GUIDING ISSUES OF ARTIFICIAL LIGHT USE IN URBAN LANDSCAPE ARCHITECTURE

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by
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A Practicum Submitted to the Faculty of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of

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Adrian and Elizabeth,

whose love, friendship, patience and understanding have helped
sustain me through years of hard work.

Abstract

The principles of human expectation, safety and security, legibility, and physiological characteristics of the human eye and brain all contribute to the perception of urban outdoor space at night. Illuminating engineering, lighting design, and environmental psychology have contributed to a greater understanding of these principles and their impact in terms of artificial light use in urban landscape architecture. The information gathered on artificial light use was achieved through an extensive literature review on illuminating engineering, lighting design and environmental psychology. The contributions of each are summarized in Chapter One. Chapters Two and Three focus on human perception and the physiology of vision, and lighting technology respectively. Emphasis has been placed on their implications in terms of implementation, safety and security, legibility, aesthetics, and the design process. Chapter Four synthesizes this information and generates lighting principles for landscape architects. These results are applied to a proposed urban park design located within the downtown area of Winnipeg, Manitoba. Special attention was given to the implementation of these principles into a cohesive lighting scheme.

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Introduction

The intent of this practicum is to demonstrate an applied knowledge of research principles outlined in environmental psychology, illuminating engineering, and lighting design, and to demonstrate the necessity of these principles in the enhancement of the urban environment at night. The discourse is intended to reveal a synthesis of research on perception, physiology and vision, lighting technology, and landscape architecture and consequently, their contribution in enhancing perceived safety and security, legibility, and design intent. The goal is to promote artificial light as a significant design tool based on the principles outlined above, and, to maintain aspects of the sublime nature first associated with its use in the late 18th century:

> People stood overwhelmed with awe, as if in the presence of the supernatural. The strange weird light exceeded only by the power of the sun, rendered the square as light as midday…men fell on their knees, groans were uttered at the sight and many were dumb with amazement (Nye, 1990).

The exploration of these topics encourages a progression of thought beyond the conception of conventional light use, and promotes its potential as a defining element in urban landscape architecture. It acknowledges the significance of artificial light as a modifier of human behaviour, and seeks to establish a method of approach to implement its use with greater care and consideration. It suggests that a defining element of place can be fashioned from the sublime characteristics associated with the use of artificial light in the space at night.

Objectives

The main objective of this practicum is to explore the issues surrounding the use of artificial light in urban outdoor space. The goal is to provide a synthesis of research, contributed by environmental psychology, lighting design and illuminating engineering, and to integrate this knowledge within the field of landscape architecture, thus providing the basis for a set of guidelines to be widely applicable, yet demonstrated within a chosen site. Specific objectives are as follows:

1. To integrate the principles of environmental psychology, lighting design, lighting technology, principles of physiology and vision and landscape architecture and apply the results of this research to a chosen site within the downtown area of Winnipeg.
2. To provide a brief description of current artificial lighting methods, equipment and by-products (light quality, heat, colour, etc.) and their significance in terms of implementation.
3. To provide a description and understanding of processes involved in the perception of light such as expectations and adaptation, and consequently, to identify their importance to human behavior.
4. To illustrate the importance of artificial light as a defining element in the legibility of Winnipeg's urban landscape after dark.

5. To synthesize the above principles in order to extract critical issues of light use such as perception, expectations, and qualitative aspects (colour rendering), and consequently, to incorporate this knowledge in landscape architecture to increase the perception of public urban space; create safe and secure nighttime environments; enhance legibility; strengthen visual aesthetics of the downtown at night.

Site Location

The site chosen for the application of this research is located in the downtown area of Winnipeg, Manitoba (Figure 4.1). The site is bounded by Edmonton Street, Hargrave Street, York Ave, and the buildings on the north side of Broadway. The site was chosen as a design site for a Masters' II Studio in Landscape Architecture in fall term, 1999. For the purposes of this studio, the existing parking lot was to be zoned as a civic open space for the downtown. A design proposal prepared by Tanya Goertzen of the Masters' II Studio forms the basis for the application of research in this text. Therefore, attention will focus on lighting principles and theories, rather than on layout and design. Appendix A describes site design programming issues and ideas.

Methods

An extensive literature review was conducted on artificial light and lighting methods, both in terms of implementation and perception, in order to obtain a comprehensive understanding on the effects of its use. A site analysis was undertaken for the immediate site as well as for adjacent site conditions and characteristics. This highlights conventional site analysis elements such as sun angle, vegetation, wind direction and speed, and climate. Furthermore, analysis was also conducted on existing infrastructure, noting any opportunities and constraints which might exist. This particular aspect of the analysis focused on observing informal gathering spaces which exist in or adjacent to the site, as well as documenting existing transit, telephone and seating amenities. Opportunities and constraints identified within the preceding analysis were used to establish criteria for the lighting and landscape design best suited for the characteristics and use of the site. Lastly, a site design proposal was prepared. This illustrates a synthesis of material generated by the preceding topics together with materials outlined through the analysis of opportunities and constraints currently at the site. The design proposal for the site illustrates the implementation of guidelines used in the lighting program, and is presented in the final phase in the form of site plan, drawings and text.

1

ELEMENTS OF DESIGN

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Often, we look upon the urban landscape at night oblivious to the technology surrounding us. Artificial light, despite unrecognized potential, remains a tool of largely functional use. Many professionals including illuminating engineers, lighting designers and landscape architects use artificial light to help people to navigate the environment at night, to provide safety and security, and to highlight aesthetic architectural and natural features. Many environmental psychologists document the effects of lighting on human behavior and on our surroundings. However, despite the breadth of information collected by these professionals, the implementation of lighting by landscape architects generally does not effectively draw upon available resources. This results in site designs which often do not effectively respond to issues of:

- Perception
- Legibility[1]
- Safety and Security
- Aesthetics – those provided by artificial light and lighting elements

The purpose of Chapter One is to develop a discussion regarding the contributions made to lighting, such as perception, technological advancements, and lighting theories, by illuminating engineering, environmental psychology and lighting design. This research will provide the foundation for the development and synthesis of lighting theories, and their application by landscape architects within the urban landscape. It will examine professional contributions made, provide the foundation for a synthesis of lighting research and help guide questions of lighting intention and application in the urban landscape.

Environmental Psychology

Environmental psychology began to take shape in the 1960's in response to social and political problems of the time (Altman, 1990; Proshansky, 1990; Craik, 1990). Public concern over the degradation of the physical environment and the outbreak of the Vietnam war manifest itself in increased consideration of civil rights, pollution, urban decay and the destruction of the natural landscape occurring worldwide (Altman, 1990). Strong criticism was growing in environmental design and social science fields at the time about the apparent disregard given to these issues by their parent disciplines. As a result, a collection of diverse professionals including landscape architects, urban planners and sociologists combined with psychologists and behavioral geographers to address these growing concerns. The result of this collaboration became the broad profession of environmental psychology (Altman, 1990).

Broadly stated, environmental psychology is the study of the psychological facets of person-environment relations (Altman, 1990). Proshansky (1990) defines environmental psychology as the science that studies the interactions and relationships between people and their environments. It centres on the study of human comprehension of everyday physical environments, and the methods by which the results of these studies can be utilized to provide a systematic assessment of place (Craik, 1966 p.147). Understanding what governs these interactions and relationships, will impart on landscape architects the ability to assess more accurately and influence the creation of outdoor space, consequently, facilitating future design intervention. It provides insight and understanding regarding topics such as perception, adaptation, and legibility within the urban landscape (Proshansky, 1990).

Furthermore, the research contributed by environmental psychology should enable landscape architects to clarify design objectives in response to specific user needs. A designer's ability to understand and assess the landscape based on those qualities outlined above by Proshansky (1990), will enhance the design of urban space. Research has shown that the appearance of the physical environment has important effects on human experience. Hanyu (1997) suggests:

> The appearance of a place can evoke strong emotions or inferences about such things as the significance or friendliness of an area. It can, consequently, affect spatial behaviour.

Further research suggests that these inferences, if positive, can attract individuals to a place. Conversely, places inferring a negative association can in fact, lead people to avoid or escape activity within a space (Hanyu, 1997). Environmental aesthetics have been of primary concern to design professionals such as landscape architects and architects. Many contributions have filtered down to landscape architecture from environmental psychology. Many have affected the outcome and approach which landscape architects have taken in addressing community and environmental needs. They range from studies done on human privacy and territorial behaviour, to research on the various needs of people of different demographic origin, and their desired environmental requirements (Lang, 1991). However, despite design decisions based on professional experience and training, research indicates a disparity in the evaluation of space between the general public and design professionals. Consequently, many environments designed according to the subjective preferences of design professionals fail to satisfy user needs (Hanyu, 1997).

Two particular urban designers who have contributed to a broader understanding of environment and community needs are Aldo Rossi, and Mattheus Ungers. They have attempted to create spaces which provide continuity between peoples' environments and their identification with place (Lang, 1991). Many environmental psychologists agree that the primary function of design is to provide appropriate contexts for people - to evaluate a space when its function is seen in human terms (Canter, 1990). However, Rapoport (1990), suggests that too often architects are unable to maintain the necessary objectives required to achieve a design which responds to the general public's identification of place. The suggestion is that design professions often make decisions based on the subjective needs of their own concern, not those of the general public, resulting in the reduced ability to identify accurately users' problems (Hanyu, 1997; Rapoport, 1990; Canter, 1990). Environmental psychology stresses the need for problem identification. A main premise behind its development is that the general public are unable to distinguish whether something has been well designed because they are unable to identify which qualities the design must meet, and why. Simply put, environmental psychologists suggest the importance of the profession involves the study of what is liked or important, for whom, where, and why (Rapaport, 1990). It underlies the need for landscape architects to address problems arising from site, context, and users, and make evaluative design judgments based on fundamental knowledge and theory. Furthermore, it demands that the profession explicate the design objectives in such a way that they may be interpreted by the general public.

This need for understanding the interactions and relationships is critical in creating environments based on the users' needs. Design based on research completed by environmental psychologists provides insight and understanding regarding human-environment issues in the urban landscape (Proshansky, 1990). It will provide landscape architects with the ability to enhance, through effective design, legibility within the urban landscape at night, and as a result, strengthen the credibility of the profession.

Illuminating Engineering

Generally speaking, illuminating engineering is dedicated to the scientific and technical aspects of lighting, with growing interest in issues of lighting design (Murdoch,1985). According to Murdoch, the basic knowledge of illuminating engineering is based on a foundation of the following principles:

- To provide a foundation in the science and mathematics of light, sight and lighting.
- To develop the analytical tools and skills required for quantitative lighting calculations.
- To present lighting measurement techniques and instruments.
- To give an historical perspective of scientific and engineering achievements relevant to lighting.
- To present the current state of knowledge in the field of illumination.
- To provide a reference and updating base for those whose knowledge of lighting is incomplete.
- To include sufficient detail, examples, problems, and references allowing for self-study without formal instruction, or academic prerequisites.
- To consider the implications of quality and aesthetics.

In summary, illuminating engineering considers quality and aesthetics as well as technical and quantitative considerations, thus allowing the development of applied solutions (Murdoch, 1985). Based on the above qualities, illuminating engineering can be viewed as an important bridge between the science of lighting and its use by landscape architects.

The contributions made by illuminating engineering to landscape architecture have largely revolved around the technological aspects of illumination. For example, vast improvements in lighting technology and equipment - such as increased fixture efficiency, colour rendering ability, and fiber optics - provide a greater palette of design tools and design alternatives for individuals responsible for the implementation of lighting schemes (Leccese, 1998; Sorvig, 1999).

Furthermore, illuminating engineers have provided valuable information concerning the use of light and its behaviour within the context of the urban environment. Architects, landscape architects and environmental psychologists benefit from key information related to critical design issues such as reflection, refraction, intensity, diffusion, and glare (Murdoch, 1985). For example, studies conducted on light have revealed that a unit of reflected light (*footlambert*[2]) plays a greater role in the process of seeing rather than a direct unit of light (*footcandle*[3]) emitted from the lamp or light source (Moyer,1992; Murdoch, 1985).

In addition, the core of the research by illuminating engineers has contributed to the physiological implications associated with artificial light and its effect on the human visual system. This research illustrates the importance of lighting beyond its more tangible characteristics of light and colour. It stresses the importance of the physiological and psychological change which can result from people's interaction with artificial light. In many ways this research provides a greater understanding of the processes involved in human sight such as *transient adaptation*[4](Lloyd, 1985; Murdoch, 1985).

Consequently, the information supplied by illuminating engineering to landscape architecture enables designers to achieve lighting within the urban landscape which:

- Responds to the issues of perception addressed by environmental psychologists and provides designers with necessary equipment such as fixtures, lamps and switches, which enable the appropriate response to the objectives of a design.
- Permits landscape architects to understand why they need to implement appropriate lighting based on informed decisions and not solely on subjective opinion (Rapoport, 1990). It educates the landscape profession on the social responsibility of their work. That is, to provide safe, secure, legible environments.
- Responds to issues of safety and security within the landscape at night.
- Informs landscape architects about lighting implementation, and the benefits of energy efficiency and cost savings associated with a well considered installation.
- Enables landscape architects to implement lighting schemes in a manner which contributes to the positive character of the urban fabric at night. Furthermore, it permits the creation of schemes which satisfy the qualities deemed important by

environmental psychologists and which contributes to enhanced spatial and psychological legibility of the landscape at night.

- Allows landscape architects to respond to design issues in more creative and unique ways.

Lighting Design

Broadly stated, lighting design is founded on the creative use of lighting principles outlined by the Illuminating Engineering Society (IES). Lighting designers focus on creative design which responds to specific client and project needs (Moyer, 1992).

The design process followed by lighting designers is similar to that followed by other environmental design professions such as architecture, landscape architecture and interior design. By and large, lighting designers begin with basic analysis of site and user needs. According to Moyer (1992), this involves:

- Client and professional interviews
- Site photographs
- Review of site plan (architectural and landscape architectural features)
- Review of planting plan

However, the integration of lighting design and site design, should be a collaborative process which begins in the conceptual phase. They should be resolved concurrently to ensure that both work together to address the design program.

Client and professional interviews provide the lighting designer with an opportunity to understand design intentions of the architect and/or landscape architect, and the influence this may have on the lighting design. This phase is also critical in determining the possibility of conflicts which may arise during the implementation of new lighting equipment and excavation requirements with existing soil, electrical and irrigation conditions. Soil tests will ensure that appropriate fixture selection is made and prevent fixture corrosion resulting from chemical incompatibilities with local soil conditions. This process of analysis is then followed with the development of a conceptual plan based on synthesis of the above research (Moyer, 1992). The following best summarizes the contributions of lighting design to this practicum:

- It strengthens the synthesis of lighting technology, environmental psychology and human physiology with landscape architecture. It achieves this through a comprehensive understanding of lighting methods and their subsequent importance in terms of implementation based on scientific study (Moyer, 1992).
- It responds in great detail to relevant issues in landscape architecture such as the importance of lighting terminology and lighting techniques (Moyer, 1992). This discussion of lighting terminology and methods not only helps us achieve design criteria, it reinforces the understanding of objectives required to satisfy the need of human-environment relations and interactions.
- Lighting design research contributes extensively to lighting methods relevant to landscape architecture such as front lighting, back lighting, down-lighting, and up-lighting, and discusses their importance in terms of implementation.

- It clarifies underlying principles of reflectance associated with a broad range of exterior products, objects, and plant materials and how they contribute toward reflectance properties within the visual field. For example: grass, concrete, and paint.
- It provides information on lighting equipment such as fixture and lamp characteristics, beam spread, focusing, and operating requirements.
- In addition to the synthesis of the above data, lighting designers provide additional information on installation, and qualitative issues of design. For example, they discuss the importance of view, mood, atmosphere, balance, composition, and rhythm and in turn how these qualities can be considered and appropriately applied in a lighting design (Moyer, 1992).

Summary

Environmental psychology, illuminating engineering and lighting design help establish a theoretical basis for artificial lighting. Environmental psychology deals primarily with the interaction between humans and the built environment. It is a study of the interactions and relationships which occur in human-environment contexts. The relevance of human-environment relationships in the context of this practicum is fundamentally focused on artificial light within urban landscapes. It involves the study of human reaction to various artificial light sources, equipment, and lighting methods. It determines the impact of these elements upon human behaviour, perception of space designed with artificial light, and perception of the landscape in general.

The theories developed by environmental psychology research, have in many instances, served as a catalyst in performing the technical study of artificial light and its methods of implementation. Illuminating engineering provides the foundation for this information. It deals with considerations devoted to quality and aesthetics of light, as well as the technical and quantitative considerations required to enable the development of applied solutions.

Lighting design serves as the link between the technical, qualitative and quantitative considerations of artificial light, as well as the psychological aspects related toward environment. It acts as a bond between the ephemeral qualities based on theories of light, and those more tangible aspects associated with design. Lighting design achieves these goals through the utilization of lighting equipment installed appropriately within the landscape to enhance legibility and influence perception.

Typically, effective lighting schemes are not proposed by landscape architects, even though lighting dramatically impacts the use and perception of a site at night. This often results in site designs which may function appropriately during the day, but not at night. Lighting schemes should be implemented with a full appreciation for principles in lighting design, illuminating engineering, environmental psychology and landscape architecture.

Notes

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[1] Legibility refers to our ability to move through space with greater understanding and clarity of direction.

[2] Measurement of luminance or quantity of light reflected off the surface of an object. The eye quantifies brightness in footlamberts, rather than footcandles, making this measurement more important than footcandles.

[3] Measurement of illumination or quantity of light falling on a subject.

[4] Describes a process of physiological change which the eye must undergo when adapting from light to dark space, and vice versa.

2

THE PHYSIOLOGY OF VISION AND THE PERCEPTION OF LIGHT

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Designing an outdoor lighting scheme requires a thorough understanding of the human eye's response to artificial light. This demands a comprehensive grasp of the physiological changes which the body and mind must undergo in order to achieve day and nighttime vision. This chapter places emphasis on understanding the relevance of physiological changes inherent in the eye and brain, and consequently how they affect human perception of space. Chapter Two will also discuss the role of human expectations as well as the quantitative and qualitative effects of artificial light on behavior and human interpretation of outdoor space. It will discuss issues of perception connected with the use of artificial light at night, as well as the importance of safety and security, legibility, and aesthetics to the achievement of a cohesive lighting scheme. These issues are essential in defining intent and meaning within the urban landscape at night. They contribute greatly to human interpretation of place, and thus merit consideration by landscape architects in assessing their influence on the perception of designed urban space. The following chapter will explore these issues and their importance in terms of implementation in design.

The Physiology of Vision

The physiology of vision is a process commonly attributed to the eye, despite the fact that the brain shares equal responsibility in the task (Boyce, 1981). When referring to the human "visual system", it is important to understand that the process of seeing is far more than just a physiological function of the body. Sight also provides a bridge between the physiological and psychological. In essence, our visual experiences would mean little without our psyche to interpret and attribute meaning to them. Conversely, our psychological interpretation of space would differ greatly without our visual senses to reinforce it (Boyce, 1981; Lam,1977). Understanding how the human visual system operates – and in turn how the eye and brain interpret and process external stimuli around us – is fundamental to understanding the impact of artificial light as a design tool within the urban landscape.

In general terms, light enters our eye as raw data. This data is controlled through an extensive complex of nerves, muscles and ligaments that comprise the eye. This practicum considers those portions of the eye which are directly affected, or responsible for the control and interpretation of light.

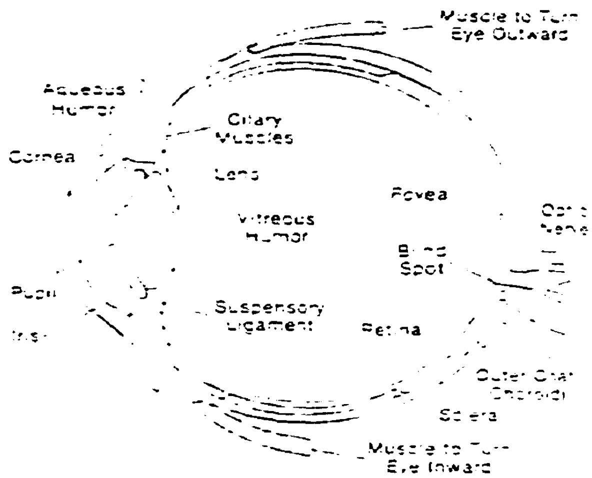

Figure 2.1 Fovea diagram

The human eye responds to changes in light. When light enters our eyes it first strikes a layer of light sensitive cells – the retina – which is comprised of two distinctly different cell varieties. The first of these two variety of cells are the *cones*. Cones comprise the area of the retina directly behind the pupil. They have their greatest concentration here in an area referred to as the *fovea* (Fig. 2.1) The fovea is the area of the eye where vision has the greatest acuity. This fact is generally supported by evidence which suggests that humans have the highest visual acuity when they focus directly upon an object – that is, when the object is focused on by the central most portion of the eye (Murdoch, 1985 ; Hopkinson, 1969). Cones are described as light sensitive because of photopigments contained within their cellular makeup. This pigment plays an important role in protecting the cells against damage, but more importantly, it enables the eye to adjust to various levels of brightness. It is also important to note that cones are the cells which are most sensitive to higher light levels, and hence colour (Boyce,1981; Moyer, 1992; Hopkinson, 1969).

The second of the two light sensitive cells is referred to as the *rods*. This group of cells operates most efficiently after dark, when colour is almost non-existent (Hopkinson, 1969). As light levels decrease, rod vision becomes more acute as a result of a regeneration of *rhodopsin*[5]; colour vision eventually disappears (Moyer, 1992). This loss of colour vision can be attributed to monochromatic functioning of the rods. In addition, because the rods are dispersed primarily along the periphery of the retina, night vision will be best when objects are viewed slightly to either side of a person's central vision (Hopkinson, 1969; Moyer, 1992). This dispersal of rod cells along the periphery of the retina not only aids a person's ability to view things more accurately at night, but it also assists perception of differences in contrast as opposed to brightness. The rods of the eye developed out of a necessity to provide safety within the landscape; to provide as much light as possible, and warn us of changes in the visual field which might not be visible centrally (Hopkinson, 1969). As a result, the rods are largely responsible for detecting movement within our field of view at night (Hopkinson, 1969; Moyer, 1992).

Within the urban environment one would seldom come across conditions which are solely light or dark. The iris, or colored portion of the human eye, is a shutter-like mechanism covering the pupil (black portion of the eye) and responsible for controlling sight under varying light levels. It enables the human eye to voluntarily and involuntarily respond to various lighting levels by controlling the amount of light permitted to the retina. In circumstances where light levels are high, the iris closes over the pupil thereby limiting light stimuli to the retina.

The process referred to as *photopic vision*, describes the physiological condition where light saturates the rods, resulting in a bleaching of rhodopsin, rendering them temporarily ineffective. The process is reversed by a counter-process referred to as *scotopic vision*, which allows the rhodopsin to regenerate when light levels diminish (Moyer, 1992, Hopkinson, 1969). During the scotopic phase of vision, the human eye is unable to interpret a great amount of detail. Interim periods of brightness and darkness, when both the cones and rods are partially active, are times of *mesopic vision*. Essentially, this is a transitory phase when vision begins to interpret colour (Boyce, 1969).

Design Implications

Understanding the general behaviour of both the cones and rods in the process of vision as well as the resulting transitional changes in our vision from brightness to darkness helps to explain human reaction to illuminated outdoor space after dark. This process of vision simplifies the understanding required by landscape architects to incorporate lighting elements into a site by educating practitioners about the reaction of the eye and brain to various levels of brightness. Understanding the transitional changes inherent in our visual system at night enables designers to respond not only to site features, but also to user needs. For example, fixture location and placement which respond to pedestrian movement can reduce the occurrence of disability glare. This allows the viewer to maintain contact with the boundaries of a space and instills a sense of safety and security (Moyer, 1992).

Despite the formidable potential of the human visual system, it cannot operate over the range of brightness levels (photopic through scotopic) simultaneously (Boyce, 1969). Each successive change in brightness level requires an accompanying space of time for the eye to respond appropriately. However, it should be noted that adaptation times will vary relative to the amount of brightness required by the eye to compensate – a process described as transient adaptation (Lam, 1977; Boyce, 1981). Adaptation from dark to light spaces generally occurs quickly, within a span of 7 to 12 minutes. However, outdoors at night, adaptation from light to dark is more often required and may take anywhere from 20 minutes to one hour (Moyer, 1992; Boyce, 1969). In most cases adaptation times will vary dependent upon the disparity between light sources. However, when extreme changes in brightness are experienced by the viewer, momentary disorientation can occur (Moyer, 1992). For example, any person who has experienced the transition on a bright sunny afternoon when entering a dark room will have experienced this phenomenon. Despite this fact, most people are unaware of this phenomenon occurring. It is a process which occurs almost uninterrupted within our daily lives. Therefore, because our eyes continually adjust to changes in spectrum of light, quantity of light, location of response within the retina, and length of exposure, the designer should always be conscious of the location of light sources within the field of view.

