system will provide better visibility with lower illumination levels than presently exist on some parts of the campus.



KINGSTON HALL - By day



Same view at night. Loss of quality

C. SENSE OF PLACE AND CHARACTER

The newcomer to Queen's is first struck by a sense of history. There are few examples of such a concentration of heritage buildings anywhere in the country. The lighting should reflect this character, both in the formal progression of the fixtures, and in the appearance of the fixtures themselves. Queen's has an invaluable asset in its architecture and mature trees. At present, this asset is often minimized by the use of excessively bright, poorly coloured sources that in most cases obscure the buildings and turn the surrounding foliage brown and unnatural.

D. SPATIAL COMPOSITION AND ORIENTATION

It is important that the new lighting clarify wayfinding, provide points of reference and establish a hierarchy of spaces. With the exception of University Avenue and Union Street, there are few strong axes for orientation on campus.

At present, pedestrian circulation is chaotic for newcomers. Few visual cues exist that would guide them through the many pathways that abound between buildings. As well, due to the placement of buildings, few routes are linear. In areas of similar architecture, distinguishing between buildings can prove difficult to the uninitiated. New lighting must guide the novice through the campus both by day and night. The establishment of a distinct hierarchy of pathways through the campus would define the pedestrian routes and indicate their relative importance.

New night lighting will give a clear definition to the spatial composition of campus through the selective identification of key elements, such as Grant Tower or Douglas Library. Orientation will be given by creating distinctive zones, lines, intersections, and focal points, and by defining spaces and buildings. Courtyards should be enhanced in order to re-inforce visual cues that can be used as orientation points.

The proposed lighting will be used to mark or identify, to create visual foci, to define, and to connect. Lighting will mark entrances to and spaces within the main campus. It will identify passages between spaces. It will mark intersections of streets or walkways or centres of activity. It will emphasize various focal points in these spaces such as statues or fountains. Lighting will be employed to create visual events where none currently exist. For example, a group of lights might be placed in the center of a particular space to distinguish that space in the night environment from some other space; or a particular building of a group of buildings might be floodlit to provide a terminus or focus at one end of a walkway.

By varying lighting intensities, or numbers of fixtures, relative emphases can be placed on various areas. In this way the perception of the campus as a whole will be created, and the focus placed on the centre of the campus. In addition to the practical advantage of this focus, the visual picture is made substantially richer and more satisfying.





SPATIAL COMPOSITION & BUILDING EMPHASIS - MAIN CAMPUS

E. PEDESTRIAN CIRCULATION

People must be able to move through the campus in a straightforward fashion with a clear indication of how to navigate to other destinations or zones. The pathways must cater to the pedestrian if activity is to be fostered. Clearly defined and accentuated intersections, landmarks, and greens contribute to the night time orientation of pedestrians and motorists alike.

Lighting must illuminate and show contrasts between buildings and pavement in order to lead the pedestrian safely through the "pathways" which link one zone to another. The pedestrian lighting must enable the person to sense movement and to see destination goals. General lighting should not be glaringly harsh or excessively bright. Colour, three-dimensionality and depth should be perceived realistically. The scale of shadows, fixture spacings, sizes, lighting angles and heights should be compatible with and complimentary to human scale and normal walking speeds. Lighting levels should be modulated to provide a sense of direction, focal points and interest. Furthermore, elements of sparkle and movement can add stimulation and a sense of liveliness to the pedestrian paths.

Primary pedestrian circulation routes must be easily identified, while secondary routes should be less imposing, such that the hierarchial differences are obvious.

One of the greatest single aids to pedestrian orientation would be a re-organization and alignment of landscape elements and paving patterns into a cohesive system or grid. At present, numerous seemingly arbitrary pathways, the placement of buildings and the lack of identifiable corridors and intersections inhibit the wayfinding process.

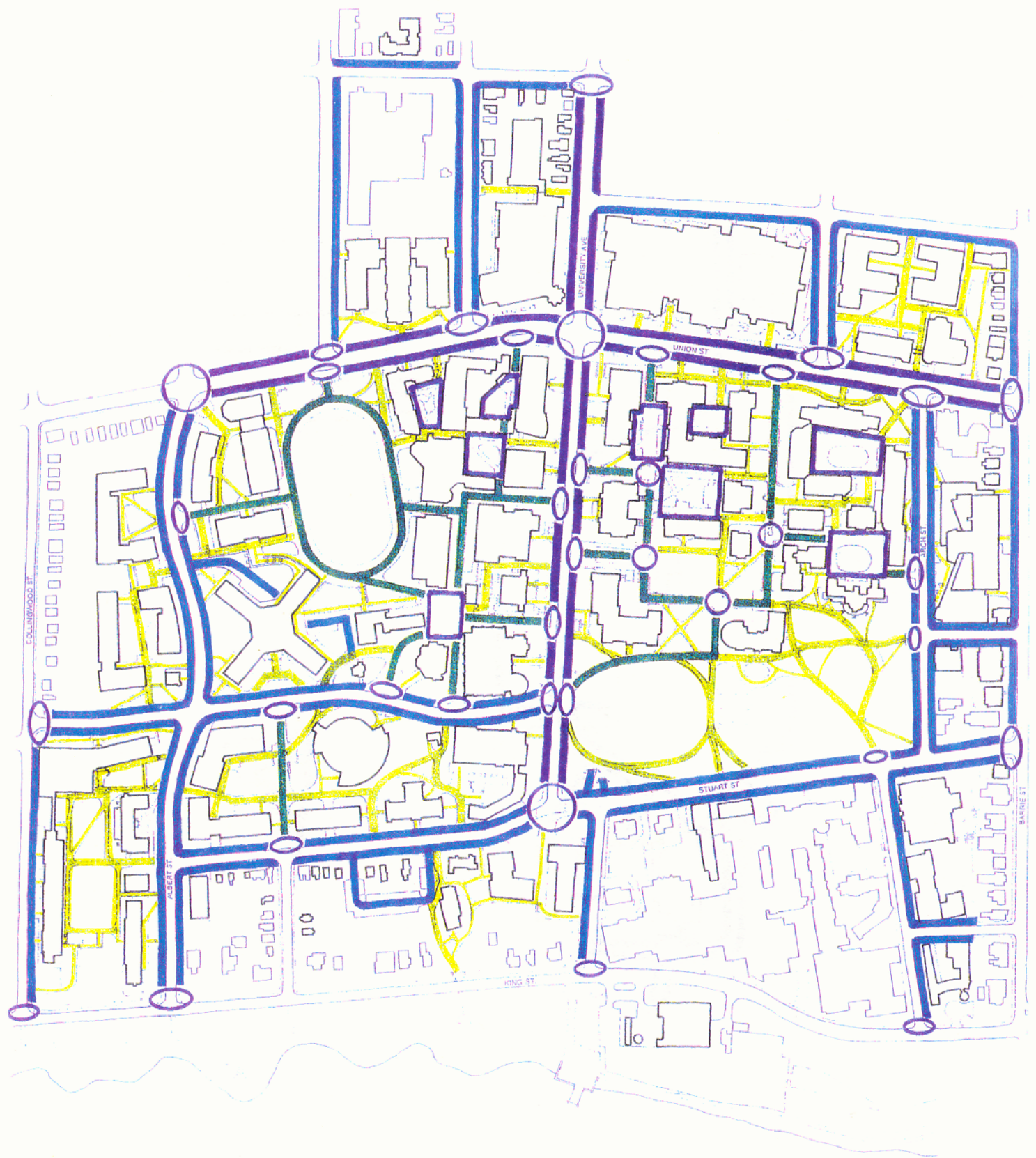
F. VEHICULAR CIRCULATION AND PARKING

The new lighting will signal a change of place to motorists entering the campus from the surrounding drives and city streets. Lighting at entrances and intersections will set a unique tone to the campus.

Entrances, gateways or portals to the campus will be given a special importance. Upon arrival, one should be given an impression of the character of the University and the magnitude of the area. Special fixtures or groupings may be used as part of this expression. The shape of the light fixtures in the day and the light effect at night can reinforce a harmonious concept.

Primary vehicular routes such as Union Street and University Avenue should be differentiated from secondary roads such as Arch Street or West Stuart Street by means of varied fixture spacing, stature or intensity. Bus stops should be clearly identifiable at night, possibly through the use of coloured light.

Entrances to parking facilities should be recognized as such, yet not dominate the visual field with the degree of impact accorded to intersections. The lots themselves would need to be dealt with on a case by case basis. Some larger lots could undoubtedly be equipped with shielded roadway style fixtures, while smaller lots could be dealt with utilizing a more pedestrian-scale approach.



CIRCULATION - MAIN CAMPUS



CIRCULATION - WEST CAMPUS

G. BUILDINGS AND LANDMARKS

One of Queen's greatest assets is its wealth of heritage architecture. Seldom does an opportunity exist for lighting to enhance the appearance of an institution to the extent it does on this campus.

Well lit buildings will provide very important points of orientation and a sense of place at night. Buildings of historical or architectural significance and night activity centres will stand out from their neighbours. The soft ambient revelation of the building facades will define the enclosure of the spaces and form a light backdrop for silhouetting trees and vegetation.

The solutions for building lighting will be numerous and related to individual architectural features and viewing positions. In this report, an overview of the more widely applicable lighting solutions are offered.

Lighting one building from the surface of an adjacent structure is a simple solution. This method will provide general flood lighting on the facade of a building, but, obviously, is limited to those buildings close to each other, or those that offer a good aiming angle.

Another method of lighting the facade of a building is from an existing light pole. This solution could be most useful in lower buildings and those with a texture worth highlighting. Lights may also be ground mounted in some situations, particularly if the building is set back in the landscape and the shrubbery offers adequate cover for the fixture housings.

Using wall bracket lights on the side of a building can contribute to lighting the building and the sidewalk. They can add character as well as give the building an appropriate scale at the lower level. The style of fixture depends on both the type of architecture to which it is attached, and its location on the campus.

The management of the interior light from buildings often defines their shape and provides indirect light for the outdoor space. Policies must be established to determine which lights will remain on late at night and after the building is closed. Emergency and security lighting circuits can often be assigned to the fixtures which give the best aesthetic or most effective exterior light. Using this method, the building is illuminated without the cost of additional exterior lighting.

Relative indoor/outdoor light quantities must be well designed to be effective. At building entrances and lobbies the light should be balanced to provide a welcome, safe entry, but never too bright to cause difficulty seeing as one exits into the night. Exterior fixtures should provide an acceptable transition that allows the eye to adapt to changes in light from one zone to another.

Many of the strategies for lighting buildings may be employed for lighting landmarks and monuments, depending on their size and location on the campus. In a few instances, the art object can be spotlighted from fixtures mounted on nearby buildings. When this is not feasible a monument can be illuminated from floodlamps mounted on existing light posts or on posts of their own. Base floodlighting is an especially successful technique for art because it provides depth and enhances the three-dimensional and textural aspects of the sculptural form. The source selected to illuminate each building, monument, or sculpture will depend on the colour, texture, and form of the object to be lit.

Solutions for each area or building must be appropriate to the overall lighting design. The relative importance of architectural features should be demonstrated through a hierarchy of lighting.

Grant Tower is probably the most prominent architectural feature on campus. Lighting, whether through the type of source or the intensity, should differentiate it from the other heritage structures.

Other buildings of historical importance are the Douglas Library, Ontario, Kingston and Richardson Halls, the old Arts Building, Summerhill and the south face of Fleming Hall, Jemmet Wing. The streetside facades of Richardson Hall, the older portion of the Physical Education Centre and the Agnes Etherington Art Centre also require some emphasis, as do the building facades in the old medical courtyard.

