University of Southern Queensland

Faculty of Health, Engineering & Sciences

Reduced Road Lighting Standards During Times Associated With Low Traffic Volumes

A dissertation submitted by

Mark Nicholas Zeller

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ABSTRACT

The current standards associated with lighting road and streets in Australia give no guidance to the incorporation of dimming into lighting schemes. It is hypothesised that by dimming road lighting during times when few people are using the road there will be little effect on the safety of the roads during these times. Implementing a dimming scheme could maintain the level of safety required at night when traffic volumes are high and could save electricity when the high standard of lighting is not required. One of the two main objectives is to investigate whether crashes and traffic volumes follow the same temporal trends, justifying the basis behind this project. The second objective is to determine if a dimming scheme could be cost effective in the long term if the social cost of crashes and social cost of carbon is considered. This is done by identifying three exemplar sites for review, creating three different treatments of applying dimming, redesigning the sites using these dimming treatments then comparing the costs associated with each site and dimming treatment to determine the most cost effective solution. The main outcome of this project is that, in the current social and economic environment, dimming is not the most effective method in reducing the costs associated with road lighting.

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Limitations of Use

CERTIFICATION OF DISSERTATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other institution, except where specifically stated.

Mark Nicholas Zeller

Student Number: 0050025838

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Signature

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Date

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CHAPTER 1– INTRODUCTION

1.1. Justification for the Research Project

With the high cost of electricity in Australia and the very real threat of climate change and its extreme consequences, it is becoming increasingly important to implement strategies to reduce our electricity consumption. The responsibility to do so lies on governments, organisations and individuals. One way for governments to reduce their electricity consumption is to review road lighting and implement strategies to improve its efficiency.

> "There are approximately 2.28 million street lighting lamps in service in Australia, with around 33% on main roads and 67% on local roads. The annual energy cost of public lighting in Australia exceeds $125 million (and more than $250m including maintenance). Street lighting is the single largest source of greenhouse gas emissions from local government, typically accounting for 30 to 60 per cent of their greenhouse gas emissions."(Ironbark Sustainability 2011, p.iii)

Figure 1 is a breakdown of the costs, energy, number of lights, and greenhouse gas emissions of different electricity distributors within Australia in 2011.

Distributor	Total est. energy cost (GST exc.)	Total annual energy (kWh)	Number of lights	Total annual greenhouse (tCO2-e)
Aurora	$ 2,495,605	27,728,949	48,047	9,705
AusGrid	$ 13,089,475	145,438,615	245,688	155,619
Citipower/Powercor	$ 12,909,820	143,442,449	229,744	196,516
Endeavour Energy	$ 10,140,718	112,674,648	188,887	120,562
Energex	$ 15,287,085	169,856,495	319,964	173,254
Ergon Energy	$ 7,274,946	80,832,730	134,424	82,449
Essential Energy	$ 7,525,477	83,616,406	145,130	89,470
ETSA Utilities	$ 9,364,947	104,054,967	218,631	88,447
Horizon Power	$ 2,698,415	29,982,385	32,189	30,768
Jemena	$ 4,152,884	46,143,153	77,271	63,216
Main Roads Authorities	$ 7,544,200	83,824,445	67,680	77,852
PAWA	$ 1,387,731	15,419,233	22,410	11,873
Roads ACT*	$ 4,079,988	45,333,201	73,188	48,507
SP AusNet*	$ 6,859,991	76,222,120	127,778	104,424
United Energy	$ 7,769,721	86,330,233	139,310	118,272
Western Power*	$ 12,454,934	138,388,157	211,607	128,701
Grand Total	**$ 125,035,937**	**1,389,288,187**	**2,281,949**	**1,499,635**

Figure 1: Road Lighting Numbers, Energy and Greenhouse in Australia in 2011

(Ironbark Sustainability 2011, p.7)

Global warming as a result of increased greenhouse gas emissions due to human activity is set to become humanities biggest challenge with a 40% chance of temperatures rising by more than four degrees Celsius by the end of the century if no action is taken (World Bank 2012, p.23), a scenario likely to trigger widespread crop failures, malnutrition and dislocate large numbers of people from land inundation by rising seas. It is because of this every human effort must be made to significantly reduce our greenhouse gas emissions before we are forced to.

Energy savings and greenhouse gas emission reductions for road lighting can be obtained in several ways which include:

1. By replacing the existing street lights with more efficient lights with the same standard of roadway illumination.
2. By converting existing timers to PE (Photo Electric) controlled systems so that luminaires are not switched on until the daylight intensity has reduced to a certain level.
3. By dimming or switching off the lamps at times when high standards of lighting are not required.

All of these solutions are effective methods of achieving energy savings however there has been much more investigation into the first two options. The Draft Street Lighting Strategy (Ironbark Sustainability 2011) proposes a method of achieving energy efficiency savings through infrastructure upgrades. This strategy recommends replacing all mercury vapour lamps with the most energy efficient alterative resulting in a 27% reduction in the energy used for road lighting (p.9). This strategy does not investigate replacement using LED (Light Emitting Diode) technology which was only considered a new technology at the time of publication. This technology has improved significantly since the report was produced and several LED options are now available for both Category V and Category P applications.

The strategy makes note that the third solution of using dimmers requires changes to AS/NZS1158, is considered difficult and "it is not expected that on scale dimming would be an attractive wide scale option currently in Australia" (Ironbark Sustainability 2011, p.40). This viewpoint indicates that this option had been ruled out without thorough investigation.

Despite the negativity towards the option of dimming, this option is still a valid one and requires research to quantify the costs and benefits of such a proposal.

1.2. Ethics of the Proposal

Engineers Australia (2010) Code of Ethics guidelines on professional conduct states that sustainability should be promoted by "[Balancing] the needs of the present with the needs of the future generations … [by] identifying sustainable outcomes [and considering] all options in terms of their economic, environmental and social consequences"

Ethically, dimming has contradictory ethical viewpoints. Although difficult to compare the three ethical issues associated with the proposal are:

- Economic benefits.
- Economic consequences.
- Environmental benefits.
- Road safety consequences.

The economic benefits of electricity cost savings are (in the current economic environment) difficult to justify as no loss of life could be expected from reducing government operating costs and the savings per resident, if passed on through council rates and vehicle registration, would be considered quite small due to the high incomes of Australians. If the savings were not passed on through rates or vehicle registration and were used to pay off government debt, financial sustainability would be much easily achieved by councils. Energex supplies electricity to street lights provided by Transport and Main Roads Rate 3 lighting under tariff code 9350 (Major Contributed – above 100W HPS lamps) for $0.30/light/day and tariff code (Minor Contributed – below 100W HPS lamps) for 9300 $0.12/light/day (Energex, p.17, 2013).

There are long term economic benefits associated with reducing greenhouse gas emissions and the associated reduction in the frequency and intensity of extreme weather events. Some of these benefits include stable food prices, health system costs (i.e. heatstroke from heat waves, injury from unpredictable weather systems, malnutrition), and reduced inflation of insurance premiums. The value of these benefits will increase over time. The US government has estimated the social cost of carbon between 2010 and 2050 (Table 1) in the report titled *Technical Update of the*

Social Cost of Carbon for Regulatory Impact Analysis. It has been calculated that the 1999 average carbon dioxide emission rate from coal power stations is 0.95Kg/KWh (US Department of Energy and Environmental Protection Agency, 2000).

Table 1: Social Cost of CO2, 2010-2050 in 2007 Dollars per Metric Ton of CO2 (Interagency Working Group on Social Cost of Carbon, United States Government 2013)

Discount Rate Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010	11	33	52	90
2011	11	34	54	94
2012	11	35	55	98
2013	11	36	56	102
2014	11	37	57	106
2015	12	38	58	109
2016	12	39	60	113
2017	12	40	61	117
2018	12	41	62	121
2019	12	42	63	125
2020	12	43	65	129
2021	13	44	66	132
2022	13	45	67	135
2023	13	46	68	138
2024	14	47	69	141
2025	14	48	70	144
2026	15	49	71	147
2027	15	49	72	150
2028	15	50	73	153
2029	16	51	74	156
2030	16	52	76	159
2031	17	53	77	163
2032	17	54	78	166
2033	18	55	79	169
2034	18	56	80	172
2035	19	57	81	176
2036	19	58	82	179
2037	20	59	84	182
2038	20	60	85	185
2039	21	61	86	188
2040	21	62	87	192
2041	22	63	88	195
2042	22	64	89	198
2043	23	65	90	200
2044	23	65	91	203
2045	24	66	92	206
2046	24	67	94	209
2047	25	68	95	212
2048	25	69	96	215
2049	26	70	97	218
2050	27	71	98	221

The economic consequences of the proposal would be the increased heath system costs and the costs of emergency services associated with injuries and deaths caused by increased road accidents. The detrimental effects of these consequences would stay relatively constant over time. Table 2 gives the social costs used by the Department of Transport and Main Roads for undertaking a cost benefit analysis.

Table 2: Crash Social Costs Expressed in 2007 Dollars ((Department of Transport and Main Roads 2008)

Type		Costs
Fatal	....	$2,144,096
Hospitalisation	....	$529,203
Moderate Injury	....	$17,869
Minor Injury	....	$17,869
Property	....	$7,534

Environmental benefits of the proposal include a reduction in upward waste light and greenhouse gas emissions. Upward waste light has detrimental effects on astronomers' ability to view the night sky and is a disturbance to animals (especially nocturnal). Environmental benefits of delaying or reducing the effects of climate change are vast including the destruction of coral reef ecosystems from ocean acidifying, the loss of wildlife habitat caused by the encroachment of deserts, and the lack of stability in ecosystems caused by unpredictable weather events.

Road safety consequences of the proposal would be immediate and would result in an increased number of injuries and deaths on the roads. Section 2.3 demonstrates how dimming will almost definitely make the roads less safe at night. The time dependant dimming proposed has been chosen for this reason under the hypothesis that with less vehicles on the road the potential hazards a driver might encounter has significantly reduced. The detrimental effects of these consequences would stay relatively constant over time.

1.3. Aims and Objectives

The aim of this work is to investigate the feasibility of allowing reduced lighting standards for lit roadways during times of low traffic volumes. This work questions the need for the same level of lighting to be provided during all hours of the night considering the significant variability in traffic volumes throughout the night.

To achieve the project aim, this report will:

1. Review current literature relevant to the project aim.
2. Investigate the correlation between road lighting, temporal patterns of traffic volumes, crash data and crime data.
3. Evaluate a number of sites which have distinctly different lighting schemes and identify 3 distinctly different sites with the potential for reducing lighting standards.
4. Propose possible lighting treatments for the subject sites and investigate the cost to implement the treatments
5. Investigate the long term economic costs associated with the proposed treatments at the subject sites and determine if dimming is feasible.

1.4. Outline of Dissertation

Chapter 2 of the dissertation reviews literature relating to five distinctly different elements, these are:

1. Road lighting in Australia which aims to answer the following questions:
   - What is AS/NZS1158?
   - What standards and guidelines are used in Australia and Queensland?
   - How are area lighting schemes designed using AS/NZS1158?
   - Who is responsible for providing road lighting and what are the current implications of not adhering to AS/NZS1158?
2. What road lighting technology currently exists and what are the properties of each technology.
3. The effectiveness of the current road lighting standards in reducing crashes and crime.
4. Temporal Patterns of Traffic Volume, Crash Data and Crime Data and any correlation between these variables and road lighting.
5. Strategies which have been implemented in other countries to reduce electricity consumption from road lighting.

Chapter 3 outlines the methodology used to develop this report and to achieve the project objectives.

Chapter 4 is devoted to crash data analysis with further investigation into the correlation between the temporal patterns of traffic volume and crash data beyond the work mentioned in the literature review.

Chapter 5 compares several possible sites and chooses three exemplar sites for review. The chapter describes the chosen sites, review the current lighting environment at each site and investigates the crash history.

Chapter 6 defines the dimming treatment options which were compared at the selected sites.

Chapter 7 presents the results of the redesigned layouts and summarises the treatment options and the electricity demand associated with each option.

Chapter 8 quantifies the costs associated with each treatment and compares the treatment costs with that of the base (existing) layouts.

Chapter 9 concludes the dissertation. It presents a summary of research achievements together with a discussion on their significance and recommendations for further research.

1.5. Summary of Outcomes

Three unique sites have been analysed with three different methods of dimming. It was concluded that the most economical method of dimming when retrofitting existing infrastructure lit to a V3 standard is by installing both 250W and 150W lamps on a single pole and using 250W lamps before dimming commences then switching to the 150W lamps. When installing new infrastructure, LED lamps have been hypothesised to be the most economical solution based on the findings of this report.

In the current environment, dimming is only considered economical when traffic volumes are low (less than approximately 0.7 crashes per year on average). With the additional costs associated with creating new standards and the relatively small number of sites which would benefit from dimming, it has been concluded that dimming is not a feasible option.

CHAPTER 2 – LITERATURE REVIEW

2.1. Road Lighting in Australia

2.1.1. AS/NZS 1158

AS/NZS1158 – Lighting for Road and Public Spaces (Joint Technical Committee LG-002 2005) is a technical standard relevant in Australia and New Zealand. Internationally, the standard used is CIE 115:2010 – Lighting of Roads for Motor and Pedestrian Traffic.

AS/NZS1158 outlines information such as:

- The objectives of road and public space lighting.
- The technical parameters of which road and public space lighting is assessed.
- Design methods.
- Luminaire electronic data formats.
- Design documentation requirements.
- Luminaire design, installation and testing requirements.

Currently the AS/NZS1158 standard is developed by a Technical Committee known as Joint Technical Committee LG-002, consisting of a number or organisations that represent various interest groups across the industry. The current technical committee (in 2013) includes the following organisations:

- Astronomical Society of Australia
- Australian Industry Group
- Australian Local Government Association
- Centre for Pavement Engineering Education
- CIE Australia Inc.
- Consumers Federation of Australia
- Department of Transport and Main Roads, Queensland
- Energy Efficiency & Conservation Authority of New Zealand
- Energy Networks Association
- Equipment Energy Efficiency Committee
- For Information

- IES: The Lighting Society
- Ingenium
- Institute of Public Works Engineering Australia
- Lighting Council New Zealand
- Lighting Council of Australia
- Local Government and Shires Associations of New South Wales
- Main Roads Western Australia
- Municipal Association of Victoria
- New Zealand Transport Agency
- Roads and Maritime Services
- Standards New Zealand

2.1.2. Road Lighting in Queensland

The extent of use of AS/NZS1158 as a road lighting design standard is defined by the relevant road authority. In Queensland the relevant road authorities include the Department of Transport and Main Roads and individual local governments such as Toowoomba Regional Council and Sunshine Coast Regional Council.

In Queensland there are three stakeholders involved in the supply of road lighting, these include the electricity supply corporation, the local government authority and the state government authority. There are three electricity supply tariffs associated with road lighting referred to as Rate 1, 2 and 3. The tariff defines which entity is deemed responsible for designing, building, and maintaining of the infrastructure. Rate 1 and 2 lighting ultimately become assets of the electricity supply corporation (e.g. Ergon Energy or Energex) while Rate 3 lighting becomes an asset of the Department of Transport and Main Roads.

There are different design standards associated with the three tariffs. Lighting schemes for Rate 1 and 2 tariffs are designed and constructed using the appropriate electricity supply corporation's technical manuals which, for energex and ergon energy, is the Public Lighting Design Manual (Taylor 2012) and the Public Lighting Construction Manual. Rate 3 lighting is designed using the Road Planning and Design Manual (Department of Transport and Main Roads 2004) along with relevant Standard Drawings and Technical Specifications. Individual councils may also have lighting requirements integrated within their planning schemes.

2.1.3. Lighting Categories and Design Rules

The AS/NZS1158 technical standard outlines two distinct Lighting Categories; Category V and Category P. Category V lighting is "applicable to roads on which the visual requirements of motorists are dominant" (Joint Technical Committee LG-002 2005) and Category P lighting is "applicable to roads and other outdoor public spaces on which the visual requirements of pedestrians are dominant." (Joint Technical Committee LG-002 2005)

Lighting categories are broken down further into subcategories, Category V has five subcategories which vary based on operating characteristics such as the type of road, traffic volume, pedestrian volume, vehicle speed, and access restrictions. For roads, Category P also has five subcategories which are based on the type of road, pedestrian/cycle activity, risk of crime, and the need to enhance prestige.

The category and subcategory chosen for a particular road is chosen ultimately by the asset owner. Figure 2 gives a guide on the classification of roads and public spaces. Based on this guide, documents such as the Public Lighting Design Manual (Taylor 2012) and the Road Planning Design Manual (Department of Transport and Main Roads 2004) give more detailed instructions on how to classify roads (Refer Figure 3, Figure 4 and Figure 5).

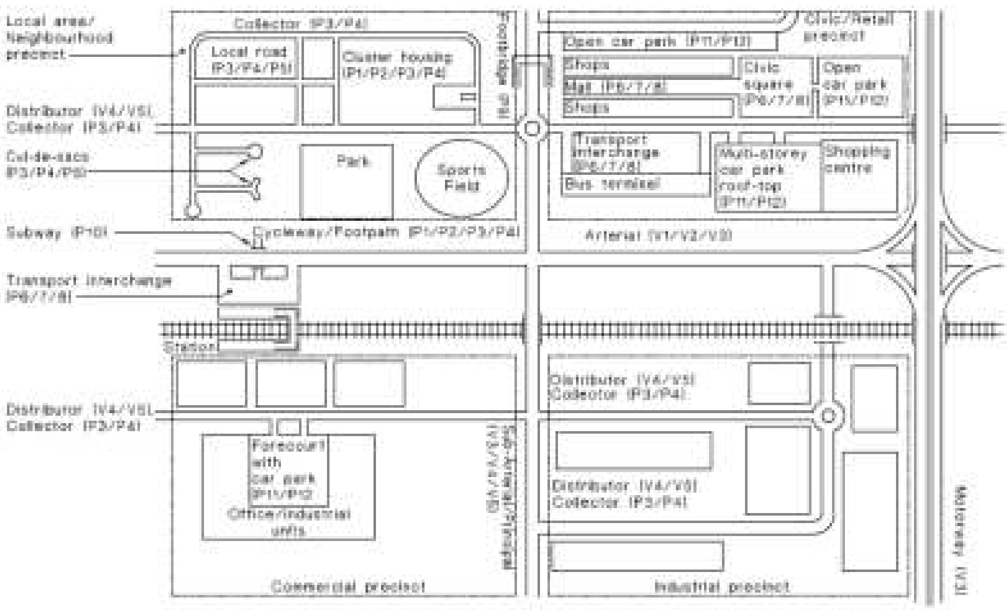


Figure 2: Example road and public space types and indicative lighting categories and subcategories (ASNZS1158.1.1:2005, p.8)

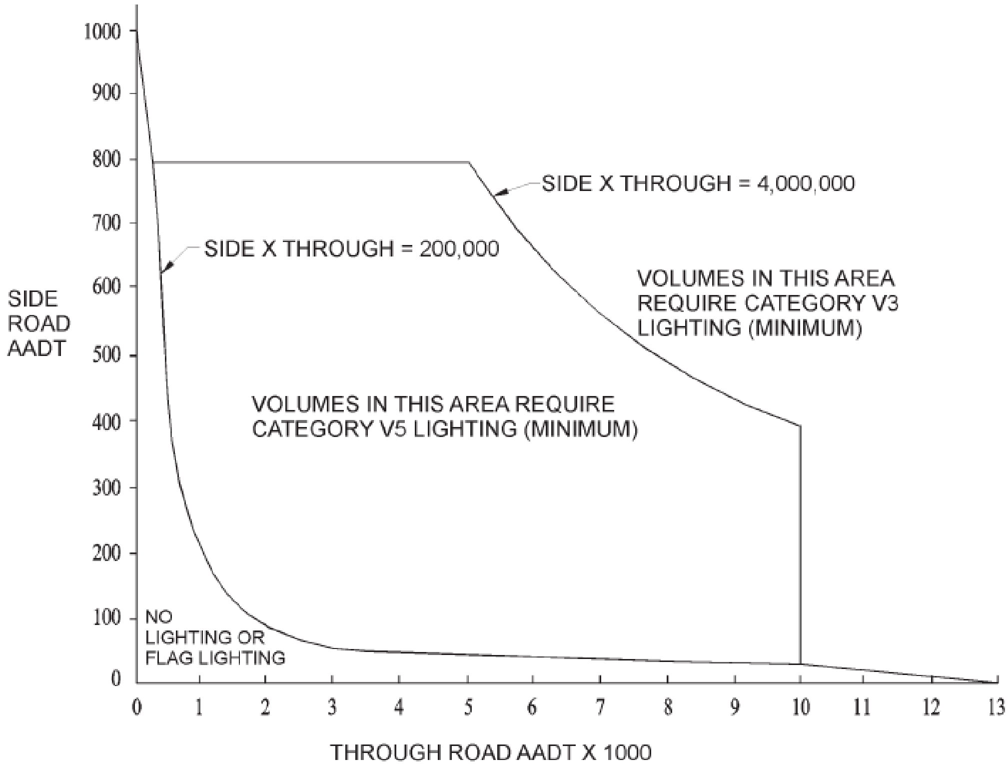


Figure 3: Warrants for Consideration of Road Lighting at Intersections (Department of Transport and Main Roads 2004, p.17-4)

Sub Section	Typical Example	Application
V3		Applied for highways and major arterial roads that carry high through traffic volume with no access for traffic between interchanges
V5		For sub arterial or principle roads that predominantly carry moderate to low speed through traffic from one region to another

Figure 4: Subcategories of Category V Lighting utilised by Queensland DNSPs (Taylor 2012, p.21)

Sub Section	Typical Example	Application
P3 - 4		Local collection roads used for accessing abutting properties and common areas, pedestrian path and cycle ways.
P5		Local roads used for accessing abutting properties and common areas
P6 - 8		Outdoor shopping precincts, malls, open arcades, town squares, civic centres , transport terminals and interchanges
P9		Stairs and ramps
P11		Public car park spaces, aisles, circulation roadways. There are three sub categories for this category.
P12		Designated parking spaces specifically intended for people with disabilities

Figure 5: Subcategories of Category P Lighting utilised by Queensland DNSPs (Taylor 2012, p.22)

Once the lighting category has been chosen the following step is to specify the technical parameters which will be used in the lighting design. Table 3 and Table 4 outline the technical parameters used for designing Category V and Category P roads respectively.

Table 3: Lighting technical parameters used in Category V designs (AS/NZS 1158.1.1:2005, p.10)

Parameter	Symbol
Upward waste light ratio	$UWLR$
Average carriageway luminance	$\bar{L}$
Overall uniformity	U_O
Longitudinal uniformity	U_L
Threshold increment	TI
Surround (verge) illuminance ratio	E_S
Point illuminance	E_{PH}
Illuminance (horizontal) uniformity Cat V	U_{EI}

Table 4: Lighting technical parameters used in Category P designs (AS/NZS 1158.3.1:2005, p.14)

Parameter	Symbol
Average horizontal illuminance	$\overline{E_h}$
Point horizontal illuminance	E_{Ph}
Illuminance (horizontal) uniformity Cat P	U_{E2}
Point vertical illuminance	E_{Pv}

The design values of these technical parameters varies based on the road category and subcategory. For Category V roads, the use of certain technical parameters is determined by the design method used which is based on the road element being lit (Refer Table 5). There are three design methods;

- The use of design rules specified in the standard.
- Illuminance based computer calculations.
- Luminance based computer calculations.

For Category P roads, all of the technical parameters are used in all situations (Refer Table 6). The luminaire types specified have certain glare and upward waste light ratio criteria. The design methods used in Category P designs are;

- The use of design rules specified in the standard.
- Illuminance based computer calculations.

It is quite common for lighting designs to utilise several different design methods and technical parameter values as the geometry of individual roads is usually quite complex and there are often intersections with different category and subcategory roads.

Table 5: Values of Light Technical Parameters for Category V Lighting (AS/NZS 1158.1.1:2005, p.15)

1	2	3	4	5	6	7	8	9	10
Lighting subcategory	Light technical parameters								
	For straight sections, curves and intersections						For intersections and other specified locations		For all applications
	Average carriageway luminance[c),d)] ($\overline{L}$) cd/m²	Overall uniformity[c),d)] (U_o)	Longitudinal uniformity[d)] (U_L) In Australia	Longitudinal uniformity[d)] (U_L) In New Zealand	Threshold increment[e)] (TI) %	Surround verge illuminance[d)] (U_s) %	Point horizontal illuminance[c),d)] (E_{ph}) lx	Illuminance (horizontal) uniformity[e)] Cat V (U_{E2})	Upward waste light ratio[e)] (UWLR) %
V1	1.5	0.33	0.5	0.3	20	50	15	8	3
V2	1.0	0.33	0.5	0.3	20	50	10	8	3
V3	0.75	0.33	0.5	0.3	20	50	7.5	8	3
V4[b)]	0.5	0.33	0.5	0.3	20	50	5	8	3
V5	0.35	0.33	0.5	0.3	20	50	3.5	8	3

a) The calculated value for U_o may be less than 0.33, provided the corresponding value for $\overline{L}$ is 10% or more above the specified minimum, but shall in no case be less than 0.31.

b) V4 is the minimum subcategory recommended for application in New Zealand.

c) These values are maintained.

d) Compliance is achieved by being greater than or equal to the applicable table value.

e) Compliance is achieved by being less than or equal to the applicable table value.

NOTES:

1 For the purpose of determining compliance with Table 2.2, the specified light technical parameters should be taken as being justified to two decimal places.

2 See Table 2.1 for typical applications of each of the lighting subcategories for which light technical parameters are specified.

3 The specification of separate requirements for U_L in Australia and New Zealand arises from differences in the method of calculating this parameter, particularly the assumed observer position chosen (see Clauses 3.2.1 and 3.3.2).

4 See Section 3 for the design methods and requirements for use in assessing compliance with the specified light technical parameters.

Table 6: Values of Light Technical Parameters and Permissible Luminaire Types for Roads in Local Areas and for Pathways (AS/NZS1158.3.1:2005, p.18)

1	2	3	4	5	6
Lighting subcategory	Light technical parameters				Permissible luminaire type (see Table 2.10)
	Average horizontal illuminance[a,b)] ($\overline{E}_h$) lux	Point horizontal illuminance[a,b)] (E_{Ph}) lux	Illuminance (horizontal) uniformity[c)] Cat. P (U_{E2})	Point vertical illuminance[a,b)] (E_{Pv}) lux	
P1	7	2	10	2	Type 4 where part of a road reserve or Types 2, 3, 4 or 6 elsewhere
P2	3.5	0.7	10	0.7	
P3[e)]	1.75	0.3	10	0.3[d)]	
P4[e)]	0.85	0.14	10	N/A	
P5[e)]	0.5	0.07	10	N/A	

a) These values are maintained.

b) Compliance is achieved by being greater than or equal to the applicable table value.

c) Compliance is achieved by being less than or equal to the applicable table value.

d) The vertical illuminance requirement only applies when subcategory P3 is selected for application to pathways, i.e. it does not apply for local roads.

e) The values for New Zealand for subcategories P3 and P3R are also subject to the lamp source lumen derating values as per Clause 2.6. The New Zealand values are as per the table below. In New Zealand, when the luminaires are to be supported on existing reticulation poles, the subcategories P3R and P4R may be designated and the following reduced levels applied:

2.1.4. Road Lighting and the Law

AS/NZS 1158 is not a legal document.

> "[AS/NZS 1158] is a voluntary standard that is commonly complied with nationally, particularly in new developments. In existing (commonly rural or urban fringe) areas it is common to have areas which do not comply with these standards. The reason for this compliance is most likely due to risk of claims against street lighting providers if accidents occur." (Ironbark Sustainability 2011, p.3)

A legislation search on the Australasian Legal Information Institute website confirms that the standard is referenced in various legislation such as the *State Environmental Planning Policy (Infrastructure) 2007* (New South Wales Department of Planning and Infrastructure 2007) which refers to the UWLR standards specified in AS/NZS1158. Councils also specify compliance with AS/NZS1158 in planning schemes associated with new developments.

A case law search on the Australasian Legal Information Institute website confirms that the standard is referenced in court cases associated with road crashes. The standard of road lighting was questioned in the case *Estephan v Lynsey Finch and Ors* (2007) where the standard of lighting at an intersection was questioned when building a case against the Liverpool City Council.

2.2. Road Lighting Technology

Table 7 compares the options available for lamp types and their characteristics. LEDs, New Generation Metal Halide and Compact Fluorescents have dimming capabilities. In recent times LED technologies have improved and Table 8 details the technical characteristics of Philips LED Roadster lamps with efficacy up to 98 lm/W.

Table 7: Lamp Types and Characteristics (RightLight 2011)

Lamp type	**Typical efficacy** (lumens/lamp watt)	**Colour appearance** (^{o}K)	**Colour rendition**	**Typical lamp service life** (hours[1])	**Comments**
High Pressure Sodium (HPS) E = Elliptical T = Tubular Super T = Tubular High output * denotes lamps with internal igniters	50W – E – 70 lm/W 50W – T – 88 lm/W 70W – E – 80 lm/W 70W – T – 94 lm/W 100W – E – 85 lm/W 100W – T – 107 lm/W 110W – E – 72 lm/W * 150W – E – 97 lm/W 150W – T – 116 lm/W 210W – E – 86 lm/W * 220W – E – 91 lm/W * 250W – E – 108 lm/W 250W – T – 133 lm/W 400W – E – 120 lm/W 400W – T – 141 lm/W	Warm yellow 2000^{o}K	Acceptable	16,000 to 20,000	High efficacy, large range of wattages. Long lamp life. Main lamp used in most types of road lighting upgrades. Universal lamp burning position.
Metal Halide (MH) (Only ceramic MH lamps are shown as these have longer life, higher output and less colour shift than quartz MH lamps)	G12 35W – 92 lm/W G12 70W – 97 lm/W E27 70W – 97 lm/W E40 150W – 98 lm/W E27 70W – 89 lm/W E27 100W–90 lm/W E27 150W – 98 lm/W E40 250W – 105 lm/W	Warm white to white 3000^{o}K - 4200^{o}K	Very good to excellent	8,000 to 12,000[3]	Large range of different lamp base types and wattages. High efficacy. Can be retrofitted to operate off sodium control gear in certain situations where white light is desirable. Some MH lamps can have colour shift (appearance) over life. Orientation of lamp can impact on lamp life. Some MH lamps must only be used in enclosed luminaires.
New Generation Metal Halide (NGMH) e.g. CosmoPolis or UrbanWhite	45W – 95 lm/W 60W – 114 lm/W 90W – 116 lm/W 140W – 118 lm/W	Warm white 2600^{o}K – 2850^{o}K	Very good to excellent	12,000 to 16,000	High efficiency, natural white light colour. Orientation of lamp can impact on lamp life. Medium lamp life, smaller physical sized lamp may mean smaller luminaire and easier end-of-life disposal. Electronic control gear available for stepped dimming.
Compact Fluorescents (CFLs)	26W – 65 lm/W 32W – 75 lm/W 42W – 69 lm/W 57W – 69 lm/W	Warm white to cool white 2700^{o}K – 4000^{o}K	Very good to Excellent	8,000 to 12,000	Ideal for smaller luminaires or feature lighting. Light output is dependent on ambient luminaire temperature 10^{o} C – 70^{o} C. Lamp holders and lamp can be subject to vibration due to size of lamp. Control gear available for dimming applications.
Linear Fluorescent	1 x 20W T12 38mm 55 lm/W 1 x 30W T12 38mm 70 lm/W 1 x 18W T8 26mm 75 lm/W 1 x 30W T8 26mm 80 lm/W 1 x 36W T8 26mm 93 lm/W 1 x 14W T5 16mm 86 lm/W 1 x 24W T5 16mm 73 lm/W 1 x 39W T5 16mm 79 lm/W 1 x 49W T5 16mm 78 lm/W 1 x 54W T5 16mm 73 lm/W	Warm white to daylight. 2700^{o}K – 6500^{o}K	Very good to excellent, large range of colour properties available	T12 - 6000 to 8000 T8 - 10,000 to 12,000 T5 - 16,000 to 18,000	Difficult to control light distribution within luminaires. Electronic control gear is available for control purposes; and coloured lamps are also available for effect lighting. The operating temperature of T5 lamps influences the maximum luminous flux and service life. Pre-heat control gear should be used to achieve desired service life.
LED [2] (lamp efficacy includes control gear or driver losses therefore it is difficult to compare with other lamp types)	30 LEDs 60W 55-42 lm/W 80 LEDs 159W 56-42 lm/W 120 LEDs 234W 57-43 lm/W (efficacies based on 3500^{o}K – 6000^{o}K LEDs, other colour temperature LEDs are available)	White to daylight 3500^{o}K – 6000^{o}K	Excellent	50,000 [2]	Long life, high output. Difficult to control light distribution via reflector or optics (very directional). Light output and life affected by operating temperature. Solid state no gas or filaments. Output easily adjusted or can be dimmed with no detrimental effect. Low disposal costs. Instant start, no warm up or cool down period.
Incandescent	75W 12 lm/W 100W 13 lm/W 150W 14 lm/W 200W 15 lm/W	Warm 2700^{o}K	Good	1,000	Common lamp, cheap but very short lamp life. Not often used in road lights but can be found within Belisha beacons on pedestrian crossings.
Mercury Vapour	50W – 40 lm/W 80W – 50 lm/W 125W – 54 lm/W 250W – 56 lm/W 400W – 60 lm/W 160W self ballast – 19 lm/W 250W self ballast – 22 lm/W	White 3400^{o}K	Good /poor	12,000 plus	Lumen depreciation is rapid in early life. Universal lamp position. High disposal costs due to chemical composition. An inefficient lamp that should no longer be used for new installations.
Low Pressure Sodium (LPS)	SOX18 – 100 lm/W SOX35 – 131 lm/W SOX55 – 147 lm/W SOX90 – 150 lm/W SOX135 – 167 lm/W	Monochromatic yellow	Poor	12,000 to 16,000	High efficacy but poor colour rendition. Has been superseded by technology. Physically a large lamp requiring a large luminaire. Generally no longer used for road lighting (only used for specific applications).
Induction	QL55W – 65 lm/W QL85W – 70 lm/W	Warm white 3000^{o}K	Very good	60,000	Extremely long life with good efficiency and instant start. Used in situations where lamp replacement is expensive. Physically a large size lamp requiring a large luminaire. Can be used on DC systems.

Table 8: Philips Roadstar Technical Information (Philips 2013)

Lamp technical information for GPLS GPLM

LED = Philips Lumileds Rebel ES, CRI = 70, CCT = 4000K (+/- 350K)

LED rated life = 100,000 hrs [1] - Driver rated life = 50,000 hrs

Luminaire	Lamp	Typical delivered lumens [2]		Typical lamp wattage (W)	Typical system wattage [3] (W)	Typical current @ 120 V (A)	Typical current @ 240 V (A)	Typical current @ 277 V (A)	LED current (mA)	HPS equivalent [4]	Luminaire Efficacy Rating (Lm/W)	
		Full Cutoff	Hyper Extensive								Full Cutoff	Hyper Extensive
GPLS	40W30LED4K-ES	3605	3680	40	45	0.38	0.19	0.16	400	50 W	80	82
	60W30LED4K-ES	4340	4530	60	68	0.57	0.28	0.25	600	70 W	64	67
	40W49LED4K-ES	4490	4585	42	47	0.39	0.20	0.17	285	70 W	96	98
	65W49LED4K-ES	6005	6135	65	72	0.60	0.30	0.26	428	100 W	83	85
	90W49LED4K-ES	7195	7345	90	102	0.85	0.43	0.37	571	100 W	71	72
GPLM	105W79LED4K-ES	9380	9445	105	119	0.99	0.50	0.43	428	150 W	79	79
	150W79LED4K-ES	11450	11695	150	170	1.42	0.71	0.61	600	200 W	67	69
	130W98LED4K-ES	12015	12290	130	147	1.23	0.61	0.53	428	200 W	82	84
	180W98LED4K-ES	14390	14695	180	204	1.70	0.85	0.74	571	250 W	71	72

2.3. Road Lighting and its Effectiveness in Crash Reduction

Joint Technical Committee LG-002 (2005) state that the facilitation of safe movement is one of the principal objectives of road lighting. Category V lighting is used on roads where the requirements of motorists are dominant and crash reduction is priority.

