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THE WESTERN AUSTRALIAN LOCAL GOVERNMENT ASSOCIATION AND THE SUSTAINABLE ENERGY DEVELOPMENT OFFICE

WESTERN AUSTRALIAN LOCAL GOVERNMENT ASSOCIATION

Sustainable Energy Development Office
Government of Western Australia

IMPROVED STREET LIGHTING STUDY FOR GREENHOUSE & SAFETY BENEFITS

INSTITUTIONAL AND TECHNICAL REVIEW

JUNE 2007

TOWN OF MOSMAN PARK

PROSPER IN PEACE

CITY of SWAN

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IMPROVED STREET LIGHTING STUDY
FOR
GREENHOUSE & SAFETY BENEFITS

EXECUTIVE SUMMARY

This report covers an Institutional and Technical Review of current street lighting in Western Australia with the primary aim of upgrading street lighting to Australian Standards in the most energy efficient way.

Local Government is responsible for most street lighting in Western Australia. Western Power acts as a service provider to Local Government for the majority of street lighting. Main Roads WA is responsible for street lighting of freeways and major highways. Some major routes are a shared responsibility of Main Roads WA and Local Government.

A large proportion of street lighting in Western Australia is below Australian Standard requirements. Mercury vapour lamps are used for most Local Government street lighting. Mercury vapour lamps have proved reliable for street lighting but the future is likely to lie with a combination of compact fluorescent, metal halide and high pressure sodium lamps that are typically twice as energy efficient as mercury vapour.

Australia and New Zealand Standard 1158 recommends lighting levels much lower than European, British and American standards. Australia enjoys a warmer, drier climate and night vision is not commonly impeded by snow, hail and fog.

A number of initiatives have been taken in Australia to bring street lighting up to standard and reduce energy consumption. Notable examples are Midvale, Mosman Park, Subiaco, and Joondalup in Western Australia and, in the Eastern States of Australia, in Coffs Harbour, Banyule and South Sydney. The Australian Greenhouse Office has had a study undertaken entitled *"Public Lighting in Australia – Energy Efficiency Challenges and Opportunities".*

Appendix E to this report contains details of the Western Australian trial areas of Midvale, Mosman Park and Subiaco. Measurements have been recorded regularly to monitor the performance of the street lighting over two years. A total of 265 streetlights have been monitored every three months over the two year period.

The energy efficient streetlights are performing at least as reliably as the old mercury vapour streetlights.

Appendix G contains a number of scenarios comparing compliance, energy, greenhouse gas emission, lamp cost and lamp life.

It is possible for Local Government to halve energy consumption of street lighting with no drop in performance. An option is to improve street lighting to AS/NZS 1158 and still achieve energy savings.

IMPROVED STREET LIGHTING STUDY
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01	28-09-04	Initial Draft	Mike Sage	Mike Sage
02	29-09-04	Prelim Draft	Mike Sage	Mike Sage
03	30-09-04	Prelim Draft	Mike Sage	Mike Sage
04	11-02-05	Final Draft incorporating WP comments (pages 5, 29, 30 & 31) & SEDO comments (pages 1 & 33) and measurements	Mike Sage	Mike Sage
05	08-03-05	Committee draft incorporating comments from meeting on 22-2-05	Mike Sage	Mike Sage
06	04-05-05	SEDO comments incorporated	Mike Sage	Mike Sage
07	31-01-06	Draft Interim Report	Mike Sage	Mike Sage
08	27-3-06	Interim report	Mike Sage	Mike Sage
09	6-9-06	Revised Interim report	Mike Sage	Mike Sage
09A	26-9-06	Revised Interim report	Mike Sage	Mike Sage
10	16-11-06	Final INTERIM report	Mike Sage	Mike Sage
11	31-12-06	FINAL REPORT	Mike Sage	Mike Sage
11 A	21-05-07	FINAL REPORT May 2007	Mike Sage	Mike Sage
11 B	6-06-07	FINAL REPORT June 2007	Mike Sage	Mike Sage

1 INTRODUCTION

The purpose of this research program is to ensure awareness and encouragement that new and upgraded street lighting, meets not only the requirements of complying with the relevant Australian Standards for illuminance level, safety and cost effectiveness, but also meets or exceeds world best practice in terms of energy efficiency.

Australian Standards for street lighting are appropriate, recommending lighting levels that are adequate without being excessive. Australian Standards require lower lighting levels than European and North American standards because of the clearer weather in Australia.

The Institutional issues relate to Local Government who are responsible for street lighting, the Underground Power Program (UPP) under which new street lighting is installed as part of the undergrounding process, the Office of Energy who is the administrator of the UPP, and Western Power who is the major street lighting service provider to Local Government.

The Technical issues relate to energy efficiency, street lighting meeting Australian Standards, technology options and comparisons of Western Australian practice with national and world practice.

2 BASIS OF REPORT

This report is based on the following sources:

- AS/NZS1158.3.1: 2005 Pedestrian area lighting
- AS/NZS1158.1: 2005 Road lighting
- Austroads: Guide to Traffic Engineering Practice, Part 12- Roadway Lighting: 2004
- IES (NA) Recommendations for Road lighting
- IESNA G-1-03 Guideline for Security Lighting for People, Property, and Public Spaces
- BS/EN 13201 – Road lighting
- State Underground Power Proposals – Guidelines for Round Four Major Residential Projects

3 METHODOLOGY

The methodology used to develop this report includes:

- Liaison with Western Power, Town of Mosman Park, City of Subiaco and City of Swan to identify trial sites.
- Assess current practice in metropolitan and regional Western Australia.
- Identify Australian and worldwide street lighting best practice.
- Review existing street lighting in Mosman Park, Subiaco and Swan against the criteria of greenhouse gas reduction, energy efficiency, safety benefits, economic performance and maintenance (economic cost/benefit).

- Consider appropriate technologies, improvements to tariffs and contracts to reduce energy and improve lighting quality, improvements to tariffs and contracts to improve maintenance, recommended actions to improve lighting services.
- Regular monitoring of the selected trial sites.

4 DEFINITIONS

Average Carriageway Luminance (L) - The average luminance of a given section of the road carriageway when viewed from the observer's position.

Average Illuminance (E) - The average lighting levels at ground level measured in the horizontal plane. For the Category P4 & P5 streets, the results measured and recorded in this column are the average over the whole street.

Average Lamp Life - Time taken until 50% of lamps has reached end of life.

Colour Temperature – An indication of the colour appearance of a lamp measured in degrees Kelvin (K). 2700K indicates a warm colour, 5000K indicates a cool colour.

Depreciation – The loss of light output over time as lamps age and optical surfaces collect dirt and deteriorate.

Disability Glare – Glare resulting in reduced visual performance, often accompanied by discomfort.

Efficacy - A measure of lamp output efficiency, with units of lumen/watt

Flat Glass Luminaires – Luminaires with no light emitting above the horizontal giving low glare & low obtrusive light.

Fluorescent Lamps – Lamps that can give "white light". Compact fluorescent lamps present the ordinary tubular lamp in a small package.

Flange Mounted Pole - a pole manufactured with a flange at the bottom to bolt down to a concrete footing.

Footing - concrete base for a flanged pole.

Glare – Condition of vision in which there is discomfort or reduction of ability to see, or both, caused by an unsuitable distribution or range of luminance, or to extreme contrasts in the field of vision.

Glare Control Mark – A measure of discomfort glare produced by a street light in a particular situation. This mark is on a scale of 1 to 9 with higher numbers being more comfortable.

High Pressure Sodium (HPS) Lamps – Lamps with a yellow colour appearance. Used on freeways.

Illuminance – The amount of lighting at a particular point, measured in lux.

Ingress Protection – or "IP rating", a two digit code that indicates resistance to ingress of solids and liquids, the first digit refers to solids, the second to liquids eg IP55 means dust-protected & water-jet proof. Higher numbers indicate better protection

Illuminance Uniformity (Ue) - This is a measure that relates average illuminance to maximum illuminance. The higher the figure, the greater the problems of excessive contrast of the highest illumination point.

Lamp – a generic term for a man made source of light sometimes colloquially referred to as a "globe" or "bulb".

Light Output – The total luminous flux emitted by a lamp or luminaire.

Luminance – the brightness of an object or surface. Measured in units of cd/m^2 (candela per square metre).

Low Pressure Sodium (LPS) Lamps – Lamps with a distinctive yellow colour. The light emitted by this lamp distorts the colours of blue, green and red, but produced a high quantity of light for the quantity of energy consumed.

4 DEFINITIONS

Longitudinal Luminance Uniformity (UI) – The ratio of minimum to maximum carriageway luminance in a longitudinal line along the road through the observer's position. The closer this figure is to 1, the more even is the luminance.
Luminaire – A light fitting or "fixture" including lamps, optical system and any electrical control gear.
Minimum Illuminance (Emin) - The minimum measured lighting level recorded in the measurement area, the measurements taken at ground level in the horizontal plane
Mercury Vapour (MV) Lamps – Lamps with a blue-white colour.
Metal Halide Lamps – Lamps which can give "white light"- more efficient than mercury vapour.
Mounting Height – The vertical distance between the centre of a luminaire and the surface of the carriageway immediately beneath the lighting.
Nominal Height – The vertical distance between the bottom of the baseplate or ground line (as applicable) and
(a) For columns with outreach arms - a horizontal line at the highest level of the outreach arm centre-line.
(b) For post-top columns – the highest point of the column excluding any fixing spigot.
Observer's Position - A reference position on the road from which theoretical calculations are based. Approximately where a driver would sit when driving down the road.
Obtrusive Light - Spill light causing annoyance distraction, discomfort, or reduction in vision.
Outreach - The distance measured horizontally from the centre of a bracket-mounted luminaire, to the centre of the column or pole, or the wall face to which the bracket is attached.
Overall Luminance Uniformity (Uo) – The ratio of minimum carriageway luminance to the average luminance. The closer this figure is to 1, the more even the luminance.
Peak Intensity - The highest value of luminous intensity from a given luminaire.
Planting Depth - The length of the column that is buried below ground level.
Reliability – in this report reliability is taken as the percentage of street lights working at a given time.
Repair time – the time taken from report of failure to restoration of the street light
Standards – Australian Standards include:

AS1158	Public Lighting
AS1428	Design for Access & Mobility
AS1680	Interior Lighting
AS2293	Emergency Lighting
AS2560	Sports Lighting
AS2890	Off Road Car Parks
AS4282	Obtrusive Light

Spill Light – Light which falls outside the boundary of the property on which the lighting installation is sited
Surround Illuminance Ratio (ES) - The ratio between the average illuminance of the road verge to the adjacent section of carriageway. The higher the ratio, the more effectively will verge details be discernible to drivers.
Threshold Increment – A measure of disability glare produced by a street lighting in a particular situation. The higher numbers correspond to greater disability glare.
Uniformity Ratio – The ratio of maximum illuminance to average illuminance.
Upcast Angle - The angle between the axis of the luminaire fixing and the horizontal.
Uplift - (For pole-mounted bracket arms) - the vertical distance between the intersection of the bracket arm centre-line with the supporting face and the highest level of the bracket arm centre-line.

5 INSTITUTIONAL REVIEW

5.1 BACKGROUND

In Western Australia, as in other states of Australia, Local Governments are responsible for the provision of street lighting. An exception is certain major roads where the responsibility for road lighting lies with Main Roads WA or is shared between Mains Roads WA and Local Government.

The arrangement in Western Australia, where Local Government is responsible for street lighting but employs the electricity supply authority to be the street lighting service provider, is also the case in other parts of Australia and in New Zealand.

In Britain, street lighting is a Local Government responsibility and Local Government; through the County Councils take care of the design, installation, maintenance and ownership of street lighting. The electricity supply authority provides an electricity supply to each light pole via a "service cut out" within the light pole. This service cut out is the dividing line between the supply authority and the County Council. If there is power at the service cut out, the County Council know maintenance is their responsibility. If there is no power at the service cut out, the County Council requests the supply authority to repair.

In Britain there is a need to replace aged public lighting and local authorities can apply for grants from central government to fund lighting improvements.

In Western Australia, there is an historical arrangement where Local Governments have requested Western Power, previously SECWA and SEC, to install streetlights on power poles. Before the formation of the SEC, street lighting was provided by Local Governments who were the local electricity undertakings. During 2006 Western Power was split. "Synergy" is the retial entity that bills local government for street lighting and "Western Power" claims ownership of street lighting equipment. Under the present State Government contestability policy Synergy and Western Power claim that lighting is not contestable.

Early Street lighting in Subiaco [1]

The Western Australian Local Government Association strongly advocates the contestability of street lighting and has published an Infopage 05-001-03-0014

5.2 CURRENT PRACTICE IN WESTERN AUSTRALIA

5.2.1 INTRODUCTION

Western Australia has a stock of 199 552 street lights that consumed 90.2 GWh of energy in 2002/2003. Approximately 40% of these street lights serve major roads and 60% minor roads. In Australia, major street lighting accounts for 30% of the numbers of street lights but 53% of the energy, whereas minor street lights account for 70% of the numbers but 47% of the energy[6].

In accordance with the recognized road hierarchy, minor roads are Local Access Roads and Local Distributor Roads. Major roads are the District Distributors. Principally, minor roads are lit for pedestrian security (AS/NZS 1158 Category P lighting) and major roads for vehicle safety (AS/NZS 1158 Category V lighting).

While the minor roads have a higher number of street lights, they are of lower power than major road street lights.

5.2.2 MINOR ROADS

Most minor roads in Western Australia have substandard lighting. With streetlights spaced 80 m apart, the section of road halfway between the streetlights is a black spot receiving no light. Observation, measurement and calculation have confirmed this.

Typically what was called "half standard" street lighting was installed. This meant streetlights generally installed on every second power pole. The spacing was consequently four street frontages, about 80 m, generally too far apart to achieve compliance with Australian Standards.

For minor roads, 50 W, 80 W, and 125 W mercury vapour streetlights are typical with a mounting height of about 7.5 m with overhead power and 6.5 m with underground power.

Through the 1990's, Western Power upgraded many minor road streetlights to 80 W mercury vapour.

5.2.3 MAJOR ROADS

For major roads, 250 W high pressure sodium and older 250 W and 400 W mercury vapour streetlights are typical with a mounting height of about 9 m with overhead power and 10.5 m, or 12.5 m with underground power.

For the major roads, high pressure sodium lamps are energy efficient. However, a further improvement in energy efficiency can be obtained with bi-level control. Bi-level control of a high pressure sodium lamp halves the energy consumption and the light output. In effect lighting to Category V3 can be reduced to Category V5. This should be acceptable as there appears to be a reduction in traffic flow about 9pm on weeknights. Thus full lighting can be maintained during times of high traffic flow and half lighting when traffic flow reduces.

Bi-level control requires a "supplementary impedance", an extra switching wire, and a 7 day time switch, or similar device.

5.3 UNDERGROUND POWER

With the advent of the State Underground Power Policy in 1990, the Underground Power Program was launched. This programme facilitates the undergrounding of power with funding contributions from Western Power and Local Government. The aim is to have power underground in half of the metropolitan area by 2010.

By necessity, this program has to replace the streetlights mounted to power poles with new streetlights on new steel poles. With the initial trial and stages 1 and 2 of this program, streetlights were replaced on a "like for like" basis, that is, the number of existing streetlights was counted, and then replaced with the same number of new streetlights. If Local Government wanted lighting to achieve Australian Standards, Local Government had to pay for the additional streetlights needed to achieve compliance.

The Round Four Guidelines state:

"Western Power streetlights funded as part of a project will use standard Western Power galvanized poles and luminaires that will provide lighting levels to Australian Standards.

Additional streetlighting requirements such as the use of decorative poles/luminaires or increasing the lighting levels to a higher Australian Standard category may be installed at an additional cost to the local government. ………"

Consequently the Underground Power Program has now moved from "like for like" street lighting to street lighting which meets Australian Standards. The applicable Australian Standard for the lighting of minor roads AS/NZS 1158.3.1 tables five Categories of lighting, from P5 to P1. The standard prescribes four Light Technical Parameters to be met, rather than just one "minimum level". Western Power's Newsletters under "Streetlighting" typically state:

"The new streetlights are designed to conform as closely as possible to the relevant Australian Standard and are located quite differently to the old lights. The new lights will be located one metre from the edge of the roadway, more closely spaced and where possible, placed on the extensions of side boundaries and alternated to both sides of the road". [2]

It is noted that specific Categories of the relevant Australian Standard (AS/NZS 1158) are not quoted in the Office of Energy documentation.

5.4 IMPROVEMENTS

Western Power has been moving forward with more efficient street lighting technology and examples of this include:

- High pressure sodium lamps were used in Stratton in ordinary functional streetlights and in the underground power project in Claremont in decorative "Kensington" streetlights.
- In Midvale, Western Power replaced 80 W mercury vapour streetlights with 70 W metal halide streetlights. The result has seen substandard street lighting raised to Category P4 of AS/NZS 1158.3.1 with lower energy consumption.
- Western Power introduced a range of decorative streetlights in 2000. Initially this range included 80 and 125 W mercury vapour lamps and 70, 150, and 250 W high pressure sodium lamps. The current range of Western Power decorative streetlights includes 70, 150, and 250 W metal halide lamps in addition to 50, 80 and 125 W mercury vapour lamps and 70, 150 and 250 W high pressure sodium lamps.

Western Power is investigating but has not yet trialled fluorescent streetlights. Western Power's concern has been with the reliability of fluorescent technology. These have been available for some years. The 42 W compact fluorescent lamp introduced in 1994 has a similar output to the 80 W mercury vapour lamp but consumes half the energy. The T5 (16 mm diameter) linear fluorescent lamps introduced in 1996 combine high efficacy with long life. A 2 x 24 W T5 streetlight has a similar output to an 80 W mercury vapour streetlight but consumes 55% of the energy.

Modern fluorescent lamps such as the 42 W compact fluorescent lamp and the T5 linear fluorescent lamps are dependent on electronic control gear for their operation. Electronic control gear provides these modern lamps with a stable operating regime. Western Power is concerned about the ambient temperatures in Western Australia that may exceed manufacturer's ratings and shorten the life of the electronic control gear.

The Public Transport Authority is insisting on electronic control gear for all lamps (metal-halide & fluorescent) for the railway stations for the new Mandurah line.

5.5 FUNDING

Western Power and its predecessors SECWA and SEC originally funded the installation of streetlights and then recovered the cost from Local Government through tariffs based on the wattage of the lamp and the burning hours. At present many Local Governments on contract with Western Power pay for street lighting on the basis of an annual "Street Vision" charge that is fixed each year.

Through the Underground Power Program and new residential developments, half of the metropolitan area will have improved street lighting by 2010. However, some of the early underground power project areas have non-conforming street lighting.

6 TECHNICAL REVIEW

6.1 LAMP TECHNOLOGY

Two important characteristics of lamps used for street lighting are the energy efficiency and the lamp life.

The energy efficiency of lamps is measured as "efficacy". This is the ability of the lamp to produce visible light (measured in lumens) from electrical energy (measured in watts). Efficacy is measured in terms of lumens/watt. A lamp with 100% energy efficiency would have an efficacy of 683 lumens/watt. Practical lamps have efficacies in the range 10 to 200 lumens/watt.

The life of lamps may be measured as rated life or as "economic life". Rated life is the time at which 50% lamp mortality has been reached. Economic life is the time at which the light output has depreciated to 70% of the initial light output and should be replaced.

While the mercury vapour lamp has been a reliable source for minor street lighting in many parts of Australia and overseas, its status is now challenged by lamps that are more efficient.

At present, the contenders for replacing mercury vapour lamps are high pressure sodium, metal halide, and fluorescent lamps. Technologies which have not been considered are: low pressure sodium lamps which have poor colour; LED's which are not efficient and have too low power, and induction lamps that are very expensive.

6.2 MERCURY VAPOUR LAMPS

Mercury vapour lamps were developed in the 1930's and their efficacy has not improved since then.

Mercury vapour lamps have:

- A poor efficacy of 40 to 50 lumens/watt.
- A Colour Rendering Index of about 50 with a blue-white output deficient in red that renders skin tones poorly.
- A long life of 16,000 hours typically.
- Have a high mercury content.

One advantage of the mercury vapour lamp is its long and reliable life. Mercury vapour lamps may operate for over a decade, but as each year goes by, its output diminishes. After four years of operation at 4,000 hours per year, a mercury vapour lamp will produce about 65 to 70% of its initial output, but still consume the same amount of energy.

The disposal of mercury vapour lamps should be considered a serious problem. Each 80 W lamp contains 14 mg of mercury.

6.3 HIGH PRESSURE SODIUM LAMPS

High pressure sodium lamps:

- Have high efficacy, around 90-120 lumens/watt.
- Have poor colour rendition with a Colour Rendering Index of 22 and a distinctive golden colour.
- Have long life of 24,000 hours typically.
- Have low mercury content.

High pressure sodium lamps are a reliable light source for road lighting offering high efficacy and long life. The life of high wattage lamps is around 20,000 hours while the life of low wattage lamps is around 12,000 hours. A development of this lamp is the twin arc tube lamp, essentially two lamps in one envelope. This lamp offers double the life.

High pressure sodium lamps are used for lighting minor roads in New Zealand and in England. One disadvantage of these lamps is their poor colour rendition that does not accurately render skin tones, clothing colours, and vehicle paintwork. The primary purpose of minor road lighting is security and high pressure sodium lighting fails to provide colour identification for security.

Under photopic (day) vision, the eye is most sensitive to yellow light. Under scotopic (night) vision, the eye is most sensitive to blue light. Minor road lighting is in the mesopic (between photopic and scotopic) range of vision. What this means is that the predominantly yellow light from high pressure sodium lighting is not as effective as the white light from metal halide and fluorescent lamps. The latest edition of AS 1158.3.1 recognises this and recommends that a de-rating factor of 75% be applied to high pressure sodium lighting for Categories P4 and P5.

High pressure sodium lighting is valid for highway lighting and is used by Main Roads WA and Western Power for major roads.

6.4 METAL HALIDE LAMPS

Metal-halide lamps were developed in the 1960's and may be considered to have evolved from mercury vapour lamps.

Metal-halide lamps:

- Offer high energy efficiencies of around 80 lumens/watt
- Have excellent colour rendering giving "white light" with Colour Rendering Indices between 65 and 80. Their strong blue and green component makes them particularly well suited to night vision.
- Have suffered from short life of about 6,000 hours (1½ years) but developments in recent years have extended life to 12,000 hours for low wattage lamps (3 years) and up to 20,000 hours (5 years) for larger wattage lamps. Philips has a 60W metal halide lamp, branded "Cosmo-white", with a 12 000 hour rated life. Venture have metal halide lamps with long life, claiming 75% survival at 15 000 hours.
- Have low mercury content.

The Lighting Strategy for the City of Perth has designated this lamp for Perth's "White Light". One example is the Eastern Gateway to Perth where the Great Eastern Highway passes Burswood Casino. Other examples are the Thorn "Urbi" luminaires in many of the City of Perth's streets.

6.5 FLUORESCENT LAMPS

Fluorescent lamps:

- Offer high efficacy of between 80 and 100 lumens/watt.
- Offer "white light" with a Colour Rendering Index of 80 giving excellent colour rendering of red, blue and green.
- Have a life varying from 12,000 hours to 36,000 hours.
- Have low mercury content.

T5 (16mm diameter) fluorescent lamps are linear fluorescent lamps but with a smaller diameter to the conventional 26 mm lamps. These lamps run on electronic control gear and have very high efficacy (about 100 lumens/watt) and a long life of about 20,000 hours. A trial of these lamps is being established in Victoria.

One Australian manufacturer, Pierlite has produced a streetlight using two x 14 W and 2 x 24 W, T5 (16 mm diameter) lamps with electronic control gear. These lamps have a rated life of 20,000 hours. The 14 W lamps have an efficacy of 100 lumens/watt and the 24 W lamps 80 lumens/watt. A street lighting trial of T5 lamps is being established in Victoria.

T5 lamps in general are manufactured to give optimal output at 35^0C whereas most fluorescent lamps are optimised at 25^0C. In outdoor applications there is a possibility that the lamps may only give 80% of full output.

Streetlights with compact fluorescent lamps are available from a number of manufacturers. These lamps have an efficacy of 80 lumens/watt and a life of 12,000 hours.

Sylvania have a 42W compact fluorescent lamp with a claimed life of 28 000 hours. This is an "amalgam" type fluorescent lamp.

Old technology fluorescent lamps have been used in Australia, particularly around the Sydney metropolitan area. Twin 18 W linear fluorescent lamps with wire wound ballasts have been typical. These are T8 (26 mm diameter) lamps with a rated life of about 10,000 hours.

6.6 LOW PRESSURE SODIUM LAMPS

Low pressure sodium lamps have been used rarely in the past in Australia for street lighting but are being replaced because of their poor colour characteristics. These lamps have no Colour Rendering Index. These lamps have a monochromatic yellow colour that does not support colour vision, however they do have an extremely high efficiency of 200 lumens/watt.

Low pressure sodium lamps have been used in very few countries with limited success. These lamps have a limited future and are only of historical interest.

6.7 LIGHT EMITTING DIODES

Light emitting diodes (LED's) are a promising light source but the efficacy of white LED's is poor and the power is limited. LED's offer extremely long life.

LED's are a promising light source, but at present are not yet suitable for street lighting because of their low efficacy. LED's have been trialled in Australia but not where compliance with AS/NZS 1158 is required.

At the time of this report, high efficiency LED's are appearing to emerge.

6.8 INDUCTION LAMPS

The induction lamp is a type of fluorescent lamp that offers extremely long life. The cost is very high and makes these lamps appropriate only when maintenance access is extremely difficult.

Induction lamps are not suitable for large scale street lighting as their cost, about $1000, is prohibitive.