The modernist face of Stirling Hall is unique, and as an auditorium with considerable night traffic it should be lit accordingly. Entrances to other auditoriums should also be rendered in a hospitable light to enhance their value as meeting places. This type of entrance also exists at Etherington, Harrison-Lecaine, Ellis, Dunning and Dupuis Halls. On the west campus, the water tower is architecturally deserving as a focal point for night lighting.

H. SIGNAGE AND WAYFINDING

Lighting must work with the signage to facilitate wayfinding throughout the campus area. Not only do light fixtures provide illumination, but they create points of reference for circulation routes and intersections both by day and night.

Signage must be properly illuminated in order to be of use at night, so a high degree of co-ordination between these two plans must exist in order to create a successful medium for the message.

Existing signage along campus streets is presently chaotic and difficult to find. At night, many of the signs are poorly lit. New signs should be placed in such a way as to ensure they receive maximum illumination from the adjacent lights. Some major signs may have specific lights directed toward them.

I. VEGETATION AND LANDSCAPE

The University is fortunate to have a wealth of mature trees. These older, larger trees enhance the visual, thermal and even acoustical properties of the campus. Unfortunately, trees often interfere with the distribution of light in the night environment. With larger trees, pruning of the lower branches to a level just above pedestrian height will ensure the reduction of shadows and blockage. This is difficult, if not impossible to do with smaller trees, as they could be completely denuded in the process. Future plantings must take the lighting into consideration.

The most critical height of vegetation with regards to lighting and safety is from roughly knee height to an arms length or two above the head (Roughly 0.5 to 2.5 meters). The absence of visual obstacles in this area permits the passage of light to the observer and minimizes shadows. It also permits light to shine unobstructed from any vertical surface in the distance, allowing the pedestrian the ability to see objects or other people by contrast. Large open areas are made safe in this way as long as a clear and open vista exists between the observer and the illuminated vertical surface.

J. EVENTS, GATHERINGS AND EXHIBITS

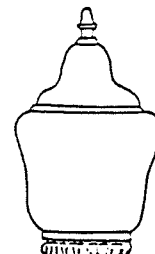
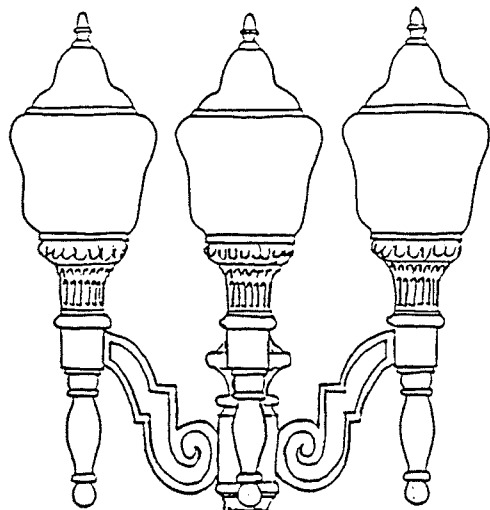
Lighting systems must be able to respond to special activities. Squares and greens will become staging areas for meetings and entertainment. The permanent lighting should not be expected to fulfill these needs. High power outlets will be located at key positions to plug in portable theatrical lighting and sound systems. Many post lights should have 110v outlets for small events and holiday lighting displays.

K. SEASONAL CHANGE

The lighting system must work for all seasons. There should be no need for different lighting fixtures, or lighting effects for different times of the year. A good lighting design takes into account thick foliage and bare trees. Wet, slippery, or icy pavements must be illuminated to be apparent without reflected glare. Even windy, cold, open spaces should appear warm and inviting in the winter.

L. FLEXIBILITY FOR FUTURE GROWTH

Lighting design guidelines, when applied, must allow for campus growth and program changes. Future perceptions of the campus will stimulate new lighting expressions. New light sources, new technology and equipment will evolve and be integrated into the system in future years.



Nodal

Typical

PROPOSED PEDESTRIAN SCALE LIGHT FIXTURES

VII CONSIDERATIONS IN LIGHTING DESIGN

A. PEDESTRIAN FIXTURE SELECTION CRITERIA

Whether day or night, light fixtures can be useful, unifying elements, adding order to our visual scene. A hierarchy of fixtures in the same "family" gives a sense of the relative importance of pathways or routes, while maintaining the context of the larger design. Hierarchies can be established in many ways. A single fixture can be mounted at different heights, or placed with different spacing or rhythms. In systems with the same spacing, the fixture can vary in form, as can the intensity or colour of the light.

Regardless of the hierarchy, all fixtures must be appropriate to their surroundings and reflect the mood and purpose of the institution or setting. Their design must also take into account the psychological and physiological reaction of individuals to the management of that light.

Queen's has one of the richest collections of heritage architecture in the country. It would therefore be appropriate to use light fixtures that reflect this history as well as the intellectual context of the campus.

In order to maintain a sense of pedestrian scale, fixture height should be in the 3.4 to 4m range, and should have a traditional appearance. Studies of local history suggest the use of an 'acorn' type luminaire mounted on a classical post. Many existing fixtures at building entrances indicate that the use of a hexagonal luminaire would also be appropriate. Photometric and psychological factors indicate that a white light source in the output range of 3000 to 5000 lumens is most suitable for a single luminaire.

Metal halide is a possible choice. Compact fluorescent sources should not be ruled out, as thermostat switching and proper thermal design can offset the problems of Canadian winters. Inductive sources, while expensive at this time, show great potential for savings in terms of power and maintenance and are not affected by the cold.

No direct or reflected view of the lamp should be possible. An opal diffuser and/or refractor is preferable, and the emitting surface should be as large as possible in order to decrease brightness. Maximum brightness should be kept below 2400 cd/m² (approx. the brightness of the full moon)

In addition to the regular, single luminaire post lamp, the use of similar multi-luminaire 'nodal' fixture of the same family is recommended at the intersection of routes and at important entrances. Using fixtures at intersections not only supplies more light to these areas, it adds important emphasis. Whether at night or day they say, "You have arrived".

Existing street lights that are to be retained should be converted to a metal halide source and equipped with large shields where appropriate.

The pedestrian fixtures used on the west campus should conform to the same technical criteria as those on the main campus, yet not necessarily be the same design. A more modern expression may be more appropriate. Upgrading of the existing mercury vapour opal diffuser fixtures to a more efficient, less bright source is a viable option.

B. PEDESTRIAN FIXTURE SPACING CRITERIA

The spacing of fixtures will be determined by architectural and compositional criteria. Movement and rhythm through the campus will be important in deciding the height and space between units. The quantity and quality of the light itself will be determined in harmony with the desired spacing.

Investigation of circulation has revealed what appears to be four distinct levels of circulation on campus: primary and secondary routes with vehicular and pedestrian traffic, and internal, pedestrian only routes (with service access) at primary and secondary levels.

Differentiation between these circulation types could be established through various means. Fixtures in one area could be taller than the other, or of different proportions, or formally different, or a combination of these elements.

Primary vehicular routes would require a cross-road pairing in order to visually re-enforce them in as strong a fashion as possible. Spacing between pairs would be roughly 15m. Streetlights would need to be retained due to roadway width, but would require enhancement in terms of light source quality and glare control. In many cases, fixture placement can be adjusted to accommodate existing street light locations, but situations may arise that might necessitate the relocation of an existing streetlight.

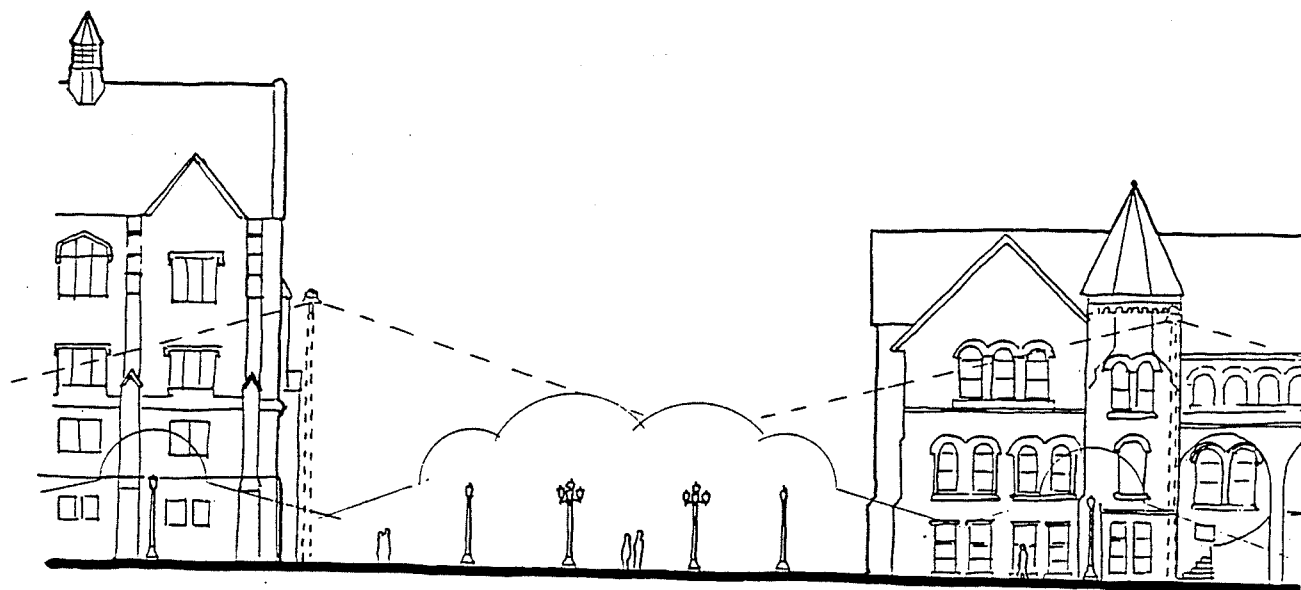
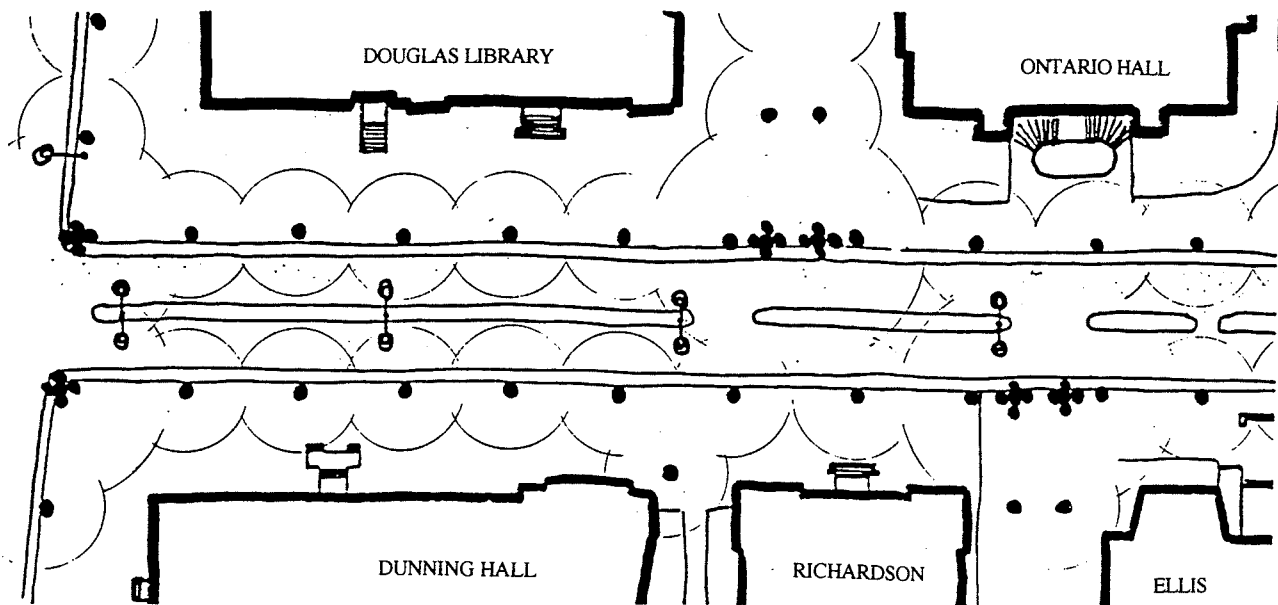
Secondary vehicular routes would utilize a staggered pattern, with fixtures spaced roughly 20m on each side, with cross street offset of 10m. This progression is less strong than the primaries. These roads are generally narrow enough to allow the deletion of street lights altogether. The present low pressure sodium fixtures in these areas generate an unacceptable light quality, and are not retro-fittable to other sources. Wider secondary vehicular areas may require street lighting, but these areas represent a small portion of the total secondary circulation.