Research indicates that the human eye is attracted to the brightest objects within the field of view. This necessitates an understanding of the eye's response to light (Moyer, 1992). If a viewer focuses attention on an area containing a bright source for several seconds or minutes, dark adaptation may be broken. The process of dark adaptation has to begin anew when the viewers shift their attention to another darker point of view. However, many circumstances arise where more than one visible brightness source exists. These circumstances can cause difficulty for the viewer. When multiple bright sources exist, the eye will move from one source to the other, resulting in repeated contraction and dilation of the ocular (ciliary) muscles surrounding the eye. It is these muscles which are primarily responsible for any adjustments of the iris, and as with any other muscle within the body, repetitive movement will result in fatigue and strain (Hopkinson, 1969). When this occurs, the viewer may suffer from eye discomfort, headaches and disorientation (Boyce, 1981; Moyer, 1992).

Brightness and Perception

It has been established that the human visual system involves far more than just "seeing". In fact, what we "see" involves far more than just interpreting visual stimuli emitted from the sun or an artificial light source. When designing for the urban landscape at night, it is imperative to design for the human eye's response to dark environments (Moyer, 1992). As discussed, the human eye can respond to immense changes in luminance levels quite efficiently. Lam (1977), suggests that these changes in brightness can vary as much as one million times when comparing objects under brightness levels experienced during a sunny afternoon to those experienced during a moonlit evening. For many years argument has focused on the need to provide "adequate light" based on quantitative data and analysis. Many manufacturers supply quantitative data based on specific task lighting. However, this quantitative data does not consider external factors such as surface material, reflectance qualities, colours, and human expectation – factors which all influence the perceived brightness of artificial light in exterior space. In fact, research done at the Pratt Institute uncovered some common fallacies behind this approach to lighting. These suggest perception as a more important consideration. For example, the study "found no correlation between their observations of apparent (perceived) brightness and actual measured footcandle levels" (Lam, 1977). The outcome of this research is simple:

> the colours and reflectance values of the room surfaces, the use of the space, time orientation, and other factors, all have an important bearing on the perception of brightness – a bearing which is not taken into account by direct footcandle levels (Lam, 1977).

Light as a stimulus and our perception of space are inextricably linked. When the lighting of an environment changes, our perception of that space changes in relation (Moyer, 1992; Lam, 1977; Gardner and Hannaford, 1993). Factors such as context and expectations dramatically affect space perception in lighted environments. For example, it is not unusual for many people to describe an overcast rainy day as "dark" or "gloomy", when in fact the actual brightness level can be significantly higher than that of a "bright" streetlamp encountered at night. Not only does this research suggest that brightness has far greater implications relative to other brightness levels present within the field of view, but it questions the relevance of energy needlessly wasted on light which exceeds perceptible human levels. Simply:

> it means that doubling the amount of light in a space will *not* make it seem twice as bright (although it *will* consume twice as much energy) (Lam, 1977).

This information is valuable in the prevention of light and energy pollution, and also in cost analysis measures provided to clients and users. Providing light based on a qualitative approach towards design intention will accomplish far greater goals than one based solely on a quantitative foundation. With an understanding of light quality and site and user expectations, the eyes require less light to make sense of the world around us, yet are still able to maintain visibility and safety (Lam,1977; Gardner, 1993).

When making evaluative judgments regarding brightness, consideration must centre on the amount of light reflected from the surfaces of objects within the field of view. Moyer (1992), suggests there are three characteristics responsible for the amount of light reflected from the surface of an object. They are:

- Colour
- Texture
- Material

However, these may be inadvertently affected by external environmental factors such as moisture, which can dramatically increase the albedo (proportion of light reflected) of a surface. Seasonal factors, such as snowfall, can also dramatically affect the reflective qualities of light. Consideration should be given to increases in ambient light resulting from snowfall accumulation. For example, switching equipment such as manual dimmers or seasonal timers can often offset differences in reflected light caused by snowfall accumulation. A colour wheel added to fiber optic illuminators, or the addition of coloured lenses to light fixtures in specific areas can add aesthetic appeal and a seasonal vibrancy.

Understanding the results of light changes to the eye is critical in the understanding of how an individual will experience a space. Not only does it provide useful insight into the manner in which every human experiences light in a space, it also provides critical information for anyone concerned with issues such as safety, security, legibility and aesthetics.

Colour and Perception

What is colour? In order to use light effectively one must understand colour and its relation to light. Often, objects within the field of view appear to have colour as an intrinsic part of their composition, revealed only when light is cast upon them. It is important to understand however, that the colour of an object is not revealed by light. It is in fact a combination of several factors. Colour is revealed by the texture and reflection unique to the object under exposure. Consequently when light falls upon an object, certain colours within the electromagnetic spectrum are absorbed by these innate surface textures, while the remaining electromagnetic light is reflected back towards the eye in the form of stimuli which our eye perceives as colour (Murdoch, 1985; Gardner, 1993; Lam, 1977). For example, bananas appear yellow because they absorb all light within the visible spectrum except yellow, which is reflected from its surface towards the eye.

Objects exist that have the ability to absorb all light within the visible portion of the electromagnetic spectrum and there are some objects that can reflect all visible light as well. For example, objects that absorb all visible light are referred to as black, while those, which reflect all visible light, are referred to as white.

It is important to understand that only "white" light will reveal most accurately which colour will be exposed. White light best reveals an object's true colour because it contains all visible wavelengths in the electromagnetic spectrum. Furthermore, white light is most appropriate for determining an object's colour because it responds to conditions that are most "natural" to human perception. However, understanding the processes of sight and vision can enable the designer to respond more accurately to lighting conditions which satisfy a psychological and physiological response to the eyes and brain.

Understanding the general principles inherent in natural and artificial light and how these principles affect and respond to colour within the urban landscape, will ensure a sensitive design solution. For example, to ensure that landscape elements and surfaces (benches, concrete, plant materials) appear unified and appropriate within site context, and respond as intended within the design concept, one must ensure that the objects contain proportionate amounts of the same colour. In essence, their surfaces must absorb and reflect similar amounts of spectral energy within the same wavelength(s) in a similar manner under similar a light source (Gardner, 1993). The arbitrary use of different light sources without apparent need or justification can produce an undesirable response from the viewer, as it will result in perceptible changes in hue throughout the space (Lam, 1977). Consequently, to avoid a negative perception of the lighting treatment of an outdoor space, one should maintain consistent fixture and lamp type to ensure that objects receive uniform distribution of spectral energy of the same type. Providing a lighting design that responds to the visual differentiation of objects in a space based on light source will provide useful information to satisfy physiological, psychological and orientation needs. It will also contribute towards the legibility of the site (Lam1977).

In situations where a number of different light sources are to be used, the designer should ensure that objects are carefully coordinated with light sources. That is, different classes of objects should be associated with different classes of light, thereby preventing any opportunity for misleading discrepancies as a result of direct comparison (Lam, 1977). For example, viewing a planting bed lit with a Metal Halide lamp will enhance the colour of both the leaves and flowers, while viewing it under High Pressure Sodium, will result in plants which appear dull and lifeless (Moyer, 1992).

In most instances these exacting measures are not needed to view colour. The brain's ability to compensate for subtle differences resulting from an object's surface reflectance or lamp defect, referred to as *colour constancy*[6], will often neutralize small discrepancies. Colour constancy describes a process of perception wherein the brain compensates for a person's judgment of colour based on previous experience. For example, despite our ability in certain situations to make accurate colour judgements, our brain will compensate for the colour of light by telling us that the brick wall "appears red" even though we are unable to distinguish it as red under low light levels (Lam, 1977; Moyer, 1992). However, occasions often arise when the brain is unable to compensate for low light levels. In circumstances where we are confronted with objects unfamiliar to us, colour constancy will be of little use. This results from our inability to quantitatively and qualitatively measure an object being viewed with anything existing within our previous experiences. Under such circumstances, without sufficient light, we would be unable to make any significant judgement regarding an object's colour characteristics. Circumstances such as these can often lead to an unconscious negative response in the viewer towards site and space (Hanyu, 1997). This might not be the case if the design of the site aimed to achieve specific effects. For example, if the design of the site was to accommodate a skateboard or theme park, one might expect to encounter unusual lighting and materials, and the effect would not be uncomfortable. In this example context plays an important part in subduing unusual reaction to the space. This same example might likewise prompt uneasiness in the context of a residential or conservative space (Lam, 1977).

The inappropriate use of colour will not only have negative implications on the appearance of objects, but can also have adverse effects upon the perception of a space. An unparalleled example in Winnipeg of the inappropriate use and choice of light exists at the Manitoba Legislative grounds (Appendix H). A formal garden and fountain are located on the southernmost portion of the grounds, between the Assiniboine River and Legislative building. Experiencing this landscape when all fixtures are in operation leaves the viewer bombarded by extreme light exposure, unparalleled in Winnipeg's urban landscape. This lighting scheme has resulted in a drastic decrease in use of the area. It has also earned the garden the dubious distinction of being called "purple city" as a result of the temporary appearance of a purple hue when focusing on objects directly after exiting the garden. There are few other locations within Winnipeg where such blatant disregard of appropriate lighting principles occur. An excessive number of light standards, lamp numbers, and lamp type (High Pressure Sodium), have contributed to an overabundance of poor light quality. Only issues of safe navigation through the garden at night have been addressed. There appears to have been no consideration given to aspects of "good" lighting practice such as legibility, perception, and aesthetic interpretation. Not only is this approach detrimental to garden use at night, resulting in poor colour rendering of plant material, but more importantly, the excessive amount of light greatly contributes to urban light pollution[7] and increased operating expense. Further to the issues of light pollution, current research indicates that an overabundance of "man-made" objects, such as the lighting standards in the grounds of the Legislative building, will also contribute towards a negative response to place (Hanyu, 1997).

Human perception of the luminous environment can determine the amount of visual attention attributed to elements within the field of view. For example, fixtures offering exceptional colour rendering abilities in a garden will have a positive effect on the viewer. Dramatic lighting within a sculpture garden will, in most circumstances, also result in a positive outcome. Essentially, perception of the luminous environment can determine the amount of visual attention attributed to elements within the visual field, in essence determining how stimulating or attractive a space becomes or appears to the viewer. Incorporating these factors of perception within the design of the urban landscape significantly affects the success of artificial light in defining the landscape at night (Lam, 1977).

> When the environment appears and behaves as expected, that is, when the lighting levels, gradients, patterns and colours in the visual field are relevant to the needs and expectations of the viewer, the associative links are established by prior experience in the 'experience filters' of the brain and the response is confirmed. This generally produces a positive emotional response in the perceiver (Lam, 1977).

The importance of these theories in the design of lighting within the urban landscape is imperative. The social responsibility imparted on landscape architects necessitates that the profession no longer address these issues as simply functional, but with greater intent and meaning.

> The power of light to influence perception, mood and even the outward behaviour of people, is one of the most important aspects of designing with light. That the quantity and quality of light have profound effects on the feelings and emotions of human beings is now indisputable (Gardner, 1993).

The Effects of Full-Spectrum Light Compared with Cool and Warm Light

Despite technological advances, there exists no ideal artificial source that replicates pure white light. However, many manufactures have created reasonable facsimiles often referred to as Full Spectrum Light, as well as other less successful sources commonly know as Cool and Warm Fluorescent (Veitch et al, 1991).

Perhaps one of the greater strengths of full-spectrum light over more conventional cool and warm light is its ability to provide the greatest degree of colour rendering (Boray et al., 1989). Generally, full-spectrum light has a Colour Rendering Index (CRI)[8] of 90 or higher, and typically includes more blues than standard cool white and warm white lamps do (Boray et al., 1989). The significance of greater colour rendering generally describes the light source's ability in mimicking natural daylight, thus presenting objects within the field of view with an appearance visually similar to natural daylight. Furthermore, studies of full-spectrum light have revealed less perceptual fatigue and better visual acuity (Boray et al., 1989). (FDA, 1986)

Other studies of the benefits of full-spectrum light indicate that, despite its greater ability to render the colour of skin and clothing more accurately, the effects upon impression formation of others and the environment is negligible when compared with "warm" and "cool" fluorescent light. However, results change dramatically if subjects are made aware of the lighting differences at the outset. Under these circumstances, the subject's were "amazed" by their inability to notice the benefits produced by full-spectrum fluorescent light on the appearance of skin colour (Boray et al., 1989). Conversely, earlier research on the effects of cool fluorescent light suggested that it can in fact increase the perception of greater space by as much as 16 percent. Recent attempts to replicate these findings have illustrated, however, that this is in fact false (Boray et al., 1989).

With the ability of full-spectrum light to provide greater colour rendering of both individuals and the environment around us, it may seem surprising that the benefits associated with its use appear limited. The findings however, may be attributed to colour constancy (Lam, 1977). The argument suggests that what is occurring is that the viewer is generally unaware of the benefits provided by differing light sources, and its effects upon the viewer are therefore almost negligible as a result of colour constancy. However, research has also shown that when viewers are made aware of the effects of the lighting within their environment the results change dramatically (Veitch et al., 1991; Boray et al., 1989). It should be noted that the above research was performed on short-term exposure and use, and does not suggest that the results would be achieved similarly under extended periods of exposure to full-spectrum light.

Summary

The purpose of this chapter has been to establish an understanding of common psychological concerns associated with the use of artificial light in the urban landscape. It has focused on researching problems attributed to its use and implementation, but has also examined the benefits related to increased legibility, safety and security, perception and aesthetics. In addition, further study has centered on the physiological processes associated with human interaction to artificial light.

The research performed on the psychological phenomenon connected with artificial light indicates that factors such as brightness, light colour, and location, as well as the physical characteristics of the light fixture can impact, both positively and negatively, human perception of exterior space. The research reveals the importance of understanding the human eye's response to artificial light. For the purposes of this practicum the following were identified as pertinent principles concerning the physiology of sight and the perception of space based on artificial light.

- Human sight cannot accommodate photopic and scotopic sight simultaneously. In order to reduce the negative effects of transient adaptation, the number of fixtures and the distance between fixtures should be carefully considered.
- Placement of light fixtures within the landscape should avoid disability glare.
- The rods located in the human eye are largely responsible for detecting movement within the field of view at night. Therefore the use of light in conjunction with human perception of movement can aid awareness and impact the perception of security and safety.
- The human eye is attracted to the brightest object within the field of view. This can provide a valuable design tool to direct human movement throughout a space.
- Human interpretation of artificial light is based partially on the user's prior experience, expectation and context. If the context meets with the user's expectations of the space, the use of unconventional lighting techniques will be acceptable. Any visual discrepancies encountered by the eye and brain will be compensated for by the phenomenon of colour constancy.
- Brightness is a relative term unique to existing and proposed site lighting and context.
- Quantitative measurements of light have little influence on human perception of space.

- Human perception of space changes in relation to the lighting of an environment.
- Greater consideration towards light quality, and site and user expectations will require less light to make sense of the urban environment, yet maintain visibility and safety.
- The colour, texture and finish of an object are factors most responsible for the quantity of light reflected from its surface. Precipitation, in the form of rain and snow, can contribute significantly to the proportion of light reflected from an object's surface.
- Objects should be carefully coordinated with light sources. Appropriate use of lamp type in conjunction with design intent, plant materials, site use, and site features, will ensure minimum confusion to the viewer. Arbitrary use may lead to a negative response to space from the viewer.
- The physical characteristics of lighting equipment can be useful to enhance design elements such as rhythm, scale, harmony and definition. If overused, they can contribute to a negative response to place.
- The quantity and quality of light have profound effects on the feelings and emotions of human beings.

Ways of addressing these issues are examined in Chapter Four.

Notes

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[5] Rhodopsin, or visual purple, is a light sensitive protein pigment found within the rods of the retina of the eye.

[6] Colour Constancy refers to the unconscious processing mechanisms of perception which are performed automatically in our brains when viewing colours under different wavelengths of light. It describes the ability of the brain to recognize objects and characteristics under different conditions, and to compensate or these differences by comparing them to stimuli existing within our experience filters and therefore eliminating differences caused solely by lighting changes.

[7] Light pollution shall refer to excessive amounts of light trespass onto adjacent properties and sky.

[8] Colour Rendering Index refers to a classification system used to measure the ability of a light source to emulate specific electromagnetic wavelengths of the visual spectrum. It is expressed as a percentage between zero and 100.

3

TECHNOLOGY

Ω

This chapter examines technology in lighting design. It discusses the relevance of fixture size, lamp type, mounting equipment, and installations in urban lighting. Technological advances in fixture, lamp, and light quality, allow environmental designers more options in lighting the urban landscape. Often the choice of light source will involve decisions based on specific site, design, and user needs. Aspects such as beam spread, colour rendering ability, fixture rating and wattage as well as operating costs will all play an important role in determining exterior lighting needs. These characteristics will all influence the final lighting choice. However, increasing research suggests that lamp type and location play a pivotal role in creating acceptable visual effects.

Incandescent Light Sources

Incandescent lamps – or filament lamps – produce light by heating a tungsten element within a vacuum or gas-filled glass envelope (Moyer, 1992). These lamps are available in various sizes and wattage ratings. The benefits of using incandescent lamps include tight beam control, inexpensive, greater dimming capabilities, and a light colour that renders human skin tones well. Furthermore, the use of incandescent light as an interior light source also contributes to its popularity as an important exterior lighting source (Moyer, 1992). Despite the apparent benefits of incandescent lamps, they should be specified only in circumstances where a light source below 500 watts will be required, where excessive heat dissipation is not a threat to plant and site features, and where operating costs will not exceed budget constraints (Gardner, 1993; Moyer, 1992). Appendix B gives a comparison of lamp characteristics.

Tungsten-Halogen

Tungsten halogen lamps, commonly known as *Quartz*, offer several features that provide greater benefits than traditional incandescent lamps. The compact size of the lamp and fixture allows easier concealment within landscape and architectural features. Furthermore, the compact size of the lamp and filament permits the designer and user greater control over beam spread and light destination than traditional incandescent sources. Generally, tungsten-halogen lamps offer added benefits over traditional incandescent lamps through efficiency, longevity of the lamp and filament, and higher lumen maintenance in 12, 24, and 120 volt systems (Moyer, 1992; Boyce, 1981).

How they work

As with all incandescent lamps, voltage is applied through a filament of tungsten alloy, enclosed within a vacuum-sealed or gas-filled tube, until the filament becomes sufficiently hot that it glows, producing visible light. Tungsten-halogen lamps comprise a more elaborate group of the standard incandescent lamp. They still maintain the basic component of all incandescent lamps – the tungsten filament – but they have halogen gas surrounding the filament, which re-deposits evaporated tungsten back onto the filament. This process of re-circulating tungsten particles through halogen gas is known as the tungsten-halogen cycle. It is critical in the maintenance, output and longevity of the lamp because it allows the bulb to operate at a higher temperature (Moyer1992; Boyce, 1981). However, as a result of their extremely high operating temperature, tungsten-halogen lamps are extremely sensitive to shock damage. Therefore, they must be located in vandal-proof housing, or beyond reach.

Common Tungsten-Halogen fixtures

For the purposes of this practicum, Mirror-Reflector (MR), and Parabolic Aluminized Reflector (PAR) lamps were identified as the most suitable Quartz lamp varieties. These lamps were chosen because of their low operating costs, versatility of use, light quality, and beam and light control. These lamps provide the versatility required to address scale and site identified (Moyer, 1992).

Mirror-Reflector (MR)

MR lamps are the most common tungsten-halogen fixtures. They consist of a small quartz lamps surrounded by a highly reflective mirror. Available in low voltage and standard voltage[9] models, they provide the greatest flexibility within the lighting design of the landscape. Their compact size, combined with the versatility of the various beamspread options, allows their use in sites requiring a minimum of visual intervention or disturbance. In addition, these fixtures offer improved colour when compared with traditional incandescent light fixtures, as well as increased operating cost, while providing a light quality that enhances the visibility of most plant material and objects under exposure. Depending on site and user needs, there is a choice of two models of MR lamps – the MR16 and the MR11. The increased wattage and beamspread capabilities of the MR16 lamp make them most useful for general lighting purposes. MR11 and MR16 lamps are available in a range in wattages from 20 to 75watts (see Appendix B) (Moyer,1992).

MR11 lamps are smaller than the MR16 variety and are most useful in areas requiring the least amount of intrusion and in sites with well established plant and architectural features. The installation of low voltage models (12 and 24 volt) requires less site disturbance than installation of standard models with a voltage rating of 120 volts. Generally, the risk of injury due to shock is reduced when using low voltage models (Canadian Electrical Code, 1998). Furthermore, MR11 lamps provide the best alternative to the MR16 variety in confined spaces. They offer excellent flood lighting abilities with good beamspread control.

Parabolic Aluminized Reflector (PAR)

Similar to the Mirror-Reflector variety, PAR lamps combine the standard tungsten-halogen filament with a specialized reflector to restrict beam spread and light direction. Available in both low voltage and standard voltage models, PAR lamps vary from MR lamps in their ability to provide a concentrated and focused light source, with excellent optical control and high candlepower abilities. Their specific use characteristics limit their application. However, these characteristics enable designers to create accent lighting with minimal physical intrusion from fixtures, wires and mounting equipment. PAR lamps are available in various wattage and voltage ratings ranging from 45w to 500w and 12v to 120 volts (see Appendix B). Generally they are less prone to damage from rain, irrigation water, and snow than the MR variety. Some PAR fixtures are susceptible to corrosion resulting from water entering through holes in the base of the fixture (Moyer, 1992).

Low Voltage vs. 120 volt Standard

Landscape lighting has traditionally involved the use of 120 volt fixtures and lamps for operation. However, over the past two decades significant advances have been made in low voltage technology and products. This includes a process whereby standard voltage (120 volts) is significantly stepped-down (lowered) via a transformer to operating voltages of 12 – 24v. The benefits provided by low voltage technology involve greater operating efficiency, increased lamp life and greatly reduced fixture size. This makes their use in landscape projects easier (Moyer,1992). Additional benefits provided by low voltage lighting include reduced shock/electrocution hazard, as well as greatly reduced excavation requirements during installation (Canadian Electrical Code, 1998). Not only does the reduced excavation requirement limit initial cost to the client, it also lowers damage to existing plant material and built elements on the site. Low voltage lamps provide the designer and client with the ability to modify lighting as the landscape evolves. For example, lightweight fixtures providing accent or down-lighting during the initial design phase – when trees and shrubs are not yet fully matured – can be relocated as necessary. Furthermore, the relatively light weight of low voltage fixtures prevents undue stress that is a common factor with standard voltage fixtures. In renovations or on sites containing established planting, low voltage technology provides the least intrusive solution.

Despite the advantages of low voltage lighting, designers should not overlook circumstances where standard voltage light fixtures would provide greater feasibility. For example when lighting large canopied trees with dense, extensive branching systems, the use of standard voltage lamps would provide the light needed at the apex of the canopy. The most appropriate response in new installations is to provide a combination of both low and standard voltage fixtures. Careful consideration of site and client requirements and needs in the initial design phase will often help prevent any further lighting dilemmas as site use and planting matures. This is especially true of low voltage lighting equipment that requires special attention during the planning and design phase to avoid technical problems resulting from voltage drop.

Discharge Lamps

Discharge lamps produce light via two electrodes which send an electric arc through a lamp filled with mercury vapour (including mercury halide) and sodium gas. Unlike low voltage lamps, discharge varieties require a higher sustained voltage in order to maintain the arc required to operate the lamp. Generally, discharge lamps are more efficient than standard voltage incandescent lamps. As a result, this makes them very useful for flood and accent lighting required for larger scale projects.

Discharge lamps have certain disadvantages. The initial cost of purchasing the fixtures and lamps is relatively high. They often produce a high lumen output, hence limiting their potential in general landscape applications such as footpath lighting, or planting bed accents, and typically they lack optical focusing and dimming capabilities. A further disadvantage of most discharge lamps is that ballast changes, if necessary, are costly. In addition, colour constancy between lamps is often poor. This can result in drastically different colour rendering of objects or individuals within the space (Moyer, 1992).