6.9 DIMMING

It is possible to dim some types of street lighting lamps. It can be economic, especially with high wattage major road lighting, to dim lamps to about 50% to save energy. Compliance with standards can be maintained, for instance, Category V3 lighting can be dimmed to 50% and Category V5 can still be achieved. The application for dimming would be major roads that are busy in the early evening but have little traffic after 9 or 10pm.

6.10 LAMP COMPARISON

The various lamp families are compared below in Table 1:

Table 1

Lamp Type ❶	MV	HPS	MH	FL	LPS	LED	IND
Rated Life (1000 h)	24	24	6-30	10-30	10	100	100
Economic Life (1000 h)	15	24	6-20	10-20	10	100	100
Efficacy Photopic (lumens/Watt)	40-50	90-120	80	80-100	170-200	25	100
Efficacy Scotopic (lumens/Watt)	40-50	50-70	100	80-100	NA	25	100
Power Range (W)	50-400	50-250	35-400	18-57	18-180	1	100-150
CRI ❷	OK	Poor	Good	Good	Very Poor	Good	Good

NOTES
❶ MV = mercury vapour, HPS = high pressure sodium, MH = metal halide
FL = fluorescent, LPS = low pressure sodium, LED = light emitting diode, IND = Induction.
❷ CRI = colour rendering index. An index greater than 50 is good.

The data in Table 1 is derived from lamp manufacturers represented in Australia.

Table 2 shown below compares various lamp technologies in terms of power, power per kilometre (kW/km), greenhouse gas emissions (Tonnes of CO_2 per kilometre per annum), mercury content (milligrams per lamp), life in hours, and estimated annual cost including energy and scheduled maintenance. The table assumes a standard geometry with overhead power of 80 m spacing, 7.5 m mounting height, and a 20 m road reserve.

Table 2

Lamp type ❶	80 W MV	42 W CFL	2 x 24 W T5 FL	70 W MH	50 W HPS❾	70 W HPS❾	57 W CFL
Power ❷ (W)	89.5	46	50	77	55	77	63
kW/km ❸	1.2	0.6	0.65	1.0	0.7	1.0	0.8
CO_2/km ❹ (T)	4	2	2.2	3.4	2.4	3.4	2.8
Category ❺	**X**	**X**	P5	P4	**X**	P4	P5
Mercury ❻ (mg)	14	4.5	6	0.01	0.02	0.02	4.6
Lamp Life ❼ (h)	16000	28000	20000	10000	20000	20000	10000
Energy Cost ❽ p.a. per lamp	$38.14	$19.60	$21.30	$32.81	$23.44	$32.81	$26.50

NOTES
❶ MV = mercury vapour, CFL = compact fluorescent, FL = fluorescent, MH = metal halide
HPS = high pressure sodium
❷ Power per lamp measured in Watts.
❸ Power required per kilometre based on a nominal spacing of 80 m.
❹ Tonnes of CO_2 produced per kilometre per annum based on 4 000 h burning and 0.9 kg of CO_2 per kWh.

❺ AS/NZS 1158.3.1 Category, **X** = non-compliant with any Category. The non-compliance refers to the geometry (80 m spacing, 7.5 m mounting height) rather than the technology. In each case compliance could be achieved with better geometry (closer spacing or higher mounting height).
❻ Mercury content in each lamp measured in milligrams.
❼ Lamp life in hours (typical burning hours for all night streetlights are 4,000 per annum)
❽ Based on Western Power tariff Z18 ($1.1676/kW per day).
❾ Twin arc tube versions of the 70 and 50 W high pressure sodium lamps are available. These lamps have twice the life of standard lamps, that is 40 000 hours instead of 20 000 hours. These lamps offer better economy through their long life, but give yellow light that is subject to a de-rating of 75%.

The data in Table 2 is derived from lamp manufacturers represented in Australia [3].

Sample calculations for CO_2 emissions are given in Appendix C.

Where non-compliance is shown against "Category", the non-compliance is due to the minimum illuminance level of AS/NZS 1158.3.1 not being achieved. With this standard geometry 80 W mercury vapour, 42 W compact fluorescent, and 50 W high pressure sodium lamps are non-compliant, but would be compliant at spacings shorter than 80 m.

While mercury vapour lamps have proved reliable for street lighting over 70 years, it is suggested that the future lies with a combination of fluorescent, metal halide, and high pressure sodium lamps that have higher energy efficiencies.

The efficacy of mercury vapour lamps is low, between 40 and 50 lumens watt. The efficacy of fluorescent and metal halide lamps is between 80 and 100 lumens/watt.

The 42 W compact fluorescent lamp will not achieve compliance with AS/NZS 1158 with the standard geometry of 80 m spacing, 7.5 m mounting height, and 20 m road reserve. However it will give performance similar to the common 80 W mercury vapour lamp while consuming half the energy.

Two 24 W T5 fluorescent lamps can achieve compliance with AS/NZS 1158 Category P5 with an energy reduction of 37.5% compared with the non-compliant 80 W mercury vapour lamp. The 70 W metal halide and 70 W high pressure sodium lamps can achieve compliance with AS/NZS 1158 Category P4 with an energy reduction of 14% compared with the non-compliant 80 W mercury vapour lamp.

The efficacy of high pressure sodium lamps is between 90 and 120 lumens/watt in the photopic (day light) range of vision and between 50 and 70 lumens/watt in the scotopic (night) range of vision. For street lighting the range of vision lies between the photopic (daylight) and scotopic (night). High pressure sodium lamps have the highest efficacy when used for street lighting at high illuminance levels, that is, towards the photopic range, and lower efficacy at low illuminance levels.

Mercury vapour lamps have about half the efficacy of the fluorescent, metal halide and high pressure sodium lamps.

Table 3 shown below compares the annual running costs of specific lamps relative to their light output.

Table 3

Lamp type ❶	**80 W MV**	**42 W CFL**	**2 x 24 W T5 FL**	**70 W MH**	**50 W HPS**	**70 W HPS**	**57 W CFL**
Lamp Life ❷ (years)	4	5	5	2.5	5	5	2.5
Lamp cost ❸ ($)	2.95	6.99	12.50	33.00	15.00	14.50	24.60
Labour cost ❹ ($)	32.50	32.50	32.50	32.50	32.50	32.50	32.50
Plant cost ❺ ($)	42.50	42.50	42.50	42.50	42.50	42.50	42.50
Cost per re-lamp❻ ($)	77.95	81.99	87.50	108.00	90.00	89.50	99.60
Re-lamp cost pa ❼ ($)	19.49	16.40	17.50	43.20	18.00	17.90	39.84
Power ❽ (W)	89.5	46.0	50.0	77.0	55.0	77.0	63.0
Energy Cost ❾ p.a.	38.14	19.60	21.30	32.81	23.44	32.81	26.50
Running cost ❿ p.a. ($)	57.63	36.00	38.80	76.01	41.44	50.71	66.34
Light output lumens	3600	3200	3500	4900	4400	6500	4300
Running cost per kilo-lumen ($) p.a.	**16.00**	**11.25**	**11.09**	**15.51**	**9.42**	**7.80**	**15.43**

NOTES

❶ MV = mercury vapour, CFL = compact fluorescent, FL = fluorescent, MH = metal halide HPS = high pressure sodium
❷ Lamp life in hours divided by 4,000 hours per annum.
❸ Lamp cost based on lamp manufacturers' information
❹ Labour cost based on ½ hour re-lamp time @$65/hour (electrician/linesman)
❺ Plant cost based on ½ hour re-lamp time @$85/hour (plant and operator)
❻ Sum of lamp cost, labour cost, and plant cost
❼ Cost per re-lamp divided by lamp life in years
❽ Power per lamp measured in Watts
❾ Based on Western Power tariff Z18 ($1.1676/kW per day).
❿ Sum of re-lamp cost pa and energy cost pa.

Table 3 assumes that the existing street light luminaires need to be replaced and that the cost of replacement luminaires will be the same regardless of the selected technology. This assumption is based on most existing street lights being due for replacement as they would have exceeded their expected life. Prior to 2005, Australian Standards specified a life of 15 years for street light luminaires. AS/NZS 1158 – 2005 now specifies 20 years.

The running cost per kilo-lumen p.a. for the 80 W mercury vapour lamp is calculated as follows:

Re-lamp cost p.a. =	($2.95 + $32.50 + $42.50) ÷ 4 years	= $19.49
Energy cost p.a	(89.5 W ÷1000 x $1.1676/day x 365	= $38.14
TOTAL COST p.a.		= $57.63
TOTAL COST PER kilo-lumen p.a. =	$57.63 ÷ 3.6 kilo-lumens	= $16.00

6.11 COMPARISON OF PRACTICES

6.11.1 ENGLAND

In England low pressure sodium lamps have historically been preferred for both minor and major roads. This lamp was originally selected because of its high efficacy (up to 200 lumens/watt).

The lamp produces yellow monochromatic light that does not support colour vision. These lamps are being replaced by high pressure sodium lamps on major and minor roads for their superior colour characteristics.

Where there is a perceived security risk or where security cameras are in use, white light sources, such as metal halide, or compact fluorescent lamps, are favoured.

In discussion with lighting engineers from Surrey and Hampshire [4], a preference for 57 W compact fluorescent lamps was expressed. Trials had been undertaken with this lamp, high pressure sodium, and 35 W metal halide. The perception from this trial was that the 35 W metal halide lamp with its small envelope was very glary compared with the 57 W compact fluorescent lamp with its larger envelope and thus lower lamp brightness.

Mercury vapour lamps are not used for street lighting in England because of their poor efficiency.

6.11.2 NORTH AMERICA

In North America, mercury vapour lighting has been used for minor roads and high pressure sodium lighting for major roads. There is a tendency towards metal halide for its white light and high efficacy both for upgrading minor and major roads. The City of New York selected metal halide lighting for 40th Street to provide "white light" [5].

6.11.3 SOUTH AFRICA

In South Africa, a mixture of mercury vapour and high pressure sodium lamps is used for minor road lighting. Generally, mercury vapour lamps are being replaced with high pressure sodium lamps.

The lowest output lamp used is the 125 W mercury vapour. These are being replaced with 70 W high pressure sodium lamps.

With major roads, historically a mixture of high pressure sodium, low pressure sodium and mercury vapour has been used. Mercury vapour and low pressure sodium lamps are being replaced with high pressure sodium.

The national standard is NRS 10098 Part1: The lighting of public thoroughfares and Part 2: The lighting of certain specific areas of streets and highways. The City of Cape Town insists that the national standard is applied to all new street lighting. [6]

6.11.4 NEW ZEALAND

In New Zealand, high pressure sodium streetlights are preferred for major and minor roads.

6.11.5 AUSTRALIA

In Australia mercury vapour lamps have been preferred for minor road lighting. Some fluorescent lighting has also been used, particularly around the Sydney metropolitan area. More recently there have been a number of initiatives to change lamp technologies to achieve better energy efficiency.

In Western Australia there has been a number of energy efficiency driven street lighting initiatives in Midvale, Mosman Park, Subiaco and Joondalup.

In **Midvale**, 70 W metal halide streetlights have replaced 80 W mercury vapour streetlights. These streetlights are mounted on timber power poles at a spacing of 80 m. Not only has energy consumption been reduced by 14% but the lighting levels increased from substandard to AS/NZS1158.3.1 Category P4 thus enhancing security for the community.

In **Mosman Park** a combination of compact fluorescent, metal halide and high pressure sodium streetlights have replaced 80 W mercury vapour streetlights. These streetlights have been installed on steel poles as part of an Underground Power Program. The new lighting complies with AS/NZS 1158 whereas the previous lighting was substandard.

In **Subiaco**, 42 W compact fluorescent streetlights on 3.5 m and 4.5 m steel poles have replaced 80 W mercury vapour streetlights on overhead power poles. This has either been part of City installations or of an Underground Power Program. The new lighting complies with AS/NZS 1158.3.1 Category P4 whereas the previous lighting was substandard.

In **Joondalup** City Centre, the City of Joondalup proposes replacing the 1980's decorative road lighting with more energy efficient road lighting. The proposal can reduce the energy consumption by 60%. The new lighting will comply with AS/NZS 1158 whereas the old lighting was patchy and substandard.

The following techniques will be used in Joondalup:
- Efficient metal halide lamps
- Effective optical systems
- Low energy loss electronic ballasts
- Bi-level switching reducing lighting levels in the late evening when traffic decreases

Coffs Harbour in New South Wales has replaced all of their mercury vapour lamps with 50 W high pressure sodium lamps [7]. This program was initiated to save energy and thus greenhouse gas emission and was completed in September 2005. Coffs Harbour chose the high pressure sodium lamp as it was established technology and the luminaires could be upgraded to metal halide or compact fluorescent when those technologies were more mature. The luminaires have proven to be reliable and community feedback has been positive.

In **Canberra**, compact fluorescent lamps have been retrofitted to existing incandescent street lights. These lamps are 28 W self ballasted with E27 screw bases. Problems of short life have been experienced. This is being addressed with better specification to obtain lamps of better manufacture. The cold weather in Canberra may be a contributing factor to the short life of these lamps.

Banyule City Council in Victoria is trialling the Pierlite "Greenstreet" luminaire with high efficiency T5 (26 mm diameter) fluorescent lamps [8]. Twin 14 W luminaires have replaced 80 W mercury vapour luminaires on existing power poles spaced 80 m apart. Over two years these luminaires have worked well with a reduction of two thirds of the energy and greenhouse gases and positive community feedback. The luminaires have proven to be robust, reliable and with no insect or water ingress.

In Victoria, **Integral Energy** has installed about 3000 Greenstreet luminaires with success.

The **South Sydney Regional Organisation of Councils** (SSROC), through their service provider Energy Australia, from 2004, stopped installing 2 x 18 W fluorescent streetlights and installed 80W mercury vapour Sylvania Suburban streetlights as an interim measure for two years[9]. On behalf of SSROC, the consultant Next Energy is evaluating two candidate luminaires: the Pierlite 2 x 14 W and 2 x 24 W T5 Greenstreet Mark III luminaire; and the Sylvania 32 W and 42 W compact fluorescent Suburban Eco luminaire. The NSW State Government is intending to contribute $4.2 million from their Energy Saving Fund to SSROC for residential and major road lighting upgrades. From October to December 2006, the major road lighting upgrade should commence as well as pilot trials of minor road lighting to test the candidate luminaires. Large scale replacement is due to start early in 2007.

The **City of Adelaide** is converting all of its street lighting to metal halide. The reasons for this conversion are energy efficiency and the community security provided by the white light of metal halide lamps.

The **Australian Greenhouse Office** engaged Genesis to undertake a study entitled "*Public Lighting in Australia – Energy Efficiency Challenges and Opportunities".* This study required:

- An overview of public lighting in Australia.
- As assessment of the total public lighting stock in Australia.
- Assessments of the state of play in Australia regarding the timing of batch re-lamping.
- A review and assessment of significant public lighting trials in Australia & overseas.
- A range of best practice scenarios for public lighting decision makers.
- A range of robust "scenario calculators".

This report was published late in 2005 and released on 9 February 2006. [10]

The Australian Greenhouse Office is producing a guide towards energy efficient street lighting. This guide will encourage local government to consider alternatives to the 80W mercury lamp.

ICLEI, the International Council for Local Environmental Initiatives, is encouraging energy efficient street lighting through the Cities for Climate Protection program.

ICLEI ran a forum in May 2005 and in March 2006 covering many sustainability issues including street lighting.

The Cities of Armadale, Bunbury, Cockburn, Gosnells, Nedlands, Perth, the Shire of Serpentine/Jarrahdale, and the City of Subiaco have been participating in these workshops.

MEPS, Minimum Energy Performance Standards, are generally Australian Standards documents that apply to components, such as lamps and lamp control gear, rather than systems. However the MEPS document, "Minimum Energy Performance Standards, Design Energy Limits for Main Road Lighting" covers lighting systems [11]. This document applies only to Category V lighting and lists power limits per metre for different road geometries and different lighting categories.

Table 4 lists two common categories and geometries, where the following power limits are specified:

Table 4

CATEGORY	GEOMETRY	POWER LIMITS (W/m)	
		Mandatory	High Efficiency
AS/NZS 1158 V3	7m, dual carriageway	7.3	5.5
AS/NZS 1158 V5	7m, dual carriageway	6.2	5.5

6.11.6 TRENDS

Internationally there appears to be a general trend away from low pressure sodium (poor colour) and mercury vapour (poor efficacy) lamps towards better colour and higher efficacy lamps.

This trend is outlined below:

ENGLAND	LPS → HPS and some MH and CFL
NORTH AMERICA	MV → MH
SOUTH AFRICA	MV & LPS → HPS
NEW ZEALAND	MV → HPS
AUSTRALIA	MV & HPS → CF/MH/HPS

6.12 LIGHTING STANDARDS

6.12.1 NATIONAL STANDARDS

AS/NZS 1158.3.1-2005 is the current national standard covering lighting of minor roads. Changes from the 1999 edition include:

- Consideration of energy consumption and efficiency.
- Recommendations on de-rating of sodium lamps for Categories P4 and P5.
- Reductions in the maximum Upward Wasted Light Ratio (to reduce light pollution and energy wastage).
- Revisions and clarifications on lighting of local area traffic management devices, curves and intersections, and car parks.

This standard contains 12 Categories of lighting of which 5 Categories, P1 to P5 cover most minor roads and pathways. The other Categories cover town squares, transport terminals, car parks, etc.

Category P5 generally should only be applied to replacement of luminaires on existing power poles. (Refer footnote e) on page 11 of AS 1158.3.1:2005).

This standard is largely performance based and recommends a number of Light Technical Parameters to be achieved. These parameters are average lighting level (lux), minimum lighting level (lux), uniformity, and for higher Categories, vertical lighting level (lux) at face height.

The standard does not specify lighting equipment or energy consumption, but the currently published draft does require an "Energy Audit". This audit is required in general rather than specific terms.

Most lighting of minor roads in Western Australia is below the lowest Category of AS/NZS 1158.3.1. Local Government may be exposed to litigation if they have facilities that do not comply with a national standard even when that standard is not mandatory.

The Inquest dated 1 April 2004 on the death of Leon Russell Coomerang on 28 February 2002 emphasised the contribution of substandard street lighting to the death.

The State Coroner stated:

"I recommend that all Local Government bodies ensure that new roads constructed are adequately illuminated and that the illumination is at least in excess of Australian/New Zealand Standards and that in the case of existing roads regular reviews are conducted to ensure that all relevant standards are met and effective maintenance programs are in place" [12]

6.12.2 INTERNATIONAL STANDARDS

Appendix A contains a summary of the Australian & New Zealand Standard, the British and European Standard, and the North American Standards.

The comparison of Standards in Appendix A shows that South African, European and North American Standards demand higher lighting levels for pedestrian areas than AS/NZS 1158.3.1.

Category P3 of AS/NZS 1158.3.1 corresponds to the lowest Category B3 of SABS 098. AS/NZS 1158.3.1 offers Categories P4 and P5 below this level. The South African standard is thus two steps higher than the Australian Standard.

Category P3 of AS/NZS 1158.3.1 corresponds approximately to the lowest Category S6 of BS/EN 13201 in terms of average illuminance, but the minimum illuminance of Category P3 is half that of BS/EN 13201 category S6. The European standard is thus two steps higher than the Australian Standard.

Category P2 of AS/NZS 1158.3.1 corresponds to the lowest Category of the North American standard for "Residential" street lighting. AS/NZS 1158.3.1 offers Categories P3, P4, and P5 below this Category. The North American Standard is thus three steps higher than the Australian Standard.

AS/NZS 1158.3.1 therefore cannot be viewed as excessive or "gold plated" when compared to the standards of other countries. Australia enjoys a warmer, drier climate than most parts of Europe and North America and night vision is not commonly impeded by snow, hail and fog. This can possibly explain the lower lighting levels of the Australian Standard.

6.12.3 ENERGY EFFICIENCY

As previously mentioned, AS/NZS 1158.3.1:2005 does mention energy auditing, but it treats energy auditing in a qualitative rather than quantitative way. The standard states that the audit is in three parts:

- i) Hardware used (with a view to minimizing the use of capital equipment which itself requires high energy inputs during manufacture).
- ii) Electricity use in the lamp and control gear.
- iii) Energy (electricity and other) used in the maintenance of the system commensurate with ensuring reliability and the efficiency of the scheme.

Appendix E of AS/NZS 1158.3 gives the required documentation if an energy audit is requested.

6.13 OBTRUSIVE LIGHT

Western Power reports they receive as many complaints about obtrusive light as they do about poor lighting. Obtrusive light is spill light that causes annoyance, discomfort, distraction or reduction in the ability to see essential information.

Obtrusive light can affect:

- Residents, **-** Difficulty in sleeping may be experienced due to light entering bedroom windows or due to the direct view of bright light sources.

- Transport System Users, **-** Disability glare reduces the ability to see objects in the environment and reduces the visibility of transport signalling systems. Marine and air navigation are also affected by obtrusive light.

- Astronomical Observation, **-** Sky glow from lighting systems lightens the dark sky and reduces the ability to see the night sky. To the community this is a general loss of amenity but to astronomers this is a particular concern. In the vicinity of observatories there are guidelines that need to be followed to avoid obtrusive light.

Obtrusive light and energy efficient lighting go hand in hand. Obtrusive light is not only a nuisance but also a waste of energy. Raising the standard of street lighting does not necessarily mean "too much light", or obtrusive light. Efficient optical systems direct the light where it is needed and reduce obtrusive light.

AS/NZS 1158 addresses the control of obtrusive light from road lighting in terms of the maximum Upward Waste Light Ratio from roadlighting luminaires.

7 LONG TERM FIELD STUDY

7.1 MEASUREMENTS

Illuminance levels in lux are being recorded in Midvale, Mosman Park and Subiaco in Western Australia in an area that has been re-lit with energy efficient lighting and in a control area lit with existing mercury vapour streetlights. Readings are being taken under each streetlight and directly opposite the streetlight at the edge of the road. Readings are being taken on nights when the moonlight does not interfere with the readings. Readings will be taken regularly over two years commencing at the end of 2004, and being completed at the end of 2006.

The locations of the trial are recorded in Appendix D. The measurements of the trials are recorded in Appendix E.

7.2 ECONOMIC IMPACT

In Western Australia, the cost of street lighting to Local Government is of the order of $20 million per annum. This cost includes an energy component and a maintenance component. In a large Local Government area, the cost of street lighting is about $1 million per annum.

Present indications are that while modern lamps can halve energy consumption and cost, the maintenance cost may increase. The increase in maintenance cost would be due to the shorter life of some of the modern lamps and the higher purchase cost of some modern lamps compared with mercury vapour lamps.

7.3 ENVIRONMENTAL IMPACT

Street lighting is a major component of Local Government energy consumption. The metropolitan area has about 10 000 km of sealed roads and if these are lit with 80 W mercury vapour street lights at 80 m spacing, burning 4,000 hours per annum, the energy consumption is 44,750 kWh (89.5 W (including ballast losses) ÷ 1,000 x 10,000,000 m ÷ 80 m x 4,000 = 44,750 kWh).

Assuming 0.9 of CO_2 per kWh street lighting causes CO_2 emissions amounting to 40 million kg per annum or 40,000 tonnes per annum.

Synergy does not break down their street lighting accounts into energy, maintenance and ownership components. If the common 80W mercury vapour street light is considered, the ZE02 tariff is 23.53 cents per day. The ZE02 tariff includes the cost of energy, maintenance and ownership. However, at the Z18, energy only tariff, the energy cost is 9.34 cents per day. This hypothetical comparison indicates that the energy cost component is 40% of the total cost. If energy could be halved without an increase in maintenance and ownership costs, there is a potential to reduce the total cost of street lighting by 20%.

7.4 RESULTS & RECOMMENDATIONS

7.4.1 MEASUREMENTS

The measurement data sheets are presented in Appendix E.

Three maintenance criteria are stated in the Electricity Supply Association of Australia.

- DEPRECIATION – Light Technical Parameters shall not fall below 70%.
- REPAIR TIME – Luminaire failures should be repaired within 5 days.
- RELIABILITY – No less than 95% of luminaires shall be operational at any time.

Depreciation is defined as the loss of light output over time as lamps age and optical surfaces collect dirt and deteriorate. The field trials address depreciation and reliability.

The average depreciation over the period of the field trials is shown in Table 5 below:

Table 5

SITE	TECHNOLOGY	DEPRECIATION
SUBIACO	Compact Fluorescent	81%
	Mercury Vapour	83%
MIDVALE	Metal Halide	73%
	Mercury Vapour	63%
MOSMAN PARK	Compact Fluorescent	61%
	Metal Halide	77%
	High Pressure Sodium	87%
	Mercury Vapour	88%

The reliability for the period of field trials is shown in Table 6 below:

Table 6

SITE	TECHNOLOGY	RELIABILITY
SUBIACO	Compact Fluorescent	97%
	Mercury Vapour	94%
MIDVALE	Metal Halide	90%
	Mercury Vapour	80%
MOSMAN PARK	Compact Fluorescent	81%
	Metal Halide	96%
	High Pressure Sodium	80%
	Mercury Vapour	75%

A 97% reliability indicates that over the four field trials 3% of the streetlights were not working. The poorest reliability was that of the mercury vapour streetlights in the southern part of Mosman Park where 25% of the streetlights were not working.

