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NEW BRIDGEWATER BRIDGE: ARTIFICIAL LIGHT IMPACT ASSESSMENT AND MANAGEMENT PLAN

Prepared by

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1 INTRODUCTION

1.1 Project Description

The New Bridgewater Bridge Project (the project) involves the construction and operation of a new crossing across the River Derwent in Hobart Tasmania. The New Bridgewater Bridge Project is supported by a $576 million commitment from the Australian and Tasmanian Governments as part of the Hobart City Deal. This commitment represents the largest ever investment in a single transport infrastructure project in Tasmania's history. The Bridgewater Bridge is a critical part of the transport and freight link between the northern and southern regions of Tasmania.

Assessment Criteria under the Major Projects process for the project related to light pollution; Assessment Criteria, Schedule 2 states:

S2.2.7 Light pollution

The following Information requirements and matters to be addressed for clause 5.1.7 Light pollution:

- *(a) identification of potential sources of light pollution and sensitive human and wildlife receptors for both the construction and operational phases of the project;*
- *(b) an assessment of construction and operational light pollution including:*
  - *(i) consideration of existing levels of light;*
  - *(ii) consideration of different types of light pollution, and potential impact on human and wildlife receptors, with reference to any relevant guidelines or standards;*
  - *(iii) identification of the need or otherwise for construction and operational mitigation measures and strategies; and*
  - *(iv) development of construction and operational phase design, management and mitigation strategies if required.*

Where clause 5.1.7 states*:*

5.1.7 Light pollution

Provide an assessment of how the potential light pollution impacts have an acceptable impact on sensitive receptors.

This Artificial Light Management Plan addresses this component of the Major Project Impact Statement.

1.2 Scope

The assessment approach in this report and as described below is consistent with the National Light Pollution Guidelines for Wildlife ("the guidelines"; Commonwealth of Australia 2020), the principles of Dark Sky protection promoted by locally based Australasian Dark Sky Alliance (ADSA) and the International Dark Sky Association (IDA). The design requirements AS4282 Control of Obtrusive Outdoor Lighting will also be addressed.

- **Step 1: Describe the sensitive receptors:** Includes a description of local wildlife and human receptors, and dark sky values. Wildlife addressed included fauna of Conservation Significance as identified in the North Barker Natural Values Assessment (2021a), North Barker Matters of National Environmental Significance (2021b) and Marine Solutions (2021).
- **Step 2: Describe the project area lighting:** Includes a description of facilities and light sources associated with the Project Land extents and the existing light environment in addition to the results of a benchmark Artificial Light at Night (ALAN) survey of the Project Land.
- **Step 3: Impact Assessment:** Using the description of wildlife, human receptors, dark sky values and light within the Project Land extents (described in Steps 1 and 2), assess the risk of impact of artificial light to wildlife, human receptors, and dark sky values.
- **Step 4: Artificial Light Management Plan:** Outlines the application of best practice lighting design principles and mitigation measures to eliminate or minimise project area related lighting impacts to receptors identified in Step 1.
- **Step 5: Monitoring and auditing**: Outlines the approach for monitoring wildlife and artificial light, and the auditing of project area light to ensure compliance with the Artificial Light Management Plan (ALMP) described in Step 4.

Note that the guidelines include the requirement for continuous review of the impact assessment and ALMP as further information from wildlife or artificial light monitoring, modelling, or audits become available. The review should incorporate any change to the project that may affect its lighting design within the project area and provide recommendations for continual improvement.

2 DESCRIBE THE SENSITIVE RECEPTORS

This section addresses the following component of the MPIS Assessment Criteria;

S2.2.7 a) Identification of potential sources of light pollution and sensitive human and wildlife receptors for both the construction and operational phases of the project.

2.1 Wildlife

A detailed review of the available biological information has been carried out for the New Bridgewater Bridge by North Barker Ecosystem Services (NBES) and includes a Natural Values Assessment (NBES 2021a) and Matters of National Environmental Significance report (NBES 2021b). An assessment of the aquatic species potentially at risk from the project has been carried out by Marine Solutions (2021). The full output of the Commonwealth Protected Matters Search Tool as presented in NBES 2021b and was assessed for likelihood of presence and potential for significant impact.