High Intensity Discharge Lamps (HID)

All high intensity discharge lamps follow the same principles as discharge lamps. Colour and light produced from HID lamps is dependent on the type of gas in the lamp, as well as the type of phosphorous coating used to line the lamp. Adding a phosphorous coating to the lamp – a process known as colour correcting – is often done to improve light colour and quality. The result is improved light with the ability to render objects more closely to natural daylight. There are four basic types of high intensity discharge lamps that can be used in the urban landscape. They are:

1. High Pressure Sodium
2. Low Pressure Sodium
3. Mercury Vapour
4. Metal Halide

A common drawback of all HID lamps is that after accidental shutdown they must go through a "cool down" process before they can be re-lit. This is often referred to as "restrike" time, and is critical in situations where HID fixtures are providing security or safety lighting. Consequently, HID sources should not be used in conjunction with motion detection equipment.

High Pressure Sodium

High pressure sodium lamps produce light by passing an electric arc through sodium vapour. The increased pressure of the sodium vapour contained within the lamp helps increase light output while broadening the available visible portion of the colour spectrum. Although colour corrected lamp varieties offer an improved light quality - bordering on white - most high pressure sodium lamps produce a noticeably yellow light quality.

Despite the marginal increases made in colour improvements, these lamps are generally restricted to highways and parking lots, where their colour rendering abilities are less critical. However, the use of these lamps within the urban landscape should involve great care. Negative effects on the appearance of plant life and people, resulting from the limited colour produced in the visual spectrum, are often associated with its use. (Moyer, 1992).

Low Pressure Sodium

For the purposes of using light as a means of enhancing the legibility and appearance of the landscape, the monochromatic light (entirely yellow) of low pressure sodium lamps precludes it from significant usage in the terms of this practicum.

Mercury Vapour

Mercury vapour lamps produce light by passing an electric arc through mercury vapour. These lamps produce the greatest portion of their light within the blue-green spectrum of the electromagnetic field, as well as a small segment within the ultraviolet region (Moyer, 1992). Colour improvements can be made by manufacturers to improve the light quality by transforming portions of the ultraviolet light into useful white light.

The advantages of using mercury vapour lamps include their long life – 24,000hours – as well as their ability to produce an effective moonlight facsimile. Constraints include their cumbersome size, their relative inefficiency when compared to other HID sources, and the limited colour options (Moyer, 1992).

Metal Halide

Similar to mercury Vapour lamps, metal halide lamps produce light by passing an arc through mercury vapour gas. The one difference between the two lamps is the presence of small quantities of metal halides[10] within the gas. The halides react with light particles to widen the emitted light spectrum and offer the best example of white light produced by any of the HID sources (Moyer, 1992).

Metal halide lamps provide the best light for plant growth; a result of the light spectrum which they produce. Their colour rendering abilities are the best of all the HID sources. They provide the best alternative of all HID fixtures where colour quality of objects is of the utmost importance (Moyer, 1992).

The largest constraint in using metal halide lamps is the inability of manufacturers to control the amount of halide used in production. This can result in colour inconsistencies between lamps. Furthermore, ballast sensitivity to variations in operating voltage will only compound these inconsistencies while making the lamp prone to voltage drops and possible shutdown. Recent developments in electronic ballast technology have reduced many of these problems. However, retrofitting of this equipment can be costly.

Fluorescent Lamps

Fluorescent lamps produce light via a sealed glass tube containing mercury and/or argon gas with an electrode mounted at either end. When voltage is applied through both electrodes, an arc of primarily ultraviolet radiation is produced, exciting the fluorescent powder, coating the tubular walls and producing light (Moyer,1992). Benefits of fluorescent light include the ability to produce most light within the visible spectrum – as high as 90% in Full Spectrum Lamps – making it the best artificial lighting method with which to simulate natural daylight. Despite advances made in fluorescent lamp technology, most fixture sizes remain quite large – often too cumbersome for adequately concealing them within the landscape. There are however, certain fixtures that are compact enough for outdoor use.

Fluorescent lamps best suited to a cold climate such as Winnipeg's often require special protection for operation. Referred to as *Jacketed*, because of their sensitivity to cold temperatures, these lamps are surrounded by additional glass tubing to protect them from wind, air and temperature fluctuations, while providing additional heat retention to maintain optimal operating temperatures. Many outdoor fluorescent fixtures have difficulty starting – as well as maintaining proper operation – at temperatures below 10°C and get progressively less efficient as the temperature falls. Outdoor fluorescent fixtures often require low-temperature ballasts in order to operate at all.

Fluorescent lamps do provide the ability for even light distributions (wash) and are extremely energy efficient compared with the operating cost of an incandescent source. Lamp life can range from 10,000 hours in larger varieties, to 20,000 hours in more compact varieties. These benefits notwithstanding, fluorescent lamps often require expensive dimming equipment, with almost no control over beamspread. They generally produce significant amounts of light, often greater than the small amounts required during nighttime use.

Fiber Optics

Fiber optics are becoming an increasingly appealing lighting tool for use in the landscape. Primarily made from plastic, fiber optics consist of tiny strands which transmit light particles along their length. Varieties include side-emitting and end-emitting fiber optics. The lamp supplying light to the fibers is located in an enclosed illuminator or "light box," where the strands terminate (Figure 3.1). The quartz-halogen lamps supplying the illuminator are rated between 75 – 400 watts, and can sustain light in runs as long as 200 feet (Sorvig, 1999). The primary advantage of fiber optics lies in its ability to produce light without any of the constraints associated with more conventional lighting methods. For example, heat and electro-shock hazard are virtually eliminated, making this method of lighting an appealing substitute for lighting water features. The fibers can remain exposed, or be embedded in almost any material. The largest constraint in the use of fiber optics, is their inability to transmit concentrated amounts of light for floodlighting, and up-lighting of large trees and other objects (Moyer,1992; Sorvig, 1999).

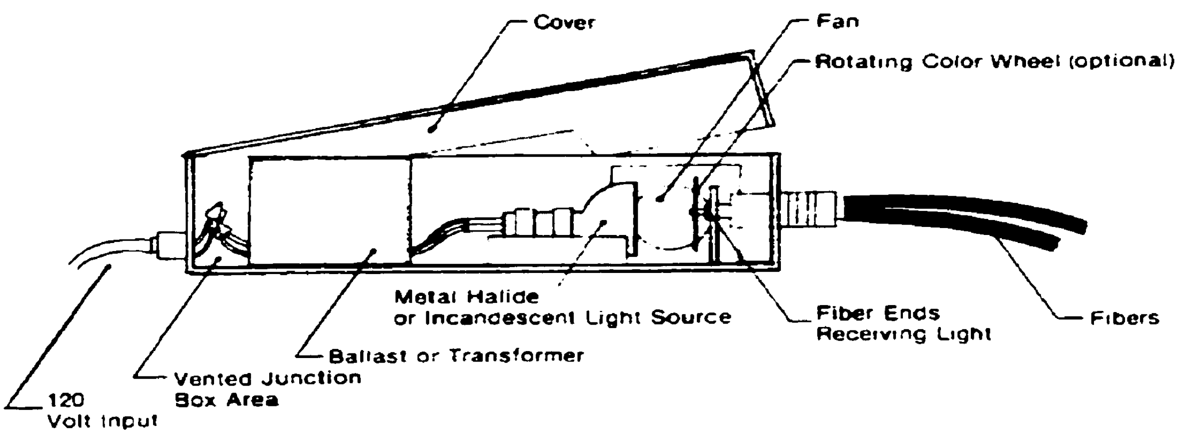

Figure 3.1 – Light box, and fiber optic cable system

Fixtures for Outdoor Use

A number of issues must be considered when selecting fixtures for outdoor use. Fixtures are the physical constructs that house the lamp assembly and wires. They can become a means of expressing design intention and meaning. A fixture can be exposed as a design element or can be concealed from view. Concealment of fixtures during the initial design phase may be required to provide additional emphasis to other design elements or site features. In addition to the issues outlined above, when selecting a fixture for outdoor use consideration must also be given to:

- Safety – heat and electric shock resistance
- Maintenance – lamp, fixture, installation
- Weather – moisture resistance, cold resistance and temperature operation

Safety

When making fixture selections, safety is imperative. Poor fixture selection can pose serious risks of burn or electrocution, and can seriously impede and destroy plant and tree growth.

Maintenance

The installation process and the location of fixtures are serious issues to consider in the construction phase if lighting is poorly addressed in the design phase. Consideration must be given to installation location prior to fixture selection to ensure appropriate maintenance and operation while in use. For example, should surface recessed HID fixtures be specified, additional space will be required around the fixture to ensure adequate heat dissipation. This will impact installation costs.

Consideration must also be given to site needs over time. Fixtures installed on trees for spot and down-lighting must take into consideration the weight of the fixture and lamp on young trees as well as the fastening method used to attach the fixture and cable to the tree. Heavy fixtures not only appear cumbersome on young trees, but can cause the tree to sag and droop, possibly affecting long-term growth. Cable should never be fastened with wire wrapped around the trunk of the tree. This can result in serious effects to tree life as it grows, resulting in eventual strangulation of the tree, damage to the bark, and possibly disease (Moyer, 1992). Instead, clear rubber tubing or clear flexible PVC (Polyvinylchloride) should be substituted.

Weather

The primary concern in selecting fixtures for outdoor use lies in their weather-proofing against water penetration. Extreme temperature variation and water penetration can seriously impede the operation of certain fixture types. For example, fluorescent fixtures used in outdoor extremes must be retro-fitted with a cold temperature ballast. However, despite technological advancements, a cold temperature ballast will often cease working below −18°C.

Summary

Technological developments continue to be made in a range of areas including fixture and lamp design, switching equipment, and fiber optics. This chapter has illustrated the variety of products in use, and the situations in which they may be applied. It has also examined professional knowledge regarding fixture and lamp sources best suited to design and site needs. Subsequently, it elaborated on advantages and disadvantages associated with specific fixture and lamp use. The following were identified as pertinent criteria for this practicum with respect to lighting technology and the utilization of lighting equipment.

- Four different lighting varieties were identified[11]. They are:

1. Incandescent

- Available in a variety of sizes, shape and wattage ratings
- Include tight beam control (enable the user to focus more controlled light beam as a result of their smaller optical source).
- Inexpensive, easy, dimming capabilities
- Colour rendering closely matched to human skin tones
- Widely acceptable to human perception resulting from its popularity as an interior light source
- Limited fixture availability in circumstances requiring a source higher than 500 watts.

- Higher initial cost.
- Incandescent light fixture weaknesses can include excessive heat dissipation and inefficient operating costs – especially in larger wattage models.

2. Tungsten-halogen (quartz) MR. and PAR.

- Improved variation of the incandescent light source – with halogen gas surrounding the filament.
- Offer the greatest compactness of incandescent light fixtures and lamp types, and provide the best opportunity for integration in the landscape (especially low voltage models). Most accommodating in mature, established landscapes.
- Increased beam and light control over conventional incandescent light sources.
- Good variety of fixture wattage ratings – excellent versatility as landscapes develop.
- Easy dimming capabilities
- Lamps provide greater energy efficiency, longer operating life, and higher lumen maintenance.
- Available in both low (12 and 24 volt), and standard 120 volt operating systems.
- Ideal for mounting in trees.
- Can be stake mounted and re-set as the landscape changes over time

- Low voltage models decrease the chance of electroshock hazard
- Reduced excavation cost incurred.
- Extremely high operating temperature – sensitive to shock damage.
- Require vandal-proof protection or beyond reach of high traffic pedestrian areas
- High heat dissipation
- Requirement of transformers on the low voltage models
- Slightly higher initial cost

3. High Intensity Discharge (H.I.D.) – General Information

- Ideal for lighting mature canopied trees where higher lumen values are required at canopy apex.
- Higher initial cost of fixtures and lamps
- High lumen output; limiting factor in their applicability for general landscape use.
- Lack of beamspread control, and dimming capabilities
- Costly maintenance associated with ballast replacement – should site or client needs change.
- Colour consistency between lamps is sometimes a limiting factor – Metal Halide.
- Re-strike times associated with many HID sources are often a limiting factor.

High Pressure Sodium

- Although colour corrected lamp varieties offer improved light bordering on white, most produce a noticeably yellow light.
- Poor light quality can have a negative effect upon the perception of plant material and people.
- Should be restricted to areas where colour quality of objects within the field of view is not a primary concern.

Low Pressure Sodium

- The monochromatic light colour (yellow), precludes it from being of significant use in urban lighting. It dramatically impedes the colour of objects under exposure.

Mercury Vapour

- Greatest portion of light emitted is within the blue-green portion of the electromagnetic spectrum.
- Provides a light quality similar in appearance to moonlight.
- Long lamp life; up to 24,000 hours
- Cumbersome size and relative energy inefficiency compared with other HID sources.
- Limited colour options

Metal Halide

- Provide the best light for plant growth as a result the emitted electromagnetic spectrum.
- Best option for uplighting large trees and large architectural objects.
- The addition of metal halides with the mercury vapour surrounding the filament increases the amount of visible light emitted. They offer the best example of white light produced by any of the HID sources.
- Best colour rendering abilities of all the HID light sources.
- Colour consistency between lamps can be a limiting factor.
- Ballast sensitivity to fluctuating operating voltage increases disposition to excessive re-strike frequency.

4. Fluorescent

- Full-spectrum fluorescent lamps provide the greatest portion of their light within the visible spectrum (up to 90%).
- Greatest degree of energy efficiency – when compared with incandescent light sources.
- Despite advances in fluorescent lighting technology, fixtures remain cumbersome and large often limiting their concealment within the landscape.

- Limited operating ability in colder climates, especially at temperatures below −10°C.
- Retrofitting with cold temperature equipment such as jacketed lamps and cold temperature ballasts increases initial cost; extends operation to temperatures of −18°C
- Lamp life – 10,000 to 20,000 hours
- Useful for uniform light distribution (wash).
- Expensive dimming requirements
- Often provide overabundance of light for intimate lighting requirements.
- Lack of any beamspread focusing control.

Research on the technological qualities of artificial lighting and equipment indicates that factors such as lamp type, fixture size, voltage rating, implementation (both in terms of installation and accommodation of lighting equipment), as well as the physical characteristics of the light fixture can impact, both positively and negatively, the design and perception of the urban landscape.

Despite the fact that one or more light varieties often illuminate a site, one source will provide better light quality suited to site, design, and user needs. This chapter has identified constraints and opportunities associated with incandescent, tungsten-halogen, high intensity discharge, and fluorescent lamps. This included light colour, operating voltage and wattage, physical aspects of the fixtures and lamps, as well as information on installation and maintenance.

The factors most critical in a technological lighting strategy include:

- Colour(s) required
- Scale
- Safety and security
- Mood
- Cost
- Ease of maintenance
- Relationship to overall design intentions and atmosphere.

Notes

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[9] For the purposes of this practicum *Standard voltage* is defined as 120volts, while *Low voltage* means 12 and 24 volts

[10] Halides are added to the mercury gas to widen the emitted colour spectrum, to produce an improved white light and to increase lamp efficiency (Moyer, 1992).

[11] Fiber optics was not identified as a separate lighting source because it often uses an incandescent or tungsten halogen lamp as its source of light.

4

ELEMENTS OF DESIGN

Ω

This chapter incorporates research on artificial light in terms of technology, environmental psychology, illuminating engineering and lighting design. The synthesis of this research forms the basis of a lighting scheme founded on sound principles of landscape architecture, technology, and lighting design. The integration of this knowledge will form the basis for guidelines to be implemented within the site.

Site analysis

A contextual map (Figure 4.1)[12] illustrates the relationship of the site to major features located in Winnipeg's downtown, including The Forks National Historic Site, the Assiniboine River, and the Manitoba Legislative Grounds. In addition, the site offers the benefit of maintaining a close connection to Winnipeg's business district (Broadway), as well as such other amenities as hotel, shopping and convention facilities. Consequently, the site is regarded as a catalyst for Winnipeg's downtown infrastructure, while also serving as a gathering spot for local residents.

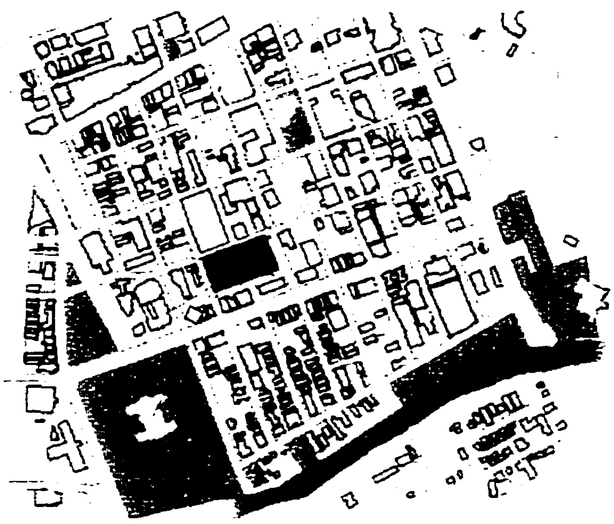

Figure 4.1 Contextual map illustrating site in downtown Winnipeg. Red area indicates location of site.

Currently, the site is surrounded by a number of artificial lighting sources. The principle sources are high pressure sodium fixtures mounted on standard, 10 meter high green steel Cobra head street fixtures, or on wood hydro poles (Appendix G). These occur primarily on Edmonton and Hargrave Street and York Ave. Several mercury vapour fixtures mounted on wood poles also exist. Existing buildings surrounding the site, such as the Winnipeg Convention Centre, contribute "light trespass" in the form of fluorescent and incandescent signage. A major dilemma therefore, is to satisfy criteria outlined in the preceding chapters, and to overcome the constraints outlined in the site analysis. This will involve careful planning of site use with introduced lighting elements. Subsequent discussion will examine conceptual methods of approach to deal with the opportunities and constraints of artificial light, and the technology associated with its use.

Proposed Site Design

Prior to discussion of lighting design elements proposed for the site, an overview of the site is presented. This discussion is intended to reinforce the premise that lighting can be used to strengthen conceptual design ideas and intent.

> **CONCEPT STATEMENT**
> The purpose of extracting lines of vision and action is to design for views which visually work out from the site to place itself within the context of downtown Winnipeg. This site is not merely a unique central public park space to downtown, it is the heart of downtown which collects energy from its composite of structures, landscapes and people. It acts like a prism by collecting the energy of this dense urban environment and re-distributes this energy core to different parts of the site, thereby accommodating specific activities in some areas. Other areas are defined simply by the concentrated energy which resides in these places. The collective space focuses this energy and gives it definition. It physically connects to its context, and on detailed scales, responds to the nature of the fabric within which it is placed (Goertzen, 1999).

The urban nature of the site raises issues which must be addressed to create an environment that evokes a feeling of security. In order to create a safe and secure nighttime urban environment, designers must free the viewers' unconscious processing mechanisms from fear of harm. This involves the use of well-controlled, maintained and designed lighting elements that respond to human perception, brightness, contrast, safety and security, and legibility. This will enable pedestrians to operate comfortably and to appreciate the amenities offered by the space. This practicum focuses on specific areas within the proposed site design that are more heavily used at night. These areas include:

- Central piazza

- Reflecting pond and Waterfall
- Tree paving grids
- Pathways (Pedestrian Corridors)

Site programming is discussed in detail in Appendix A. The lighting design will concentrate on reinforcing the relationship of site design to context, and on enhancing the cohesiveness of site elements to form a vocabulary which strengthens site legibility and aesthetics during nighttime use. The design will concentrate on lighting strategies which seek to enhance public perception and use of urban space at night.

Lighting Strategies

As discussed, key areas have been identified within the proposed site design as providing potential conflict in the public use of space at night. Generally, the design of the site maintains fluent sight lines that connect the interior piazza to the existing surroundings, making it visible from external vantage points. These sight lines are reinforced with visual nodes established on adjacent city streets where the sight lines converge. These nodes will become the locations for LED pavers and light standards as identified in Figure 4.2. For this reason, the piazza is the most visible space, and therefore will require less attention in terms of safety and security lighting (Appendix D illustrates a Lighting Layout Plan for the site).

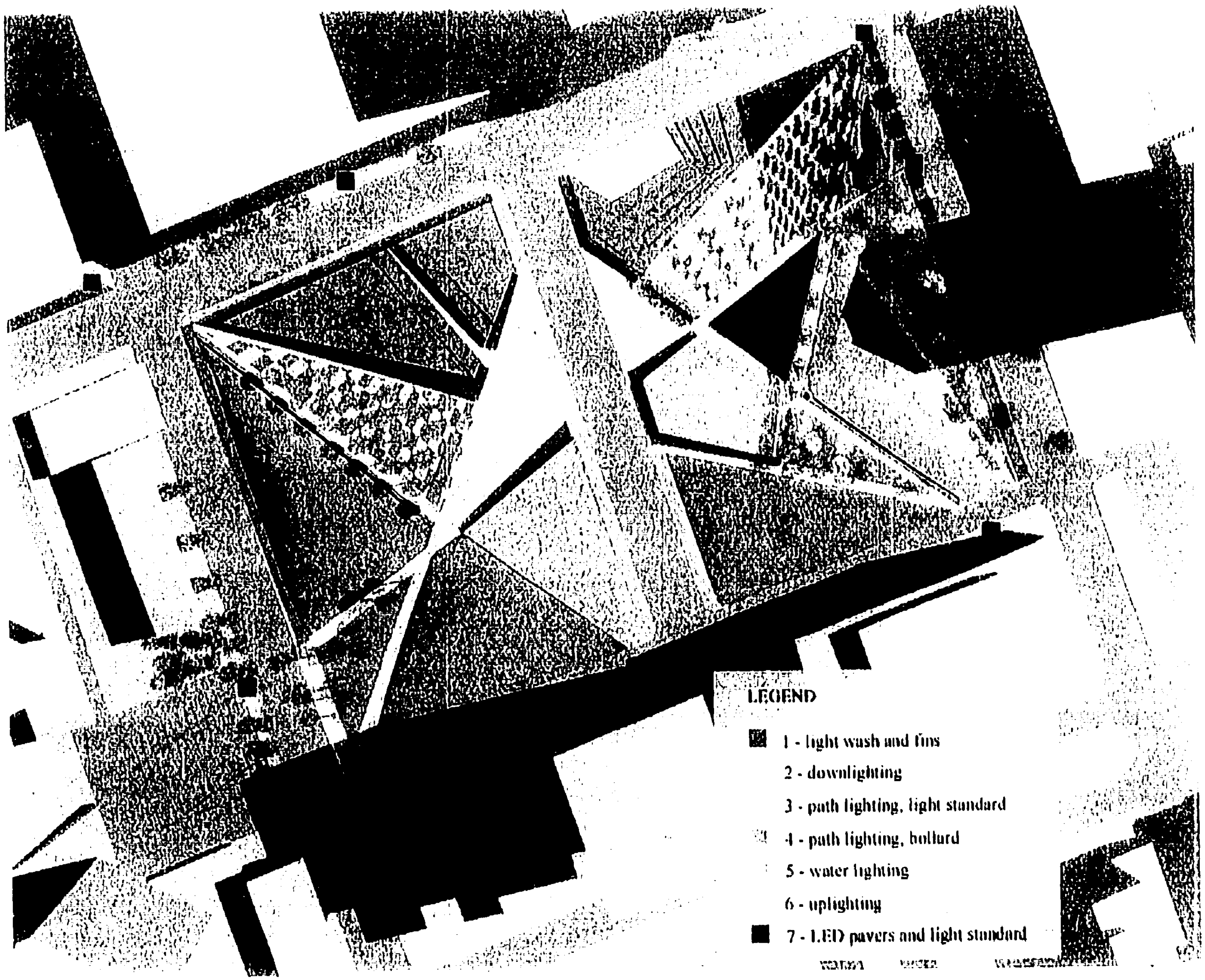

Figure 4.2 Lighting Typology illustrating lighting strategy by area.

FootLambert and Footcandles

As discussed in Chapter Two, the human eye is attracted to the brightest object within the field of view. Exploiting this principle of human physiology can provide a unique opportunity for presenting the urban landscape at night. Appendix C illustrates a conceptual lighting plan of the site with proposed levels of illumination. Both footcandles (fc)[13] and footlamberts (fl)[14], as well as the relevant reflectance levels (P), associated with the surface materials used, are necessary to present an accurate description of lighting transitions involved in the space. The importance of supplying footlambert levels rather than footcandle levels is due largely to the reflectance of surface materials used in portions of the site. *Footcandle* is a term used to describe a measurement of illumination or quantity of light falling on an object[15]. A footcandle measurement, however, does not take into consideration the absorption of light particles by surface materials, or refraction of light waves through air. *Footlambert* is the term used to describe the quantity of light reflected off the surface of an object (Murdoch, 1985; Moyer, 1992; Boyce, 1981). The eyes see luminance or footlamberts, rather than footcandles, and this value will therefore be given precedence in this practicum.