The greenhouse gas emissions are indicated in Table 7 below:

Table 7

SITE	TECHNOLOGY	AS/NZS 1158 COMPLIANCE	ENERGY PER km p.a.	GREENHOUSE GAS PER km p.a.
SUBIACO	CFL	P4	1.32 kW	4.8 T *
	MV	**X**	1.12 kW	4 T
MIDVALE	MH	P4	1.0 kW	3.4 T
	MV	**X**	1.12 kW	4 T
MOSMAN PARK	CF	P5	0.57 kW	2.1 T
	MH	P4	1.13 kW	4 T
	HPS	P3	1.37 kW	4.9 T
	MV	**X**	1.12 kW	4 T

* Greenhouse Gas Emissions in Subiaco increased because the previous mercury vapour lighting was well below standard and the new lighting aimed to comply with Australian Standards.
X The lighting does not comply with AS/NZS1158**.**

7.4.2 DISCUSSIONS ON MEASUREMENTS

Depreciation

The depreciation results indicate:

- In Subiaco there are similar rates of depreciation for compact fluorescent and mercury vapour lamps.
- In Midvale there is a higher depreciation rate for mercury than metal halide lamps.
- In Mosman Park there is a higher depreciation rate for compact fluorescent and metal halide lamps when compared with high pressure sodium and mercury vapour lamps. The high pressure sodium & mercury vapour lamps in Mosman Park have similar depreciation rates.

Reliability

The reliability results have to be weighed against the following considerations:

In Subiaco, many compact fluorescent lamps have been replaced as a result of water ingress into the luminaires. The water ingress is a luminaire problem rather than a lamp technology problem.

In Midvale, the City of Swan discontinued their Bulk Globe Replacement (BGR) program with Western Power on 1 July 2005. This was due to a lack of funding rather than any dissatisfaction with the BGR program.

In Mosman Park, there were initial problems with poor quality manufacture of compact fluorescent lamps. This was rectified by sourcing lamps of better quality.

The reliability figures reflect observations at the time of the field trials. Lamps may have had to be replaced in between the times of the field trials.

The poorest reliability in the field trials is that of the mercury vapour street lights in Mosman Park. What is encouraging is that the newer technologies are exhibiting better reliability than mercury vapour. This is surprising as it has been claimed that mercury vapour, despite its poor energy efficiency, has a long reliable life.

In both Midvale and Mosman Park, the reliability of the mercury vapour street lights is so poor, 80% and 75%, as to present a safety and security hazard. With these streetlights normally spaced 80 m apart, there is a blackspot of about 20 m in between. With failed streetlights the spacing could extend to 160 m resulting in a blackspot of 100 m with no lighting.

At this stage, the field trials are indicating that the newer technologies of compact fluorescent, high pressure sodium and metal halide lamps are performing similarly to mercury vapour lamps in terms of depreciation and reliability.

Greenhouse Gas Emissions

In Subiaco the emissions have increased 20% mainly because the lighting has been improved to comply with Category P4 of AS/NZS 1158 which required a significant number of new streetlights whereas the old lighting was below standard spacings of 80 m and more.

In Midvale the emissions have dropped 15% even though the lighting has been improved to Category P4 of AS/NZS 1158. It is noted that there are no additional streetlights.

In Mosman Park, emissions have remained the same where metal halide lighting to Category P4 of AS/NZS 1158 has been installed to replace below standard lighting. Emissions on Local Distributor roads have increased 22% where high pressure sodium lighting has been installed to the higher Category P3 of AS/NZS 1158, replacing previously below standard lighting. Similar to Subiaco, there was also a significant increase in the number of streetlights.

7.4.3 RECOMMENDATIONS

This report submits the following recommendations:

- **Standards**
  WALGA encourage Local Government to adopt AS/NZS 1158 as a policy for technical design of streetlight networks. AS/NZS is appropriate, and should not be considered as excessive. There is a risk to Local Government if they do not comply with a national standard.
- **Efficient light technologies**
  WALGA encourage Western Power and Local Government to use the more efficient lamp technologies in new and replacement street lights.
- **Underground Power Program**
  The Office of Energy encourages energy efficient street lighting for Underground Power Projects, and specifies appropriate AS/NZS 1158 Categories.
- **Synergy/Western Power Invoicing**
  Synergy provides a price breakdown listing maintenance, replacement, energy, and administrative costs to individual Local Government clients.
- **Mercury**
  On overhead power systems, the 80 W mercury street light at 80 m spacing does not comply with AS/NZS 1158. Mercury vapour lamps have half the efficiency of modern lamps. Consequently the use of mercury vapour lamps should be phased out by responsible authorities.
- **Western Power**
  WALGA request Synergy and Western Power to include fluorescent lamps such as compact fluorescent and T 5 fluorescent lamps in their available stock.
- **Energy Efficient Street Lighting Technologies**
  For minor road lighting two technologies are available to Local Government:
  - 42 W compact fluorescent
  - 2 X 24 W T5 fluorescent

Both lamps are mature, not emerging technologies. The compact fluorescent lamp has been available since 1982 and the 42 W version since the early 1990's. T5 fluorescent lamps have been available since the mid 1990's. Both lamp technologies are available in Australian made street lights.
These technologies are equivalent in light output to the common 80 W mercury vapour lamp and offer a halving of energy consumption and greenhouse gas emissions.

8 REFERENCES

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5 New Notions of Night Light, Henri Bérubé, Security Management, December 1994.Toronto

6 Email correspondence with the City of Cape Town Public Lighting Manager & staff, January 2006.

7 Telephone discussions with Rob Fletcher of Coffs Harbour (02 6648 4415) August 2004. CD available entitled "Coffs Harbour City Council Energy Efficient Street Lighting Info".

8 Telephone discussion with lighting manufacturer Pierlite who supplied streetlights to Banyule, 2004, and with Paul Brown (03 9433 3219) ex Banyule environmental officer.

9 An article entitled "Street lighting review", Engineers Australia, October 2002.

10 Public Lighting in Australia – Energy Efficiency Challenges and Opportunities, Australian Government Department of Environment and Heritage, Australian Greenhouse Office Final Report 2005 (prepared by Genesis Automation, Kevin Poulton & Associates, and Deni Greene Consulting Services).

11 Minimum Energy Performance Standards, design Energy Limits for Main Road Lighting, National Appliance and Equipment Energy Efficiency Program, Report No: 2005/18.

12 Inquest of the Western Australian State Coroner on the death of Leon Russell Coomerang on 28 February 2002, 1 April 2004

1 TABLE OF APPENDICES

APPENDIX A

LIGHTING STANDARDS

AS/NZS 1158.3.1: 2005- ROAD LIGHTING- Pedestrian Area Lighting
AS/NZS 1158.1:2005- ROAD LIGHTING- Vehicular Traffic Lighting
BS EN 13201 – Road Lighting
IES North America Recommendations for Road lighting
IES North America Guidelines for Security
Lighting for People, Property and Public Spaces.
South African SABS 098
Comparison of Standards

AS/NZS 1158.3.1:2005 Pedestrian area lighting

Roads & Pathways

Lighting Category❷		P1❸	P2❸	P3	P4	P5	P6	P7	P8
Type Of Road Or Pathway		MIXED VEHICLE & PEDESTRIAN TRAFFIC Pedestrian or cycle orientated pathways, eg footpaths, including along arterial roads, walkway, lanes, park paths, cycle paths (P1 to P4 apply) Collector roads or non-arterial roads which collect and distribute traffic in an area, as well as serving abutting properties Local roads or streets used primarily for access to abutting properties including residential properties. Common area, forecourts of cluster housing					GENERALLY PEDESTRIAN MOVEMENT ONLY • Areas primarily for pedestrian use, e.g. city, town, suburban centres, including outdoor shopping precincts, malls, open arcades, town squares, civic centres MIXED PEDESTRIAN & VEHICLE TRAFFIC • Transport terminals and interchanges, service areas		(similar to P1)
Selection Criteria ❶❸	Activity	n/a	High	Med	Low	Low	Ped only N/A Mixed - High	Med	Low
	Risk of crime	High	Med	Low local roads -	Low	Low	High	Med	Low
	Need to enhance prestige	n/a	High	Med	n/a	n/a	High	Med	n/a
1.1.1.1.1.1 Light Technical Parameters									
Maintained Average Horizontal Illuminance (lux)		7	3.5	1.75	0.85	0.5	21	14	7
Maintained Horizontal; Illuminance (lux)		2	0.7	0.3	0.14	0.07	7	4	2
Maximum Horizontal llluminance Uniformity E_{max}/E_{ave} (U...)		10	10	10	10	10	10	10	10
Maintained Vertical Illuminance ❹ (E_v) lux		2	0.7	0.3❺	n/a	n/a	7	4	2

Connecting Elements and Outdoor Car Parks

Lighting Category	P9	P10	P11a	P11b	P11c	P12
Type Of Road Or Pathway	Steps, ramps, footbridges, pedestrian ways.	Subways, including associated ramps or steps ❻	Parking spaces, aisles and circulation roadways ❼			Parking spaces for people with disabilities ❼
Night time vehicle or pedestrian movements	N/A	N/A	High	Medium	Low	N/A
Night time occupancy			>75%	>25%, <75%	<25%	
Risk of crime			High	Medium	Low	
1.1.1.1.1.2 Light Technical Parameters						
Maintained average horizontal Illuminance (lux) Eh	Same as for highest lighting category applying to adjacent connected areas but, where forming part of a road or pathway, to not less than Category P8	35	14	7	3.5	-
Maintained horizontal; Illuminance (lux)		17.5	3	1.5	0.7	>14 & >Eh
Maximum horizontal Illuminance Uniformity E_{max}/E_{ave} (U_p)		10	10	10	10	-
Maintained vertical Illuminance ❹ (E_v) lux		17.5	3	1.5	-	-

NOTES:

❶The highest level of selection criteria that is deemed appropriate for the road or pathway will determine the applicable lighting category.
❷P3, P4 & P5 apply across the whole road reserve. P1 & P2 apply only to the formed footpath
❸Where there are good vertical reflecting surfaces alongside the pathway, the next lower lighting category may be selected
❹Applies at 1.5m above the surface of the area.
❺The vertical illuminance requirement for Category P3 applies to pathways not local roads
❻Subway walls should have a light colour
❼Luminaires should be located to highlight obstruction and hazards. For indoor car parks refer to AS1680.2.1

AS/NZS 1158.1.1: 2005 - ROAD LIGHTING - Vehicular Traffic Lighting

Lighting Category	V1	V2	V3		V4	V5
1.1.2 APPLICATIONS Note: for all applications the upward waste light ratio should not exceed 6%	Arterial or main roads in central and regional activity centres of capital and major provincial cities, and other areas with major abutting traffic generators	Arterial roads that predominantly carry through traffic from one region to another, forming principal avenues of communication for traffic movements with major abutting traffic generators	Arterial roads that predominantly carry through traffic from one region to another, forming principal avenues of communication for traffic movements	Freeways, motorways and expressways consisting of divided highways for through traffic with no access for traffic between interchanges and with grade separation at all intersections	Sub-arterial or principal roads which connect arterial or main roads to areas of development within a region, or which carry traffic directly from one part of a region to another part.	
1.1.2.1.1.1 Light Technical Parameters						
Minimum Average Luminance L(cd/m^2) (maintained)	1.5	1.0	0.75		0.5	0.35
Min Overall Uniformity U_o	0.33	0.33	0.33		0.33	0.33
Min Longitudinal Uniformity Ul	0.5	0.5	0.5		0.5	0.5
Max Threshold Increment TI(%)	20	20	20		20	20
Min Surround Illuminance ES(%)	50	50	50		50	50
At Intersections - Min Point horizontal Illuminance E_{min}, lux (maintained)	15	10	7.5		5	3.5
Max Illuminance Uniformity E_{max}/E_{min}	8	8	8		8	8
Max Upward Waste Light Ratio %	3	3	3		3	3

Notes on reflectance characteristics:
R1 = light diffuse road (eg concrete)
R2 = diffuse & specular (eg asphalt with artificial brightener in aggregate)
R3 = slightly specular, typical highways and MRWA design standard
R4 = mostly specular, very smooth texture

RECOMMENDATIONS OF BS EN 13201:2003 ROAD LIGHTING

CATEGORY	LIGHT TECHNICAL PARAMETERS	
Conflict areas, shopping streets complex intersections, roundabouts, queuing areas	**Horizontal Illuminance**	
	E (ave) lux	Uniformity min
CE0	50	0.4
CE1	30	0.4
CE2	20	0.4
CE3	15	0.4
CE4	10	0.4
CE5	7.5	0.4
Paths and residential roads:	**Horizontal Illuminance**	
	E (ave) lux	E (min) lux
S1	15	5
S2	10	3
S3	7.5	1.5
S4	5	1
S5	3	0.6
S6	2	0.6
S7	Performance not determined	
Paths and residential roads:	**Hemispherical Illuminance**	
	E hs(ave) lux	Uniformity min
A1	5	0.15
A2	3	0.15
A3	2	0.15
A4	1.5	0.15
A5	1	0.15
A6	Performance not determined	
Pedestrian areas to reduce crime:	**Semi-circular illuminance**	
	E sc, (min) lux	
ES1	10	
ES2	7.5	
ES3	5	
ES4	3	
ES5	2	
ES6	1.5	
ES7	1	
ES8	0.75	
ES9	0.5	

E (ave) = Average illuminance of vehicular and pedestrian surfaces (maintained)
E (min) = Minimum illuminance of vehicular and pedestrian surfaces (maintained)
Esc, (min) = Semi-cylindrical Illuminance (maintained)

IES NORTH AMERICA RECOMMENDATIONS FOR ROAD LIGHTING

ROAD & AREA CLASSIFICATION		Freeway		Expressway			Major			Collector			Local		
		Class A	**Class B**	**Commercial**	**Intermediate**	**Residential**	**Commercial**	**Intermediate**	**Residential**	**Commercial**	**Intermediate**	**Residential**	**Commercial**	**Intermediate**	**Residential**
Average Luminance L_{ave} (cd/m^2)		0.6	0.4	1.0	0.8	0.6	1.2	0.9	0.6	0.8	0.6	0.4	0.6	0.5	0.3
Luminance Uniformity L_{ave}/L_{min}		3.5		3	3	3.5	3	3	3.5	3	3.5	4	6		
Luminance Uniformity L_{max}/L_{min}		6	6	5	5	6	5	5	6	5	6	8	10		
Veiling Luminance Ratio (maximum)❶ L_v/L_{ave}		0.3		0.3			0.3			0.4			0.4		
Average Maintained Illuminance, lux															
Road Surface Classification	❷ R1	6	4	10	8	6	12	9	6	8	6	4	6	5	3
	❸ R2 & R3	9	6	14	12	9	17	13	9	12	9	6	9	7	4
	❹ R4	8	5	13	10	8	15	11	8	10	8	5	8	6	4
Illuminance Uniformity E_{ave}/E_{min}		3		3			3			4			6		

Notes:

❶ L_v = veiling Luminance
❷ R1 = light diffuse road (eg concrete)
❸ R2 = diffuse & specular (eg asphalt with artificial brightener in aggregate), R3 = slightly specular, typical highways
❹ R4 = mostly specular, very smooth texture

IES (NORTH AMERICA) GUIDELINES FOR SECURITY LIGHTING FOR PEOPLE, PROPERTY AND PUBLIC SPACES

		E_h	E_v	U (ave/min)
Unoccupied Spaces (acceptable losses): - storage yards, industrial equipment areas and container terminals		5-20	-	8
Unoccupied Spaces (unacceptable losses): - storage yards, industrial equipment areas and container terminals		10-20	-	6
Building Façade		-	5-20	8
Building Interior		10	-	6
Facial Identification		-	5-8	4
Guarded Facilities:	Entrances & gatehouse inspection	100		3
	Guardhouse interior	❷	❶	
A.T.M.'S (Exterior):	Face of ATM	-	150	3
	Within 3.5m	100	-	-
	3.5 to 15.2m	20	❶	3
	Supported Parking 18.5m			
	Side of building out to 12.2m when ATM within 3.5m of corner			
A.T.M.'S (Interior):	Face of ATM	-	150	3
	Preparation of ATM	150	❶	3
	Other areas of enclosure	100	❶	-
Parking Facilities Garages & Covered Parking Spaces	On pavement	60	❶	4
	Gathering points (stairs, elevator, ramps)	50		
Parking Garages for the Elderly	Entrance	500	❶	4
	Exterior walkways around senior facilities			
Parking Lots, Areas for Public Parks	Open parking spaces	30	❶	4
	Park trails and walkway	6		
	Likely loitering areas	10		
Supermarket, Major Retail Parking	Parking lot	30	❶	4
	Low activity – close-in parking	50		
Fast Food Restaurants	General Parking	30	❶	3
	Drive up window out to 9.1m	60		
	Refuse area	30		
Convenience Stores & Gas Stations	Pump Island	60	❶	4
	Sidewalks, refuse areas & grounds	30		
	Interior of store	300		
Single Family Residences	Exterior doorways	-	8	-
Multi-family Residences	Common areas	30	❶	4
	Mail box areas	100		
Senior Housing	Hallways/Room Entrances (Active hours)	300	❶	-
	Hallways/Room Entrances (Sleeping hours)	100		
Schools & Institutions	General Parking	30	❶	4
	Sidewalks & footpaths	10		
Law enforcement, Fire, Ambulance & other Emergency Service Facilities	Within 18.2m of all vehicle and pedestrian movement areas	80	❶	3
	General parking and walkways	30		
Hotel & Motels	General Parking	30	❶	4
	Sidewalk and grounds	10		

❶ Ev 5 to 8 lux or ≥ 25% Eh
❷ Interior illuminance should be minimum recommended for specific task performance.

RECOMMENDED LIGHTING VALUES OF SABS 098 (amdt 1996)

Part 1 STREETS AND FOOTWAYS

Lighting Category	Type of Street	Min. average horizontal illuminance	Min. horizontal illuminance	Min. semi-cylindrical illuminance
B1	Residential streets in high density residential areas and medium to high traffic volume traffic	5	1	2
B2	Residential streets in medium density residential areas and medium volume traffic	3	0.6	1
B3	Residential streets in low density residential areas and low volume traffic	2	0.4	0.6
C1	Wholly pedestrian in city centre	10	3	7.5
C2	Wholly pedestrian in local shopping malls	7.5	1.5	3

Part 2: Roadway Lighting

Lighting Category	Type of Road	Without Median												With Median											
		Max traffic volume during darkness (motor vehicles per hour)																							
		>600				300				100				>900				600				200			
		L_n	U_o	U_l	TI	L_n	U_o	U_l	TI	L_n	U_o	U_l	TI	L_n	U_o	U_l	TI	L_n	U_o	U_l	TI	L_n	U_o	U_l	TI
A1		2	0.4	0.7	15	1.5	0.4	0.7	20	1	0.4	0.6	20	2	0.4	0.7	15	1.5	0.4	0.7	20	1	0.4	0.6	20
A2		1.5	0.4	0.7	20	1	0.4	0.6	20	0.8	0.4	0.5	20	1.5	0.4	0.7	20	1	0.4	0.6	20	0.8	0.4	0.5	20
A3		1	0.4	0.6	20	0.6	0.4	0.5	20	0.5	0.4	0.5	20	1	0.4	0.6	20	0.6	0.4	0.5	20	0.5	0.4	0.5	20
A4		0.75	0.4	0.5	20	0.5	0.4	0.5	20	0.3	0.3	0.5	25	0.75	0.4	0.5	20	0.5	0.4	0.5	20	0.3	0.3	0.5	25

L_n = min Luminance cd/m^2
Uo = Overall luminance uniformity
Ul = Longitudinal luminance uniformity
TI = Threshold Increment %

COMPARISON OF STANDARDS

LIGHTING LEVEL	Australia and New Zealand AS/NZS 1158.3.1			South African SABS 098 Pt 1			Britain and Europe BS/EN 13201			North America IESNA ❶		
	Cat.	Ave Lux	Min Lux	Cat.	Ave Lux	Min Lux	Cat.	Ave Lux	Min Lux	Cat.	Ave lux	Min lux
							S1	15	5			
							S2	10	3			
	P1	7	2	B1	5	1	S3	7.5	1.5	C ❷	9	❸
	P2	3.5	0.7	B2	3	0.6	S4	5	1.0	I ❷	7	❸
	P3	1.75	0.3	B3	2	0.4	S5	3	0.6	R ❷	4	❸
	P4	0.85	0.14				S6	2	0.6			
	P5	0.5	0.07				S7	Not specified				

NOTES

❶ Assumes R2 or R3 reflectance characteristic of road
❷ C = Commercial, I = Intermediate, R = Residential.
❸ Uniformity of 6:1 (average to minimum).

APPENDIX B

COMPARISON OF NATIONAL PRACTICES

COMPARISON OF NATIONAL PRACTICES

COUNTRY	EXISTING TECHNOLOGY	TREND TECHNOLOGY
ENGLAND	LPS	HPS and some MH and CFL
NORTH AMERICA	MV	MH
SOUTH AFRICA	MV & LPS	HPS
NEW ZEALAND	MV	HPS
AUSTRALIA	MV & HPS	CF/MH/HPS

Notes
CF = compact fluorescent
HPS = high pressure sodium
LPS = low pressure sodium
MH = metal halide
MV = mercury vapour

APPENDIX C

GREENHOUSE GAS SAMPLE CALCULATION

GREENHOUSE GAS – SAMPLE CALCULATIONS

Assumptions:

1. 80 W mercury vapour lamp – energy consumption with ballast losses 89.5 W.
2. 80 m street light spacing.
3. Street lights burn 4 000 hours per annum.
4. CO_2 emissions in Western Australia = 0.9 kg/kWh.

Sample calculation for one 80 W lamp (per annum)

CO_2 emission = lamp power (W) ÷ 1000 x burning hours x CO_2 coefficient (kg/kWh)

= 89.5 W ÷ 1000 x 4 000 h x 0.9 kg/kWh = **322 kg**.

Sample calculation for one kilometre of street lighting (80 W @ 80 m) per annum

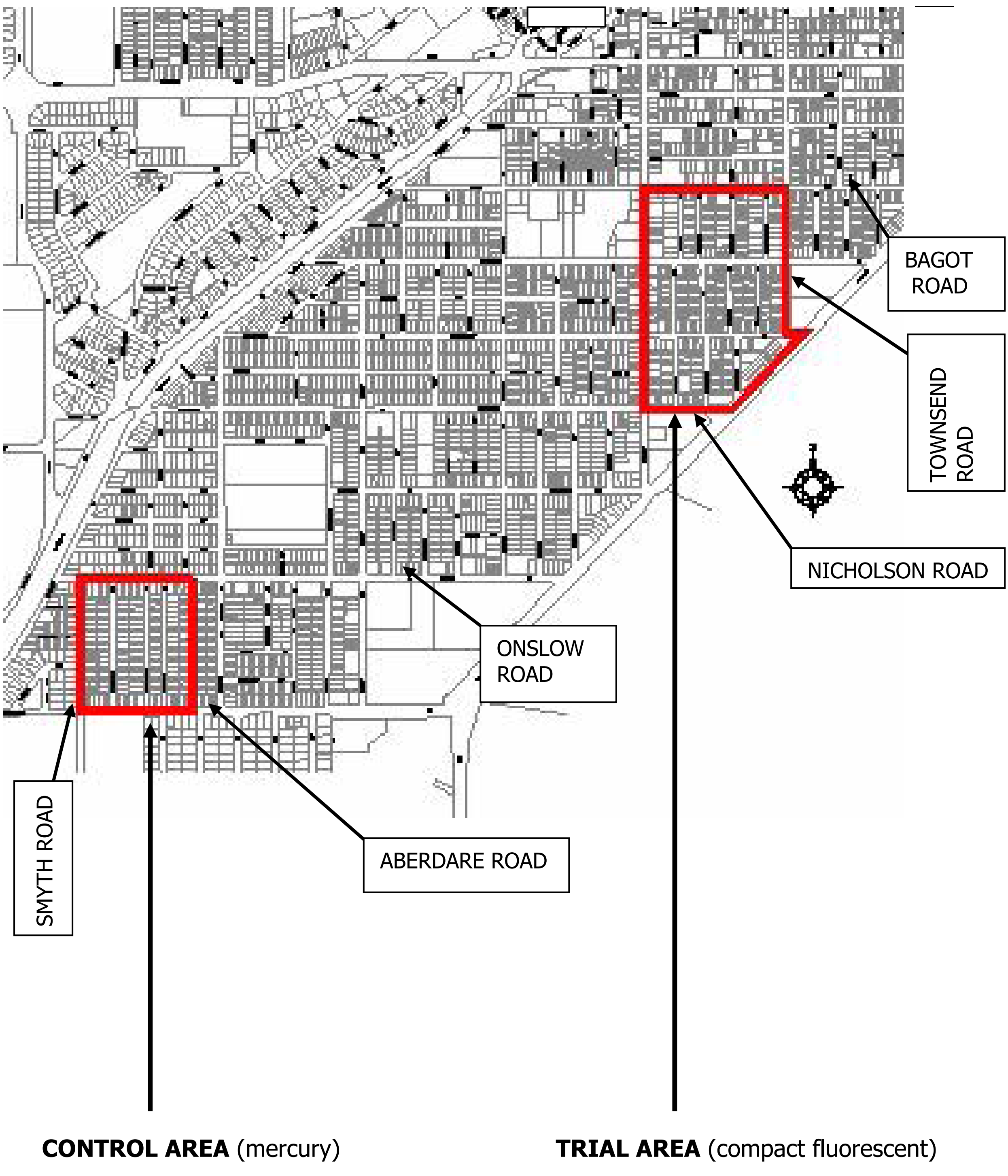
CO_2 emission = lamp power (W) ÷ 1000 ÷ spacing (m) x 1000 x burning hours x CO_2 coefficient (kg/kWh)

= 89.5 W ÷ 1000 ÷ 80 m x 1000 x 4 000 h x 0.9 kg/kWh = **4 027 kg** = **4T**.