Primary pedestrian only routes would use a spacing of roughly 15m and again use formal pairing. The main difference between these routes and the vehicular routes is width. The pedestrian routes are much narrower, which allow the pairing to read much more strongly. The narrowest pathway width would be determined by requirements of service vehicle access and snow removal. Secondary pedestrian routes would utilize staggered spacing of approx. 15m (or 30m per side) or 15m placement on one side only, depending on the requirements of the site conditions.

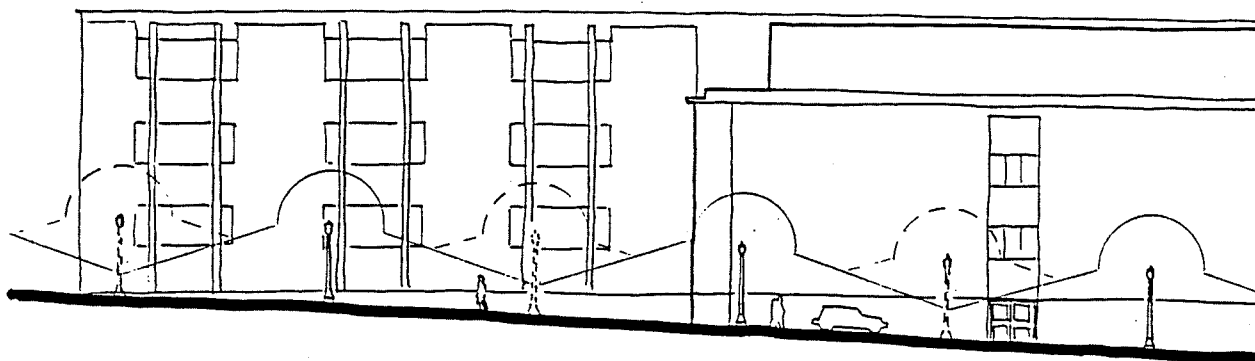
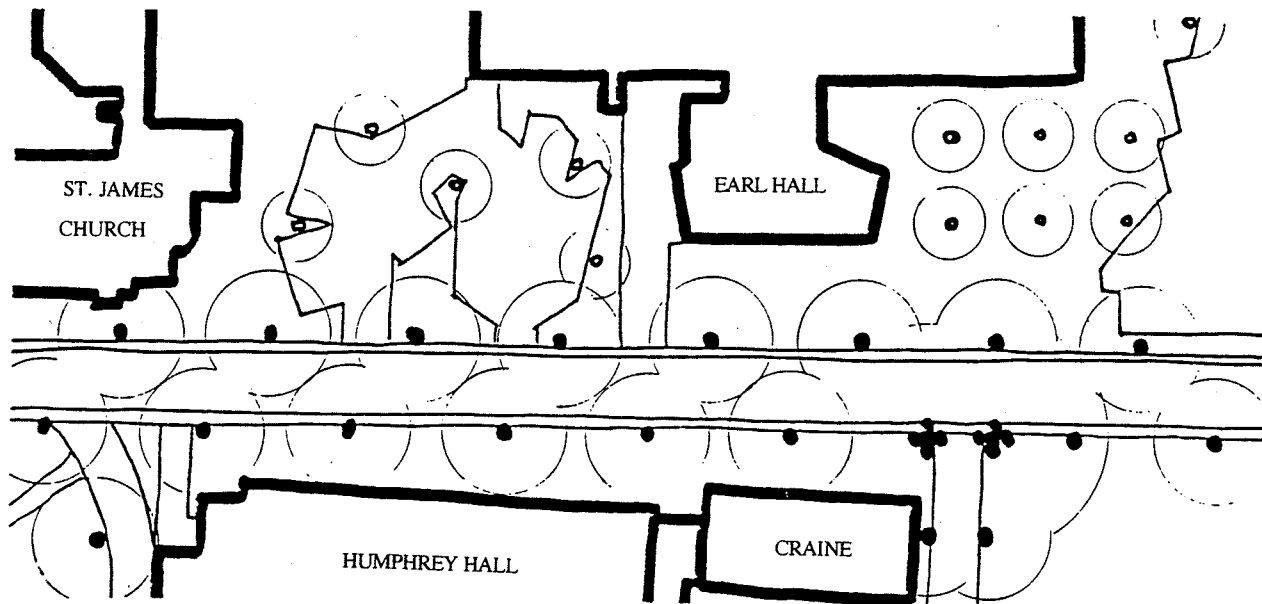
These preliminary spacing distances are only rough guidelines, and implementation would vary according to specific applications, considering intersections and building entrances and locations.

There is a historical element of fixture spacing that should be noted. Only through the advent of high output H.I.D. sources has urban fixture spacing widened to what is now normally used with Cobra-heads lights. Traditionally, fixture spacing was very similar to that proposed, as luminaires were initially low output gas mantle, and later incandescent sources.

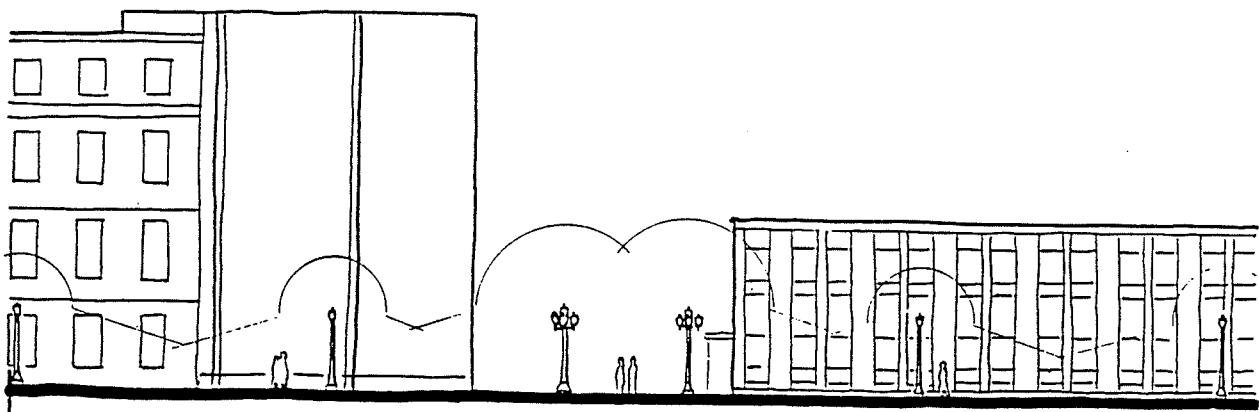
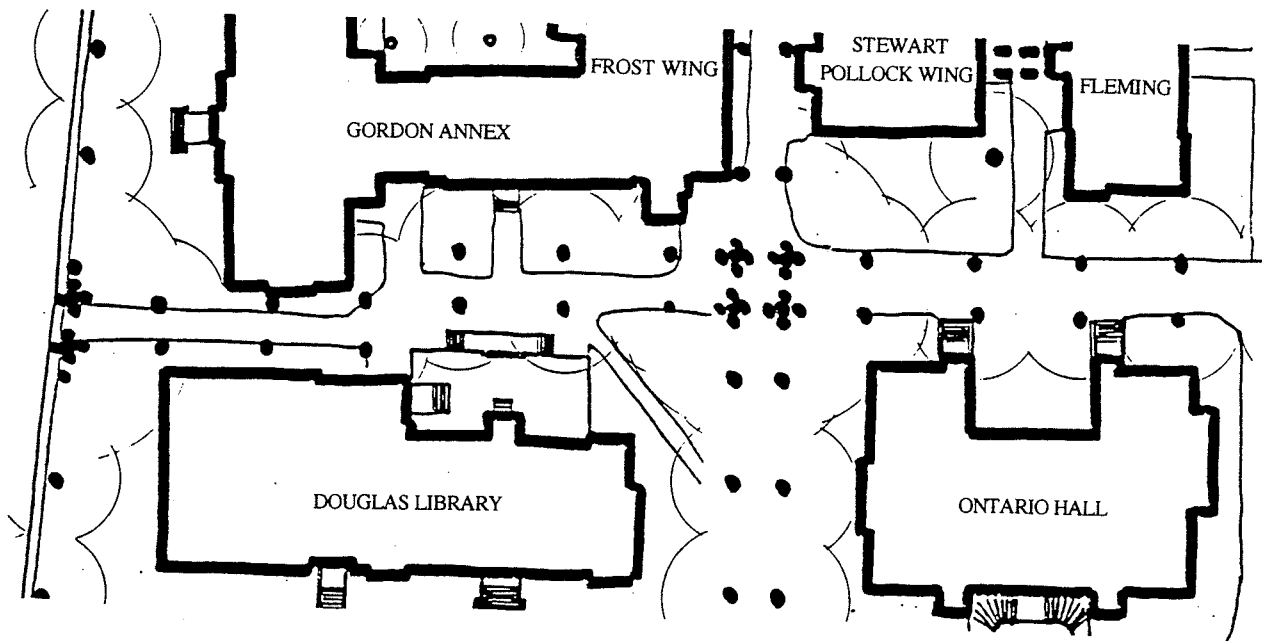
On the west campus, the spacing of fixtures can work around the existing main route spacing of about 20 meters. In this fashion, many existing locations can be retained.