The relevance of the luminance transitions which occur throughout the site will dramatically impact not only the way a participant is introduced to the space, but also how they perceive and move through it. Moyer (1992), suggests that when individuals are moving through space, they feel greater comfort when they are progressing toward an area of higher brightness. This theory is adopted in the conceptual lighting plan illustrated in Figure 4.3. Here, footlambert levels introduced around the periphery of the site are generally between a value of 1.0 fl and 1.2 fl. The 1.2 fl used will occur at a level slightly greater than that occurring on adjacent city streets. The introduction of a marginal increase in luminance level will set the precedence for the remainder of the site. Following this introduction, luminance levels will gradually increase as the participant progresses inward, culminating with the greatest luminance level at the central piazza (4.0 fl). This point will serve as the major focal point within the lighting design. Despite a marginal increase in the footcandle level of the piazza (10.0 fc), the footlambert value will in fact be four times greater than that occurring along the paths. This demonstrates the importance of reflectance values in calculating brightness levels perceived by the human eye. In this case, the central piazza contains red-brown interlocking paving blocks with a reflectance value of 40%,[16] while paths leading into the piazza are surfaced with a paving block with a reflectance of 15%. Under these circumstances the path surfaces, due to their low reflectance value, absorb a greater amount of light energy and require 6.67 fc and 10.0 fc respectively, to sustain a level of 1.0 fl and 1.5footlambert. Surface areas separating paths and piazza – for example turf, gravel, and planting grids - will require increased brightness levels due to their greater importance within the lighting scheme. Because these areas form a greater portion of the site, their lighting levels will correspond with their associated surface qualities to ensure a smooth transition between areas. Essentially, not only will an increased brightness level maintain visual interest on designated areas, it will also serve as a brightness bridge between lighting transitions, effectively reducing the occurrence of transient adaptation.

The only exception to increased levels of brightness throughout the site will occur in the reflecting pond and adjacent areas. Here, lower levels of brightness are proposed to offset the relatively low luminance values associated with point source fiber optics. Maintaining a value within the 1.0 fl level adjacent to the pond and of 0.8-0.7 fl over the pond itself will ensure the added contrast necessary for the desired effect required by the fiber optics. In order to achieve the relatively low levels of light required above the pond, minimum reflectance glare from adjacent fixtures must be ensured.

In certain circumstances the retaining walls can serve as a visual barrier, restricting the cones of vision. The end result is the creation of dark undefined spaces adjacent to and around corners. Such visual barriers occur in Area 1 (Figure 4.2). The proposed solution to this problem entails the creation of a light "wash" along the walls adjacent to major walkways. The light wash strategy responds to the argument that human vision senses movement most accurately within the peripheral field of vision. This premise is strengthened by the argument that providing a light wash along those walls adjacent to pathways will enhance the contrast of figures against a lighter backdrop provided by the wash (Hopkinson, 1969; Moyer, 1992) (Appendix E, Detail 2 of Drawing L3).

Low voltage mirror-reflector lamps (MR) will be used to provide the desired light output. These lamps were chosen based on their ability to provide excellent flood[17] distribution, with good beamspread control. A louvered fixture lens will be used in conjunction with an adjustable fixture to obtain optimal directional capability while guaranteeing minimum glare (Figure 4.4).

Walkways and paths adjacent to corners of converging retaining walls in Area 1 were identified as areas where apparent safety may be lower. To prevent any concealment behind adjoining retaining walls, directional light will be projected close to intersecting points by way of light "fins", casting shadows and providing a cautionary signal of impending danger to anyone approaching (see Appendix E, Details 1 and 2 of Drawing L5). MR lamps supplying a soft graze[18] of light will be used in conjunction with fixtures partially recessed within the retaining walls, and containing appropriate lens louvers to prevent glare.

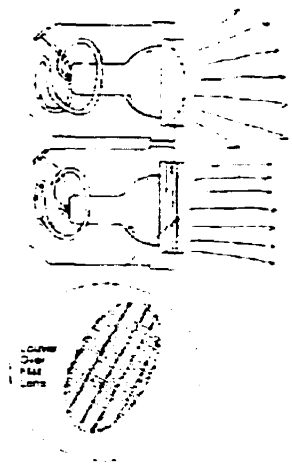

Figure 4.4 – Fixture with louvered lens

Research indicates that transitional changes inherent in our visual system when moving from light to dark space, can have a profound impact on the way we perceive our environments. A landscape which uses pockets of light interspersed with darkness will result in a regular shift from photopic to scotopic vision (also know as transient adaptation), and possibly lead to eye strain, headache or fatigue. The user can be left feeling disoriented, unsafe and, consequently, leave with a negative perception of the space (Lam, 1977; Boyce 1981; Moyer, 1992). In order to avoid transient adaptation that occurs under these circumstances, a *brightness bridge* will be implemented in the design. Brightness bridge is a term which refers to "fill" light, used in the interim periods of brightness to soften the transition from brightness point to brightness point within the landscape. The primary role in applying this technique is to reduce the ratio of light between sources and, consequently, to alleviate the instances of transient adaptation. Therefore, lighting elements proposed on the site will maintain a brightness ratio to surrounding areas of between 3:1 and 5:1 from pathways lit to a level between one and five footcandles (Moyer, 1992). Area 2 in Figure 4.2 indicates where brightness bridges are achieved by means of down-lighting through the tree canopies.

Paths

The criteria used for lighting pathways is largely based on the complexity of the path. Moyer (1992) suggests that two types of paths are generally identified - *simple* and *complex*[19]. For example, simple paths using material with little pattern and high reflectance – such as concrete – will require less light as opposed to darker materials with stronger texture qualities, such as red brick or crushed stone. Conversely, complicated paths typically require a higher quantity of light to maintain psychological comfort for the user (Moyer, 1992).

The use of pockets of light has generally been established as an undesirable effect within the urban landscape. Research suggests that patterns of light and dark should be avoided along pathways. This results from a tendency for the eyes to be attracted toward bright and dark contrast within the field of view. The end result may be that people direct involuntary attention toward the light pattern of the path and not toward the desired elements within the landscape. There are, however, exceptions to this rule. When the pattern of light introduced along a path creates an evenly distributed show of light, such as shadow patterns cast from down-lighting through a tree canopy (Example, Area 3 in Figure 4.2), the eye tends to be less attracted to changes in contrast (Moyer, 1992) (Perspective 3, Appendix F). Where pathways will be lit along one side by light standards, as in Area 3, or under circumstances where additional path lighting is to be supplemented by lighting one side of the path with bollards, as in Area 4, consideration will be given to:

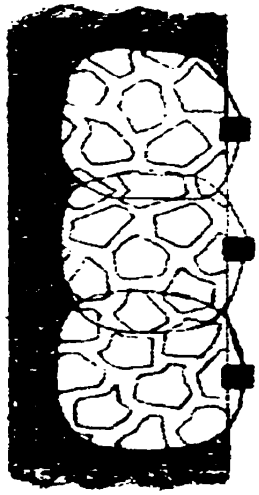

Figure 4.5 overlap required between adjacent fixtures

- The overlap of beamspread from adjacent fixtures to ensure adequate light output at the edge of the two fixtures (Figure 4.5). This guarantees sufficient brightness to compensate for higher light output directly beside the fixture.
- Ensuring a minimum light ratio of 4:1 of the required footlamberts at the fixture to the extent of its beamspread capabilities. For example, the pathway between Areas H and N of the proposed lighting plan requires a footlambert level calculated at 1.0 fl. However, at the midpoint between the two fixtures, the footlambert level should not drop below 0.25 fl. Ensuring a ratio as close to 1:1 will provide the best solution. However, maintaining a minimum ratio of 4:1 will ensure a sufficient continuity of light for safe navigation.

Figure 4.6 relation of fixture height to plant material and adjacent pathway.

In circumstances where fixtures are concealed by plant material adjacent to the path, such as Area 4, the head of the fixture must maintain a minimum of six inches clearance above the mature height of plant material to effectively light both planting and walkway surface (Figure 4.6) (Moyer, 1992).

Water Features

The use of light in conjunction with a water feature requires consideration of the following four criteria described by Moyer (1992):

- Refraction of light
- Effect of light on aerated or turbulent water
- Effect of light on flat or smooth water
- Dispersion of light in water

Major water elements in the site (Area 5) require not only an understanding of their importance within the composition at night, but also an understanding of the physical properties of light associated with its use in water. Comprehending these properties will ensure a cohesive integration of water features within the composition.

Refraction of light

The physical properties of light are altered by the density of materials through which it passes. This occurs when the velocity of light, in response to the material through which it is passing, changes, causing the beam of light to inflect in direction. Light traveling through the air into water tends to increase in angle from the downward perpendicular, while light exiting from water into air tends to increase in angle from the upward perpendicular. When the aiming angle of a light source under water reaches 49 degrees, all light will be reflected back under the water with none passing into the air (Moyer, 1992).

Effect of light on aerated or turbulent water

The outcome of directing light on aerated and turbulent water is largely dependent upon the bubbles created. In these circumstances light particles react with the bubbles – through reflection and refraction – to create a glowing appearance. The bubbles also enable the design to be enhanced through the introduction of a coloured source. In order to create a glowing effect within the water, as in the strip of water in Area 5, fixtures are to be located directly below the source of turbulence (see Appendix E, Detail 1 of Drawing L3).

Effect of light on flat or smooth water

Where the desire is to maintain a smooth, unbroken water surface, as in the pond in Area 5, lighting elements should be located outside the body of water. The main objective is to create the desired effect through the use of reflection off the water's surface.

Dispersion of light in water

When light travels through different media, such as water, it becomes scattered by the water particles with which it comes in contact. The main factor to consider when using a submersible light source is depth. The perceived brightness of a light source in water will diminish 10 percent for every two inches of depth (Moyer, 1992).

Fixture location and cost are often determining factors in these types of lighting applications. Placement can dramatically offset the desired effect. For example, fixtures located below water, as in Area 5, will substantially increase not only initial cost (three to five times), but also installation and maintenance costs. Regrettably the effect of above-water fixtures tends to be less dramatic. For the purposes of this practicum, only submersible fixtures are proposed.

Despite their lower costs, non-submersible fixtures are not without constraints. When locating fixtures above-water, care must be taken to ensure the fixture is properly aimed. The angle of direction should not exceed 35° from the downward perpendicular. This will reduce glare, and direct the viewer's attention to desired areas within the field of view.

Reflecting Pond

The reflecting pond located on the eastern portion of the site will be a major focal point. The primary light source will be supplied through fiber optic elements (Appendix E, Details 1 and 2 of Drawing L4). These elements will conform to existing grid elements used to define the planting grid to the north. Their principal role is to accentuate underlying geometry and to contribute to overall legibility, and site vocabulary (Perspective 2, Appendix F). Safety issues, such as electric shock hazard associated with lighting this type of water feature, will be non-existent. The fiber optic light box, acting as the source for the pond, will be located several meters away, providing ample buffer from any potential threat. Low voltage MR lamps recessed under the cantilevered edge of the pond will enhance its appearance at night

Water Wall

The water-wall located on the site will be defined at night through placement of light fixtures located below grade at a point just above water collection. The fixtures will be situated directly in front of the water shining at its surface (see Appendix E, Detail 1 of Drawing L3). This method was chosen based on the desired outcome of the falls. The smooth *weir*[20] of the water-wall necessitates the use of this lighting method by limiting the creation of water bubbles. The fixtures, located at the water collection point, provide sparkle from the mist emanating at the collection area. Furthermore, the acute aiming angle will enhance the entire height of the wall as water falls from above and is augmented by the sparkle of light of its surface.

Plant Material (Tree Grid)

The large planting grid located in North-West corner of the site will serve as a major lighting element in the overall design (Area 6 on Figure 4.2). Here, light will strengthen legibility of the site and make underlying conceptual ideas visible. Highlighting the grid of hard and soft surfaces will enhance design intention within

Figure 4.7 fixture aiming

the space by night. Fixtures will be recessed in conjunction with the underlying grid, based on the hierarchy of tree planting established in the conceptual design. Planting material chosen for this area include Silver Maple. This method of lighting is referred to as *accenting* (Perspective 1, Appendix F). In order to provide sufficient light to maintain the desired effect as the trees mature, three-120 volt fixtures per tree, combined with parabolic aluminized reflector (PAR) lamps are proposed (Appendix E, Detail 3 of Drawing L5). Three fixtures per tree were chosen to maintain adequate light around the base of the canopy, and prevent the creation of *hot spots*[21](see Figure 4.7). Specifically, PAR38 lamps in a fixture with adjustable aiming capabilities will be used. These lamps provide excellent optical control to light beamspread, and when combined with higher output lamps, ensure lighting meets the required changes to aiming as the site matures.

To further enhance design intention, elements located off the site on adjacent streets, in Area 7, will serve as visual "light" markers to orient oneself to both the space and surroundings, while strengthening perceivable boundaries (Appendix E, Drawing L7). These points are located along sight lines and emphasize conceptual derivatives based on site analysis, but function as threads which stitch the site within the greater urban context. These "light" markers will consist of light standards, circled with light emitting diode (LED) paving blocks.

In parts of Area 2, where planting is more randomly distributed, the lighting used will largely reflect design intent. These areas will use an informal lighting technique referred to as *moonlighting* (Appendix E, Detail 4 of Drawing L5). The premise behind this method of lighting is that placement of fixtures within tree canopies, carefully downlighting adjoining canopies and pathways. This enhances the space below the canopy, and reinforces design intent by maintaining a "natural" lighting approach. Here mercury vapour, which most accurately represents the colour of moonlight, will provide a soft shadow patterning of light on adjacent pathways and amongst trees. This method of lighting alleviates the need for additional lighting elements along adjacent walkways, and presents a less intrusive light treatment. Furthermore, it also serves as an effective brightness bridge, connecting contiguous spaces visually. (Moyer, 1992).

Street Lighting

In order to respond to site vocabulary, pedestrian-scale light standards are proposed along Edmonton and Hargrave Streets, and York Avenue (Appendix E, Drawing L7 and L6). These lighting elements shall comply with the brightness values identified in Appendix C.

Conclusions

Artificial light plays an important part in revealing the landscape around us at night. It can uncover obstacles on a path and enable people to navigate a space effectively. More importantly, artificial light dramatically affects human perception, safety and security, legibility and the aesthetics of the urban landscape at night. Carefully introduced lighting elements can direct movement, highlight natural and architectural features, reveal site design intention, and enhance aesthetic appeal. The incorporation of these lighting elements with landscape architecture involves a collaborative process which must begin at the conceptual design phase.

Typically, lighting design, illuminating engineering, and environmental psychology operate in isolation from each other, and their contributions have little or nothing to do with each other. This process often results in lighting schemes which may not be ideal. Landscape architects can serve as the collaborating force that addresses the contributions of these various fields, but also serves to address the site design and the lighting design simultaneously. Although illuminating engineers and environmental psychologists contribute to our quantitative and qualitative understanding of light, these principles remain for the most part theoretical, and are only addressed by lighting designers after completion of site design. In addition, site design often occurs in the absence of the lighting designers, resulting in lighting schemes which are superficial, and site designs which do not address principles set forth by illuminating engineers and environmental psychologists.

A lighting scheme which responds to the lighting principles, psychological theories and methods of lighting application outlined in Chapters One through Four will result in the best possible solution. It will enable landscape architects to maintain design objectives, respond to specific site lighting needs, and satisfy human issues of perception, safety, and security. Consequently, it will provide an environment for use 24 hours a day.

Notes

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[12] Figure 4.1 illustrates the location of the site (indicated in red), surrounding landmarks (yellow) and green spaces (green) as well as the Assiniboine River (blue).

[13] Measurement of illumination or quantity of light falling on an object.

[14] Measurement of luminance or quantity of light reflected off the surface of an object. The eye qauntifies brightness in footlamberts, rather than footcandles, making this measurement more important than footcandles.

[15] For the purposes of this practicum, pathway light levels will maintain a brightness between one and five footcandles (Kaufman, 1981; Moyer, 1992).

[16] Reflectance values as determined by the Illuminating Engineering Handbook (Kaufman, 1981).

[17] Floodlighting - describes a lighting process that involves an even distribution of light applied perpendicular to the object under exposure. This lighting method produces a flat, shadowless effect often used to enhance shape.

[18] Graze refers to a lighting technique used to emphasize texture. It involves the application of light close to the surface. Lights can be aimed up, down or across a surface.

[19] For the purposes of this practicum "simple paths" refers to walkways that require less visual attention due in part to their shape, and the construction materials used. "Complicated paths" shall be used to describe walkways that are irregular in shape and elevation and material.

[20] Refers to the edge that the water falls over when making a vertical drop.

[21] Hot spot is a term used to describe unbalanced or high brightness points which may arise from poorly planned or aimed fixtures.

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Appendix A

SITE DESIGN PROGRAMMING

Ω

PROGRAMMING

The site has been broken down into several areas for the purposes of describing activities' programming for these areas. Please refer to the attached diagram for the following discussion.

A – Regular Turf Areas

As indicated on the diagram, these areas include three mounds, both sloped areas adjacent to the small restaurants and kiosks (H), and the seating steps. All of these areas provide a wide range of seating opportunities with degrees of sun and shade, private and public exposures, and formal and informal settings. The intention is to provide for a wide range of user preferences, considering near-by office employees, apartment and hotel residents, and other downtowners.

- The three mounds are intended to serve as informal seating areas, with varying degrees of privacy, and sunny to semi-shady light conditions. These are flexible spaces expected to be occupied at any time of day.
- The sloped areas adjacent to the restaurants provide a formal seating area, with semi-public exposure to York Ave, and full sunlight conditions. It is expected these seating areas will be primarily serve the clientele of the shops, as well as other people on their lunches and dinners. These areas will likely be most heavily occupied during these times.
- The seating steps will function similarly to the sloped areas, servicing the clientele of the adjacent kiosks and piazza during meal-times. This area, however, is entirely public in nature, and consequently, is expected to attract passers-by. The seating in this area is much more formal, and will experience full and partial sunlight due to the neighboring trees.

B - Naturalized Native Grass Areas

These include both the mound and sloped area adjacent to the pool (D), and a sloped area opposite Carlton St. These areas contribute to the overall sculptural qualities of the site, by providing the unique textures, colors and animation of tall grasses. These areas are not intended for heavy pedestrian use, although minimal use is acceptable following a minimum establishment period of two years. (These areas should be reasonably fenced during the two year establishment period to prevent trampling and encourage snow accumulation.)

C – Forested Areas

All three areas have relatively exposed locations adjacent to peripheral and internal sidewalks. These areas contribute to the sculptural qualities of site as above, and are not intended for heavy pedestrian use. It is recommended that you allow a minimum establishment period of five years in these areas to allow the less visible seedlings and shrubs to establish. These areas should be securely fenced to prevent the trampling of the understorey, and encourage snow accumulation.

D – Pool and Waterwall Areas

These areas include the central pool, the small rock trough to the north, and the adjacent water wall.

- The central pool is intended for use year-round, during both days and evenings. Peripheral seating benches are located around the pool, providing varying degrees of sun and shade in a formal secluded setting. This area will operate as a small skating area for residents during the winter months (generally from mid November to March). During the summer, the pool should generally be open mid May to late September.
- The waterwall and adjacent trough will operate year-round, equipped with ambient heat sensors which will operate below freezing to heat the rock in the trough and the water pipes for the waterwall.

E – Piazza Area

The intention of the piazza area is to provide a flexible public gathering space for all users, including the clientele of the shops and kiosks (H). Buskers and vendors are encouraged in this space, as are festival performers and artists.

F - Parking Lot

This parking area has been preserved, although the orientation of the parking spaces have been altered to reinforce the connection to the rest of the site and to the adjacent wall which connects the site to the law courts. This parking lot also accommodates 48 rather than 44 cars. Underground parking has been provided for on site with access from Carlton St.

G – Tree Paving Grids

These areas are both surrounded by sidewalks, and so it is expected that heavy pedestrian use will occur here. While it is intended for pedestrian use, it is recommended that precautions be taken to allow the establishment of these large canopy trees. These areas should be securely fenced to prevent premature damage for a period of five years.

H – Small Restaurants and Kiosks

These areas include the small restaurants lining a pedestrian corridor across from the Convention Centre, as well as a row of kiosks facing the piazza across Carlton St. The purpose of the small restaurants is to provide take-out food, much like "Soup Pierre" on Corydon, for all users year-round, both days and evenings. These restaurants will provide a unique Winnipeg sampling of local culture, and attract off-site users. The kiosks will function as more flexible structures, providing temporary space for festival vendors and others during the summer. In the winter, these structures will be converted for use as skate change facilities, adjacent to the skating pond. It is expected that the kiosks will operate primarily during daylight hours in the summer, and all day during the winter.

I – Sculptural Rock Garden

Much like the tall grass and forested areas, this space is intended to add to the sculptural qualities of the site. It is expected that this area will not be heavily traversed, however user interaction is encouraged.

J – Pedestrian Corridors

All of these areas are integral to the design, providing essential access points to the interior of the site. These areas should be kept in good condition in accordance with the maintenance policy as outlined below.