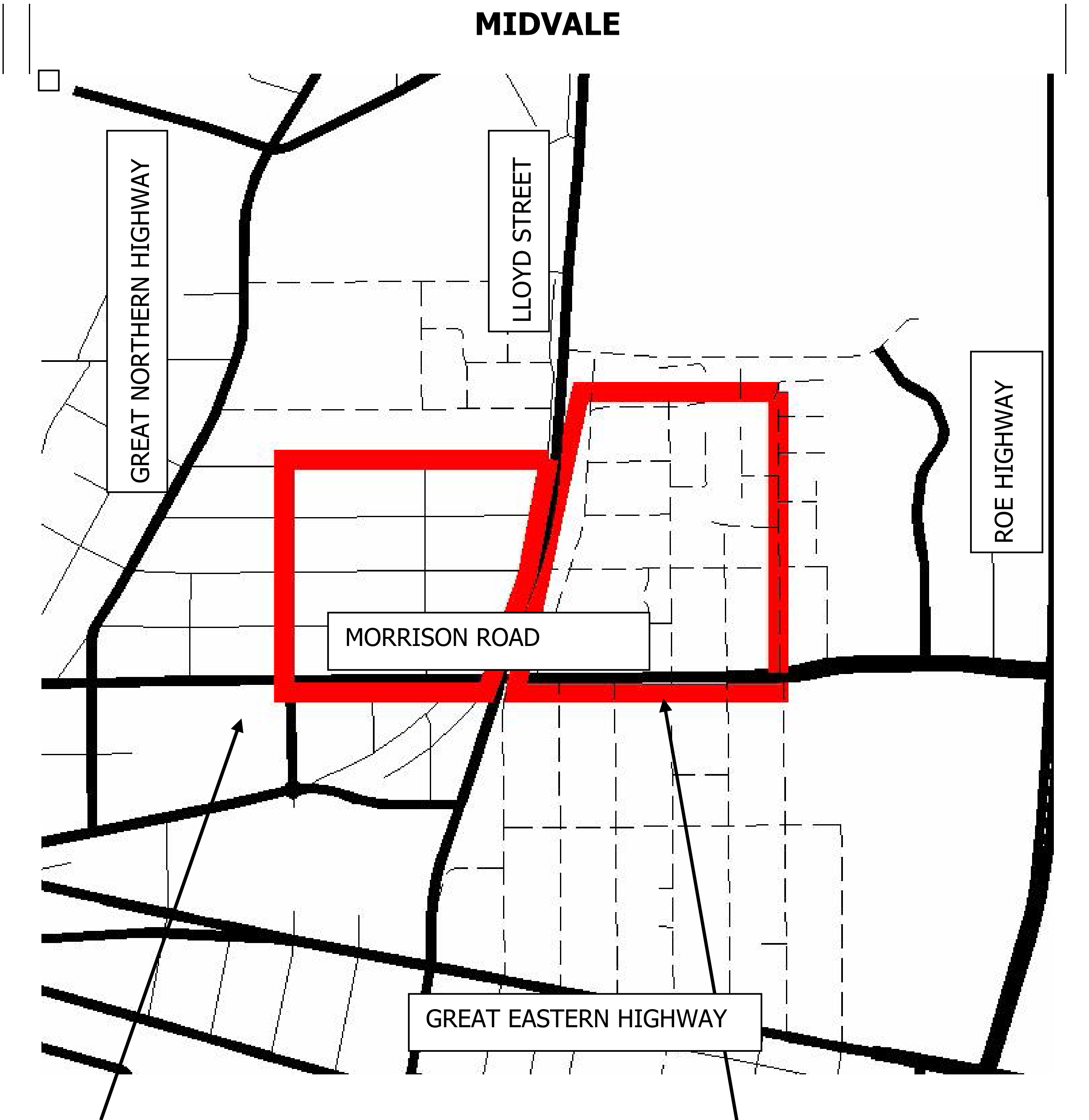
APPENDIX D

LOCATIONS OF FIELD TRIALS

SUBIACO


BAGOT ROAD
TOWNSEND ROAD
NICHOLSON ROAD
ONSLOW ROAD
SMYTH ROAD
ABERDARE ROAD
CONTROL AREA (mercury)
TRIAL AREA (compact fluorescent)

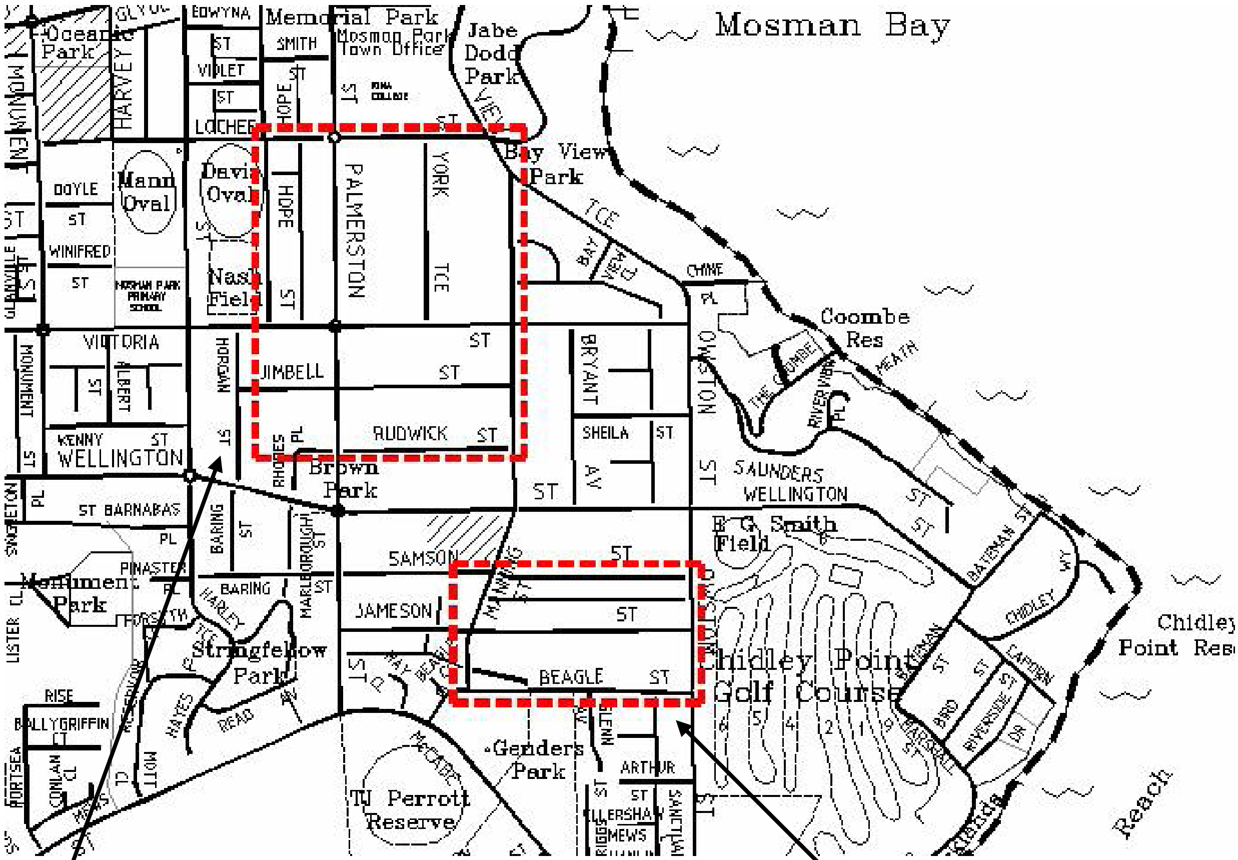
MIDVALE



CONTROL AREA (mercury)

TRIAL AREA (metal halide)

MOSMAN PARK



CONTROL AREA (mercury)

TRIAL AREA (metal halide/high pressure sodium/compact fluorescent)

APPENDIX E

FIELD TRIAL MEASUREMENTS

SUBIACO

LUMINAIRE TYPE	STREET	POLE NUMBER	ILLUMINANCE UNDER STREETLIGHT				ILLUMINANCE ACROSS ROAD				DEPRECIATION
			Trial 1	Trial 2	Trial 3	Trial 4	Trial 1	Trial 2	Trial 3	Trial 4	
CF	Hamersley Road	P1	12.90	13.00	12.00	11.00	0.40	1.00	1.20	1.50	14.73
CF		P2	15.40	13.00	15.00	13.80	0.70	1.00	1.00	1.00	10.39
CF		P3	8.00	8.20	17.00	14.00	0.50	0.64	1.60	3.00	17.65
CF		P4	10.00	9.90	0.00	8.00	0.15	0.34	0.00	0.50	20.00
CF		P5	13.50	15.00	14.00	13.00	0.20	0.50	1.10	0.70	3.70
CF		P6	12.30	12.00	11.00	8.50	0.30	0.49	0.50	0.40	30.89
CF		P7	12.20	12.00	11.00	11.00	0.20	0.60	0.70	1.30	9.84
CF		P8	13.00	13.00	12.00	13.00	0.30	1.00	1.10	1.10	0.00
CF		P9	11.80	10.00	10.00	9.90	0.20	0.36	0.40	0.40	16.10
CF	Heytesbury Road	P1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
CF		P2	12.80	14.00	13.00	13.00	0.20	4.90	0.60	0.45	0.00
CF		P3	13.70	7.00	17.00	13.00	0.60	0.71	2.60	1.40	5.11
CF		P4	15.00	18.00	14.00	14.00	0.20	0.40	0.50	0.50	6.67
CF		P5	10.20	9.50	9.30	8.60	0.20	0.45	0.80	0.50	15.69
CF		P6	6.60	7.10	14.60	12.70	0.30	0.37	1.20	0.90	13.01
CF		P7	12.10	13.00	12.00	0.00	0.15	0.45	0.50	0.00	NA
CF		P8	11.10	13.00	11.00	9.60	0.10	0.55	0.40	0.50	13.51
CF		P9	12.40	13.00	10.00	9.20	0.40	0.70	0.80	0.10	25.81
CF	Rupert Street	P1	17.30	19.00	15.90	13.00	0.40	1.80	2.30	2.10	24.86
CF		P2	10.00	12.00	8.10	7.60	0.30	1.40	1.40	1.10	24.00
CF		P3	11.20	12.00	11.00	11.00	11.20	1.70	1.90	0.90	1.79
CF		P4	10.90	11.00	10.00	11.00	10.90	1.70	2.30	2.00	9.09
CF		P5	12.50	12.00	12.00	19.20	0.30	2.00	2.00	4.00	4.00
CF		P6	13.60	15.00	13.00	12.00	0.50	1.50	0.40	1.20	11.76
CF		P7	10.30	8.90	8.00	3.20	0.40	1.10	1.10	0.80	68.93
CF		P8	7.80	8.70	7.80	6.70	0.20	1.10	1.10	1.20	14.10
CF		P9	7.80	8.70	7.30	7.00	0.30	1.10	1.00	7.00	10.26
CF		P10	5.60	5.80	5.70	5.10	0.20	0.60	0.90	0.90	8.93
CF		P11	13.50	15.00	12.20	12.00	0.75	2.40	1.80	2.20	11.11
CF		P12	12.60	12.00	7.60	11.00	0.40	2.00	2.00	2.00	12.70

CF		P13	9.00	8.40	7.30	6.40	0.40	1.10	1.20	1.20	28.89
CF		P14	8.80	7.90	11.00	11.00	0.30	1.20	2.50	2.10	10.23
CF		P15	8.70	6.50	17.30	10.00	0.20	0.70	1.40	1.01	42.20
CF		P16	11.40	10.10	10.30	9.20	1.10	8.84	1.10	0.70	19.30
CF	Salisbury Street	P1	10.90	14.00	0.00	0.00	0.45	2.40	0.00	0.00	NA
CF		P2	10.40	11.00	9.90	10.00	0.40	2.00	2.10	1.50	3.85
CF		P3	0.40	6.70	7.10	7.00	0.40	1.50	1.80	1.40	1.41
CF		P4	7.60	8.50	7.50	7.70	0.40	1.20	1.60	1.30	9.41
CF		P5	10.60	12.00	2.60	6.60	0.06	1.30	0.10	1.00	37.74
CF		P6	12.50	15.00	14.00	13.00	0.90	1.20	0.70	0.90	13.33
CF		P7	16.10	18.00	16.00	17.00	0.60	1.90	3.10	1.50	5.56
CF		P8	8.50	10.00	8.10	9.10	0.10	0.25	1.10	1.10	9.00
CF		P9	10.50	9.40	8.50	5.00	0.50	1.50	1.70	1.60	52.38
CF		P10	9.00	0.53	5.40	4.90	0.40	0.70	1.00	0.40	45.56
CF		P11	16.70	16.00	14.00	11.20	0.90	2.30	2.80	2.00	32.93
CF		P12	11.60	12.00	11.00	9.70	0.50	1.90	1.60	1.40	16.38
CF		P13	7.80	8.00	7.20	5.60	0.20	1.50	1.40	1.30	28.21
CF		P14	6.10	6.20	6.80	6.30	0.30	1.00	1.30	1.10	7.35
CF		P15	11.50	12.00	10.00	8.00	0.40	2.00	2.10	2.10	30.43
CF		P16	13.20	14.00	13.00	8.50	0.80	2.00	2.20	1.80	35.61
CF	Finlayson Street	P1	5.70	7.10	16.50	6.30	0.20	1.80	3.00	1.80	61.82
CF		P2	9.90	10.00	18.90	6.50	0.30	1.80	1.60	1.70	34.34
CF		P3	8.50	8.90	8.70	7.60	0.30	1.80	1.70	1.50	10.59
CF	Chester Street	P1	10.70	11.00	9.30	8.00	0.40	1.20	1.60	1.70	25.23
CF		P2	10.50	12.00	10.00	6.40	0.50	1.50	2.00	2.00	39.05
CF		P3	12.40	13.00	9.40	17.00	0.60	2.50	1.50	3.10	24.19
CF		P4	9.90	11.00	9.50	8.70	0.60	1.70	2.00	1.90	12.12
CF		P5	9.20	9.70	20.00	17.00	0.40	1.50	3.30	2.60	15.00
CF	Kershaw Street	P1	9.50	10.00	4.70	6.50	0.20	0.30	0.30	0.60	31.58
CF		P2	8.20	8.40	7.70	6.80	0.40	1.30	1.30	0.10	17.07
CF		P3	17.80	19.00	17.00	17.00	0.80	1.80	2.20	1.80	4.49
CF		P4	11.60	13.00	11.00	21.00	0.50	1.00	1.60	3.10	5.17
CF		P5	10.40	11.00	9.20	7.90	0.30	1.30	1.60	1.30	24.04
CF	Robinson Street	P1	13.80	13.00	12.10	11.00	0.70	1.70	2.00	1.10	20.29
CF		P2	11.00	10.00	8.20	4.10	0.60	1.75	1.50	1.50	62.73
CF		P3	8.80	9.20	8.60	7.90	0.30	1.20	2.00	1.70	10.23

CF		P4	12.60	14.00	12.00	12.00	0.50	2.00	2.30	2.40	4.76
CF		P5	8.00	7.70	7.30	6.60	0.40	1.60	1.60	1.50	17.50
CF	Proclamation Street	P1	12.40	12.00	18.80	17.00	0.40	1.50	3.00	2.70	9.57
CF		P2	8.30	11.00	8.10	7.20	0.30	1.10	1.20	1.20	13.25
CF		P3	9.30	10.00	0.00	20.00	0.40	1.20	0.00	2.90	NA
CF		P4	10.80	13.00	22.00	18.00	0.40	1.30	1.30	2.50	18.18
CF		P5	9.20	10.00	9.00	8.30	0.20	1.10	3.70	1.50	9.78
CF	Townsend Road	P1	8.00	8.80	7.80	7.40	0.15	0.25	0.60	0.50	7.50
CF		P2	11.70	13.00	11.00	12.00	0.15	0.17	0.70	0.80	7.69
CF		P3	31.60	19.00	13.00	13.00	19.30	5.60	1.40	0.80	58.86
CF		P4	11.80	12.00	11.00	11.40	0.09	0.32	0.50	0.40	3.39
CF		P5	10.40	9.60	15.00	13.10	0.14	3.80	0.70	0.70	12.67
CF		P6	0.00	0.00	7.30	5.50	0.00	0.00	0.70	0.25	NA
CF		P7	8.50	7.00	7.30	7.30	0.15	0.33	0.70	0.70	14.12
CF		P8	8.60	8.20	7.00	6.60	0.15	0.45	0.40	0.52	23.26
CF		P9	12.10	13.00	12.00	11.40	0.20	4.50	0.50	0.38	5.79
									AVERAGE DEPRECIATION		81.32
	PERCENTAGE SURVIVAL		97.60	97.60	96.30	96.30					
				AVERAGE SURVIVAL		96.95					
MV	Smyth Road	P1	0.13	0.74	2.70	0.40	0.13	0.72	1.00	3.50	85.19
MV		P2	2.80	3.80	5.90	2.70	0.35	1.10	1.80	1.60	3.57
MV		P3	4.00	4.30	11.00	12.00	0.15	0.91	2.50	2.50	NA
MV		P4	3.40	3.70	12.00	10.00	0.15	0.74	2.90	2.10	16.67
MV		P5	5.00	5.10	11.00	7.00	0.30	1.00	2.20	2.20	36.36
MV		P6	3.50	3.80	7.40	14.00	0.40	0.90	2.00	0.30	NA
MV		P7	4.90	0.00	14.00	37.00	0.40	0.00	2.30	18.00	NA
MV	Hopetoun Terrace	P1	1.70	0.11	4.90	2.90	0.20	0.59	1.50	2.10	40.82
MV		P2	0.70	0.94	6.30	7.00	0.03	0.25	1.80	2.50	NA
MV		P3	0.15	0.12	1.00	0.80	0.13	0.19	1.80	0.80	20.00
MV	Commercial Street	P1	1.50	1.50	0.00	6.10	0.20	0.49	0.00	1.20	NA
MV		P2	6.10	6.30	10.00	11.00	0.13	0.92	1.40	1.60	NA
MV		P3	5.40	5.20	6.80	7.20	0.16	1.00	1.30	1.90	3.70
MV		P4	5.80	6.10	7.60	7.80	0.40	1.10	1.70	1.70	NA
MV		P5	8.70	9.90	10.00	10.00	1.00	2.10	2.20	2.40	0.00

MV	Murchison Street	P1	1.70	4.90	1.40	1.80	1.40	1.20	1.90	0.30	63.27
MV		P2	4.50	4.50	8.70	8.50	1.40	1.30	1.90	2.60	2.30
MV		P3	4.80	5.40	8.10	7.60	1.10	1.60	2.70	2.20	6.17
MV		P4	7.00	7.00	9.00	8.10	1.80	2.00	2.70	2.40	10.00
MV		P5	4.50	4.90	7.90	7.80	1.80	1.70	3.00	2.70	1.27
MV		P6	5.80	6.10	9.20	8.60	1.80	1.40	2.40	2.60	6.52
MV		P7	6.70	8.10	8.80	8.30	2.00	1.80	1.80	1.90	5.68
MV		P8	6.60	6.60	0.00	0.00	2.30	2.30	0.00	0.00	NA
MV	Yilgarn Street	P1	7.90	7.80	0.00	13.00	1.00	2.10	0.00	3.60	NA
MV		P2	6.00	5.70	5.70	5.80	1.20	2.00	1.90	2.40	3.33
MV		P3	6.00	6.30	6.00	7.30	1.00	1.70	1.90	2.40	4.76
MV		P4	6.20	1.40	0.00	0.40	0.65	0.12	0.00	1.80	NA
MV		P5	5.90	6.10	0.00	8.80	0.80	1.80	0.00	3.20	NA
MV		P6	5.50	5.50	8.60	9.10	0.80	1.40	2.40	2.60	0.00
									AVERAGE DEPRECIATION		82.80
	PERCENTAGE SURVIVAL		100.00	96.6	82.80	96.6					
				AVERAGE SURVIVAL		94.00					

MIDVALE

LUMINAIRE TYPE	STREET	POLE NUMBER	ILLUMINANCE UNDER STREETLIGHT				ILLUMINANCE ACROSS ROAD				DEPRECIATION
			Trial 1	Trial 2	Trial 3	Trial 4	Trial 1	Trial 2	Trial 3	Trial 4	
MV	Hamersley street	P1	13.00	11.60	8.50	0.00	2.36	2.31	1.80	0.00	NA
MV		P2	5.72	4.96	3.90	3.50	1.25	1.28	0.80	0.80	38.81
MV		P3	9.85	9.58	7.40	7.00	2.10	2.20	1.70	1.60	28.93
MV		P4	11.45	10.24	16.80	15.30	2.87	3.02	3.50	3.40	10.57
MV		P5	8.64	0.00	0.00	0.00	3.25	0.00	0.00	0.00	NA
MV		P6	4.15	3.24	1.70	1.40	1.14	0.92	0.50	0.40	66.27
MV	North Street	P1	5.34	0.00	0.00	0.00	0.97	0.00	0.00	0.00	NA
MV		P2	6.63	6.23	5.00	4.80	2.40	2.01	1.60	1.20	27.60
MV		P3	8.40	8.05	1.00	6.10	2.62	2.55	1.70	1.60	27.38
MV		P4	5.18	4.72	4.00	3.30	1.50	1.52	1.00	0.80	36.29
MV		P5	8.68	7.41	6.80	6.80	2.00	1.75	1.50	1.40	21.66
MV		P6	7.50	7.52	6.10	6.40	1.53	1.63	1.30	1.30	14.67
MV		P7	0.11	2.21	4.20	5.50	1.19	0.20	1.40	1.60	NA
MV		P8	0.00	0.00	7.50	7.40	0.00	0.00	1.60	1.20	NA
MV		P9	4.05	0.00	12.60	11.50	0.91	0.00	3.60	2.00	NA
MV	Charles Street (west)	P1	5.62	4.63	3.50	3.60	1.57	1.36	1.00	1.10	35.94
MV		P2	4.59	3.91	2.70	2.70	1.25	1.24	0.80	0.80	41.18
MV		P3	8.30	0.00	0.00	0.00	2.13	0.00	0.00	0.00	NA
MV		P4	8.84	8.04	6.50	5.80	2.58	2.31	1.90	1.20	34.39
MV		P5	4.71	4.22	2.70	2.50	1.45	1.19	0.80	0.80	46.92
MV		P6	3.40	2.88	1.00	0.90	3.40	0.90	0.30	0.90	73.53
MV		P7	6.12	0.00	8.40	8.80	1.62	0.00	1.70	1.90	NA
MV		P8	5.23	0.00	8.30	8.90	1.55	0.00	2.40	2.40	NA
MV		P9	0.70	2.40	1.00	0.50	0.86	0.86	0.50	0.50	28.57
MV	Gartell Street	P1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
MV		P2	5.18	5.25	2.90	3.30	0.90	1.16	0.60	0.50	36.29
MV		P3	5.85	5.37	0.00	0.00	0.79	0.84	0.00	0.00	NA
MV	George Street	P1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
MV		P2	9.35	0.00	7.30	6.10	2.02	0.00	1.60	1.40	34.76
MV		P3	3.93	3.29	1.90	1.30	0.96	0.95	0.60	0.40	66.92

MV		P4	0.00	3.93	7.00	6.00	0.00	1.92	1.70	1.40	NA
MV		P5	8.39	7.56	6.60	6.40	1.84	1.70	1.70	1.40	23.72
MV		P6	5.34	5.25	3.80	3.00	1.49	1.55	1.00	0.80	43.82
									AVERAGE DEPRECIATION		63.09
	PERCENTAGE SURVIVAL		87.9	69.7	81.8	81.8					
				AVERAGE SURVIVAL		80.3					
MH	Charles Street (east)	P1	3.11	2.10	1.70	1.00	0.86	0.60	0.50	0.30	67.85
MH		P2	10.11	9.90	12.00	10.40	1.43	1.50	1.60	1.40	2.08
MH		P3	3.05	2.80	2.30	1.90	0.92	0.88	0.80	0.60	37.70
MH		P4	5.95	12.00	10.50	9.60	1.25	2.50	1.90	1.90	20.00
MH		P5	0.62	3.50	2.80	2.60	1.20	1.10	0.70	0.80	25.71
MH		P6	4.60	3.90	3.00	2.60	1.05	1.10	1.00	0.80	43.48
MH		P7	2.92	2.30	3.60	3.50	0.44	0.47	0.60	0.70	21.23
MH	Wroxton Street	P1	16.92	15.00	13.00	15.00	1.62	1.50	0.93	2.70	11.35
MH		P2	5.12	12.00	10.10	10.40	1.87	2.90	2.10	2.10	13.33
MH		P3	6.05	4.70	3.70	3.40	1.48	1.20	0.91	0.70	43.80
MH		P4	5.17	4.50	3.70	0.00	1.60	1.20	1.10	0.00	NA
MH		P5	7.85	7.75	12.00	10.50	0.98	1.40	1.10	1.20	1.27
MH		P6	1.29	0.00	7.00	7.80	1.22	0.00	1.80	2.40	NA
MH		P7	5.38	4.80	4.00	2.40	1.69	1.50	1.00	0.60	55.39
MH		P8	6.68	5.50	4.12	0.00	3.17	2.50	2.30	0.00	NA
MH		P9	5.98	0.00	11.60	11.50	1.43	0.00	2.40	2.40	NA
MH		P10	9.07	8.90	7.80	2.50	2.58	2.80	2.20	0.60	72.44
MH	Henry Street	P1	4.56	3.80	0.00	0.00	1.10	1.00	0.00	0.00	NA
MH		P2	8.85	7.80	7.30	6.60	1.74	1.60	1.20	1.10	25.42
MH		P3	6.24	5.70	4.50	0.00	1.45	1.30	1.00	0.00	NA
MH		P4	3.45	2.80	2.30	2.00	0.92	0.86	0.80	0.60	42.03
MH	Ferguson Street	P1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
MH		P2	4.68	9.30	6.40	6.80	1.20	2.60	1.30	1.90	26.88
MH		P3	3.89	3.50	0.00	0.00	1.26	1.20	0.00	0.00	NA
MH		P4	10.05	10.00	9.90	8.80	2.03	2.00	2.00	1.50	12.44
MH		P5	5.28	11.00	6.50	6.70	1.48	3.10	2.00	1.70	39.09
MH		P6	5.91	14.00	11.00	9.30	1.88	3.80	2.60	2.50	33.57
MH		P7	0.00	12.00	5.70	9.50	0.00	2.40	2.30	1.40	NA
MH		P8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA

MH		P9	4.68	10.00	8.90	9.50	1.11	2.40	2.00	2.00	5.00
MH	Wellaton Street	P1	4.94	0.00	8.80	7.90	1.70	0.00	2.50	1.70	NA
MH		P2	3.26	3.90	7.90	2.30	1.59	1.20	1.10	0.60	29.45
MH		P3	10.03	9.60	3.00	7.80	2.45	2.20	2.20	1.80	22.23
MH		P4	5.38	4.70	3.50	3.00	1.29	1.07	0.10	0.80	44.24
MH	Warde Street	P1	6.89	5.60	5.70	4.90	2.52	1.50	4.40	3.50	28.88
MH		P2	5.37	4.70	10.00	9.50	1.26	1.30	1.70	2.00	12.48
MH		P3	8.72	8.10	7.50	0.00	1.73	1.90	1.20	0.00	NA
MH		P4	9.15	9.40	7.20	8.90	1.82	1.90	1.10	1.70	2.73
MH	Eric Street	P1	8.48	8.40	7.50	7.40	2.21	2.40	1.90	1.30	12.74
MH		P2	6.31	5.30	4.30	2.60	1.48	1.30	1.00	0.60	58.80
MH	Roger Street	P1	4.93	4.10	18.00	18.70	1.03	1.10	2.90	2.90	16.84
MH		P2	8.14	11.00	9.80	19.40	1.54	2.10	1.90	2.40	10.91
MH		P3	5.70	0.00	0.00	15.40	1.48	0.00	0.00	3.40	NA
MH		P4	0.00	9.60	7.30	19.10	0.00	1.90	1.30	3.50	NA
MH		P5	5.42	10.00	8.10	8.30	1.25	2.50	1.80	1.80	17.00
MH		P6	7.96	7.70	6.10	6.60	1.51	1.70	1.30	1.50	17.09
MH	Kingston Place	P1	5.98	13.00	9.90	8.50	1.72	4.20	2.80	2.40	34.62
MH		P2	5.66	4.70	4.40	0.00	0.57	0.70	0.60	0.00	NA
MH		P3	5.08	4.40	12.90	10.30	1.75	1.70	9.40	3.20	20.16
MH		P4	6.61	5.80	4.80	5.10	0.25	0.50	0.70	1.00	22.84
MH	Egan Place	P1	6.04	11.10	8.70	2.70	2.10	3.40	2.90	2.60	55.30
MH		P3	10.92	10.15	8.10	8.30	1.43	0.92	1.10	1.10	23.99
MH		P3	0.00	15.00	12.20	11.80	0.00	4.24	2.50	2.20	21.33
MH		P4	9.05	9.40	7.70	7.40	3.74	3.60	3.00	2.70	18.23
MH		P5	8.78	8.10	6.90	7.00	3.04	2.60	2.50	2.30	20.27
MH		P6	6.51	0.00	13.30	11.80	0.43	0.00	0.70	1.60	NA
MH	Ewart Grove	P1	10.38	11.00	9.40	8.90	3.26	2.80	2.90	3.00	14.26
MH		P2	4.22	7.40	5.60	5.20	1.50	2.10	1.80	1.30	29.73
MH		P3	9.53	7.40	12.00	10.30	0.78	1.40	2.00	1.80	22.35
									AVERAGE DEPRECIATION		72.87
	PERCENTAGE SURVIVAL		93.20	88.10	91.50	86.40					
				AVERAGE SURVIVAL		89.80					

MOSMAN PARK

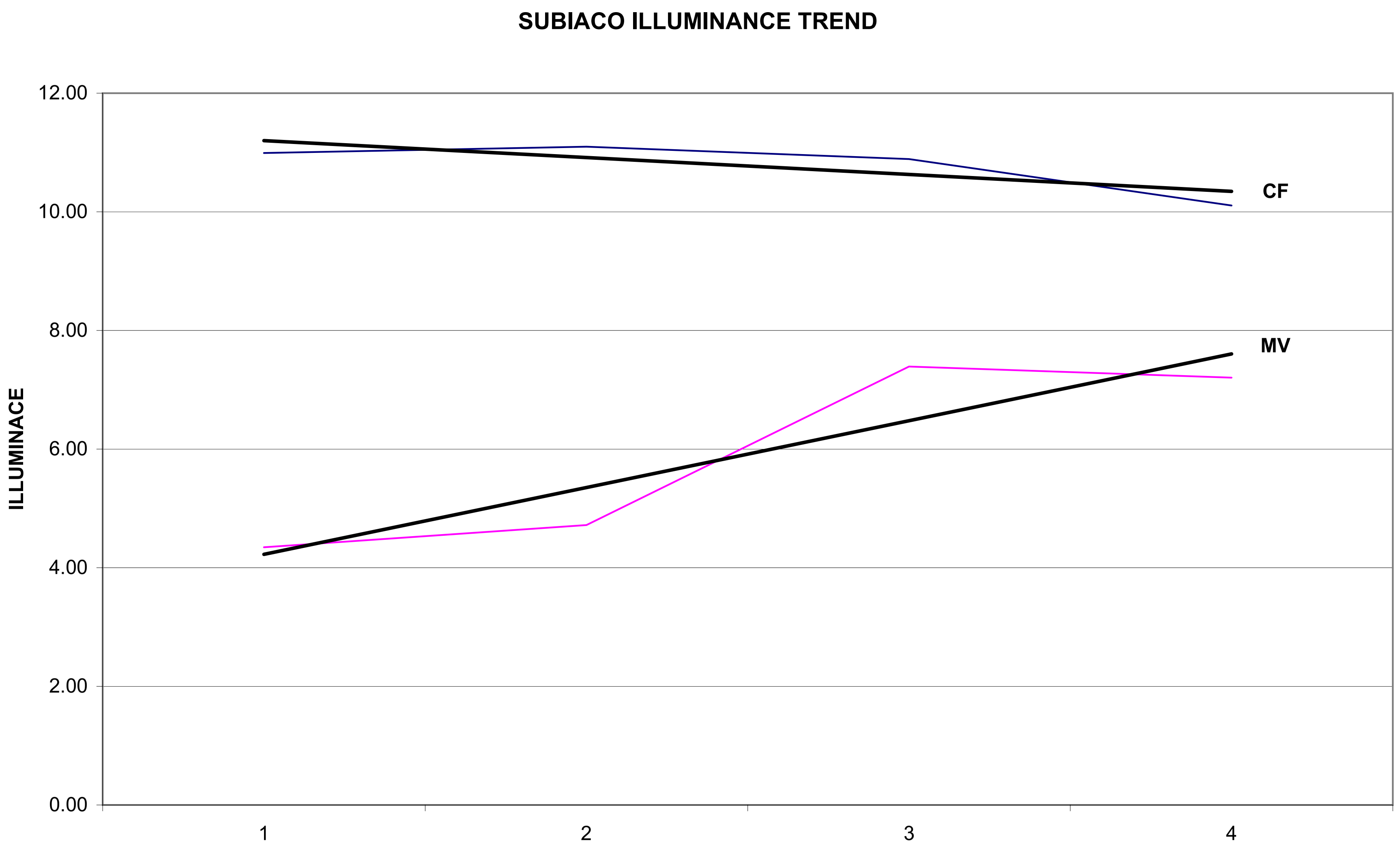
LUMINAIRE TYPE	STREET	POLE NUMBER	ILLUMINANCE UNDER STREETLIGHT				ILLUMINANCE ACROSS ROAD				DEPRECIATION
			Trial 1	Trial 2	Trial 3	Trial 4	Trial 1	Trial 2	Trial 3	Trial 4	
HPS	Glyde Street	P1	20.00	19.10	19.70	22.00	1.00	4.72	5.60	5.90	1.50
HPS		P2	19.00	17.18	20.10	21.00	0.70	4.98	5.40	5.30	9.58
HPS		P3	15.00	13.75	11.70	14.00	0.50	2.50	2.70	2.60	6.67
HPS		P4	19.00	19.50	0.00	0.00	1.40	6.20	0.00	0.00	NA
HPS		P5	22.00	0.00	0.00	0.00	1.20	0.00	0.00	0.00	NA
HPS	Palmerston Street	P7	22.50	20.30	18.50	21.00	1.50	5.68	4.70	6.20	6.67
HPS		P8	24.20	21.60	20.00	0.00	1.50	5.36	2.60	0.00	NA
HPS		P9	22.00	23.30	0.00	0.00	1.00	5.08	0.00	0.00	NA
HPS		P10	20.50	14.70	14.70	14.00	1.30	2.22	4.10	4.30	31.71
HPS		P11	21.20	22.70	18.30	15.00	1.20	5.20	4.50	4.30	29.25
HPS		P12	0.00	20.60	20.40	19.00	1.60	5.67	6.40	5.90	7.77
									AVERAGE DEPRECIATION		86.70
	PERCENTAGE SURVIVAL		90.90	90.90	72.70	63.60					
				AVERAGE SURVIVAL		79.53					
MH	Edwyna Street	P1	20.00	10.40	18.30	19.00	3.80	2.06	10.10	11.00	5.00
MH	Hope Street	P1	22.60	21.60	19.70	19.00	10.00	14.40	13.00	12.00	15.93
MH		P2	18.00	16.80	12.90	13.00	3.50	10.40	7.20	7.60	27.78
MH		P3	19.00	16.55	14.20	12.00	4.00	5.65	5.50	4.60	36.84
MH		P4	19.00	23.30	12.40	20.00	4.00	13.50	2.20	11.00	14.16
MH		P5	23.00	21.20	18.60	20.00	11.30	12.50	9.80	12.00	13.04
MH	Solomon Street	P1	21.50	19.40	18.50	18.00	0.09	5.07	5.40	4.70	16.28
MH		P2	21.00	17.40	16.70	16.00	1.20	3.58	4.00	3.70	23.81
MH		P3	24.00	19.50	18.70	19.00	1.20	5.00	5.70	5.10	20.83
MH		P4	20.00	19.50	17.40	17.00	0.04	2.90	3.00	3.20	15.00
MH		P5	25.10	21.80	20.50	19.00	1.60	5.86	5.60	5.40	24.30
MH	Violet Street	P1	22.20	21.30	8.80	25.00	3.10	10.47	2.20	12.00	60.36
MH	Smith Street	P1	20.50	18.70	16.90	16.00	1.20	5.21	4.50	4.90	21.95
MH	Lochee Street	P4	0.00	0.00	19.40	0.00	0.00	0.00	7.00	0.00	NA

MH		P5	21.00	19.20	18.10	17.40	1.20	5.84	5.70	5.10	17.14
MH		P6	21.20	19.20	18.90	18.10	1.00	3.75	3.90	4.00	14.62
MH		P7	21.00	20.30	18.80	19.00	1.00	5.26	5.10	4.80	9.52
MH		P8	0.10	16.00	14.10	7.00	0.10	5.82	4.40	3.50	56.25
									AVERAGE DEPRECIATION		76.89
	PERCENTAGE SURVIVAL		94.40	94.40	100.00	94.40					
				AVERAGE SURVIVAL		95.80					
CF	Black Lane	P1	6.00	2.66	0.00	5.60	4.40	1.96	0.00	3.80	NA
CF		P2	0.00	4.88	2.60	0.00	0.00	3.32	1.60	0.00	NA
CF	Birchley Lane	P1	6.80	3.25	2.70	3.10	4.70	2.61	1.90	2.10	54.41
CF		P2	5.60	5.00	2.80	3.00	1.90	4.30	2.20	1.10	46.43
CF	Sibbald Lane (South)	P1	4.60	3.60	6.80	6.60	2.40	2.21	3.70	4.10	2.94
CF		P2	6.00	3.35	6.50	6.50	3.20	1.96	3.90	3.80	44.17
CF	Sibbald Lane (north)	P1	4.60	2.49	0.00	0.00	3.40	2.20	0.00	0.00	NA
CF		P2	0.00	0.00	5.30	4.00	0.00	0.00	4.00	2.60	NA
CF		P3	4.30	2.40	3.30	2.20	3.00	1.26	1.20	1.10	48.84
									AVERAGE DEPRECIATION		60.64
	PERCENTAGE SURVIVAL		77.80	88.90	77.80	77.80					
				AVERAGE SURVIVAL		80.58					
MV	Lochee Street	P1	0.00	0.00	7.90	0.00	0.00	0.00	1.30	0.00	NA
MV		P2	0.00	0.00	22.30	0.00	0.00	0.00	7.10	0.00	NA
MV		P3	0.00	0.00	18.90	0.00	0.00	0.00	7.50	0.00	NA
MV	York Terrace	P1	3.60	0.00	4.30	4.30	0.50	0.00	1.30	1.50	0.00
MV		P2	3.60	3.70	3.90	3.70	0.44	1.04	1.40	1.30	5.13
MV		P3	1.70	1.70	2.10	1.70	0.24	0.43	0.90	0.50	0.00
MV		P4	3.50	3.11	3.00	3.40	0.01	1.02	1.10	0.80	2.86
MV	Manning Street	P1	3.70	3.77	2.50	3.70	0.60	0.90	1.00	1.00	0.00
MV		P2	0.80	0.82	1.10	1.00	0.02	0.15	0.20	0.30	9.09
MV		P3	0.60	0.00	1.90	2.50	0.02	0.00	0.20	1.00	NA
MV		P4	3.50	0.00	1.70	1.60	0.01	0.98	0.90	0.90	54.29
MV	Victoria Street	P1	2.40	2.80	2.60	2.60	0.20	0.67	0.80	0.80	7.14
MV		P2	0.02	0.00	0.00	0.00	0.10	0.00	0.00	0.00	NA

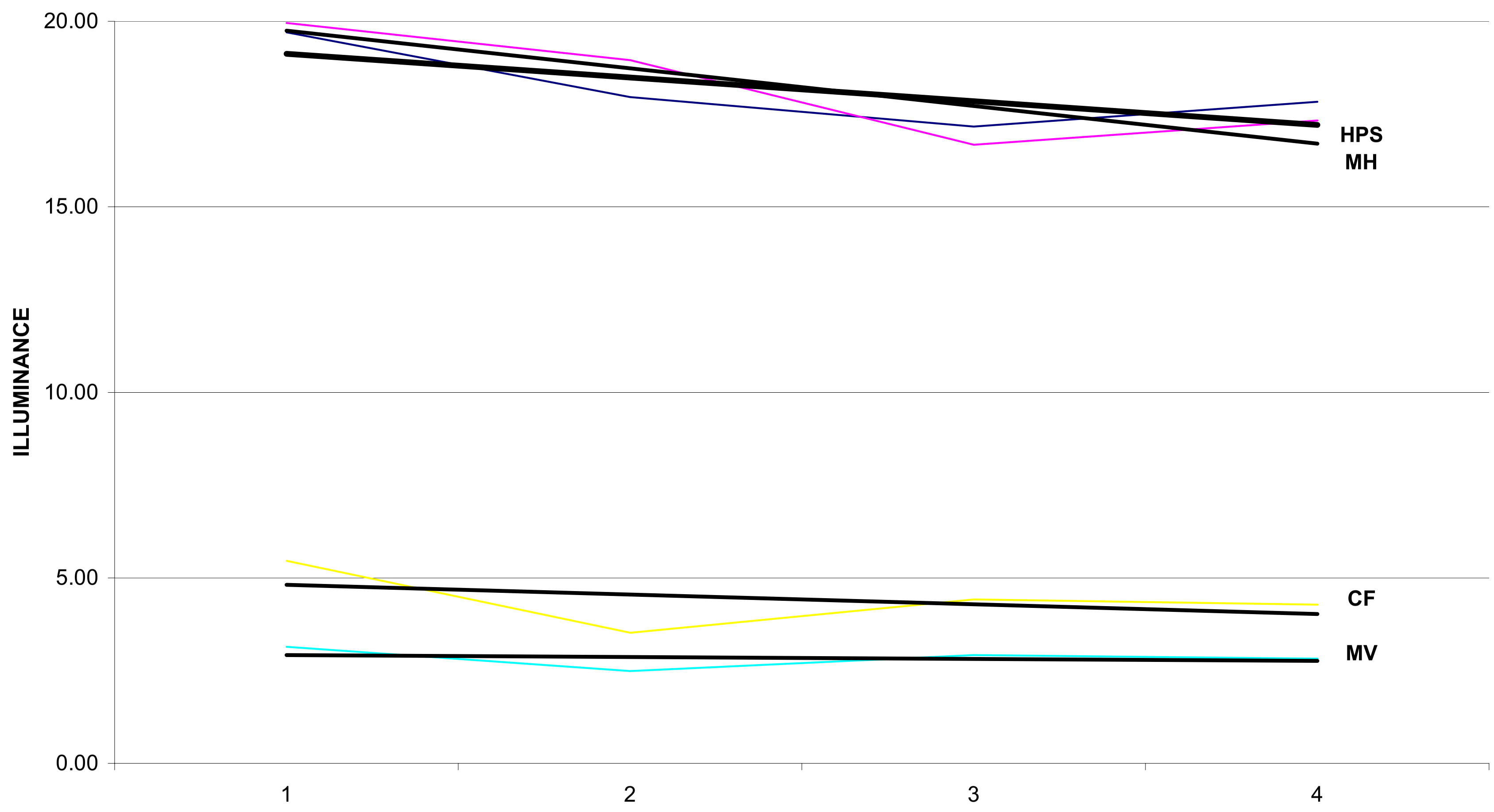
MV		P3	3.20	3.72	2.90	3.00	0.15	0.73	1.00	0.90	6.25
MV		P4	5.60	4.71	5.60	5.40	1.10	1.78	2.10	2.00	3.57
MV		P5	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	NA
MV	Palmerston Street	P1	2.00	1.96	2.00	2.00	0.25	0.90	1.10	1.00	0.00
MV		P2	2.60	2.35	3.00	2.20	0.25	0.90	1.10	1.10	15.38
MV		P3	1.80	1.28	1.50	1.50	0.20	0.63	0.70	0.80	16.67
MV		P4	0.60	0.00	0.00	0.00	0.10	0.00	0.00	0.00	NA
MV		P5	6.00	4.87	4.70	3.40	1.90	4.00	3.50	1.00	43.33
MV		P6	0.00	0.00	18.20	0.00	0.00	0.00	4.10	0.00	NA
									AVERAGE DEPRECIATION		88.31
	PERCENTAGE SURVIVAL		81.80	63.60	86.40	68.20					
				AVERAGE SURVIVAL		75.00					

APPENDIX F

ILLUMINANCE DEPRECIATION GRAPHS


SUBIACO ILLUMINANCE TREND
ILLUMINACE
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1
2
3
4
CF
MV

MOSMAN PK ILLUMINANCE TREND



MIDVALE

LUMINAIRE TYPE	STREET	POLE NUMBER	ILLUMINANCE UNDER STREETLIGHT				ILLUMINANCE ACROSS ROAD				DEPRECIATION
			Trial 1	Trial 2	Trial 3	Trial 4	Trial 1	Trial 2	Trial 3	Trial 4	
MV	Hamersley street	P1	13.00	11.60	8.50	0.00	2.36	2.31	1.80	0.00	NA
MV		P2	5.72	4.96	3.90	3.50	1.25	1.28	0.80	0.80	38.81
MV		P3	9.85	9.58	7.40	7.00	2.10	2.20	1.70	1.60	28.93
MV		P4	11.45	10.24	16.80	15.30	2.87	3.02	3.50	3.40	10.57
MV		P5	8.64	0.00	0.00	0.00	3.25	0.00	0.00	0.00	NA
MV		P6	4.15	3.24	1.70	1.40	1.14	0.92	0.50	0.40	66.27
MV	North Street	P1	5.34	0.00	0.00	0.00	0.97	0.00	0.00	0.00	NA
MV		P2	6.63	6.23	5.00	4.80	2.40	2.01	1.60	1.20	27.60
MV		P3	8.40	8.05	1.00	6.10	2.62	2.55	1.70	1.60	27.38
MV		P4	5.18	4.72	4.00	3.30	1.50	1.52	1.00	0.80	36.29
MV		P5	8.68	7.41	6.80	6.80	2.00	1.75	1.50	1.40	21.66
MV		P6	7.50	7.52	6.10	6.40	1.53	1.63	1.30	1.30	14.67
MV		P7	0.11	2.21	4.20	5.50	1.19	0.20	1.40	1.60	NA
MV		P8	0.00	0.00	7.50	7.40	0.00	0.00	1.60	1.20	NA
MV		P9	4.05	0.00	12.60	11.50	0.91	0.00	3.60	2.00	NA
MV	Charles Street (west)	P1	5.62	4.63	3.50	3.60	1.57	1.36	1.00	1.10	35.94
MV		P2	4.59	3.91	2.70	2.70	1.25	1.24	0.80	0.80	41.18
MV		P3	8.30	0.00	0.00	0.00	2.13	0.00	0.00	0.00	NA
MV		P4	8.84	8.04	6.50	5.80	2.58	2.31	1.90	1.20	34.39
MV		P5	4.71	4.22	2.70	2.50	1.45	1.19	0.80	0.80	46.92
MV		P6	3.40	2.88	1.00	0.90	3.40	0.90	0.30	0.90	73.53
MV		P7	6.12	0.00	8.40	8.80	1.62	0.00	1.70	1.90	NA
MV		P8	5.23	0.00	8.30	8.90	1.55	0.00	2.40	2.40	NA
MV		P9	0.70	2.40	1.00	0.50	0.86	0.86	0.50	0.50	28.57
MV	Gartell Street	P1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
MV		P2	5.18	5.25	2.90	3.30	0.90	1.16	0.60	0.50	36.29
MV		P3	5.85	5.37	0.00	0.00	0.79	0.84	0.00	0.00	NA
MV	George Street	P1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
MV		P2	9.35	0.00	7.30	6.10	2.02	0.00	1.60	1.40	34.76
MV		P3	3.93	3.29	1.90	1.30	0.96	0.95	0.60	0.40	66.92

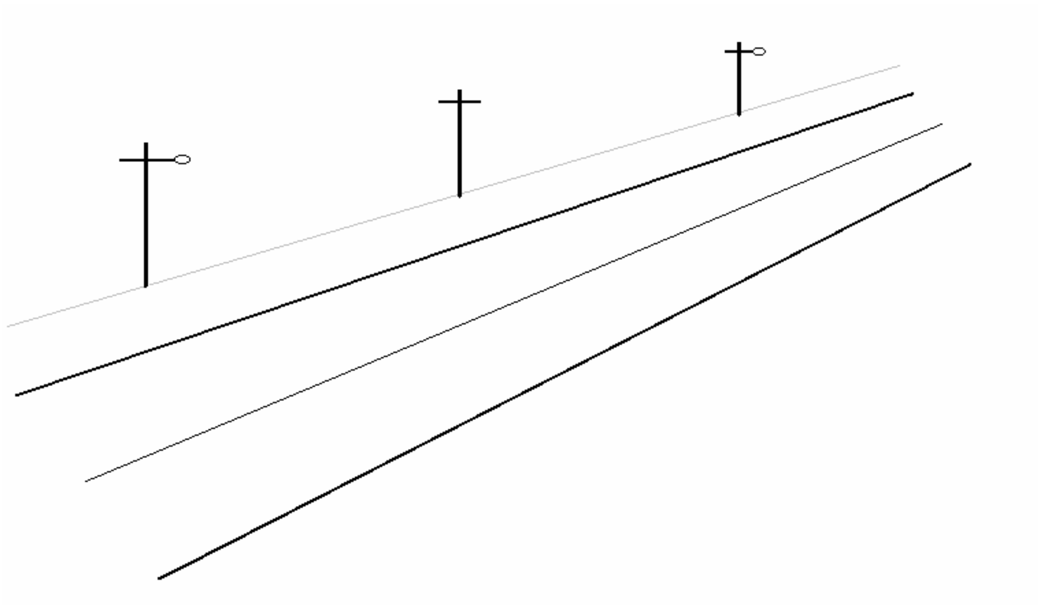
MV		P4	0.00	3.93	7.00	6.00	0.00	1.92	1.70	1.40	NA
MV		P5	8.39	7.56	6.60	6.40	1.84	1.70	1.70	1.40	23.72
MV		P6	5.34	5.25	3.80	3.00	1.49	1.55	1.00	0.80	43.82
									AVERAGE DEPRECIATION		63.09
	PERCENTAGE SURVIVAL		87.9	69.7	81.8	81.8					
				AVERAGE SURVIVAL		80.3					
MH	Charles Street (east)	P1	3.11	2.10	1.70	1.00	0.86	0.60	0.50	0.30	67.85
MH		P2	10.11	9.90	12.00	10.40	1.43	1.50	1.60	1.40	2.08
MH		P3	3.05	2.80	2.30	1.90	0.92	0.88	0.80	0.60	37.70
MH		P4	5.95	12.00	10.50	9.60	1.25	2.50	1.90	1.90	20.00
MH		P5	0.62	3.50	2.80	2.60	1.20	1.10	0.70	0.80	25.71
MH		P6	4.60	3.90	3.00	2.60	1.05	1.10	1.00	0.80	43.48
MH		P7	2.92	2.30	3.60	3.50	0.44	0.47	0.60	0.70	21.23
MH	Wroxton Street	P1	16.92	15.00	13.00	15.00	1.62	1.50	0.93	2.70	11.35
MH		P2	5.12	12.00	10.10	10.40	1.87	2.90	2.10	2.10	13.33
MH		P3	6.05	4.70	3.70	3.40	1.48	1.20	0.91	0.70	43.80
MH		P4	5.17	4.50	3.70	0.00	1.60	1.20	1.10	0.00	NA
MH		P5	7.85	7.75	12.00	10.50	0.98	1.40	1.10	1.20	1.27
MH		P6	1.29	0.00	7.00	7.80	1.22	0.00	1.80	2.40	NA
MH		P7	5.38	4.80	4.00	2.40	1.69	1.50	1.00	0.60	55.39
MH		P8	6.68	5.50	4.12	0.00	3.17	2.50	2.30	0.00	NA
MH		P9	5.98	0.00	11.60	11.50	1.43	0.00	2.40	2.40	NA
MH		P10	9.07	8.90	7.80	2.50	2.58	2.80	2.20	0.60	72.44
MH	Henry Street	P1	4.56	3.80	0.00	0.00	1.10	1.00	0.00	0.00	NA
MH		P2	8.85	7.80	7.30	6.60	1.74	1.60	1.20	1.10	25.42
MH		P3	6.24	5.70	4.50	0.00	1.45	1.30	1.00	0.00	NA
MH		P4	3.45	2.80	2.30	2.00	0.92	0.86	0.80	0.60	42.03
MH	Ferguson Street	P1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
MH		P2	4.68	9.30	6.40	6.80	1.20	2.60	1.30	1.90	26.88
MH		P3	3.89	3.50	0.00	0.00	1.26	1.20	0.00	0.00	NA
MH		P4	10.05	10.00	9.90	8.80	2.03	2.00	2.00	1.50	12.44
MH		P5	5.28	11.00	6.50	6.70	1.48	3.10	2.00	1.70	39.09
MH		P6	5.91	14.00	11.00	9.30	1.88	3.80	2.60	2.50	33.57
MH		P7	0.00	12.00	5.70	9.50	0.00	2.40	2.30	1.40	NA
MH		P8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA

MH		P9	4.68	10.00	8.90	9.50	1.11	2.40	2.00	2.00	5.00
MH	Wellaton Street	P1	4.94	0.00	8.80	7.90	1.70	0.00	2.50	1.70	NA
MH		P2	3.26	3.90	7.90	2.30	1.59	1.20	1.10	0.60	29.45
MH		P3	10.03	9.60	3.00	7.80	2.45	2.20	2.20	1.80	22.23
MH		P4	5.38	4.70	3.50	3.00	1.29	1.07	0.10	0.80	44.24
MH	Warde Street	P1	6.89	5.60	5.70	4.90	2.52	1.50	4.40	3.50	28.88
MH		P2	5.37	4.70	10.00	9.50	1.26	1.30	1.70	2.00	12.48
MH		P3	8.72	8.10	7.50	0.00	1.73	1.90	1.20	0.00	NA
MH		P4	9.15	9.40	7.20	8.90	1.82	1.90	1.10	1.70	2.73
MH	Eric Street	P1	8.48	8.40	7.50	7.40	2.21	2.40	1.90	1.30	12.74
MH		P2	6.31	5.30	4.30	2.60	1.48	1.30	1.00	0.60	58.80
MH	Roger Street	P1	4.93	4.10	18.00	18.70	1.03	1.10	2.90	2.90	16.84
MH		P2	8.14	11.00	9.80	19.40	1.54	2.10	1.90	2.40	10.91
MH		P3	5.70	0.00	0.00	15.40	1.48	0.00	0.00	3.40	NA
MH		P4	0.00	9.60	7.30	19.10	0.00	1.90	1.30	3.50	NA
MH		P5	5.42	10.00	8.10	8.30	1.25	2.50	1.80	1.80	17.00
MH		P6	7.96	7.70	6.10	6.60	1.51	1.70	1.30	1.50	17.09
MH	Kingston Place	P1	5.98	13.00	9.90	8.50	1.72	4.20	2.80	2.40	34.62
MH		P2	5.66	4.70	4.40	0.00	0.57	0.70	0.60	0.00	NA
MH		P3	5.08	4.40	12.90	10.30	1.75	1.70	9.40	3.20	20.16
MH		P4	6.61	5.80	4.80	5.10	0.25	0.50	0.70	1.00	22.84
MH	Egan Place	P1	6.04	11.10	8.70	2.70	2.10	3.40	2.90	2.60	55.30
MH		P3	10.92	10.15	8.10	8.30	1.43	0.92	1.10	1.10	23.99
MH		P3	0.00	15.00	12.20	11.80	0.00	4.24	2.50	2.20	21.33
MH		P4	9.05	9.40	7.70	7.40	3.74	3.60	3.00	2.70	18.23
MH		P5	8.78	8.10	6.90	7.00	3.04	2.60	2.50	2.30	20.27
MH		P6	6.51	0.00	13.30	11.80	0.43	0.00	0.70	1.60	NA
MH	Ewart Grove	P1	10.38	11.00	9.40	8.90	3.26	2.80	2.90	3.00	14.26
MH		P2	4.22	7.40	5.60	5.20	1.50	2.10	1.80	1.30	29.73
MH		P3	9.53	7.40	12.00	10.30	0.78	1.40	2.00	1.80	22.35
									AVERAGE DEPRECIATION		72.87
	PERCENTAGE SURVIVAL		93.20	88.10	91.50	86.40					
				AVERAGE SURVIVAL		89.80					

APPENDIX G

SCENARIOS

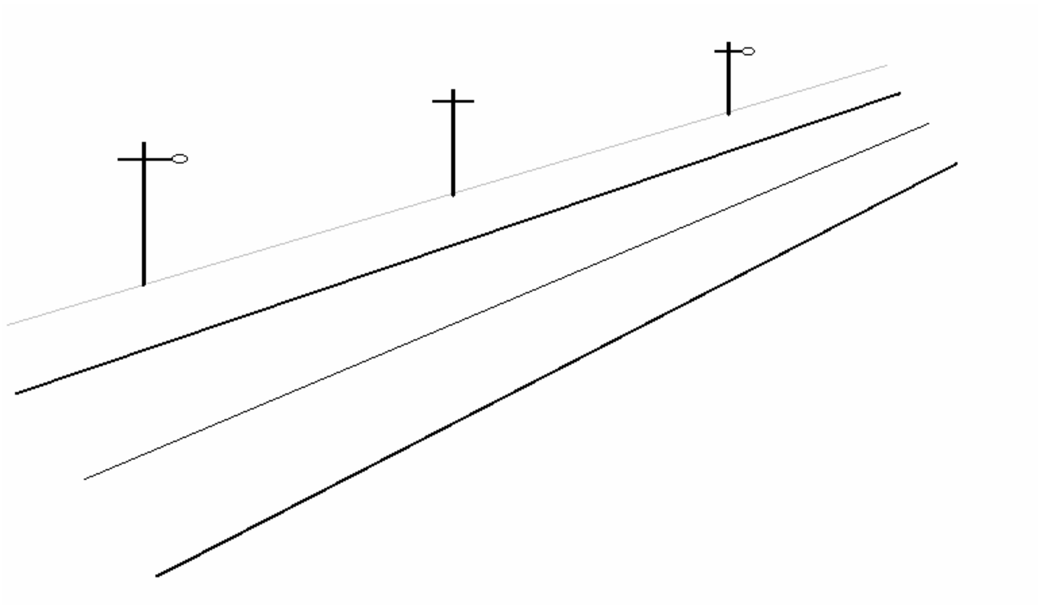
OVERHEAD POWER - 80 W MERCURY AT 80 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		✖
ENERGY ❶	1.12	kW/km
GREENHOUSE GAS ❷	4.0	T/km
LAMP COST ❸	$ 4.50	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$86	
Running cost per kilolumen	$16.00	

NOTES:
❶ Based on circuit power of 89.5 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

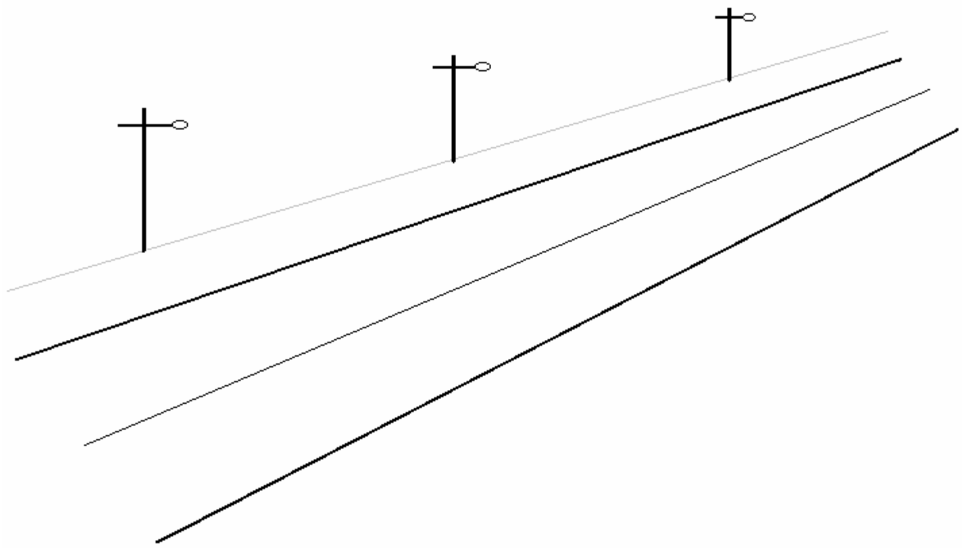
OVERHEAD POWER - 42 W COMPACT FLUORESCENT AT 80 M



KEY PERFORMANCE INDICATORS			
AS/NZS 1158 COMPLIANCE			✖
ENERGY ❶		0.6	kW/km
GREENHOUSE GAS ❷		2.0	T/km
LAMP COST ❸	$	13	
LAMP LIFE ❹		4	years
SYNERGY TARIFF p.a.		N/A	
Running cost per kilolumen		$11.25	

NOTES:
❶ Based on circuit power of 46 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

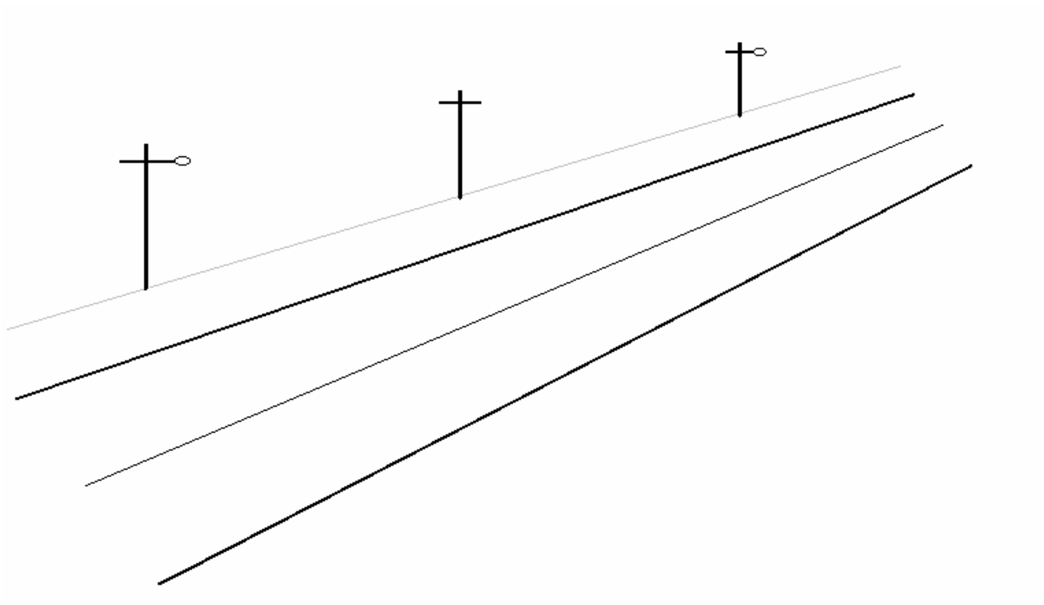
OVERHEAD POWER - 42 W COMPACT FLUORESCENT AT 40 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	1.2	kW/km
GREENHOUSE GAS ❷	4.1	T/km
LAMP COST ❸	$ 13	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	N/A	
Running cost per kilolumen	$11.25	

NOTES:
❶ Based on circuit power of 46 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

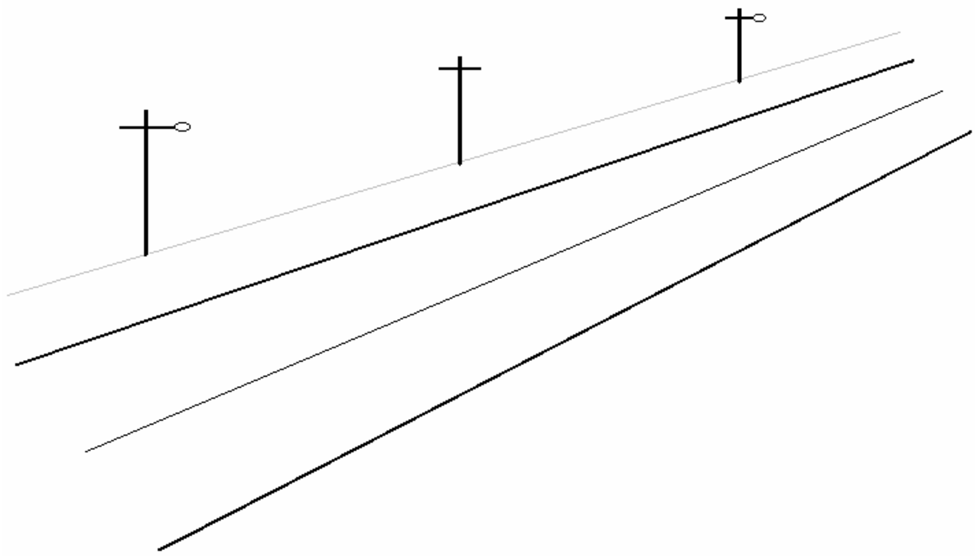
OVERHEAD POWER - 70 W METAL HALIDE AT 80 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	1.0	kW/km
GREENHOUSE GAS ❷	3.4	T/km
LAMP COST ❸	$ 40	
LAMP LIFE ❹	3	years
SYNERGY TARIFF p.a.	$129	
Running cost per kilolumen	$15.51	

NOTES:
❶ Based on circuit power of 77 W
❷ Based on 0.9 kg of CO_2 2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

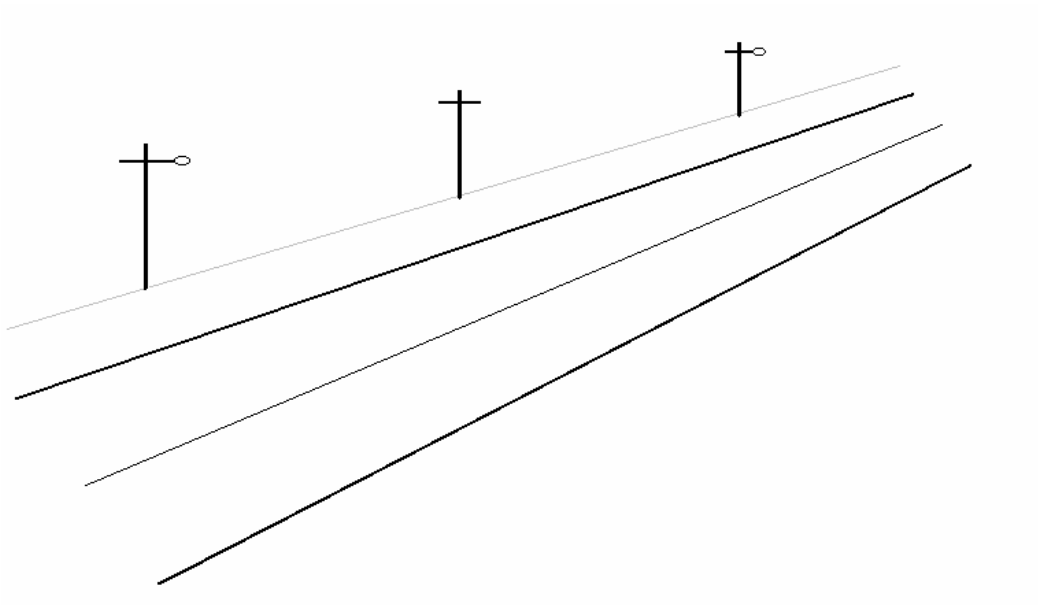
OVERHEAD POWER - 70 W HIGH PRESSURE SODIUM AT 80 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	1.0	kW/km
GREENHOUSE GAS ❷	3.4	T/km
LAMP COST ❸	$ 21	
LAMP LIFE ❹	5	years
SYNERGY TARIFF p.a.	$82	
Running cost per kilolumen	$7.80	

NOTES:
❶ Based on circuit power of 77 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

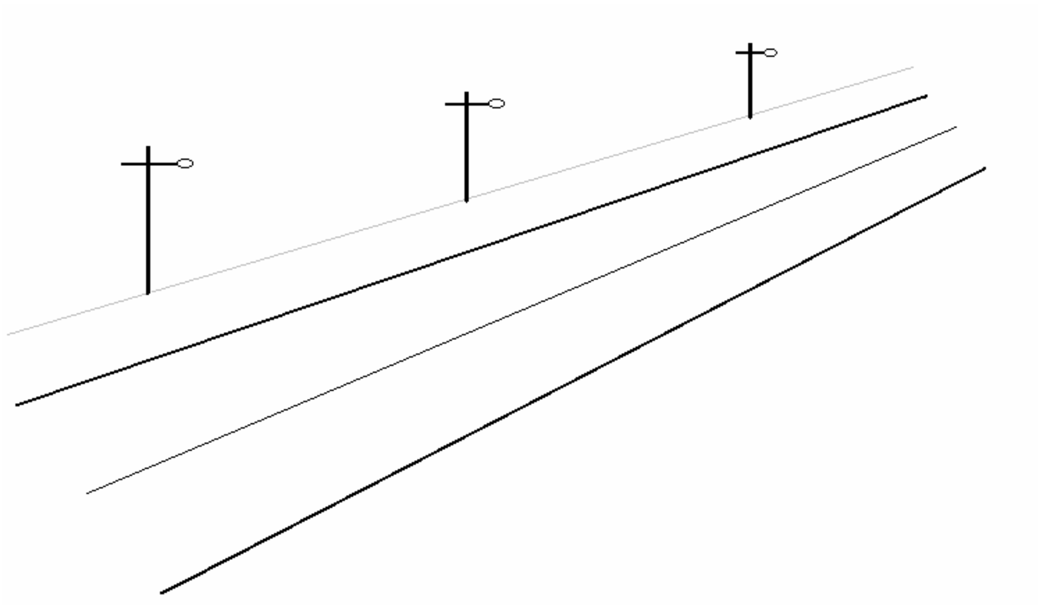
OVERHEAD POWER - 50 W HIGH PRESSURE SODIUM AT 80 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		✖
ENERGY ❶	0.69	kW/km
GREENHOUSE GAS ❷	2.5	T/km
LAMP COST ❸	$ 21	
LAMP LIFE ❹	5	years
SYNERGY TARIFF p.a.	N/A	
Running cost per kilolumen	$9.42	

NOTES:
❶ Based on circuit power of 55 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

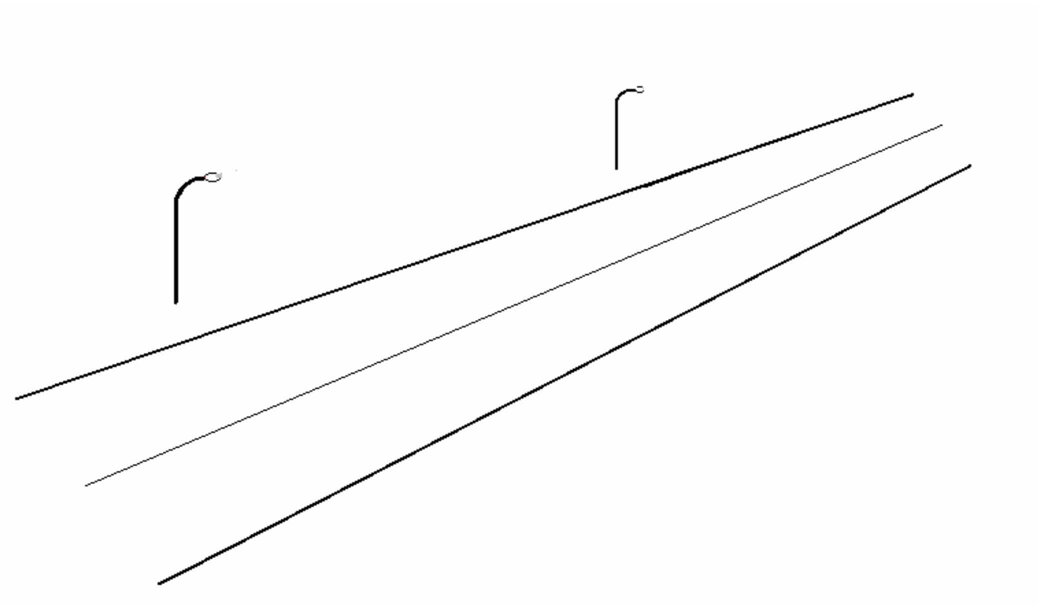
OVERHEAD POWER - 50 W HIGH PRESSURE SODIUM AT 40 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	1.38	kW/km
GREENHOUSE GAS ❷	4.95	T/km
LAMP COST ❸	$ 21	
LAMP LIFE ❹	5	years
SYNERGY TARIFF p.a.	N/A	
Running cost per kilolumen	$9.42	

NOTES:
❶ Based on circuit power of 55 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

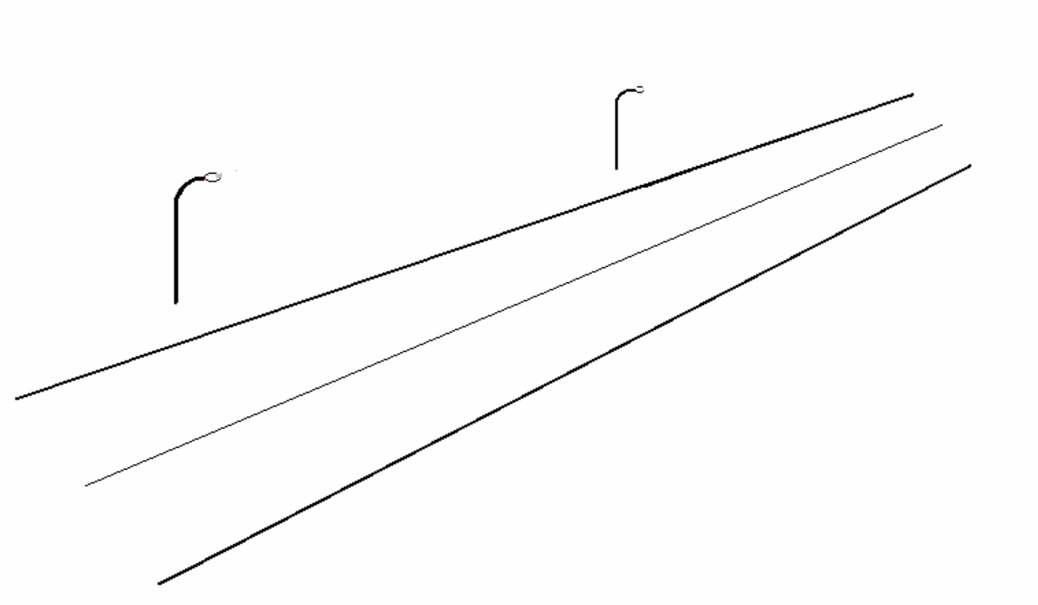
UNDERGROUND POWER - 80 W MERCURY AT 60 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	1.49	kW/km
GREENHOUSE GAS ❷	5.4	T/km
LAMP COST ❸	$ 4.50	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$86	
Running cost per kilolumen	$16.00	

NOTES:
❶ Based on circuit power of 89.5 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

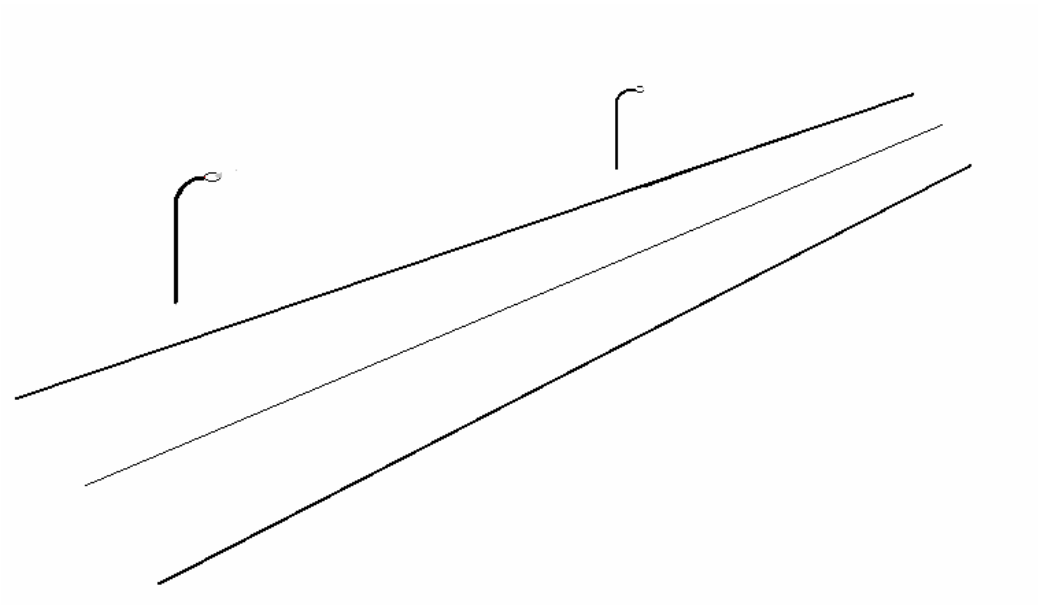
UNDERGROUND POWER – 42 W COMPACT FLUORESCENT AT 60 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	0.77	kW/km
GREENHOUSE GAS ❷	2.7	T/km
LAMP COST ❸	$ 13	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	N/A	
Running cost per kilolumen	$11.25	