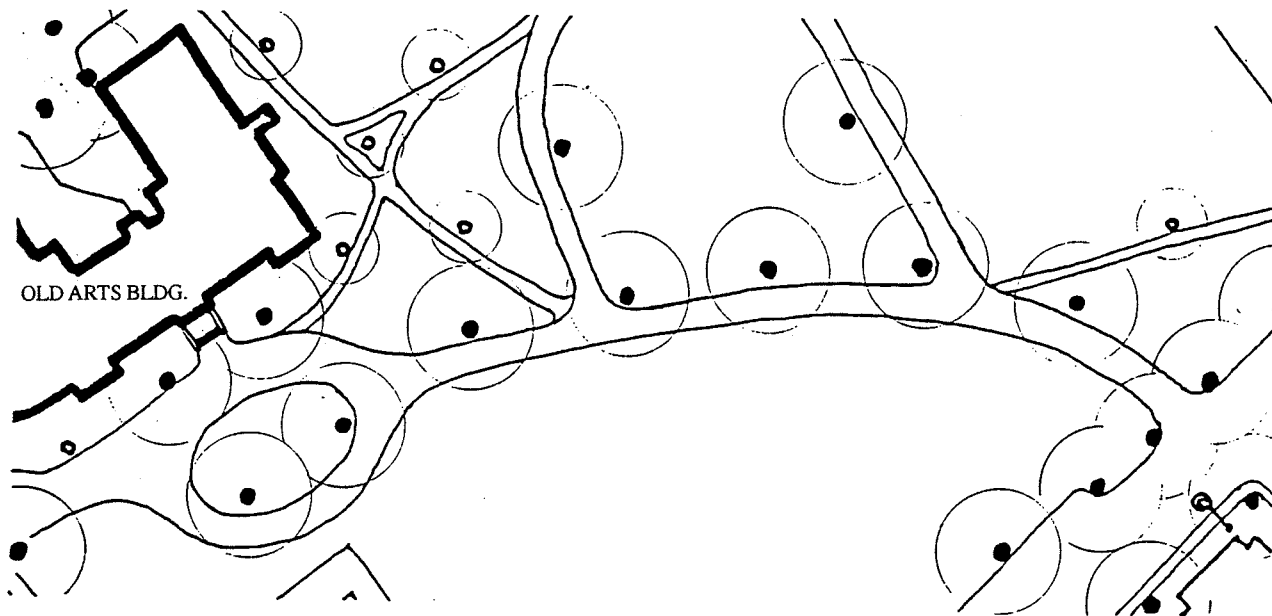
PRIMARY VEHICULAR / PEDESTRIAN ROUTES
Formal pairs, 15 m spacing



SECONDARY VEHICULAR / PEDESTRIAN ROUTES
Staggered pattern, 20 m spacing per side, 10 m offset



PRIMARY PEDESTRIAN ROUTES
Formal pairs, 15 m spacing



SECONDARY PEDESTRIAN ROUTES
In-line or staggered, 15 to 20 m spacing

C. ENERGY USAGE

The lighting principles follow an energy conservation strategy that takes into account design objectives as well as value. Sources must not be selected solely on the basis of their efficiency. The efficacy of high wattage sources must be weighed against their colour, potential for glare, and the consequent diminishment of visibility. In general, if colour can be disregarded, the source which provides the highest efficiency with the longest life will result in the lowest long-term costs.

As mentioned earlier in this report, colour has a very important impact upon our perception of the environment. While high pressure sodium sources have a higher efficacy than metal halide sources, the importance of "realistic colour" in lighting the environment makes the choice of incandescent, compact fluorescent, inductive, and metal halide sources more attractive.

One of the most obvious, but least considered means of energy conservation through lighting design is the avoidance of lighting spaces or surfaces that do not need to be lit. This dictates the necessity for selecting fixtures that control light output and direct it as desired. The relatively low lighting levels required for night time vision maximizes the possibilities for energy conservation, and for minimum maintenance and low initial fixture costs.

Controls for exterior lighting also are important in managing energy. Conservation efforts in selecting efficient lamps and fixtures are wasted if lights remain on when not needed. Therefore, a number of systems can be incorporated to minimize the energy use to only those times when light is required. See item F below: Lighting Control Systems.

Energy conservation is a vital factor in the selection of lighting sources and fixtures. It should be emphasized that minimizing energy use, without concern for all the integrated criteria, can be counter-productive. If the lighting system does not achieve the goals providing safety, visibility, comfort, and if it does not make the campus a desirable place to be, then all the energy used will have been wasted.

D. COST CONSIDERATIONS

Total cost and energy expended for the various lighting systems within the campus play a major role in creating a smoothly operating and efficient atmosphere. In respect to a lighting scheme for the University, first-cost, life-cycle cost, and energy use must all be considered in addition to performance, visibility and other aesthetic categories.

In order to select the optimum light fixture with the physical and operational characteristics that best integrate them into the campus environment over a long life span, some premium must be paid. In practice, this cost increment is not great. Standard, restored, replicated or existing fixtures, sometimes with optical modifications or lamp type change, will frequently meet the criteria. Even the cost of the modifications becomes slight, especially when compared with benefits, if basic materials and finishes are standard.

The ordering of significant quantities of fixtures of one type at one time can change the cost of a custom or restored unit into that of a standard unit. This suggests that relamping large areas of the campus at once will be less expensive in cost per fixture. Most standard units are "manufactured to order" when quantities needed are large. For quantity orders, care in the selection and design of fixtures translates into appropriate lighting over a long life.

For example, a Canadian made custom fixture of traditional design would cost roughly \$1500.00 per unit, (not installed) for the first 50 or so units. Cost per fixture would drop roughly 10% on subsequent orders.

By comparison, an imported, standard item of similar design, would be about 40% more costly; conversely, the cheapest acceptable minimalist ball globe fixture, is only about 20% less expensive than the local custom item. Balancing both cost and aesthetics would favour the local custom option.

Life-span of sources is important, both because of the cost of the lamp and the maintenance costs associated with lamp replacement. Because the major cost of relamping is labour, not the lamp itself, lamps should be chosen for maximum life, keeping in mind of course, other requirements such as colour and intensity. A uniform life span will help to prevent intermittent burnouts by allowing simultaneous relampings in large areas. For lamp life ratings refer to Appendix C: Life.

Energy costs can be minimized in two ways: firstly, by selecting the most energy efficient lamps and fixtures that meet a wide variety of criteria; secondly, by providing control systems that manage the on/off cycles by both minimizing the "on" time to only when required.

The recommendations in this report, if implemented according to the Master Plan, would result in an increased maintenance cost of roughly 60% due to higher fixture density. The long term electricity cost, however, could decrease by approximately 25%, as a result of the use of less bright sources.

E. RE-USE OF EXISTING LIGHTING EQUIPMENT

Upon approval of the general lighting concepts and specific site lighting objectives, existing lighting equipment can be assessed for its suitability. If existing fixtures are deemed appropriate or merely need a minor modification, they will be incorporated into the final solution, realizing significant cost savings. A general inventory has been made, resulting in the following general comments.

Many public parts of the campus are lit with wall or roof mounted H.I.D. floodlights. Regardless of source type, fixture condition or the cost of new installations, it is strongly recommended that these fixtures be removed as they are detrimental to pedestrian night-time vision. Lights of this type typically blind the observer rather than illuminate what the observer is trying to see.

The post mounted "hat" type H.I.D. fixtures used throughout the campus are also not recommended as their style and light source type are inconsistent with the new lighting concept and master plan.

Opportunities exist to re-use these H.I.D. fixtures in areas such as the West Campus, and in service or parking areas where exposure is minimal or there are no requirements for consistency with main or secondary routes. Minor modifications or lamp type change may be all that is required.

Numerous existing incandescent building entrance fixtures, typically of appropriate historical design, can probably be retained with little or no modification. While Queen's has raised concerns of the energy costs of these fixtures, it should be kept in mind that a psychologically inviting entry is very important and often overlooked.

As each phase of the master plan is implemented, all existing fixtures implicated in that phase will be reviewed to determine whether they should remain, remain with modification, or be removed.

For more specific commentary on existing fixtures, see Appendix F: Existing Fixture Inventory.

F. CONTROL SYSTEMS

Any lighting solution that addresses concerns of safety, energy use, aesthetic appreciation is dependent on lighting being turned on and off at appropriate times. New facilities often control exterior lighting by combinations of timers or light intensity photo-optic sensors integrated into a central control computer.

Retrofitting with computer control systems is often cost prohibitive. Installing independent timers or photo-optic sensors to control a zone of lighting is however very cost effective and easily implemented. These sensors can be pre-set to assure appropriate on/off times, and take into account seasonal changes of daylight hours. They can also allow for the phasing of zones to be turned on so as to minimize the cost of peak demand load energy premiums.

Where minimum outdoor starting temperature is a concern, such as with compact fluorescents, sensors can be integrated with thermostats to assure lamps are turned on or kept on when outdoor temperatures become too low.

There may be instances where new sensors should be added to existing interior lighting systems to aid in the lighting of exterior areas immediately adjacent to buildings. The interior ground floor perimeter lighting could be left on to illuminate the grounds through windows in lieu of a more costly option of adding new exterior lighting.

G. MAINTENANCE

Maintenance of the lighting system on the Queen's University campus is vital to preserving the success of the design. If relamping and repair of electrical problems are not done, the best of lighting efforts will be worthless. Consequently, the design and selection of fixtures should be carefully considered for ease of repair, relamping and cleaning, and longevity as well as their vandal-resistant capabilities.

It is important that maintenance, operations and security personnel have a clear policy governing procedures to detect burnt out lamps, to assure limited access to controls with tamper proof switches and to effect timely repairs or replacements. This is the only way to maintain optimum security and appearance with minimal energy costs.

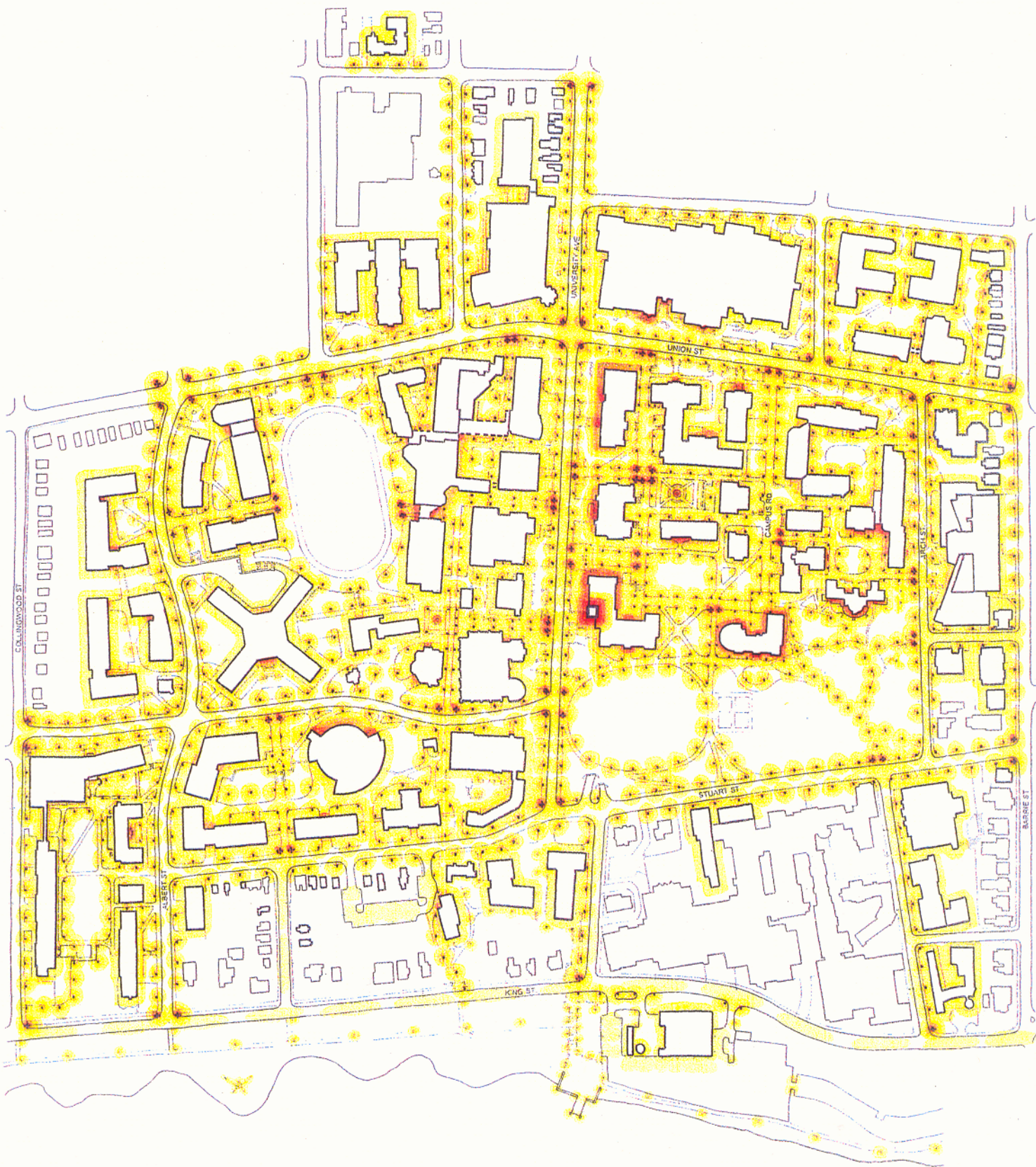
The new lighting design can facilitate maintenance and simplify stocking and replacement by the use of standardized fixtures. It will ease the cost of relamping by keeping the types and sizes of luminaires to a minimum. A wise fixture selection combined with a tight maintenance program will ensure the lighting design realizes its maximum potential.