> "Category V lighting is acknowledged to be an effective accident counter-measure. It has been demonstrated that Category V lighting can provide significant community benefits and that the costs involved in providing the lighting can be offset by the financial returns from the reduction in road accidents. Studies in Australia and New Zealand, and in other countries, have led to the conclusion that Category V traffic route lighting is likely to reduce night time casualty accidents by about 30%, taken over the road network." (Joint Technical Committee LG-002 2005, Part 1.1, p.3)

Category P lighting is not intended to reduce crashes with Joint Technical Committee LG-002 (2005) stating that

> "…with certain exceptions, [Category P lighting] not meant to provide drivers with adequate visibility if motor vehicle traffic is present at the location; for this the vehicle headlights are used. The exceptions are where there is interactive pedestrian and vehicular activity present in designated areas, e.g. transport interchanges, car parks." (Joint Technical Committee LG-002 2005, Part 3.1, p.6)

The 30% reduction in night time crashes is a commonly quoted figure which is based on the results of several studies. The Austroads Technical Report – Road Safety Engineering Risk Assessment Part 6: Crash Reduction Factors (Turner, Imberger, Roper, Pyta & McLean 2010) reviews a number of studies and has compiled the following night time crash reduction percentages for new road lighting installations based on location:

- All Sites – 35% Reduction, Medium Confidence
- Intersections – 50% Reduction, Medium Confidence
- Mid-Block – 40% Reduction, Medium Confidence
- Rural – 30% Reduction, Low Confidence
- Urban – 30% Reduction, Low Confidence
- Rural Intersection – 40% Reduction, Medium Confidence
- Urban Intersection – 20% Reduction, Low Confidence

The road surface average luminance also has an effect on the effectiveness of road lighting. Quantifying the impact of road lighting on road safety – A New Zealand Study (Jacket & Firth 2012) investigates the dose-response relationship between luminance and crashes. The study delves further to investigate this relationship with various road conditions (wet and dry), traffic volumes, locations (mid-block and intersections), and time of the night (pre and post-midnight). The results were graphed as follows:

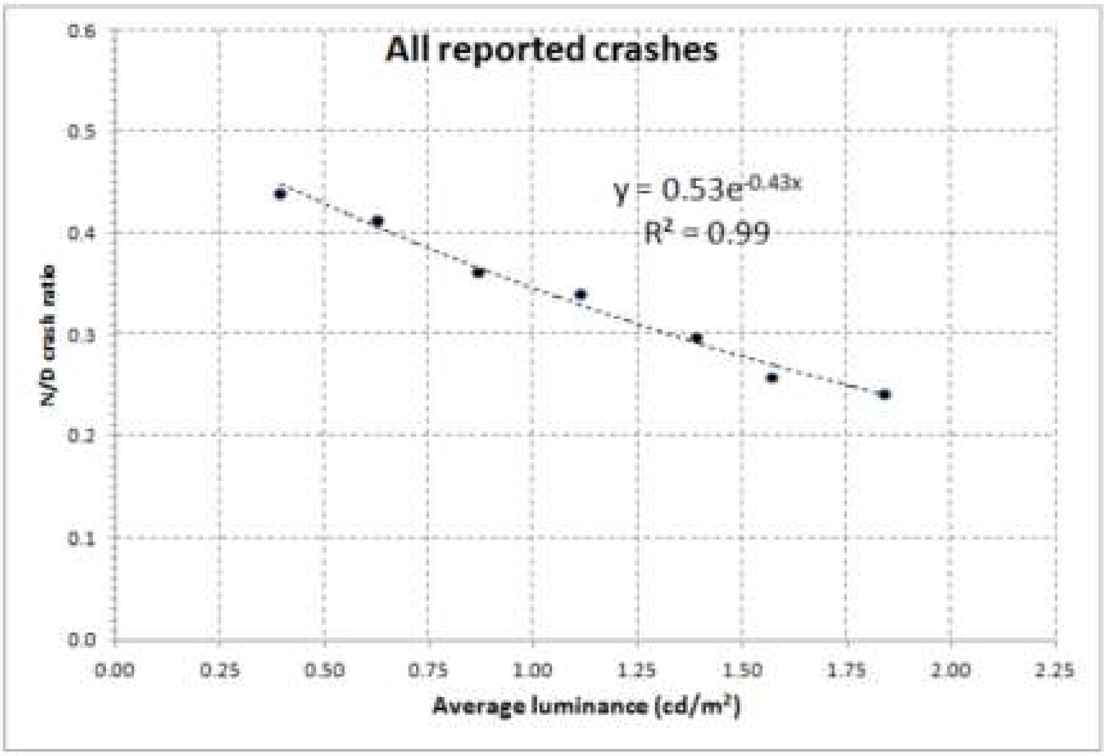


Figure 6: The relationship between average luminance and the night to day crash ratio for all reported crashes. (Jacket & Firth 2012, p.6)

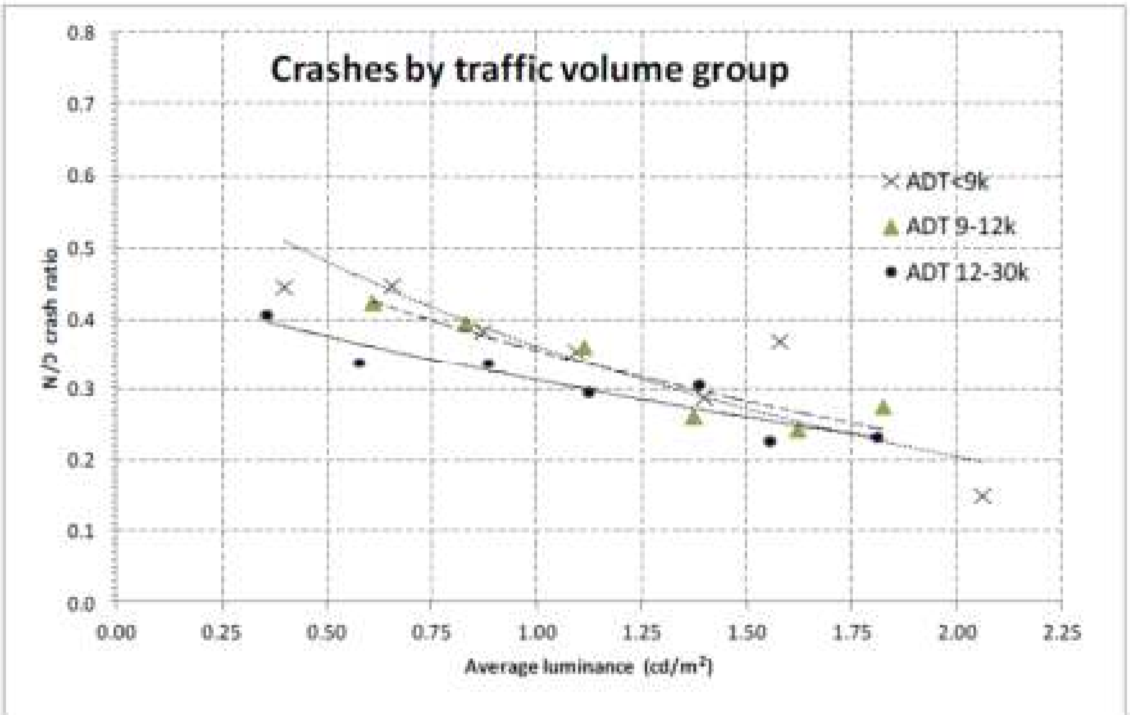


Figure 7: The relationship between average luminance and the night to day crash ratio for three groups of road according to traffic volume (ADT). (Jacket & Firth 2012, p.6)

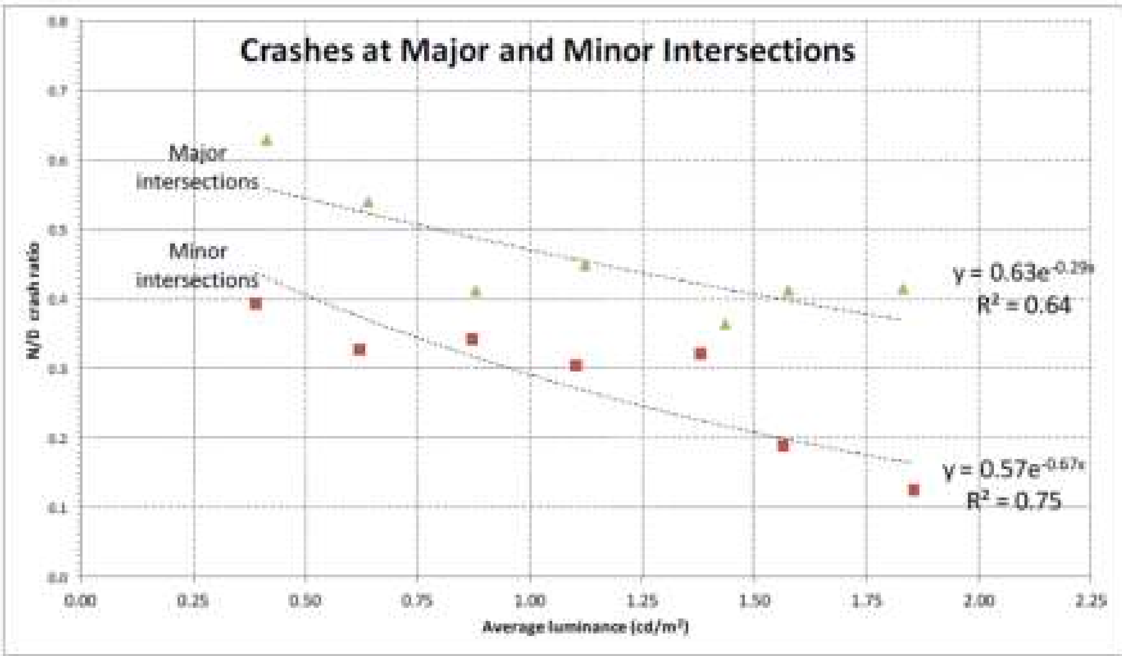


Figure 8: The relationship between average luminance and the night to day ratio for intersection crashes for Major (traffic signals and roundabouts), Minor (other intersections). (Jacket & Firth 2012, p.7)

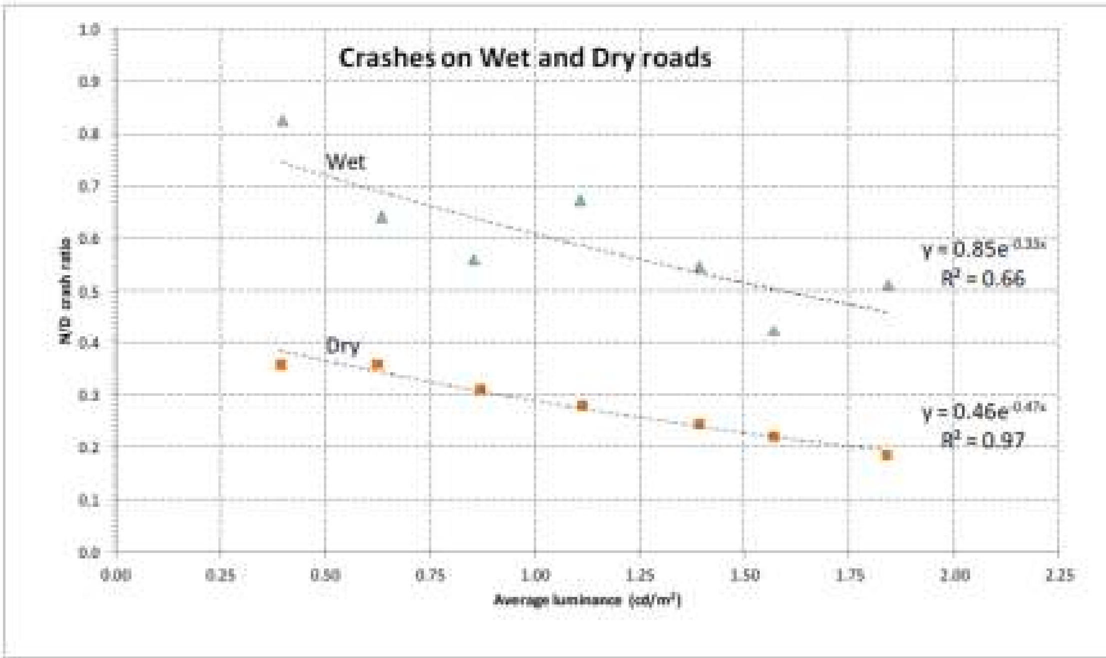


Figure 9: The relationship between average luminance and the night to day ratio for crashes on both wet roads and dry roads. (Jacket & Firth 2012, p.8)

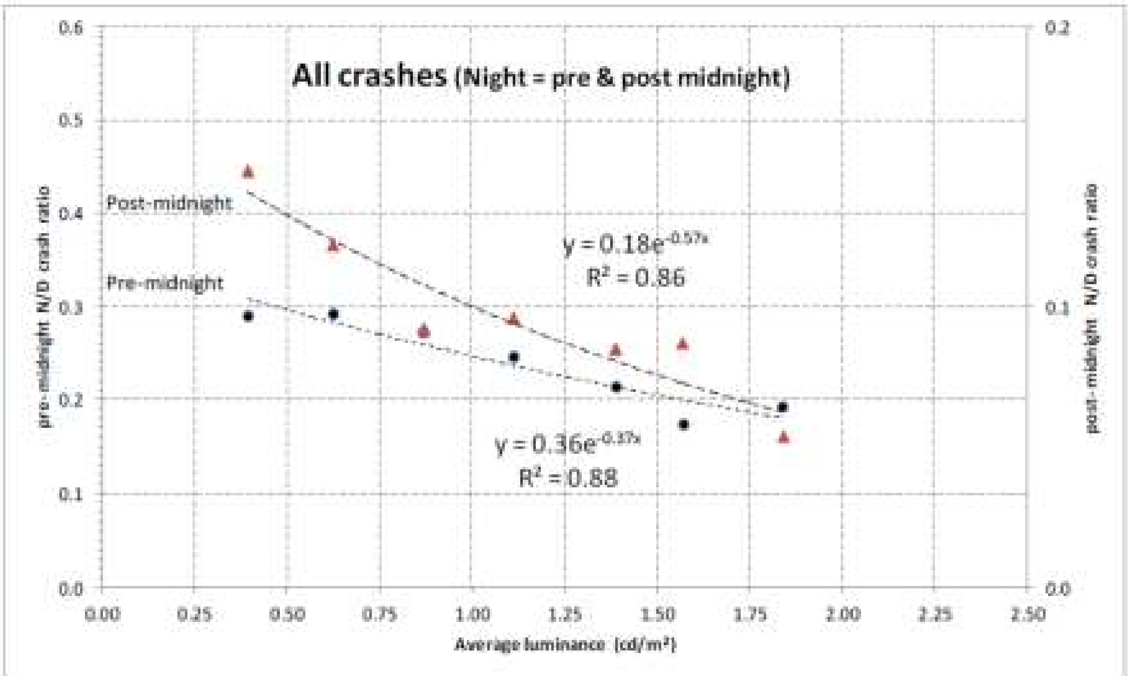


Figure 10: The relationship between average luminance and the ratio of night crashes (pre and post-midnight) to day crashes. Note the two curves are plotted on different axes as there are 3 times more crashes pre-midnight than post-midnight. (Jacket & Firth 2012, p.9)

This report demonstrates that the average luminance has a direct correlation with the night/day crash ratio. From these results and the choice of lighting category and subcategory an assumed night/day crash ratio can be assumed.

2.4. Road Lighting and Public Safety

Joint Technical Committee LG-002 (2005) states that the discouragement of illegal acts is one of the principal objectives of road lighting. It is important that any reduction in lighting standards has little or no negative effect on public safety.

> "There are two main theories of why improved street lighting may cause a reduction in crime. The first suggests that improved lighting leads to increased surveillance of potential offenders (both by improving visibility and by increasing the number of people on the street) and hence to increased deterrence of potential offenders. The second suggests that improved lighting signals community investment in the area and that the area is improving, leading to increased community pride, community cohesiveness, and informal social control." (Welsh, & Farrington 2008, p.2)

As discussed in Section 2.6, several cities have implemented programs to reduce the standard of lighting on their streets and roads. To justify this, councils have used one of two methods; reassurance that crime rates will be closely monitored in affected areas after implementation and/or referring to research undertaken which concludes that there is little or no correlation between lighting and crime. The National Evaluation Phase 1 Summary Report (1977) was developed by the United States Department of Justice and is a research paper that investigates the link between street lighting and crime. The report has been used by councils to justify the lighting reduction programs by quoting the following conclusion:

> "Although there is no statistically significant evidence that street lighting impacts the level of crime, especially if crime displacement is taken into account, there is a strong indication that increased 1ighting--perhaps lighting uniformity--decreases the fear of crime." (Tien, O'Donnell, Barnett, & Mirchandani 1977, p.93)

However report continues on to note that even with reliable and uniform data the research techniques used in the report could not have definitively concluded that lighting and crime were interrelated and recommends that funding for street lighting projects for the purpose of deterring crime is continued.

A 2008 systematic review of available research evidence titled "Effects of Improved Street Lighting on Crime" undertaken by Dr Brandon C Welsh, (Professor of Criminal

Justice and Criminology at the University of Massachusetts Lowell) and Dr David P Farrington (Professor of Psychological Criminology at Cambridge University) concluded that the research indicated that:

> "…improved street lighting significantly reduces crime, is more effective in reducing crime in the United Kingdom than the United States, and that night time crimes do not decrease more than daytime crimes"

The reviewers continue by recommending that

> "…improved street lighting should continue to be used to prevent crime in public areas. It has few negative effects and clear benefits for law-abiding citizens."

Even though conflicting conclusions can be sourced from individual research papers not linked to this review (such as the Chicago Alley Lighting Project (2000) which reported a significant increase in crime after lighting was improved) the comprehensive nature of the review affirms the validity of its conclusions.

Joint Technical Committee LG-002 (2005) state that Category P lighting is acknowledged to be an effective counter both to the occurrence of crime and to the fear of crime. Depending on the type of road, the subcategory P1, can be considered effective for areas with a High risk of crime. Similarly, subcategories P2 and P3 can be considered effective for areas with a Medium risk of crime.

2.5. Temporal Patterns of Traffic Volumes, Road Crashes and Crime

2.5.1. Temporal Patterns of Traffic Volumes

Different sites usually experience differing temporal patterns of traffic. This is due to origin and destination demand of different streets, suburbs and cities. Most roads follow a very similar pattern of temporal flow due to universal factors such as similar working hours (9 to 5 working day), sleeping times, socialising (nights on weekends) and shopping times (days and afternoons on weekends). As the majority of the population follow this pattern, temporal flows of traffic for the entire road network can be assumed to follow a pattern. This pattern is evident in Figure 11 where the traffic volumes at a number of sites in the Twin Cities Metropolis Area (USA) were investigated.

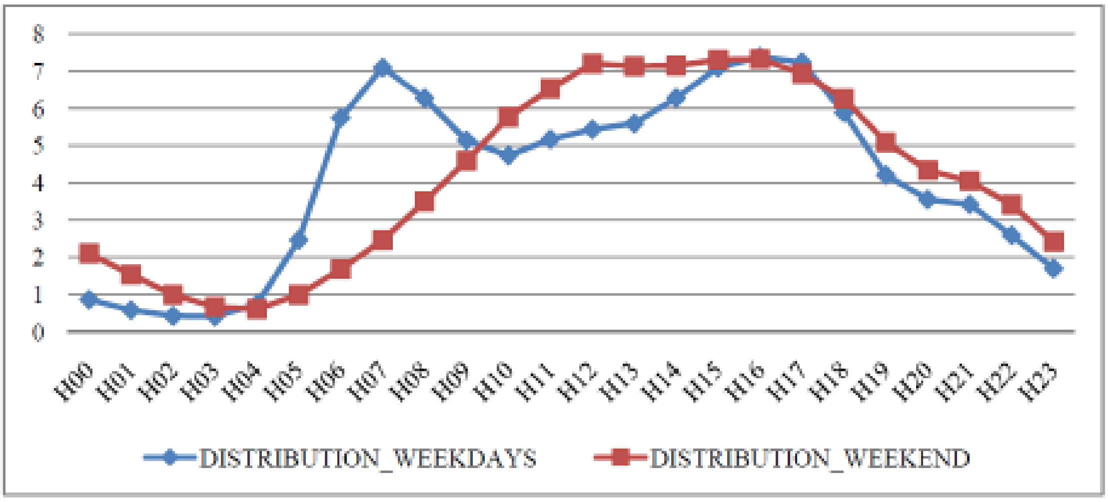


Figure 11: Distribution of Average Total Traffic Volume - Weekdays and Weekends (Kim, Park & Sang 2008, p.14)

2.5.2. Temporal Patterns of Road Crashes

The 2009 Road Traffic Crashes in Queensland report (CONROD 2012) shows a clear relationship between number of fatalities and hospitalisation crashes, time of day and day of week. The data in table form is shown in Table 9 and Table 10, and in graph form in Figure 12 and Figure 13. Similarly to the temporal distribution of traffic, road crashes are shown to follow different patterns on weekdays compared to weekends.

Table 9: All Road Fatalities by Time of Day, Queensland 2004-2009 (CONROD 2012, p.29)

Time	2004	2005	2006	2007	2008	2009		2009 v 2008		2009 v 2004 to 2008 average	
	No.	No.	No.	No.	No.	No.	%	Change	%	Change	%
Midnight-2am	16	18	19	33	17	21	6.3%	4	23.5%	0.4	1.9%
2am-4am	21	24	23	17	19	15	4.5%	-4	-21.1%	-5.8	-27.9%
4am-6am	22	24	13	22	13	21	6.3%	8	61.5%	2.2	11.7%
6am-8am	25	18	23	24	24	27	8.2%	3	12.5%	4.6	20.5%
8am-10am	22	25	16	20	16	29	8.8%	13	81.3%	9.2	46.5%
10am-noon	16	33	26	30	30	23	6.9%	-7	-23.3%	-4.0	-14.8%
Noon-2pm	33	21	32	33	28	36	10.9%	8	28.6%	6.6	22.4%
2pm-4pm	38	51	44	48	46	46	13.9%	0	0.0%	0.6	1.3%
4pm-6pm	40	39	43	45	40	44	13.3%	4	10.0%	2.6	6.3%
6pm-8pm	41	32	40	32	32	25	7.6%	-7	-21.9%	-10.4	-29.4%
8pm-10pm	23	24	30	29	23	22	6.6%	-1	-4.3%	-3.8	-14.7%
10pm-midnight	14	23	26	27	40	22	6.6%	-18	-45.0%	-4.0	-15.4%
Total	**311**	**330**	**335**	**360**	**328**	**331**	**100.0%**	**3**	**0.9%**	**-1.8**	**-0.5%**

Table 10: All Hospitalised Casualties by Time of Day, Queensland 2004-2009 (CONROD 2012, p.48)

Time	2004	2005	2006	2007	2008	2009		2009 v 2008		2009 v 2004 to 2008 average	
	No.	No.	No.	No.	No.	No.	%	Change	%	Change	%
Midnight-2am	243	287	228	231	267	255	3.8%	-12	-4.5%	3.8	1.5%
2am-4am	143	161	149	176	175	177	2.7%	2	1.1%	16.2	10.1%
4am-6am	223	234	226	246	240	265	4.0%	25	10.4%	31.2	13.3%
6am-8am	444	454	439	480	551	557	8.3%	6	1.1%	83.4	17.6%
8am-10am	639	669	644	641	747	676	10.1%	-71	-9.5%	8.0	1.2%
10am-noon	664	631	584	633	683	718	10.8%	35	5.1%	79.0	12.4%
Noon-2pm	660	666	614	613	682	732	11.0%	50	7.3%	85.0	13.1%
2pm-4pm	892	870	885	820	998	993	14.9%	-5	-0.5%	100.0	11.2%
4pm-6pm	962	987	841	915	1,058	952	14.3%	-106	-10.0%	-0.6	-0.1%
6pm-8pm	619	682	548	598	657	628	9.4%	-29	-4.4%	7.2	1.2%
8pm-10pm	385	366	391	376	387	370	5.5%	-17	-4.4%	-11.0	-2.9%
10pm-midnight	354	302	338	326	393	349	5.2%	-44	-11.2%	6.4	1.9%
Total	**6,228**	**6,309**	**5,887**	**6,055**	**6,838**	**6,672**	**100.0%**	**-166**	**-2.4%**	**408.6**	**6.6%**

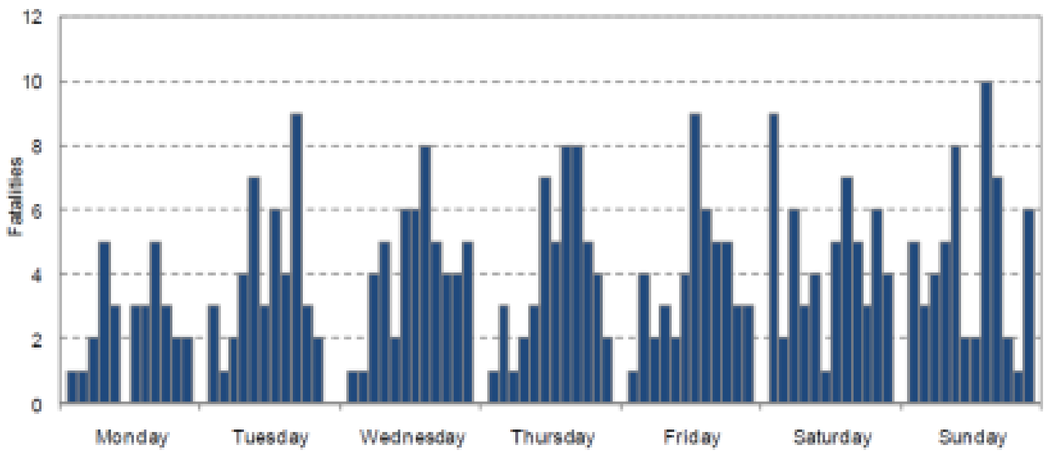


Figure 12: Fatalities by Time of Day and Day of Week Queensland, 2009 (CONROD 2012, p.29)

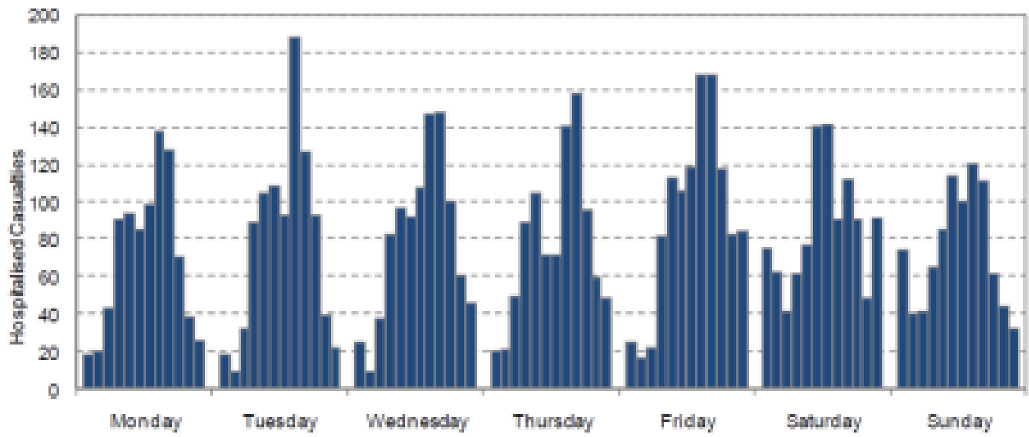


Figure 13: Hospitalised Casualties by Time of Day and Day of Week Queensland, 2009 (CONROD 2012, p.47)

2.5.3. Temporal Patterns of Crime

Different types of crimes experience different temporal patterns. The Crime Statistics 2011/2012 report (Victoria Police 2012) includes graphs of showing the temporal trends in recorded crime during 2011/2012 fiscal year (Refer APPENDIX B). From this data it is evident that different crime types experience different temporal patterns. The following crimes clearly experience the highest percentage of offences during the late hours of the night where street lighting during this time could possibly have a positive impact on these statistics:

- Rape
- Arson
- Property Damage
- Burglary (Aggravated)
- Burglary (Other)
- Theft from Motor Vehicle
- Theft of Motor Vehicle

Although the report does discuss crimes by geographic location, further investigation could be carried out with these statistics to review the likelihood of the crimes listed above based on the standard of lighting in these localities.

2.6. Strategies Implemented Worldwide to Reduce Road Lighting Electricity Consumption

Street light reduction programs have been implemented in many councils worldwide. Those listed here are only a few of the many who have implemented programs.

2.6.1. City of Colorado Springs

Program Outline (Leavitt 2012)

- Turning off 8,000 to 10,000 streetlights to save money.
- Yearly savings of over $1.2 million.
- Least energy efficient streetlights targeted (Mercury Vapour).
- Lights kept on at
    - Signalised intersections.
    - Mid-block crosswalks.
    - School areas.

2.6.2. City of Santa Rosa

Program Outline (City of Santa Rosa 2013)

- Yearly savings of $400,000.
- Estimated greenhouse gas reduction of 1,000 tons
- All lights kept on at
  - signalised intersection
  - pedestrian crosswalks
  - high pedestrian zones
- One light will remain on at
  - Un-signalised intersections.
  - Key traffic safety locations where there has been a documented history of traffic safety issues.
- Programmable photocell timers will be installed on remaining street lights.
- Referred to Street Lighting Projects - National Evaluation Program Phase I Report for justification regarding reduced crime.

2.6.3. Essex County

Program Outline (Essex County Council 2012)

- Implemented to save money, reduce carbon emissions and light pollution.
- Part night lighting involving some lights being switched off between 12am and 5am.
- Pilot scheme resulted in no increase in recorded crime and delivered energy savings of 20%.
- Lights kept on at
  - Major lit inter urban dual carriageway traffic routes.
  - Conflict sites e.g. roundabouts, lit by columns greater than 6m high.
  - Sites where street lights installed for accident remedial measures.
  - Town Centre type development where there is one or more of the following features: CCTV sites; High proportion of high security premises (e.g. banks, jewelers etc.); High crime risk; High

concentration of people at night such as Transport interchanges, nightclubs etc.

- Main approaches to areas defined in the section above, where there is a mix of development between residential and commercial/industrial i.e. not exclusively residential.
- Sites where the police can demonstrate that there will be an increase in crime if the lights are switched off.
- Remote footpaths and alleys linking residential streets.
- Where there is a statutory requirement. Where the configuration of street lighting columns is considered excessive, consideration is to be given to removing 1 in 2 lights with the remaining lights left on full night operation

2.7. Discussion

By reviewing the available literature, it is evident that there is definitely scope to implement a scheme to reduce road lighting standards during times associated with low traffic volumes. Such schemes have been successfully implemented in other countries with significant financial and environmental benefits. It is clear that reducing standards will definitely increase the number of road crashes and will very likely increase crime rates if lighting is reduced below P category standards. As can be seen in Figure 6, Figure 7, Figure 8, Figure 9, and Figure 10, the level of luminance and day/night crash ratio follows the form of exponential decay which means that the law of diminishing return applies as the level of illumination increases.

In order to implement such a proposal, a system must be put in place to provide councils and engineers a set of prescriptive standards to work by to reduce the risk of litigation. The greater community must also agree with the intent of and justification for the proposal where support could be obtained through savings to council rates. Furthermore, community support and awareness of the scheme could result in increased alertness when driving during times of reduced standards, resulting in improvements in crash data.

Reducing standards could be done in many ways depending on the existing infrastructure and the financial support for such projects. For example, replacing existing lamps with LEDs would have significant upfront costs however would result in significantly greater cost and greenhouse gas emission savings over time due to the technologies energy efficiency and extended lifespan. LED's ability to be dimmed would mean that when the lighting standard is reduced, the uniformity of illumination would remain constant. On the other hand, by retaining the existing lamps and turning a percentage (say half) when the reduction scheme is in force, would require a much less initial investment however the uniformity of illumination would be modified significantly, especially if done in areas which require illuminance based design.

Although, not mentioned in Section 2.5.2, the AUSTROADS report titled Road Safety Engineering Risk Assessment Part 6: Crash Reduction Factors (2010) also gave expected crash reduction rates for other treatments (e.g. installation of RRPM's has been shown to result in a 5% crash reduction (p.37) while improving site distance has been shown to achieve a 30% crash reduction(p.96)). While these crash reduction percentages are not guaranteed, incorporating such upgrades with a lighting reduction scheme could mitigate the negative effects of reduced standards.

CHAPTER 3– METHODOLOGY

The research and work undertaken for this project has followed the following methodology:

1. Crash Data Analysis – In order to find justification for or against the proposal the nature of night time crashes needs to be investigated further. Data has been obtained from TMR and will be used to find noteworthy relationships between the temporal patterns of traffic volumes and road crashes.
2. Site Selection – This involved selecting a number of sites which were considered "possibly" appropriate for implementing a dimming treatment. After the sites were selected, information on these sites was sourced from site inspections and "as constructed" data. The sites with the greatest potential for the proposal were chosen.
3. Base Layouts – AutoCAD software was used to create base layouts of the subject sites using aerial photography and information obtained from "as constructed" drawings and site inspections.
4. Review Existing Lighting Arrangements – Lighting designs were undertaken using the Perfect Lite software package and isolux drawings were produced using TMR's internal AutoCAD lighting design plugin. Where the existing lighting arrangements did not conform to the current standards, the existing layouts were modified so that the target standard of lighting was achieved. These new layouts then became the base layout.
5. Treatment Method – Based on the information discussed in CHAPTER 2 and the existing lighting arrangements, methods of reducing the lighting standard during times of low traffic volumes were developed. This also involved selection of the most appropriate luminaire type for the proposal.
6. Undertake Proposed Lighting Designs – The sites were then redesigned using the proposed treatment methods and the results compared in terms of electricity consumption and new infrastructure requirements.
7. Quantifying and Compare the Costs – Formulas for roughly calculating the costs associated with each treatment were used to quantify the total costs between 2010 and 2050 in 2007 dollars. These costs were then compared with the costs of the base layouts to determine if the proposed treatment could be considered cost effective.
8. Review Findings and Conclude Project

CHAPTER 4 –CRASH DATA ANALYSIS

4.1. Typical Temporal Patterns of Traffic Volumes across Queensland

As noted in Section 2.5.1, traffic volumes follow distinctly different patterns on weekdays and weekends. 2009 traffic count data from 148 sites in the Metropolitan Region (encompassing the Brisbane City Council) has been obtained from TMR and analysed to produce Table 11 and Figure 14.

Table 11: Typical Temporal Patterns of Traffic Volumes on State Controlled Roads in the TMR Metropolitan Region

Hour	Weekdays	Weekends
0	0.33%	1.01%
1	0.22%	0.60%
2	0.23%	0.46%
3	0.34%	0.44%
4	0.95%	0.64%
5	3.25%	1.41%
6	5.64%	2.13%
7	7.08%	3.30%
8	7.52%	5.32%
9	5.88%	7.24%
10	5.59%	8.35%
11	5.67%	8.78%
12	5.71%	8.47%
13	5.82%	7.76%
14	6.92%	7.53%
15	8.10%	7.32%
16	8.16%	7.05%
17	7.76%	6.39%
18	5.39%	4.91%
19	3.17%	3.27%
20	2.30%	2.56%
21	1.95%	2.24%
22	1.28%	1.69%
23	0.74%	1.14%

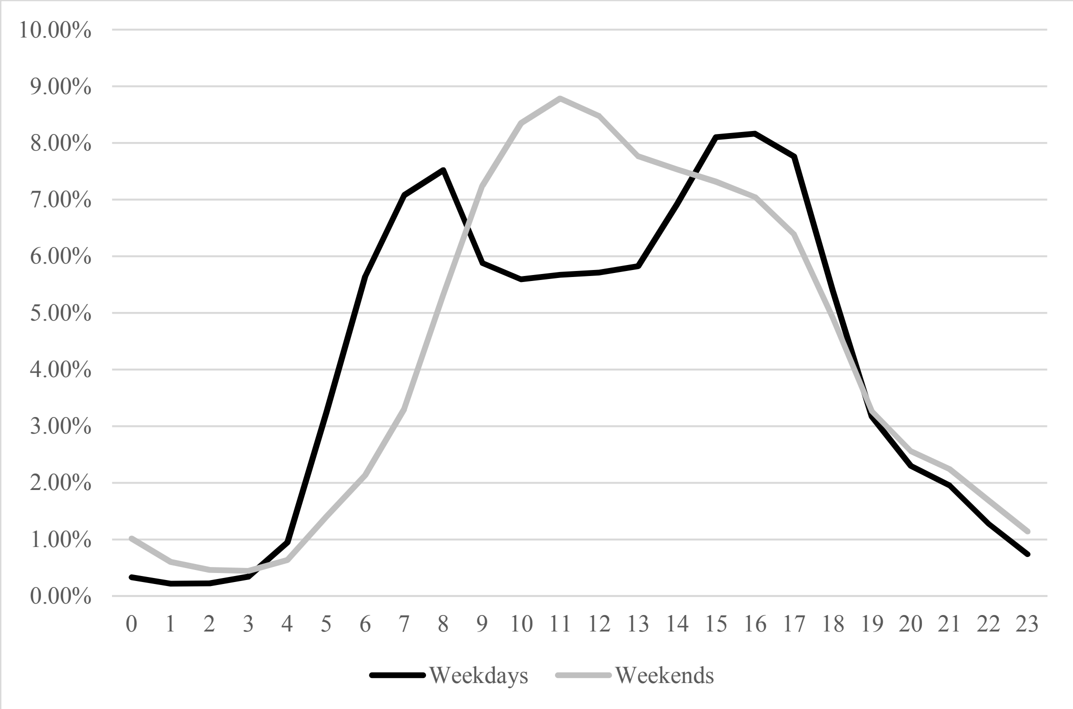


Figure 14: Typical Temporal Patterns of Traffic Volumes on State Controlled Roads in the TMR Metropolitan Region

4.2. Typical Temporal Patterns of Road Crashes across Queensland

Crash data from 2010 has also been obtained from TMR. This data included in the data set were crashes which were reported to the police and met the following criteria:

- The crash occurred on a public road, and
- A person was killed or injured, or
- At least one vehicle was towed away, or
- The value of the property damage is $2500 or more to property other than vehicles.

This data was then filtered by weekday (total for all weekdays) and weekend (total for Saturday and Sunday) and then broken down by time-of-day. By expressing the resultant values as percentages of the total for all weekdays and total for Saturday and Sunday, a typical timescale percentage breakdown of weekday and weekend crashes was obtained (Table 12 and Figure 15).

Table 12: Typical Temporal Patterns of Road Crashes on All Roads in 2010

Hour	Weekdays	Weekends
0	1.25%	3.39%
1	0.96%	3.24%
2	0.72%	2.72%
3	0.86%	2.11%
4	0.88%	1.96%
5	2.25%	2.28%
6	3.52%	2.54%
7	5.58%	2.62%
8	7.87%	3.30%
9	5.45%	5.35%
10	4.97%	6.35%
11	5.24%	7.12%
12	5.28%	7.22%
13	5.18%	5.55%
14	6.36%	6.49%
15	9.06%	5.76%
16	8.22%	5.60%
17	7.66%	5.45%
18	5.26%	5.23%
19	3.81%	3.95%
20	2.84%	3.12%
21	2.69%	2.86%
22	2.21%	2.96%
23	1.87%	2.84%

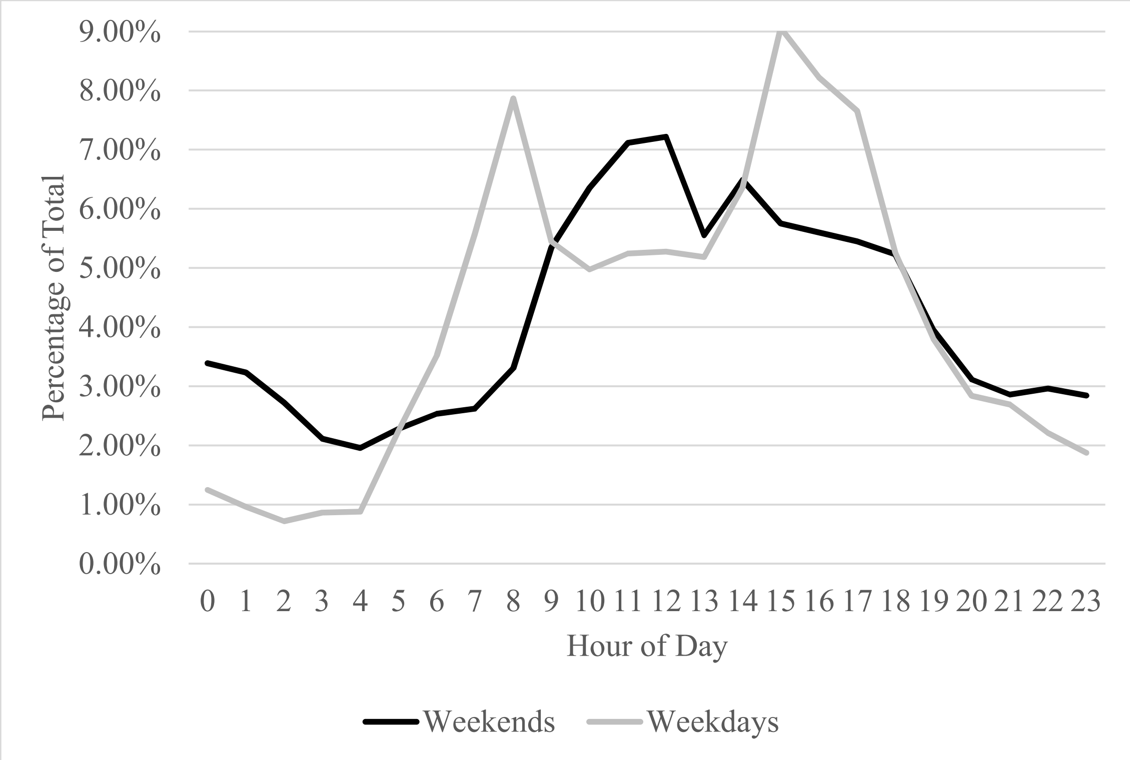


Figure 15: Typical Temporal Patterns of Road Crashes on All Roads in 2010

Figure 16 and Figure 17 graphically compare the temporal patterns of volumes and crashes.

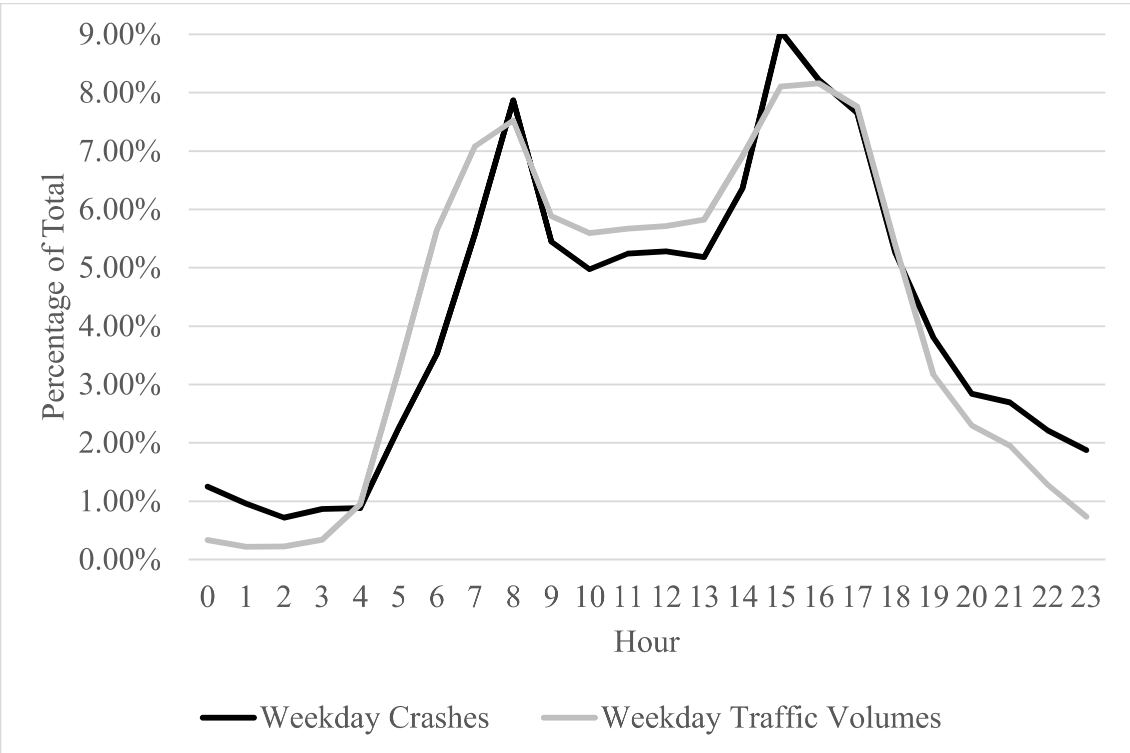


Figure 16: Weekday Comparison Between Typical Temporal Patterns of Traffic Volumes on State Controlled Roads in the TMR Metropolitan Region and Typical Temporal Patterns of Road Crashes on All Roads in 2010

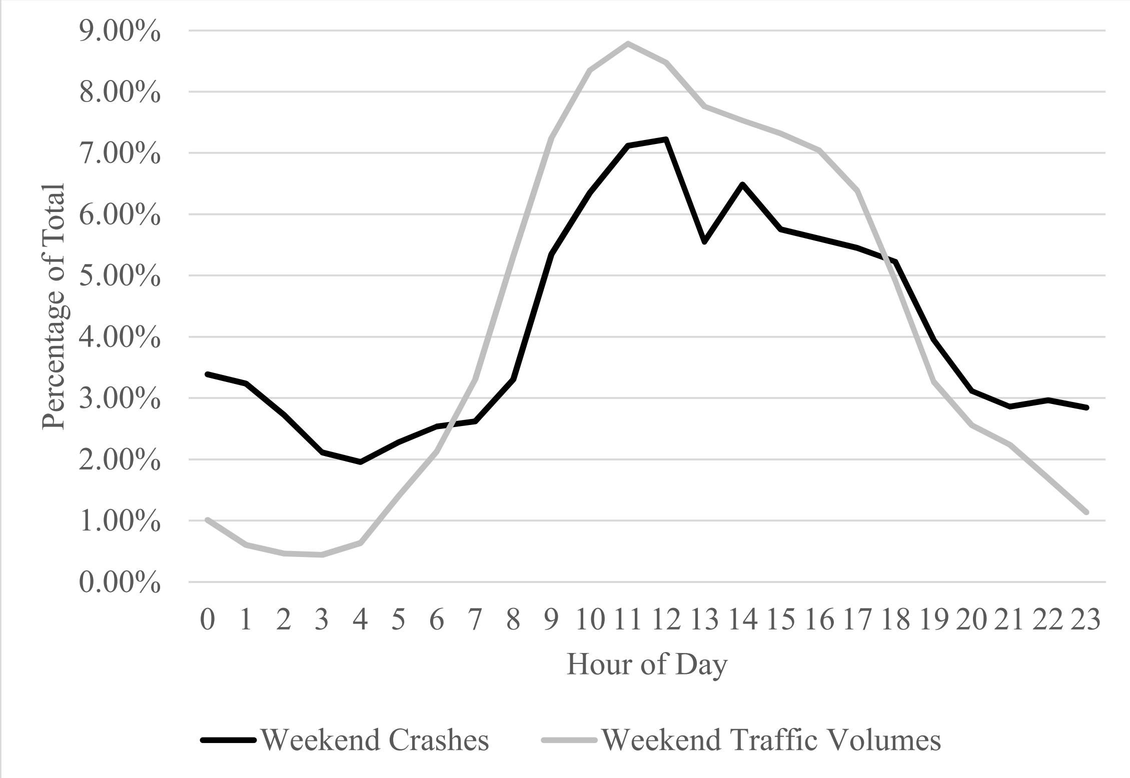


Figure 17: Weekend Comparison between Typical Temporal Patterns of Traffic Volumes on State Controlled Roads in the TMR Metropolitan Region and Typical Temporal Patterns of Road Crashes on All Roads in 2010

4.3. The Effect of Alcohol and Drugs on Typical Temporal Patterns of Road Crashes across Queensland

After noting a significant night time disparity between the crash and traffic volume percentages (especially on weekends) it was hypothesised that this alcohol and drugs may be responsible. The time scale percentage of crashes listing alcohol or drugs as a contributing factor for that particular hour is presented in Table 13, Figure 18 and Figure 19.