NOTES:
❶ Based on circuit power of 46 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

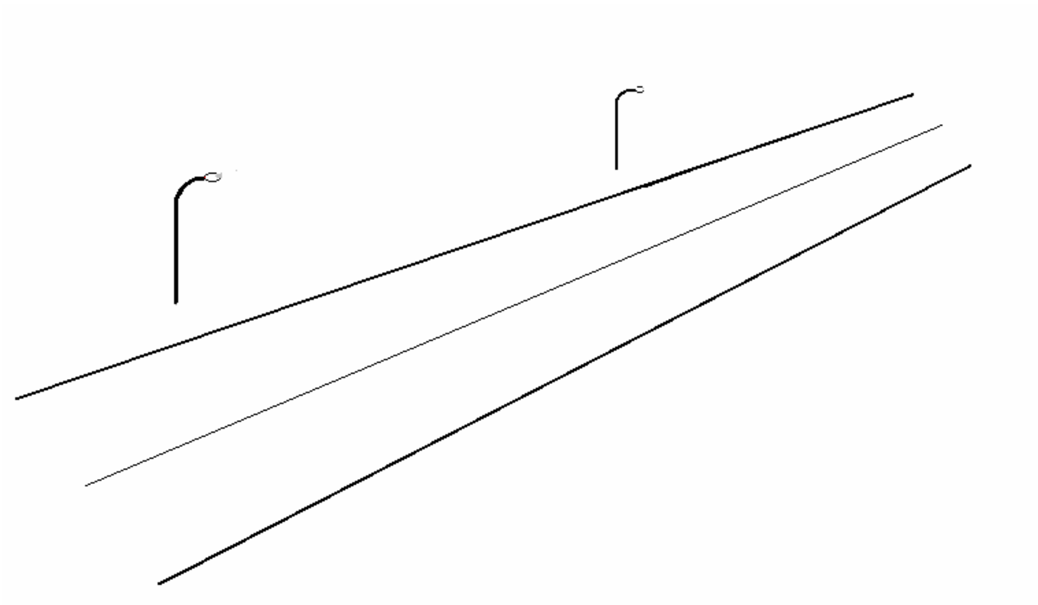
UNDERGROUND POWER - 70 W METAL HALIDE AT 70 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	1.1	kW/km
GREENHOUSE GAS ❷	4.0	T/km
LAMP COST ❸	$ 40	
LAMP LIFE ❹	3	years
SYNERGY TARIFF p.a.	$129	
Running cost per kilolumen	$15.51	

NOTES:
❶ Based on circuit power of 77 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

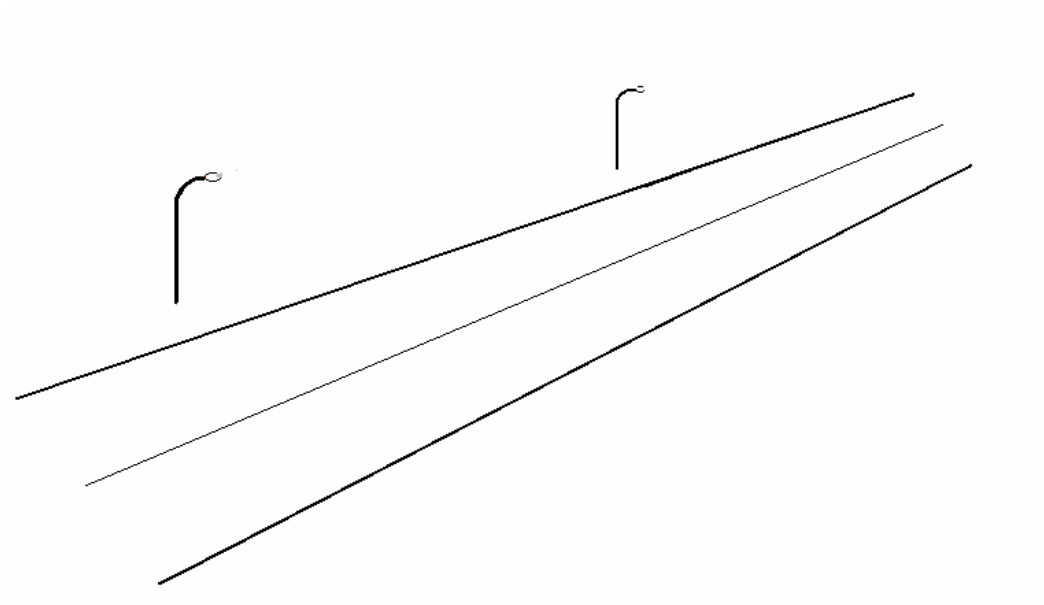
UNDERGROUND POWER - 70 W HIGH PRESSURE SODIUM AT 60 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		**Category P4**
ENERGY ❶	1.28	kW/km
GREENHOUSE GAS ❷	4.7	T/km
LAMP COST ❸	$ 21	
LAMP LIFE ❹	5	years
SYNERGY TARIFF p.a.	$82	
Running cost per kilolumen	$7.80	

NOTES:
❶ Based on circuit power of 77 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

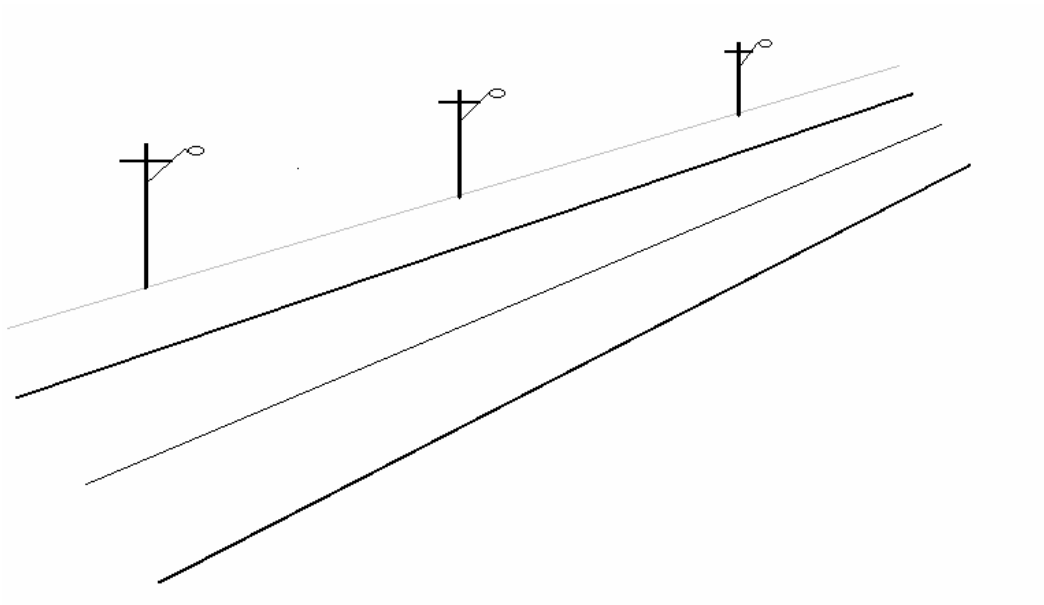
UNDERGROUND POWER - 50 W HIGH PRESSURE SODIUM AT 60 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE	✖	
ENERGY ❶	0.92	kW/km
GREENHOUSE GAS ❷	3.3	T/km
LAMP COST ❸	$ 21	
LAMP LIFE ❹	5	years
SYNERGY TARIFF p.a.	N/A	
Running cost per kilolumen	$9.42	

NOTES:
❶ Based on circuit power of 55 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year

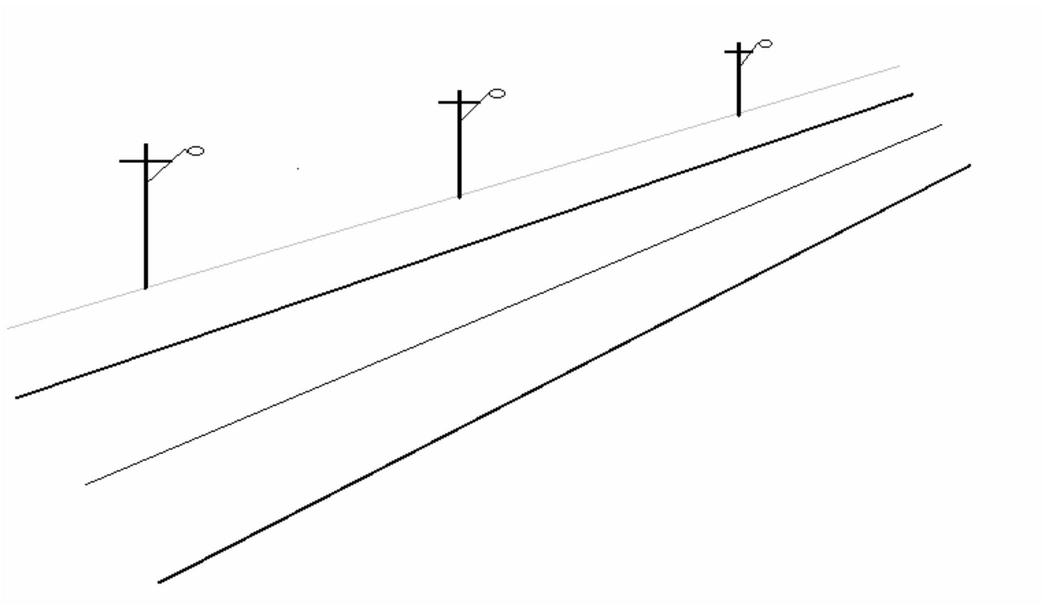
OVERHEAD POWER - 250 W HIGH PRESSURE SODIUM AT 40 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		Category V3
ENERGY ❶	6.9	kW/km
GREENHOUSE GAS ❷	25	T/km
LAMP COST ❸	$ 20	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$161	
Running cost per kilolumen	$5.05❺	

NOTES:
❶ Based on circuit power of 276 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year
❺ Based on 4 year lamp life, lamp cost of $20.00, the labour and plant costs listed in Table 3, circuit power of 276 W, energy cost at ZE18 tariff, and lamp output of 28 000 lumens.

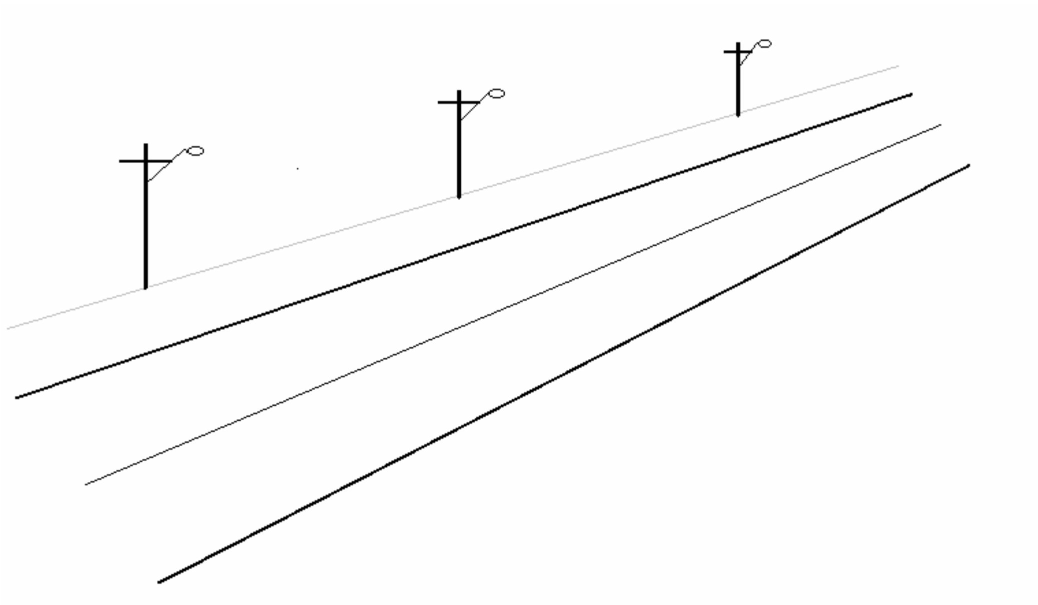
OVERHEAD POWER - 400 W MERCURY AT 40 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		Category V3
ENERGY ❶	10.7	kW/km
GREENHOUSE GAS ❷	39	T/km
LAMP COST ❸	$ 10	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$232	
Running cost per kilolumen	$8.50❺	

NOTES:
❶ Based on circuit power of 429 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year
❺ Based on 4 year lamp life, lamp cost of $10.00, the labour and plant costs as listed in Table 3, circuit power of 429 W, energy cost at ZE18 tariff, and lamp output of 24 000 lumens

OVERHEAD POWER - 150 W HIGH PRESSURE SODIUM AT 40 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		Category V5
ENERGY ❶	4.2	kW/km
GREENHOUSE GAS ❷	15	T/km
LAMP COST ❸	$ 22	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$125	
Running cost per kilolumen	$6.61❺	

NOTES:

❶ Based on circuit power of 168 W

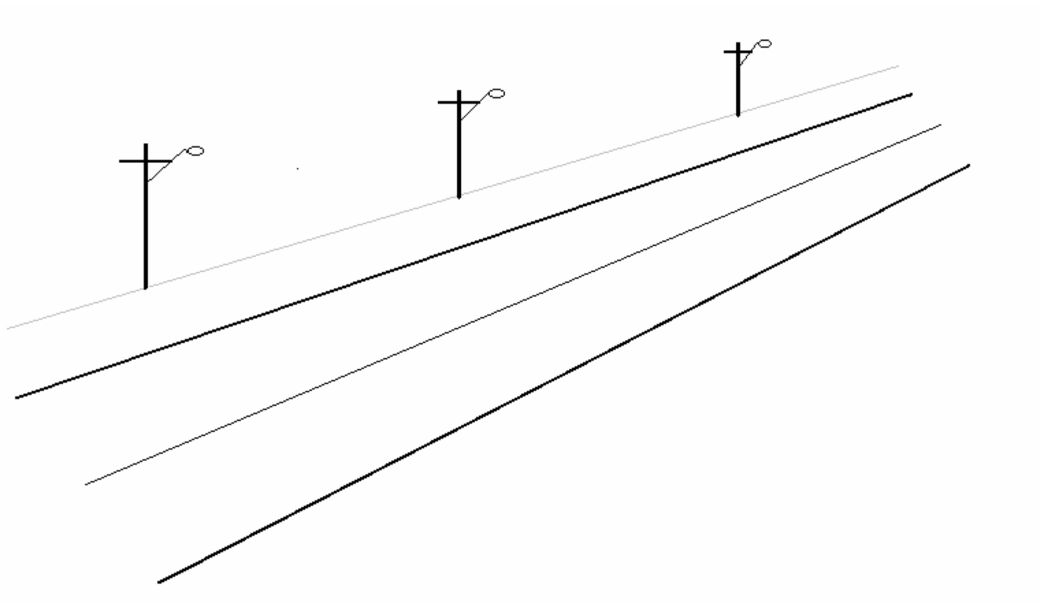
❷ Based on 0.9 kg of CO_2 per kWh

❸ Based on manufacturer information

❹ Based on 4 000 hours of operation per a year

❺ Based on 4 year lamp life, lamp cost of $22.00, the labour and plant costs as listed in Table 3, circuit power of 168 W, energy cost at ZE18 tariff, and lamp output of 14 500 lumens

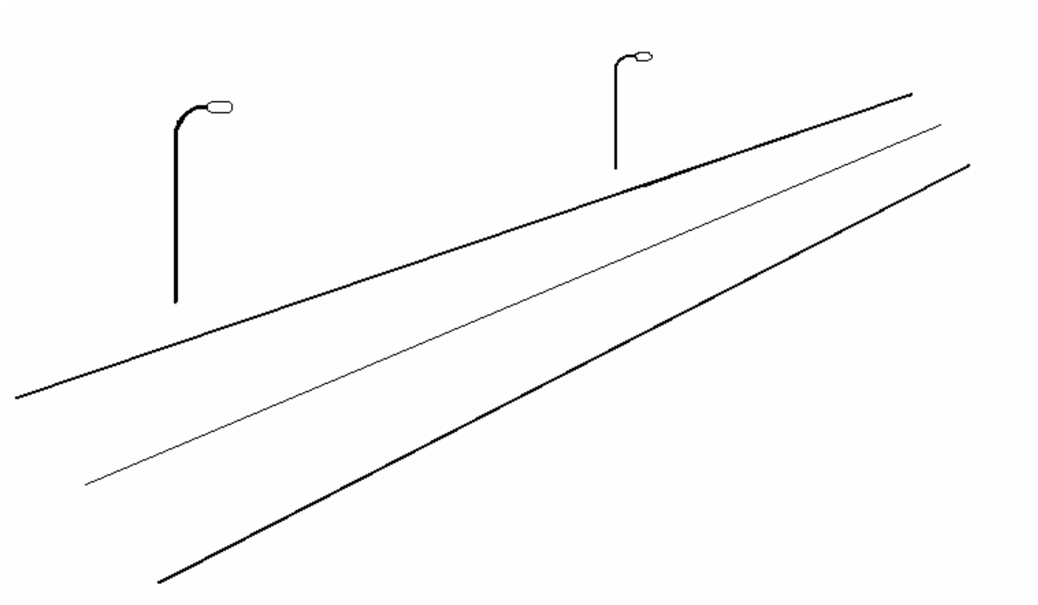
OVERHEAD POWER - 250 W MERCURY AT 40 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		Category V5
ENERGY ❶	6.9	kW/km
GREENHOUSE GAS ❷	25	T/km
LAMP COST ❸	$ 10	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$173	
Running cost per kilolumen	$9.77❺	

NOTES:
❶ Based on circuit power of 276 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year
❺ Based on 4 year lamp life, lamp cost of $10.00, the labour and plant costs as listed in Table 3, circuit power of 271 W, energy cost at ZE18 tariff, and lamp output of 14 000 lumens

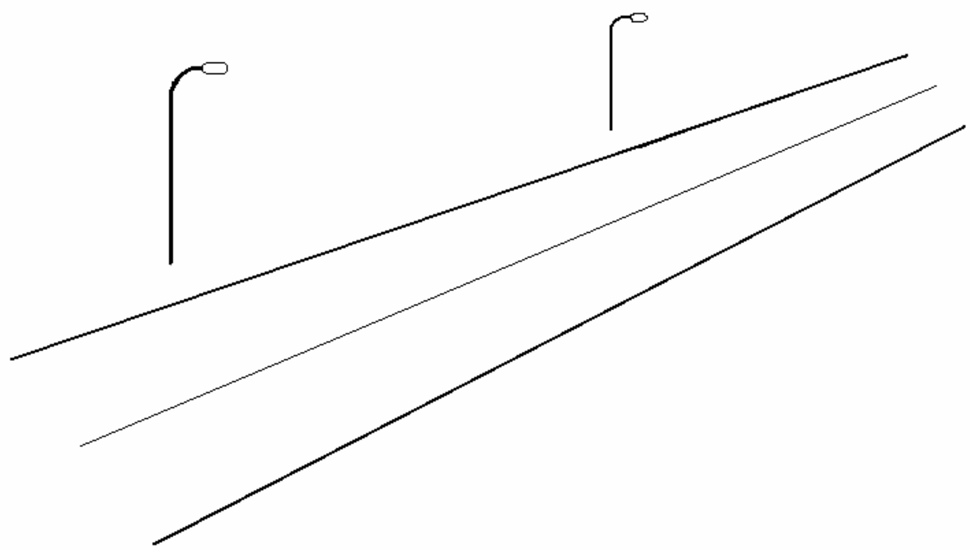
UNDERGROUND POWER - 250 W HIGH PRESSURE SODIUM AT 60 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		Category V3
ENERGY ❶	4.6	kW/km
GREENHOUSE GAS ❷	16.6	T/km
LAMP COST ❸	$ 20	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$161	
Running cost per kilolumen	$5.05❺	

NOTES:
❶ Based on circuit power of 276 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year
❺ Based on 4 year lamp life, lamp cost of $20.00, the labour and plant costs as listed in Table 3, circuit power of 276 W, energy cost at ZE18 tariff, and lamp output of 28 000 lumens

UNDERGROUND POWER - 150 W HIGH PRESSURE SODIUM AT 60 M



KEY PERFORMANCE INDICATORS		
AS/NZS 1158 COMPLIANCE		Category V3
ENERGY ❶	2.8	kW/km
GREENHOUSE GAS ❷	10	T/km
LAMP COST ❸	$ 22	
LAMP LIFE ❹	4	years
SYNERGY TARIFF p.a.	$125	
Running cost per kilolumen	$6.61❺	

NOTES:
❶ Based on circuit power of 168 W
❷ Based on 0.9 kg of CO_2 per kWh
❸ Based on manufacturer information
❹ Based on 4 000 hours of operation per a year
❺ Based on 4 year lamp life, lamp cost of $22.00, the labour and plant costs as listed in Table 3, circuit power of 168 W, energy cost at ZE18 tariff, and lamp output of 14 500 lumens

APPENDIX H

BRIEF

BRIEF September 2004

Improved Street Lighting Study for Greenhouse and Safety Benefit – Project Brief

Institutional and Technical Review

a. Conduct an Institutional and Technical review of the current situation in Western Australia. The institutional issues would relate to Western Power, the Office of Energy, the State Underground Power Programme and a comparison between Council owned street lights and Streetvision. The Technical issues would include luminaire choices and adherence to the Australian Standards and comparisons of efficiencies with other Australian States as well as World's best practice.

b. Prepare a report on outcomes of the Institutional and Technical Review. The Report will include recommendation on how the efficiency of street lighting could be improved in Western Australia.

c. Prepare a seminar designed and conducted on the outcomes of the Institutional and Technical Review.

2. Monitoring Programme

2.1 The monitoring will cover about 200 new streetlights in each of Mosman Park North, Subiaco Underground Power Area, and Midvale and about 50 control old mercury vapour streetlights in each of Mosman Park South, Subiaco overhead power area, and Midland adjacent Midvale.

2.2 Prepare an initial report (2004) outlining the area of the study with maps showing location of streetlights and then submit report to WALGA. Each local government will provide GIS information to the consultant in AutoCAD format.

2.3 Develop monitoring methodology with the Streetlighting Steering Group. Monitor by means of twelve bimonthly by night visits to each streetlight. Each Local Government will report to the consultant any streetlights burning during the day ie. (faulty PE switches). Submit data to WALGA.

2.4 Prepare interim Report (2005) on the outcomes of Monitoring and Reporting for Three Study Sites at 12 Months. The Interim Report should draw on and include outcomes and finding of 1.2 and 1.3 in establishing interim recommendations.

2.5 Prepare final report on the 24 month monitoring trial including link to recommendations from Institutional and Technical Review. Submit to WALGA.

2.6 Prepare a seminar designed and conducted to report project outcomes to stakeholders. Subject to level of interest, this may be conducted in parallel with the Institution and Technology seminar.

APPENDIX I

LIGHTING MEASUREMENT MAPS

LEGEND

22.0	ILLUMINANCE LEVEL IN LUX
OUT	INDICATES STREETLIGHT OUT OF ORDER
•○	STREETLIGHT

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

Western Australian Local Government Association

Field Trials 1

Midvale - Area 1

Sage Consulting Engineers Pty. Ltd.