Appendix B

LAMP CHARACTERISTICS AND OPERATING DATA

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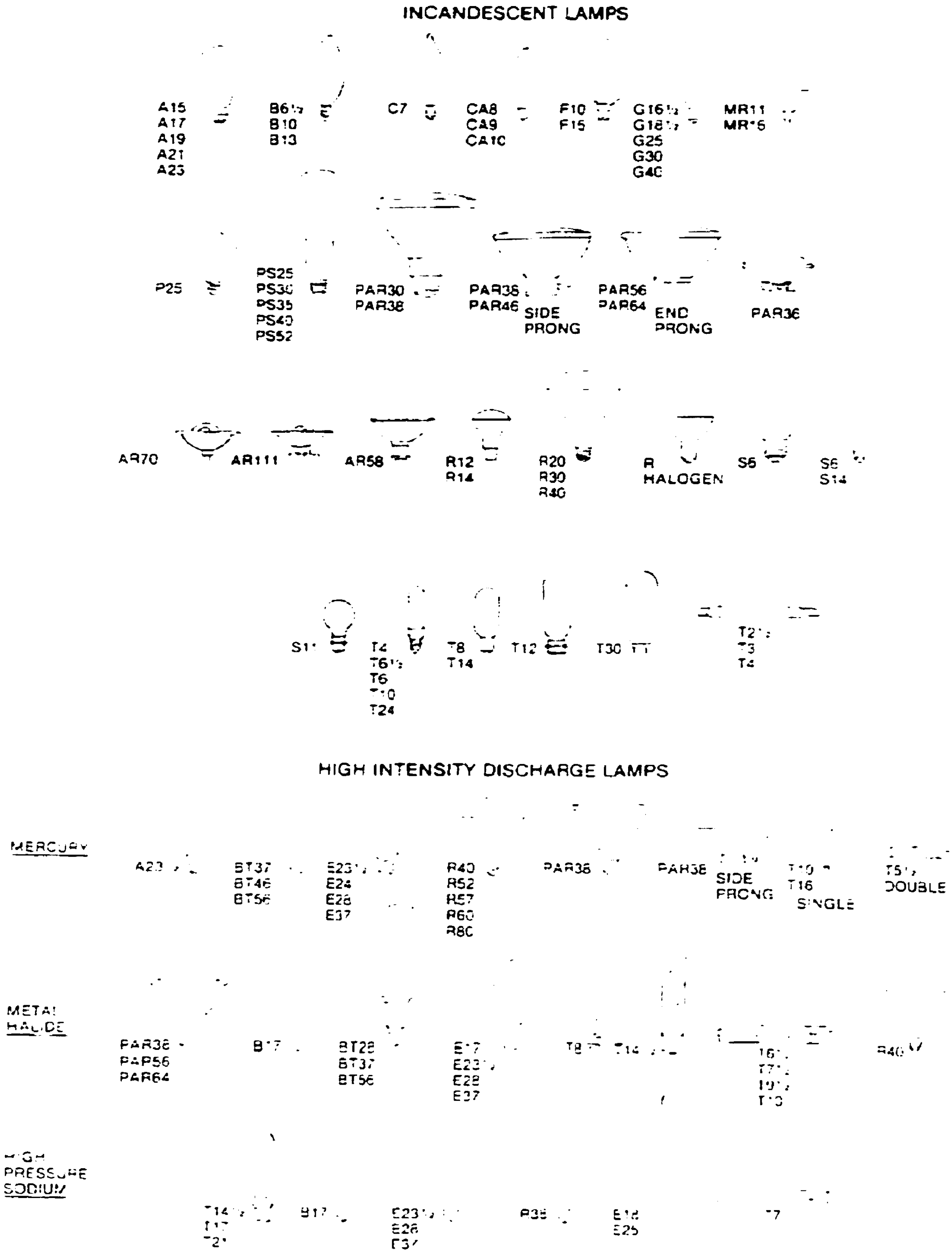
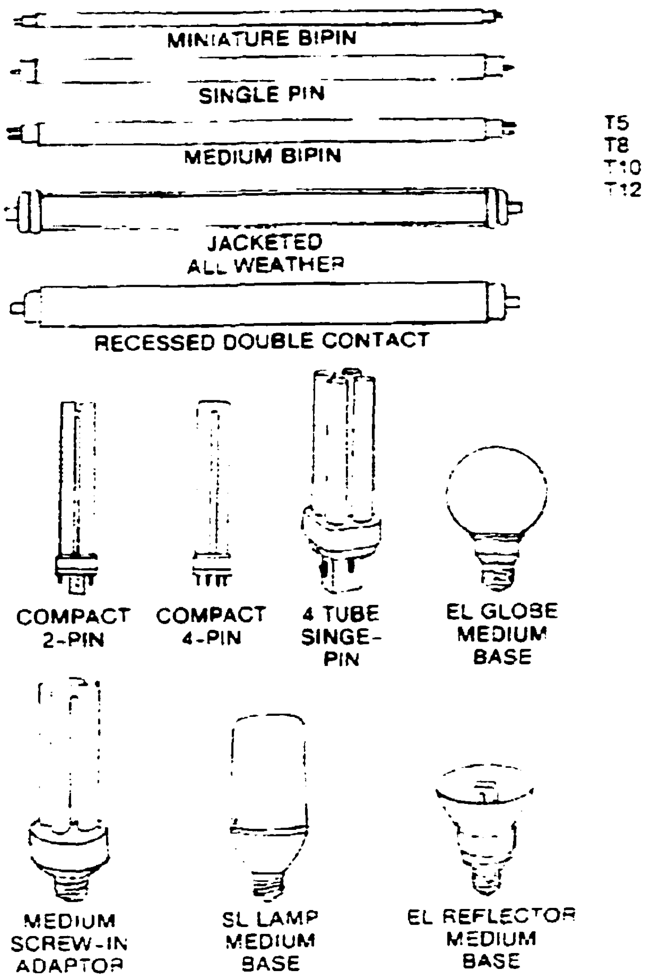
LAMP COMPARISON CHART

LAMP CATEGORY CATEGORY	WATTAGE RANGE	EFFICACY (lumens per watt)	LIFE in hours	TRANSFORMER BALLAST	START/POWER INTERRUP.	INTERCHANG-ABILITY
INCANDESCENT	Less than 1 — 1,500+	7 — 24 17 Avg	750 — 2,000 Special Lamps as low as 10 hours	120 — 135 volts None required All voltages below 120 require transformer Quantity of lamps per transformer based on lamp wattage	Immediate start No restrike delay	Within same base type up to fixture max wattage
FLUORESCENT	4 — 220	20 — 95 Standard F40 Magnetic ballast 60 — 75 Electronic ballast 40 — 95 Compact type Manu. data list	7500 — 20,000	Ballast required Up to 3 lamps per ballast	Immediate Start Pre-heat Few seconds delay No restrike delay	Within same base type, voltage and wattage ONLY
MERCURY VAPOR	40 — 1,000	50 — 60 Good color and or low wattage as low as 20	16,000 — 24,000 Self ballasted 12 — 15,000	Ballast required 1 lamp per ballast	Start and restrike 3+ minutes	Within same base, voltage and wattage
METAL HALIDE	70 — 1,500	75 — 125	6,000 — 20,000	Ballast required 1 lamp per ballast	Start 2 — 5 minutes Restrike 10 — 20 minutes	Within same base voltage and wattage
HIGH PRESSURE SODIUM	35 — 1,000	[illegible] Low wattage as low as [illegible]	24,000 [illegible] color [illegible]	Ballast required 1 lamp per ballast	Start 1 — 4 minutes Restrike 1/2 — 1 minute	Within same base voltage and wattage
LOW PRESSURE SODIUM	18 — 180	Up to 180	10,000 — 18,000	Ballast required 1 lamp per ballast	Start 7 — 15 minutes Restrike 1 minute	Within same base, voltage and wattage



Examples of incandescent and H.I.D. lamp shapes.



Examples of fluorescent shapes and bases.

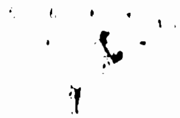
LIGHTING APPROACH

	UP LIGHT		DOWN LIGHT	
EFFECT	**PURPOSE**	**FIXTURE LOCATION**	**PURPOSE**	**FIXTURE LOCATION**
WASH	FILL	FRONT	FILL	FRONT
GRAZE	FILL or ACCENT*	FRONT*	FILL or ACCENT*	FRONT*
SHOW TEXTURE (Trunk)	ACCENT	*SIDE, FRONT** or BACK*	ACCENT	*SIDE, FRONT** or BACK*
HALO (Trunk)	ACCENT	BACK	ACCENT	BACK
SILHOUETTE	ACCENT	BACK	ACCENT	BACK
SHADOWS: (On Vertical Surface)	FILL	SIDE	NO	
MOONLIGHTING: (Shadows on Horizontal Surface)	NO		FILL	OVER or IN TREE**
GLOW	ACCENT	UNDER CANOPY	NO	
DETAIL AND COLOR	NO		FILL or ACCENT	OVER CANOPY

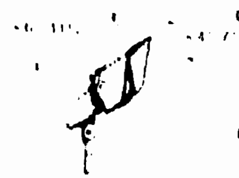
* Requires fixture location close to object
** Requires shining through leaves and branches

INCANDESCENT AND HIGH INTENSITY DISCHARGE

ROUND BODY

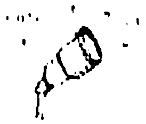
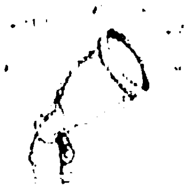
FIXTURE SHAPE Shape, Size, and Lamps will vary with manufacturer	Open or Closed	Lamp Type & Wattage	Louver & Shielding Availability and Types	Mounting Types Available
	Closed or Open	PAR38 45 TO 300 WATTS	Custom louver Short or Long Shroud	Stake w/splice Box, Above grade Junction Box, Surface Mount
	Closed	R40 75 to 150 WATTS	Custom Louver/ Shroud Required	Same as above
	Closed	PAR20 50 WATTS	Custom Louver Shroud Optional	Same as above
	Closed	R20 50 WATTS	Custom Louver Shroud Required	Same as above
	Closed	MR16 20 to 75 WATTS	Custom Louver Short or Long Shroud	Stake w/ Splice Box, Surface Mount, Extension Stem
	Closed	Mercury Vapor ER20 50 WATTS	Custom Louver	Tree Mount w/ Remote Transformer Box
	Closed	MVPAR38 100 to 175 WATTS	Custom Louver	Above or Below Grade Ballast Box
	Closed	MVR40 100 to 175 WATTS	Custom Louver	Integral Below Grade Ballast Box
	Closed	HPS E17 35 WATTS	Custom Louver	Same as above
	Closed	E23 1/2 35 to 100 WATTS	Custom Louver	Same as above

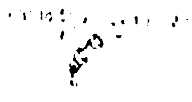
SQUARE HEAD

FIXTURE SHAPE Shape, Size, and Lamps will vary with manufacturer	Open or Closed	Lamp Type & Wattage	Louver & Shielding Availability and Types	Mounting Types Available
	Open or Closed	PAR38 45 to 300 WATTS	Custom Louver/ Shroud Optional	Stake w/splice Box, Above Grade Junction Box, Below Grade Junction Box, Surface Mount
	Closed	PAR20 50 WATTS	Custom Louver/ Shroud Optional	
	Closed	R20 50 WATTS	Custom Louver	Same as above
	Open or Closed	PAR36 20 to 75 WATTS	Custom Louver	Stake w/Splice Box, Above Grade Junction Box, Below Grade Junction Box w/ Transformer, Surface Mount, Extension Stem
	Closed	MR16 20 to 75 WATTS	Louver Option or Custom Louver	
	Closed	MVR40 100 to 175 WATTS	Mercury Vapor Custom Louver/ Shroud Optional	Below Grade Ballast Box
	Closed	MVPAR38 100 WATTS	Custom Louver	Same as above
	Closed	HPS E17 35 to 150 WATTS	Custom Louver/ Shroud Optional	Same as above
	Closed	E23 35 to 100 WATTS	Custom Louver	Same as above

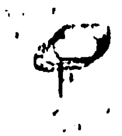
INCANDESCENT AND HIGH INTENSITY DISCHARGE

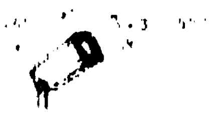
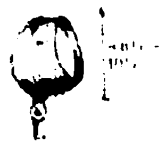
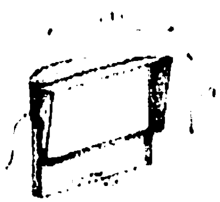
CYLINDRICAL HEAD

FIXTURE SHAPE Shape, Size, and Lamps will vary with manufacturer	Open or Closed	Lamp Type & Wattage	Louver & Shielding Availability and Types	Mounting Types Available
	Closed or Open	PAR38 45 to 300 WATTS	Custom Louver	Stake w/Splice Box Above Grade Junction Box Below Grade Junction Box Surface Mount
	Open or Closed	PAR36 20 to 75 WATTS	Louver Option or Custom Louver	Same as above may also use w/extension stem
	Closed	MR16 20 to 75 WATTS	Louver Option or Custom Louver	Integral Stake Below Grade Junction Box w/transformer Extension Stem Wall Plate
		Mercury Vapor		
	Closed	MVR40 100 WATTS	Custom Louver Shroud Optional	Surface or Below Grade Ballast Box
	Closed	MVPAR38 100 WATTS	Custom Louver	Same as above
		HPS		
	Closed	T17 or B17 100 WATTS	Custom Louver Shroud Optional	Same as above

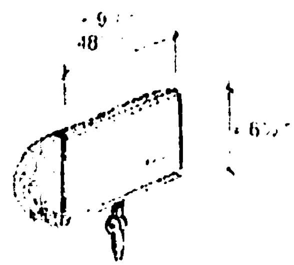
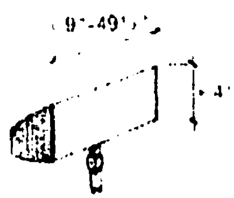
FIXTURE SHAPE Shape, Size, and Lamps will vary with manufacturer	Open or Closed	Lamp Type & Wattage	Louver & Shielding Availability and Types	Mounting Types Available
RIBBED BACK				
	Open	PAR38 45 to 300 WATTS	Custom Louver Wire Guard	Stake w/Splice Box
	Open or Closed	R40 75 to 500 WATTS	Custom Louver/ Wire Guard	Stake w/Slice Box Extension Stem
CYLINDRICAL BODY				
	Closed	MR16 20 to 50 WATTS	Louver Option or Custom Louver	Tree Mount, Wall Plate Stake w/Splice Box
	Closed	MR11 20 to 35 WATTS	Louver Option or Custom Louver	Stake w/Junction Box Extension Stem, Below Grade Junction Box
WITH CUFF				
	Closed	MR16 20 to 50 WATTS	Louver Option or Custom Louver, Extension Cuff	Same as above
	Closed	MR11 20 to 35 WATTS	Louver Option or Custom Louver, Extension Cuff	Same as above

INCANDESCENT AND HIGH INTENSITY DISCHARGE

FIXTURE SHAPE Shape, Size, and Lamps will vary with manufacturer*	Open or Closed	Lamp Type & Wattage	Louver & Shielding Availability and Types	Mounting Types Available
BULLET SHAPE 	Closed	PAR38 up to 150 WATTS	Integral Shield w/ Lamp Guard	Below Grade Junction Box Surface Mount
	Closed	PAR30 up to 75 WATTS	Integral Shield Custom Louver	Spike Extension Stem
	Closed	PAR20 up to 60 WATTS	Integral Shield Custom Louver	Same as above
	Closed	PAR36 12 to 75 WATTS	Integral Shield w/ Lamp Guard	Same as above
	Closed	MR16 20 to 50 WATTS	Integral Shield Custom Louver	Same as above
	Closed	T4 Tri up to 75 WATTS	Integral Shield Custom Louver	Same as above
	Closed	1141 18 WATTS	Integral Shield Custom Louver	Same as above
	Closed	1156 26 WATTS	Integral Shield Custom Louver	
SHIELDED BULLET 	Closed	T4 Tri 75 WATTS	Integral Shield Custom Louver	Same as above
	Closed	A19 75 WATTS	Integral Shield Custom Louver	Same as above
	Closed	Mercury Vapor 75 WATTS	Integral Shield Custom Shield	Below Grade Ballast Box

FIXTURE SHAPE Shape, Size, and Lamps will vary with manufacturer	Open or Closed	Lamp Type & Wattage	Louver & Shielding Availability and Types	Mounting Types Available
SQUARE BODY 	Closed	PAR20 50 WATTS	Custom Louver Glare Shield	Above Grade and Below Grade Junction Box with Transformer, Stake Extension Stem Tree and Wall Mount
		MR16 20 to 75 WATTS	Custom Louver Glare Shield	
		AR70 50 to 75 WATTS	Custom Louver Glare Shield	
SPHERE SHAPED HEAD 	Closed	PAR38 300 & 500 WATTS	Optional Louver Shield and Rock Guard	Below Grade Junction Box
	Closed	R40 300 WATTS	Same as above	Same as above
	Closed	PAR56 240 WATTS	Same as above	Same as above
	Closed	HPS E23 1/2 150 WATTS	Same as above	Below Grade Ballast Box
	Closed	MVPAR38 100 WATTS	Same as above	Same as above
	Closed	MVR40 175 WATTS	Same as above	Same as above
	Closed	MH E17 175 WATTS	Same as above	Same as above
SQUARE FACE 	Closed	MV 100 to 250 WATTS	Integral Shield Custom Louver	Yoke Arm Mounting Bracket
		MH 175 to 250 WATTS	Integral Shield Custom Louver	Same as above
		HPS 150 to 400 WATTS	Integral Shield Custom Louver	Same as above

* Also Available in Fluorescent

FIXTURE SHAPE		Lamp	Louver & Shielding	Mounting
Shape , Size and Lamps will vary with manufacturer	Open or Closed	Type & Wattage	Availability and Types	Types Available
		FLUORESCENT		
ROUNDED BODY				
	Closed	T5 6 WATTS	Optional Hood, Custom Louver	Above or Below Grade Junction Box, Portable Spear,
	Closed	T8 15 WATTS	Optional Shield, Internal Louver	Surface Mount, Tree Mount
	Closed	T10 60 WATTS	Optional Hood, Custom Louver	Same as above
	Closed	T12 30 to 40 WATTS	Optional Hood, Internal Louver	Same as above
	Closed	Compact 9 to 13 WATTS	Optional Hood, Custom Louver	Same as above
FLAT BACK				
	Closed	Compact 9 WATTS	Custom Louver	Above or Below Grade Junction Box,
	Closed	(2) Compact 13 WATTS	Custom Louver	Surface Mount, Portable Spear
	Closed	T8 30 WATTS	Custom Louver	Same as above
	Closed	T10 40 WATTS	Custom Louver	Same as above
	Closed	T-12 40 WATTS	Custom Louver	Same as above

Appendix C

CONCEPTUAL LIGHTING PLAN

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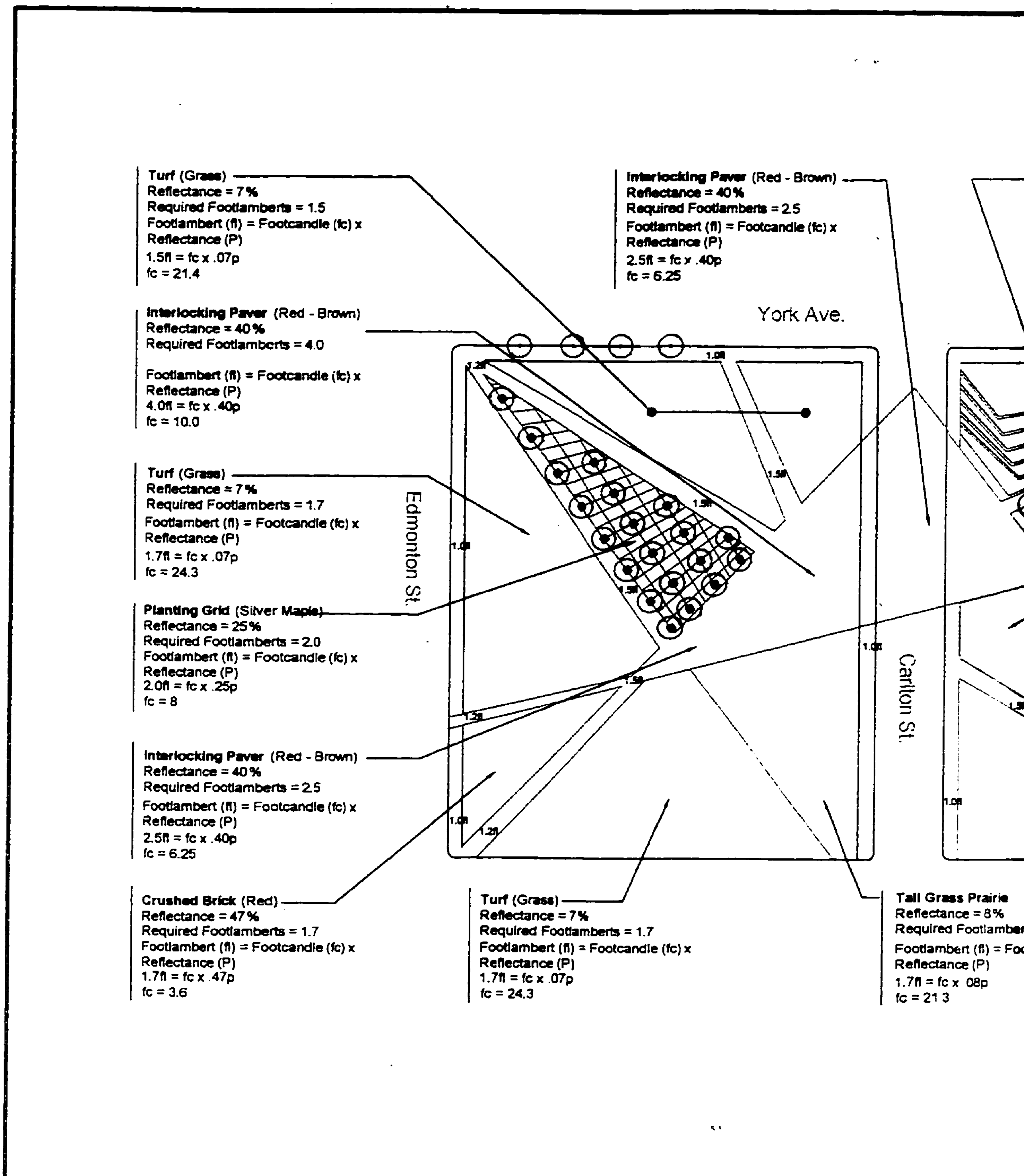
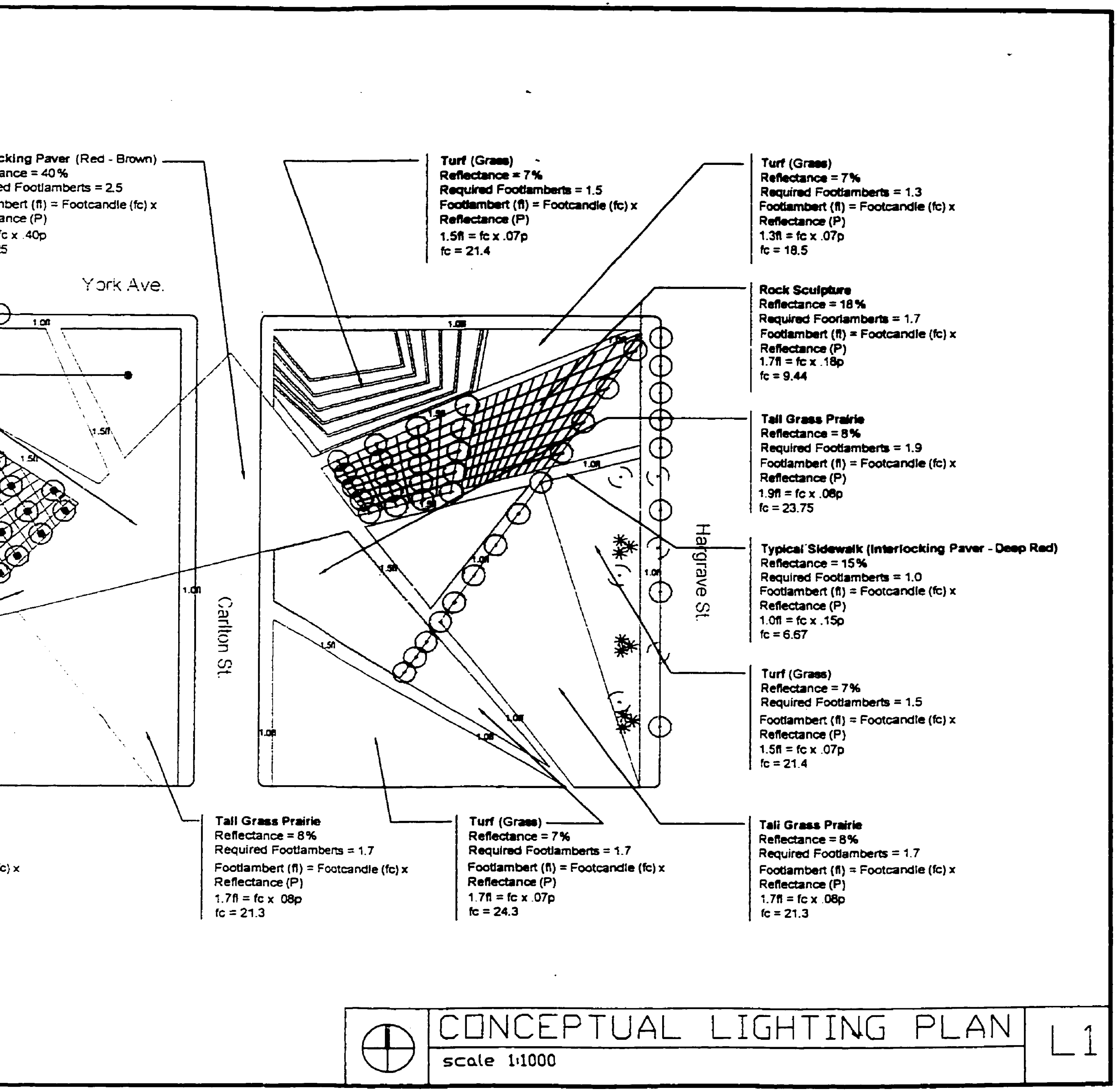
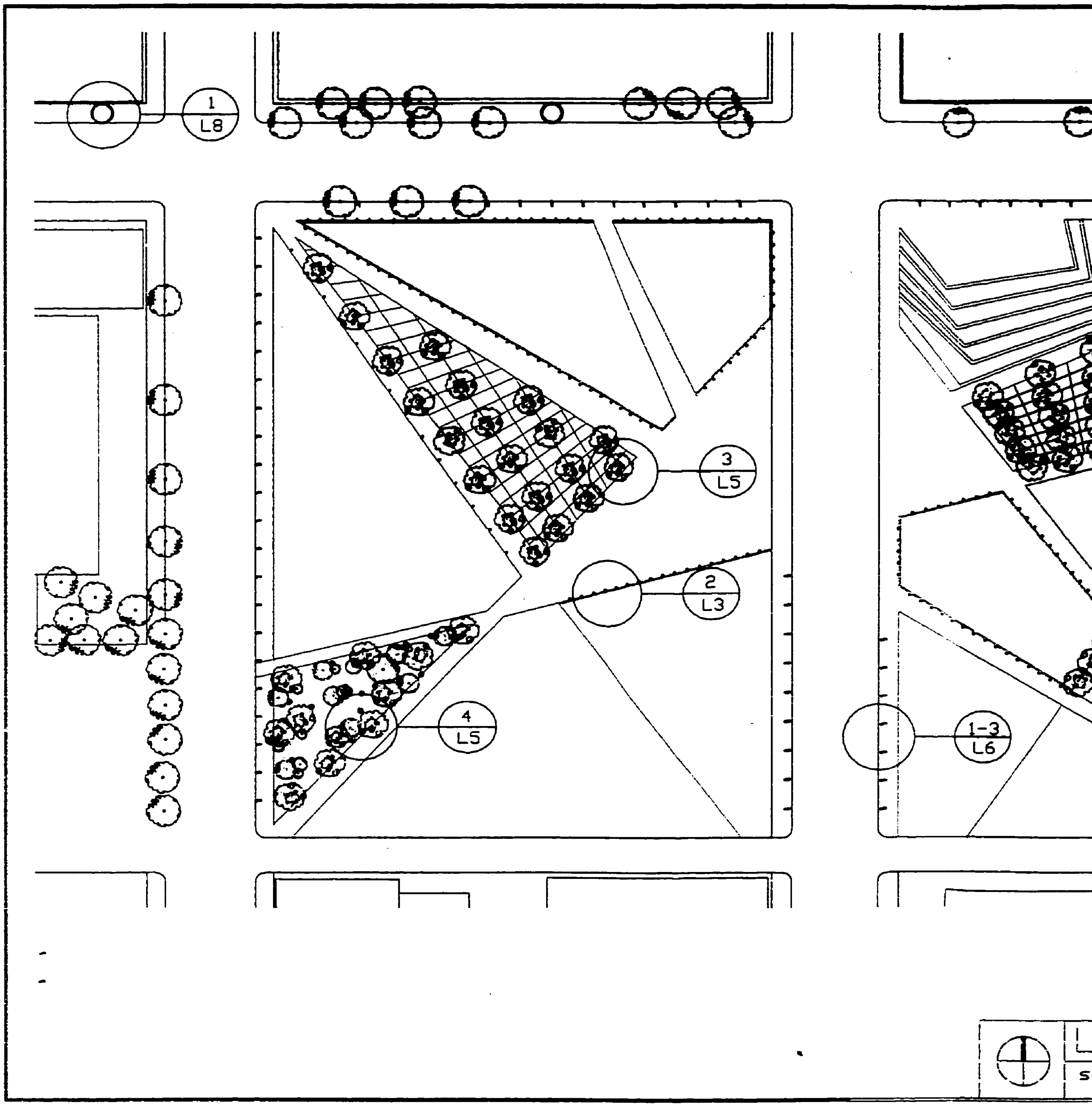