It is evident that even though alcohol and drugs contribute to significantly higher percentages of crashes during the night there still exists a disparity in the night time traffic volumes (percentage of total daily volume) compared with the night time crashes (percentage to total daily crashes). This signifies that even when alcohol and drugs are taken into account, crashes are more likely to occur during darkness than during the day.

Table 13: Typical Percentage of Crashes with Alcohol or Drugs Listed as a Contributing Factor by Time of Day.

Hour	Weekdays	Weekends
0	36%	45%
1	36%	48%
2	33%	49%
3	34%	39%
4	19%	44%
5	7%	37%
6	4%	23%
7	2%	17%
8	2%	7%
9	2%	5%
10	3%	6%
11	3%	4%
12	2%	4%
13	3%	5%
14	4%	7%
15	5%	9%
16	5%	11%
17	7%	13%
18	10%	20%
19	14%	25%
20	19%	24%
21	23%	27%
22	28%	34%
23	32%	41%

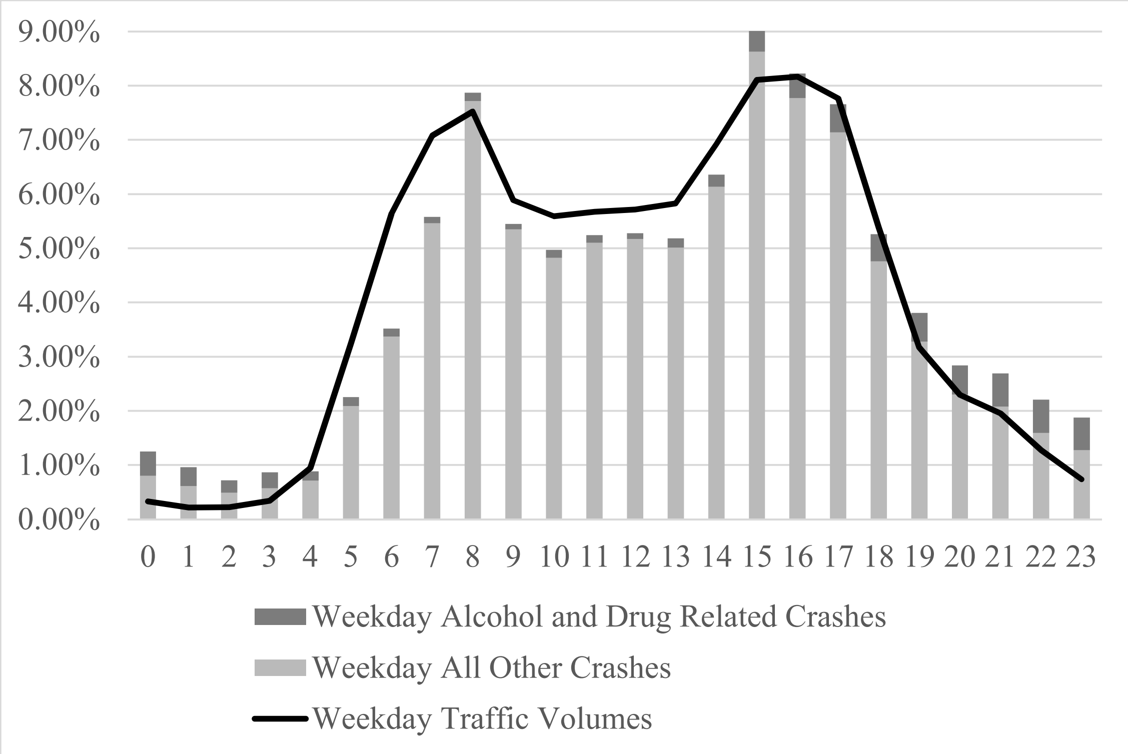


Figure 18: Weekday Typical Percentage of Crashes with Alcohol or Drugs Listed as a Contributing Factor by Time of Day.

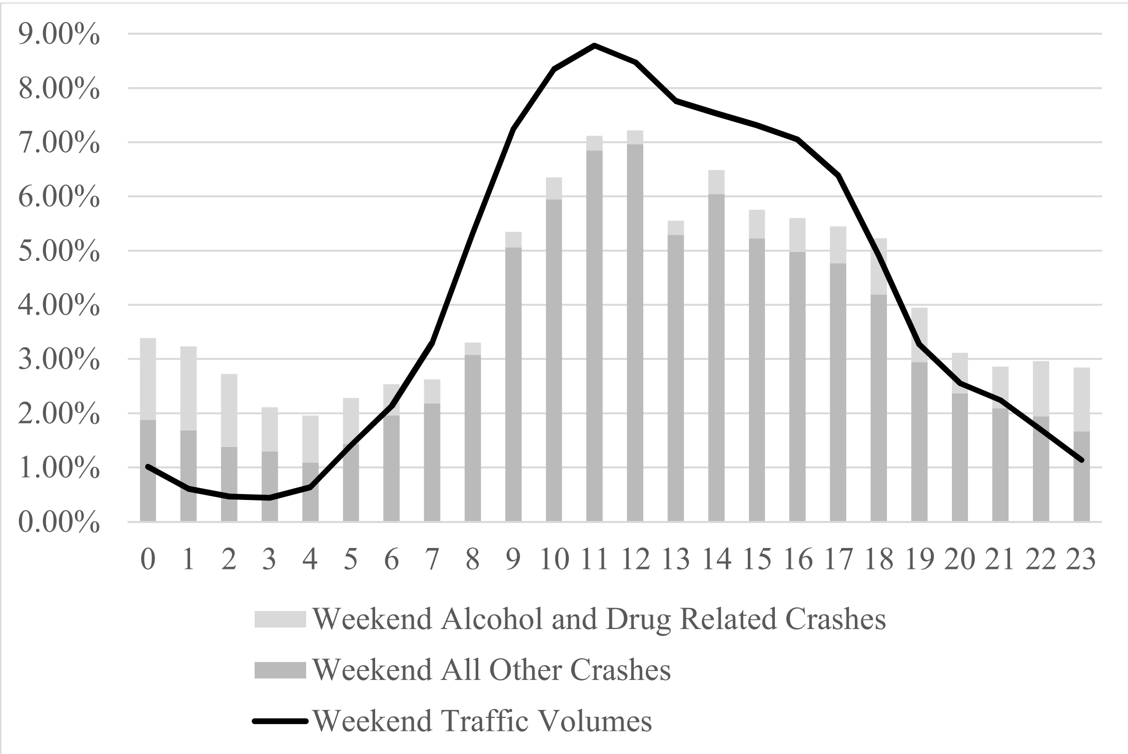


Figure 19: Weekend Typical Percentage of Crashes with Alcohol or Drugs Listed as a Contributing Factor by Time of Day.

4.4. Typical Crash Severity Ratios

The crash data entries also listed crash severity in one of five categories; Property Damage Only, Minor Injury, Medical Treatment, Hospitalisation, and Fatal. These crash severity categories correspond to those listed in Table 2 so that cost benefit analyses can be undertaken for road project proposals.

From the data, the crash severity was analysed and Table 14 was created to determine the likelihood of a crash having a certain severity.

Table 14: Crash Severity Ratio as a Percentage of Total Crashes

Severity	Percentage of Total Crashes
Property Damage Only	41%
Minor Injury	11%
Medical Treatment	24%
Hospitalisation	23%
Fatal	1%

4.5. Discussion

The temporal patterns of traffic volumes and crash numbers indicate that from 6pm to 4am on weekdays and 6pm to 6am on weekend, crashes are disproportionately high compared to traffic volumes (as a ratio with the total). For example, at 1am on weekends the 0.60% of the total traffic contribute to 3.24% of the crashes. Even when the crashes from drugs and alcohol are removed (which can contribute up to 49% of hourly crashes) the 1am weekend hourly crashes is 1.69%, over 2.5 times the hourly traffic volume percentage.

This disproves the hypothesis that motorists travelling at night during times of low traffic volumes are less likely to be involved in crashes. From this, it be deduced that the standard of lighting has a greater effect on reducing crashes than the hazards created by higher traffic volumes.

CHAPTER 5 – SITE SELECTION

5.1. Selection Criteria

Based on the factors discussed in Chapter 2, it would be most appropriate to implement a dimming scheme on a section of road which is of a Category V standard as it will still satisfy the crime reduction standards if kept above a Category P standard while maintaining a certain level of effectiveness for crash reduction. To be able to determine the possible consequences in terms of an increase in crashes, the work undertaken by Jacket and Firth (2012) and discussed in Section 2.3 will be used. Because of this, the most appropriate roads to review are those lit to a V3 standard (average carriageway luminance = $0.75cd/m^2$) as they are common throughout Queensland and have a fair amount of room to move while still maintaining an average carriageway luminance above $0.35cd/m^2$ (the level when Figure 6, Figure 7, Figure 8, Figure 9 and Figure 10 begin to become relevant).

Three specific roadway elements will be considered.

- A highway interchange on-ramp – In some locations interchanges are lit to a high standard considering the major road often times has no route lighting and, depending on the interchange type, may not have overly hazardous conflict points between traffic travelling in an opposing direction. Interchanges usually are designed to the highway standard with any hazards located within the clear zone protected by safety barriers. Highway interchanges are usually in 100-110km/hr speed environments.
- A signalised at-grade intersection – Designed predominantly using illuminance based design, an at-grade intersection can present numerous conflict points between opposing traffic. At-grade intersections also often have increased numbers of hazards such as signal posts, power poles, and pedestrians. Signalised intersections are usually located in 60-80km/hr speed environments.
- Mid-block on an urban arterial road – Often lit to V3 standard, urban arterial roads often have a centre median and can have accesses from abutting properties. Hazards include; power poles, landscaping, structures (such as bus shelters) and parked cars. Mid-block carriageways are usually posted at 60-80km/hr.

5.2. Site Comparison

APPENDIX C details the full site comparison. From this comparison Site D, E and I have been considered the most appropriate for analysis.

5.3. Site D – Bruce Highway and Boundary Road Interchange Southbound On-Ramp (Redesigned)

Figure 20: Boundary Road Interchange On-Ramp (Google Earth, 2013)

5.3.1. Site Description

Located 34km north of the Brisbane CBD the Boundary Road interchange is located in the suburb of North Lakes. It is a closed diamond interchange which has two signalised intersections located at the conflict points with the minor road (Boundary Road).

5.3.2. Current Lighting

The on-ramp is currently lit to a (near) V3 standard with 250W high pressure sodium aeroscreen luminaires with a 12m mounting height. The lighting of the ramp is designed using luminance based design with illuminance based design at the convergence area. This analysis will only analyse the convergence area because the luminance based design is reviewed in the mid-block location described in section 5.5.

The lighting requirement for the convergence area is as follows:

> "(i) *On the carriageway* The whole of the converging carriageway from 10m before the point at which the median ends to where the convergence is completed. It also includes a 3m wide strip of the through carriageway which is contiguous with the section of the converging carriageway described above.
>
> (ii) *On the surrounds* That portion of the surrounds within 3m of the converging carriageway, abutting the area described in Item (i). It also includes the applicable portions of the medians or islands that fall within the area described in Item (i)." (Joint Technical Committee LG-002 2005, Part 1.1, Clause 3.2.2.5 (a), p.20)

These standards are displayed graphically below in Figure 21.

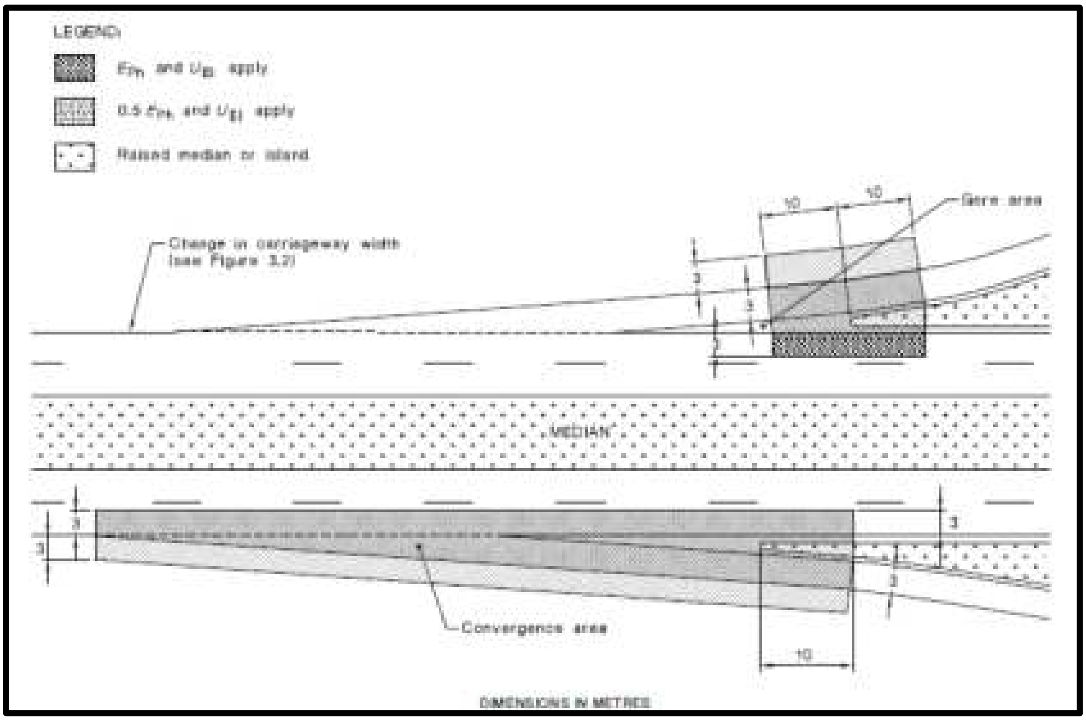


Figure 21: Typical Minimum Design Area for Channelized Converging/Diverging Traffic Streams (Joint Technical Committee LG-002 2005, Part 1.1, p.22)

As shown on drawing INT-001 (APPENDIX D) the existing lighting arrangement at the convergence area of the on-ramp does not satisfy the requirements of AS/NZS1158 and a redesigned layout shown on drawing INT-002 (APPENDIX D) has been used as the base design.

5.3.3. Crash History

Around the merge area between the Bruce Highway and Boundary Road Southbound on ramp there have been 13 crashes with the earliest crash being recorded in 1992 (APPENDIX G). The crashes are a mixture of severity however no fatalities have been recorded. For the purposes of this report, it is assumed that the on ramp merge will witness 0.7 crashes every year.

5.4. Site E – David Low Way and Runway Drive Signalised Intersection

Figure 22: David Low Way and Runway Drive Intersection

5.4.1. Site Description

The David Low Way and Runway Drive intersection is located in the suburb of Pacific Paradise on the Sunshine Coast and is subject to traffic travelling to and from the Sunshine Coast Airport (to the north) along with the traffic travelling to and from the suburbs; Mudjimba, Marcoola and Coolum. Nearby shopping centres, sporting fields and industrial developments also generate trips through the intersection.

5.4.2. Current Lighting

The intersection is lit to a V3 standard with 250W high pressure sodium areoscreen luminaires at a 12m mounting height. The lighting layout at the intersection has been determined using illuminance based design methods with the approaches designed using luminance spacing design. Similar to the Boundary Road on-ramp design only the illuminance criteria will be evaluated in this analysis.

Three illuminance based lighting criteria are required at the intersection.

1. Intersection where the design area comprises of the following elements:

    "(a) *On the roadway* The surface of the roadway extending at least 10m beyond the prolongation of the kerblines of the intersection roads and further extending, as appropriate, to include relevant roadway features and potential traffic conflicts in or near the intersection.

    (b) *On the surrounds* The areas abutting the perimeter of the roadway as defined in Item (a), and within 3m of it, over verges, islands and medians." (Joint Technical Committee LG-002 2005, Part 1.1, Clause 3.4.3.1, p.27)

2. Diverging traffic streams where the design area comprises of the following elements:

    "(A) *On the carriageway* The area of the diverging carriageway, from 10m before to 10m after the nose of the raised separator island. It also includes a 3m wide strip of the through carriageway contiguous with the section of the diverging carriageway described above.

    (B) *On the surrounds* That portion of the surrounds within 3m of the diverging carriageway, abutting the area described in Item(A). It also includes the applicable portion of any medians or islands that fall within the area described in Item(A)." (Joint Technical Committee LG-002 2005, Part 1.1, Clause 3.2.2.5 (b)(ii), p.21)

3. Converging traffic streams with the same criteria used as the interchange on-ramp at the Boundary Road Interchange.

These three design criteria are displayed graphically in Figure 23.

As shown on drawing SIG-001 (APPENDIX E) the existing lighting arrangement does satisfy the requirements of AS/NZS1158 and has been used as the base design.

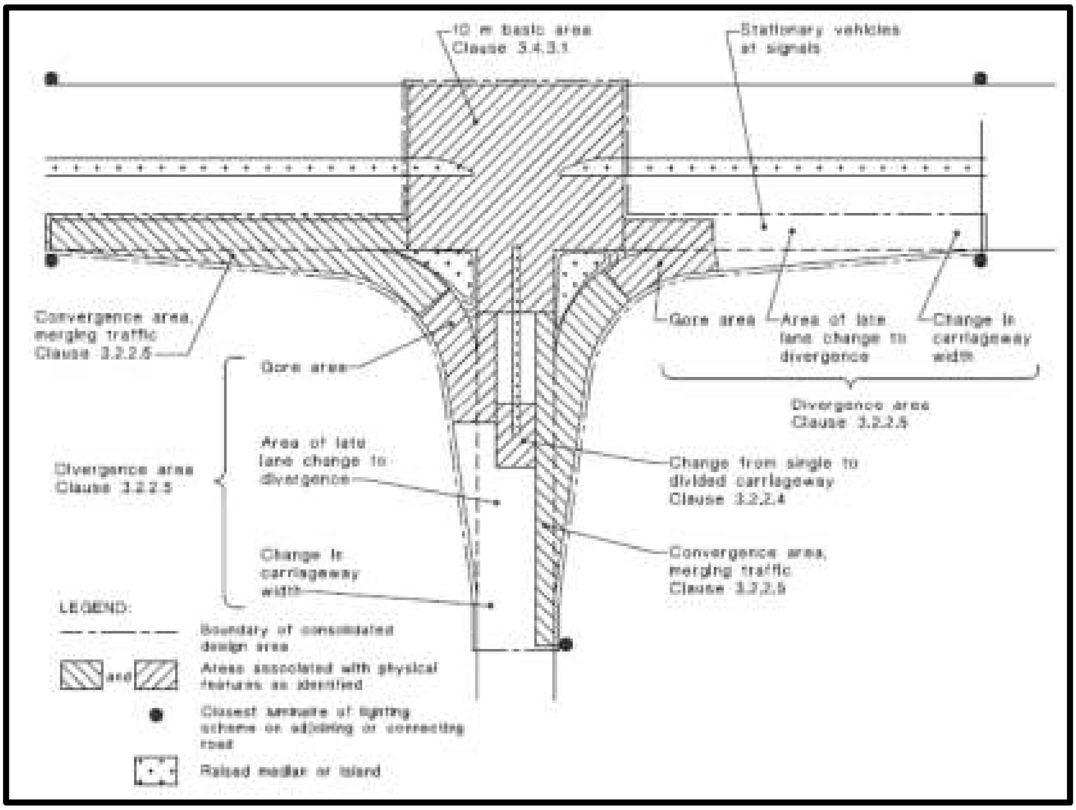


Figure 23: Example of the Analysis of a Complex Intersection to Determine the Illuminance (Joint Technical Committee LG-002 2005, Part 1.1, p.30)

5.4.3. Crash History

Since the intersection was constructed in 2009 there has only been 2 road crashes (APPENDIX H). One crash resulted in property damage only and the other in hospitalisation. The low crash history of the intersection is most likely due to its high standard of geometric design but could also be due to the lag time between the date of the crash and the input into the database. Nevertheless, for the purposes of this report, it is assumed that the intersection will witness 0.5 crashes every year.

5.5. Site I – Anzac Avenue, Mewes Rd to Bremner Rd (Redesigned)

Figure 24: Anzac Avenue - Mewes Road to Bremner Road (Google Earth, 2013)

5.5.1. Site Description

Anzac Avenue is the main urban arterial road connecting Redcliffe to the Bruce Highway. The section of Anzac Avenue between Mewes Road and Bremner Road is located in the suburb of Rothwell and has two carriageways each with three lanes and a 3m shoulder. The two carriageways are separated by a 10m depressed median in which the lighting is situated. A channelized right turn lane is located on the approach to the Bremner Road intersection resulting in a change of carriageway width.

5.5.2. Current Lighting

The lighting along this section of road is to a (near) V3 standard with 250W high pressure sodium aeroscreen luminaires at a 12m mounting height. The section of road is subject to luminance based (spacing) design with the channelized right turn lane subject to the following design rule:

> "*Diverging traffic lanes* Where there is an increase in the number of lanes on a carriageway … a luminaire of the type used in the design shall be placed within 5m of the point where the lanes start to diverge." (Joint Technical Committee LG-002 2005, Part 1.1, Clause 3.2.2.3(b), p.18)

As shown on drawing MID-001 and spacing calculation outputs MID-001-AA and MID-001-BB (APPENDIX F) the existing lighting arrangement does not satisfy the requirements of AS/NZS1158 and a redesigned layout shown on drawing MID-002 (APPENDIX F) has been used as the base design.

5.5.3. Crash History

Along the mid-block area between the Mewes Road and Bremner Road intersections there have been 26 crashes with the earliest crash being recorded in 1991 (APPENDIX I). The crashes are a mixture of severity however no fatalities have been recorded. For the purposes of this report, it is assumed that the area will witness 1.2 crashes every year.

CHAPTER 6– DIMMING TREATMENTS

To maintain a satisfactory level of safety for motorists all dimming treatments will be assessed against a V5 standard resulting in an average carriageway luminance of 0.35cd/m^2 (Table 5). The most appropriate dimming method would have been dimming the existing 250W HPS lamps however this option was ruled out because the lamp type cannot be dimmed (Table 7). Three treatments will be considered, they are:

1. Treatment 1 – Dimming to 150W high pressure sodium lamps
2. Treatment 2 – Dimming by switching every second lamp off
3. Treatment 3 – Replacing existing lamps with LED's and dimming

The first attempt for applying each treatment has been to utilise each existing pole at the subject sites. If the resulting technical parameters did not meet the desired (V5) standard then the pole placement has been modified to do so.

6.1. Treatment 1 – Dimming to 150W High Pressure Sodium Lamps

This treatment involves installation of 150W high pressure sodium aeroscreen luminaires on the same outreaches as the existing 250W high pressure sodium aeroscreen luminaires. After midnight the 250W lamps will be switched off and the 150W lamps will be switched on.

6.2. Treatment 2 – Dimming by Switching Lamps Off

This treatment involves programming control equipment to switch off a percentage of the lamps (preferably half) to achieve a dimming type result. The lamps to be switched off would be determined in the design stage to ensure the most effective lighting treatment is achieved.

6.3. Treatment 3 – Replace existing lamps with 180W LED Lamps

Treatment 3 involves recovering the existing 250W high pressure sodium luminaires and replacing them with 180W LED luminaires which are considered equivalent to 250W high pressure sodium lamps (Table 8). Because LEDs possess the ability to be dimmed by reducing the current, no other infrastructure modifications would be required for dimming. Because of efficiency losses as the luminaires are dimmed, Table 8 will be used to calculate an approximate wattage for the dimmed scenario. This is discussed further in CHAPTER 8.

CHAPTER 7 – CALCULATIONS AND RESULTS

7.1. Calculation of Maintenance Factors

One of the essential inputs into a lighting design is the maintenance factor (MF). This is a variable which is used to account for the reduction in luminaire light output over time due to pollution and lamp lumen deprecation due to ageing. It is the product of the Lamp Lumen Maintenance Factor (LLMF) and the Luminaire Maintenance Factor (LMF). The three luminaires used in the dimming treatments (Rexel 250W HPS Aero, Rexel 150W HPS Aero and Philips 180W Led) are all rated above IP60 which gives them a maximum possible maintenance factor of 0.8. (Joint Technical Committee LG-002 2005, Part 1.1, p.13). LMF can then be calculated from Table 15 assuming a 36 month cleaning interval and medium pollution category which gives all lamp types a LMF of 0.87.

Table 15: Luminaire Maintenance Factors (Joint Technical Committee LG-002 2005, Part 1.2, p.63)

Cleaning interval	Typical luminaire maintenance factors (Note 1)					
	Ingress Protection Number of Lamp Chamber					
	IP54			IP6X		
	Pollution category (Note 2)					
months	High	Medium	Low	High	Medium	Low
12	0.89	0.90	0.92	0.91	0.92	0.93
18	0.87	0.88	0.91	0.90	0.91	0.92
24	0.84	0.86	0.90	0.88	0.89	0.91
36	0.76	0.82	0.88	0.83	0.87	0.90
48	0.66	0.76	0.86	0.75	0.84	0.89

The LLMF for the high pressure sodium lamps can be calculated from. Figure 25. With approximately 4200 burning hours per year and a 36 month cleaning interval (12600 total burning hours), LLMF=0.88. Therefore MF (high pressure sodium) = 0.87x0.88=0.77.

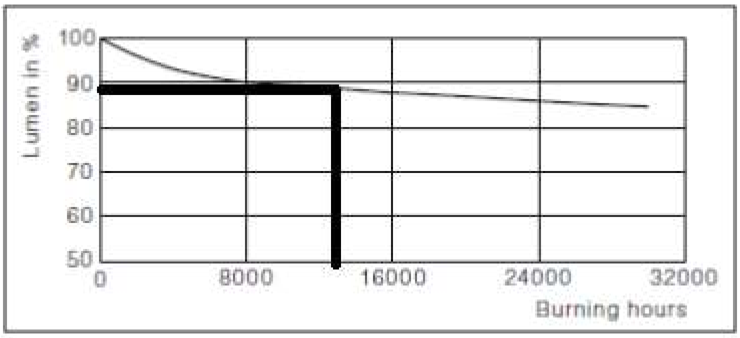


Figure 25: High Pressure Sodium Lamp Lumen Deprecation Factors (Joint Technical Committee LG-002 2005, Part 1.2, p.93)

The LLMF for the LED lamps can be calculated using Figure 26. With approximately 4200 burning hours per year and a 36 month cleaning interval (12600 total burning hours), LLMF=0.95. Therefore MF (LED) = 0.87x0.95=0.83 which is rounded down to the maximum value of 0.8 for IP6X.

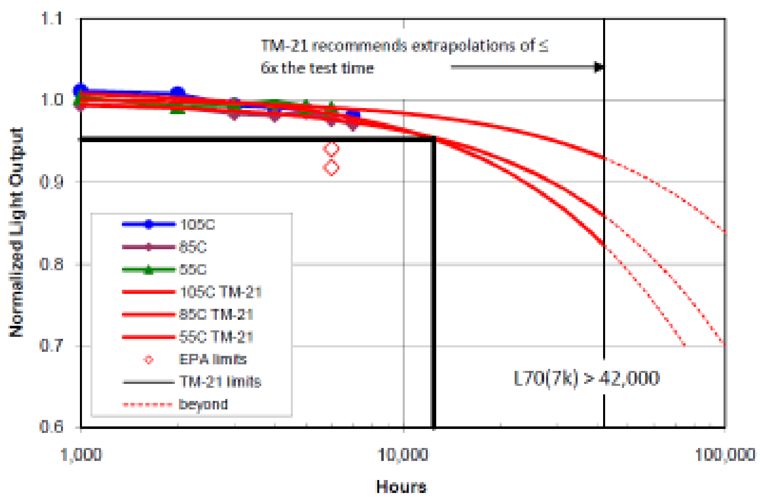


Figure 26: LED Lamp Lumen Deprecation Factors for 4000K @ 0.7A (Philips 2013)

7.2. Site D – Bruce Highway and Boundary Road Interchange Southbound On-Ramp (Redesigned)

7.2.1. Base Layout

The base layout (drawing number INT-002 in APPENDIX D) is a redesign of the existing arrangement (drawing number INT-001 in APPENDIX D). This base layout has 13 High Pressure Sodium 250W lights. Representing the current (undimmed) scenario, lamps will run from dusk to dawn using 3.250kWh per hour of operation.

The design satisfies the V3 requirements of AS/NZS1158 in the area where E_{PH} (7.5) and U_{EI} (8) apply with the layout achieving E_{MIN}=7.5 lux and U_{EI}=4.5. In the area where 0.5E_{PH} (3.75) and U_{EI} (8) apply the layout achieves E_{MIN}=8 lux and U_{EI}=3.9.

7.2.2. Treatment 1 – Dimming to 150W High Pressure Sodium Lamps

The Treatment 1 layout (drawing number INT-003 in APPENDIX D) represents the dimmed scenario where 150W High Pressure Sodium lamps are switched on when dimming commences. The layout has exactly the same number of lights (13) as the base layout and has at the same pole positions so that the two luminaires can be installed on the one pole. The 150W High Pressure Sodium lights will use 1.950kWh per hour of operation.

The design satisfies the V5 requirements of AS/NZS1158 in the area where E_{PH} (3.5) and U_{EI} (8) apply with the layout achieving E_{MIN}=3.5 lux and U_{EI}=4.9. In the area where 0.5E_{PH} (1.75) and U_{EI} (8) apply the layout achieves E_{MIN}=3 lux and U_{EI}=5.

7.2.3. Treatment 2 – Dimming by Switching Lamps Off

The Treatment 2 layout (drawing number INT-004 in APPENDIX D) represents the dimmed scenario when 6 of the 13 250W lights are switched off when dimming commences resulting in 7 250W lights in operation. During dimming, the 7 lights still in operation will use 1.750kWh per hour of operation.

The design does not satisfy the V5 requirements of AS/NZS1158 in the area where E_{PH} (3.5) and U_{EI} (8) apply with the layout achieving E_{MIN}=1 lux and U_{EI}=31. In the area where 0.5E_{PH} (1.75) and U_{EI} (8) apply the layout only achieves E_{MIN}=1 lux and U_{EI}=30. It is impossible for this treatment to achieve the V5 requirements of AS/NZS1158.

7.2.4. Treatment 3 – Replace existing lamps with 180W LED Lamps

The Treatment 3 layout (drawing number INT-005 in APPENDIX D) represents the undimmed scenario when lamps from the base layout are replaced with 180W LED lamps. In this layout only luminaires are replaced and no new poles are required. During undimmed operation the 13 lights will use 2.340kWh per hour of operation.

The design does not satisfy the V3 requirements of AS/NZS1158 in the area where E_{PH} (7.5) and U_{EI} (8) apply with the layout achieving E_{MIN}=6 lux and U_{EI}=3.7. In the area where 0.5E_{PH} (3.75) and U_{EI} (8) apply the layout only achieves E_{MIN}=3 lux and U_{EI}=5.7.

To create a layout where the LED lamps do satisfy the V3 requirements of AS/NZS1158 Treatment 3A has been investigated. Dimming has not been investigated for Treatment 3 as Treatment 3A will investigate this.

7.2.5. Treatment 3A – Redesign Layout with 180W LED Lamps and Dimming

The Treatment 3A layout (drawing number INT-006 in APPENDIX D) represents the undimmed scenario when 180W LED lamps are positioned to achieve the V3 requirements of AS/NZS1158. The layout maintains the same number of lights as the base layout (13) but does require new poles. During undimmed operation, the 13 lights will use 2.340kWh per hour of operation.

The design satisfies the V3 requirements of AS/NZS1158 in the area where E_{PH} (7.5) and U_{EI} (8) apply with the layout achieving E_{MIN}=8 lux and U_{EI}=2.8. In the area where 0.5E_{PH} (3.75) and U_{EI} (8) apply the layout achieves E_{MIN}=5 lux and U_{EI}=3.4.

During dimmed operation the lamps will be dimmed to 44% of their maximum output so that (assuming that light distribution from the lamps is unchanged when dimmed) the design satisfies the design satisfies the V5 requirements of AS/NZS1158 in the area where E_{PH} (3.5) and U_{EI} (8) apply with the layout achieving E_{MIN}=3.5 lux (0.44 x 8) and U_{EI}=2.8. In the area where 0.5E_{PH} (1.75) and U_{EI} (8) apply the layout achieves E_{MIN}=2.2 lux (0.44 x 5) and U_{EI}=5. Assuming no efficiency losses occurring when dimmed, during dimmed operation, the 13 lights will use 1.030kWh per hour of operation (0.44 x 2.340).

7.3. Site E – David Low Way and Runway Drive Signalised Intersection

7.3.1. Base Layout

The base layout (drawing number SIG-001 in APPENDIX E) represents the current lighting layout at the intersection. The arrangement has 13, 250W High Pressure Sodium lights which, during operation, use 3.250kWh per hour of operation.

The design satisfies the V3 requirements of AS/NZS1158. There are several areas where E_{PH} (7.5) and U_{EI} (8) apply. Out of all these areas the layout achieves the worst values of E_{MIN}=8 lux and U_{EI}=3.5. In the areas where 0.5E_{PH} (3.75) and U_{EI} (8) apply the layout achieves the worst values of E_{MIN}=6 lux and U_{EI}=3.2.

7.3.2. Treatment 1 – Dimming to 150W High Pressure Sodium Lamps

The Treatment 1 layout (drawing number SIG-002 in APPENDIX E) represents the dimmed scenario for the treatment. The arrangement has 13, 250W High Pressure Sodium lights which are on before dimming commences, using 3.250kWh per hour of operation. The dimmed scenario has 13, 150W High Pressure Sodium lights which use 1.950kWh per hour of operation.

The design satisfies the V5 requirements of AS/NZS1158. There are several areas where E_{PH} (3.5) and U_{EI} (8) apply. Out of all these areas the layout achieves the worst values of E_{MIN}=4 lux and U_{EI}=3.3. In the areas where $0.5E_{PH}$ (1.75) and U_{EI} (8) apply the layout achieves the worst values of E_{MIN}=3 lux and U_{EI}=3.2.

7.3.3. Treatment 2 – Dimming by Switching Lamps Off

The Treatment 2 layout (drawing number SIG-003 in APPENDIX E) represents the dimmed scenario for the treatment. The arrangement has 13, 250W High Pressure Sodium lights which are on before dimming commences, using 3.250kWh per hour of operation. The dimmed scenario has 8, 250W High Pressure Sodium lights which use 2.000kWh per hour of operation.

The design satisfies the V5 requirements of AS/NZS1158. There are several areas where E_{PH} (3.5) and U_{EI} (8) apply. Out of all these areas the layout achieves the worst values of E_{MIN}=5 lux and U_{EI}=4.6. In the areas where $0.5E_{PH}$ (1.75) and U_{EI} (8) apply the layout achieves the worst values of E_{MIN}=4 lux and U_{EI}=3.7.

7.3.4. Treatment 3 – Replace existing lamps with 180W LED Lamps

The Treatment 3 layout (drawing number SIG-004 in APPENDIX E) represents the undimmed scenario when lamps from the base layout are replaced with 180W LED lamps. In this layout only luminaires are replaced and no new poles are required. During undimmed operation the 13 lights will use 2.340kWh per hour of operation.

The design does not satisfy the V3 requirements of AS/NZS1158. There are several areas where E_{PH} (3.5) and U_{EI} (8) apply. Out of all these areas the layout achieves the worst values of E_{MIN}=3 lux and U_{EI}=5.3. In the area where $0.5E_{PH}$ (3.75) and U_{EI} (8) apply the layout achieves the worst values of E_{MIN}=2 lux and U_{EI}=4.3.

To create a layout where the LED lamps do satisfy the V3 requirements of AS/NZS1158 Treatment 3A has been investigated. Dimming has not been investigated for Treatment 3 as Treatment 3A will investigate this.

7.3.5. Treatment 3A – Redesign Layout with 180W LED Lamps and Dimming

The Treatment 3A layout (drawing number SIG-005 in APPENDIX E) represents the undimmed scenario when 180W LED lamps are positioned to achieve the V3 requirements of AS/NZS1158. The layout maintains the same number of lights as the base layout (13) but does require new poles. The poles located on the legs of the intersection have been moved closer to the intersection to achieve this and could possibly result in the number of lights required for mid-block lighting adjacent the intersection. During undimmed operation, the 13 lights will use 2.340kWh per hour of operation.

The design satisfies the V3 requirements of AS/NZS1158. There are several areas where E_{PH} (7.5) and U_{EI} (8) apply. Out of all these areas the layout achieves the worst values of E_{MIN}=8 lux and U_{EI}=3.7. In the areas where 0.5E_{PH} (3.75) and U_{EI} (8) apply the layout achieves the worst values of E_{MIN}=5 lux and U_{EI}=2.8.

During dimmed operation the lamps will be dimmed to 44% of their maximum output so that (assuming that light distribution from the lamps is unchanged when dimmed) the design satisfies the design satisfies the V5 requirements of AS/NZS1158 in the area where E_{PH} (3.5) and U_{EI} (8) apply with the layout achieving E_{MIN}=3.5 lux (0.44 x 8) and U_{EI}=3.7. In the area where 0.5E_{PH} (1.75) and U_{EI} (8) apply the layout achieves E_{MIN}=2.2 lux (0.44 x 5) and U_{EI}=2.8. Assuming no efficiency losses occurring when dimmed, during dimmed operation, the 13 lights will use 1.030kWh per hour of operation. (0.44 x 2.340).

7.4. Site I – Anzac Avenue, Mewes Rd to Bremner Rd (Redesigned)

7.4.1. Base Layout

The base layout (spacing calculation MID-001-AA, spacing calculation MID-001-BB, and drawing number MID-002 in APPENDIX F) is a redesign of the existing arrangement (spacing calculation MID-001-AA, spacing calculation MID-001-BB, and drawing number MID-001 in APPENDIX F). The arrangement has 22, 250W High Pressure Sodium lights which, during operation, use 5.500kWh per hour of operation. The design satisfies the V3 requirements of AS/NZS1158 outlined in Table 5.

7.4.2. Treatment 1 – Dimming to 150W High Pressure Sodium Lamps

The Treatment 1 layout (spacing calculation MID-003-AA, spacing calculation MID-003-BB, and drawing number MID-003 in APPENDIX F) represents the dimmed scenario where 150W High Pressure Sodium lamps are switched on when dimming commences. The layout has exactly the same number of lights (22) as the base layout and has at the same pole positions so that the two luminaires can be installed on the one pole. The 150W High Pressure Sodium lights will use 3.300kWh per hour of operation. The design satisfies the V5 requirements of AS/NZS1158 outlined in Table 5.

7.4.3. Treatment 2 – Dimming by Switching Lamps Off

The Treatment 2 layout (spacing calculation MID-001-AA, spacing calculation MID-001-BB, and drawing number MID-004 in APPENDIX F) represents the dimmed scenario when 10 of the 22 250W lights are switched off when dimming commences resulting in 12, 250W lights in operation. During dimming, the 12 lights still in operation will use 3.000kWh per hour of operation.

The design does not satisfy the V5 requirements of AS/NZS1158 outlined in Table 5 and it is impossible for this treatment to achieve these requirements.

7.4.4. Treatment 3 – Replace existing lamps with 180W LED Lamps

The Treatment 3 layout (spacing calculation MID-005-AA, spacing calculation MID-005-BB, and drawing number MID-005 in APPENDIX F) represents the undimmed scenario when lamps from the base layout are replaced with 180W LED lamps. In this layout only luminaires are replaced and no new poles are required. During undimmed operation the 22 lights will use 3.960kWh per hour of operation.

The design does not satisfy the V3 requirements of AS/NZS1158 outlined in Table 5. To create a layout where the LED lamps do satisfy the V3 requirements of AS/NZS1158 Treatment 3A has been investigated. Dimming has not been investigated for Treatment 3 as Treatment 3A will investigate this.

7.4.5. Treatment 3A – Redesign Layout with 180W LED Lamps and Dimming

The Treatment 3A layout (spacing calculation MID-005-AA, spacing calculation MID-005-BB, and drawing number MID-006 in APPENDIX F) represents the undimmed scenario when 180W LED lamps are positioned to achieve the V3 requirements of AS/NZS1158 (utilising Clause 3.1.2 of AS/NZS1158 where spacing can be increased by 10% for a maximum of two consecutive spans). The layout required 26 new lights and poles. During undimmed operation, the 26 lights will use 4.680kWh per hour of operation.

The design satisfies the V3 requirements of AS/NZS1158 outlined in Table 5.

During dimmed operation the lamps will be dimmed to 50% of their maximum output so that (assuming that light distribution from the lamps is unchanged when dimmed) the design satisfies the design satisfies the V5 requirements of AS/NZS1158. Assuming no efficiency losses occurring when dimmed, during dimmed operation, the 26 lights will use 2.340 kWh per hour of operation (0.5 x 4.680).

7.5. Summary

Table 16 is a summary of the information presented in this chapter.

Table 16: Summary of Options

Site	Treatment	New Poles	New Luminaires	Pre Dimming Electricity Demand	Post Dimming Electricity Demand	Pre Dimming Standard	Post Dimming Standard
D	Base	0	0	3250W		V3	
	1	0	13	3250W	1950W	V3	V5
	2	0	0	3250W	1750W	V3	None
	3	0	13	2340W	N/A	None	N/A
	3A	13	13	2340W	1030W	V3	V5
E	Base	0	0	3250W		V3	
	1	0	13	3250W	1950W	V3	V5
	2	0	0	3250W	2000W	V3	V5
	3	0	13	2340W	N/A	None	N/A
	3A	13	13	2340W	1030W	V3	V5
H	Base	0	0	5500W		V3	
	1	0	22	5500W	3300W	V3	V5
	2	0	0	5500W	3000W	V3	None
	3	0	22	3960W	N/A	None	N/A
	3A	26	26	4680W	2340W	V3	V5

7.6. Discussion

For all three sites, dimming using treatment 1 and 3A resulted in V5 standard lighting after midnight, where treatment 2 was only effective for Site E. Treatment 3 did not achieve V3 pre dimming standard on any site. The electricity savings from using LED's in treatment 3A was significant in the pre dimmed and post dimmed scenarios. From the treatment 1 results, the treatment 3A electricity demand was approximately 15% to 40% less to achieve the same standard of lighting.

Due to the different light spread output of the LED lamps compared with HPS lamps (Figure 27) it was much more difficult to achieve compliant layouts, especially for Site I where luminance based design was used. Design wise, the high pressure sodium lamps were better suited to all three sites. For large complex projects (with the brand and model of lamps used in this comparison) it is very likely that more LED lamps will be required to achieve the same standard of lighting as High Pressure Sodium lamps.