VIII SUMMARY AND MASTER PLAN DRAWINGS

The lighting design proposed for the Queen's University Campus is intended to meet comprehensive design criteria as well as to further enhance the image of this university as an important centre for education not only in Kingston, but in Canada and throughout the world. Lighting will contribute to the Queen's environment by enhancing its reputation as an exciting, safe and comfortable place, to study, work, and live.



WEST CAMPUS - MASTER PLAN



IX APPENDICES

APPENDIX A

PSYCHOLOGY OF NIGHT LIGHTING

The psychology of lighting can be subdivided into two general categories; lighting which helps one to perform intellectual tasks, and lighting which helps to achieve desirable emotional responses.

Intellectual Tasks:

In a sense, the assistance of night lighting for intellectual tasks is as necessary a function as is lighting to assist one in physical movement. Movement is aimless if we cannot see where we are, where we want to go, and choose an appropriate route to get there. Thus, another basic function of night lighting, and one which is essential, is to help to give order to the campus at night. Lighting can be used to create visual identification of places, routes and destinations. Lighting also should assist in explaining these physical parts of the environment, and in differentiating between them by setting up hierarchies of relative importance between places, routes and destinations.

To accomplish these objectives, lighting can be used to mark or identify, to create visual focal points, to define, and to connect. Lighting can mark entrances to the campus and to various spaces within each area. It can identify passages between buildings or between spaces. It can mark intersections of walkways or seats of activity. It can emphasize existing focal points within spaces such as statues. In addition, lighting can, by the relative numbers of fixtures and their placement, create a hierarchy of visual importances between these functions, and within each function. Lighting also must be employed to emphasize graphic signs for direction, information and orientation, even if this is accomplished by locating signs under lights, rather than by installing special sign lighting.

Lighting can be employed to create visual events on which to focus where none had existed. For example, a group of lights might be placed in the center of a particular space to distinguish that space in the night environment from some other space; or a particular building of a group of buildings might be floodlit to provide a terminus or focus at one end of a walkway. By varying lighting intensities, or numbers of fixtures, relative emphases can be placed on various foci. In addition to the practical gain from relative brightness emphases, the visual picture is made subjectively richer and more satisfying.

Outdoor lighting can help to define various "ideas" in the landscape. It can bring shape and definition to a particular space which otherwise would be incomprehensible at night. It can, by the rhythm and location of fixtures show that a walkway really is a passage from here to there, and in the process show that here and there are linked together.

Lighting also can define the limits or boundaries of the core zone if its character is sufficiently contrasted with the city lighting that surrounds it.

There is an aspect of security lighting that is intellectual. This is the role of general lighting to signal danger and illuminate one's options in the event that danger is recognized: how far one is from the safety of a building, where other people are, where any refuge might be, the characteristics of the danger.

Emotional Tasks:

The emotional and aesthetic use of lighting in the night landscape environment are well known, but we have said that lighting no longer can be employed solely for these purposes. Lighting will either further aesthetic and emotional aims as a consequence of its functional purposes, or it will interfere with those aims. With careful planning and design, lighting can contribute to the aesthetic value of the campus both at night and during the day, as well as perform its necessary practical functions. The physical appearance of the luminaire; the colour, shape and scale; the placement, sequences, and rhythms of location; the continuity of fixture types; and the appearance of the lighting quality: the brightness and color of the source; and the characteristics of the light pattern; all will evoke emotional and aesthetic response in the viewer.

These visual aspects of lighting and lighting instruments must be constructively employed to strengthen general landscape goals. For example, lighting can be used to help provide a sense of life, stimulation and vitality-or the opposite, a feeling of quiet. In a sense, these qualities follow naturally from innate human needs: lighting is not required if there are no people. We sense that where there is light there is life, or the potential for life. Lighting that spills over beyond areas that must be lighted, and light reflected from surfaces that must be lighted helps to light the whole night landscape and gives one a sense of the created environment, of foliage and buildings. Use of a full continuous spectrum source gives one a sense of the richness and natural quality of materials and also provides continuity with daytime perception. The scale and the rhythms of the lighting fixtures themselves can add a sure sense of scale to spaces, giving them character, and help to tell us not only that we are in a space, but what size of space it is.

By virtue of the physical needs of people for lighting, and the placement of lighting to meet those needs, the installation can speak eloquently. To the extent that human needs invite emotional response, lighting should suggest a unified view and a consistent approach to solutions. Lighting may be viewed as an integral strengthening of the grand design of its environment. The placement of groups of fixtures should be sympathetic and responsive to the specific environment with the result, at best, verging on poetry.

In addition to its potential for enhancing our sense of beauty, lighting can make us feel safe. Indeed, the psychological aspect of security may be the real reason for providing enough lighting for personal safety. Psychologically, lighted places suggest activity and safety. They imply that we will be able to see danger in time to do something about it and that others can see us if we are in trouble. They suggest to the criminals that they will be seen and possibly apprehended. Thus lighting should give us the feeling that we are safe from potential danger. If we can see that no one is in the area surrounding us, we feel safe. Lighting seen in this regard is lighting that reduces fear. It also intimidates the criminal, who is no longer able to operate "in the dark".

APPENDIX B

VISION: BASIC CONCEPTS

Luminance is equal to illuminance (incident light) times reflectance (reflectivity of the surface). In the Illuminating Engineers Society, terminology, luminance is expressed in units of candelas per square metre.

We seldom will use lux to describe incident illuminance. In reality we see by photometric brightness units of luminance and not lux, or illuminance.

Day, night, dark vision:

Relating our three types of vision to units of measurement, we find that daytime or "photopic" vision is generally associated with eye adaptation to a luminance of at least 3 cd/m^2 . Dark vision, or "scotopic" vision is associated with adaptation to a luminance less than 0.034 cd/m^2 . Night vision, or "mesopic" vision, with luminance conditions between photopic and scotopic vision, is associated with adaptation to a luminance that is between roughly 3.4 and 0.034 cd/m^2 .

What do these luminances mean in terms of designing a night environment for visual perception - assuming, of course, that to duplicate daylight, brightness is neither possible nor desirable?

Scotopic vision:

We are able to walk confidently by moonlight in a meadow when returning from fishing, enjoy the scenery and the stars, guided by the beacon effect of a glowing window in a farmhouse.

Moonlight provides 0.2 lux of illuminance and perhaps 0.02 to 0.034 cd/m^2 of brightness under such conditions. Here we are using scotopic vision.

Mesopic vision:

When we reach the farmhouse we can read by candlelight or lamp light by holding the book in a favorable position with about 10 lux of illuminance and perhaps 2.7 cd/m^2 of brightness. Here we use mesopic vision.

We can again go outside, take another walk and return to the farmhouse with little adaptive difficulty; but we cannot take our book with us and read it without the candle. Therefore, optimum night lighting would seem to be attained somewhere between these two lighting levels. In fact, most human vision researchers agree that night vision will improve dramatically as the illumination level is increased from 0.2 lux (moonlight) to 10 lux , where vision that utilizes the "cones" of the eye begins to be dominant.

Importance of Colour:

While the photopic receptor system can readily perceive colours throughout the visible spectrum, peak sensitivity is in the yellow range. The scotopic system relies more on wave frequencies in the blue green range. Sources that are deficient in blue prevent the scotopic receptor "rods" from reaching the level of acuity of which they are capable. The scotopic system is also largely responsible for the detection of motion, and peripheral vision is almost entirely dependent on the 'rods'. Recent research also indicates that we are also reliant on this system even when the photopic "cone" receptors are in full use (ie. interior conditions). Overall, this means that blue deficient sources are particularly inappropriate for night lighting applications.

The control system in the human eye that is responsible for pupil size, (which in turn controls light intensity on the retina and depth of field focus) is also dependent on blue light. The eye gauges total light intensity at night using predominantly the blue portion of the spectrum as an indicator. While viewing a blue deficient sodium source at night we sense less radiant energy than is actually being emitted. As a result, pupil size becomes too large. The viewer is blinded by glare, and will experience an "aura" or "halo" around the source due to retina "over exposure". This in turn obscures all other less pronounced information in the field of vision. Also, visual acuity (or focus) is reduced for approximately 1/3 of the population who do not have proper corrective eyewear because when the pupil is too large, the depth of field of focus is reduced, thereby reducing the chance that the image will be properly focussed on the viewer's retina.

It is proposed that exterior lighting levels should be designed for mesopic, or night vision and yet occasionally be brighter in selected areas to convey the appearance of brightness. Although the surfaces will seem bright, the sources will not cause a night vision adaptation problem. This is the best system to ensure enough visibility for personal safety.

Limits of brightness design:

The primary surfaces we light should have brightness of no less than 0.034 cd/m^2 (about the brightest of moonlight) and will rarely be greater than 3.4 cd/m^2 to keep within the bounds of mesopic vision. A few surfaces should exceed 7 to 17 cd/m^2 and these should have short transient viewing periods.

Where the design strays below 0.034 cd/m^2 , as it will at considerable distances from luminaires, visibility potential will be reduced. These levels are appropriate to areas where there are no vital visual tasks and safety is not an issue. If the eye strays above 3.4 cd/m^2 for too long a duration, night vision adaptation will begin to be lost, and with this loss, an ability to see beyond the immediate location. In this circumstance, one's sense of security and comfort will be compromised. This problem occurs with overbright street lighting, which in fact reduces the ability to see into the shadows.

Maximum brightness:

We have used the moon as our reference source, and we will also use it as a guide to the maximum brightness of luminaires to be used to achieve this night vision oriented lighting. The maximum photometric brightness of the moon is 2400 cd/m^2 . This may be exceeded without losing our night vision adaptation only if the areas of higher luminance are kept at least 15 degrees off and above the usual line of sight. The principal luminaires to be used should have a brightness of less than 2400 cd/m^2 when viewed at less than 15 degrees above the line of sight. This may be exceeded occasionally.

Street lighting luminaires presently used in most applications can have excessive brightnesses. For this project, we propose using luminaires that are oriented to the pedestrian as well as to the automobile, and are much shorter than street-lighting poles. For effective night lighting, the brightness of the source is critical.

Visual tasks:

Do these low brightness levels provide illumination sufficient for the "tasks" of night movement, identification and general observation? As noted, one can easily walk across a meadow by moonlight, which has a luminance of 0.021 to 0.034 cd/m^2 . Pragmatically, it has been observed that one can move safely around a rough construction site at night with incident illumination of from 0.2 to 0.1 lux, or approximately from 0.02 to 0.01 cd/m^2 ground brightness. At the lower end of this brightness range movement can be problematic, while at the high end of the range, colors become perceptible.