Turf (Grass)
Reflectance = 7%
Required Footlamberts = 1.5
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
1.5fl = fc x .07p
fc = 21.4
Interlocking Paver (Red - Brown)
Reflectance = 40%
Required Footlamberts = 2.5
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
2.5fl = fc x .40p
fc = 6.25
Interlocking Paver (Red - Brown)
Reflectance = 40%
Required Footlamberts = 4.0
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
4.0fl = fc x .40p
fc = 10.0
York Ave.
Turf (Grass)
Reflectance = 7%
Required Footlamberts = 1.7
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
1.7fl = fc x .07p
fc = 24.3
Edmonton St.
Planting Grid (Silver Maple)
Reflectance = 25%
Required Footlamberts = 2.0
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
2.0fl = fc x .25p
fc = 8
Carlton St.
Interlocking Paver (Red - Brown)
Reflectance = 40%
Required Footlamberts = 2.5
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
2.5fl = fc x .40p
fc = 6.25
Crushed Brick (Red)
Reflectance = 47%
Required Footlamberts = 1.7
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
1.7fl = fc x .47p
fc = 3.6
Turf (Grass)
Reflectance = 7%
Required Footlamberts = 1.7
Footlambert (fl) = Footcandle (fc) x Reflectance (P)
1.7fl = fc x .07p
fc = 24.3
Tall Grass Prairie
Reflectance = 8%
Footlambert (fl) = Fo
Reflectance (P)
1.7fl = fc x 08p
fc = 21 3


cking Paver (Red - Brown)
ance = 40%
ed Footlamberts = 2.5
bert (fl) = Footcandle (fc) x
ance (P)
c x .40p
Turf (Grass)
Reflectance = 7%
Required Footlamberts = 1.5
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.5fl = fc x .07p
fc = 21.4
Turf (Grass)
Reflectance = 7%
Required Footlamberts = 1.3
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.3fl = fc x .07p
fc = 18.5
York Ave.
Rock Sculpture
Reflectance = 18%
Required Foorlamberts = 1.7
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.7fl = fc x .18p
fc = 9.44
Tall Grass Prairie
Reflectance = 8%
Required Footlamberts = 1.9
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.9fl = fc x .08p
fc = 23.75
Typical Sidewalk (Interlocking Paver - Deep Red)
Reflectance = 15%
Required Footlamberts = 1.0
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.0fl = fc x .15p
fc = 6.67
Carlton St.
Hargrave St.
Turf (Grass)
Reflectance = 7%
Required Footlamberts = 1.5
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.5fl = fc x .07p
fc = 21.4
c) x
Tall Grass Prairie
Reflectance = 8%
Required Footlamberts = 1.7
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.7fl = fc x 08p
fc = 21.3
Turf (Grass)
Reflectance = 7%
Required Footlamberts = 1.7
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.7fl = fc x .07p
fc = 24.3
Tall Grass Prairie
Reflectance = 8%
Required Footlamberts = 1.7
Footlambert (fl) = Footcandle (fc) x
Reflectance (P)
1.7fl = fc x .08p
fc = 21.3
CONCEPTUAL LIGHTING PLAN
scale 1:1000
L1

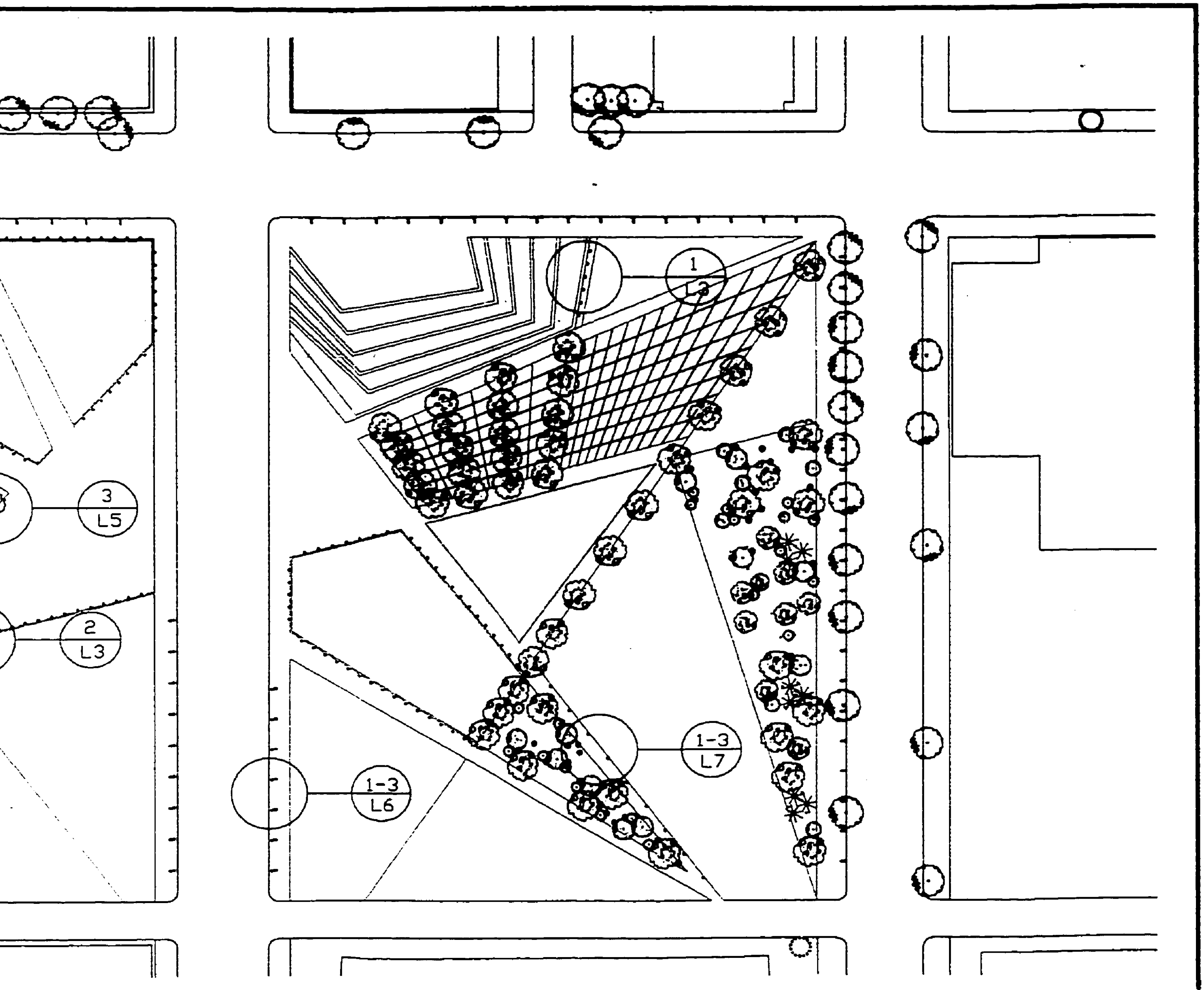
Appendix D

LIGHTING LAYOUT PLAN

Ω



1
L8
3
L5
2
L3
4
L5
1-3
L6



LIGHTING LAYOUT PLAN

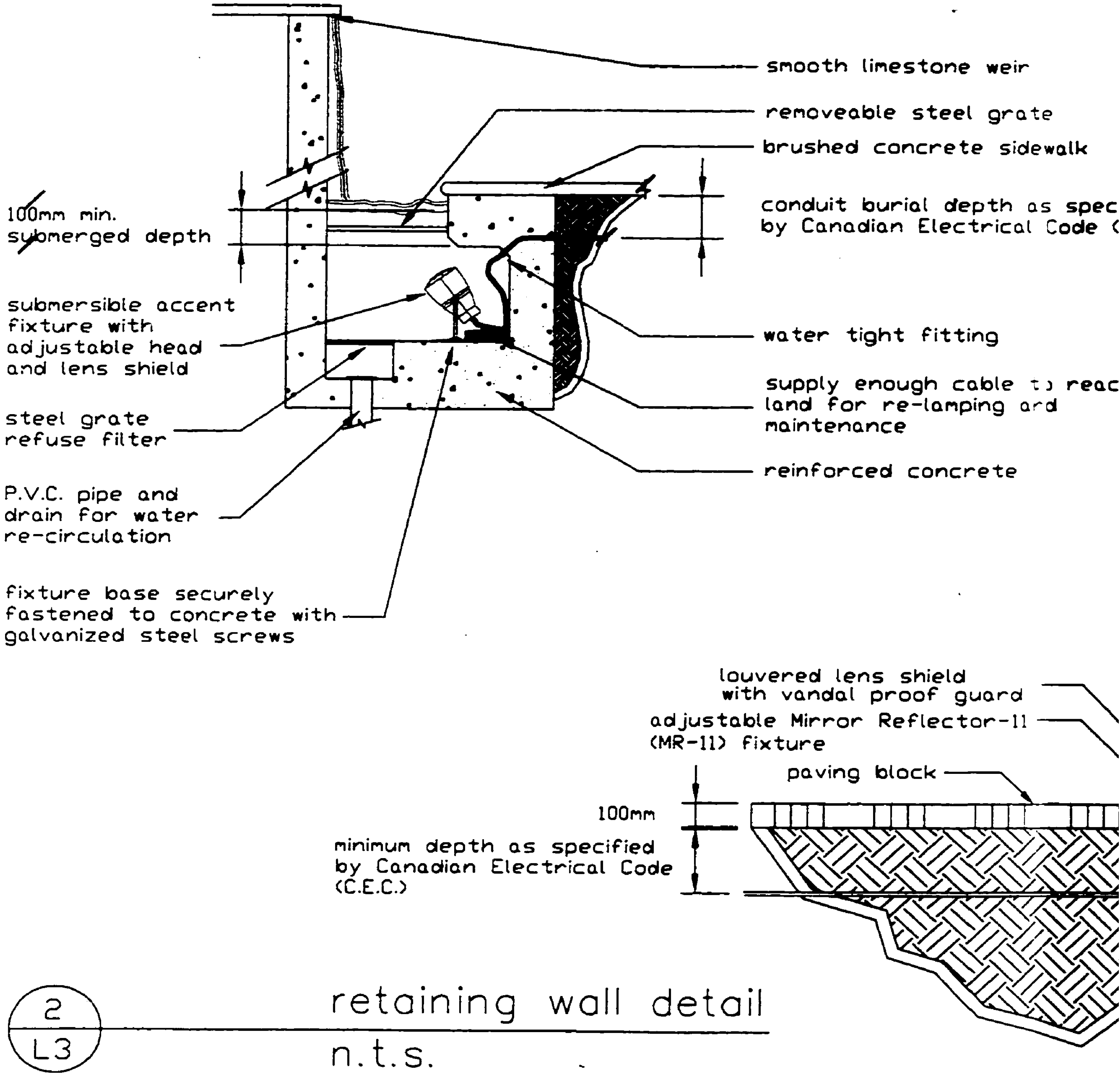
scale 1:750

L2

Appendix E

LIGHTING DETAILS

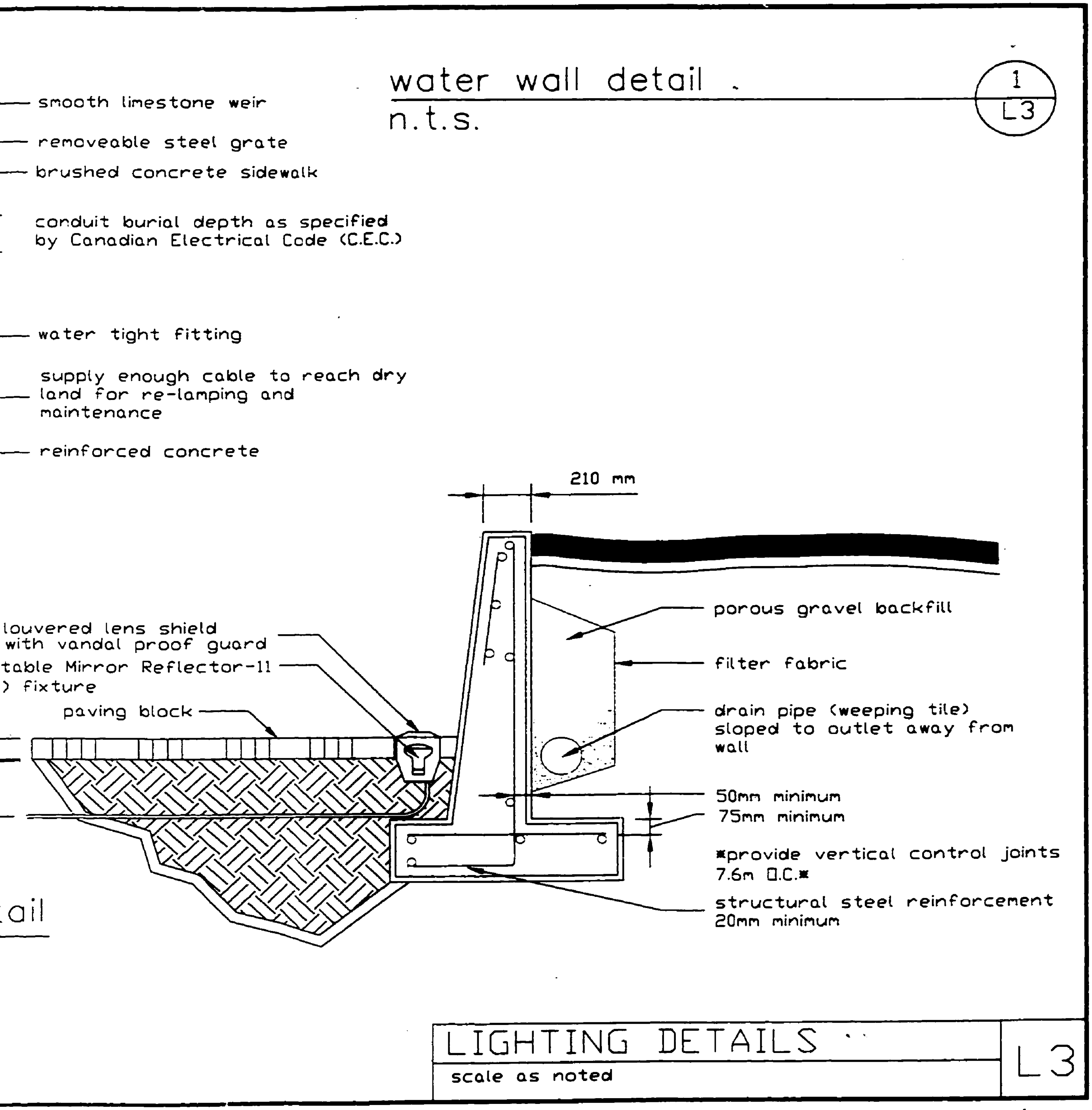
Ω

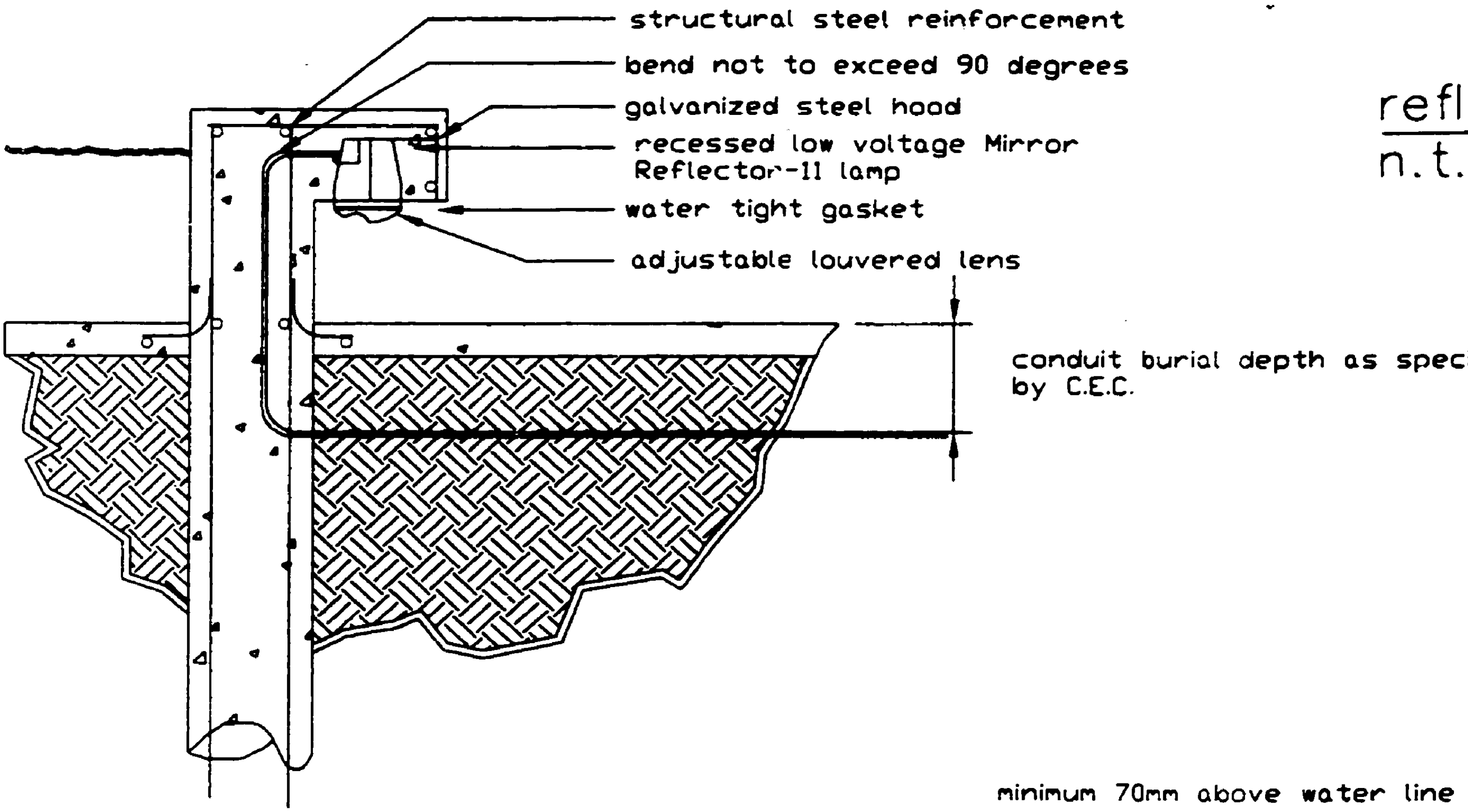


2
L3

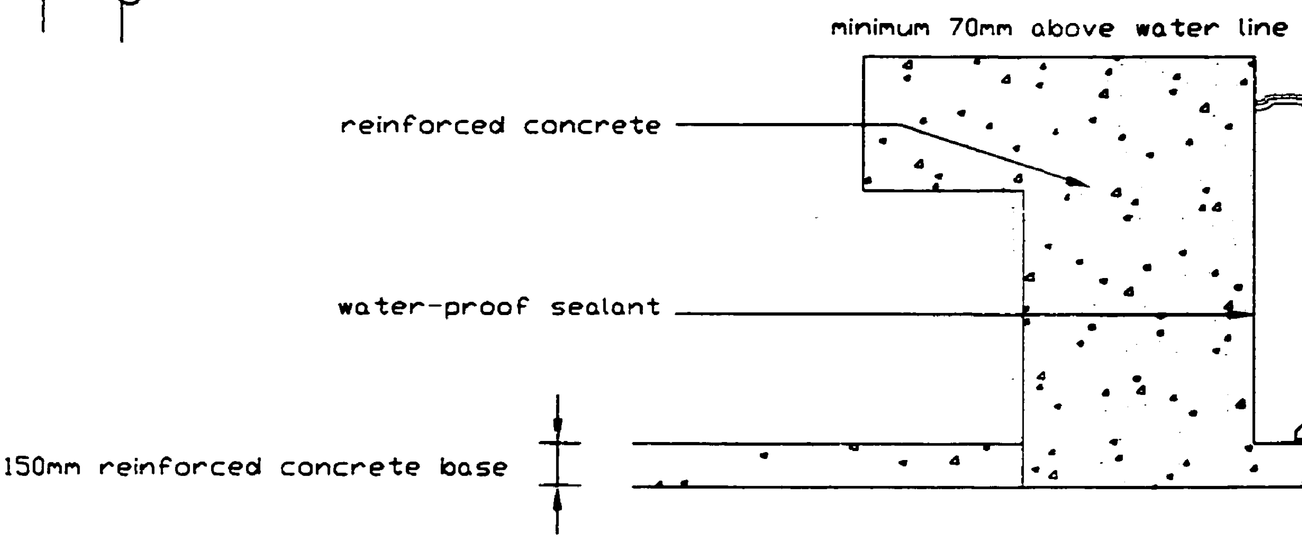
retaining wall detail

n.t.s.


water wall detail
n.t.s.
1
L3
smooth limestone weir
removeable steel grate
brushed concrete sidewalk
conduit burial depth as specified
by Canadian Electrical Code (C.E.C.)
water tight fitting
supply enough cable to reach dry
land for re-lamping and
maintenance
reinforced concrete
louvered lens shield
with vandal proof guard
table Mirror Reflector-11
) fixture
paving block
ail
210 mm
porous gravel backfill
filter fabric
drain pipe (weeping tile)
sloped to outlet away from
wall
50mm minimum
75mm minimum
*provide vertical control joints
7.6m O.C.*
structural steel reinforcement
20mm minimum
LIGHTING DETAILS
scale as noted
L3

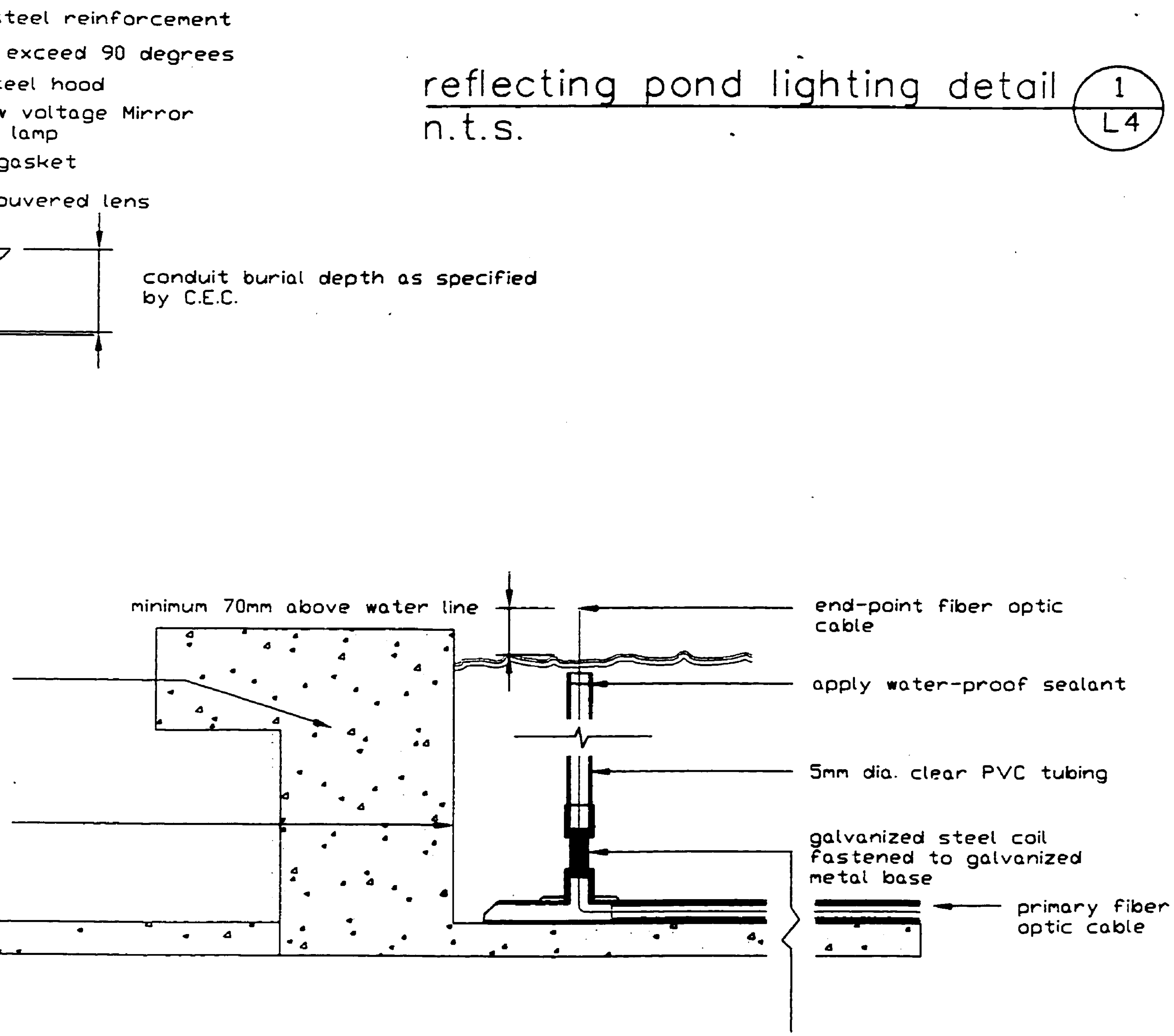


refl
n.t.