The species of fauna identified as warranting further assessment under the Commonwealth Environmental Protection and Biodiversity Conservation Act (EPBCA) or the Tasmanian Threatened Species Protection Act (TSPA) identified as potentially present within 5 km of the project area, or with a potential to occur based on habitat were identified by NBES as:

Threatened mammals

- *Dasyurus macutaltus,* spotted tail quoll *(*Vulnerable under EPBCA)
- *Dasyurus viverrinus,* eastern quoll (Endangered under EPBCA*)*
- *Perameles gunnii gunnuu,* eastern barred bandicoot (Vulnerable under EPBCA)
- *Sarcophilius harrisii,* Tasmanian devil (Endangered under TSPA and EPBCA)

The assessment found no evidence to indicate the project site represents critical habitat for the threatened mammals and they are therefore not considered further in this assessment.

Threatened avifauna

- *Botaurus poiciloptilus,* Australian bittern (Endangered under EPBCA)
- *Podiceps cristatus,* great crested grebe (Vulnerable under TSPA)
- *Aquila audax subsp. Fleayi,* Tasmanian wedge tailed eagle (Endangered under TSPA and EPBCA)
- *Haliaeetus leucogaster,* white-bellied sea eagle (Vulnerable under TSPA and listed under EPBCA)
- *Lathamus discolor,* swift parrot (Endangered under TSPA, Critically Endangered under EPBCA)

The NBES Natural Values Assessment report recognised Australian bittern habitat was present (blue shaded area, **Figure 1**) however none were observed during the field surveys. The limited potential habitat was deemed unsuitable for nesting or permanent occupation with any use restricted to occasional forging or shelter.

The great crested grebe was observed during the field surveys for this project with a pair observed in courtship behaviour outside the project area. The minor amount of suitable habitat within the project area, relative to the broader area, indicates the project area is not critical habitat for this species.

The Tasmanian wedge-tailed eagle and white-bellied sea eagle have the potential to overfly or forage in the area. No known or potential breeding sites occur within or adjacent to the project land.

While past records for the swift parrot indicate they have occasionally been observed in the region, the project area was assessed as a minor foraging habitat for the species. Swift parrots are migratory and primarily nectar feeders, preferring nectar from flowering *Eucalyptus spp.* In Tasmania, their breeding habitat is highly selective and determined by the occurrence of flowering in their two main food trees *Eucalyptus globulus* and *Eucalyptus ovata* (Webb *et al.* 2014) and the availability of tree cavities in large trees with small entrances, deep chambers and wide floors, which are rare (Webb et al. 2012).

Despite their non-threatened status, the importance of the project area for nesting, foraging, and roosting/loafing by waterbirds in general was recognised by the NBES (2021) report. The report noted that roadkill records were dominated by black swans, and this was attributed to decreased visibility as a result of winter fog when the swans forage close to the road. The report identified light pollution as a potential risk factor for birds and recommended any mitigation and management measures should be included in the Construction Environment Management Plan.

While not of significance as an Important Bird Area (Dutton et al 2009) or RAMSAR site, the wetlands in the vicinity of the Bridgewater Bridge are recognised as nationally important by the Commonwealth (Commonwealth, Important wetlands) supporting use by great crested grebes (**Figure 2**) as well as:

- *Cygnus atratus*, black swans,
- *Anas superciliosa,* Pacific black duck,
- *Biziura lobata,* musk duck ,
- *Anas rhynchotis,* Australasian shoveler,
- *Egretta novaehollandiae,* white-faced heron,
- *Anas castanea,* chestnut teal,
- *Vanellus miles,* masked lapwing,
- *Phalacrocorax carbo,* great cormorant,
- *Circus approximans,* marsh harrier,
- *Chroicocephalus novaehollandiae,* silver gull,
- *Fulica atra,* Eurasian coot,
- *Microcarbo melanoleucos,* little pied cormorant,
- *Ardea alba,* great egret,
- *Pelecanus conspicillatus,* Australian pelican,
- *Gallinula mortierii,* native hen, and

- *Poliocephalus poliocephalus,* hoary-headed grebe.

Threatened fish

- *Prototroctes maraena,* Australian grayling (Vulnerable under EPBCA).