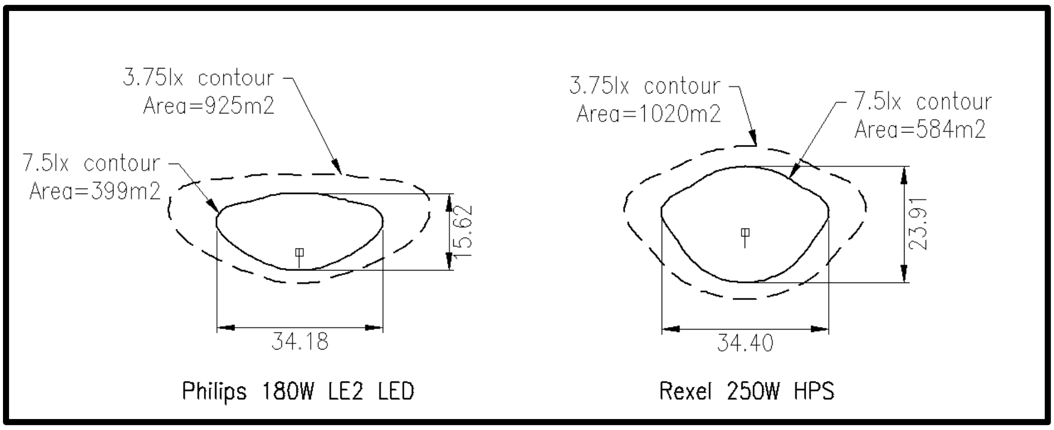


Figure 27: LED and High Pressure Sodium Lux Plot Comparison

CHAPTER 8 – COST COMPARISON

8.1. Methodology

The cost comparison adds up the costs associated with the initial construction costs to retrofit (replacing the existing lights and poles with the proposed), the social costs of crashes, the social cost of carbon, the electricity supply costs and the maintenance costs of replacing the lamps. The costs are added up between 2010 and 2050 and are expressed in 2007 dollars.

For simplicity this cost comparison assumes that the lighting will be dimmed at midnight so that Figure 10 can be used to estimate the resultant night/day crash ratio. This means that of the typical 4200hours/year of lamp usage, 2100hours/year will occur in the undimmed scenarios and 2100hours/year in the dimmed scenarios.

8.1.1. Initial Construction Costs

The initial construction costs are calculated as the sum of the cost of new poles required at $10,000 each and the cost of new luminaires at $1000 each. These figures have been assumed.

8.1.2. Electricity Supply Costs

The electricity supply costs will be calculated using the current cost of supply of $0.30/light/day (from Section 1.2). For Treatment 1, electricity will be charged per pole to avoid charges applying to both 250W and 150W lamps. It is assumed that the cost of electricity supply has not changed since 2007 and will rise in line with inflation, therefore this figure (expressed in 2007 dollars) will not change between 2010 and 2050.

8.1.3. Social Costs of Crashes

The average luminance for the illuminance based design criteria is assumed to be the same as the luminance based design criteria (i.e. V3=0.75cd/m2 and V5=0.35cd/m2 from Figure 5). The number of crashes occurring in the pre-midnight, undimmed scenario at V3 standard is calculated using the pre-midnight N/D crash ratio from Figure 10.

$$
\begin{aligned}
CR_{V3Pre} &= 0.36e^{-0.37x}, \text{ where } x = 0.75 \\
&= 0.273
\end{aligned}
$$

The number of crashes occurring in the post-midnight, undimmed scenario at V3 standard is calculated using the post-midnight N/D crash ratio from Figure 10.

$$CR_{V3Post} = 0.18e^{-0.57x}, \text{ where } x = 0.35$$
$$= 0.117$$

The number of crashes occurring in the post-midnight, undimmed scenario at V5 standard is calculated using the post-midnight N/D crash ratio from Figure 10.

$$CR_{V5Post} = 0.18e^{-0.57x}, \text{ where } x = 0.35$$
$$= 0.147$$

Firstly, the base layout day, pre-midnight and post-midnight average number of crashes per year is calculated. The number of day crashes calculated from the base layout is then used for each alternative treatment to calculate the pre-midnight and post-midnight crashes for the treatment.

From the calculated number of pre-midnight and post-midnight crashes for each treatment, Table 14 is then used to break the number of crashes down further by crash severity. The social cost of the crashes can be calculated using Table 2. Even though it is expected that the number of crashes at each site will likely rise as traffic volumes rise in the future, for simplicity the expected number of crashes has been kept constant between 2010 and 2050.

8.1.4. Social Cost of Carbon

The yearly social cost of carbon is calculated by multiplying the electricity usage in kilowatt hours (from Table 16) by the number of hours the lamp will run, by the average greenhouse gas emission rate for coal (from Section 1.2), and then by the social cost of carbon for the year in question with a 3% discount rate (from Table 1). The sum of the yearly social cost of carbon between 2010 and 2050 is then calculated.

8.1.5. Maintenance Costs

The maintenance costs are calculated using the typical lamp life of 20,000 hours for High Pressure Sodium lamps and 50,000 hours for LED lamps using Table 7. The total number of hours of operation over the 41 years is divided by the lamp life then multiplied by the assumed cost of lamp replacement of $1000.

8.2. Results

The calculations for the cost comparison can be found in APPENDIX J, APPENDIX K, and APPENDIX L. The results from the cost benefit analysis is tabulated below in Table 17.

Table 17: Cost Comparison for Sites with Proposed Treatments

Site	Treatment	Costs	Difference With Base Layout
D	Base	$4,614,621	
	1	$4,619,989	$5,368 more expensive
	2	Layout not to V5 Post-Midnight Standard	
	3A	$4,675,011	$60,390 more expensive
E	Base	$3,344,886	
	1	$3,342,443	$2,443 less expensive
	2	$3,307,063	$37,823 less expensive
	3A	$3,397,465	$52,579 more expensive
H	Base	$7,741,873	
	1	$7,916,717	$174,844 more expensive
	2	Layout not to V5 Post-Midnight Standard	
	3A	$8,073,673	$331,800 more expensive

8.3. Discussion

The results demonstrate that the costs associated with lighting vary significantly from site to site. The largest contributor to site costs are the social costs of crashes which contributed to approximately 95% of costs for all three sites. A small increase in the average number of crashes per year from 0.5 (Site E) to 1.2 (Site I) resulted in the costs increasing significantly.

A large contributor to the cost of treatment 3A in all three scenarios was the cost of retrofitting. The retrofitting costs for treatment 3A were; $143,000 for Site D, $143,000 for Site E and $286,000 for Site I. When these costs are removed (i.e. new construction work) for Site D and Site E, treatment 3A becomes more cost effective than the Base Layout. This however is not the case for Site I due to its larger social cost of crashes.

Treatment 1 was the most cost effective dimming solution at all three sites.

CHAPTER 9– CONCLUSIONS

9.1. Assumptions

The results presented in this report are based on a fair number of assumptions which include but are not limited to:

- There are no electrical significant electrical losses in the lighting schemes analysed.
- The social cost of carbon will follow a 3% discount rate between 2010 and 2050.
- The cost of supply, installation and maintenance of road lighting lamps and poles.
- The cost of supply, installation and maintenance of HPS lamps is equal to that of LED lamps and poles.
- Electricity supply prices or pricing structure for road lighting will rise with inflation between 2010 and 2050.
- The social cost of crashes will rise with inflation between 2010 and 2050.
- The crash severity ratio does not change from site to site
- The yearly number of crashes at the sites will not rise between 2010 and 2050.

9.2. Justification Supporting the Proposal

The report successfully demonstrated that, under the assumptions listed above, where crash numbers are low for a particular site (less than about 0.7 crashes/year), dimming can be considered a cost effective treatment. If dimming were to be implemented by retrofitting, Treatment 1 (Dimming to 150W high pressure sodium lamps) is the most cost effective solution. If dimming infrastructure were to be installed on new work it is likely that treatment 3A (using LED lamps) would present the most cost effective solution.

9.3. Challenges with the Proposal

The dimming proposal however has four main challenges.

The first challenge is that once crash numbers for a particular site are moderate to high (more than about 0.7 crashes/year) dimming does not represent a cost effective solution.

Even though in some situations the benefit of dimming can be proven using the methodology of this report, the second challenge is that the implementation of such a proposal would require significant resources to develop new standards, analyse crash data and design the retrofitted infrastructure. Such a task would be enormous and the costs of this have not been incorporated in these results. The proposed treatments are only possible on sites currently lit to a V3 standard. This poses a problem because only a small number of roads are lit to this standard with the majority being V5 or P category. This further adds pressure to the costs noted in the previous statement as with less possible sites for implementation, the cost of developing new standards on a per site basis grows.

The current electricity cost structure for road lighting represents the third challenge to the dimming proposal. The current structure is based on a price/light/day and all lights over 100W are charged the same so essentially there is no incentive in improving the efficiency as 150W HPS, 180W LED and 250W HPS lamps all have the same running costs.

The fourth challenge is that the social cost of carbon is calculated worldwide and the savings are unlikely to be directly experienced in the locality where the lighting is located. For example; a reduction in carbon emissions in Australia may lessen the severity of a bushfire in California. This is a difficult concept to understand and using the social cost of carbon as justification for implementing dimming treatments is unlikely to achieve public support.

9.4. Recommendations

Considering the justification of the proposal and challenges towards the proposal, it is recommended that the proposal is not feasible under the current environment. The proposal may become feasible in the future if the electricity pricing structure changes or the social cost of carbon is found to be larger than that calculated by the USA

Environmental Protection Agency. The social cost of carbon associated with road lighting can be removed from the equation if the electricity used can be generated from renewable sources such as solar, wind or geothermal which produce negligible whole of life carbon emissions.

A carbon offset program or renewable energy contribution structure would be a more appropriate way to reduce the carbon emissions associated with street lighting. Considering that a 250W high pressure sodium lamp would use approximately 3kWh a night, a relatively cheap investment in solar (approximately $3000 which is $/kW the cost of the Sunshine Coast Solar Farm) will produce enough daily electricity to offset the night time usage.

9.5. Further Work

The cost comparisons only investigated the cost of retrofitting existing infrastructure. Further work could be undertaken to investigate the costs associated with installation of lights in new infrastructure. This is especially needed to compare LED with High Pressure Sodium lamps as the cost of installing LED lamps contributed to a significant cost of retrofitting.

With the higher quality of the light colour output of LEDs compared with HPS lamps it is possible that the night/day crash ratios used in this report are not relevant to LEDs because light quality may have a positive impact on crashes, possibly improving the night/day crash ratios of the pre and post-midnight scenarios. Further research could investigate this hypothesis and quantify the benefits.

CHAPTER 10 – REFERENCES

CONROD 2012, *2009 Road Traffic Crashes in Queensland*, Queensland Government, Department of Transport and Main Roads, Online, viewed 25/05/2013, <http://www.tmr.qld.gov.au/~/media/Safety/Transport%20and%20road%20statistics/Road%20safety/Road_traffic_crashes_in_qld_2009.pdf>.

Corporate Statistics: Business Services Department Victoria Police 2012, *Crime Statistics 2011/12*, Victoria Police, Online, viewed 25/05/2013, <http://www.police.vic.gov.au/content.asp?Document_ID=782>.

Department of Transport and Main Roads 2004, *Road Planning and Design Manual*, Queensland Government, Department of Transport and Main Roads, Online, viewed 20/05/3013, <http://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Road-planning-and-design-manual.aspx>.

District Court of New South Wales 2007, *Estephan v Lynsey Finch and Ors [2007] NSWDC 285*, AustLII, viewed 25/05/2013, <http://www.austlii.edu.au/au/cases/nsw/NSWDC/2007/285.html>.

Ironbark Sustainability 2011, *Draft Street Lighting Strategy*, Commonwealth of Australia, Equipment Energy Efficiency Committee, Online, viewed 20/05/3013, <http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Lighting/Street_Lighting/Draft-streetlight-Strategy.pdf>.

Jacket, M, Hutt, L, & Firth, W 2012, 'Quantifying the impact of road lighting on road safety – A New Zealand Study', in Australasian Road Safety Research, Policing and Education Conference 2012: *proceedings of the Australasian Road Safety Research, Policing and Education Conference 2012* Wellington, New Zealand.

Joint Technical Committee LG-002 2005, *AS/NZS1158.1.1:2005 Lighting for roads and public spaces*, Standards Australia/Standards New Zealand, Online, viewed 25/05/2013, <http://www.saiglobal.com>.

Kim, C, Park, Y & Sang, S 2008, 'Spatial and Temporal Analysis of Urban Traffic Volume', in 2008 ESRI International User Conference: *proceedings of the 2008 ESRI*

International User Conference ESRI, <http://proceedings.esri.com/library/userconf/proc08/papers/papers/pap_1613.pdf>.

Morrow, E, Hutton, SA 2000, *The Chicago Alley Lighting Project: Final Evaluation Reprot*, Illinois Criminal Justice Information Authority, Chicago.

New South Wales Department of Planning and Infrastructure 2007, *State Environmental Planning Policy (Infrastructure) 2007*, NSW Government, Online, viewed 25/05/2013, <http://www.planning.nsw.gov.au/PolicyandLegislation/Legislationandplanninginstruments/ListofStatePolicies/InfrastructureSEPP2007/tabid/240/language/en-US/Default.aspx>.

Philips 2013, *Lamp Technical Information (IES Files Download)*, Philips, viewed 22/05/2013, <http://www.lumec.com/products/luminaires/serie_roadstar.html?A>.

RightLight 2011, *Road Lighting Lamp Characteristic Table*, RightLight, viewed 22/05/2013, <http://www.rightlight.govt.nz/sites/default/files/Road%20Lighting%20Lamp%20Characteristic%20Table%2025Nov09.pdf>.

Standards Australia 2013, *Standards and the Law*, Standards Australia, viewed 22/05/2013, <http://www.standards.org.au/StandardsDevelopment/What_is_a_Standard/Pages/Standards-and-the-Law.aspx>.

Standards Australia 2013, *Standards Development PUBLIC PORTAL: LG002 LIGHTING FOR ROADS AND PUBLIC SPACES - Constitution*, Standards Australia, viewed 22/05/2013, <http://sdpp.standards.org.au/ActiveProjects.aspx?SectorName=Energy&CommitteeNumber=LG-002&CommitteeName=Lighting for Roads and Public Spaces#simple2>.

Taylor, D 2012, *Public Lighting Design Manual*, Energex & Ergon Energy, Online, viewed 20/05/3013, <http://www.energex.com.au/upload/technical_documents/20121121_071957_7413751.pdf>.

The World Bank 2012, *Turn Down the Heat: Why a 4oC Warmer World Must Be Avoided*, International Bank for Reconstruction and Development / The World Bank, Online, viewed 20/05/2013, <http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf>.

Tien, J, O'Donnell, VF, Barnett, AI & Mirchandani, PB 1977, *National Evaluation Program Phase 1 Summary Report - Street Lighting Projects*, United States Department of Justice, Washington DC.

Turner, B, Imberger, K, Roper, P, Pyta, V, & McLean, J 2010, *Road Safety Engineering Risk Assessment Part 6: Crash Reduction Factors*, Austroads Ltd, Sydney.

Welsh, B, Farrington, DC 2008, *Effects of improved street lighting on crime*, Campbell Systematic Reviews, Oslo.

Leavitt, J 2012, *Over 30 percent of City's streetlights to go dark to help keep City in black.*, City Of Colorado Springs, viewed 25/05/2013, <http://www.springsgov.com/News.aspx?NewsID=295>.

City of Santa Rosa 2013, *Street Light Reduction Program*, City of Santa Rosa, viewed 25/05/2013, <http://ci.santa-rosa.ca.us/departments/publicworks/streetlightreduction/Pages/default.aspx>.

Essex County Council 2012, *Part Night Lighting*, Essex County Council, viewed 25/05/2013, <http://www.essexhighways.org/Street-Lighting/Part-Night-Lighting.aspx>.

Engineers Australia 2010, *Our Code of Ethics*, Engineers Australia, Online, viewed 26/05/2013, <http://www.engineersaustralia.org.au/ethics>

Google Earth 7.0 2013, *Anzac Avenue Rothwell 27°13'00" S 153°03'36" E, elevation 8M*, viewed 28/07/2013, <http://www.google.com/earth/index.html>.

Google Earth 7.0 2013, *Bruce Highway and Boundary Road 27°12'39" S 152°59'29" E, elevation 28M*, viewed 28/07/2013, <http://www.google.com/earth/index.html>.

Department of Transport and Main _Roads 2008, *RISC Crash Costs Update*, Online, viewed 2/8/2013, <http://www.tmr.qld.gov.au/business-industry/Road-systems-and-engineering/Software/RISC.aspx>.

Interagency Working Group on Social Cost of Carbon, United States Government 2013, *Technical Support Document -Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis*, Online, viewed 2/8/2013, <http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf>.

Energex 2013, *Tariff Schedule - 1 July 2013 to 30 June 2014*, Online, viewed 2/8/2013, <http://www.energex.com.au/__data/assets/pdf_file/0009/157356/2013-14_Tariff-Schedule.pdf>.

US Department of Energy and Environmental Protection Agency 2000, *Carbon Dioxide Emissions from the Generation of Electric Power in the United States*, Online, viewed 2/8/2013, <ftp://ftp.eia.doe.gov/environment/co2emiss00.pdf>.

Philips 2013, *LED Reliability and Lumen Maintenance*, viewed 5/8/2013, <http://www.philipslumileds.com/technology/lumenmaintenance>.

Sunshine Coast Regional Council 2013, *Sunshine Coast Solar Farm*, Online, viewed 31/08/2013, <http://www.sunshinecoast.qld.gov.au/sitePage.cfm?code=solar-farm>.

APPENDIX A – PROJECT SPECIFICATION

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project

PROJECT SPECIFICTION

FOR: Mark ZELLER

TOPIC: REDUCED ROAD LIGHTING STANDARDS DURING TIMES ASSOCIATED WITH LOW TRAFFIC VOLUMES

SUPERVISOR: Les Bowtell

PROJECT AIM: To investigate the feasibility of allowing reduced lighting standards for lit roadways during times of low traffic volume.

PROGRAMME: **(Issue A, 27 March 2013)**

1. Investigate the economic and environmental costs associated with electricity consumption for road lighting purposes.
2. Review the Australian Standards for road lighting (AS1158) and other relevant literature from which road lighting standards have been derived.
3. Investigate the possible issues (safety, crime etc.) associated with reducing the lighting standards.
4. Identify exemplar sites suitable for review. This would be done by evaluating a number of sites which have distinctly different lighting schemes and/or traffic flow characteristics and identifying 3 distinctly different sites with the potential for reducing lighting standards.
5. Propose a lighting treatment/s for the subject site e.g. LED or other suitable technologies.
6. Analyse the environmental benefits and cost implications associated with implementing the proposed treatment/s.

AGREED:

Mark Zeller (student), Les Bowtell (supervisor)

APPENDIX B– CRIME STATISTICS (TEMPORAL TRENDS)

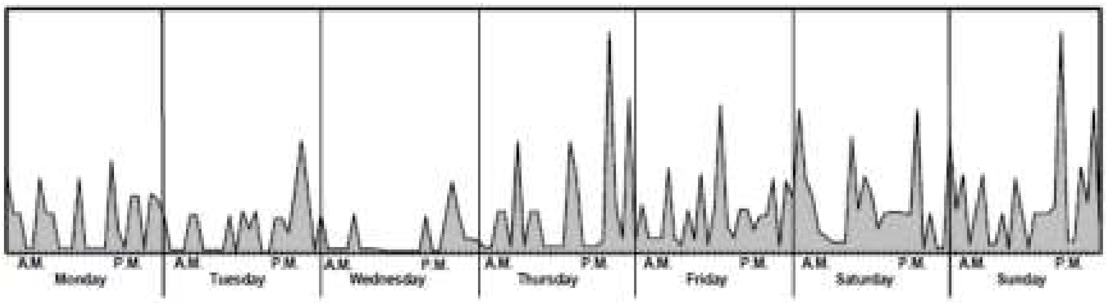


Figure B.1: Homicide (Victoria Police: Crime Statistics 2011/2012, 2012)

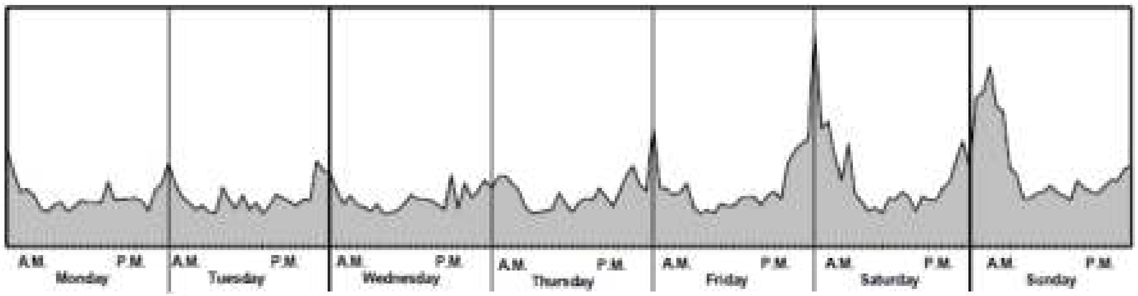


Figure B.2: Rape (Victoria Police: Crime Statistics 2011/2012, 2012)

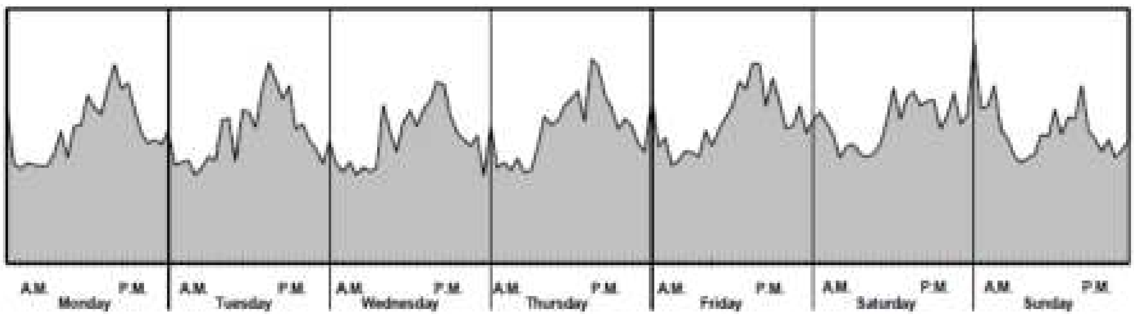


Figure B.3: Sex (non-Rape) (Victoria Police: Crime Statistics 2011/2012, 2012)

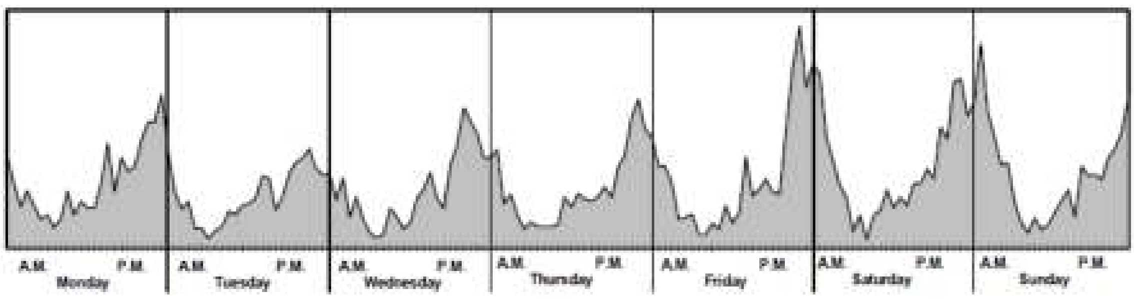


Figure B.4: Robbery (Victoria Police: Crime Statistics 2011/2012, 2012)

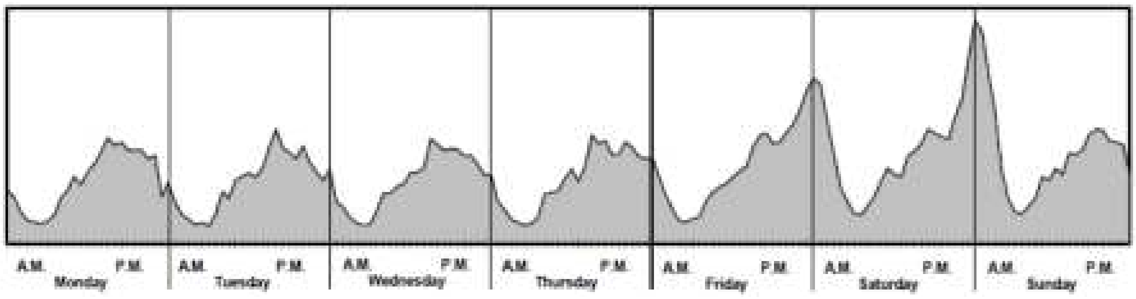


Figure B.5: Assault (Victoria Police: Crime Statistics 2011/2012, 2012)

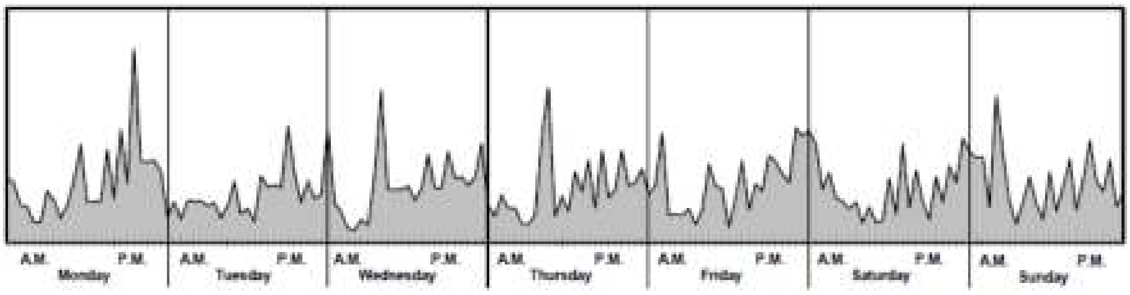


Figure B.6: Abduction / Kidnap (Victoria Police: Crime Statistics 2011/2012, 2012)

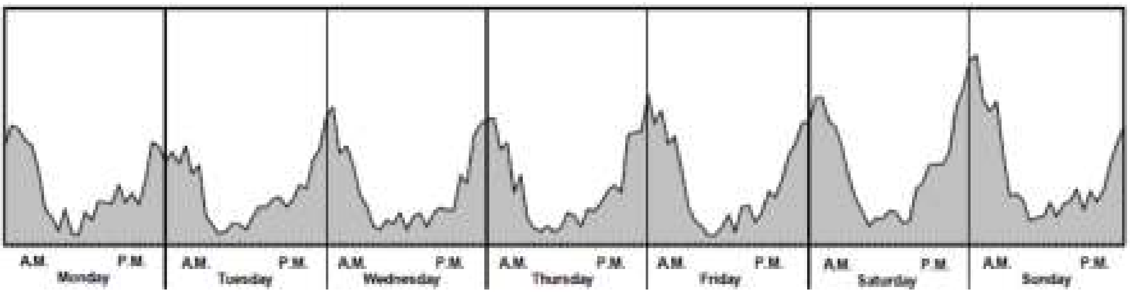


Figure B.7: Arson (Victoria Police: Crime Statistics 2011/2012, 2012)

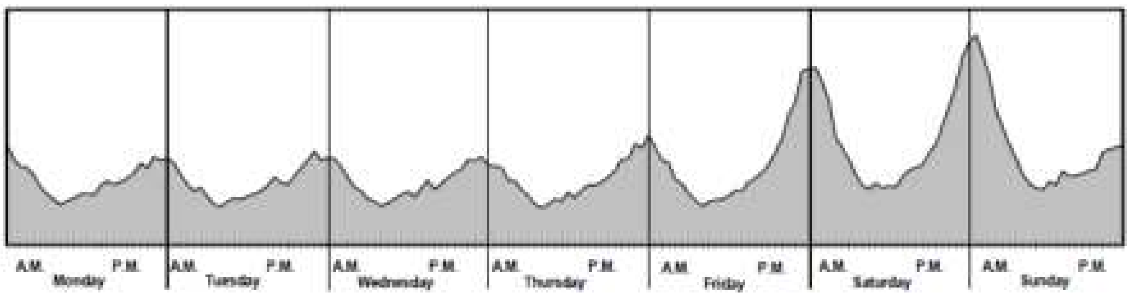


Figure B.8: Property Damage (Victoria Police: Crime Statistics 2011/2012, 2012)

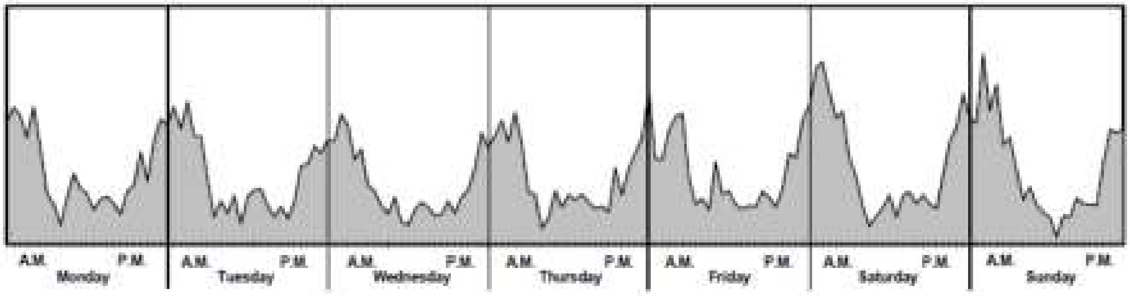


Figure B.9: Burglary (Aggravated) (Victoria Police: Crime Statistics 2011/2012, 2012)

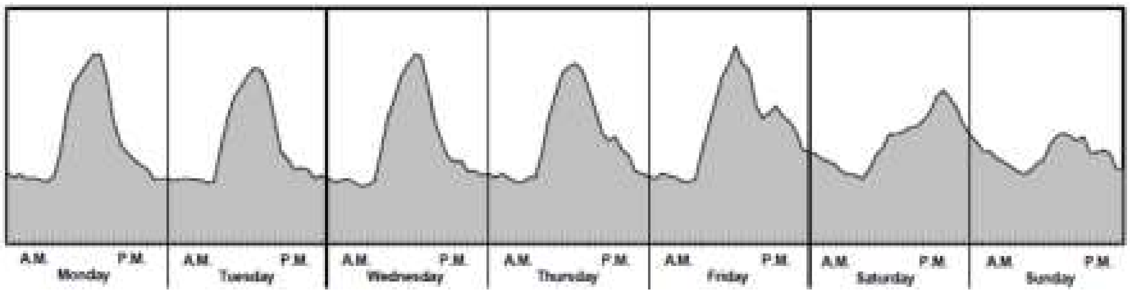


Figure B.10: Burglary (Residential) (Victoria Police: Crime Statistics 2011/2012, 2012)

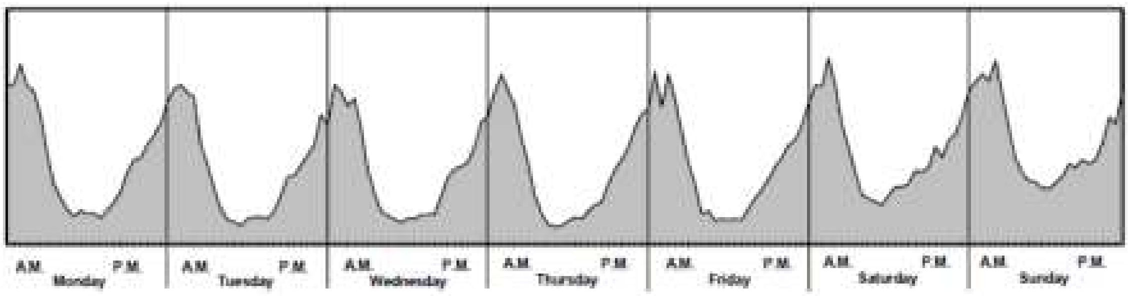


Figure B.11: Burglary (Other) (Victoria Police: Crime Statistics 2011/2012, 2012)

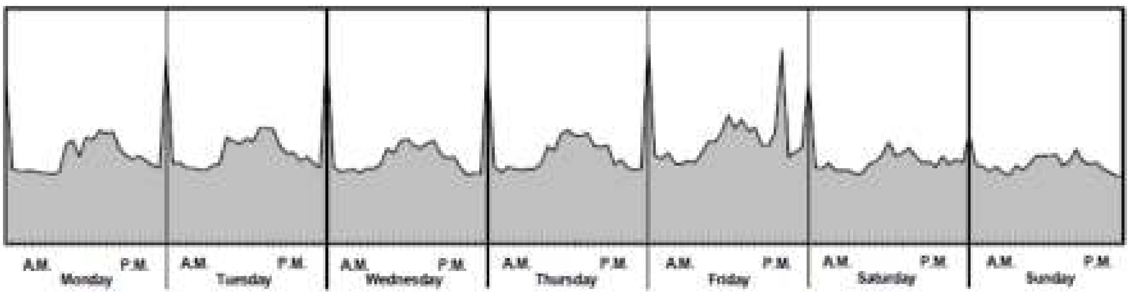


Figure B.12: Deception (Victoria Police: Crime Statistics 2011/2012, 2012)

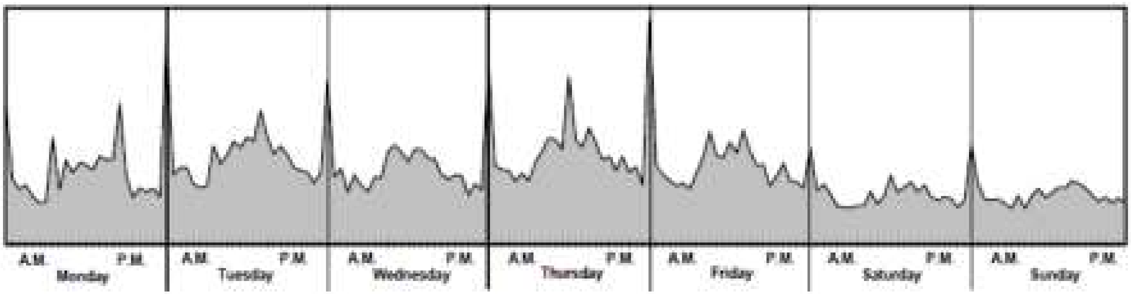


Figure B.13: Handle Stolen Goods (Victoria Police: Crime Statistics 2011/2012, 2012)

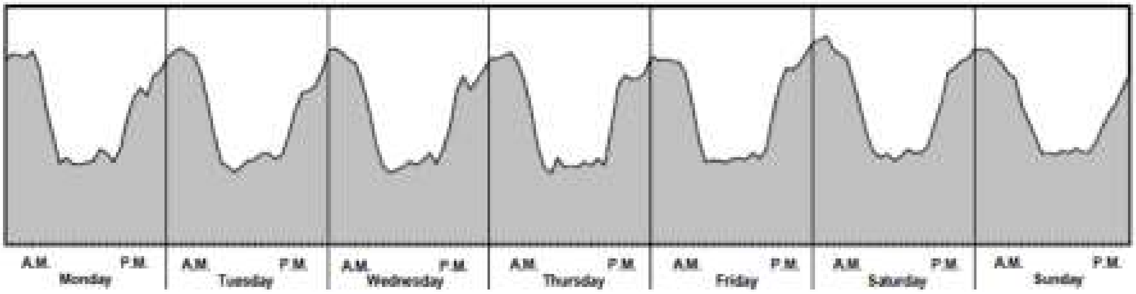


Figure B.14: Theft from Motor Vehicle (Victoria Police: Crime Statistics 2011/2012, 2012)

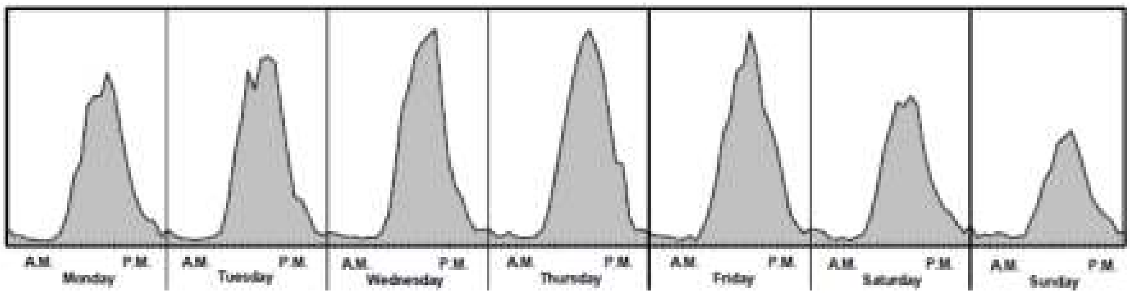


Figure B.15: Theft (Shopsteal) (Victoria Police: Crime Statistics 2011/2012, 2012)

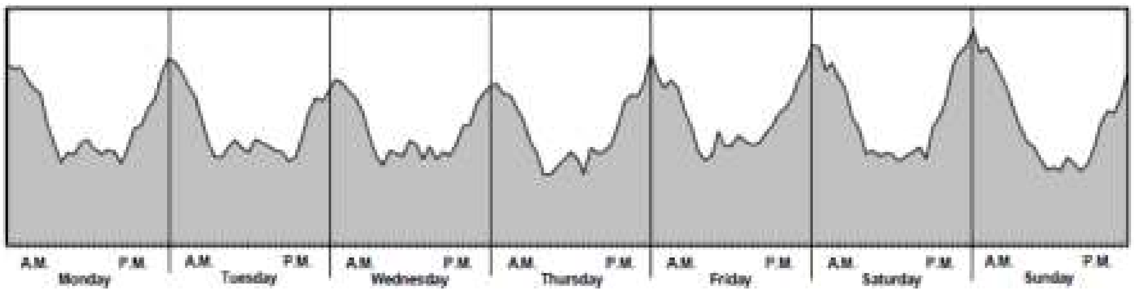


Figure B.16: Theft of Motor Vehicle (Victoria Police: Crime Statistics 2011/2012, 2012)

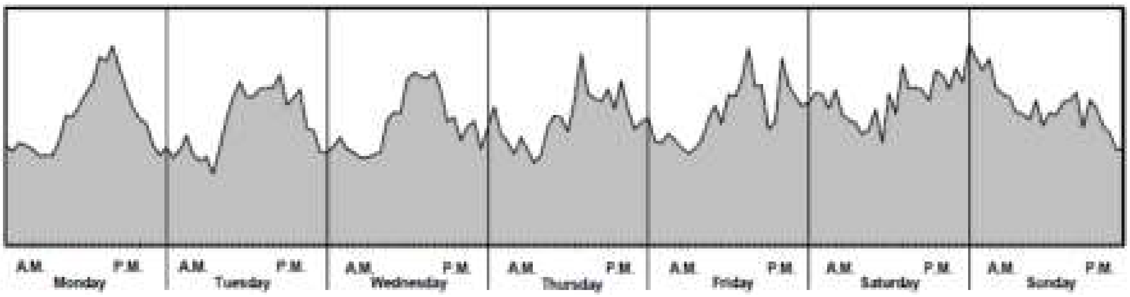


Figure B.17: Theft (Bicycle) (Victoria Police: Crime Statistics 2011/2012, 2012)

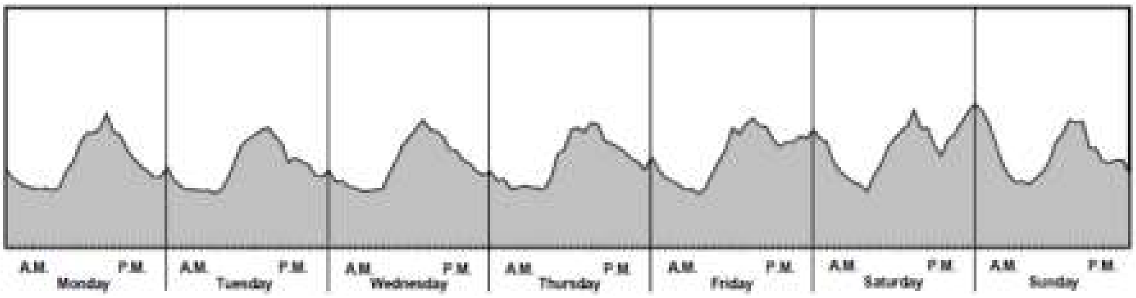


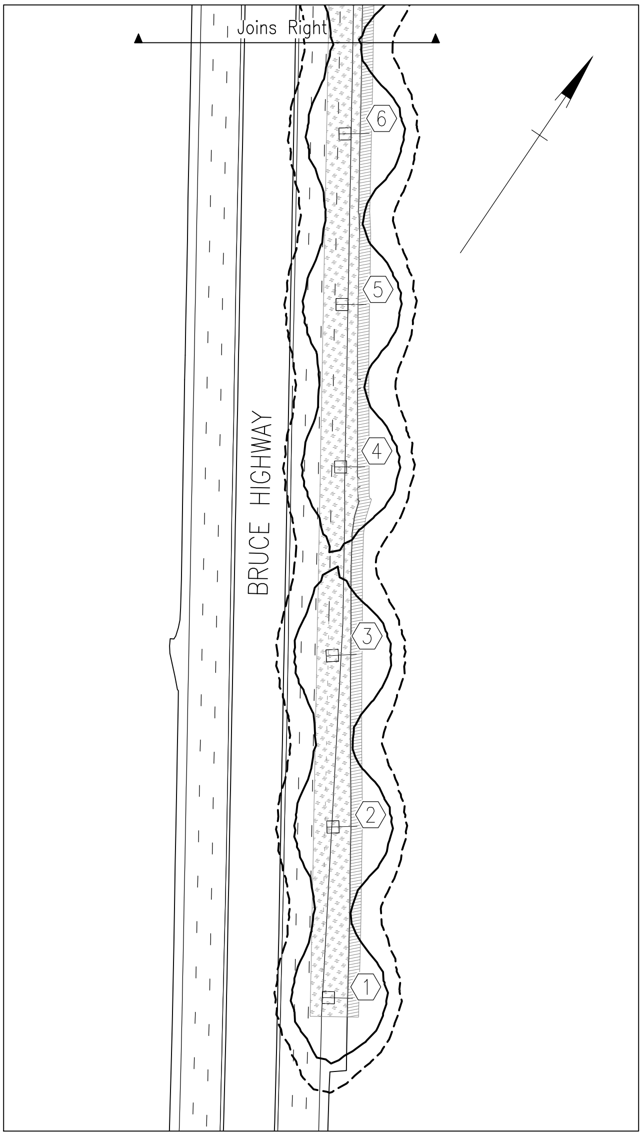
Figure B.18: Theft (Other) (Victoria Police: Crime Statistics 2011/2012, 2012)

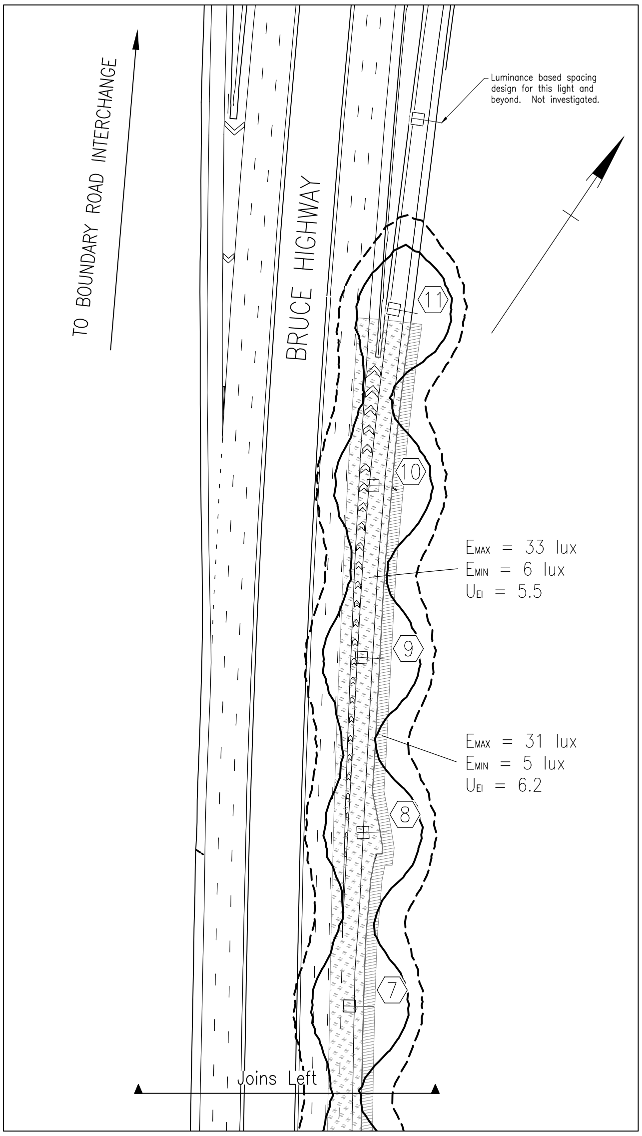
APPENDIX C – SITE COMPARISON

Table C.1: Site Comparison Table

Site Name	Geometric Description	Selected Yes/No	Justification
A - Bruce Highway and Eumundi Kenilworth Rd	Interchange On-Ramp	No	The Bruce Hwy has route lighting which effects the ability to review the on ramp diverge without analysing the route lighting also.
B - Sunshine Motorway and Maroochydore Road	Interchange On-Ramp	No	Same issue as Bruce Highway and Eumundi Kenilworth Rd
C - Bruce Highway and Boundary Road	Interchange On-Ramp	No	No route lighting exists on the Bruce Highway however the existing lighting layout does not comply with the current AS/NZS1185. Refer drawing INT-001 (APPENDIX D).
D - Bruce Highway and Boundary Road - Redesigned	Interchange On-Ramp	Yes	Redesigned to bring up to current standards. Refer drawing INT-002 (APPENDIX D).
E - David Low Way and Runway Drive	Signalised Intersection	Yes	Lighting layout is to a V3 standard and design layouts of the current design are accessible in TMR's document management system. Refer drawing SIG-001 (APPENDIX E).
F - Aerodrome Road and Maud Street	Signalised Intersection	No	Current layout is not to V3 standard.
G - Nicklin Way – Thunderbird Dr to Beach Dr	Mid-Block	No	Inconsistent road width
H - Anzac Avenue – Mewes Road to Bremner Road	Mid-Block	No	Layout is to a V3 standard and has consistent width however does not comply with standards at channelized right turn lane into Bremner Road. Refer drawing MID-001, spacing calculation MID-001-AA and spacing calculation MID-001-BB (APPENDIX F).
I - Anzac Avenue – Mewes Road to Bremner Road – Redesigned	Mid-Block	Yes	Changes to Anzac Avenue – Mewes Road to Bremner Road to fix issue at channelized right turn lane into Bremner Road. Refer drawing MID-002, spacing calculation MID-001-AA and spacing calculation MID-001-BB (APPENDIX F).