2
L4

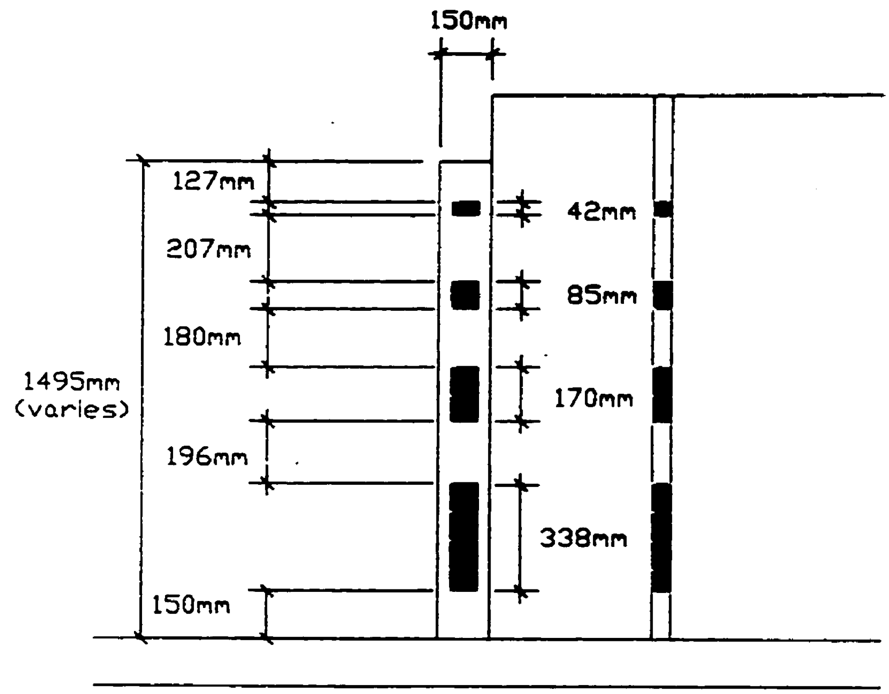
fiber optic detail
n.t.s.



LIGHTING DETAILS

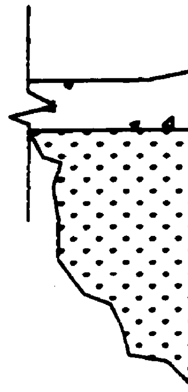
scale as noted

L4

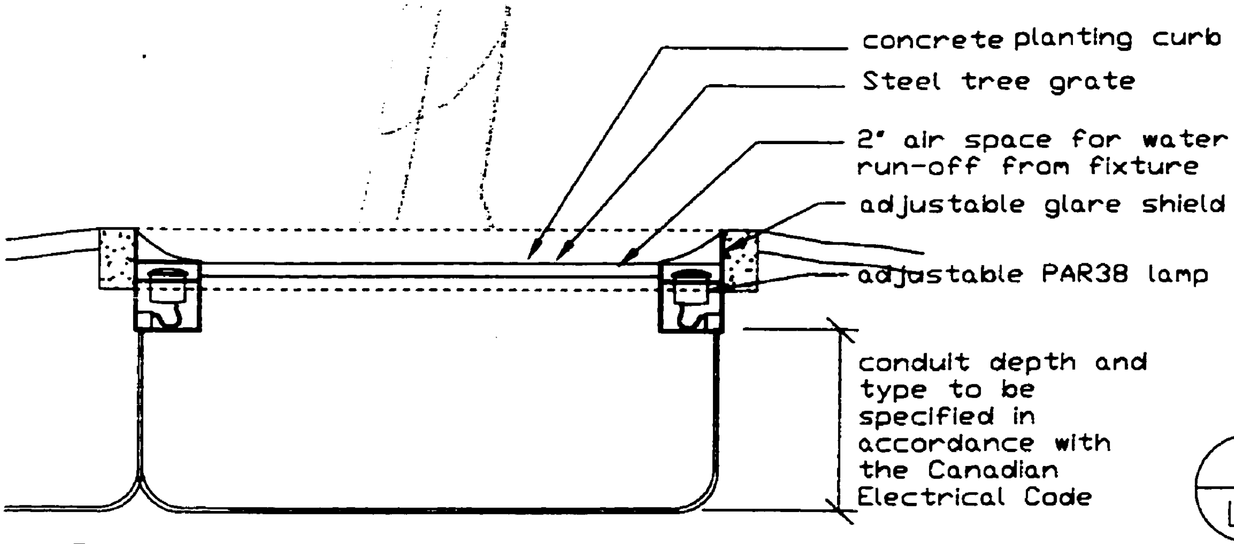


1 / L5 typical light fin elevation

n.t.s.



2 / L5



4 / L5 moonlig

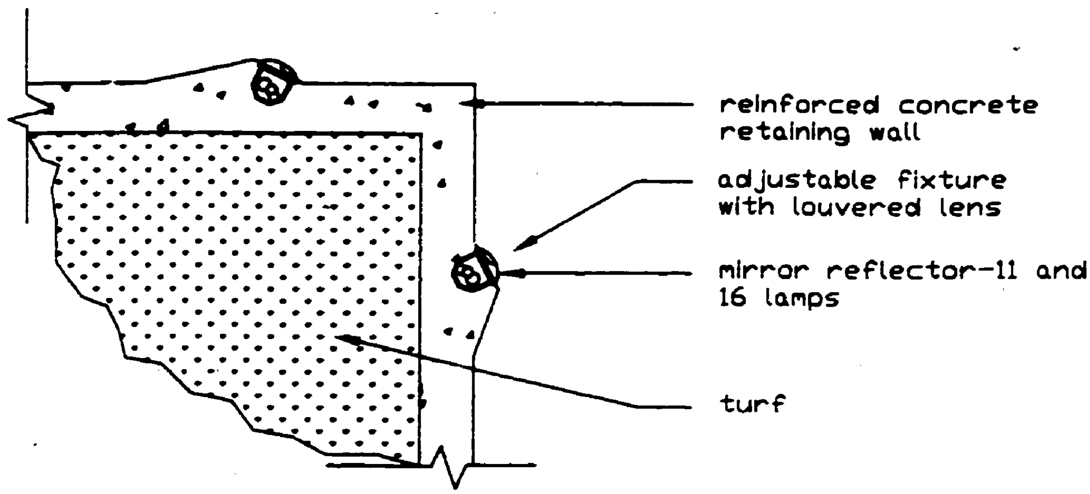
3 / L5 uplight tree detail

n.t.s.

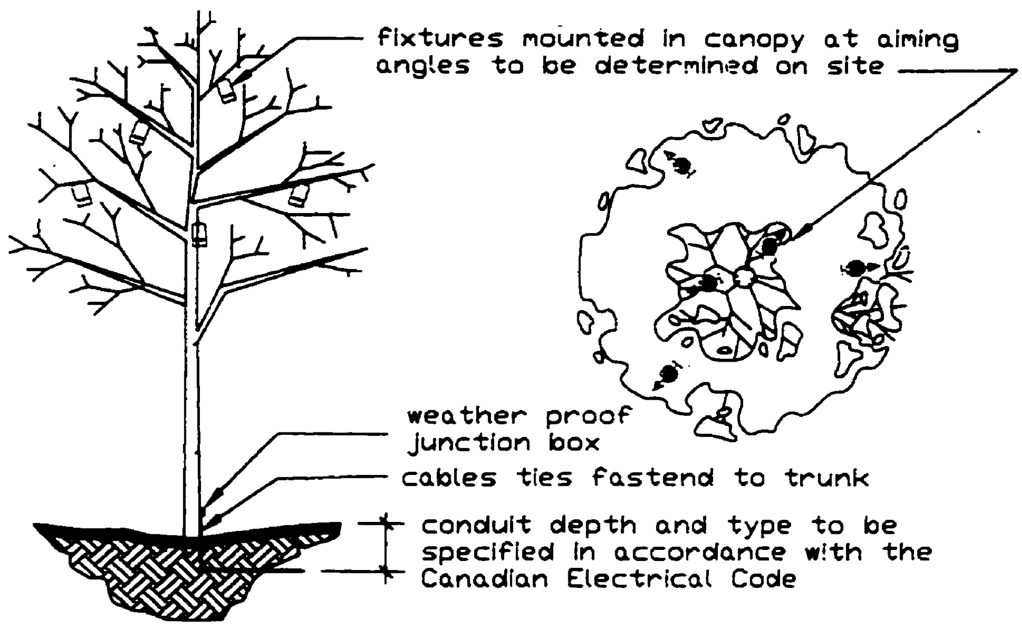
tion

concrete planting curb
Steel tree grate
2" air space for water run-off from fixture
adjustable glare shield
adjustable PAR38 lamp
conduit depth and type to be specified in accordance with the Canadian Electrical Code

tail

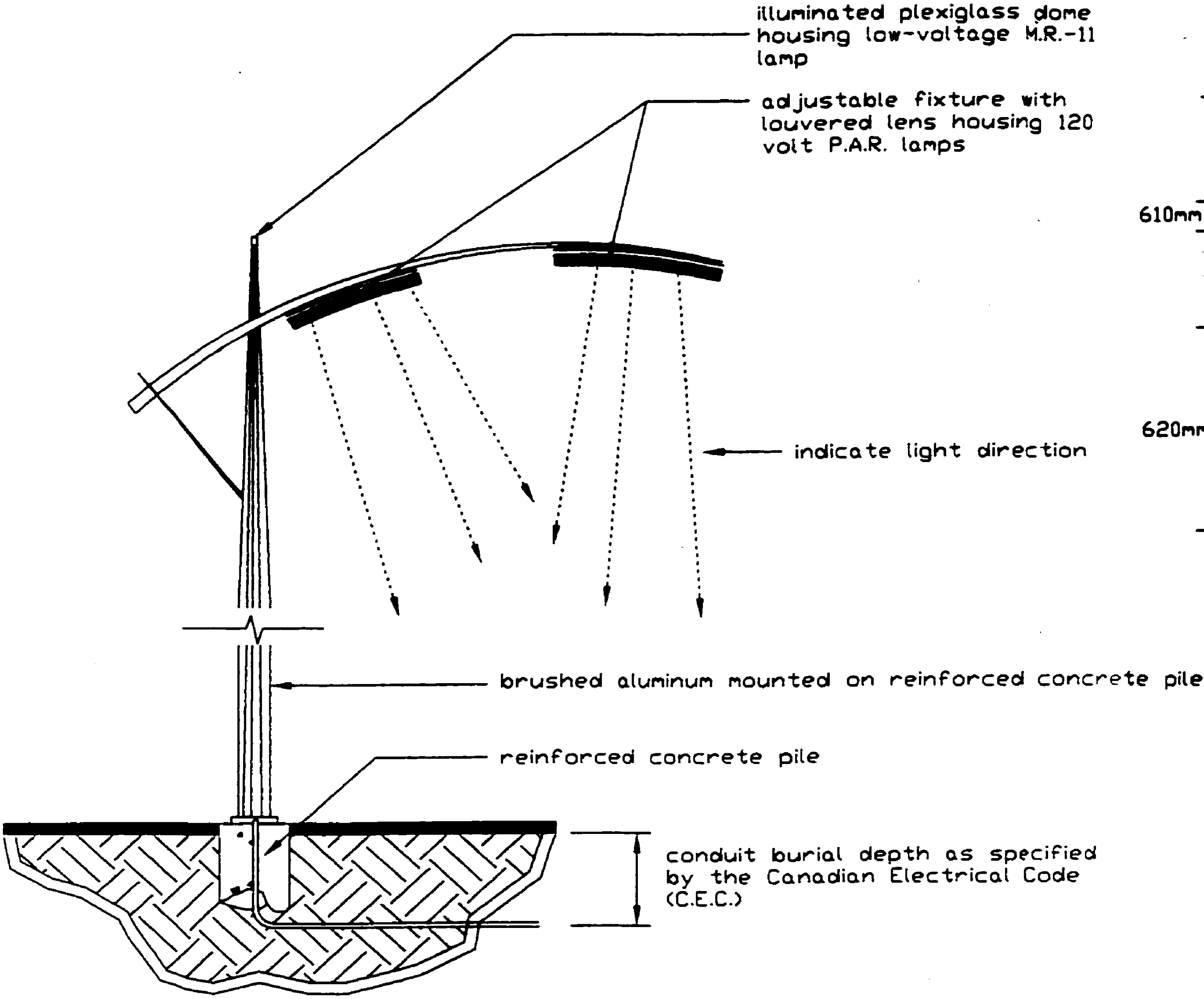


2 / L5 typical light fin plan
n.t.s.



4 / L5 moonlight/downlighting detail
n.t.s.

LIGHTING DETAILS..	L5
scale as noted	



2 / L6 typical light standard

n.t.s.

minated plexiglass dome
using low-voltage M.R.-11
p

justable fixture with
uvered lens housing 120
t P.A.R. lamps

indicate light direction

ted on reinforced concrete pile

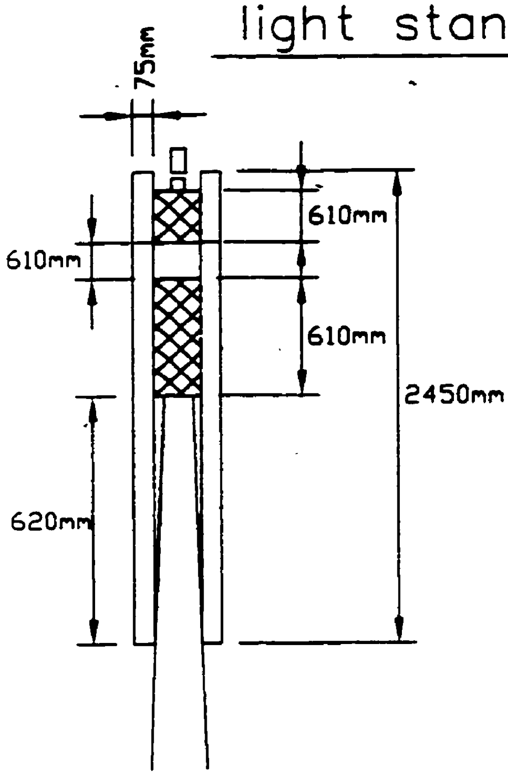
ile

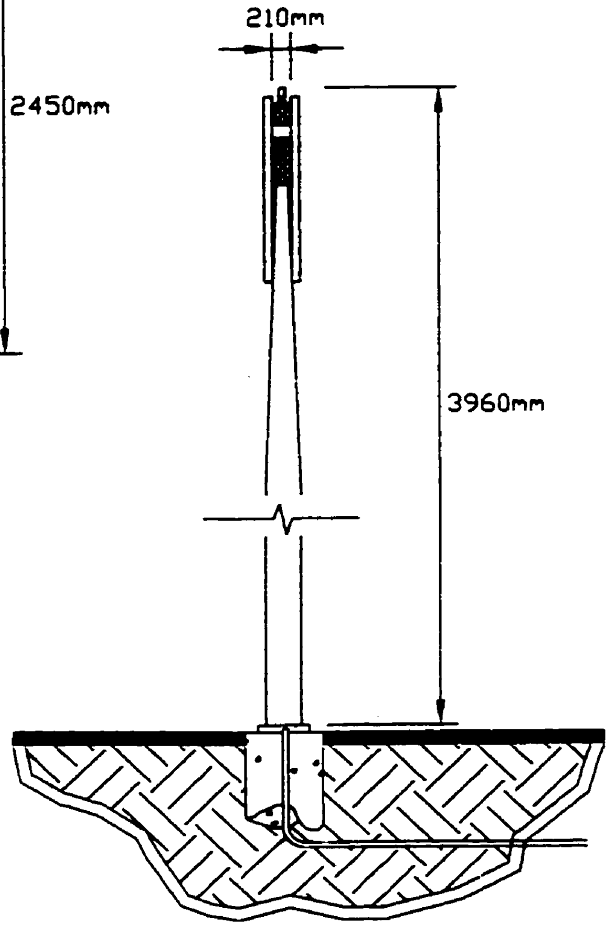
urial depth as specified
anadian Electrical Code

light standard fixture head

n.t.s.

1
L6



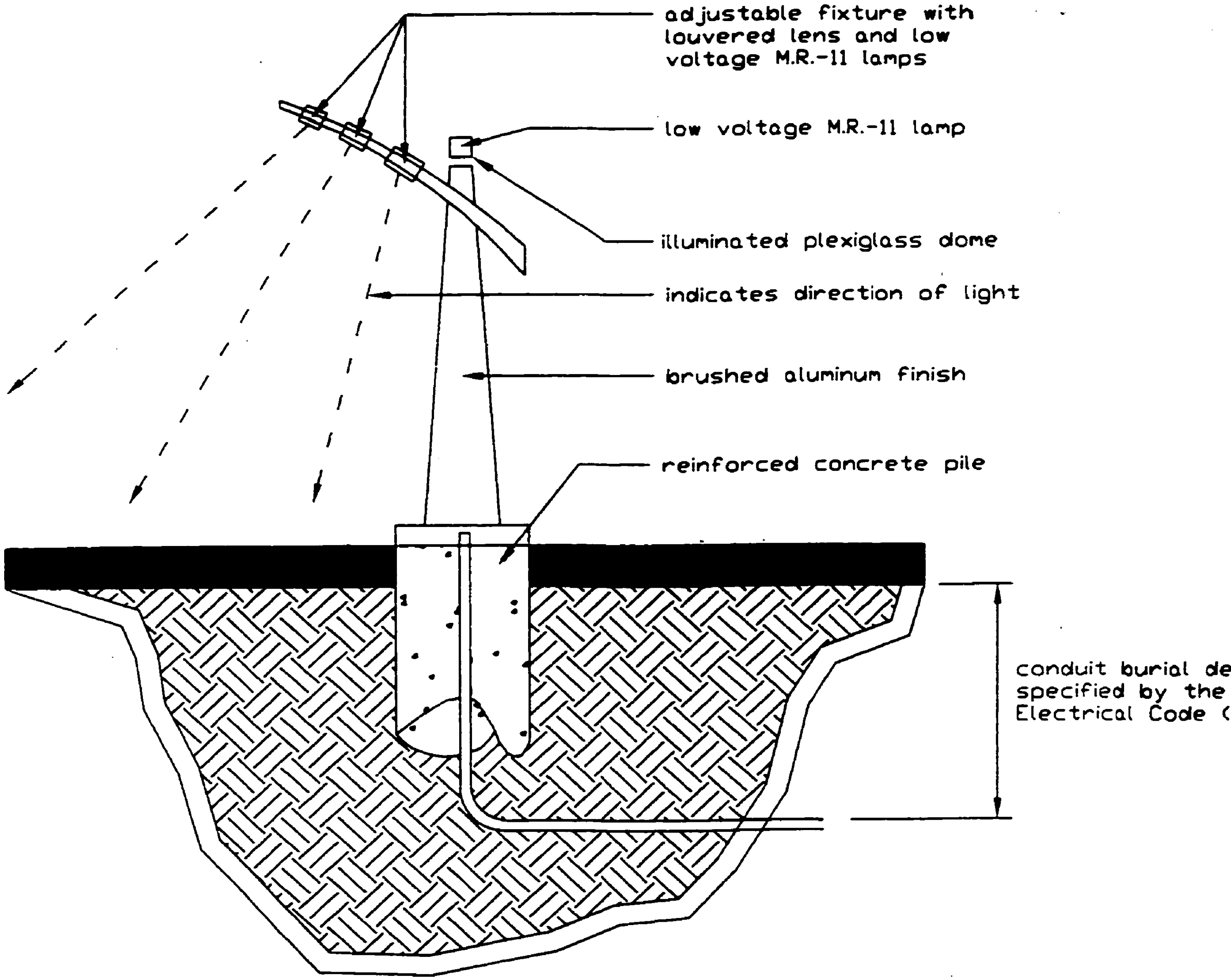


light standard front elevation

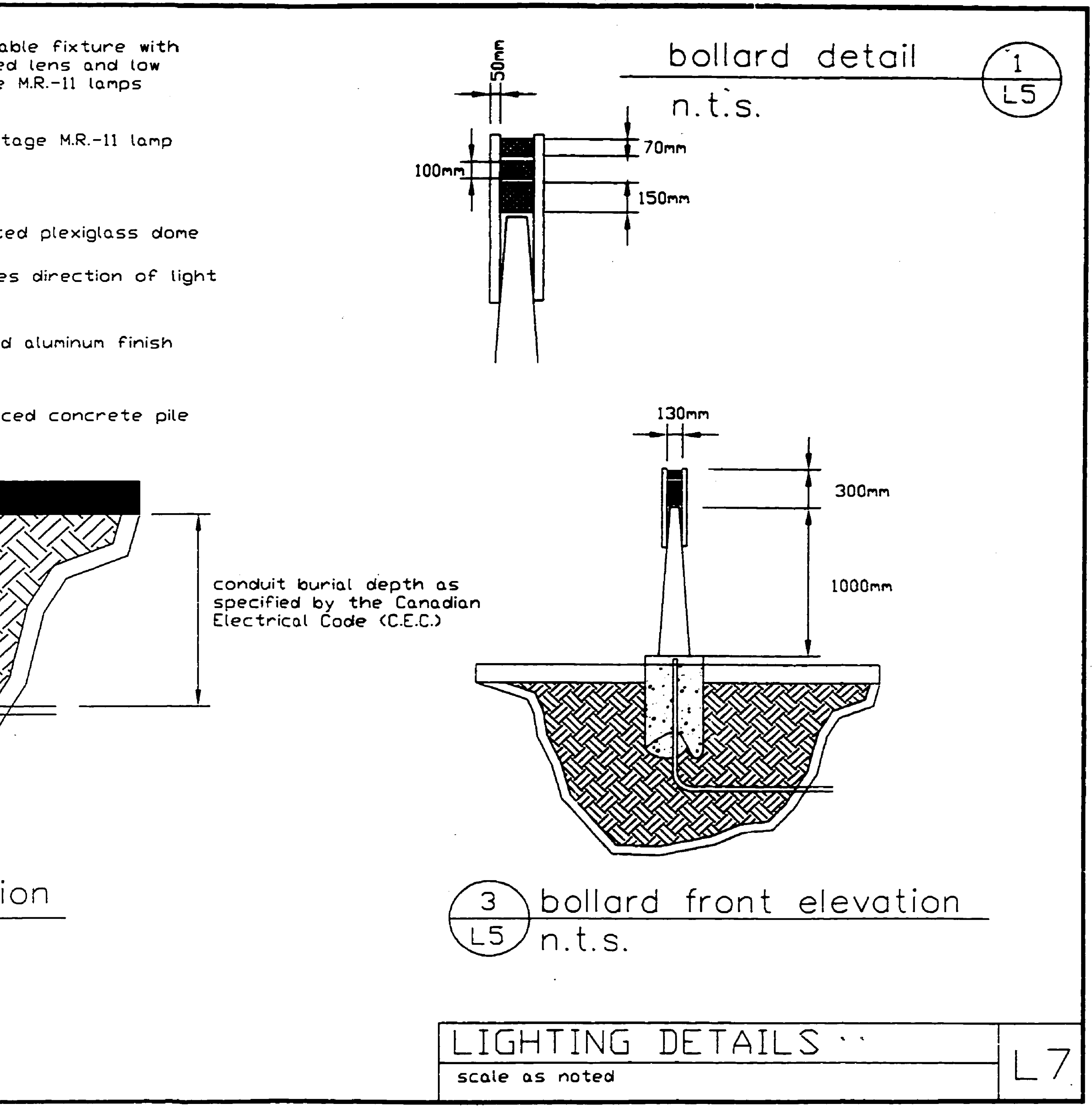
3
L6

n.t.s.