The EPBCA findings indicate this species or species habitat is known to occur within the area. Marine Solutions (2021) reported that these species occur in the mid and lower reaches of the Derwent Estuary where spawning takes place in late spring/early summer. Larvae are transported to sea in stream/river currents and return as migrating juveniles approximately 4-6 months later (Bryant and Jackson 1999). Marine Solutions (2021) therefore concluded the project has the potential to impact on this species during larval and juvenile migration in spring and early summer.

2.1.1 Literature review – birds and light

Artificial lighting from urban areas has been found to mask the natural cycles of day and night for many bird species including waterbirds, consequently altering their behaviour and activities (Aulsebrook et al. 2021). While data about artificial light effects upon all the species listed above was not available, several studies have examined effects of artificial light upon birds in the same family, as well as one study which was specifically on black swans.

For diurnal bird species, artificial light can indirectly affect sleep by shifting the time of their circadian clock (Aulsebrook et al. 2021, Dominoni et al. 2013). Light is detected by photoreceptors in their retinas and brain, altering the expression of clock genes and suppressing melatonin, a hormone that co-ordinates the internal circadian clock with the external light–dark cycle (Dominoni 2015). Light at night can also directly suppress sleep as birds can see more at night and this presents different opportunities and threats, including increased opportunities to forage and mate, as well as a greater risk of predation (Aulsebrook et al. 2020a, Yorzinski et al. 2015, Russ et al. 2014, Berger & Phillips 1994).

It has been found that artificial light can affect the behaviour of birds in flight, inducing unnecessary ascent and descent, long periods of circling, and other types of unusual manoeuvring that would be more energetically expensive than typical straight-path migratory flights (Van Doren et al. 2017). Specific hazards resulting from altered flight behaviour may include susceptibility to predation, collisions with man-made structures, and changes to stopover behaviour and destination (Loss et al. 2015). Generally, disorientation of birds in flight as a result of artificial light has been worsened with conditions that are already poor for navigation and orientation, such as a low cloud ceiling, rain, fog, strong onshore winds and darker nights with reduced moonlight (Van Doren et al. 2017, Rodríguez et al., 2014).

An ecological impact of broad-scale attraction to artificial light while airborne is the impediment of selection of extensive forest habitat for some migrating waterbirds which may select areas that are well lit in preference to less light affected habitat (McClaren et al. 2018). Given that high-quality stopover habitat is critical to successful migration, and hindrances during migration can decrease fitness, artificial lights present a potentially heightened conservation concern for migratory bird populations.

Other ecological impacts of artificial light to birds include effects upon their prey species. Foraging activity of tactile-feeding shorebirds can be affected if they are nocturnal feeders, as the distribution of prey, competitors, and predators shifts in response to artificial light (Dias 2006, Rogers et al. 2006). Estuaries represent critical habitat for migratory shorebirds that maximize their energetic intake during narrow stopover intervals in order to successfully travel long distances between breeding and wintering habitats. While some bird species appear to be advantaged by having extra time for foraging and breeding activity under artificial light (Aulsebrook et al. 2021), many species appear to experience detrimental impacts such as an increased risk of predation and altered abundance and distribution in habitats that are increasingly affected by artificial light (Dias 2006, Rogers et al. 2006, McLaren et al. 2018). It has been shown that the density of some waterbird species in suitable foraging areas declined if they were exposed to artificial lighting, with nocturnal roost sites preferentially selected with low exposure to artificial lighting (Dias 2006, Rogers et al. 2006).

Australian Bitterns forage mainly at night on a wide range of small animals, including birds, mammals, fish, frogs, yabbies, snails, insects and spiders (Direct Birdlife 2021), and this nocturnal activity could be affected by artificial light sources.

The food of the great crested grebe consists mainly of small fish and water insects and they construct nests which are floating mounds of vegetation, normally anchored to a submerged branch or reed. Prey is normally caught during deep underwater dives, but some is taken on the surface. Other grebe species are solitary nocturnal foragers on fish that vertically migrate to the surface in darkness, using bioluminescence as a cue to locate prey (Clowater 2021). Great crested grebes may also forage nocturnally, reliant upon migration of prey species in the water column and bioluminescent cues, which may be affected by increased sources of artificial light in this location. The sensitivity of this species to artificial light sources may include changes in their prey distribution, as well as deter nesting in areas where the water surface (and their nests) may be illuminated by artificial light from above. Any possible physiological effects of artificial light upon this species has not been published, but will be discussed in 2.1.1, in relation to studies upon similar species.