DRAWN: A.G.R. DATE: 5/1/2005 SCALE: 1:2000 @ A3

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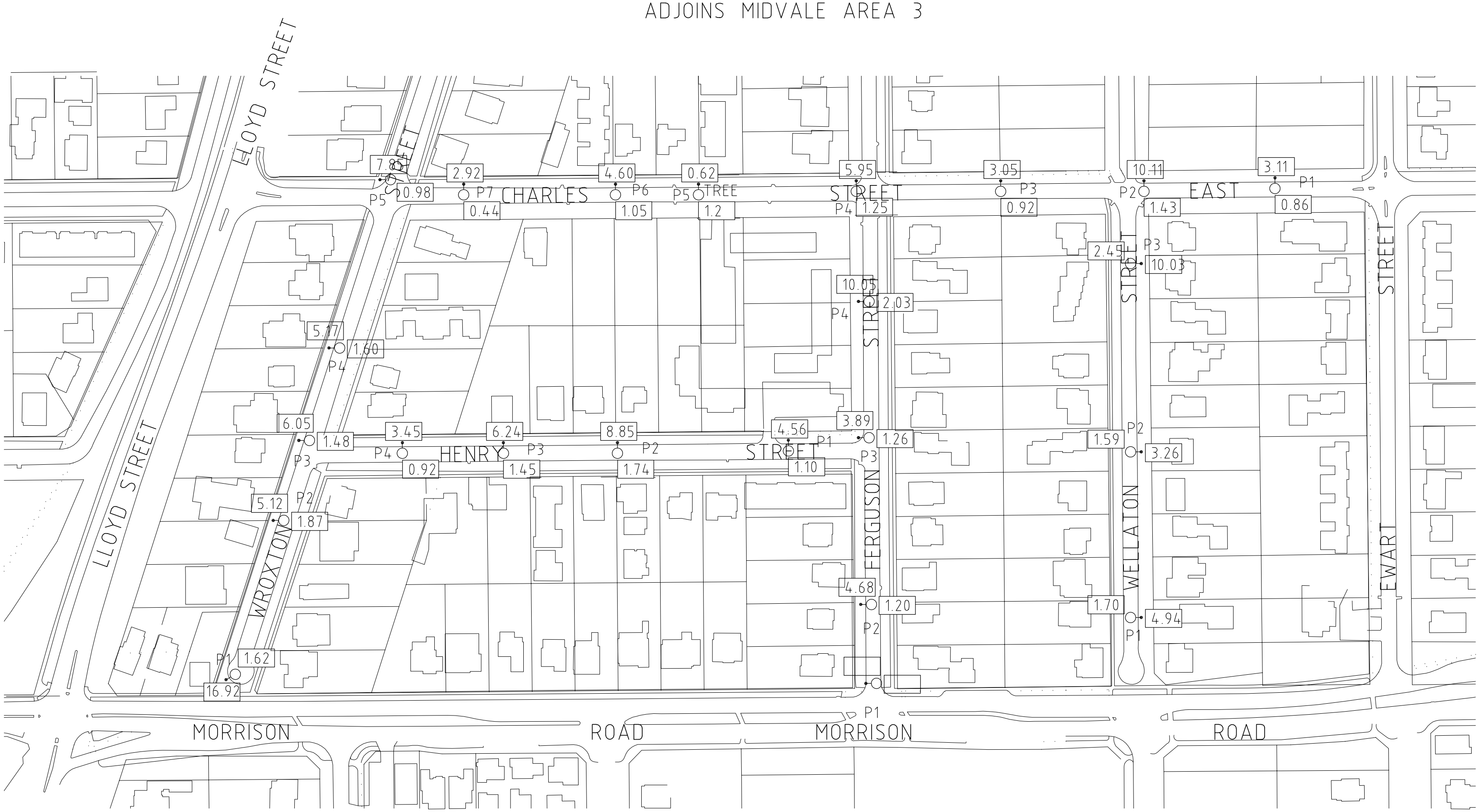
ADJOINS MIDVALE AREA 3



LEGEND

22.0 ILLUMINANCE LEVEL IN LUX

OUT INDICATES STREETLIGHT OUT OF ORDER

STREETLIGHT

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

A3

Western Australian Local Government Association

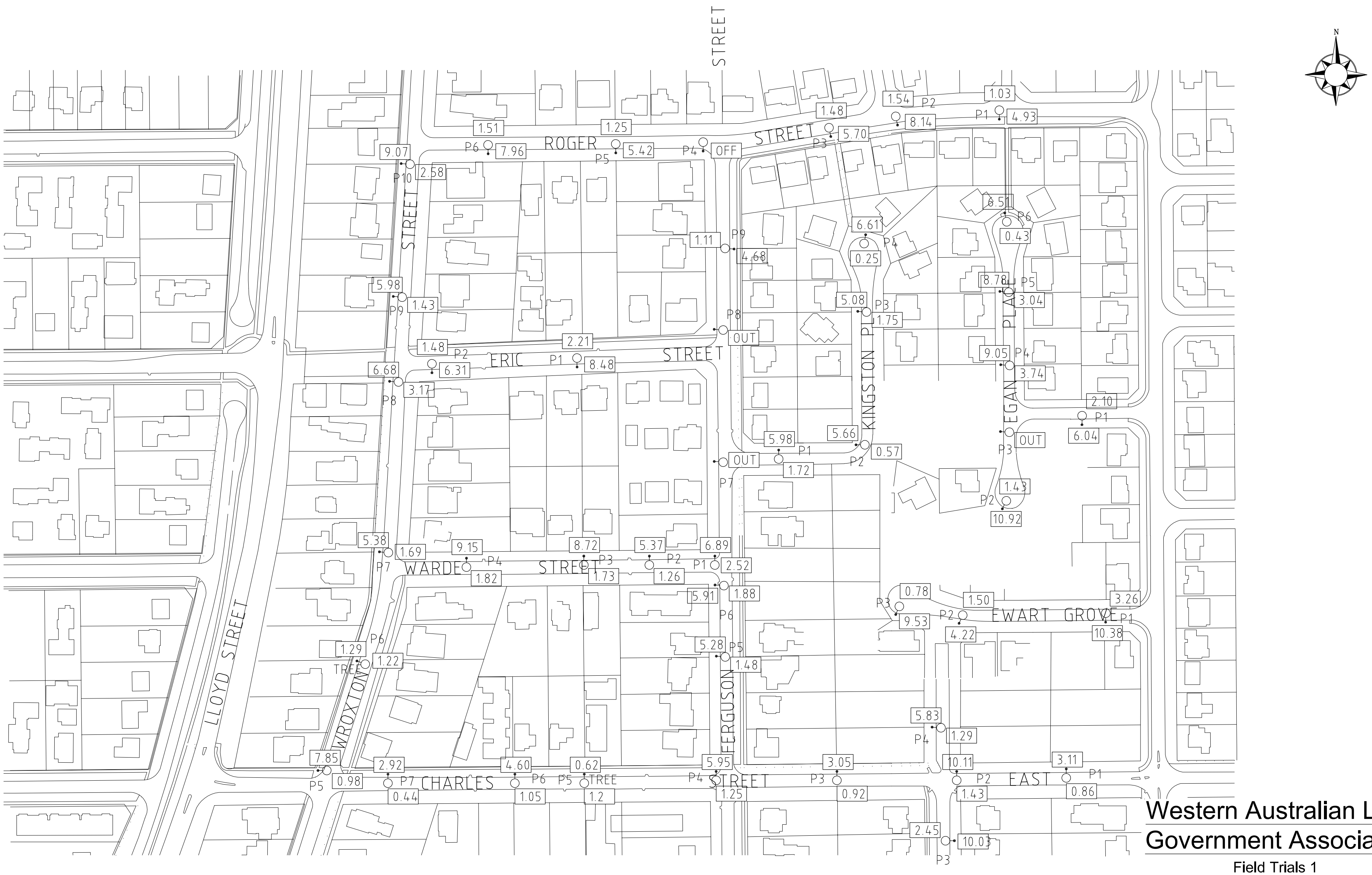
Field Trials 1

Midvale - Area 2

Sage Consulting Engineers Pty. Ltd.

DRAWN: A.G.R. DATE: 5/1/2005 SCALE: 1:2000 @ A3

S:\1390\Midvale\Lighting Feb\Midvale LR2.dwg



ADJOINS MIDVALE AREA 2

LEGEND

22.0	ILLUMINANCE LEVEL IN LUX
OUT	INDICATES STREETLIGHT OUT OF ORDER
•○	STREETLIGHT

A3

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

Western Australian Local Government Association

Field Trials 1

Midvale - Area 3

DRAWN: A.G.R. DATE: 5/1/2005 SCALE: 1:2000 @ A3

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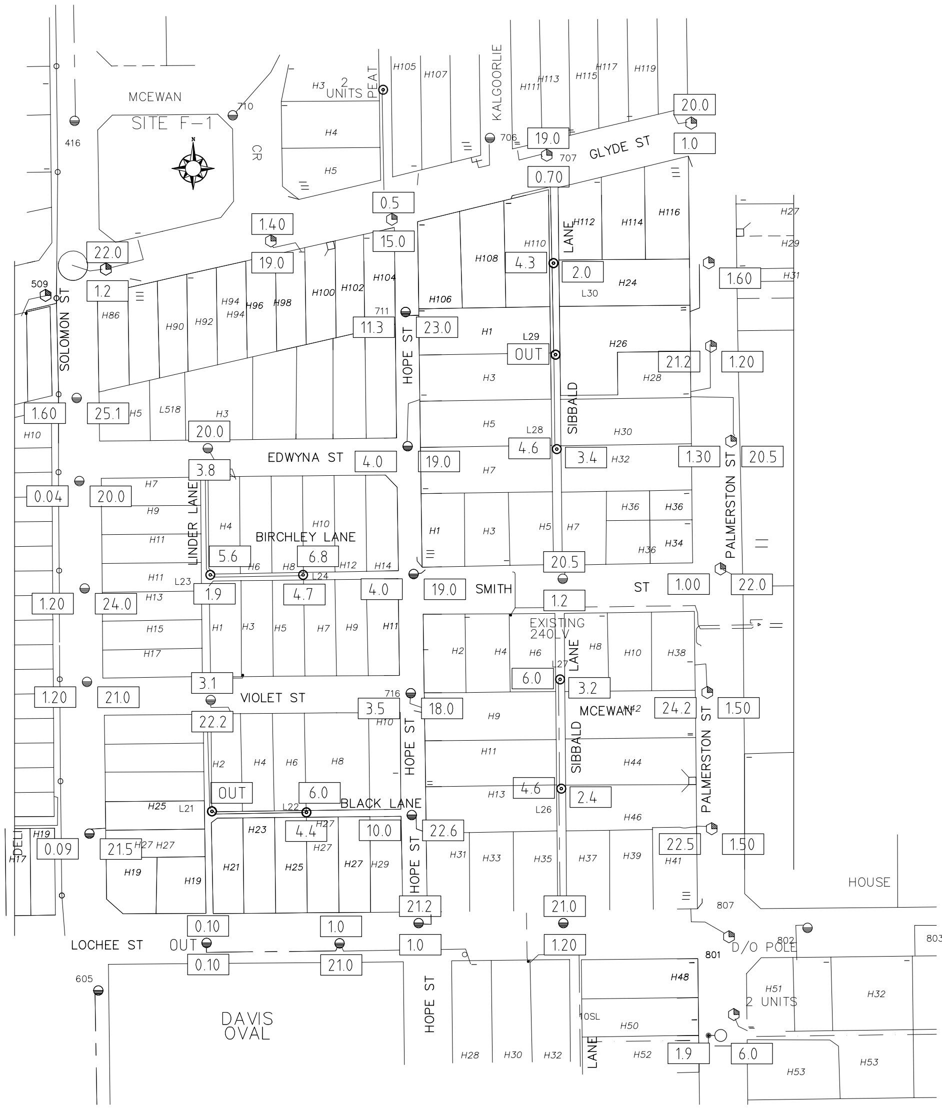

Area 1

REFER DRAWING Mosman Park LR2
FOR CONTINUATION OF AREA 2

LEGEND

22.0	ILLUMINANCE LEVEL IN LUX
OUT	INDICATES STREETLIGHT OUT OF ORDER
⊙	LANEWAY STREETLIGHT
◒	STREETLIGHT

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

Western Australian Local Government Association

Field Trials 1

Mosman Park - Area 1

Sage Consulting Engineers Pty. Ltd.

DRAWN: A.G.R. DATE: 11/2/2005 SCALE: 1:2000 @ A3

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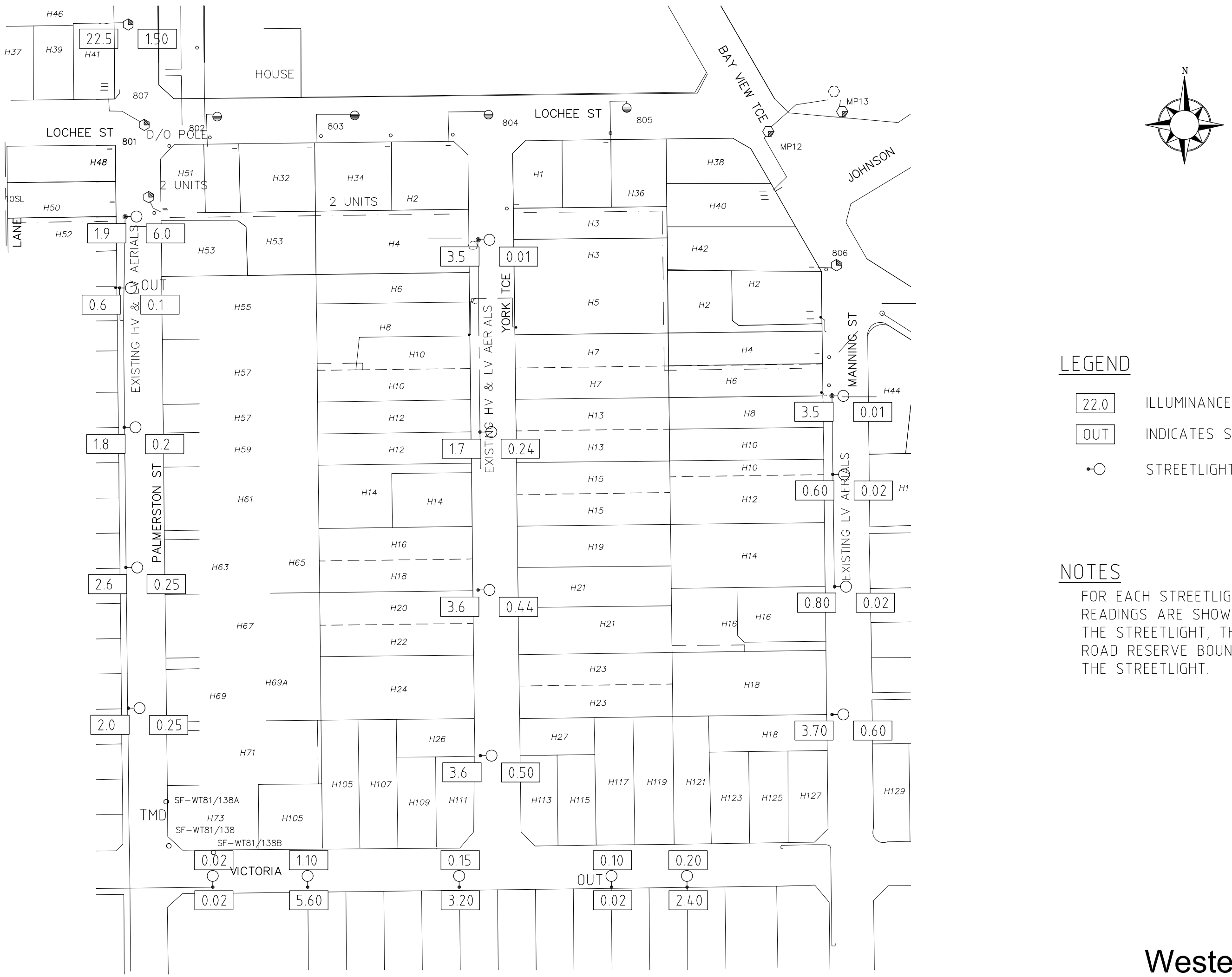
A3

REFER DRAWING Mosman Park LR1
FOR CONTINUATION OF AREA 1



Area 2

LEGEND

22.0	ILLUMINANCE LEVEL IN LUX
OUT	INDICATES STREETLIGHT OUT OF ORDER
•○	STREETLIGHT

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

Western Australian Local Government Association

Field Trials 1

Mosman Park - Area 2

Sage Consulting Engineers Pty. Ltd.

DRAWN: A.G.R. DATE: 14/2/2005 SCALE: 1:2000 @ A3

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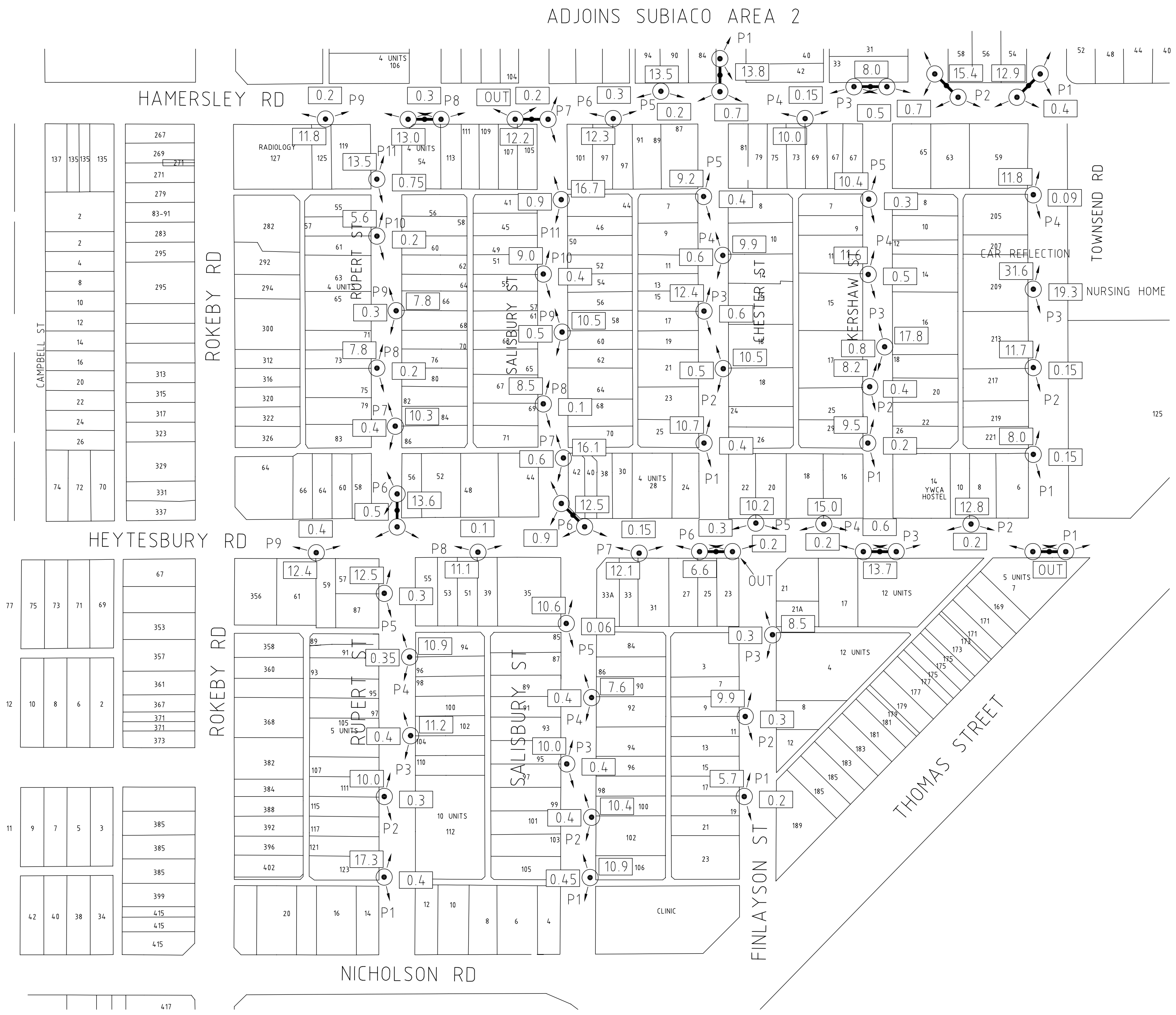
A3



LEGEND

22.0	ILLUMINANCE LEVEL IN LUX
OUT	INDICATES STREETLIGHT OUT OF ORDER
	SINGLE STREETLIGHT
	DOUBLE STREETLIGHT

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

A3

Western Australian Local Government Association

Field Trials 1

Subiaco - Area 1

Sage Consulting Engineers Pty. Ltd.

DRAWN: A.G.R. DATE: 10/2/2005 SCALE: 1:2000 @ A3

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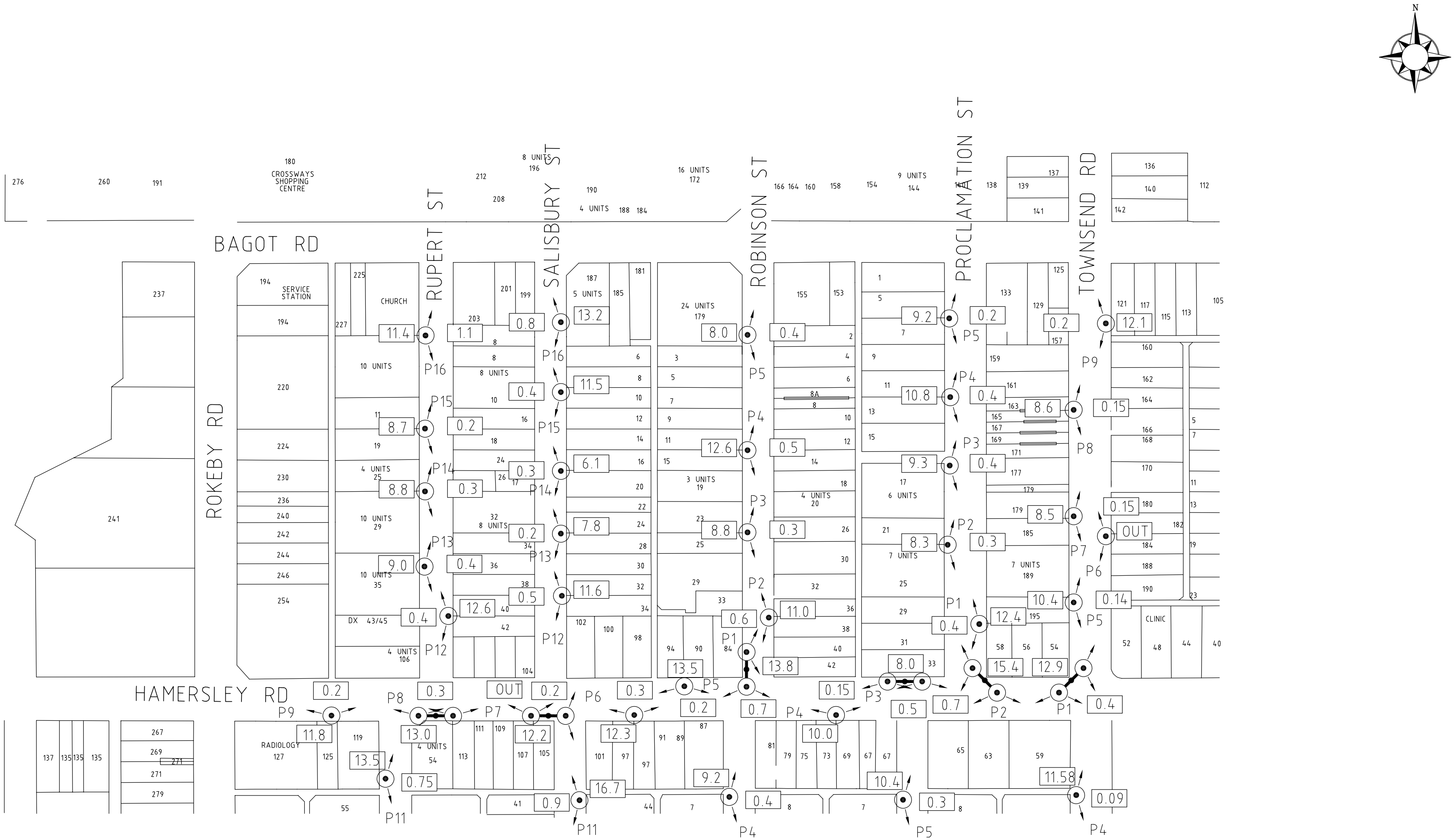

LEGEND

22.0	ILLUMINANCE LEVEL IN LUX
OUT	INDICATES STREETLIGHT OUT OF ORDER
(symbol)	SINGLE STREETLIGHT
(symbol)	DOUBLE STREETLIGHT

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

A3

Western Australian Local Government Association

Field Trials 1

Subiaco - Area 2

Sage Consulting Engineers Pty. Ltd.

DRAWN: A.G.R. DATE: 10/2/2005 SCALE: 1:2000 @ A3

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LEGEND

22.0	ILLUMINANCE LEVEL IN LUX
OUT	INDICATES STREETLIGHT OUT OF ORDER
●○	STREETLIGHT

NOTES

FOR EACH STREETLIGHT, TWO ILLUMINANCE READINGS ARE SHOWN, ONE DIRECTLY UNDER THE STREETLIGHT, THE OTHER AT THE ROAD RESERVE BOUNDARY PERPENDICULAR TO THE STREETLIGHT.

Western Australian Local Government Association

Field Trials 1

Subiaco - Area 3

Sage Consulting Engineers Pty. Ltd.

DRAWN: A.G.R. DATE: 10/2/2005 SCALE: 1:2000 @ A3

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APPENDIX J

SUMMARY OF RECOMMENDATIONS

SUMMARY OF RECOMMENDATIONS

ITEM RECOMMENDATION

1. **Standards**
WALGA encourage local government to adopt AS/NZS 1158 as a policy for technical design of streetlight networks. AS/NZS is appropriate, and should not be considered as excessive. There is a risk to local government if they do not comply with a national standard.

2. **Efficient lamp technologies**
WALGA encourage Western Power and Local Government to use the more efficient lamp technologies in new and replacement street lights.

3. **Underground Power Program**
The Office of Energy encourages energy efficient street lighting for UPP projects, and specifies appropriate AS/NZS 1158 Categories.

4. **Synergy/Western Power Invoicing**
Synergy provide a price breakdown listing maintenance, replacement, energy, and administrative costs to individual Local Government clients.

5. **Mercury**
On overhead power systems, the 80 W mercury vapour street light at 80 m spacing does not comply with AS/NZS 1158. Mercury vapour lamps have half the efficiency of modern lamps. Consequently the use of mercury vapour lamps should be phased out by responsible authorities.

6. **Western Power**
WALGA request Synergy and Western Power to include fluorescent lamps such as compact fluorescent and T5 fluorescent lamps in their available stock.

7. **Energy Efficient Street Lighting Technologies**
For minor road lighting two technologies are available to Local Government:
   - 42 W compact fluorescent
   - 2 X 24 W T5 fluorescent

   Both lamps are mature, not emerging technologies. The compact fluorescent lamp has been available since 1982 and the 42 W version since the early 1990's. T5 fluorescent lamps have been available since the mid 1990's. Both lamp technologies are available in Australian made street lights.
These technologies are equivalent in light output to the common 80 W mercury vapour lamp and offer a halving of energy consumption and greenhouse gas emissions.