LIGHTING DETAILS	L6
scale as noted	



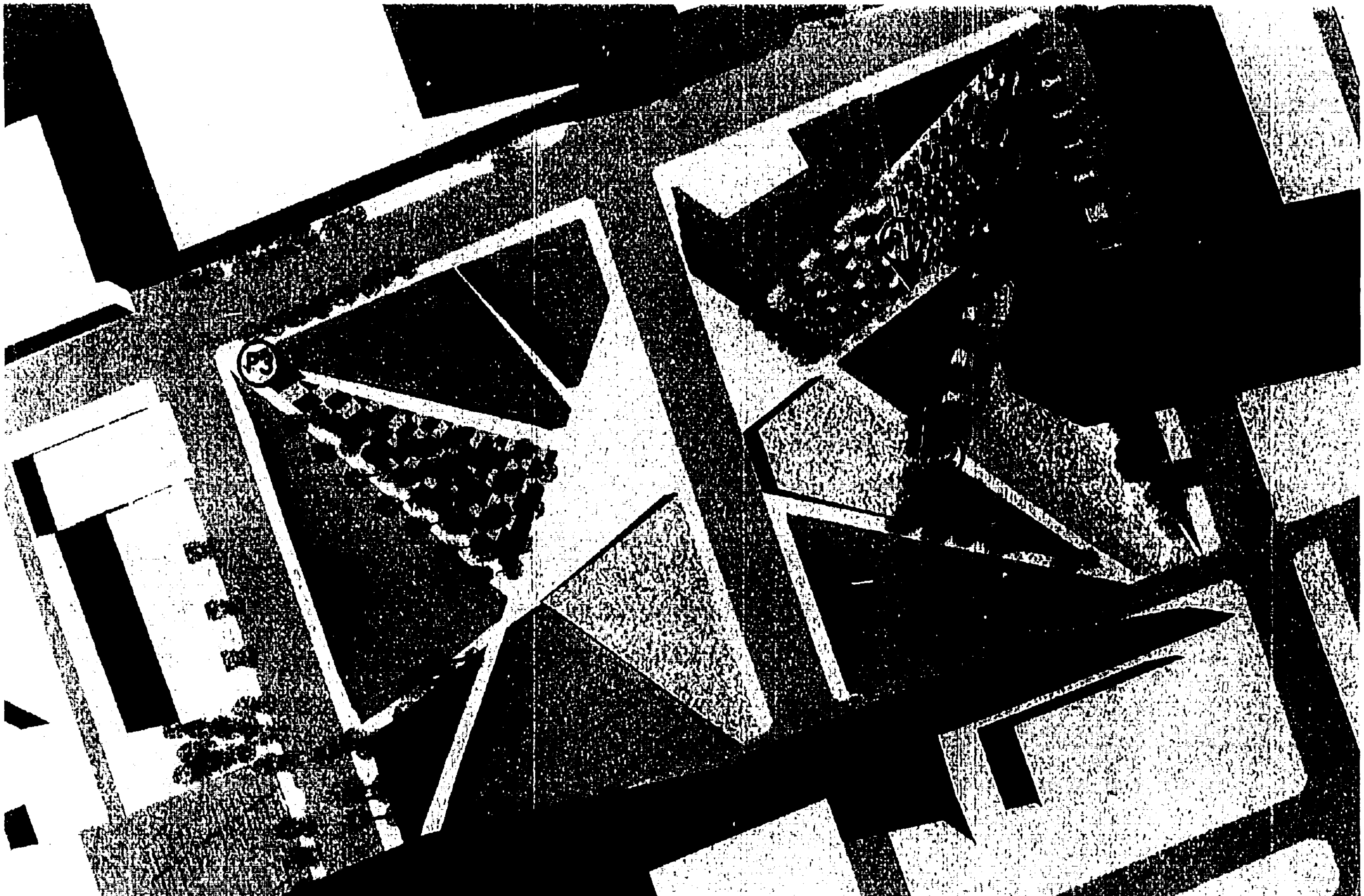
2
L5
typical bollard side elevation
n.t.s.


able fixture with
ed lens and low
e M.R.-11 lamps
tage M.R.-11 lamp
ced plexiglass dome
es direction of light
d aluminum finish
ced concrete pile
conduit burial depth as
specified by the Canadian
Electrical Code (C.E.C.)
ion
50mm
70mm
100mm
150mm
bollard detail
n.t.s.
1
L5
130mm
300mm
1000mm
3
L5
bollard front elevation
n.t.s.
LIGHTING DETAILS
scale as noted
L7

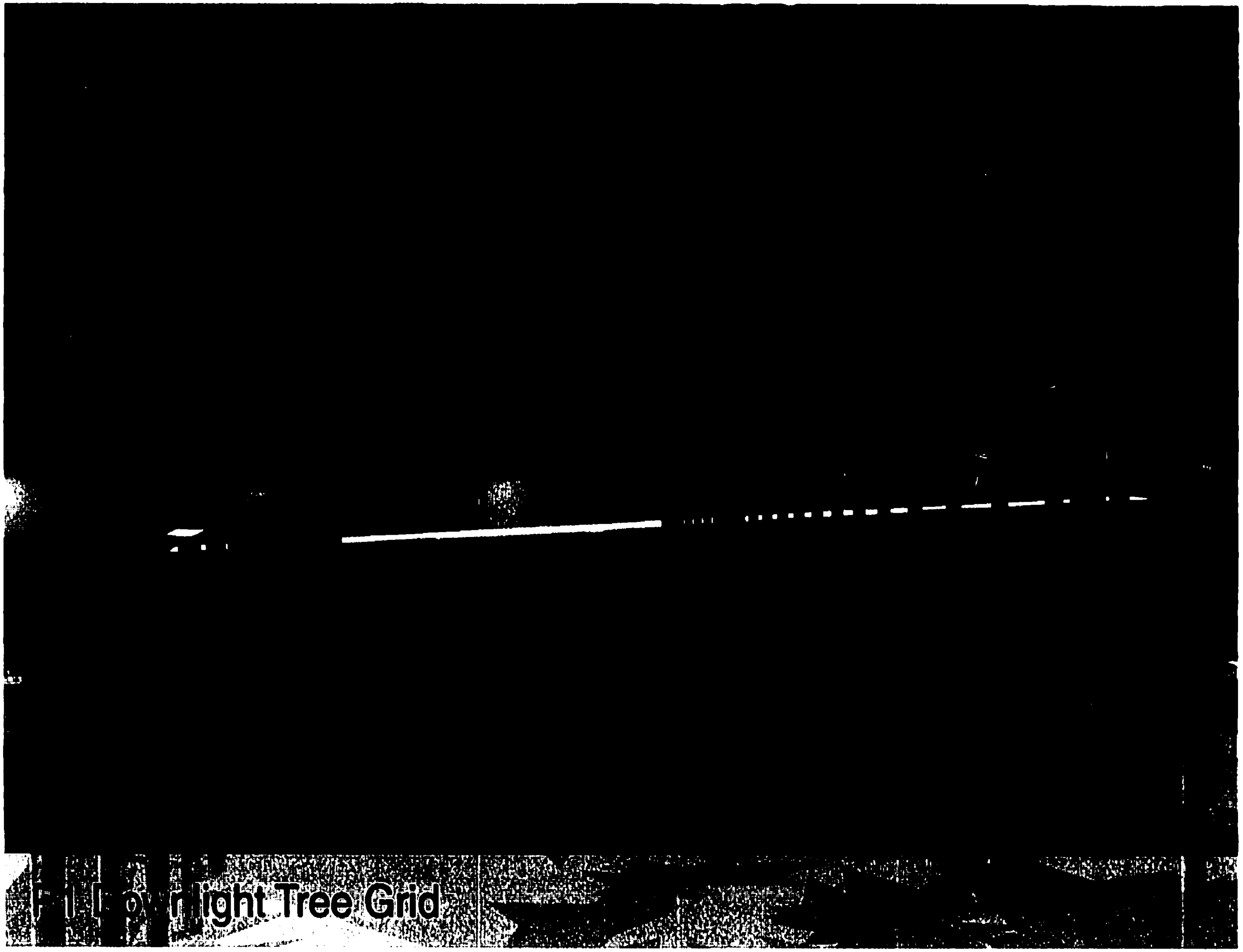
Appendix F

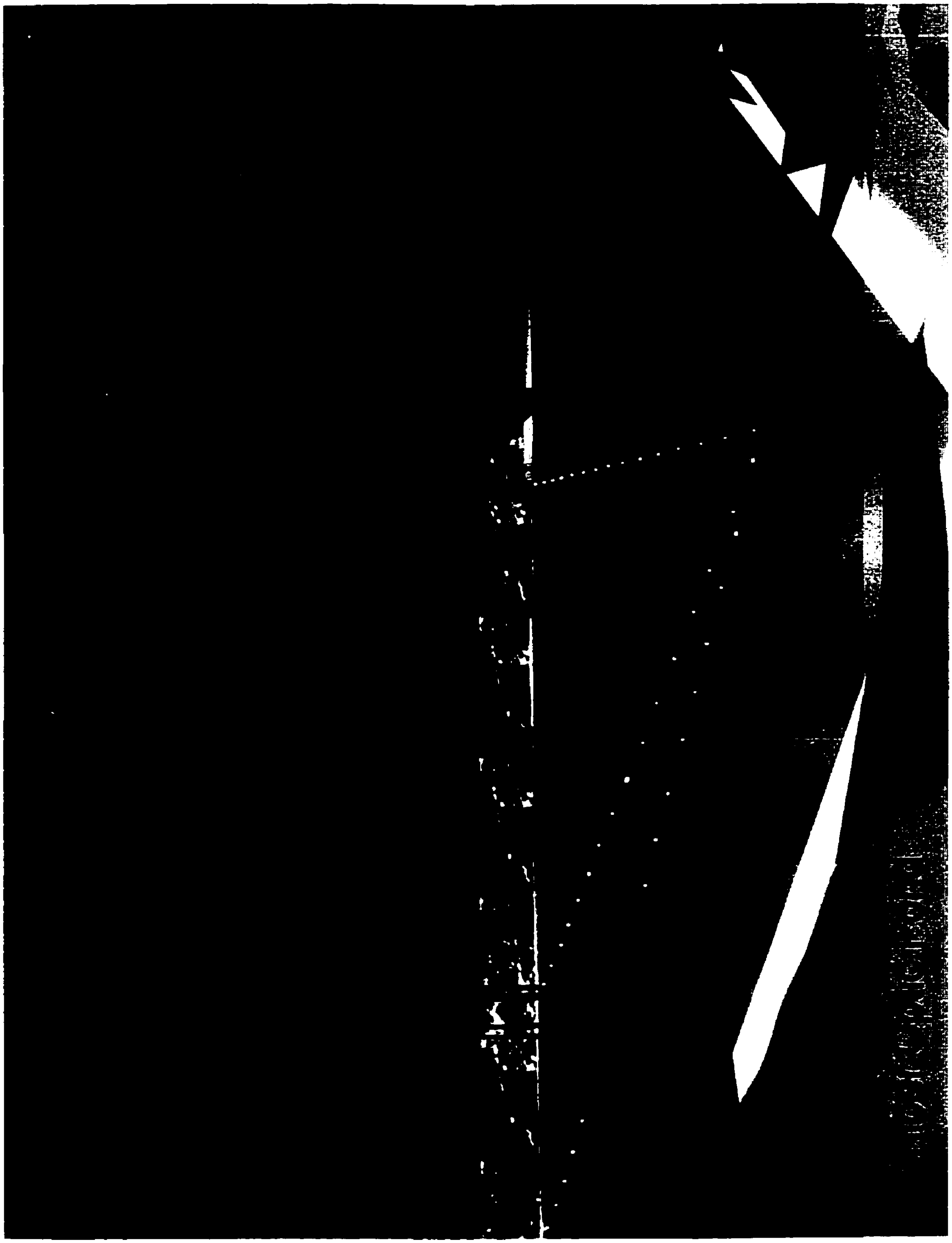
PERSPECTIVES

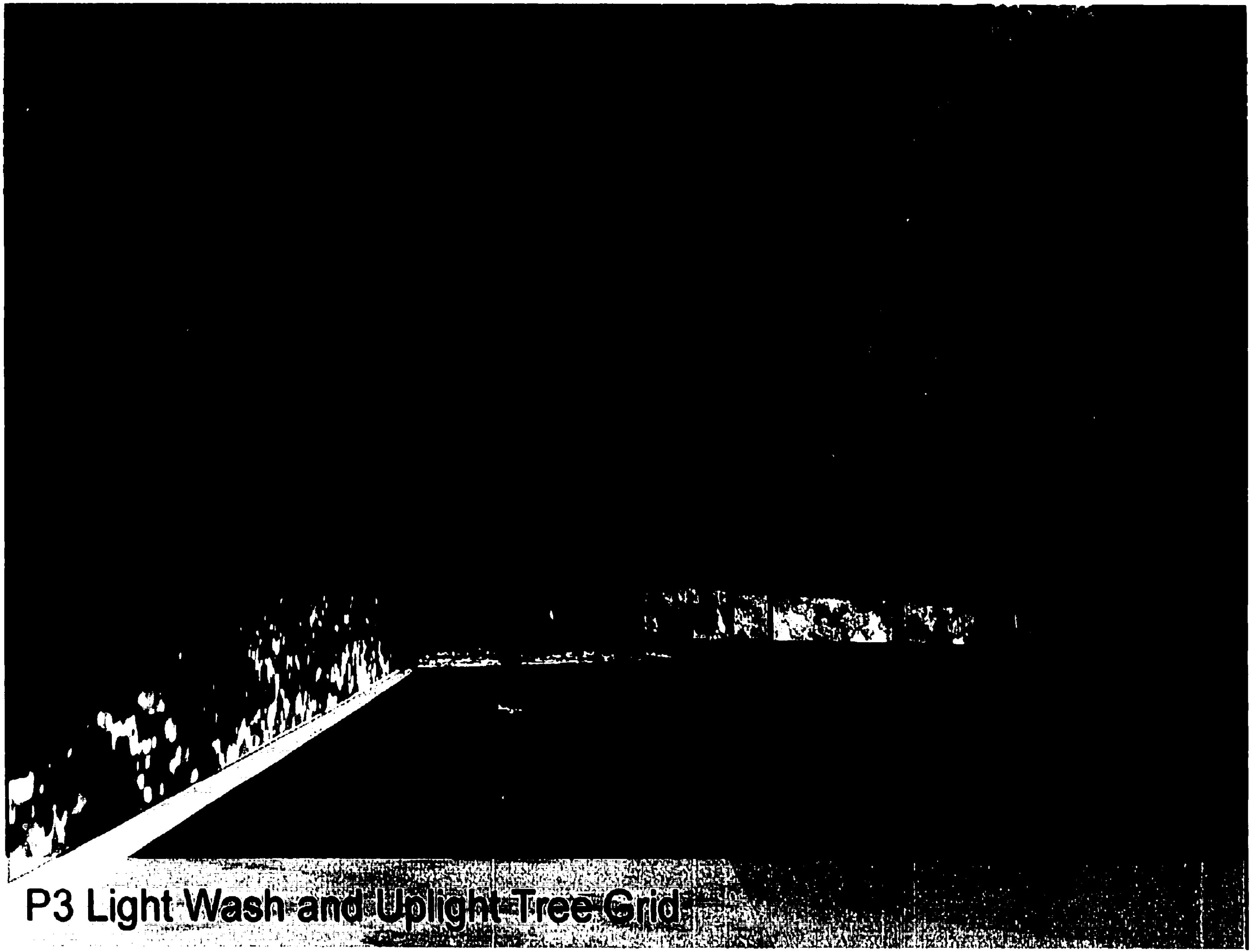
Ω



Viewpoint Diagram


Tree Grid



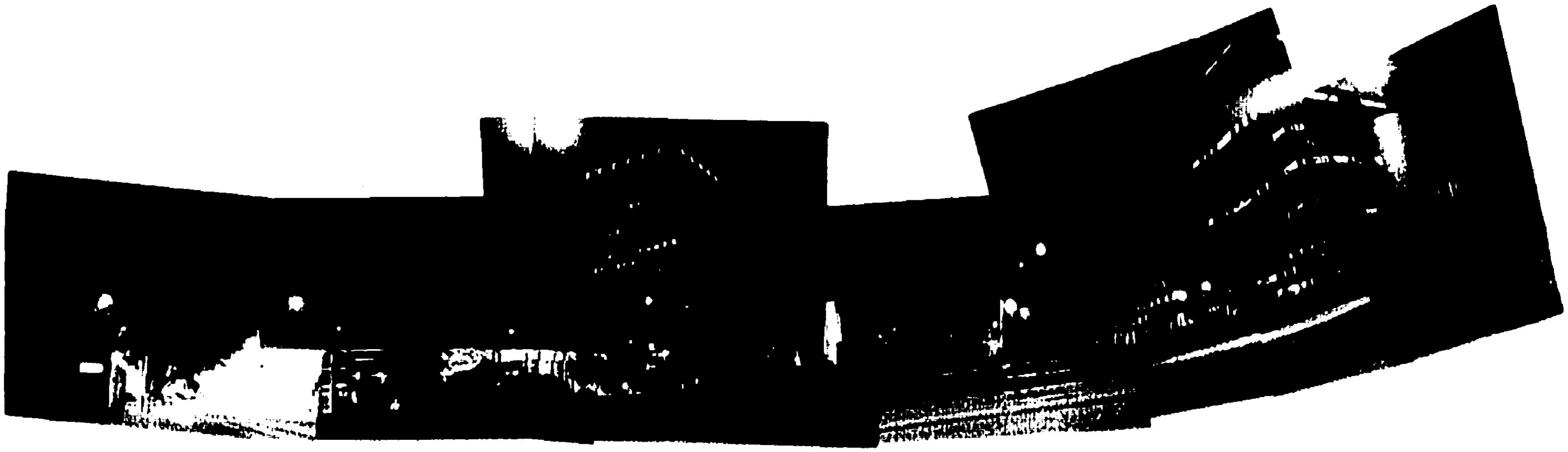

P3 Light Wash and Uplight Tree Grid

Appendix G

EXISTING SITE PHOTOGRAPHS

Ω

Northwest Corner looking Southeast

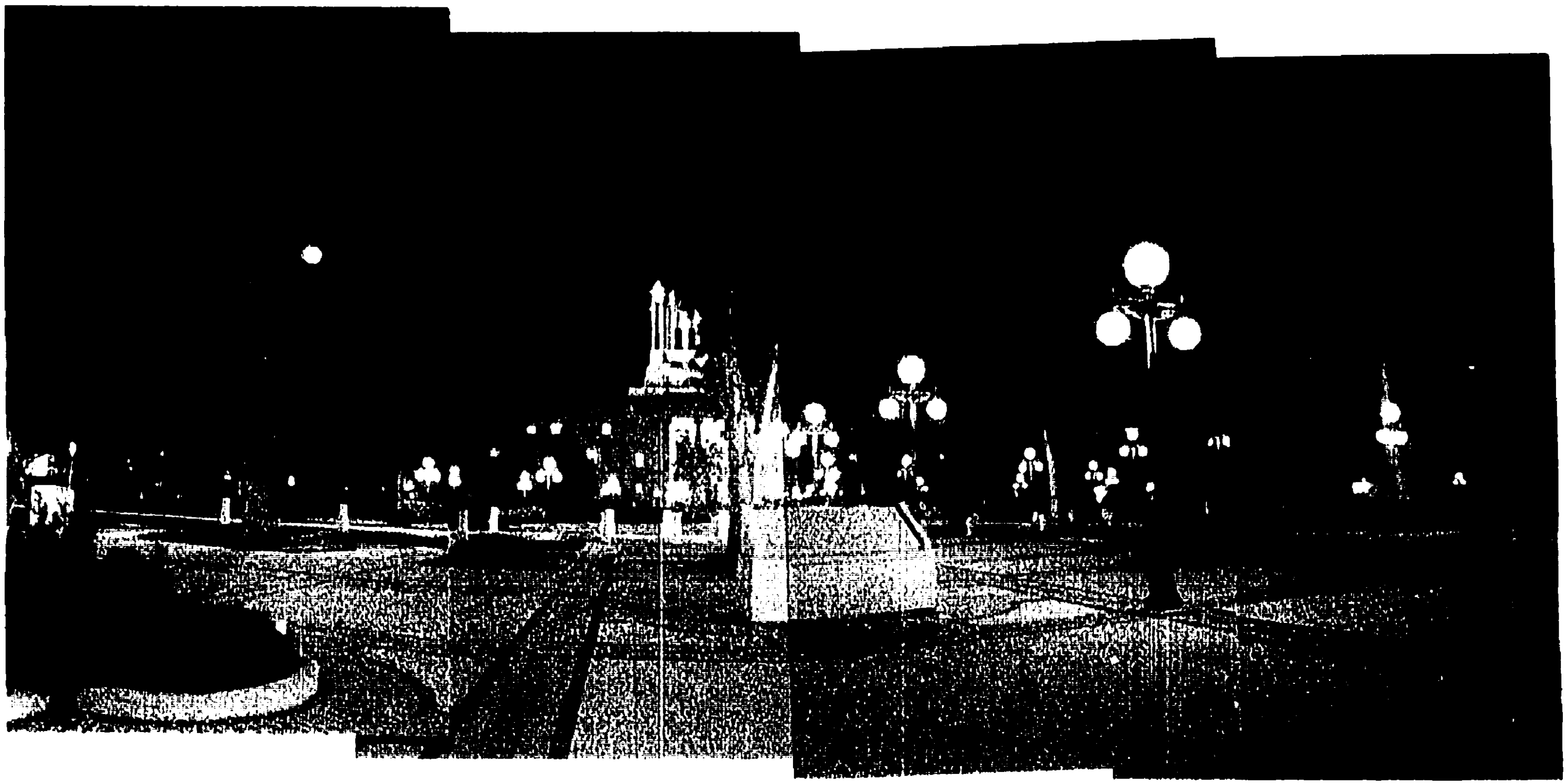


Edmonton St. looking East towards site

Appendix H

MANITOBA LEGISLATURE GROUNDS

Ω



Manitoba Legislative Grounds at night