Perception of brightness changes:

At low light levels, because the eye senses differences in intensity as a percentage of change, even a small absolute light level change is significant. A brightness change from 0.17 to 0.34 lux is a factor of 100% and would be noticeable. Thus, minor energy increases at low lighting levels can produce major changes in visual perception, while at higher levels, a much greater energy change is necessary to make a similarly meaningful visual change.

Visual efficiency vs. light levels:

Beyond a certain point, no increase in the quantity of light will improve task performance or increase safety in the environment. For various tasks, for example, the following results were observed: (from a 1970 report to the Illuminating Research Institute by Drs. R.M. Boynton and D.E. Boss) difficult tasks were performed to 95% accuracy in 43 lux. To achieve 98% accuracy required 1345 lux, while 99% accuracy necessitated 43,000 lux. We see from this that a maximum luminance level of about 2.7 cd/m^2 , which corresponds to about 10 lux from an 80% reflective surface, will allow at least 95% accuracy in difficult reading tasks, provided other factors (glare, dark adaptability, contrast and movement) properly controlled. The mesopic range allows a brightness of 3 cd/m^2 , equivalent to 13.5 - 32 lux, or more, depending on surface reflectivity.

The visual tasks to be performed outdoors are expected to be simple, such as large scale human figure discriminations and the recognition of clear, well designed graphics. Reading newspapers or writing letters are thought to be indoor activities.

Eye accommodation/adaption:

The adaptation of the eyes to darkness is a principal reason for keeping brightness levels close to the Mesopic or night vision range. The adaptation of the eye to different levels of light and darkness is brought about by two functions. In the first place, the pupil of the eye increases in size as we go into a darkened area in order to admit more light to the eyes; it tends to contract in bright light, in order to limit the amount of light that enters the eye. This process takes several minutes and as we proceed from one condition of illumination to another, we may be partially blinded until this process is completed. Under such circumstances, the cones which are color sensitive lose much of their sensitivity. In the dark, our vision depends very largely on the rods, and color discrimination is limited. The time required for complete dark adaptation is usually 30 to 40 minutes. The reverse adaptation, from darkness to light, takes place partially in seconds, and is completed in a minute or two.

Factors which affect visual discrimination, other than individual eye mechanism differences, include luminance contrast, time, luminance ratio, movement, colour, and glare.

Luminance contrast:

Luminance contrast refers to the difference in luminance of the features of the object being viewed, and in particular of the feature to be discriminated by contrast with its background. Within the campus area at night, this condition refers principally to the design and lighting of graphics and signage, such as the visibility of an arrow on a direction sign against the background of the sign.

Viewing time:

Within reasonable limits, the longer the viewing time, the greater is the ability to discriminate. This argues further for the acceptability of comparatively low night lighting levels for this project, especially in areas where movement is expected to be by foot.

Luminance ratio:

The luminance ratio is the ratio between the luminance of any two areas in the visual field, usually the area of primary visual attention and the surrounding area. To some extent, due to outdoor mesopic vision, the smaller this ratio, the greater is the ability to perceive one's total surroundings - except for objects perceived by contrast such as silhouetted figures or obstacles in a roadway.

Dynamic visual acuity:

Movement of the visual object or the observer, or both, brings into play a special type of visual acuity known as dynamic visual acuity or DVA. It is closely coupled with length of discrimination time discussed before. Such acuity generally deteriorates as a function of increased speed of movement. Obviously, more visual information can be taken in by a viewer on foot than one in an automobile.

Glare:

Glare is produced by brightness within the field of vision that is sufficiently greater than that to which eyes are adapted. Glare can cause annoyance, discomfort, or loss in visual performance and visibility. "Direct" glare is caused by light sources in the field of view. "Reflected" or specular glare is caused by reflections of high brightness from polished or glossy surfaces like building glass, metal, or wet pavement that are reflected toward the eye. The designer's objective is the creation of lighting conditions that provide adequate illumination/luminance levels while minimizing glare - except where controlled glare, as from bare filament lamps, is used for specific psychological advantage.

To minimize unwanted direct glare or contrast, low brightness sources and glare shields should be utilized. Such sources will increase the luminance of any area around the glare source to lower the luminance ratio.

Summary of Basic Visual Response Criteria:

The exterior lighting design for this project deals primarily with luminance, (the apparent brightness of surfaces or objects), rather than with illuminance, (the amount of light hitting a surface or an object), because of the true physical nature of visual perception. The design adjusts brightness, as far as practical, near the "night vision" luminance condition of from 0.034 to 3.4 cd/m^2 , equivalent to from about 0.2 lux to as much as 30 lux. For some areas we may exceed these levels. Time of viewing will, however, be controlled.

APPENDIX C

CHARACTERISTICS OF SOURCES AND LUMINAIRES

Some of the aspects of artificial light sources that must be considered in their selection are "efficacy", life, color, spectrum, directionality of light emission and size. The choice or compromise among these factors should lead to conditions of maximum visibility at least cost.

Efficacy:

By efficacy, we mean the lumen output of light per watt of energy consumed. Sources range widely in this regard. Incandescent sources range from 10 to 25 lumens per watt. Fluorescent lamps usually produce between 60 and 80 lumens per watt. High intensity discharge (HID) sources which include mercury vapor, metal halide, low and high pressure sodium lamps, vary from about 25 to more than 100 lumens per watt. Within these ranges, efficacy is a function of lamp type and total wattage. By conventional measurement techniques (ie. degree of radiant flux density), high pressure sodium delivers the most lumens per watt, with metal halide next and mercury vapour roughly half as efficient as H.P.S. (not counting ballast wattage.) These measurements determine the degree of photonic energy in the entire visible spectrum incident upon the test meter. As mentioned in Appendix B, the human scotopic sensor system relies heavily on the blue area of the spectrum for visual acuity, motion perception and peripheral vision, therefore sources like blue deficient H.P.S. do indeed deliver the most total radiant energy per watt but not the most usable energy. Recent studies vary on the exact degree of effect of blue on total visual ability, but several conversion factors have been forwarded for "meter" lumens per watt to "pupil" lumens per watt. Even the least favourable of these put metal halide on par or ahead of H.P.S. in terms of pupil efficacy. In general, for any source type, the larger the total wattage, the greater the efficacy and the greater the source brightness. Consequently, the efficacy of high wattage sources must be weighed against their potential for glare, color, emitting power, and resulting degradation of surrounding visibility. Too often, sources are selected entirely on the basis of their efficacy.

Life:

Life of sources is important both because of the cost of the lamp, and costs associated with lamp replacement. The major cost of relamping is usually labor, not the lamp itself. Relative to lumen depreciation, and consistent with other requirements, lamps should be chosen for maximum life. "Lamp life" is rated at the point at which 50% of the lamps will still be burning, but group relamping should take place before this time. Rated lamp life of incandescent sources varies from 750 to 8,000 hours; exterior fluorescent lamps last about 10,000 hours, and HID from 1,500 to more than 24,000 hours. Compact fluorescent lamp life is 10,000 to 20,000 hrs., and inductive sources have lifespans reportedly in excess of 60,000 hrs. Relamping should be scheduled for the number of burning hours which relate to a preselected percentage of initial lumen output. Many HID sources are needlessly bright, and overpowered lamps are sometimes used solely for their life cycle advantages over low wattage HID sources.

Colour:

The colour spectrum of light emitted from different sources varies widely. Sources may emit a light spectrum which is richer in some colours than in others, and which may be smoothly continuous or discontinuous between colours with little energy between "bursts" of specific colour energy. The ideal light is the white light of sunlight which we regard psychologically and physiologically as the norm.

Incandescent light has a continuous and broad spectrum which correlates most closely to human perception of all artificial sources to sunlight in the distribution and continuity of colours. The incandescent spectrum tends to be comparatively richer in red and yellow light but slightly deficient in blue and green light, when compared to sunlight.

HID sources vary greatly in colour output but typically have grossly discontinuous spectra that tend to concentrate light energy in narrow, intense bands of colour. When a spectrum of light includes components of blue, green and red light - and their relative intensities can vary significantly - the eye and brain integrate these colours into a perception of "white" light. But colour rendering of materials will be more or less uneven and the result will be perceived as "unnatural".

It should be noted that HID sources with the same Colour Rendering Index (CRI) do not necessarily exhibit the same colour, or tendency to enhance a particular coloured object. The colour rendering index is an average of many spectral tests, and in no way indicates which areas of the spectrum that each source favours. Even two sources which the eye equates as the same colour temperature may exhibit different CRI's, with the more discontinuous "metamer" having the lower index rating.

Clear mercury vapor lamps produce light that is bluish-green and is flattering to foliage, but unflattering to people and reddish building materials. These lamps can be phosphor-coated to give more red output, but the coating effectively increases the source size to the dimensions of the outer glass lamp envelope, making optical control of the light emission more difficult and cumbersome.

Metal halide lamps are the most appropriate of the high output HID sources for exterior use in terms of colour. Their spectrum is rich in yellows, blues and greens, but includes enough red to produce an approximation of "white" light reminiscent of daylight. Metal halides are significantly better in providing a fuller spectrum metamer, so that people, the landscape and the full range of materials used in the design of the project will be seen in their truest hue. However, metal halide lamps exhibit a degree of "drift" from their specified colour temperature over time, particularly if left longer than the normal replacement period.

High pressure sodium lamps, which are employed to illuminate the streets in many cities, produce light which is yellow-orange, not even hinting at "white" - with almost no blue-green component. This light is relatively kind to people and reddish building materials, but turns the green of foliage to a dirty brown and makes landscape plantings appear to be dead or dying.

Fluorescent sources specifically for exterior use are not provided with the phosphor coatings to produce "warm" light. Recently, however, high output lamps that can be used in thermal enclosures are available in a variety of colour temperatures and high colour rendering indexes.

Compact fluorescent sources operate using the same principles as fluorescents. They have excellent colour rendition and temperature options, but are not used in cold weather exterior applications without making accommodations for this factor in the fixture design. Lamps must be jacketed to maintain heat (hence lumen output), and must be thermostatically switched to remain lit below critical temperatures. The advantage of compact fluorescent is their relatively low lumen output, which is much more appropriate to non-blinding pedestrian scale fixtures and spacings.

Inductive sources are the newest on the market. Their colour and CRI, like the compact fluorescents, are of the same type as "T8" fluorescent lamps, yet they have no thermal constraints. Being new, the initial cost is high.

In terms of the illusion of "daylight white" light, and in colour rendering ability, incandescent sources are best, compact fluorescent, inductive, and high CRI fluorescents are next best, with metal halide following in the hierarchy.

Directionality:

For our purposes, all sources except fluorescent lamps emit light energy more or less evenly in a 360 degree sphere. Fluorescent lamps emit significantly greater energy perpendicular to their longitudinal axis than they do from their ends, or parallel to their longitudinal axis. This directional characteristic is important to the use of sources in fixtures intended to give 360 degree spherical dispersion, as frequently desired for landscape, street or building illumination

Source Size:

The size of the source is of great importance where control of the directionality and control of light is sought by means of optical characteristics of the luminaire which encloses it. The larger the source, the more difficult is the problem of control, and the larger the fixture must be to effect control. For this reason, where great control and compact fixtures are required, clear incandescent lamps are appropriate because their filament sizes most nearly approximate an ideal "point" source. When the interior surface of a glass lamp is treated with phosphor or other coatings, the size of the source is increased in proportion to the dimensions of the globe, making control a larger-scaled operation. Fluorescent tubes are comparatively large in diameter and length. HID lamps have intermediate sized arc tubes which are amenable to control if phosphor coatings are not added to improve colour output. Lighting for large areas, such as streets and parking lots, require control to balance brightness or glare while directing adequate illumination for general area lighting.