APPENDIX D – BRUCE HIGHWAY AND BOUNDARY ROAD SOUTHBOUND ON-RAMP (REDESIGNED): LIGHTING LAYOUTS





STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 250W HPS – AEROSCREEN	3	12	1.3
2	REXEL 250W HPS – AEROSCREEN	3	12	1.6
3	REXEL 250W HPS – AEROSCREEN	3	12	1.6
4	REXEL 250W HPS – AEROSCREEN	3	12	1.9
5	REXEL 250W HPS – AEROSCREEN	3	12	2.1
6	REXEL 250W HPS – AEROSCREEN	3	12	2.4
7	REXEL 250W HPS – AEROSCREEN	3	12	2.7
8	REXEL 250W HPS – AEROSCREEN	3	12	1.8
9	REXEL 250W HPS – AEROSCREEN	3	12	1.5
10	REXEL 250W HPS – AEROSCREEN	3	12	1.3
11	REXEL 250W HPS – AEROSCREEN	3	12	1.4

LEGEND

Street Light
2 Station Number
7.5 Lux Contour
3.75 Lux Contour
E_{PH} & U_{EI} Apply
$0.5E_{PH}$ & U_{EI} Apply

Scales

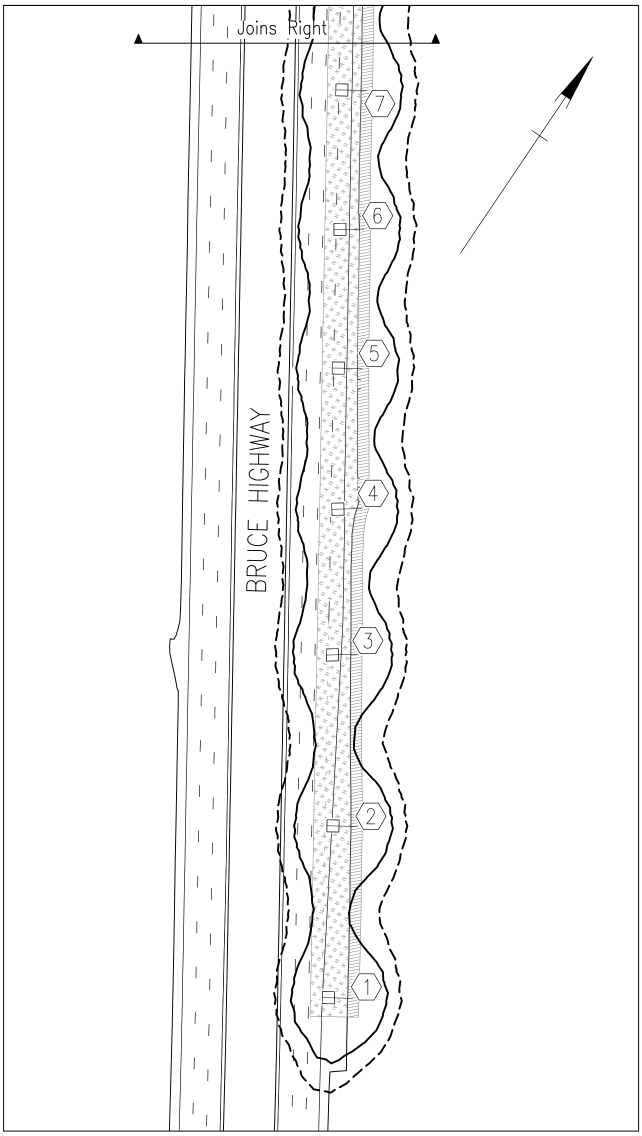
0 10 20 30 40m

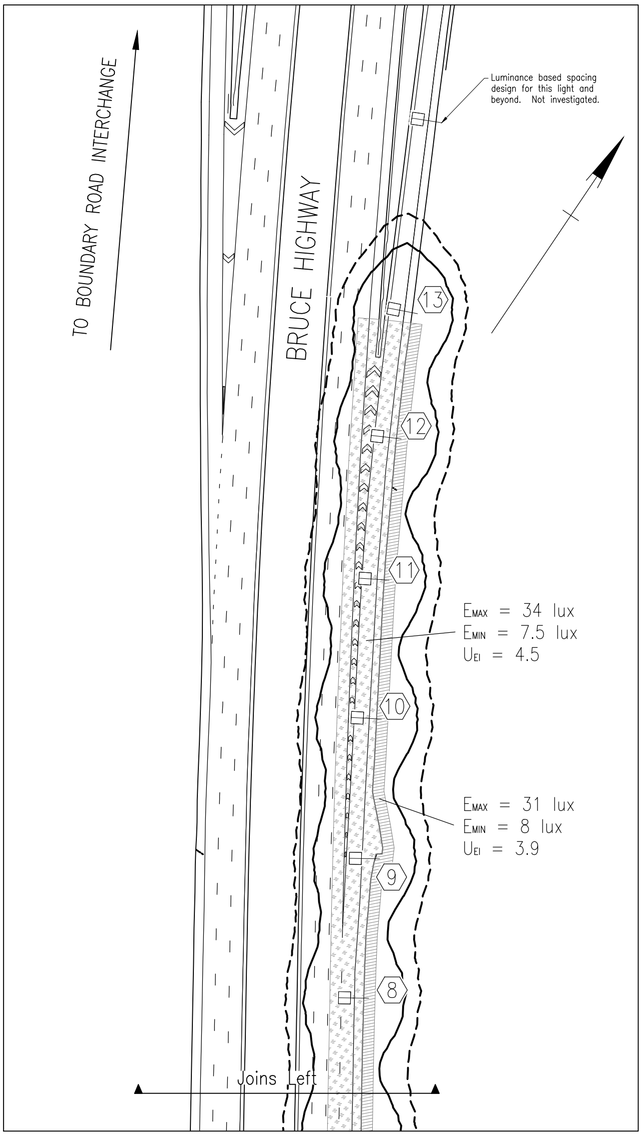
Dimensions shown in metres except where shown otherwise

BRUCE HIGHWAY
BOUNDARY ROAD INTERCHANGE
EXISTING LIGHTING ARRANGEMENT

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	INT–001





STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 250W HPS – AEROSCREEN	3	12	1.3
2	REXEL 250W HPS – AEROSCREEN	3	12	1.6
3	REXEL 250W HPS – AEROSCREEN	3	12	1.6
4	REXEL 250W HPS – AEROSCREEN	3	12	1.3
5	REXEL 250W HPS – AEROSCREEN	3	12	1.3
6	REXEL 250W HPS – AEROSCREEN	3	12	1.3
7	REXEL 250W HPS – AEROSCREEN	3	12	1.3
8	REXEL 250W HPS – AEROSCREEN	3	12	1.3
9	REXEL 250W HPS – AEROSCREEN	3	12	1.3
10	REXEL 250W HPS – AEROSCREEN	3	12	1.3
11	REXEL 250W HPS – AEROSCREEN	3	12	1.3
12	REXEL 250W HPS – AEROSCREEN	3	12	1.3
13	REXEL 250W HPS – AEROSCREEN	3	12	1.4

LEGEND

- Street Light
- 2 Station Number
- 7.5 Lux Contour
- 3.75 Lux Contour
- E_{PH} & U_{EI} Apply
- $0.5E_{PH}$ & U_{EI} Apply

Scales

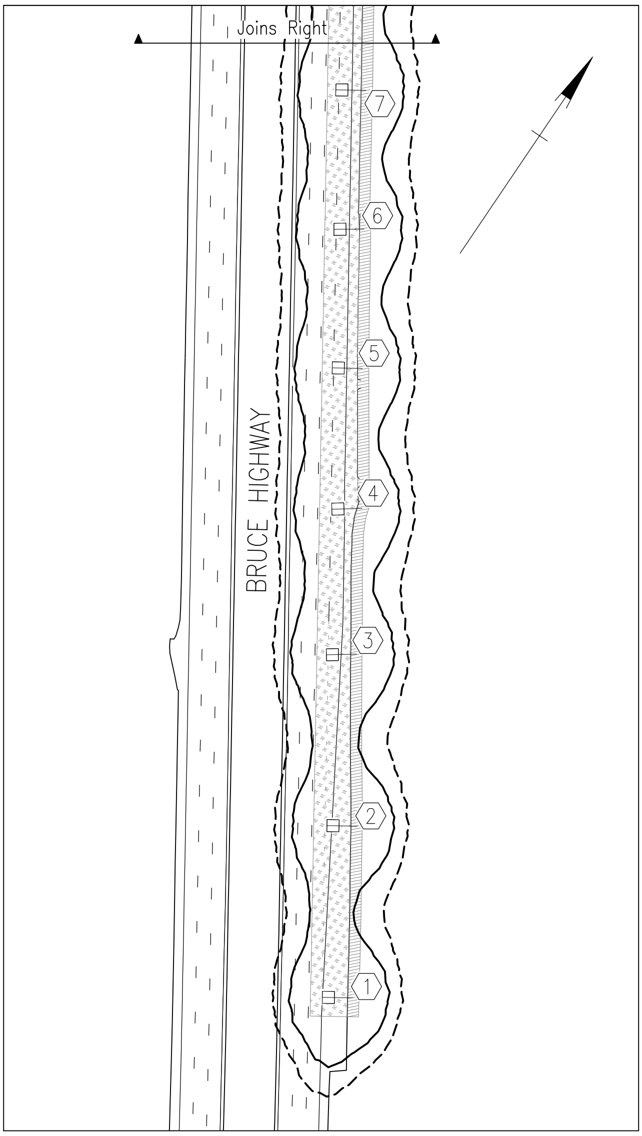
0 10 20 30 40m

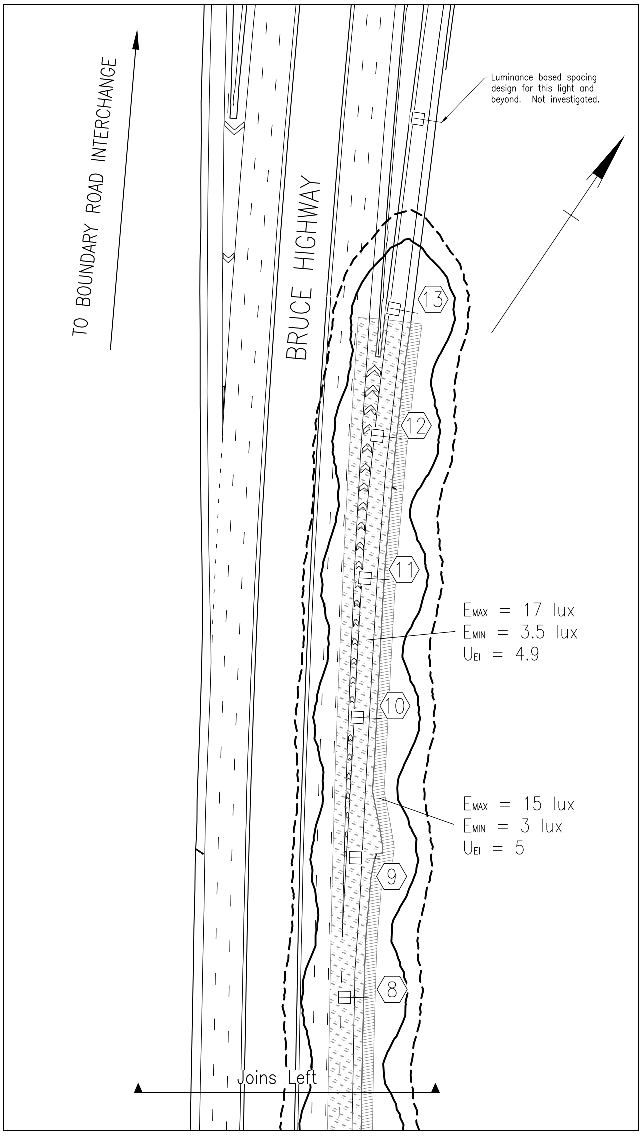
Dimensions shown in metres except where shown otherwise

BRUCE HIGHWAY
BOUNDARY ROAD INTERCHANGE
BASE LAYOUT
REDESIGNED LIGHTING ARRANGEMENT

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	INT–002





STREETLIGHT SCHEDULE				
STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 150W HPS – AEROSCREEN	3	12	1.3
2	REXEL 150W HPS – AEROSCREEN	3	12	1.6
3	REXEL 150W HPS – AEROSCREEN	3	12	1.6
4	REXEL 150W HPS – AEROSCREEN	3	12	1.3
5	REXEL 150W HPS – AEROSCREEN	3	12	1.3
6	REXEL 150W HPS – AEROSCREEN	3	12	1.3
7	REXEL 150W HPS – AEROSCREEN	3	12	1.3
8	REXEL 150W HPS – AEROSCREEN	3	12	1.3
9	REXEL 150W HPS – AEROSCREEN	3	12	1.3
10	REXEL 150W HPS – AEROSCREEN	3	12	1.3
11	REXEL 150W HPS – AEROSCREEN	3	12	1.3
12	REXEL 150W HPS – AEROSCREEN	3	12	1.3
13	REXEL 150W HPS – AEROSCREEN	3	12	1.4

LEGEND

Street Light

2 Station Number

3.5 Lux Contour

1.75 Lux Contour

E_{PH} & U_{EI} Apply

$0.5E_{PH}$ & U_{EI} Apply

Scales

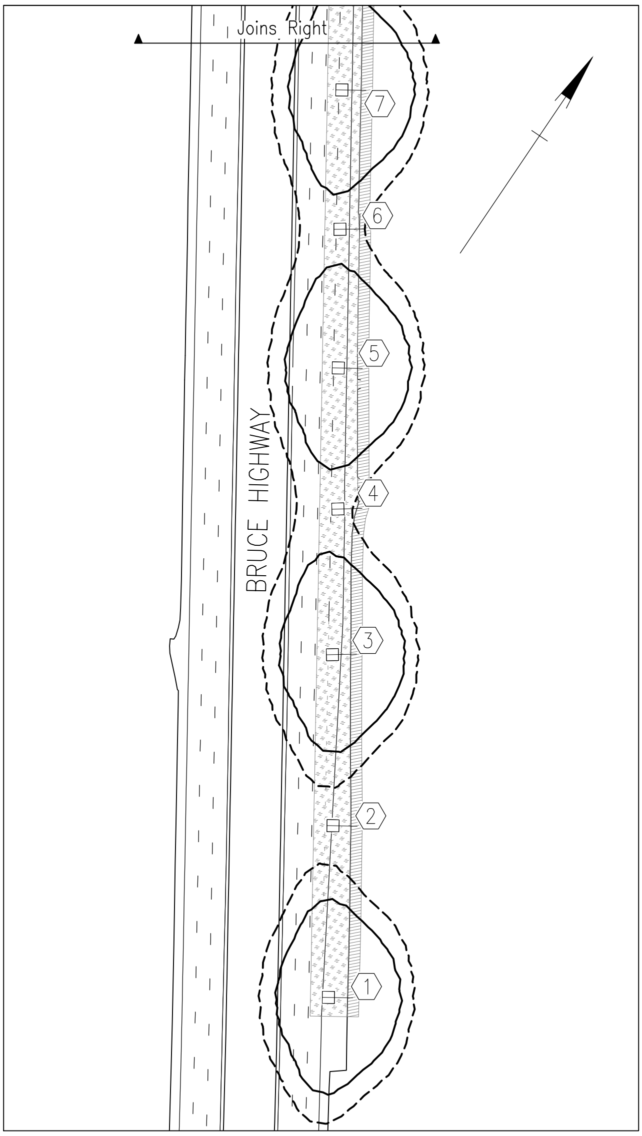
0 10 20 30 40m

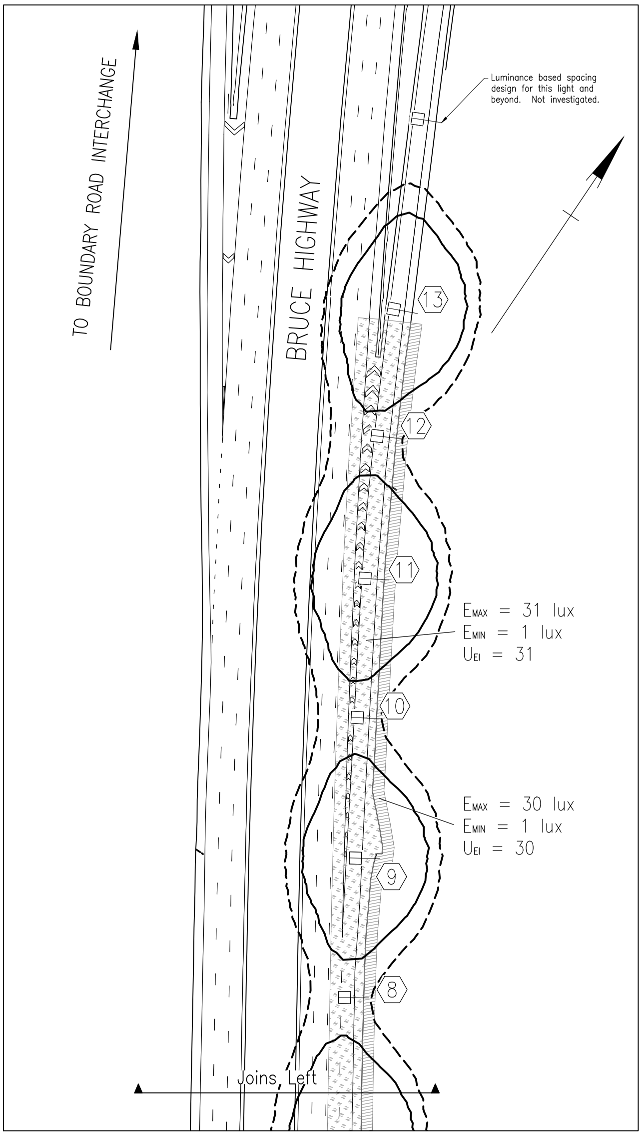
Dimensions shown in metres except where shown otherwise

BRUCE HIGHWAY
BOUNDARY ROAD INTERCHANGE
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 1 – DIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	INT-003





STREETLIGHT SCHEDULE				
STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 250W HPS – AEROSCREEN	3	12	1.3
2	REXEL 250W HPS – AEROSCREEN (OFF)	3	12	1.6
3	REXEL 250W HPS – AEROSCREEN	3	12	1.6
4	REXEL 250W HPS – AEROSCREEN (OFF)	3	12	1.3
5	REXEL 250W HPS – AEROSCREEN	3	12	1.3
6	REXEL 250W HPS – AEROSCREEN (OFF)	3	12	1.3
7	REXEL 250W HPS – AEROSCREEN	3	12	1.3
8	REXEL 250W HPS – AEROSCREEN (OFF)	3	12	1.3
9	REXEL 250W HPS – AEROSCREEN	3	12	1.3
10	REXEL 250W HPS – AEROSCREEN (OFF)	3	12	1.3
11	REXEL 250W HPS – AEROSCREEN	3	12	1.3
12	REXEL 250W HPS – AEROSCREEN (OFF)	3	12	1.3
13	REXEL 250W HPS – AEROSCREEN	3	12	1.4

LEGEND

Street Light

Station Number

3.5 Lux Contour

1.75 Lux Contour

E_{PH} & U_{EI} Apply

0.5E_{PH} & U_{EI} Apply

Scales

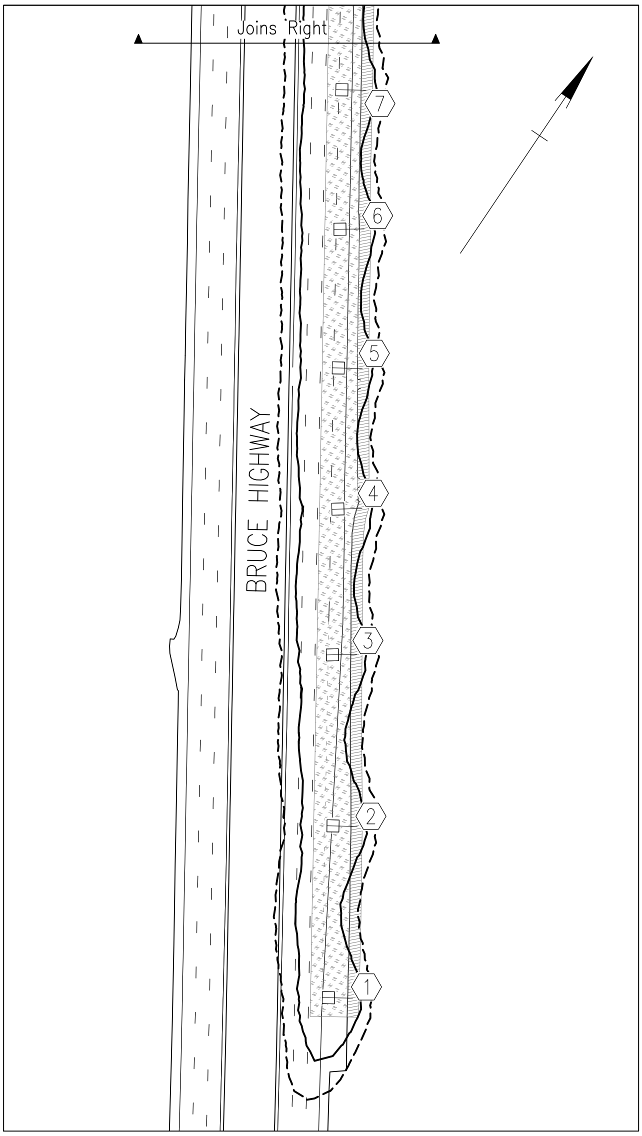
0 10 20 30 40m

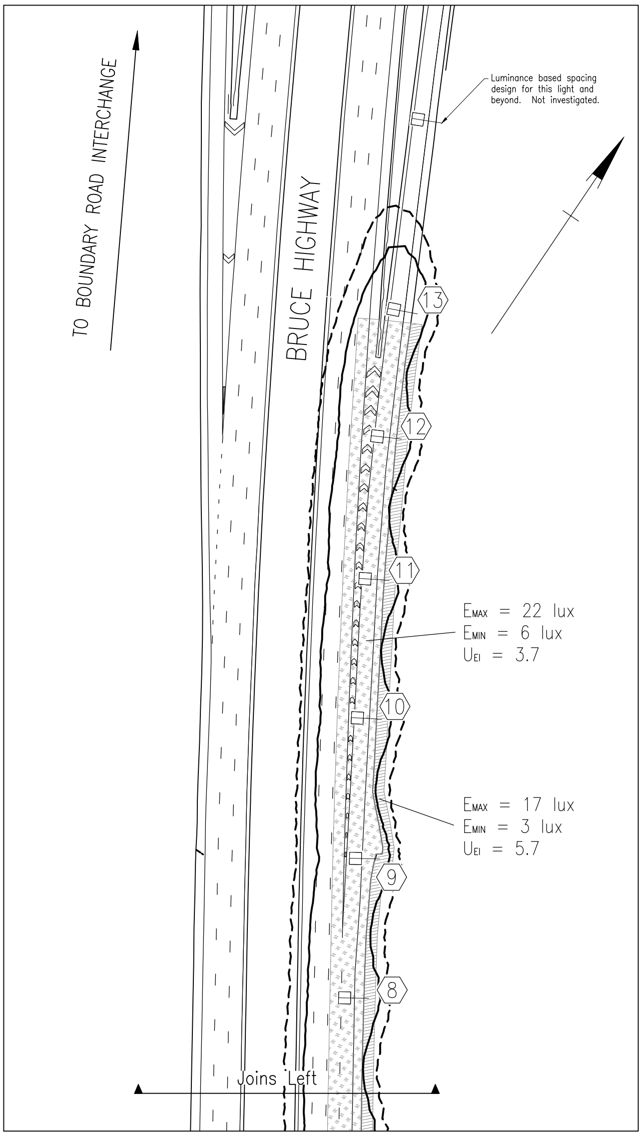
Dimensions shown in metres except where shown otherwise

BRUCE HIGHWAY
BOUNDARY ROAD INTERCHANGE
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 2 – DIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
Drawing Number	INT–004





STREETLIGHT SCHEDULE				
STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	PHILIPS 180W LED LE2	3	12	1.3
2	PHILIPS 180W LED LE2	3	12	1.6
3	PHILIPS 180W LED LE2	3	12	1.6
4	PHILIPS 180W LED LE2	3	12	1.3
5	PHILIPS 180W LED LE2	3	12	1.3
6	PHILIPS 180W LED LE2	3	12	1.3
7	PHILIPS 180W LED LE2	3	12	1.3
8	PHILIPS 180W LED LE2	3	12	1.3
9	PHILIPS 180W LED LE2	3	12	1.3
10	PHILIPS 180W LED LE2	3	12	1.3
11	PHILIPS 180W LED LE2	3	12	1.3
12	PHILIPS 180W LED LE2	3	12	1.3
13	PHILIPS 180W LED LE2	3	12	1.4

LEGEND

Street Light

(2) Station Number

7.5 Lux Contour

3.75 Lux Contour

E_{PH} & U_{EI} Apply

$0.5E_{PH}$ & U_{EI} Apply

Scales

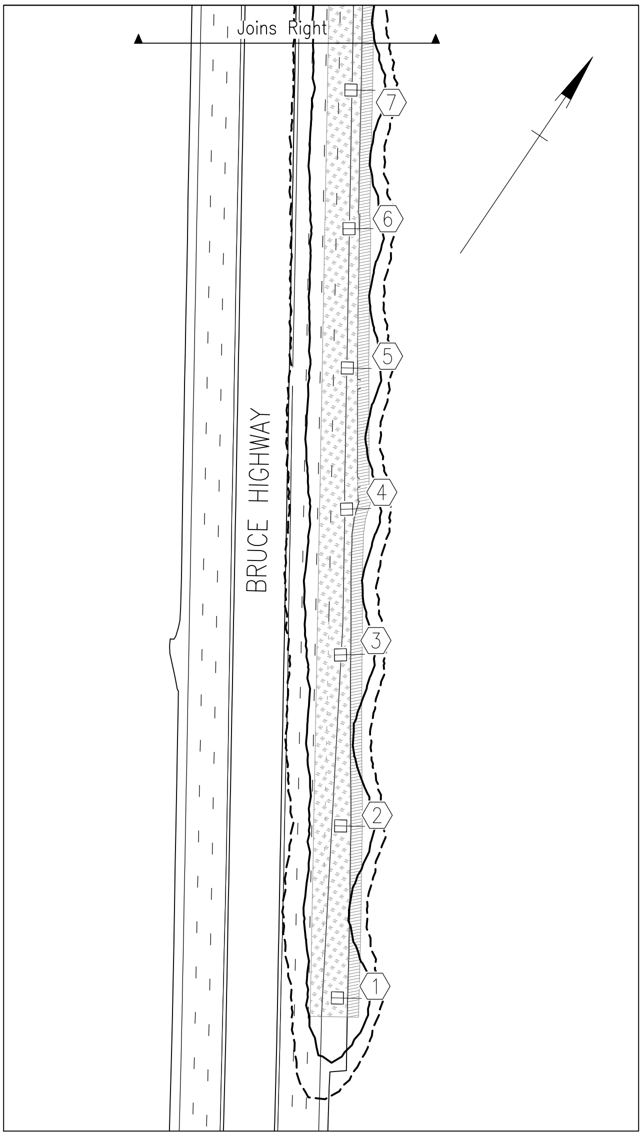
0 10 20 30 40m

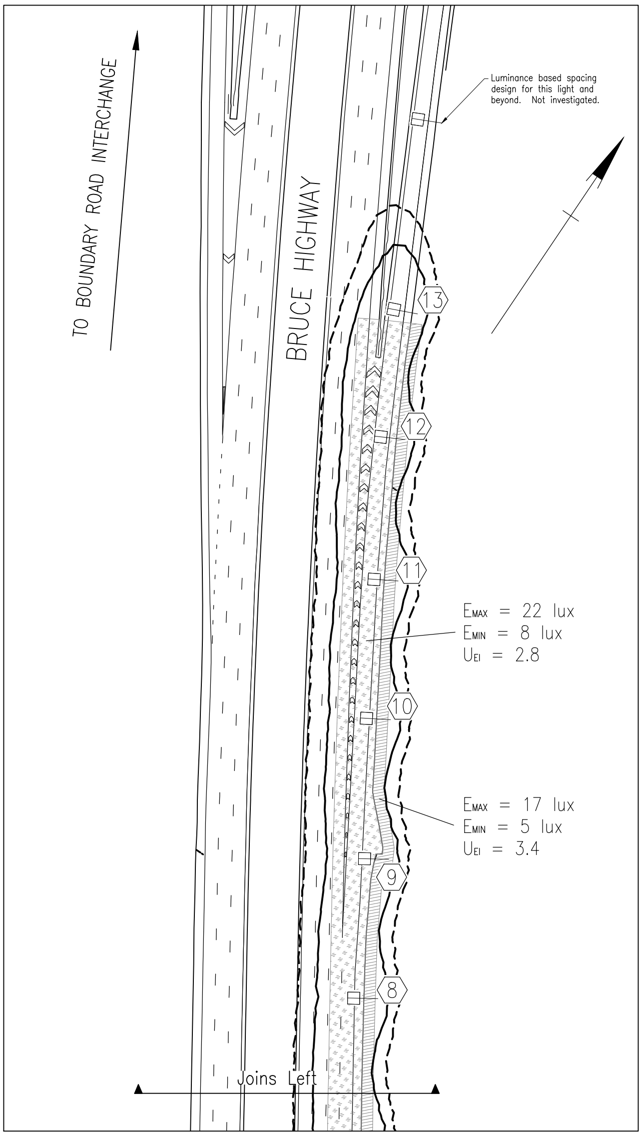
Dimensions shown in metres except where shown otherwise

BRUCE HIGHWAY
BOUNDARY ROAD INTERCHANGE
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 3 – UNDIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	INT-005





STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	PHILIPS 180W LED LE2	3	12	3.7
2	PHILIPS 180W LED LE2	3	12	3.7
3	PHILIPS 180W LED LE2	3	12	3.7
4	PHILIPS 180W LED LE2	3	12	3.7
5	PHILIPS 180W LED LE2	3	12	3.7
6	PHILIPS 180W LED LE2	3	12	3.7
7	PHILIPS 180W LED LE2	3	12	3.7
8	PHILIPS 180W LED LE2	3	12	3.7
9	PHILIPS 180W LED LE2	3	12	3.7
10	PHILIPS 180W LED LE2	3	12	3.7
11	PHILIPS 180W LED LE2	3	12	3.7
12	PHILIPS 180W LED LE2	3	12	2.2
13	PHILIPS 180W LED LE2	3	12	1.4

LEGEND

Street Light

Station Number

7.5 Lux Contour

3.75 Lux Contour

E_{PH} & U_{EI} Apply

$0.5E_{PH}$ & U_{EI} Apply

Scales

0 10 20 30 40m

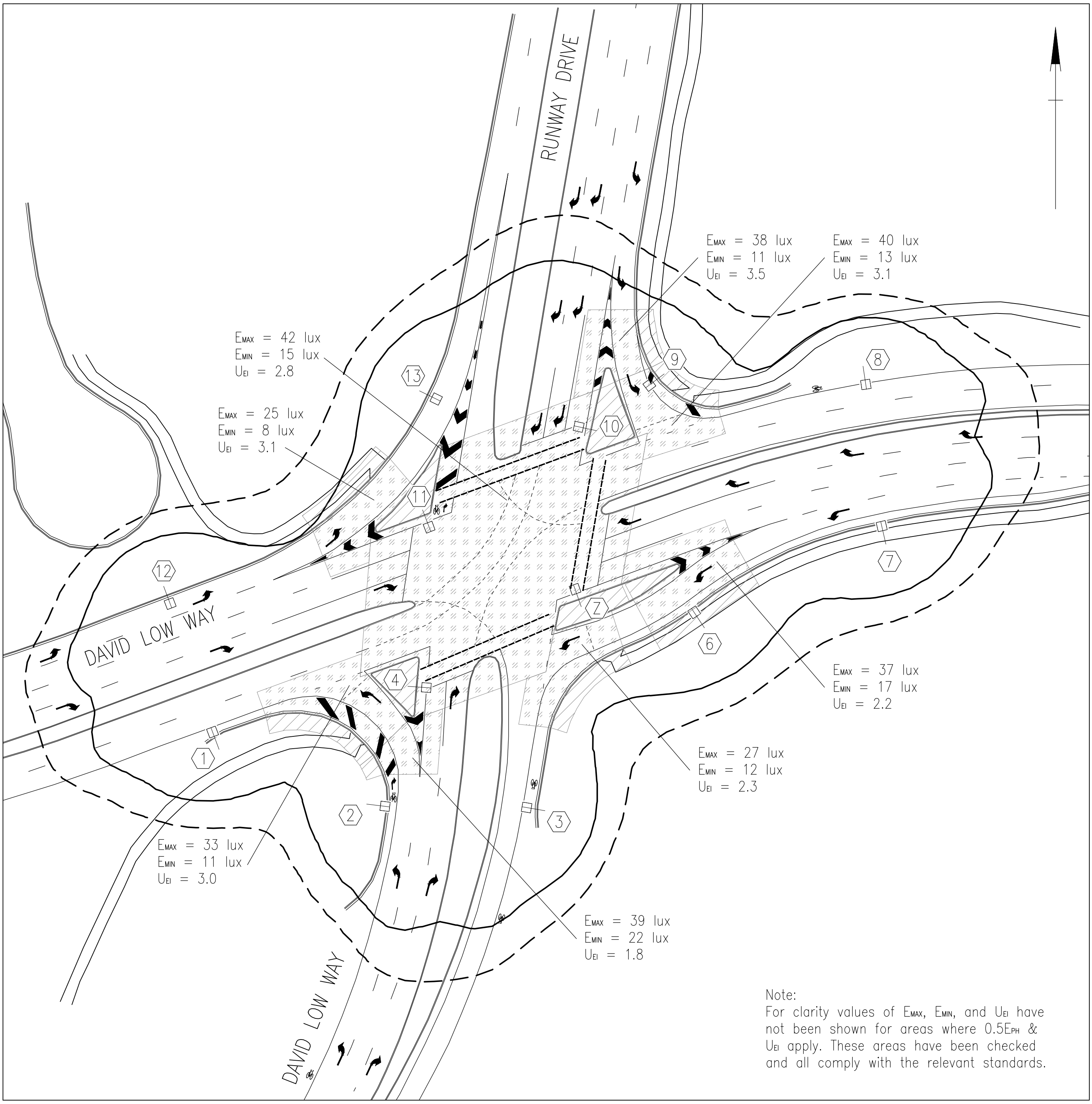
Dimensions shown in metres except where shown otherwise

BRUCE HIGHWAY
BOUNDARY ROAD INTERCHANGE
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 3A – UNDIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	INT-006

APPENDIX E – DAVID LOW WAY AND RUNWAY DRIVE SIGNALISED INTERSECTION: LIGHTING LAYOUTS



Note:
For clarity values of E_{MAX}, E_{MIN}, and U_{EI} have not been shown for areas where $0.5E_{PH}$ & U_{EI} apply. These areas have been checked and all comply with the relevant standards.

STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)
1	REXEL 250W HPS – AEROSCREEN	4.5	12
2	REXEL 250W HPS – AEROSCREEN	4.5	12
3	REXEL 250W HPS – AEROSCREEN	4.5	12
4	REXEL 250W HPS – AEROSCREEN	4.5	12
5	REXEL 250W HPS – AEROSCREEN	4.5	12
6	REXEL 250W HPS – AEROSCREEN	4.5	12
7	REXEL 250W HPS – AEROSCREEN	4.5	12
8	REXEL 250W HPS – AEROSCREEN	4.5	12
9	REXEL 250W HPS – AEROSCREEN	4.5	12
10	REXEL 250W HPS – AEROSCREEN	4.5	12
11	REXEL 250W HPS – AEROSCREEN	4.5	12
12	REXEL 250W HPS – AEROSCREEN	4.5	12
13	REXEL 250W HPS – AEROSCREEN	4.5	12

LEGEND

Street Light
2 Station Number
7.5 Lux Contour
3.75 Lux Contour
E_{PH} & U_{EI} Apply
$0.5E_{PH}$ & U_{EI} Apply

Scales

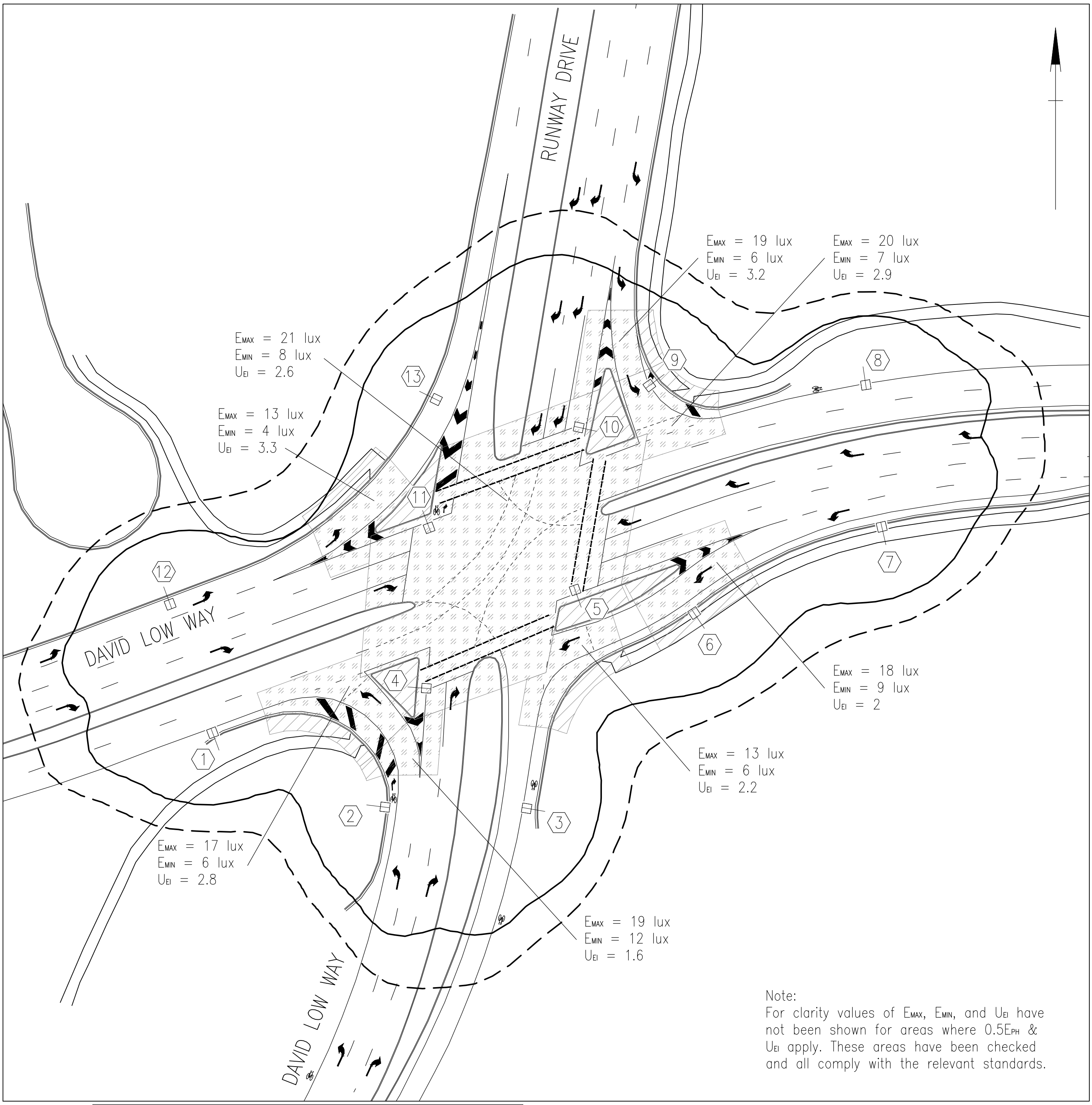
0 5 10 15 20m

Dimensions shown in metres except where shown otherwise

DAVID LOW WAY
RUNWAY DRIVE INTERSECTION
BASE LAYOUT
EXISTING LIGHTING ARRANGEMENT

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	SIG-001



Note:
For clarity values of E_{MAX}, E_{MIN}, and U_{EI} have not been shown for areas where $0.5E_{PH}$ & U_{EI} apply. These areas have been checked and all comply with the relevant standards.

STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)
1	REXEL 150W HPS – AEROSCREEN	4.5	12
2	REXEL 150W HPS – AEROSCREEN	4.5	12
3	REXEL 150W HPS – AEROSCREEN	4.5	12
4	REXEL 150W HPS – AEROSCREEN	4.5	12
5	REXEL 150W HPS – AEROSCREEN	4.5	12
6	REXEL 150W HPS – AEROSCREEN	4.5	12
7	REXEL 150W HPS – AEROSCREEN	4.5	12
8	REXEL 150W HPS – AEROSCREEN	4.5	12
9	REXEL 150W HPS – AEROSCREEN	4.5	12
10	REXEL 150W HPS – AEROSCREEN	4.5	12
11	REXEL 150W HPS – AEROSCREEN	4.5	12
12	REXEL 150W HPS – AEROSCREEN	4.5	12
13	REXEL 150W HPS – AEROSCREEN	4.5	12

LEGEND

- Street Light
- 2 Station Number
- 3.5 Lux Contour
- 1.75 Lux Contour
- E_{PH} & U_{EI} Apply
- $0.5E_{PH}$ & U_{EI} Apply

Scales

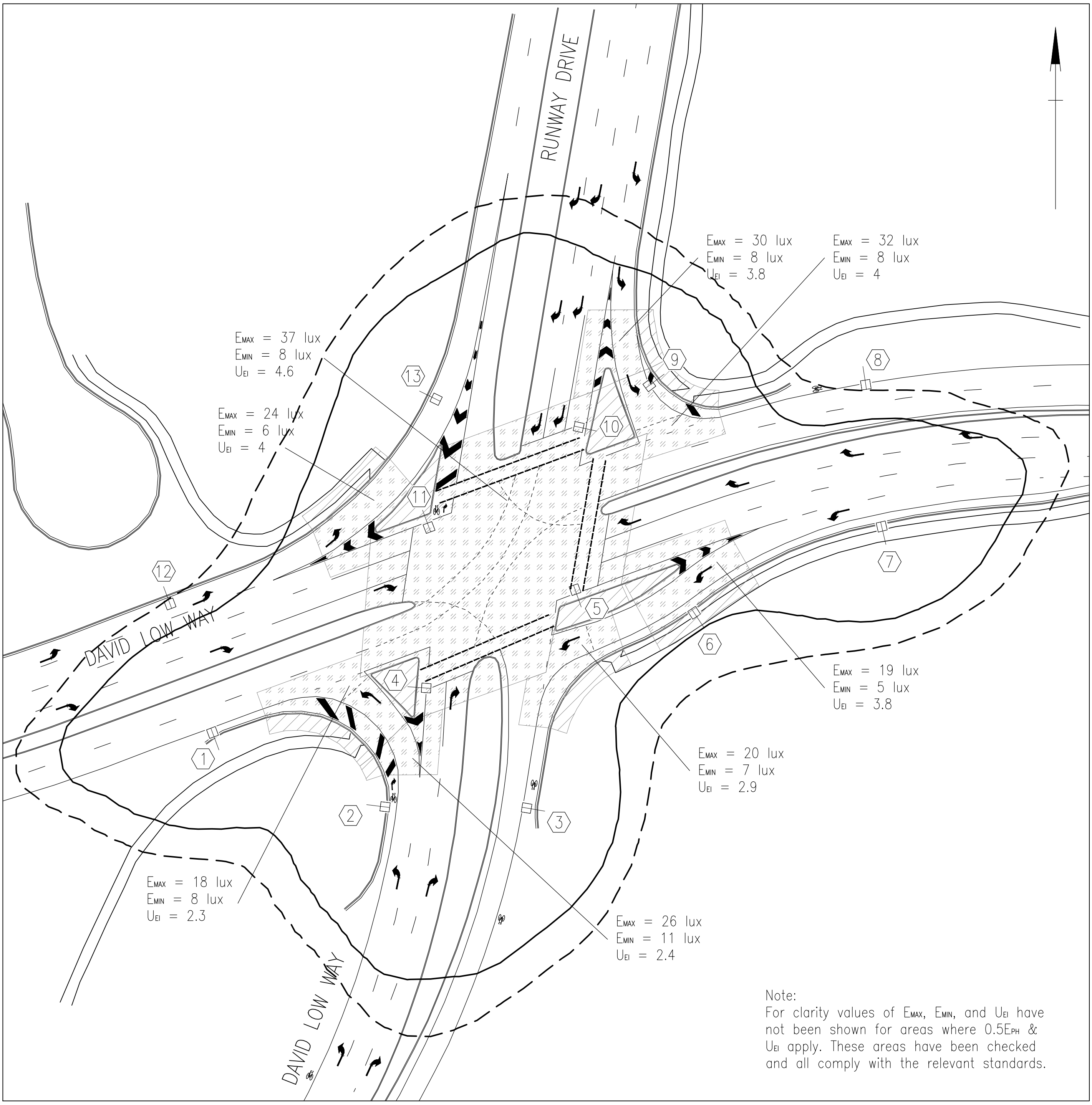
0 5 10 15 20m

Dimensions shown in metres except where shown otherwise

DAVID LOW WAY
RUNWAY DRIVE INTERSECTION
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 1 – DIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	SIG-002



STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)
1	REXEL 250W HPS – AEROSCREEN	4.5	12
2	REXEL 250W HPS – AEROSCREEN	4.5	12
3	REXEL 250W HPS – AEROSCREEN	4.5	12
4	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12
5	REXEL 250W HPS – AEROSCREEN	4.5	12
6	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12
7	REXEL 250W HPS – AEROSCREEN	4.5	12
8	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12
9	REXEL 250W HPS – AEROSCREEN	4.5	12
10	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12
11	REXEL 250W HPS – AEROSCREEN	4.5	12
12	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12
13	REXEL 250W HPS – AEROSCREEN	4.5	12

LEGEND

Street Light

2 Station Number

3.5 Lux Contour

1.75 Lux Contour

E_{PH} & U_{EI} Apply

$0.5E_{PH}$ & U_{EI} Apply

Scales

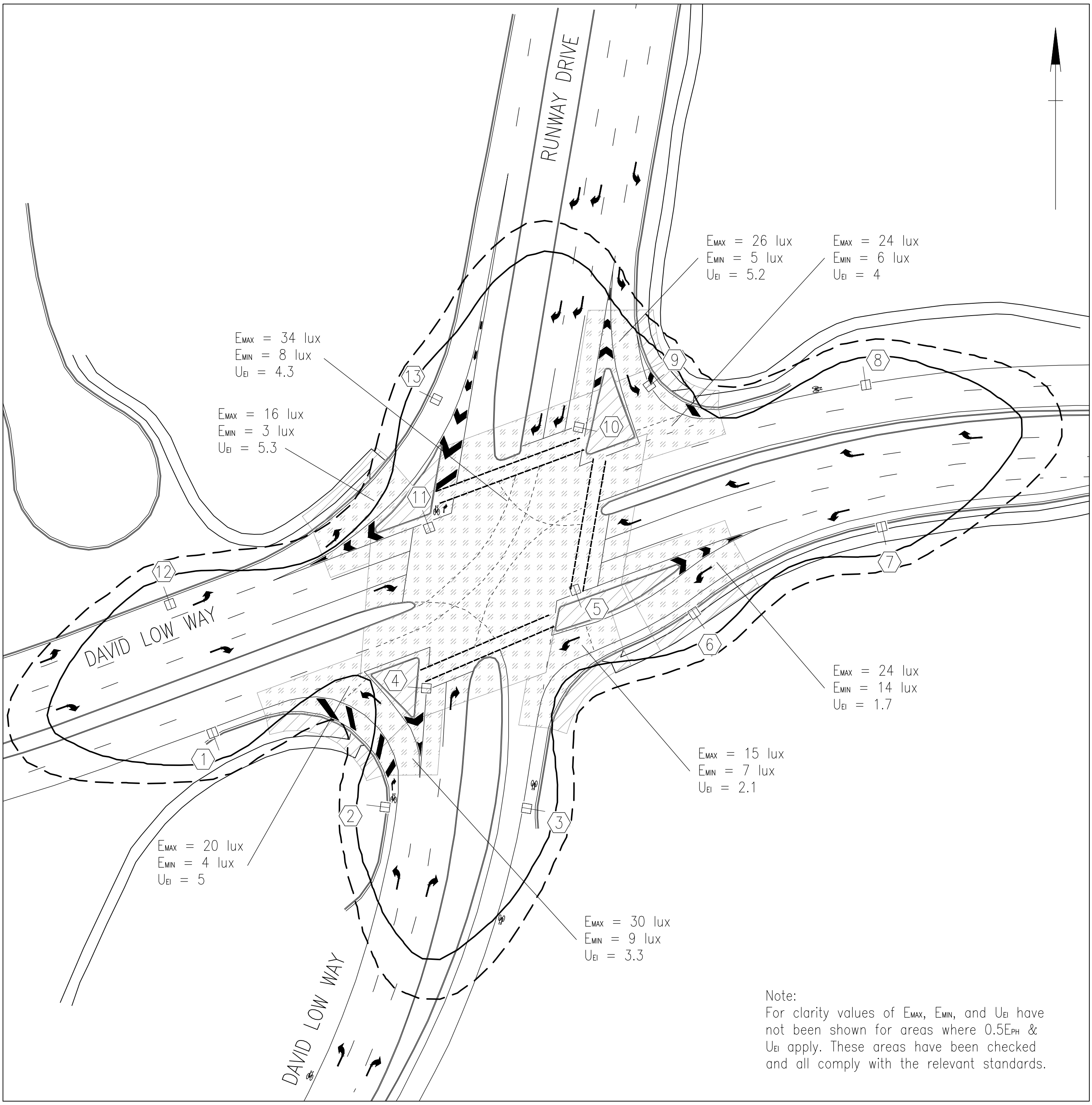
0 5 10 15 20m

Dimensions shown in metres except where shown otherwise

DAVID LOW WAY
RUNWAY DRIVE INTERSECTION
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 2 – DIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	SIG-003



STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)
1	PHILIPS 180W LED LE2	4.5	12
2	PHILIPS 180W LED LE2	4.5	12
3	PHILIPS 180W LED LE2	4.5	12
4	PHILIPS 180W LED LE2	4.5	12
5	PHILIPS 180W LED LE2	4.5	12
6	PHILIPS 180W LED LE2	4.5	12
7	PHILIPS 180W LED LE2	4.5	12
8	PHILIPS 180W LED LE2	4.5	12
9	PHILIPS 180W LED LE2	4.5	12
10	PHILIPS 180W LED LE2	4.5	12
11	PHILIPS 180W LED LE2	4.5	12
12	PHILIPS 180W LED LE2	4.5	12
13	PHILIPS 180W LED LE2	4.5	12

LEGEND

Street Light

2 Station Number

7.5 Lux Contour

3.75 Lux Contour

E_{PH} & U_{EI} Apply

$0.5E_{PH}$ & U_{EI} Apply

Scales

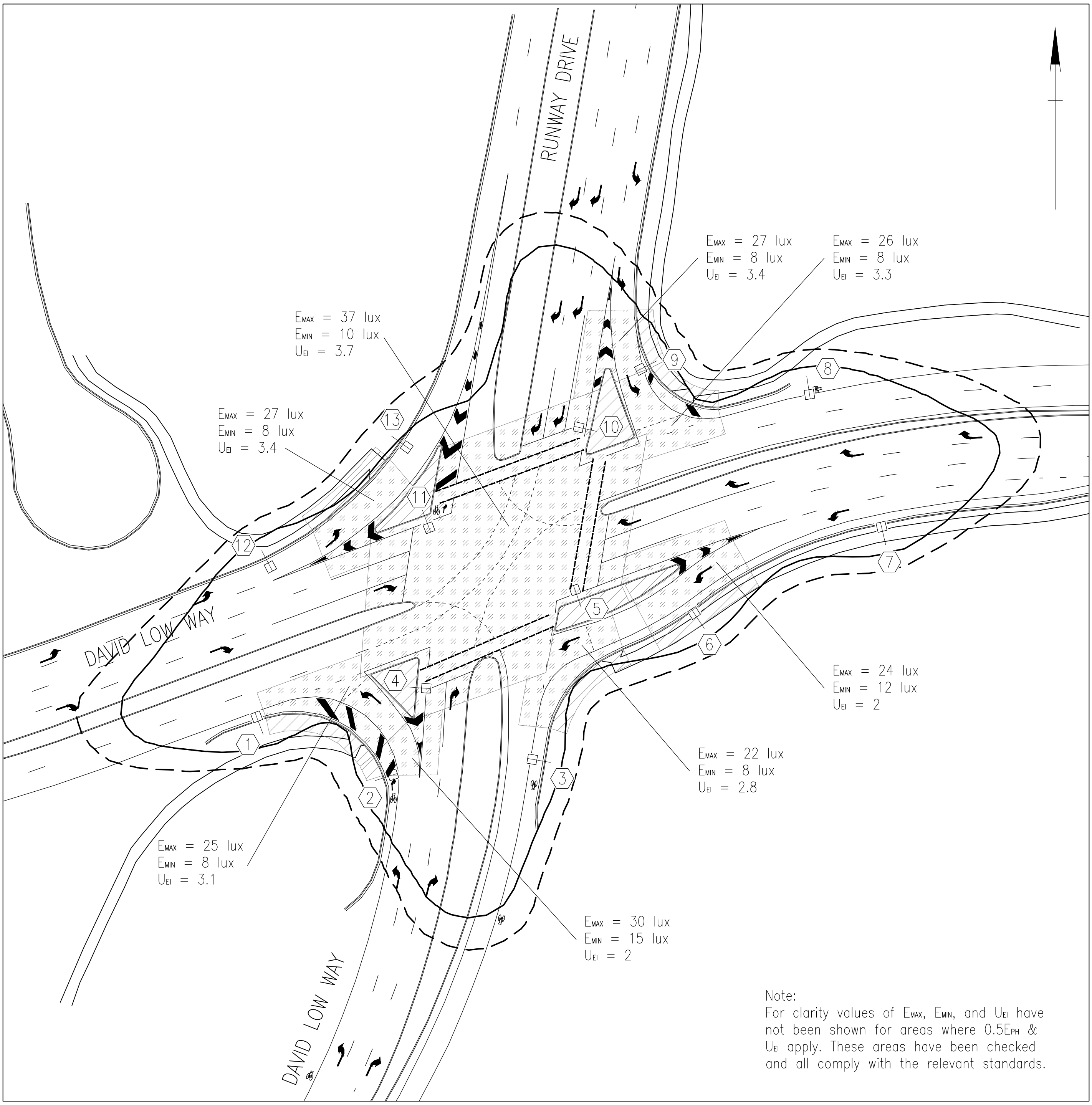
0 5 10 15 20m

Dimensions shown in metres except where shown otherwise

DAVID LOW WAY
RUNWAY DRIVE INTERSECTION
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 3 – UNDIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	SIG-004



Note:
For clarity values of E_{MAX}, E_{MIN}, and U_{EI} have not been shown for areas where $0.5E_{PH}$ & U_{EI} apply. These areas have been checked and all comply with the relevant standards.

STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)
1	PHILIPS 180W LED LE2	4.5	12
2	PHILIPS 180W LED LE2	4.5	12
3	PHILIPS 180W LED LE2	4.5	12
4	PHILIPS 180W LED LE2	4.5	12
5	PHILIPS 180W LED LE2	4.5	12
6	PHILIPS 180W LED LE2	4.5	12
7	PHILIPS 180W LED LE2	4.5	12
8	PHILIPS 180W LED LE2	4.5	12
9	PHILIPS 180W LED LE2	4.5	12
10	PHILIPS 180W LED LE2	4.5	12
11	PHILIPS 180W LED LE2	4.5	12
12	PHILIPS 180W LED LE2	4.5	12
13	PHILIPS 180W LED LE2	4.5	12

LEGEND

- Street Light
- 2 Station Number
- 7.5 Lux Contour
- 3.75 Lux Contour
- E_{PH} & U_{EI} Apply
- $0.5E_{PH}$ & U_{EI} Apply

Scales

0 5 10 15 20m

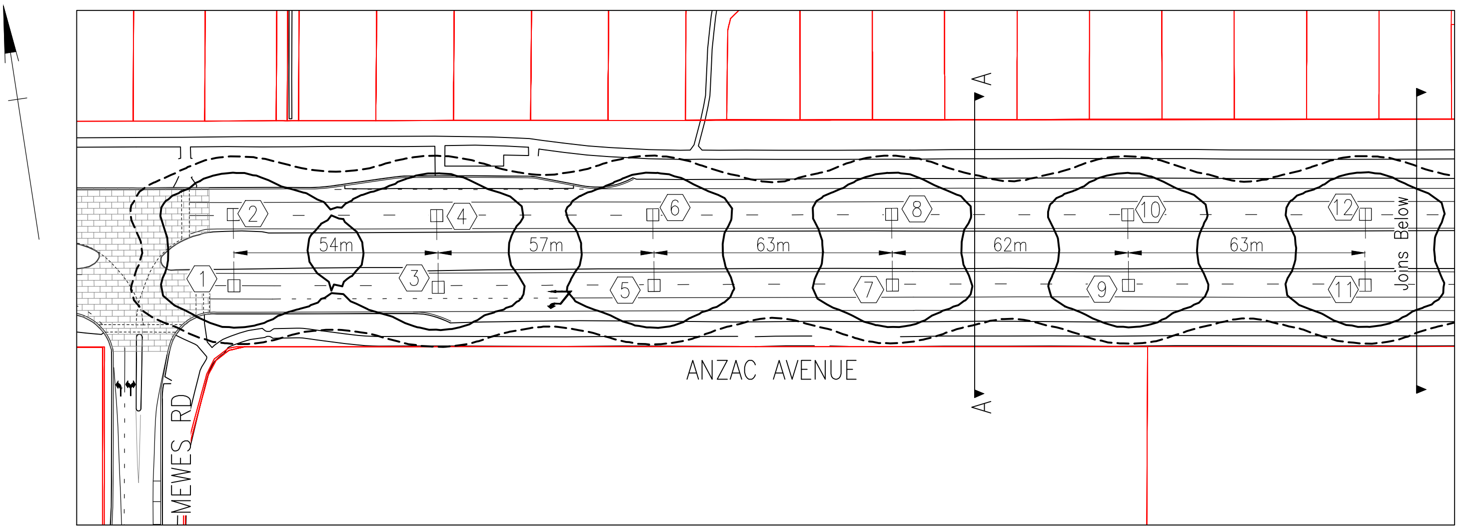
Dimensions shown in metres except where shown otherwise

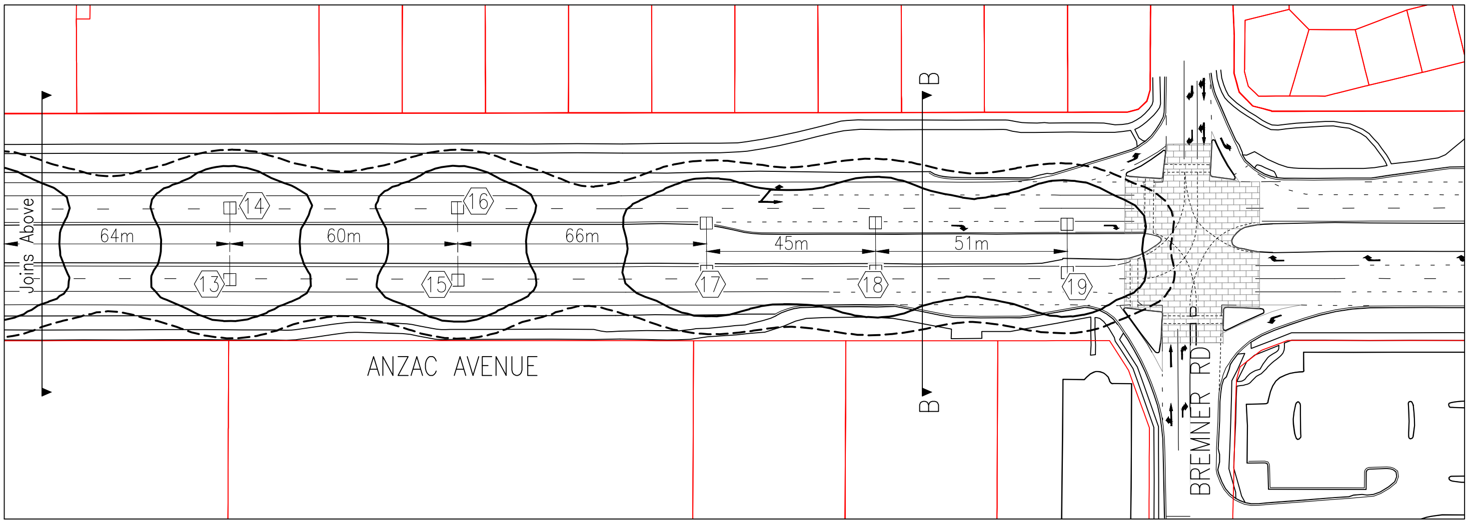
DAVID LOW WAY
RUNWAY DRIVE INTERSECTION
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 3A – UNDIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	SIG-005

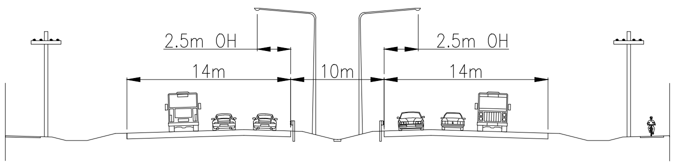
APPENDIX F – ANZAC AVENUE MEWES DRIVE TO BREMNER DRIVE MID-BLOCK (REDESIGNED): LIGHTING LAYOUTS AND CALCULAITON



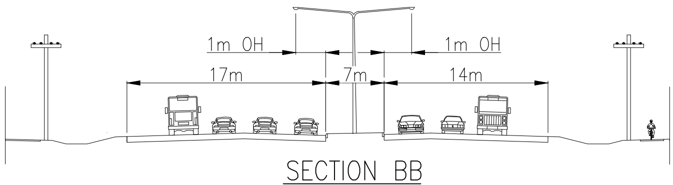


STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
2	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
3	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
4	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
5	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
6	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
7	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
8	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
9	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
10	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
11	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
12	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
13	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
14	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
15	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
16	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
17	2xREXEL 250W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side
18	2xREXEL 250W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side
19	2xREXEL 250W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side



SECTION AA



SECTION BB

LEGEND

	Street Light
2	Station Number
	7.5 Lux Contour
	3.75 Lux Contour
	Illuminance Based Design Applies

Scales

0 10 20 30 40m

Dimensions shown in metres except where shown otherwise

ANZAC AVENUE
MEWES ROAD TO BREMNER ROAD
EXISTING LIGHTING ARRANGEMENT

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	MID-001

MID-001-AA

Transport and Main Roads
****

RESULTS FOR RUNNING SAASTAN WITH NOMINATED SPACINGS
[AUSTRALIA MODE]

Job name: MID-001-AA

Luminaire I-table: C:\Documents and Settings\mnzelle\Desktop\3006.cie
Luminaire Description: OPTISPAN AERO 250 QMRD99A
Lamp Wattage & Type: 250W HIGH PRESSURE SODIUM
Light Source: HPS
Stores Code: 3006
Luminous Flux: 28 Klms
Upcast Angle: 5 Degrees
Arrangement: 6 Dual-Central
Mounting Height: 12 m
Maintenance Factor: 0.77
Median Width: 10 m
Overhang 1st Row: 2.5 m
Outreach Size: 4.5
Road Surface: CIE R3
Traffic Flow: One Way ---->

Lighting Category: V3
Carriageway Width: 14 m

Spacing (m)	Traffic Direct-ion	Lbar (>=0.75) or(>=0.83)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V3
50.00	Normal	1.01	0.33	0.77	.02	11.45	68.01	93.36	YES
51.00	Normal	.99	0.32	0.76	.02	11.56	68.12	93.42	YES
52.00	Normal	.97	0.32	0.74	.02	11.66	68.08	93.43	YES
53.00	Normal	.96	0.32	0.73	.02	11.76	68.01	93.45	YES
54.00	Normal	.94	0.32	0.71	.02	11.85	68.02	93.40	YES
55.00	Normal	.92	0.32	0.70	.02	11.97	68.01	93.36	YES
56.00	Normal	.91	0.32	0.69	.02	12.08	68.11	93.43	YES
57.00	Normal	.89	0.32	0.67	.02	12.18	68.07	93.43	YES
58.00	Normal	.88	0.32	0.66	.02	12.29	68.02	93.44	YES
59.00	Normal	.86	0.32	0.65	.02	12.39	68.03	93.40	YES
60.00	Normal	.85	0.32	0.64	.02	12.50	68.02	93.36	YES
61.00	Normal	.83	0.32	0.63	.02	12.61	68.10	93.41	YES
62.00	Normal	.82	0.32	0.62	.02	12.72	68.07	93.46	NO
63.00	Normal	.81	0.32	0.61	.02	12.82	68.02	93.42	NO
64.00	Normal	.80	0.32	0.60	.02	12.92	68.05	93.39	NO
65.00	Normal	.78	0.31	0.59	.02	13.05	68.02	93.36	NO
66.00	Normal	.77	0.32	0.58	.02	13.16	68.08	93.42	NO
67.00	Normal	.76	0.32	0.57	.02	13.27	68.05	93.46	NO
68.00	Normal	.75	0.31	0.56	.02	13.26	68.03	93.41	NO
69.00	Normal	.74	0.31	0.55	.02	13.49	68.05	93.40	NO
70.00	Normal	.73	0.31	0.54	.02	13.62	68.02	93.36	NO

NOTE: Where 'Normal' &/or 'Oncoming' lines are shown, compliance with the nominated Category, at a particular spacing, is only applicable when there is a 'Yes' on each line i.e. ANY 'No' indicates failure at that spacing.

PleVcat - Vers 5.08 (Built: 18/10/12) Run: 29/ 8/2013 at 16:55:21

MID-001-BB

Transport and Main Roads
****

RESULTS FOR RUNNING SAASTAN WITH NOMINATED SPACINGS
[AUSTRALIA MODE]

Job name: MID-001-BB

Luminaire I-table: C:\Documents and Settings\mnzelle\Desktop\3006.cie
Luminaire Description: OPTISPAN AERO 250 QMRD99A
Lamp Wattage & Type: 250W HIGH PRESSURE SODIUM
Light Source: HPS
Stores Code: 3006
Upcast Angle: 5 Degrees
Mounting Height: 12 m
Luminous Flux: 28 Klms
Arrangement: 7 Dual-Twin Stagg.
Maintenance Factor: 0.77
Median Width: 7 m
Overhang 1st Row: 1 m
Outreach Size: 4.5
Overhang 2nd Row: 1 m
Outreach Size: 4.5
Road Surface: CIE R3
Traffic Flow: One Way ---->

Lighting Category: V3
Carriageway Width: 14 m

Spacing (m)	Traffic Direct-ion	Lbar (>=0.75) or(>=0.83)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V3
50.00	Normal	1.00	0.41	0.75	.02	11.33	80.20	98.46	YES
51.00	Normal	.98	0.40	0.75	.02	11.43	80.26	98.46	YES
52.00	Normal	.96	0.40	0.74	.02	11.52	80.26	98.47	YES
53.00	Normal	.94	0.40	0.72	.02	11.61	80.17	98.42	YES
54.00	Normal	.92	0.39	0.71	.02	11.71	80.19	98.45	YES
55.00	Normal	.91	0.39	0.70	.02	11.83	80.20	98.46	YES
56.00	Normal	.89	0.39	0.69	.02	11.91	80.26	98.45	YES
57.00	Normal	.88	0.39	0.69	.02	11.99	80.26	98.47	YES
58.00	Normal	.86	0.39	0.68	.02	12.10	80.17	98.42	YES
59.00	Normal	.85	0.39	0.67	.02	12.19	80.19	98.45	YES
60.00	Normal	.83	0.38	0.66	.02	12.30	80.20	98.46	YES
61.00	Normal	.82	0.38	0.65	.02	12.39	80.26	98.44	YES
62.00	Normal	.80	0.38	0.64	.02	12.49	80.26	98.47	YES
63.00	Normal	.79	0.37	0.64	.02	12.59	80.17	98.42	YES
64.00	Normal	.78	0.36	0.63	.02	12.69	80.20	98.45	YES
65.00	Normal	.77	0.36	0.62	.02	12.80	80.20	98.46	YES
66.00	Normal	.76	0.35	0.60	.02	12.89	80.27	98.44	YES
67.00	Normal	.75	0.35	0.59	.02	12.99	80.26	98.47	YES
68.00	Normal	.73	0.35	0.59	.02	13.07	80.17	98.42	NO
69.00	Normal	.72	0.34	0.58	.02	13.17	80.20	98.46	NO
70.00	Normal	.71	0.34	0.57	.02	13.30	80.20	98.46	NO

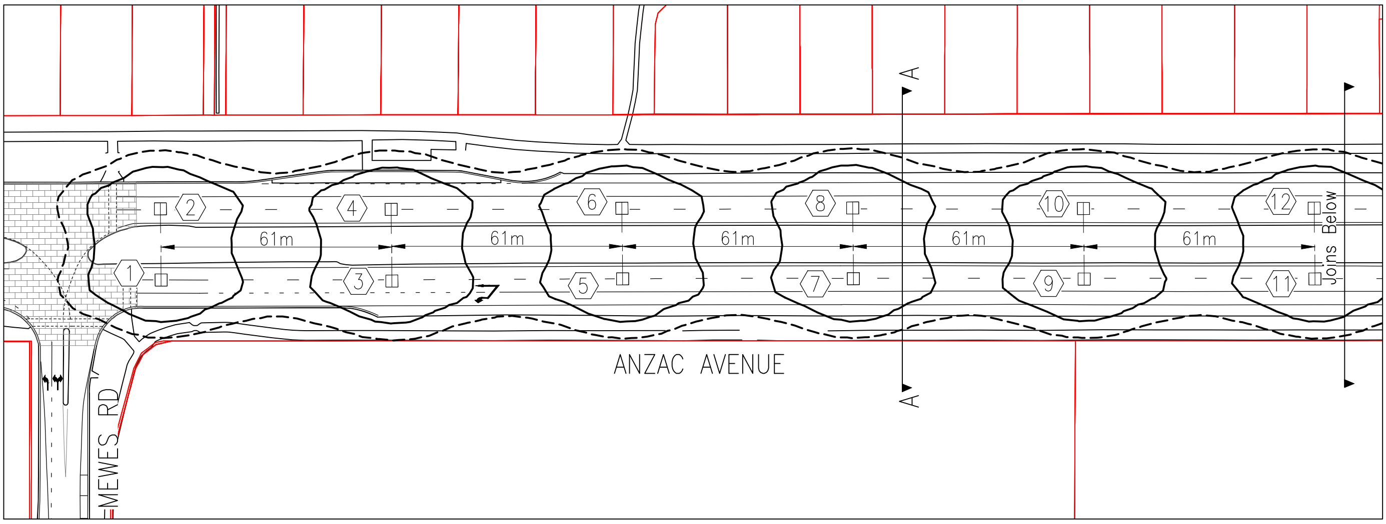
MID-001-BB

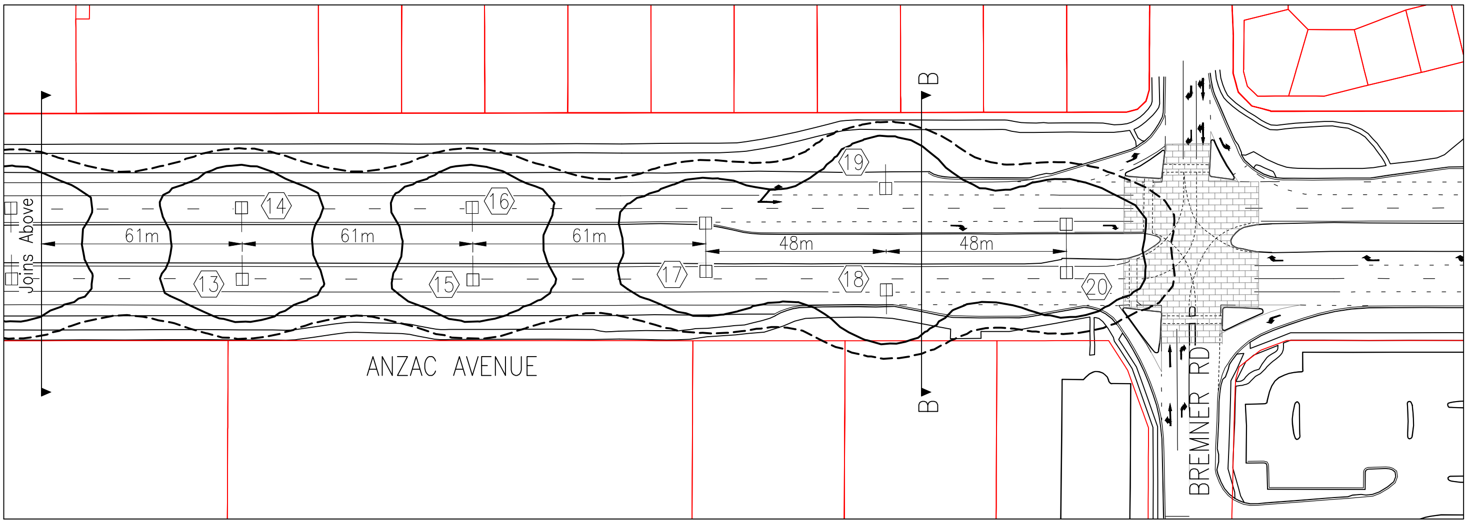
Lighting Category: V3 Carriageway Width: 17 m

Spacing (m)	Traffic Direct-ion	Lbar (>=0.75) or(>=0.83)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V3
50.00	Normal	.87	0.35	0.74	.02	10.65	81.98	99.92	YES
51.00	Normal	.86	0.34	0.73	.02	10.72	82.06	99.86	YES
52.00	Normal	.84	0.34	0.72	.02	10.80	82.05	99.87	YES
53.00	Normal	.82	0.33	0.71	.02	10.88	81.96	99.88	YES
54.00	Normal	.81	0.33	0.70	.02	10.97	81.99	99.91	YES
55.00	Normal	.79	0.33	0.69	.02	11.07	81.98	99.92	YES
56.00	Normal	.78	0.32	0.69	.02	11.14	82.07	99.86	NO
57.00	Normal	.77	0.32	0.68	.02	11.24	82.06	99.87	NO
58.00	Normal	.75	0.32	0.68	.02	11.33	81.95	99.87	NO
59.00	Normal	.74	0.32	0.68	.02	11.41	81.99	99.91	NO
60.00	Normal	.73	0.30	0.67	.02	11.50	81.98	99.92	NO
61.00	Normal	.72	0.29	0.66	.02	11.58	82.07	99.84	NO
62.00	Normal	.70	0.29	0.65	.02	11.67	82.06	99.87	NO
63.00	Normal	.69	0.29	0.65	.02	11.76	81.96	99.88	NO
64.00	Normal	.68	0.29	0.65	.02	11.85	81.99	99.91	NO
65.00	Normal	.67	0.29	0.66	.02	11.96	81.98	99.92	NO
66.00	Normal	.66	0.29	0.64	.02	12.03	82.07	99.84	NO
67.00	Normal	.65	0.29	0.63	.02	12.13	82.06	99.88	NO
68.00	Normal	.64	0.29	0.63	.02	12.19	81.96	99.88	NO
69.00	Normal	.63	0.29	0.62	.02	12.28	81.99	99.91	NO
70.00	Normal	.62	0.29	0.61	.02	12.38	81.99	99.92	NO

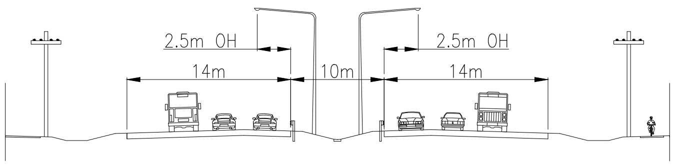
NOTE: Where 'Normal' &/or 'Oncoming' lines are shown, compliance with the nominated Category, at a particular spacing, is only applicable when there is a 'Yes' on each line i.e. ANY 'No' indicates failure at that spacing.