Energy Cost/Conservation:

Energy conservation has become a significant issue in the design of large-scale projects, not only because of an energy shortage and higher energy costs, but also because of the public attitude toward energy use. This might be called the "energy ethic" of design. Projects such as this have the opportunity and the obligation to display an approach to energy conservation that, if emulated on a broad scale, would result in more value received, and less energy consumed.

Rather than concentrating on creating a design which merely uses a lower amount of energy, the lighting designers believe that the most important aspect of energy conservation is the elimination of energy waste. Lighting levels should be consistent with visual requirements, and should meet the established project criteria, not only minimize energy use. The illumination levels, moreover, should be no higher than what is necessary for safety, comfort and meeting the various design objectives.

The key is in selecting efficient sources that produce the desired effect. For example, although fluorescent sources are more efficient than incandescent sources, they do not provide the sparkle, excitement, directional control and warmth of incandescent lamps and, thus, are not appropriate choices where such qualities are necessary. From this point of view, an incandescent or a metal halide lamp may, indeed, be the most efficient source available to achieve the intended result.

A final suggestion is to provide light as simply as possible. Toward this end, all decorative lighting should be functional, and functional lighting should be decorative. Where one fixture can replace two, conservation thrives.

APPENDIX D

SOURCE COMPARISON: METAL HALIDE vs. HIGH PRESSURE SODIUM

In appropriate wattages, the improved metal halide requires only about 17% more energy to provide a given luminous flux than does the high pressure sodium source. The metal halide lamp is relatively efficient among the many available sources. The high pressure sodium lamp is potentially the most efficient available lamp - hence its extensive use for street lighting.

One factor is frequently overlooked. The efficacy of a lamp (lumens per watt) only represents potential output. It requires a ballast to achieve that output. The technology associated with metal halide ballasts assures an output of between 90-100% of full rated lamp lumens. The high pressure sodium ballasts, on the other hand, can only guarantee an output which ranges between 50-100% of full output. This means that high pressure sodium could be producing half its rated output, which puts its overall efficiency well below that of metal halide. For example, a high pressure sodium lamp rated at 130 lumens per watt, could produce as little as 70 lumens per watt, while the lowest rated metal halide lamps 100 lumens per watt, will drop no lower than 90.

The ratio of relative efficacy becomes even less advantageous for the high pressure sodium lamp when the realities of good visibility, comfortable light levels and natural color rendition are evaluated. Too much monochromatic light will not serve the visual needs of the campus users. It must be kept in mind that the visual goals of the project, and the effect of high pressure sodium on the night environment.

Even when lumen output is identical, the orange high pressure sodium and white metal halide light colors do not provide equally for the level of vision recommended for safe movement, for recognizing obstacles, and for avoiding potentially dangerous situations. High pressure sodium light is monochromatically biased and does not allow full visual discrimination between objects, surfaces and textures. Psychological preference for broad spectrum white light and the energy cost premium make the metal halide superior.

The campus, physically, is composed of street surfaces, vegetation, building materials, and human inhabitants. If one's visual perception is restricted, unnatural, partial or distorted, if their reality, uniqueness and character are denied, then their purpose and value at night will be lost. The considerable financial and intellectual investment in them will likewise be wasted.

In a theatrical production when a red light is turned on an outdoor scene, it is transformed into something unreal and unnatural with connotations of decay created from the dead appearance of green foliage and grass. Without reference to our normal, natural, light colour sense, our surroundings seem disturbing and unfriendly. A similar phenomenon occurs along streets lighted by high pressure sodium sources where the natural reality and beauty of landscaping and architectural materials are transformed and devalued in the deceptive name of efficiency.

For the pedestrian, the typical city street scene under high pressure sodium becomes a glaring and menacing environment to be hurried through. What really has happened to our visual picture results from the narrow band high pressure sodium source. This nearly monochromatic source has rendered the living landscape in one narrow colour range - red and black - which restricts the spectrum of our color sense. The result is flat and disorienting. Under such light, it makes no difference whether or not fine materials are used and are well maintained. Such lighting is unsuitable to achieve a visual environment which is friendly, rich in colour, interesting, or stimulating, and which allows the fine building and plant materials to be seen and appreciated in a natural way.

Finally, both the state-of-the-art and future directions in lamp and ballast technology favor metal halide. The colour spectrum, lamp life and ballast efficiencies continue to improve. When carefully analyzed and evaluated with human needs in mind, high pressure sodium sources cannot be considered as a main source of light for this project. Existing high pressure sodium fixtures can be retrofitted on a phased basis, within the existing structure of fiscal restraints.

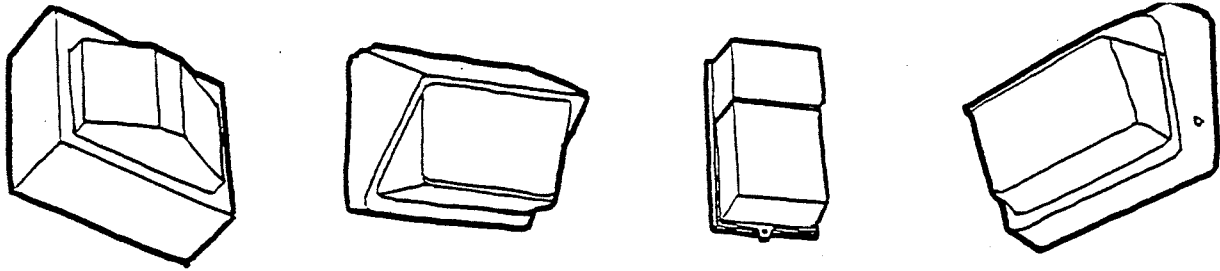
APPENDIX E

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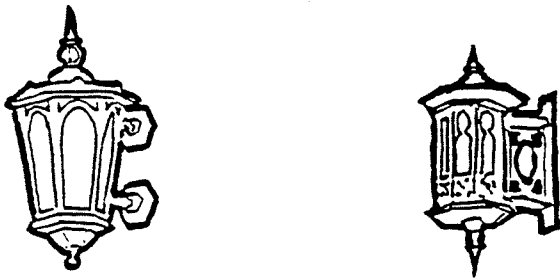
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Area Light : Wall Mounted

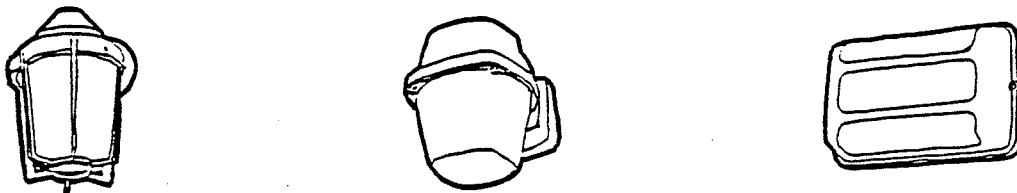
Lensed H.P.S.



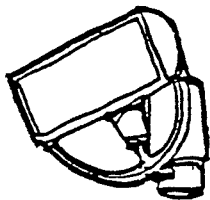
Traditional Entrance Fixtures



Low Intensity Entrance Fixtures



H.I.D. Floodlights - (Wall or Roof Mounted)



Incandescent Floodlights



APPENDIX F

ANALYSIS OF EXISTING FIXTURE INVENTORY

Area Lights: Wall Mounted

Lensed High Pressure Sodium (H.P.S.)

The majority of the lighting on campus is high pressure sodium. Due to the intensity of the source and lack of shielding inherent in the design, they are largely responsible for the harsh glare and light trespass problem on campus. Apart from being excessively bright, they are often placed in a way that does not allow for an overlap with illumination from other light sources, creating deep shadows behind trees and other buildings. When used as entrance lights, their location and brilliance virtually renders the building and its entrance ways invisible.

High pressure sodium lights make it extremely difficult for the eye to differentiate between colours at night. Colour differentiation is an important aspect of object perception and therefore has direct implications on safety. This same characteristic makes H.P.S. lighting extremely unflattering to foliage, turning branches and plants brown and unnatural.

Traditional Entrance Fixtures

These classically styled fixtures are a perfect compliment to the heritage architecture on campus. Soft, incandescent, low intensity lamps create warm, inviting entrances and contribute both functionally and aesthetically to the lighting design.

Low Intensity Entrance Fixtures

Low intensity fixtures, the most common being the "pickle jar" incandescent, provide enough light to enter or exit a building comfortably. A few small low pressure sodium units are also used around campus, but these impose even greater limitations on colour differentiation than their high pressure sodium counterparts and are not well suited to this usage. There are also several instances where these modern fixtures have been inappropriately used on heritage buildings.

High Intensity Discharge (H.I.D.) Floodlights - (Wall or Roof Mounted)

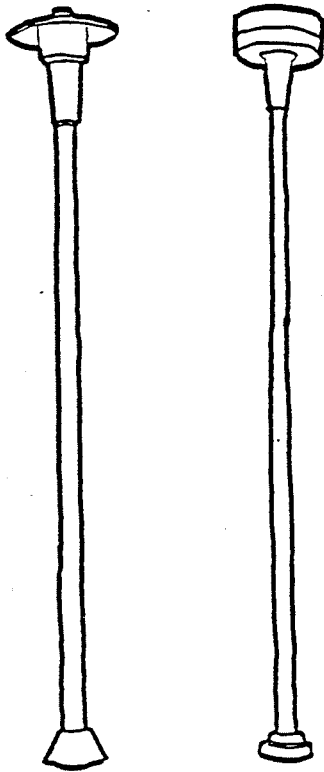
These floodlights are the worst offenders in terms of glare, contrast, and light trespass. Their brilliance blinds the eye to the building on which they are mounted and plunges the surrounding area into darkness. Light "trespasses" into areas that should be free of glare and excessive brightness.

Incandescent Floodlights

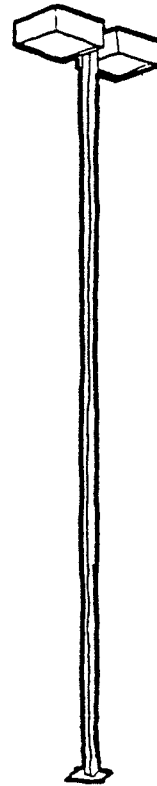
Incandescent floodlights have been used with great success in many courtyard areas. They provide a sparkling and welcoming quality to green areas, yet have none of the blinding glare that characterizes the high intensity sodium sources.

Pedestrian Scale Lights :

Post Mounted H.I.D.



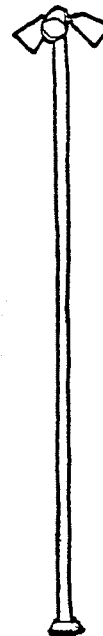
Shoebox H.I.D.



Traditional



Post Mounted Incandescent Floodlights



Pedestrian Scale Lights:

Post Mounted High Intensity Discharge (H.I.D.).

There are two main types of pedestrian scale post fixtures used on the Queen's campus: the high intensity sodium "top hat" refractor variety used on the Main Campus, and the mercury opal variety seen on West Campus.

The Main Campus fixtures have several desirable features. Their scale is not intimidating, they have 'hats' which prevent light from trespassing upwards, as well as refractors that lessen the intensity of the light.

On the negative side, the high pressure sodium source has poor colour rendition. The lights have been overpowered to compensate for the wide spacing between fixtures causing extreme contrasts with the darkness beyond. Unfortunately, the style of these fixtures does little to compliment the heritage character of the surrounding architecture.

The West Campus fixtures generate "white light" that is on the bright end of the acceptable scale. They have no features to allow for control of light distribution but their modernist style is more in keeping with the character of the campus.

Shoebox High Intensity Discharge (H.I.D.)

These high intensity lights are used primarily around Botteral Hall, though the odd single fixture of this type, with a variety of light sources may be found throughout both campuses. These lights can be appropriate for use with modern architecture, have reasonable glare control and are usually equipped with aesthetically acceptable mercury vapour sources with slightly less than moderate efficiency.

Traditional

Traditionally styled lighting fixtures are located at the entrances of the Douglas Library, Chown Hall, Lasalle Building and the Union Street entrance of the John Deutsch Center. This type of fixture is very appropriate for use with heritage buildings. Unfortunately, the library fixtures have been converted to high intensity discharge sources from the original incandescent. This and the use of tinted glass produces an unnatural orange light. They have no particular redeeming lighting properties other than ambient emissions or glow. With a low intensity source such as an incandescent bulb, an inviting entrance can be easily reinstated. This example of lighting design is remarkable for its appropriateness to heritage applications.

Post Mounted Incandescent Floodlights

Post mounted floodlights are used sparingly throughout the main campus but appear in great numbers in the MacIntosh Corry precinct, along the south walkway and in the courtyards. Though the limited life capacity of an incandescent bulb coupled with their mounted positioning may have slightly increased maintenance concerns, the aesthetic benefits of this system are considerable. The focussed nature of the lamps and fixtures allows for good illumination of the ground and vertical surfaces without excessive glare. The colour of the surrounding foliage is also enhanced. While these floodlights do not contribute significantly to the ease of orientation or pathfinding on campus, the obvious benefits of using many low intensity sources are well demonstrated by the welcoming atmosphere they create and the noticeable lack of glare or shadows.

Incandescent Ball Globes

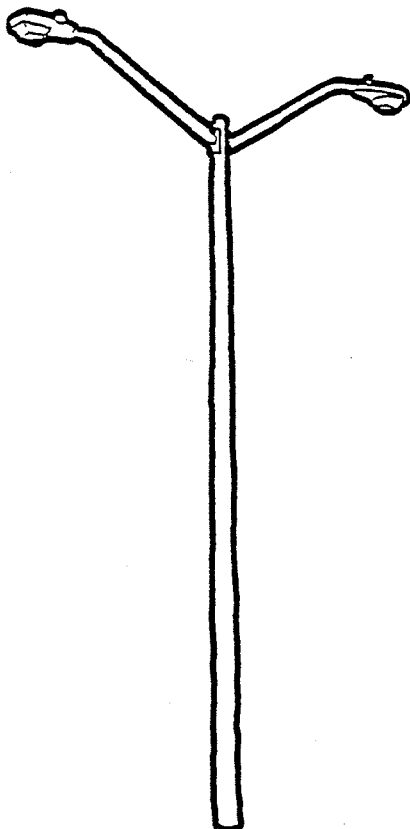


Bollards

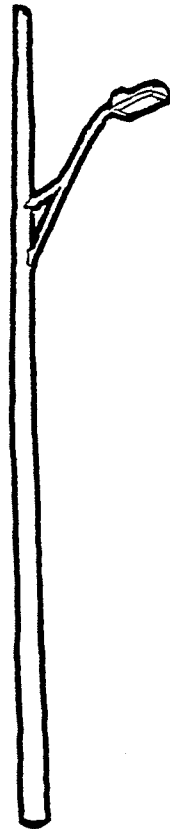


Roadway and Parking Post Mounted

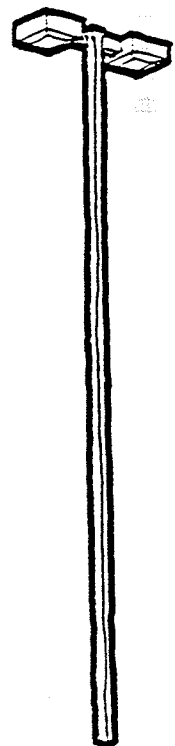
Cobrahead H.P.S. or M.V.



Low Pressure Sodium



Shoebox H.P.S.



Incandescent Clear Ball Globes

Found only in front of Humphrey and Harkness Halls, these clear globe fixtures are not the best examples of this modernist style. The light they produce is flattering to the surrounding landscape but their clear globes make even the relatively low incandescent sources appear somewhat glaring.

Bollards

Bollards are found on the West Campus in incandescent form and at the Donald Gordon Center with mercury vapour sources and frosted lenses. This particular model has no lighting properties save ambient glow. The mercury vapour units are glaring and particularly blinding because of their intensity and location in the observers line of vision.

Roadway and Parking: Post Mounted

Cobrahead - High Pressure Sodium or Mercury Vapour

The cobrahead fixture in sodium form is found throughout the main campus and the city. The mercury vapour version of this light is more commonly found in parking lots. Regardless of the lamp type, the unshielded cobrahead produces an unreasonable amount of glare at distances far beyond the range at which the light level is useful or effective for vision.

Most of the view behind a cobrahead light is rendered imperceivable by contrast. This fixture type is the major source of urban light pollution, a problem that can be easily diminished by placing a simple shield over the fixture.

Low Pressure Sodium (L.P.S.)

Low pressure sodium or "goldfinger" street fixtures are used throughout the campus but are most prominent on Arch and Barrie Streets. While this light may produce the most 'meter' lumens per watt, the useable light absorbed by the pupil is much less. The reason for this lies in the fact that the human eye relies heavily on the blue range of the light spectrum for night vision. Low pressure sodium light emissions are totally devoid of blue light. The unnatural yellow light that is produced makes colour differentiation virtually impossible and renders both humans and foliage indistinguishable, camouflaging would be attackers. In the worst case, victims would be unable to identify even the colour of their assailant's clothes. This property alone makes this light source the most inappropriate for use on a university campus.

Shoebox - High Pressure Sodium (H.P.S.)

The lensed version of the H.P.S. used in the Queen's parking lots is less glaring than the cobrahead, but more so than the cutoff version of this fixture. Again, the use of high pressure sodium is a poor choice for colour differentiation and human appeal.

APPENDIX G

GLOSSARY OF SELECTED LIGHTING TERMS

ACCOMMODATION	The process by which the eye changes focus from one distance to another.
ADAPTATION	The process which takes place as the eye adjusts to the brightness or the colour of the visual field. The term is also used, usually qualified, to denote the final stage of the process. For example, 'dark adaptation' denotes the state of the eye when it has become adapted to very low luminance.
AMBIENT LIGHTING	Lighting throughout an area that produces general illumination.
BRIGHTNESS	Luminosity. The human perception of luminance.
BRIGHTNESS RATIO	The ratio between the brightness of any two areas in the field of view. I.E.S. recommended ratios for the area adjacent to the task are 1:3 desirable and 1:5 minimum. Ratios for the general surrounding are 1:5 desirable and 1:10 maximum.
CLEAR SKY	One that has less than 30% cloud cover.
COLOUR APPEARANCE	Of a light source; subjectively, the hue of a white surface illuminated by the source; the degree of warmth associated with the source colour. Lamps of low correlated colour temperature are usually described as having a warm colour appearance, and lamps of high correlated colour temperature as having a cool colour appearance.
COLOUR RENDERING	A general expression for the colour appearance of objects when illuminated by light from a given source compared, consciously or unconsciously, with the appearance under light from some reference source. 'Good colour rendering' implies similarity of appearance to that under an acceptable light source such as daylight. The colour rendering properties of a lamp relate to this effect under specified conditions. The Colour Rendering Index (CRI) of sources most commonly uses the incandescent lamp as the reference source.
CORRELATED COLOUR TEMPERATURE	(Unit: Kelvin, K) The temperature of a full radiator (black body) which emits radiation having a chromaticity nearest to that of the light source being considered. E.g: The colour of a full radiator at 2856 K is the nearest match to that of a tungsten filament lamp. 4874 K is the nearest match to noon sunlight, and 6774 degrees K is a combination of clear sky and sun.
DARK ADAPTATION	The process by which the retina becomes adapted to a luminance less than 0.034 candela per square metre.

GLARE	The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.
Disability glare	Glare which impairs the ability to see detail without necessarily causing visual discomfort.
Discomfort glare	Glare which causes visual discomfort without necessarily impairing the ability to see detail.
Direct glare	Glare caused when excessively bright light source in the visual field are seen directly. E.g: lamps which are inadequately shielded.
Reflected glare	A term used to describe various visual effects, such as reduction of contrast, discomfort or distraction, produced by the reflection of light sources or other bright areas in glossy or semi-matt surfaces. "Veiling" reflection.
ILLUMINANCE	(Unit: Lux) The luminous flux density at a surface i.e., the luminous flux incident per unit area. (This quantity was formerly known as the 'illumination value' or 'illumination level'.) One Lux is equal to one lumen per square metre. One footcandle is equal to one lumen per square foot. One footcandle = 10.76 Lux.
ILLUMINATION	The process of lighting an object.
LIGHT LOSS FACTOR (LLF)	Maintenance factor used in calculating illuminance after a given period of time and under given conditions. It takes into account temperature and voltage variations, dirt accumulation on luminaire and room surfaces, lamp depreciation, relamping and cleaning procedures and cleanliness of the environment.
LUMINAIRE	A complete lighting unit, including lamps, lampholders, wiring reflectors, lenses or shields.
LUMINANCE	The physical measure of the stimulus which produces the sensation of luminosity (brightness) in terms of the intensity of the light emitted in a given direction (usually towards the observer) by unit area of a self-luminous or transmitting or reflecting surface. It is measured by the luminous intensity of the light emitted or reflected in a given direction from a surface element divided by the area of the element in the same direction. The SI unit is the candela per square metre or NIT.
LUMINOSITY	A term which expresses the visual sensation associated with the amount of light emitted from a given area. It is the subjective correlate of luminance.
LUMINOUS EFFICACY	The ratio of the luminous flux emitted by a lamp to the power consumed by it. Unit: lumens per Watt.
LUX-HOUR (lx-h)	A unit of illumination overtime. It is the density of light (lumens per square metre) delivered in one hour.

**MAINTAINED
ILLUMINANCE**

The mean illuminance throughout the maintenance cycle of an installation and averaged over the relevant area; this area may be the whole area of the working plane in an interior or the area of the visual task and its immediate surround. Calculated by use of a Light Loss Factor (LLF).

OVERCAST SKY

One that has 100% cloud cover; the sun is not visible.

**PARTLY CLOUDY
SKY**

One that has 30 to 70% cloud cover.

RADIATION

Visible

The visible range (violet to red light) has been defined as covering the wavelengths from 380-770 nm (nanometers).

Ultraviolet

Radiation of wavelengths shorter than 400 nm. U.V. radiation from the sun, sky and most artificial light sources is in the range 300-400 nm. It is invisible and has a strong damaging effect on many museum materials. The proportion of U.V. emitted by a light source may be expressed as milliwatts of U.V. radiation per 100 lumens (mW/100lm). UV-A = 315-400 nm; UV-B = 280-315 nm; UV-C = 100-280 nm.

Infrared

Radiation of wavelengths longer than 760 nm lying beyond the red end of the visible spectrum. Near infrared = 770-1400nm; Far infrared = 5000-10000nm.

**SPECTRAL
DISTRIBUTION**

- (a) Continuous spectrum; A light source emitting radiation at all wavelengths throughout the visible range is said to have a continuous spectrum; a tungsten filament lamp is an example.
- (b) Line spectrum; When radiation is confined to a limited number of wavelengths, the light source is said to have a line spectrum; examples are a high-pressure mercury and a low pressure sodium discharge lamp. The fluorescent lamp has both a continuous and a line spectrum.

VISUAL ACUITY

The measure of ability to distinguish fine detail.