PleVcat - Vers 5.08 (Built: 18/10/12) Run: 29/ 8/2013 at 16:57:30

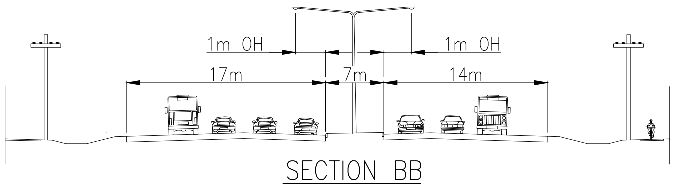




STREETLIGHT SCHEDULE				
STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
2	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
3	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
4	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
5	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
6	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
7	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
8	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
9	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
10	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
11	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
12	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
13	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
14	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
15	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
16	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
17	2xREXEL 250W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side
18	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
19	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
20	2xREXEL 250W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side



SECTION AA



SECTION BB

LEGEND

(symbol)	Street Light
2	Station Number
(solid line)	7.5 Lux Contour
(dashed line)	3.75 Lux Contour
(hatching)	Illuminance Based Design Applies

Scales

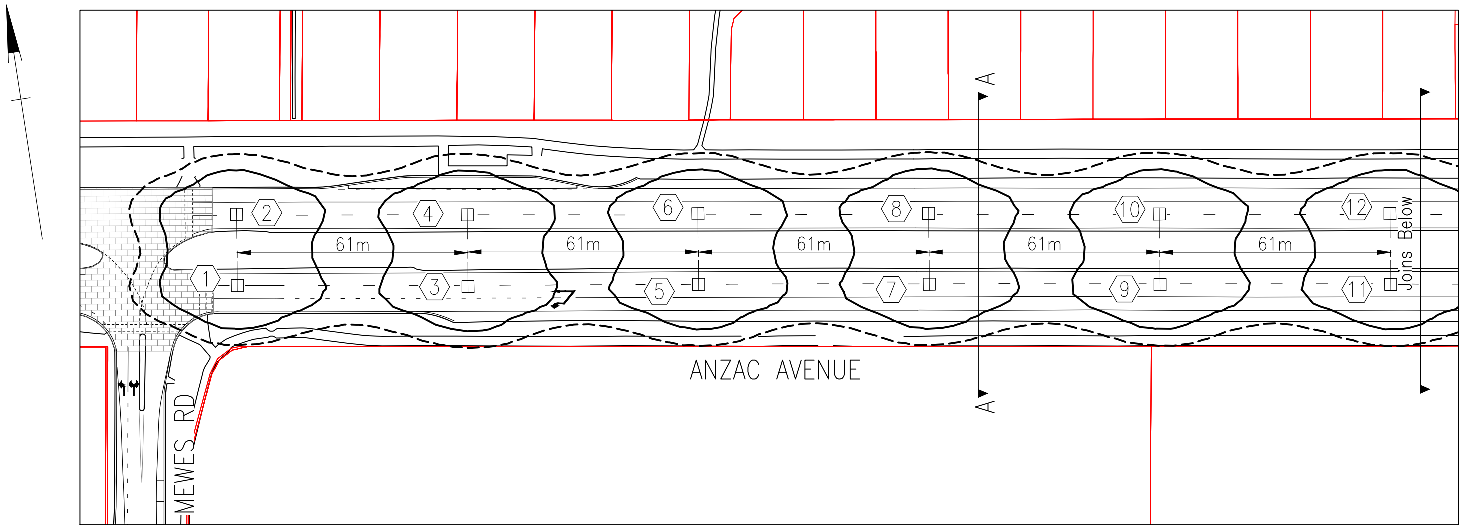
0 10 20 30 40m

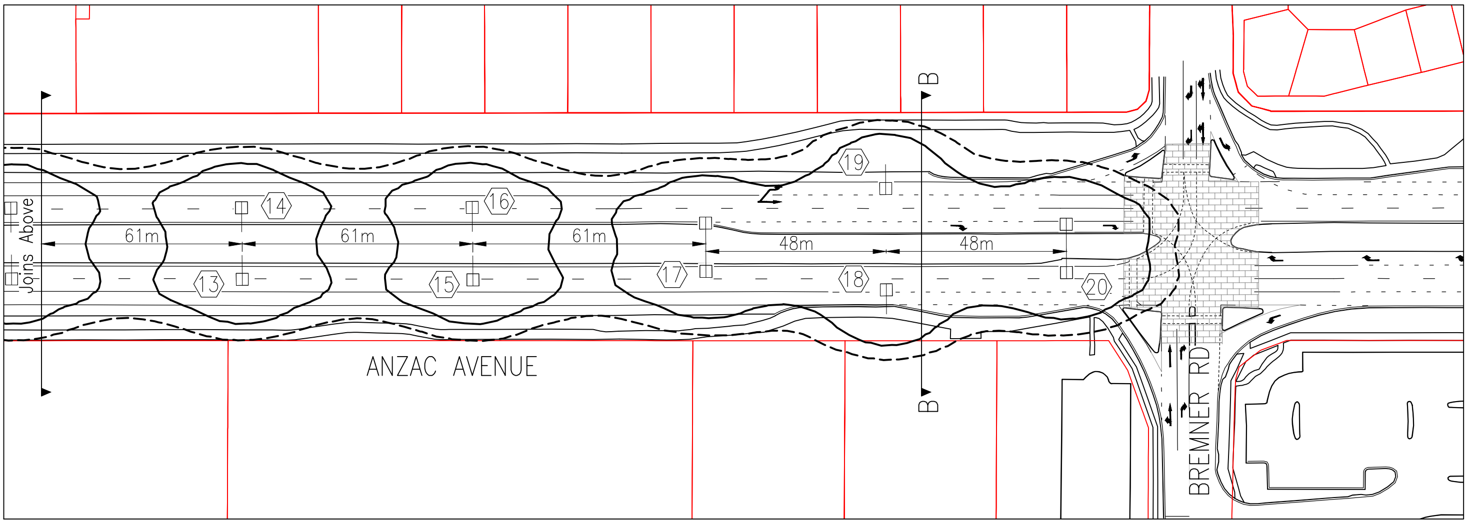
Dimensions shown in metres except where shown otherwise

ANZAC AVENUE
MEWES ROAD TO BREMNER ROAD
BASE LAYOUT
REDESIGNED LIGHTING ARRANGEMENT

UNIVERSITY OF SOUTHERN QUEENSLAND

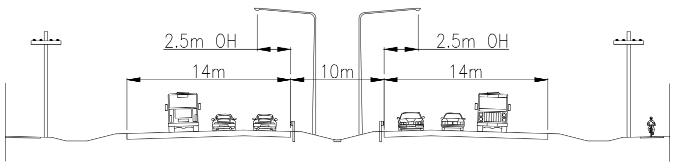
SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	MID-002



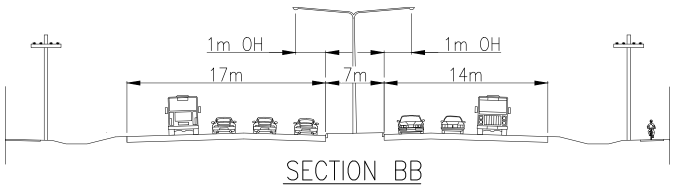


STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
2	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
3	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
4	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
5	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
6	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
7	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
8	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
9	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
10	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
11	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
12	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
13	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
14	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
15	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
16	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
17	2xREXEL 150W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side
18	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
19	REXEL 150W HPS – AEROSCREEN	4.5	12	2.0
20	2xREXEL 150W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side

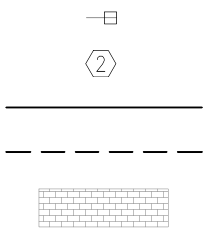


SECTION AA



SECTION BB

LEGEND



Street Light
Station Number
3.5 Lux Contour
1.75 Lux Contour
Illuminance Based Design Applies

Scales

Dimensions shown in metres except where shown otherwise

ANZAC AVENUE
MEWES ROAD TO BREMNER ROAD
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 1 – UNDIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	MID–003

MID-003-AA

Transport and Main Roads
****

RESULTS FOR RUNNING SAASTAN WITH NOMINATED SPACINGS
[AUSTRALIA MODE]

Job name: MID-003-AA

Luminaire I-table: C:\Documents and Settings\mnzelle\Desktop\3004.cie
Luminaire Description: OPTISPAN AERO 150 QMRD99A
Lamp Wattage & Type: 150W HIGH PRESSURE SODIUM
Light Source: HPS
Stores Code: 3004
Upcast Angle: 5 Degrees
Mounting Height: 12 m
Luminous Flux: 14.5 Klms
Arrangement: 6 Dual-Central
Maintenance Factor: 0.77
Median Width: 10 m
Overhang 1st Row: 2.5 m
Outreach Size: 4.5
Road Surface: CIE R3
Traffic Flow: One Way ---->

Lighting Category: V5 Carriageway Width: 14 m

Spacing (m)	Traffic Direct-ion	Lbar (>=0.35) or(>=0.38)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V5
50.00	Normal	.52	0.32	0.78	.00	10.18	67.82	93.19	YES
51.00	Normal	.51	0.32	0.77	.00	10.28	68.00	93.39	YES
52.00	Normal	.50	0.32	0.75	.00	10.37	67.95	93.34	YES
53.00	Normal	.49	0.32	0.74	.00	10.41	67.86	93.28	YES
54.00	Normal	.48	0.31	0.72	.00	10.50	67.85	93.23	YES
55.00	Normal	.47	0.31	0.71	.00	10.60	67.82	93.19	YES
56.00	Normal	.46	0.32	0.70	.00	10.70	67.99	93.39	YES
57.00	Normal	.46	0.32	0.68	.00	10.79	67.94	93.34	YES
58.00	Normal	.45	0.32	0.67	.00	10.88	67.86	93.27	YES
59.00	Normal	.44	0.31	0.66	.00	10.97	67.86	93.22	YES
60.00	Normal	.43	0.31	0.64	.00	11.07	67.82	93.19	YES
61.00	Normal	.43	0.31	0.64	.00	11.16	67.97	93.35	YES
62.00	Normal	.42	0.32	0.63	.00	11.25	67.94	93.32	YES
63.00	Normal	.41	0.31	0.62	.00	11.35	67.86	93.25	YES
64.00	Normal	.41	0.31	0.61	.00	11.43	67.88	93.22	YES
65.00	Normal	.40	0.31	0.60	.00	11.54	67.82	93.19	YES
66.00	Normal	.39	0.31	0.59	.00	11.53	67.94	93.36	YES
67.00	Normal	.39	0.31	0.58	.00	11.63	67.92	93.31	YES
68.00	Normal	.38	0.31	0.57	.00	11.72	67.86	93.24	NO
69.00	Normal	.38	0.30	0.56	.00	11.94	67.88	93.22	NO
70.00	Normal	.37	0.30	0.54	.00	12.05	67.82	93.19	NO
71.00	Normal	.37	0.30	0.54	.00	12.04	67.95	93.35	NO
72.00	Normal	.36	0.30	0.53	.00	12.13	67.86	93.28	NO
73.00	Normal	.36	0.30	0.51	.00	12.23	67.85	93.24	NO
74.00	Normal	.35	0.30	0.50	.00	12.32	67.82	93.22	NO
75.00	Normal	.35	0.30	0.49	.00	12.43	67.82	93.19	NO
76.00	Normal	.34	0.29	0.48	.00	12.53	67.94	93.34	NO
77.00	Normal	.34	0.29	0.47	.00	12.63	67.86	93.28	NO
78.00	Normal	.34	0.29	0.46	.00	12.72	67.85	93.24	NO
79.00	Normal	.33	0.29	0.45	.00	12.81	67.83	93.22	NO
80.00	Normal	.33	0.29	0.44	.00	12.93	67.82	93.19	NO

NOTE: Where 'Normal' &/or 'Oncoming' lines are shown, compliance with the nominated Category, at a particular spacing, is only applicable when there is a 'Yes' on each line i.e. ANY 'No' indicates failure at that spacing.

MID-003-BB

Transport and Main Roads
****

RESULTS FOR RUNNING SAASTAN WITH NOMINATED SPACINGS
[AUSTRALIA MODE]

Job name: MID-003-BB

Luminaire I-table: C:\Documents and Settings\mnzelle\Desktop\3004.cie
Luminaire Description: OPTISPAN AERO 150 QMRD99A
Lamp Wattage & Type: 150W HIGH PRESSURE SODIUM
Light Source: HPS
Stores Code: 3004 — Luminous Flux: 14.5 Klms
Upcast Angle: 5 Degrees — Arrangement: 7 Dual-Twin Stagg.
Mounting Height: 12 m — Maintenance Factor: 0.77
Median Width: 7 m
Overhang 1st Row: 1 m — Overhang 2nd Row: 1 m
Outreach Size: 4.5 — Outreach Size: 4.5
Road Surface: CIE R3
Traffic Flow: One Way ---->

Lighting Category: V5 — Carriageway Width: 14 m

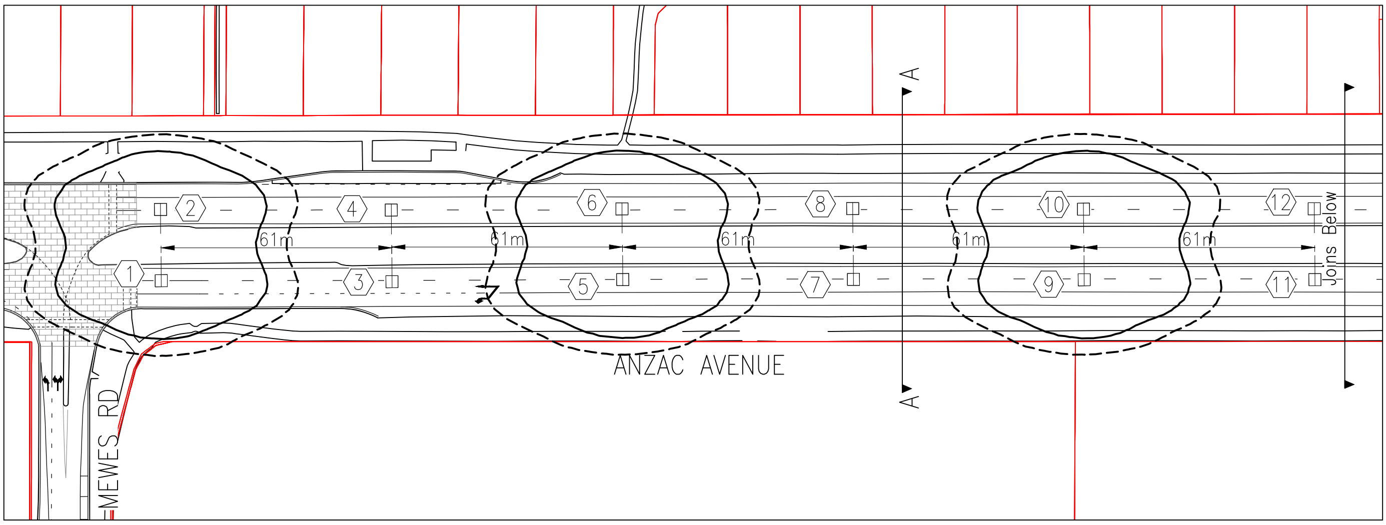
Spacing (m)	Traffic Direct-ion	Lbar (>=0.35) or(>=0.38)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V5
50.00	Normal	.51	0.40	0.75	.00	9.99	80.31	98.47	YES
51.00	Normal	.50	0.40	0.75	.00	10.07	80.27	98.48	YES
52.00	Normal	.49	0.40	0.74	.00	10.15	80.28	98.52	YES
53.00	Normal	.48	0.39	0.72	.00	10.24	80.25	98.39	YES
54.00	Normal	.47	0.39	0.71	.00	10.32	80.28	98.43	YES
55.00	Normal	.46	0.39	0.70	.00	10.43	80.31	98.47	YES
56.00	Normal	.45	0.39	0.70	.00	10.50	80.26	98.46	YES
57.00	Normal	.45	0.39	0.69	.00	10.59	80.29	98.53	YES
58.00	Normal	.44	0.39	0.68	.00	10.67	80.25	98.38	YES
59.00	Normal	.43	0.38	0.68	.00	10.75	80.28	98.43	YES
60.00	Normal	.42	0.38	0.67	.00	10.85	80.31	98.47	YES
61.00	Normal	.42	0.38	0.66	.00	10.93	80.26	98.47	YES
62.00	Normal	.41	0.37	0.65	.00	11.02	80.29	98.53	YES
63.00	Normal	.40	0.37	0.64	.00	11.10	80.24	98.39	YES
64.00	Normal	.40	0.36	0.63	.00	11.18	80.29	98.44	YES
65.00	Normal	.39	0.36	0.62	.00	11.28	80.31	98.47	YES
66.00	Normal	.39	0.35	0.60	.00	11.36	80.27	98.47	YES
67.00	Normal	.38	0.35	0.60	.00	11.45	80.29	98.53	YES
68.00	Normal	.37	0.34	0.59	.00	11.51	80.25	98.39	YES
69.00	Normal	.37	0.34	0.58	.00	11.59	80.29	98.44	YES
70.00	Normal	.36	0.34	0.57	.00	11.72	80.31	98.47	YES
71.00	Normal	.36	0.33	0.55	.00	11.80	80.27	98.50	YES
72.00	Normal	.35	0.33	0.55	.00	11.84	80.29	98.52	YES
73.00	Normal	.35	0.32	0.54	.00	11.92	80.24	98.39	NO
74.00	Normal	.34	0.32	0.54	.00	12.01	80.29	98.44	NO
75.00	Normal	.34	0.32	0.52	.00	12.11	80.31	98.47	NO
76.00	Normal	.34	0.32	0.50	.00	12.19	80.27	98.50	NO
77.00	Normal	.33	0.31	0.49	.00	12.28	80.29	98.52	NO
78.00	Normal	.33	0.31	0.48	.00	12.32	80.23	98.39	NO
79.00	Normal	.32	0.31	0.47	.00	12.41	80.29	98.45	NO
80.00	Normal	.32	0.31	0.47	.00	12.51	80.31	98.47	NO

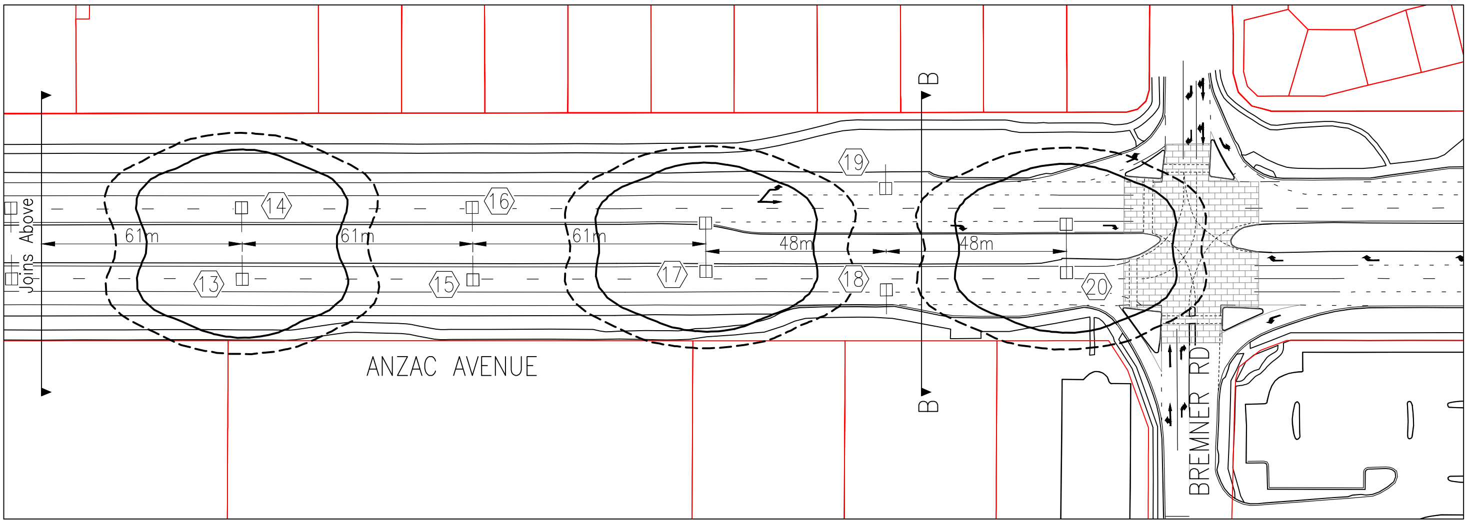
Lighting Category: V5 Carriageway Width: 17 m

Spacing (m)	Traffic Direct-ion	Lbar (>=0.35) or(>=0.38)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V5
50.00	Normal	.45	0.35	0.74	.00	9.35	82.00	99.82	YES
51.00	Normal	.44	0.34	0.73	.00	9.42	81.94	99.68	YES
52.00	Normal	.43	0.34	0.72	.00	9.49	81.97	99.73	YES
53.00	Normal	.42	0.33	0.72	.00	9.56	81.93	99.74	YES
54.00	Normal	.41	0.33	0.70	.00	9.62	81.97	99.79	YES
55.00	Normal	.40	0.33	0.70	.00	9.70	82.00	99.82	YES
56.00	Normal	.40	0.32	0.69	.00	9.77	81.95	99.68	YES
57.00	Normal	.39	0.32	0.69	.00	9.85	81.98	99.74	YES
58.00	Normal	.38	0.32	0.69	.00	9.93	81.92	99.74	NO
59.00	Normal	.38	0.32	0.68	.00	10.00	81.98	99.79	NO
60.00	Normal	.37	0.30	0.67	.00	10.08	82.00	99.82	NO
61.00	Normal	.37	0.29	0.66	.00	10.17	81.95	99.68	NO
62.00	Normal	.36	0.29	0.65	.00	10.24	81.98	99.74	NO
63.00	Normal	.35	0.29	0.66	.00	10.32	81.92	99.74	NO
64.00	Normal	.35	0.29	0.65	.00	10.40	81.98	99.79	NO
65.00	Normal	.34	0.28	0.66	.00	10.48	82.00	99.82	NO
66.00	Normal	.34	0.28	0.64	.00	10.55	81.96	99.67	NO
67.00	Normal	.33	0.28	0.63	.00	10.63	81.98	99.74	NO
68.00	Normal	.33	0.28	0.63	.00	10.69	81.92	99.74	NO
69.00	Normal	.32	0.28	0.62	.00	10.77	81.98	99.79	NO
70.00	Normal	.32	0.28	0.62	.00	10.86	82.00	99.82	NO
71.00	Normal	.31	0.28	0.60	.00	10.96	81.96	99.71	NO
72.00	Normal	.31	0.28	0.59	.00	11.04	81.98	99.74	NO
73.00	Normal	.31	0.28	0.59	.00	11.05	81.92	99.74	NO
74.00	Normal	.30	0.28	0.57	.00	11.13	81.98	99.79	NO
75.00	Normal	.30	0.27	0.56	.00	11.22	82.00	99.82	NO
76.00	Normal	.29	0.26	0.54	.00	11.29	81.96	99.72	NO
77.00	Normal	.29	0.26	0.53	.00	11.37	81.98	99.74	NO
78.00	Normal	.29	0.27	0.52	.00	11.45	81.92	99.74	NO
79.00	Normal	.28	0.27	0.51	.00	11.53	81.98	99.80	NO
80.00	Normal	.28	0.26	0.50	.00	11.62	82.00	99.82	NO

NOTE: Where 'Normal' &/or 'Oncoming' lines are shown, compliance with the nominated Category, at a particular spacing, is only applicable when there is a 'Yes' on each line i.e. ANY 'No' indicates failure at that spacing.

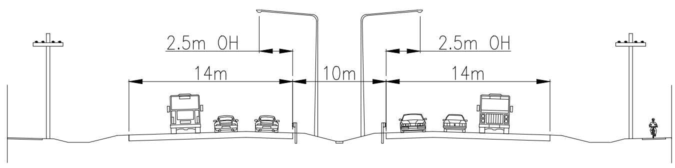
PleVcat - Vers 5.08 (Built: 18/10/12) Run: 29/ 8/2013 at 17:02:17



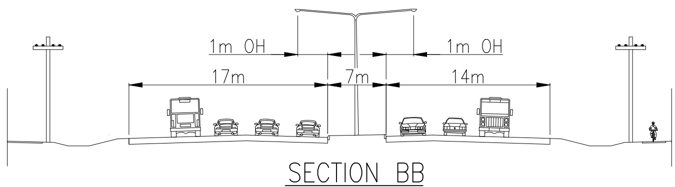


STREETLIGHT SCHEDULE

STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
2	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
3	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
4	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
5	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
6	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
7	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
8	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
9	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
10	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
11	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
12	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
13	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
14	REXEL 250W HPS – AEROSCREEN	4.5	12	2.0
15	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
16	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
17	2xREXEL 250W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side
18	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
19	REXEL 250W HPS – AEROSCREEN (OFF)	4.5	12	2.0
20	2xREXEL 250W HPS – AEROSCREEN	2x4.5	12	3.5 Each Side



SECTION AA



SECTION BB

LEGEND

Street Light	
2	Station Number
	3.5 Lux Contour
	1.75 Lux Contour
	Illuminance Based Design Applies

Scales

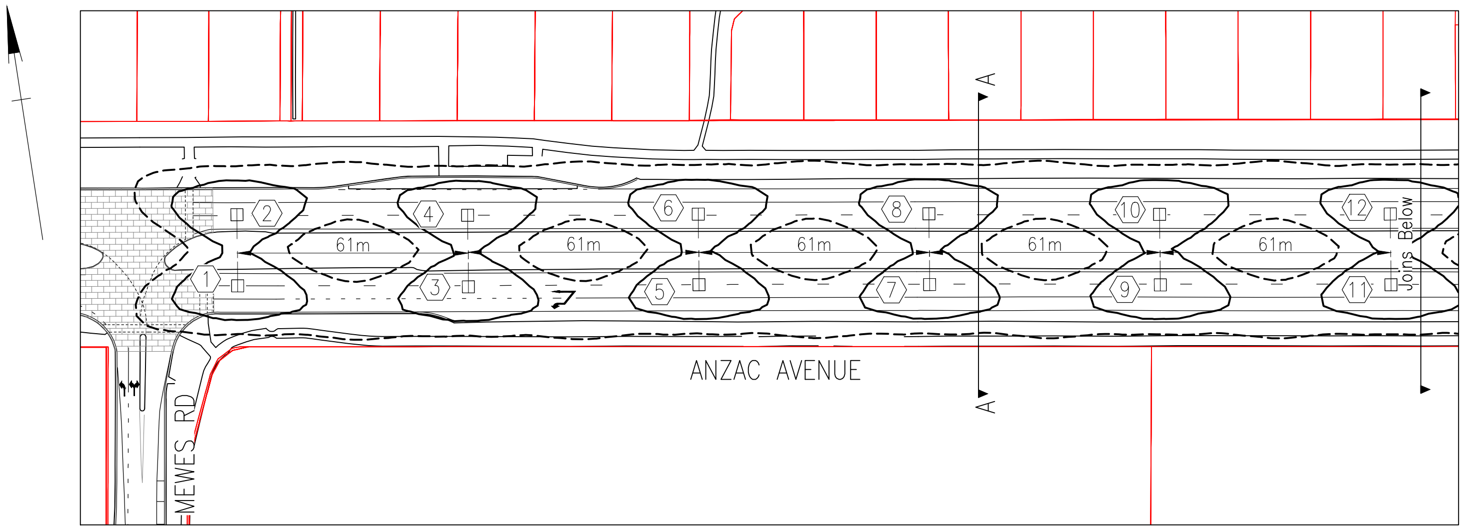
0 10 20 30 40m

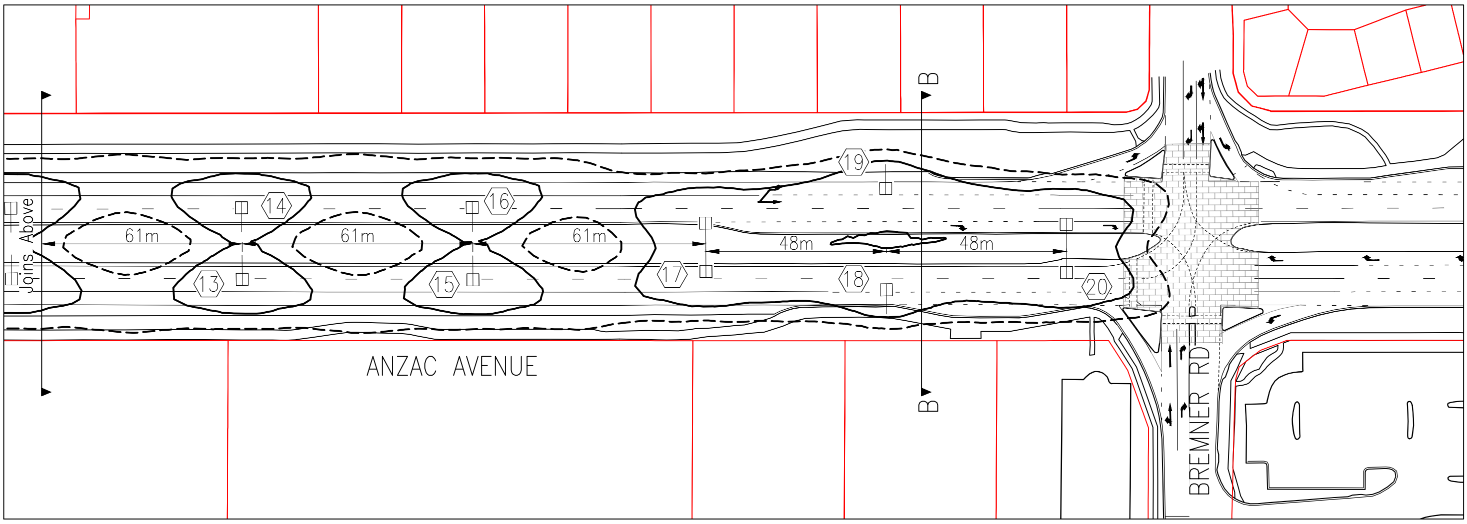
Dimensions shown in metres except where shown otherwise

ANZAC AVENUE
MEWES ROAD TO BREMNER ROAD
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 2 – DIMMED

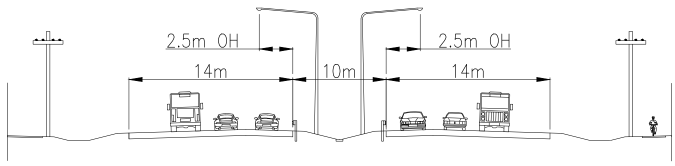
UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	MID-004

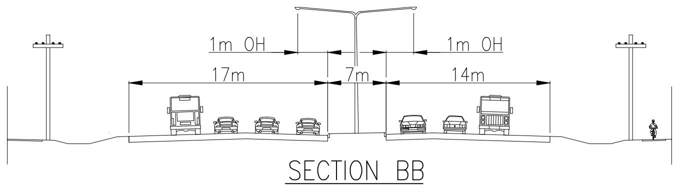




STREETLIGHT SCHEDULE				
STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	PHILIPS 180W LED LE2	4.5	12	2.0
2	PHILIPS 180W LED LE2	4.5	12	2.0
3	PHILIPS 180W LED LE2	4.5	12	2.0
4	PHILIPS 180W LED LE2	4.5	12	2.0
5	PHILIPS 180W LED LE2	4.5	12	2.0
6	PHILIPS 180W LED LE2	4.5	12	2.0
7	PHILIPS 180W LED LE2	4.5	12	2.0
8	PHILIPS 180W LED LE2	4.5	12	2.0
9	PHILIPS 180W LED LE2	4.5	12	2.0
10	PHILIPS 180W LED LE2	4.5	12	2.0
11	PHILIPS 180W LED LE2	4.5	12	2.0
12	PHILIPS 180W LED LE2	4.5	12	2.0
13	PHILIPS 180W LED LE2	4.5	12	2.0
14	PHILIPS 180W LED LE2	4.5	12	2.0
15	PHILIPS 180W LED LE2	4.5	12	2.0
16	PHILIPS 180W LED LE2	4.5	12	2.0
17	2xPHILIPS 180W LED LE2	2x4.5	12	3.5 Each Side
18	PHILIPS 180W LED LE2	4.5	12	2.0
19	PHILIPS 180W LED LE2	4.5	12	2.0
20	2xPHILIPS 180W LED LE2	2x4.5	12	3.5 Each Side

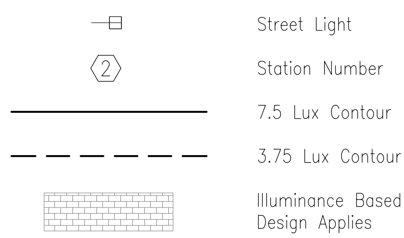


SECTION AA

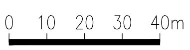


SECTION BB

LEGEND



Scales



Dimensions shown in metres except where shown otherwise

ANZAC AVENUE
MEWES ROAD TO BREMNER ROAD
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 3 – UNDIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	MID-005

MID-005-AA

Transport and Main Roads
****

RESULTS FOR RUNNING SAASTAN WITH NOMINATED SPACINGS
[AUSTRALIA MODE]

Job name: MID-005-AA

Luminaire I-table: C:\Documents and Settings\mnzelle\Desktop\Philips Roadstar\GPLM\IES Files All\GPLM-180W98LED4K-ES-LE 2 (S1008271m).cie
Luminaire Description: 180W PHILIPS LED 14422 lms
Lamp Wattage & Type: 180W LED
Light Source: LED
Stores Code: 14.422
Luminous Flux: 14.42 Klms
Upcast Angle: 5 Degrees
Arrangement: 6 Dual-Central
Mounting Height: 12 m
Maintenance Factor: 0.8
Median Width: 10 m
Overhang 1st Row: 2.5 m
Outreach Size: 4.5
Road Surface: CIE R3
Traffic Flow: One Way ---->

Lighting Category: V3
Carriageway Width: 14 m

Spacing (m)	Traffic Direct-ion	Lbar (>=0.75) or(>=0.83)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V3
30.00	Normal	1.22	0.46	0.88	.04	9.31	71.86	65.78	YES
31.00	Normal	1.18	0.45	0.86	.04	9.50	71.81	65.80	YES
32.00	Normal	1.15	0.46	0.86	.04	9.68	71.81	65.74	YES
33.00	Normal	1.11	0.45	0.84	.04	9.86	71.83	65.69	YES
34.00	Normal	1.08	0.45	0.83	.04	10.05	71.80	65.65	YES
35.00	Normal	1.05	0.45	0.82	.04	10.23	71.80	65.60	YES
36.00	Normal	1.02	0.44	0.80	.04	10.41	71.81	65.53	YES
37.00	Normal	.99	0.43	0.79	.04	10.59	71.73	65.61	YES
38.00	Normal	.97	0.41	0.78	.04	10.78	71.70	65.71	YES
39.00	Normal	.94	0.40	0.76	.04	10.96	71.75	65.68	YES
40.00	Normal	.92	0.39	0.74	.04	11.13	71.73	65.60	YES
41.00	Normal	.90	0.38	0.72	.04	11.30	71.75	65.67	YES
42.00	Normal	.88	0.37	0.70	.04	11.51	71.84	65.70	YES
43.00	Normal	.86	0.37	0.68	.04	11.69	71.90	65.66	YES
44.00	Normal	.84	0.36	0.66	.04	11.74	71.84	65.56	YES
45.00	Normal	.82	0.35	0.65	.04	11.92	71.92	65.57	YES
46.00	Normal	.80	0.35	0.63	.04	12.11	71.94	65.62	YES
47.00	Normal	.78	0.35	0.62	.04	12.28	71.91	65.54	YES
48.00	Normal	.77	0.34	0.61	.04	12.45	71.93	65.50	YES
49.00	Normal	.75	0.34	0.60	.04	12.62	71.84	65.57	YES
50.00	Normal	.74	0.34	0.59	.04	12.80	71.84	65.40	NO

NOTE: Where 'Normal' &/or 'Oncoming' lines are shown, compliance with the nominated Category, at a particular spacing, is only applicable when there is a 'Yes' on each line i.e. ANY 'No' indicates failure at that spacing.

PleVcat - Vers 5.08 (Built: 18/10/12)   Run: 29/ 8/2013 at 17:09:16

MID-005-BB

Transport and Main Roads
****

RESULTS FOR RUNNING SAASTAN WITH NOMINATED SPACINGS
[AUSTRALIA MODE]

Job name: MID-005-BB

Luminaire I-table: C:\Documents and Settings\mnzelle\Desktop\Philips Roadstar\GPLM\IES Files All\GPLM-180W98LED4K-ES-LE 2 (S1008271m).cie
Luminaire Description: 180W PHILIPS LED 14422 lms
Lamp Wattage & Type: 180W LED
Light Source: LED
Stores Code: 14.422 | Luminous Flux: 14.42 Klms
Upcast Angle: 5 Degrees | Arrangement: 7 Dual-Twin Stagg.
Mounting Height: 12 m | Maintenance Factor: 0.8
Median Width: 7 m
Overhang 1st Row:-0.5 m | Overhang 2nd Row:-0.5 m
Outreach Size: 3 | Outreach Size: 3
Road Surface: CIE R3
Traffic Flow: One Way ---->

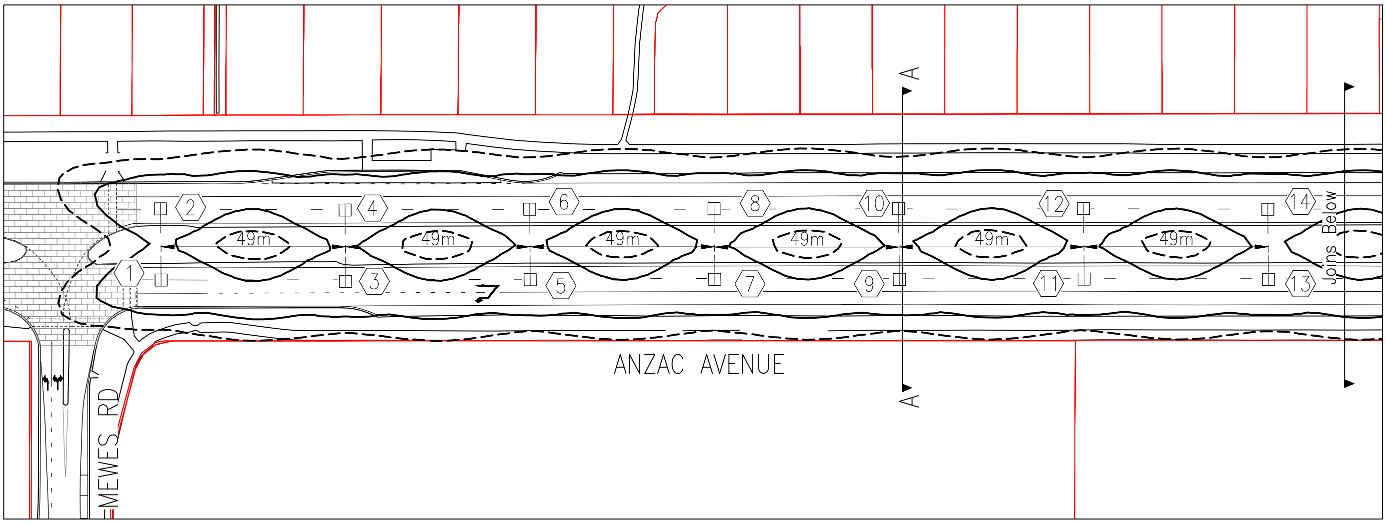
Lighting Category: V3 Carriageway Width: 14 m

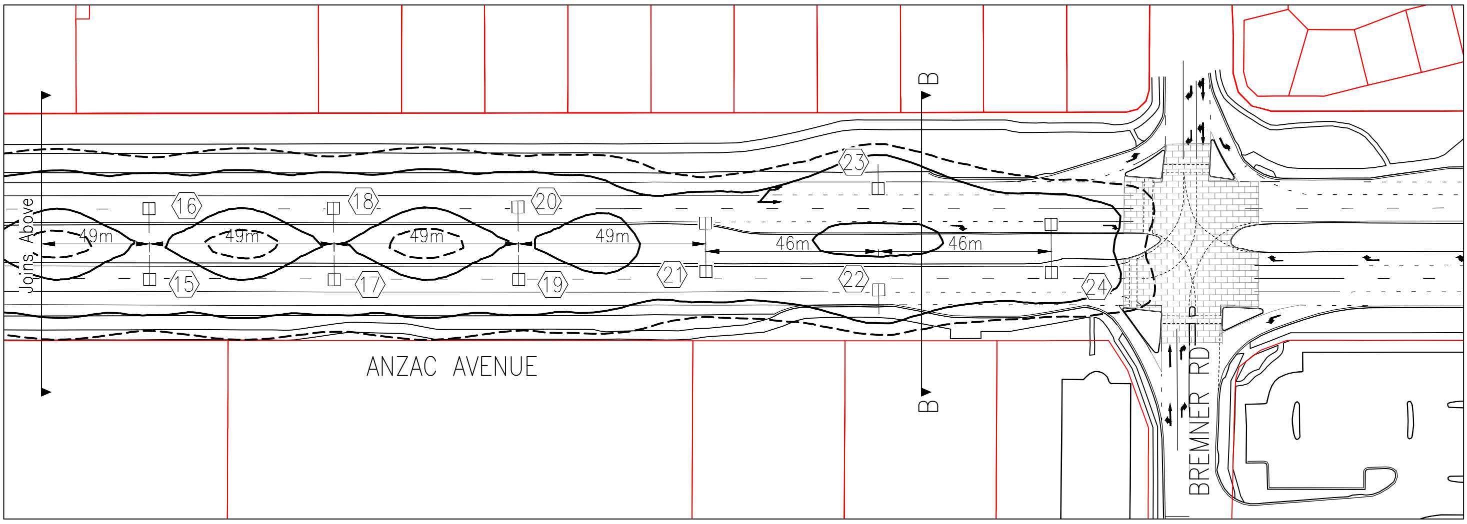
Spacing (m)	Traffic Direct-ion	Lbar (>=0.75) or(>=0.83)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V3
40.00	Normal	.90	0.47	0.69	.04	10.81	73.51	92.23	YES
41.00	Normal	.88	0.46	0.67	.04	10.98	73.48	92.34	YES
42.00	Normal	.86	0.45	0.65	.04	11.14	73.47	92.31	YES
43.00	Normal	.84	0.44	0.64	.04	11.28	73.54	92.31	YES
44.00	Normal	.82	0.42	0.63	.04	11.46	73.50	92.23	YES
45.00	Normal	.80	0.40	0.61	.04	11.55	73.51	92.23	YES
46.00	Normal	.78	0.37	0.60	.04	11.71	73.47	92.32	YES
47.00	Normal	.77	0.35	0.59	.04	11.89	73.48	92.30	YES
48.00	Normal	.75	0.34	0.58	.04	12.05	73.52	92.26	YES
49.00	Normal	.74	0.32	0.58	.04	12.21	73.50	92.23	NO
50.00	Normal	.72	0.30	0.57	.04	12.37	73.51	92.23	NO

Lighting Category: V3 Carriageway Width: 17 m

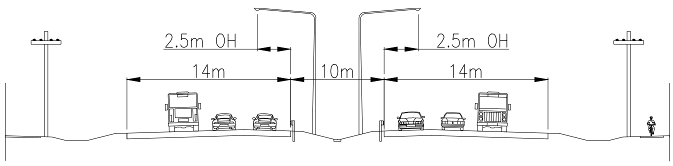
Spacing (m)	Traffic Direct-ion	Lbar (>=0.75) or(>=0.83)	Uo (>=0.33) (>=0.31)	Ul (>=0.5) "	UWLR (=<3) "	TI (=<20) "	Esl (>=50) "	Esr (>=50) "	Comply with V3
40.00	Normal	.80	0.42	0.66	.04	10.67	73.91	92.50	YES
41.00	Normal	.78	0.40	0.63	.04	10.83	73.84	92.36	YES
42.00	Normal	.76	0.39	0.61	.04	10.99	73.88	92.34	YES
43.00	Normal	.74	0.38	0.60	.04	11.13	73.86	92.54	NO
44.00	Normal	.73	0.36	0.58	.04	11.31	73.86	92.50	NO
45.00	Normal	.71	0.33	0.56	.04	11.47	73.91	92.50	NO
46.00	Normal	.69	0.31	0.55	.04	11.56	73.83	92.35	NO
47.00	Normal	.68	0.29	0.54	.04	11.72	73.87	92.33	NO
48.00	Normal	.67	0.27	0.53	.04	11.89	73.85	92.50	NO
49.00	Normal	.65	0.26	0.52	.04	12.05	73.86	92.50	NO
50.00	Normal	.64	0.24	0.51	.04	12.21	73.90	92.50	NO

NOTE: Where 'Normal' &/or 'Oncoming' lines are shown, compliance with the nominated Category, at a particular spacing, is only applicable when there is a 'Yes' on each line i.e. ANY 'No' indicates failure at that spacing.

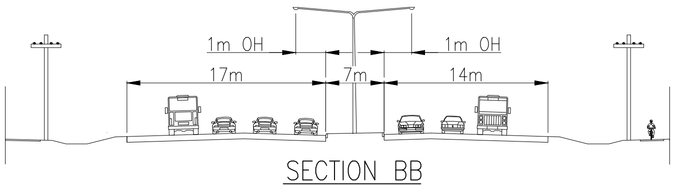




STREETLIGHT SCHEDULE				
STN No	LUMINAIRE	OUTREACH BRACKET (M)	MOUNT HEIGHT (m)	SETBACK (m)
1	PHILIPS 180W LED LE2	4.5	12	2.0
2	PHILIPS 180W LED LE2	4.5	12	2.0
3	PHILIPS 180W LED LE2	4.5	12	2.0
4	PHILIPS 180W LED LE2	4.5	12	2.0
5	PHILIPS 180W LED LE2	4.5	12	2.0
6	PHILIPS 180W LED LE2	4.5	12	2.0
7	PHILIPS 180W LED LE2	4.5	12	2.0
8	PHILIPS 180W LED LE2	4.5	12	2.0
9	PHILIPS 180W LED LE2	4.5	12	2.0
10	PHILIPS 180W LED LE2	4.5	12	2.0
11	PHILIPS 180W LED LE2	4.5	12	2.0
12	PHILIPS 180W LED LE2	4.5	12	2.0
13	PHILIPS 180W LED LE2	4.5	12	2.0
14	PHILIPS 180W LED LE2	4.5	12	2.0
15	PHILIPS 180W LED LE2	4.5	12	2.0
16	PHILIPS 180W LED LE2	4.5	12	2.0
17	PHILIPS 180W LED LE2	4.5	12	2.0
18	PHILIPS 180W LED LE2	4.5	12	2.0
19	PHILIPS 180W LED LE2	4.5	12	2.0
20	PHILIPS 180W LED LE2	4.5	12	2.0
21	2xPHILIPS 180W LED LE2	2x3.0	12	3.5 Each Side
22	PHILIPS 180W LED LE2	3.0	12	2.0
23	PHILIPS 180W LED LE2	3.0	12	2.0
24	2xPHILIPS 180W LED LE2	2x3.0	12	3.5 Each Side



SECTION AA



SECTION BB

LEGEND

- Street Light
- Station Number
- 7.5 Lux Contour
- 3.75 Lux Contour
- Illuminance Based Design Applies

Scales

0 10 20 30 40m

Dimensions shown in metres except where shown otherwise

ANZAC AVENUE
MEWES ROAD TO BREMNER ROAD
PROPOSED LIGHTING ARRANGEMENT
TREATMENT 3A – UNDIMMED

UNIVERSITY OF SOUTHERN QUEENSLAND

SUBJECT	ENG4111 & ENG4112
STUDENT NAME	MARK ZELLER
STUDENT NUMBER	0050025838
DRAWING NUMBER	MID-006

APPENDIX G - BRUCE HIGHWAY AND BOUNDARY ROAD SOUTHBOUND ON-RAMP (REDESIGNED): CRASH HISTORY

Data for Road Section : 10A - BRUCE HIGHWAY (BRISBANE - GYMPIE)

District ID	TDIST START	TDIST END	Crash Number	Crash Date	Crash Severity	Crash Severity Description	Crash DCA Code	Intersection ID	Crash DCA Description	Relative Position	Crash DCA Code Group	Crash DCA Group Description	Validation Status	Surface Type	Layer 1 Type	Layer 1 Description	Wet Surface	No Element Selected	Carriageway Code
13	9.18	9.18	20900911247	21/11/2009	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	700	---	OFF PATH- STRAIGHT: OTHER	E	21	Other	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.23	9.23	20050005800	9/03/2005	RECEIVED MEDICAL TREATMENT -	RECEIVED MEDICAL TREATMENT -	306	---	VEH'S SAME DIRECTION: LANE CHANGE RIGHT	E	5	Lane change	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.23	9.23	990024551	12/11/1999	RECEIVED MEDICAL TREATMENT -	RECEIVED MEDICAL TREATMENT -	307	---	VEH'S SAME DIRECTION: LANE CHANGE LEFT	E	5	Lane change	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.23	9.23	20020008270	8/04/2002	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.23	9.23	20020002383	1/02/2002	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	201	---	VEH'S OPPOSITE APPROACH: HEAD ON	E	2	Head-on	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.25	9.25	950021884	20/09/1995	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	702	---	OFF PATH- STRAIGHT: RIGHT OFF CWAY	E	15	Off carriageway, on straight	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.26	9.26	20600126056	30/12/2006	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	408	---	VEH'S MANOEUVRING: ENTERING FROM	E	8	Vehicle leaving driveway	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.305	9.305	20030017307	16/07/2003	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.33	9.33	20030024184	29/09/2003	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	702	---	OFF PATH- STRAIGHT: RIGHT OFF CWAY	E	15	Off carriageway, on straight	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.38	9.38	20030012713	28/05/2003	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.4	9.4	920026829	25/11/1992	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	700	---	OFF PATH- STRAIGHT: OTHER	E	21	Other	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.43	9.43	970003564	17/02/1997	RECEIVED MEDICAL TREATMENT -	RECEIVED MEDICAL TREATMENT -	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	G3	Stone Mastic Asphalt	---	13	3
13	9.43	9.43	940016181	19/07/1994	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	703	---	OFF PATH- STRAIGHT: LEFT OFF CWAY HIT OBJ	E	16	Off carriageway on straight, hit object	0	2	G3	Stone Mastic Asphalt	---	13	3

APPENDIX H - DAVID LOW WAY AND RUNWAY DRIVE SIGNALISED INTERSECTION: CRASH HISTORY

Data for Road Section : 133 - MAROOCHYDORE - NOOSA ROAD

District ID	TDIST START	TDIST END	Crash Number	Crash Date	Crash Severity	Crash Severity Description	Crash DCA Code	Intersection ID	Crash DCA Description	Relative Position	Crash DCA Code Group	Crash DCA Group Description	Validation Status	Surface Type	Layer 1 Type	Layer 1 Description	Wet Surface	No Element Selected	Carriageway Code
2	13.006	13.006	20120540840	6/06/2012	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	301	2502	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	G1	Bitumen Dense Graded Asphalt	---	2	3
2	13.01	13.01	20900532550	13/07/2009	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	101	2502	VEH'S ADJACENT APPROACH: THRU-THRU	6	1	Intersection, from adjacent approaches	0	2	G1	Bitumen Dense Graded Asphalt	---	2	1

APPENDIX I - ANZAC AVENUE MEWES DRIVE TO BREMNER DRIVE MID-BLOCK (REDESIGNED): CRASH HISTORY

Data for Road Section : 120 - REDCLIFFE ROAD

District ID	TDIST START	TDIST END	Crash Number	Crash Date	Crash Severity	Crash Severity Description	Crash DCA Code	Intersection ID	Crash DCA Description	Relative Position	Crash DCA Code Group	Crash DCA Group Description	Validation Status	Surface Type	Layer 1 Type	Layer 1 Description	Wet Surface	No Element Selected	Carriageway Code
13	11.38	11.38	910005475	28/11/1991	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.43	11.43	920002501	4/02/1992	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.47	11.47	20700073236	17/04/2007	RECEIVED MEDICAL TREATMENT -	RECEIVED MEDICAL TREATMENT -	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.47	11.47	950020952	9/09/1995	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	701	---	OFF PATH-STRAIGHT: LEFT OFF CWAY	6	15	Off carriageway, on straight	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.47	11.47	20020029910	2/12/2002	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	703	---	OFF PATH-STRAIGHT: LEFT OFF CWAY HIT OBJ	E	16	Off carriageway on straight, hit object	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.47	11.47	20060002554	1/02/2006	RECEIVED MEDICAL TREATMENT -	RECEIVED MEDICAL TREATMENT -	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.52	11.52	960003837	18/02/1996	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.6	11.6	20050029030	18/11/2005	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.62	11.62	20060004718	24/02/2006	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.63	11.63	980008551	25/04/1998	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	703	---	OFF PATH-STRAIGHT: LEFT OFF CWAY HIT OBJ	E	16	Off carriageway on straight, hit object	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.67	11.67	990024324	29/10/1999	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.67	11.67	20130239476	26/02/2013	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.67	11.67	990004796	3/11/1998	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.68	11.68	20101062774	26/11/2010	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.69	11.69	20110065708	8/12/2010	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.69	11.69	20100742796	10/08/2010	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.72	11.72	20050003968	18/02/2005	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1

13	11.82	11.82	20010004558	1/03/2001	ADMITTED TO HOSPITAL	ADMITTED TO HOSPITAL	305	---	VEH'S SAME DIRECTION: LANE SIDE SWIPE	E	5	Lane change	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.82	11.82	20800674673	21/10/2008	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.86	11.86	20700020725	4/02/2007	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.87	11.87	20010003241	12/02/2001	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	301	---	VEH'S SAME DIRECTION: REAR END	E	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.89	11.89	930011153	29/05/1993	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	702	---	OFF PATH-STRAIGHT: RIGHT OFF CWAY	E	15	Off carriageway, on straight	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.902	11.902	20800275136	1/05/2008	RECEIVED MEDICAL TREATMENT -	RECEIVED MEDICAL TREATMENT -	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.92	11.92	20050025394	10/10/2005	PROPERTY DAMAGE ONLY	PROPERTY DAMAGE ONLY	609	---	PASS & MISC: HIT ANIMAL	E	14	Hit animal	0	2	I1	Bitumen Open Graded Asphalt	---	13	3
13	11.92	11.92	970009860	7/05/1997	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	702	---	OFF PATH-STRAIGHT: RIGHT OFF CWAY	6	15	Off carriageway, on straight	0	2	I1	Bitumen Open Graded Asphalt	---	13	1
13	11.92	11.92	20020030197	3/12/2002	MINOR INJURY - FIRST AID OR NO TREATMENT	MINOR INJURY - FIRST AID OR NO	301	---	VEH'S SAME DIRECTION: REAR END	6	4	Rear-end	0	2	I1	Bitumen Open Graded Asphalt	---	13	1

APPENDIX J - BRUCE HIGHWAY AND BOUNDARY ROAD SOUTHBOUND ON-RAMP (REDESIGNED): COST COMPARISON

Site D - Bruce Highway Boundary Road Interchange
Base Layout

Initial Costs			
Number of New Poles		0	poles
Number of New Luminaires		0	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	-	

Maintainance Costs			
Pre-Midnight Number of Lamps		22	
Post-Midnight Number of Lamps		22	
Pre-Midnight Lamp Life		20000	hours
Post-Midnight Lamp Life		20000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***189,420.00***	

Electricity Costs			
Pre-Midnight Poles in Service		13	poles
Post-Midnight Poles in Service		13	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	1,424.48	
Cost of Electricty over 41 years	***$***	***58,403.48***	

Social Cost of Crashes			
Average Yearly Number of Crashes		0.7	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V3	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.117384732	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.137348146	crashes/year
Total Yearly Post-Midnight Crashes		0.059108323	crashes/year
Total Yearly Daytime Crashes		0.503543531	crashes/year
Total Yearly Social Cost of Crashes	$	106,750.52	/year
Total Cost of Crashes over 41 years	***$***	***4,376,771.24***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		5.5	KW
Post-Midnight Electricty Demand		5.5	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		23100	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***47,006.19***	

Total Cost of Treatment	***$***	***4,614,621.90***	

Year	Social Cost of Carbon	Social Cost of Carbon for Site	
2010	$33.00/tonne	$	724.19
2011	$34.00/tonne	$	746.13
2012	$35.00/tonne	$	768.08
2013	$36.00/tonne	$	790.02
2014	$37.00/tonne	$	811.97
2015	$38.00/tonne	$	833.91
2016	$39.00/tonne	$	855.86
2017	$40.00/tonne	$	877.80
2018	$41.00/tonne	$	899.75
2023	$46.00/tonne	$	1,009.47
2024	$47.00/tonne	$	1,031.42
2025	$48.00/tonne	$	1,053.36
2026	$49.00/tonne	$	1,075.31
2019	$42.00/tonne	$	921.69
2020	$43.00/tonne	$	943.64
2021	$44.00/tonne	$	965.58
2022	$45.00/tonne	$	987.53
2027	$49.00/tonne	$	1,075.31
2028	$50.00/tonne	$	1,097.25
2029	$51.00/tonne	$	1,119.20
2030	$52.00/tonne	$	1,141.14
2031	$53.00/tonne	$	1,163.09
2032	$54.00/tonne	$	1,185.03
2033	$55.00/tonne	$	1,206.98
2034	$56.00/tonne	$	1,228.92
2035	$57.00/tonne	$	1,250.87
2036	$58.00/tonne	$	1,272.81
2037	$59.00/tonne	$	1,294.76
2038	$60.00/tonne	$	1,316.70
2039	$61.00/tonne	$	1,338.65
2040	$62.00/tonne	$	1,360.59
2041	$63.00/tonne	$	1,382.54
2042	$64.00/tonne	$	1,404.48
2043	$65.00/tonne	$	1,426.43
2044	$65.00/tonne	$	1,426.43
2045	$66.00/tonne	$	1,448.37
2046	$67.00/tonne	$	1,470.32
2047	$68.00/tonne	$	1,492.26
2048	$69.00/tonne	$	1,514.21
2049	$70.00/tonne	$	1,536.15
2050	$71.00/tonne	$	1,558.10

Site D - Bruce Highway Boundary Road Interchange
Treatment 1

Initial Costs			
Number of New Poles		0	poles
Number of New Luminaires		13	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	***13,000.00***	

Maintainance Costs			
Pre-Midnight Number of Lamps		13	
Post-Midnight Number of Lamps		13	
Pre-Midnight Lamp Life		20000	hours
Post-Midnight Lamp Life		20000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***111,930.00***	

Electricity Costs			
Pre-Midnight Poles in Service		13	poles
Post-Midnight Poles in Service		13	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	1,424.48	
Cost of Electricty over 41 years	***$***	***58,403.48***	

Social Cost of Crashes			
Average Yearly Number of Crashes		0.715136774	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V5	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.14744524	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.137348146	crashes/year
Total Yearly Post-Midnight Crashes		0.074245097	crashes/year
Total Yearly Daytime Crashes		0.503543531	crashes/year
Total Yearly Social Cost of Crashes	$	109,058.89	/year
Total Cost of Crashes over 41 years	***$***	***4,471,414.38***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		3.25	KW
Post-Midnight Electricty Demand		1.95	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		10920	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***22,221.11***	

Total Cost of Treatment	***$***	***4,619,989.96***
Cost Difference with Base Layout	**$**	**5,368.06**
(-ve=lower cost, +ve=higher cost)		

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 342.34
2011	$34.00/tonne	$ 352.72
2012	$35.00/tonne	$ 363.09
2013	$36.00/tonne	$ 373.46
2014	$37.00/tonne	$ 383.84
2015	$38.00/tonne	$ 394.21
2016	$39.00/tonne	$ 404.59
2017	$40.00/tonne	$ 414.96
2018	$41.00/tonne	$ 425.33
2023	$46.00/tonne	$ 477.20
2024	$47.00/tonne	$ 487.58
2025	$48.00/tonne	$ 497.95
2026	$49.00/tonne	$ 508.33
2019	$42.00/tonne	$ 435.71
2020	$43.00/tonne	$ 446.08
2021	$44.00/tonne	$ 456.46
2022	$45.00/tonne	$ 466.83
2027	$49.00/tonne	$ 508.33
2028	$50.00/tonne	$ 518.70
2029	$51.00/tonne	$ 529.07
2030	$52.00/tonne	$ 539.45
2031	$53.00/tonne	$ 549.82
2032	$54.00/tonne	$ 560.20
2033	$55.00/tonne	$ 570.57
2034	$56.00/tonne	$ 580.94
2035	$57.00/tonne	$ 591.32
2036	$58.00/tonne	$ 601.69
2037	$59.00/tonne	$ 612.07
2038	$60.00/tonne	$ 622.44
2039	$61.00/tonne	$ 632.81
2040	$62.00/tonne	$ 643.19
2041	$63.00/tonne	$ 653.56
2042	$64.00/tonne	$ 663.94
2043	$65.00/tonne	$ 674.31
2044	$65.00/tonne	$ 674.31
2045	$66.00/tonne	$ 684.68
2046	$67.00/tonne	$ 695.06
2047	$68.00/tonne	$ 705.43
2048	$69.00/tonne	$ 715.81
2049	$70.00/tonne	$ 726.18
2050	$71.00/tonne	$ 736.55

Site D - Bruce Highway Boundary Road Interchange
Treatment 3A

Initial Costs			
Number of New Poles		13	poles
Number of New Luminaires		13	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	***143,000.00***	

Maintainance Costs			
Pre-Midnight Number of Lamps		13	
Post-Midnight Number of Lamps		13	
Pre-Midnight Lamp Life		50000	hours
Post-Midnight Lamp Life		50000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***44,772.00***	

Electricity Costs			
Pre-Midnight Poles in Service		13	poles
Post-Midnight Poles in Service		13	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	1,424.48	
Cost of Electricty over 41 years	***$***	***58,403.48***	

Social Cost of Crashes			
Average Yearly Number of Crashes		0.715136774	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V5	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.14744524	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.137348146	crashes/year
Total Yearly Post-Midnight Crashes		0.074245097	crashes/year
Total Yearly Daytime Crashes		0.503543531	crashes/year
Total Yearly Social Cost of Crashes	$	109,058.89	/year
Total Cost of Crashes over 41 years	***$***	***4,471,414.38***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		2.34	KW
Post-Midnight Electricty Demand		1.03	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		7077	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***14,400.99***	

Total Cost of Treatment	***$***	***4,675,011.84***
Cost Difference with Base Layout	**$**	**60,389.94**
(-ve=lower cost, +ve=higher cost)		

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 221.86
2011	$34.00/tonne	$ 228.59
2012	$35.00/tonne	$ 235.31
2013	$36.00/tonne	$ 242.03
2014	$37.00/tonne	$ 248.76
2015	$38.00/tonne	$ 255.48
2016	$39.00/tonne	$ 262.20
2017	$40.00/tonne	$ 268.93
2018	$41.00/tonne	$ 275.65
2023	$46.00/tonne	$ 309.26
2024	$47.00/tonne	$ 315.99
2025	$48.00/tonne	$ 322.71
2026	$49.00/tonne	$ 329.43
2019	$42.00/tonne	$ 282.37
2020	$43.00/tonne	$ 289.10
2021	$44.00/tonne	$ 295.82
2022	$45.00/tonne	$ 302.54
2027	$49.00/tonne	$ 329.43
2028	$50.00/tonne	$ 336.16
2029	$51.00/tonne	$ 342.88
2030	$52.00/tonne	$ 349.60
2031	$53.00/tonne	$ 356.33
2032	$54.00/tonne	$ 363.05
2033	$55.00/tonne	$ 369.77
2034	$56.00/tonne	$ 376.50
2035	$57.00/tonne	$ 383.22
2036	$58.00/tonne	$ 389.94
2037	$59.00/tonne	$ 396.67
2038	$60.00/tonne	$ 403.39
2039	$61.00/tonne	$ 410.11
2040	$62.00/tonne	$ 416.84
2041	$63.00/tonne	$ 423.56
2042	$64.00/tonne	$ 430.28
2043	$65.00/tonne	$ 437.00
2044	$65.00/tonne	$ 437.00
2045	$66.00/tonne	$ 443.73
2046	$67.00/tonne	$ 450.45
2047	$68.00/tonne	$ 457.17
2048	$69.00/tonne	$ 463.90
2049	$70.00/tonne	$ 470.62
2050	$71.00/tonne	$ 477.34

APPENDIX K - DAVID LOW WAY AND RUNWAY DRIVE SIGNALISED INTERSECTION: COST COMPARISON

Site E - David Low Way and Runway Drive Intersection
Base Layout

Initial Costs			
Number of New Poles		0	poles
Number of New Luminaires		0	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	-	

Maintainance Costs			
Pre-Midnight Number of Lamps		22	
Post-Midnight Number of Lamps		22	
Pre-Midnight Lamp Life		20000	hours
Post-Midnight Lamp Life		20000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***189,420.00***	

Electricity Costs			
Pre-Midnight Poles in Service		13	poles
Post-Midnight Poles in Service		13	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	1,424.48	
Cost of Electricty over 41 years	***$***	***58,403.48***	

Social Cost of Crashes			
Average Yearly Number of Crashes		0.5	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V3	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.117384732	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.098105819	crashes/year
Total Yearly Post-Midnight Crashes		0.04222023	crashes/year
Total Yearly Daytime Crashes		0.359673951	crashes/year
Total Yearly Social Cost of Crashes	$	76,250.37	/year
Total Cost of Crashes over 41 years	***$***	***3,126,265.17***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		3.25	KW
Post-Midnight Electricty Demand		3.25	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		13650	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***27,776.39***	

Total Cost of Treatment	***$***	***3,344,886.03***	

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 427.93
2011	$34.00/tonne	$ 440.90
2012	$35.00/tonne	$ 453.86
2013	$36.00/tonne	$ 466.83
2014	$37.00/tonne	$ 479.80
2015	$38.00/tonne	$ 492.77
2016	$39.00/tonne	$ 505.73
2017	$40.00/tonne	$ 518.70
2018	$41.00/tonne	$ 531.67
2023	$46.00/tonne	$ 596.51
2024	$47.00/tonne	$ 609.47
2025	$48.00/tonne	$ 622.44
2026	$49.00/tonne	$ 635.41
2019	$42.00/tonne	$ 544.64
2020	$43.00/tonne	$ 557.60
2021	$44.00/tonne	$ 570.57
2022	$45.00/tonne	$ 583.54
2027	$49.00/tonne	$ 635.41
2028	$50.00/tonne	$ 648.38
2029	$51.00/tonne	$ 661.34
2030	$52.00/tonne	$ 674.31
2031	$53.00/tonne	$ 687.28
2032	$54.00/tonne	$ 700.25
2033	$55.00/tonne	$ 713.21
2034	$56.00/tonne	$ 726.18
2035	$57.00/tonne	$ 739.15
2036	$58.00/tonne	$ 752.12
2037	$59.00/tonne	$ 765.08
2038	$60.00/tonne	$ 778.05
2039	$61.00/tonne	$ 791.02
2040	$62.00/tonne	$ 803.99
2041	$63.00/tonne	$ 816.95
2042	$64.00/tonne	$ 829.92
2043	$65.00/tonne	$ 842.89
2044	$65.00/tonne	$ 842.89
2045	$66.00/tonne	$ 855.86
2046	$67.00/tonne	$ 868.82
2047	$68.00/tonne	$ 881.79
2048	$69.00/tonne	$ 894.76
2049	$70.00/tonne	$ 907.73
2050	$71.00/tonne	$ 920.69

Site E - David Low Way and Runway Drive Intersection
Treatment 1

Initial Costs			
Number of New Poles		0	poles
Number of New Luminaires		13	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	***13,000.00***	

Maintainance Costs			
Pre-Midnight Number of Lamps		13	
Post-Midnight Number of Lamps		13	
Pre-Midnight Lamp Life		20000	hours
Post-Midnight Lamp Life		20000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***111,930.00***	

Electricity Costs			
Pre-Midnight Poles in Service		13	poles
Post-Midnight Poles in Service		13	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	1,424.48	
Cost of Electricty over 41 years	***$***	***58,403.48***	

Social Cost of Crashes			
Average Yearly Number of Crashes		0.510811981	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V5	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.14744524	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.098105819	crashes/year
Total Yearly Post-Midnight Crashes		0.053032212	crashes/year
Total Yearly Daytime Crashes		0.359673951	crashes/year
Total Yearly Social Cost of Crashes	$	77,899.21	/year
Total Cost of Crashes over 41 years	***$***	***3,193,867.41***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		3.25	KW
Post-Midnight Electricty Demand		1.95	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		10920	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***22,221.11***	

Total Cost of Treatment	***$***	***3,342,443.00***
Cost Difference with Base Layout	**-$**	**2,443.03**
(-ve=lower cost, +ve=higher cost)		

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 342.34
2011	$34.00/tonne	$ 352.72
2012	$35.00/tonne	$ 363.09
2013	$36.00/tonne	$ 373.46
2014	$37.00/tonne	$ 383.84
2015	$38.00/tonne	$ 394.21
2016	$39.00/tonne	$ 404.59
2017	$40.00/tonne	$ 414.96
2018	$41.00/tonne	$ 425.33
2023	$46.00/tonne	$ 477.20
2024	$47.00/tonne	$ 487.58
2025	$48.00/tonne	$ 497.95
2026	$49.00/tonne	$ 508.33
2019	$42.00/tonne	$ 435.71
2020	$43.00/tonne	$ 446.08
2021	$44.00/tonne	$ 456.46
2022	$45.00/tonne	$ 466.83
2027	$49.00/tonne	$ 508.33
2028	$50.00/tonne	$ 518.70
2029	$51.00/tonne	$ 529.07
2030	$52.00/tonne	$ 539.45
2031	$53.00/tonne	$ 549.82
2032	$54.00/tonne	$ 560.20
2033	$55.00/tonne	$ 570.57
2034	$56.00/tonne	$ 580.94
2035	$57.00/tonne	$ 591.32
2036	$58.00/tonne	$ 601.69
2037	$59.00/tonne	$ 612.07
2038	$60.00/tonne	$ 622.44
2039	$61.00/tonne	$ 632.81
2040	$62.00/tonne	$ 643.19
2041	$63.00/tonne	$ 653.56
2042	$64.00/tonne	$ 663.94
2043	$65.00/tonne	$ 674.31
2044	$65.00/tonne	$ 674.31
2045	$66.00/tonne	$ 684.68
2046	$67.00/tonne	$ 695.06
2047	$68.00/tonne	$ 705.43
2048	$69.00/tonne	$ 715.81
2049	$70.00/tonne	$ 726.18
2050	$71.00/tonne	$ 736.55

Site E - David Low Way and Runway Drive Intersection
Treatment 2

Initial Costs			
Number of New Poles		0	poles
Number of New Luminaires		0	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	-	

Maintainance Costs			
Pre-Midnight Number of Lamps		13	
Post-Midnight Number of Lamps		8	
Pre-Midnight Lamp Life		20000	hours
Post-Midnight Lamp Life		20000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***90,405.00***	

Electricity Costs			
Pre-Midnight Poles in Service		13	poles
Post-Midnight Poles in Service		8	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	1,424.48	
Cost of Electricty over 41 years	***$***	***58,403.48***	

Social Cost of Crashes			
Average Yearly Number of Crashes		0.510811981	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V5	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.14744524	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.098105819	crashes/year
Total Yearly Post-Midnight Crashes		0.053032212	crashes/year
Total Yearly Daytime Crashes		0.359673951	crashes/year
Total Yearly Social Cost of Crashes	$	77,899.21	/year
Total Cost of Crashes over 41 years	***$***	***3,193,867.41***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		3.25	KW
Post-Midnight Electricty Demand		1.75	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		10500	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***21,366.45***	

Total Cost of Treatment	***$***	***3,307,063.34***
Cost Difference with Base Layout	**-$**	**37,822.69**
(-ve=lower cost, +ve=higher cost)		

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 329.18
2011	$34.00/tonne	$ 339.15
2012	$35.00/tonne	$ 349.13
2013	$36.00/tonne	$ 359.10
2014	$37.00/tonne	$ 369.08
2015	$38.00/tonne	$ 379.05
2016	$39.00/tonne	$ 389.03
2017	$40.00/tonne	$ 399.00
2018	$41.00/tonne	$ 408.98
2023	$46.00/tonne	$ 458.85
2024	$47.00/tonne	$ 468.83
2025	$48.00/tonne	$ 478.80
2026	$49.00/tonne	$ 488.78
2019	$42.00/tonne	$ 418.95
2020	$43.00/tonne	$ 428.93
2021	$44.00/tonne	$ 438.90
2022	$45.00/tonne	$ 448.88
2027	$49.00/tonne	$ 488.78
2028	$50.00/tonne	$ 498.75
2029	$51.00/tonne	$ 508.73
2030	$52.00/tonne	$ 518.70
2031	$53.00/tonne	$ 528.68
2032	$54.00/tonne	$ 538.65
2033	$55.00/tonne	$ 548.63
2034	$56.00/tonne	$ 558.60
2035	$57.00/tonne	$ 568.58
2036	$58.00/tonne	$ 578.55
2037	$59.00/tonne	$ 588.53
2038	$60.00/tonne	$ 598.50
2039	$61.00/tonne	$ 608.48
2040	$62.00/tonne	$ 618.45
2041	$63.00/tonne	$ 628.43
2042	$64.00/tonne	$ 638.40
2043	$65.00/tonne	$ 648.38
2044	$65.00/tonne	$ 648.38
2045	$66.00/tonne	$ 658.35
2046	$67.00/tonne	$ 668.33
2047	$68.00/tonne	$ 678.30
2048	$69.00/tonne	$ 688.28
2049	$70.00/tonne	$ 698.25
2050	$71.00/tonne	$ 708.23

Site D - Bruce Highway Boundary Road Interchange
Treatment 3A

Initial Costs			
Number of New Poles		13	poles
Number of New Luminaires		13	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	***143,000.00***	

Maintainance Costs			
Pre-Midnight Number of Lamps		13	
Post-Midnight Number of Lamps		13	
Pre-Midnight Lamp Life		50000	hours
Post-Midnight Lamp Life		50000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***44,772.00***	

Electricity Costs			
Pre-Midnight Poles in Service		13	poles
Post-Midnight Poles in Service		13	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	1,424.48	
Cost of Electricty over 41 years	***$***	***58,403.48***	

Social Cost of Crashes			
Average Yearly Number of Crashes		0.510811981	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V5	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.14744524	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.098105819	crashes/year
Total Yearly Post-Midnight Crashes		0.053032212	crashes/year
Total Yearly Daytime Crashes		0.359673951	crashes/year
Total Yearly Social Cost of Crashes	$	77,899.21	/year
Total Cost of Crashes over 41 years	***$***	***3,193,867.41***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		2.34	KW
Post-Midnight Electricty Demand		1.03	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		7077	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***14,400.99***	

Total Cost of Treatment	***$***	***3,397,464.87***
Cost Difference with Base Layout	**$**	**52,578.84**
(-ve=lower cost, +ve=higher cost)		

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 221.86
2011	$34.00/tonne	$ 228.59
2012	$35.00/tonne	$ 235.31
2013	$36.00/tonne	$ 242.03
2014	$37.00/tonne	$ 248.76
2015	$38.00/tonne	$ 255.48
2016	$39.00/tonne	$ 262.20
2017	$40.00/tonne	$ 268.93
2018	$41.00/tonne	$ 275.65
2023	$46.00/tonne	$ 309.26
2024	$47.00/tonne	$ 315.99
2025	$48.00/tonne	$ 322.71
2026	$49.00/tonne	$ 329.43
2019	$42.00/tonne	$ 282.37
2020	$43.00/tonne	$ 289.10
2021	$44.00/tonne	$ 295.82
2022	$45.00/tonne	$ 302.54
2027	$49.00/tonne	$ 329.43
2028	$50.00/tonne	$ 336.16
2029	$51.00/tonne	$ 342.88
2030	$52.00/tonne	$ 349.60
2031	$53.00/tonne	$ 356.33
2032	$54.00/tonne	$ 363.05
2033	$55.00/tonne	$ 369.77
2034	$56.00/tonne	$ 376.50
2035	$57.00/tonne	$ 383.22
2036	$58.00/tonne	$ 389.94
2037	$59.00/tonne	$ 396.67
2038	$60.00/tonne	$ 403.39
2039	$61.00/tonne	$ 410.11
2040	$62.00/tonne	$ 416.84
2041	$63.00/tonne	$ 423.56
2042	$64.00/tonne	$ 430.28
2043	$65.00/tonne	$ 437.00
2044	$65.00/tonne	$ 437.00
2045	$66.00/tonne	$ 443.73
2046	$67.00/tonne	$ 450.45
2047	$68.00/tonne	$ 457.17
2048	$69.00/tonne	$ 463.90
2049	$70.00/tonne	$ 470.62
2050	$71.00/tonne	$ 477.34

APPENDIX L - ANZAC AVENUE MEWES DRIVE TO BREMNER DRIVE MID-BLOCK (REDESIGNED): COST COMPARISON

Site H - Anzac Avenue Mewes Road to Bremner Road
Base Layout

Initial Costs			
Number of New Poles		0	poles
Number of New Luminaires		0	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	-	

Maintainance Costs			
Pre-Midnight Number of Lamps		22	
Post-Midnight Number of Lamps		22	
Pre-Midnight Lamp Life		20000	hours
Post-Midnight Lamp Life		20000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***189,420.00***	

Electricity Costs			
Pre-Midnight Poles in Service		22	poles
Post-Midnight Poles in Service		22	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	2,410.65	
Cost of Electricty over 41 years	***$***	***98,836.65***	

Social Cost of Crashes			
Average Yearly Number of Crashes		1.2	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V3	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.117384732	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.235453965	crashes/year
Total Yearly Post-Midnight Crashes		0.101328553	crashes/year
Total Yearly Daytime Crashes		0.863217482	crashes/year
Total Yearly Social Cost of Crashes	$	183,000.89	/year
Total Cost of Crashes over 41 years	***$***	***7,503,036.41***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		5.5	KW
Post-Midnight Electricty Demand		5.5	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		23100	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***47,006.19***	

Total Cost of Treatment	***$***	***7,741,873.25***	

Year	Social Cost of Carbon	Social Cost of Carbon for Site	
2010	$33.00/tonne	$	724.19
2011	$34.00/tonne	$	746.13
2012	$35.00/tonne	$	768.08
2013	$36.00/tonne	$	790.02
2014	$37.00/tonne	$	811.97
2015	$38.00/tonne	$	833.91
2016	$39.00/tonne	$	855.86
2017	$40.00/tonne	$	877.80
2018	$41.00/tonne	$	899.75
2023	$46.00/tonne	$	1,009.47
2024	$47.00/tonne	$	1,031.42
2025	$48.00/tonne	$	1,053.36
2026	$49.00/tonne	$	1,075.31
2019	$42.00/tonne	$	921.69
2020	$43.00/tonne	$	943.64
2021	$44.00/tonne	$	965.58
2022	$45.00/tonne	$	987.53
2027	$49.00/tonne	$	1,075.31
2028	$50.00/tonne	$	1,097.25
2029	$51.00/tonne	$	1,119.20
2030	$52.00/tonne	$	1,141.14
2031	$53.00/tonne	$	1,163.09
2032	$54.00/tonne	$	1,185.03
2033	$55.00/tonne	$	1,206.98
2034	$56.00/tonne	$	1,228.92
2035	$57.00/tonne	$	1,250.87
2036	$58.00/tonne	$	1,272.81
2037	$59.00/tonne	$	1,294.76
2038	$60.00/tonne	$	1,316.70
2039	$61.00/tonne	$	1,338.65
2040	$62.00/tonne	$	1,360.59
2041	$63.00/tonne	$	1,382.54
2042	$64.00/tonne	$	1,404.48
2043	$65.00/tonne	$	1,426.43
2044	$65.00/tonne	$	1,426.43
2045	$66.00/tonne	$	1,448.37
2046	$67.00/tonne	$	1,470.32
2047	$68.00/tonne	$	1,492.26
2048	$69.00/tonne	$	1,514.21
2049	$70.00/tonne	$	1,536.15
2050	$71.00/tonne	$	1,558.10

Site H - Anzac Avenue Mewes Road to Bremner Road
Treatment 1

Initial Costs			
Number of New Poles		0	poles
Number of New Luminaires		22	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	***22,000.00***	

Maintainance Costs			
Pre-Midnight Number of Lamps		22	
Post-Midnight Number of Lamps		22	
Pre-Midnight Lamp Life		20000	hours
Post-Midnight Lamp Life		20000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***189,420.00***	

Electricity Costs			
Pre-Midnight Poles in Service		22	poles
Post-Midnight Poles in Service		22	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	2,410.65	
Cost of Electricty over 41 years	***$***	***98,836.65***	

Social Cost of Crashes			
Average Yearly Number of Crashes		1.225948755	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V5	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.14744524	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.235453965	crashes/year
Total Yearly Post-Midnight Crashes		0.127277309	crashes/year
Total Yearly Daytime Crashes		0.863217482	crashes/year
Total Yearly Social Cost of Crashes	$	186,958.09	/year
Total Cost of Crashes over 41 years	***$***	***7,665,281.79***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		5.5	KW
Post-Midnight Electricty Demand		3.3	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		18480	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***37,604.95***	

Total Cost of Treatment	***$***	***7,916,717.39***
Cost Difference with Base Layout	**$**	**174,844.14**
(-ve=lower cost, +ve=higher cost)		

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 579.35
2011	$34.00/tonne	$ 596.90
2012	$35.00/tonne	$ 614.46
2013	$36.00/tonne	$ 632.02
2014	$37.00/tonne	$ 649.57
2015	$38.00/tonne	$ 667.13
2016	$39.00/tonne	$ 684.68
2017	$40.00/tonne	$ 702.24
2018	$41.00/tonne	$ 719.80
2023	$46.00/tonne	$ 807.58
2024	$47.00/tonne	$ 825.13
2025	$48.00/tonne	$ 842.69
2026	$49.00/tonne	$ 860.24
2019	$42.00/tonne	$ 737.35
2020	$43.00/tonne	$ 754.91
2021	$44.00/tonne	$ 772.46
2022	$45.00/tonne	$ 790.02
2027	$49.00/tonne	$ 860.24
2028	$50.00/tonne	$ 877.80
2029	$51.00/tonne	$ 895.36
2030	$52.00/tonne	$ 912.91
2031	$53.00/tonne	$ 930.47
2032	$54.00/tonne	$ 948.02
2033	$55.00/tonne	$ 965.58
2034	$56.00/tonne	$ 983.14
2035	$57.00/tonne	$ 1,000.69
2036	$58.00/tonne	$ 1,018.25
2037	$59.00/tonne	$ 1,035.80
2038	$60.00/tonne	$ 1,053.36
2039	$61.00/tonne	$ 1,070.92
2040	$62.00/tonne	$ 1,088.47
2041	$63.00/tonne	$ 1,106.03
2042	$64.00/tonne	$ 1,123.58
2043	$65.00/tonne	$ 1,141.14
2044	$65.00/tonne	$ 1,141.14
2045	$66.00/tonne	$ 1,158.70
2046	$67.00/tonne	$ 1,176.25
2047	$68.00/tonne	$ 1,193.81
2048	$69.00/tonne	$ 1,211.36
2049	$70.00/tonne	$ 1,228.92
2050	$71.00/tonne	$ 1,246.48

Site H - Anzac Avenue Mewes Road to Bremner Road
Treatment 3A

Initial Costs			
Number of New Poles		26	poles
Number of New Luminaires		26	luminaires
Cost of New Poles	$	10,000.00	
Cost of New Luminaires	$	1,000.00	
Cost to reconstruct lighting	***$***	***286,000.00***	

Maintainance Costs			
Pre-Midnight Number of Lamps		26	
Post-Midnight Number of Lamps		26	
Pre-Midnight Lamp Life		50000	hours
Post-Midnight Lamp Life		50000	hours
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Cost of New Luminaires	$	1,000.00	
Cost of Maintainance over 41 years	***$***	***89,544.00***	

Electricity Costs			
Pre-Midnight Poles in Service		26	poles
Post-Midnight Poles in Service		26	poles
Cost of Electricity Supply	$	0.30	/pole/day
Yealy cost of electricty	$	2,848.95	
Cost of Electricty over 41 years	***$***	***116,806.95***	

Social Cost of Crashes			
Average Yearly Number of Crashes		1.225948755	crashes/year
Pre-Midnight Lighing Standard		V3	
Post-Midnight Lighting Standard		V5	
N/D Crash Ratio Pre-Midnight		0.272763203	
N/D Crash Ratio Post-Midnight		0.14744524	
Social Cost of Property Damage Only	$	7,534.00	/crash
Social Cost of Minor Injury	$	17,869.00	/crash
Social Cost of Medial Treatment	$	17,869.00	/crash
Social Cost of Hospitialisation	$	529,203.00	/crash
Social Cost of Fatalities	$	2,144,096.00	/crash
Property Damage Only Percentage		0.41	
Minor Injury Percentage		0.11	
Medial Treatment Percentage		0.24	
Hospitialisation Percentage		0.23	
Fatalities Percentage		0.01	
Total Yearly Pre-Midnight Crashes		0.235453965	crashes/year
Total Yearly Post-Midnight Crashes		0.127277309	crashes/year
Total Yearly Daytime Crashes		0.863217482	crashes/year
Total Yearly Social Cost of Crashes	$	186,958.09	/year
Total Cost of Crashes over 41 years	***$***	***7,665,281.79***	***dollars***

Social Cost of Carbon			
Pre-Midnight Electricty Demand		4.68	KW
Post-Midnight Electricty Demand		2.34	KW
Yearly Pre-Midnight Lamp Usage		2100	hours
Yearly Post-Midnight Lamp Usage		2100	hours
Yearly Electricty Useage		14742	KWh
CO2 Emissions for Electricity		0.00095	tonnes/KWh
Total Social Cost of Carbon over 41 years	***$***	***29,998.50***	

Total Cost of Treatment	***$***	***8,073,673.23***
Cost Difference with Base Layout	**$**	**331,799.99**
(-ve=lower cost, +ve=higher cost)		

Year	Social Cost of Carbon	Social Cost of Carbon for Site
2010	$33.00/tonne	$ 462.16
2011	$34.00/tonne	$ 476.17
2012	$35.00/tonne	$ 490.17
2013	$36.00/tonne	$ 504.18
2014	$37.00/tonne	$ 518.18
2015	$38.00/tonne	$ 532.19
2016	$39.00/tonne	$ 546.19
2017	$40.00/tonne	$ 560.20
2018	$41.00/tonne	$ 574.20
2023	$46.00/tonne	$ 644.23
2024	$47.00/tonne	$ 658.23
2025	$48.00/tonne	$ 672.24
2026	$49.00/tonne	$ 686.24
2019	$42.00/tonne	$ 588.21
2020	$43.00/tonne	$ 602.21
2021	$44.00/tonne	$ 616.22
2022	$45.00/tonne	$ 630.22
2027	$49.00/tonne	$ 686.24
2028	$50.00/tonne	$ 700.25
2029	$51.00/tonne	$ 714.25
2030	$52.00/tonne	$ 728.25
2031	$53.00/tonne	$ 742.26
2032	$54.00/tonne	$ 756.26
2033	$55.00/tonne	$ 770.27
2034	$56.00/tonne	$ 784.27
2035	$57.00/tonne	$ 798.28
2036	$58.00/tonne	$ 812.28
2037	$59.00/tonne	$ 826.29
2038	$60.00/tonne	$ 840.29
2039	$61.00/tonne	$ 854.30
2040	$62.00/tonne	$ 868.30
2041	$63.00/tonne	$ 882.31
2042	$64.00/tonne	$ 896.31
2043	$65.00/tonne	$ 910.32
2044	$65.00/tonne	$ 910.32
2045	$66.00/tonne	$ 924.32
2046	$67.00/tonne	$ 938.33
2047	$68.00/tonne	$ 952.33
2048	$69.00/tonne	$ 966.34
2049	$70.00/tonne	$ 980.34
2050	$71.00/tonne	$ 994.35