Any physiological effects of artificial light upon the Tasmanian wedge Tailed eagle or the white bellied sea eagle have not been published, however studies upon other raptor species have found that their vision was reliant upon geographical compass cues (including celestial cues at night) for their long-distance orientation (Thorup et al. 2006). Foraging opportunities for kestrel and owl species have been found to increase in urban areas due to the attraction of migrating passerines to artificial light sources (Negro et al. 2000, Canario et al. 2012). From these studies of other raptor species it can be surmised that the flight orientation of the Tasmanian wedge-tailed eagle and white-bellied sea eagle may be affected by artificial light during nocturnal flights, and that they may be attracted to artificial light if their prey species have increased at the light source as a result of attraction to it.

The sensitivity of swift parrot to artificial light sources has not been documented, however it is more likely to be detrimentally affected by the removal of suitable habitat trees by deforestation and bushfire, and predation by introduced predators (Webb et al. 2012). Swift parrots may be sensitive to light during the migration phase of its life cycle as although parrots are typically diurnal, nocturnal migration may occur (Webb *et al.* 2014). It is possible that shorter (red and ultraviolet) wavelengths of light may influence mechanisms for long distance orientation migration and prey selection in parrot species (Aidalia 2012). Based on information on passerines, attraction to white light and disorientation of migration due to red light, is possible.

One approach to mitigate any negative effects of artificial light is to alter the colour of lighting (Aulsebrook et al. 2020b). Amber lights with lower emissions of short, blue wavelengths are broadly predicted to have less impact on wildlife than blue-rich, white lights (Longcore et al. 2018). It has been found that blue wavelengths of light (around 460 to 480 nm) have the most suppressive effect on the production of melatonin across many taxa (Dominoni 2015). While the use of amber lighting may be beneficial in some contexts (Longcore et al. 2018), a study of urban tolerant black swans found that filtering streetlights to reduce emission of blue light did not help reduce impacts of suppressed sleep (Aulsebrook et al. 2020b). There is no information on the visual sensitivity of black swans, however domestic ducks were found to be more sensitive to light in the yellow to red range (577 to 633 nm) (Barber et al., 2006). Other strategies would therefore need to be used to mitigate artificial light effects in swans and ducks, in addition to the management of light colour.

Some potential consequences of artificial light among diurnal waterbird species include:

- adaptive changes in avian behaviour due to altered sleep regimes (Aulsebrook et al. 2021);
- potential reduction of aquatic prey availability with increased foraging opportunities (Santos et al. 2010);
- changes in vertical migration of aquatic prey at night for nocturnal foragers (Dias 2006, Rogers et al. 2006);
- increase in intra-specific competition (with consequential expenditure of energy) for mates due to more time invested in breeding activities at night;
- more energy invested in predator avoidance strategies than other activities required to survive (Santos et al. 2010);
- increase in some avian predatory species that may take advantage of prey attraction to artificial light, with subsequent impacts upon prey populations (Negro et al. 2000, Canario et al. 2012);
- the risk of some species such as the Silver Gull becoming an “increaser” species that can predate upon the eggs and chicks of other avian species due to their population size increasing because of the extra foraging opportunities afforded by nocturnal artificial light (Wooller & Dunlop 1979).

It is recommended that in addition to the use of amber lights, lighting designers, operations managers and land managers should consider switching off lights when they are not in use, particularly around reserves, wetlands, and other wildlife habitat to mitigate the effects of artificial lighting upon diurnal bird species (Aulesbrook et al. 2020b).

2.1.2 Literature review – freshwater fish and light

In the last 10 years studies on the impact of ALAN on freshwater fish are emerging which indicate ALAN is influencing reproductive and migratory behaviours. Exposure to artificial light at night can impact on reproduction in freshwater fish which use darkness as a cue for egg hatching and synchronising behaviours which cause fish to shoal after hatching and reduce the risk of predation (Brüning et al., 2010). For species such as Salmonids which migrate from their spawning areas to the ocean at night, exposure to ALAN can cause delays and changes in migratory behaviour, disorientation, temporary blindness and potentially increase the risk of predation (Nightingale et al., 2006).

ALAN can also impact different age classes in different ways. For example, juvenile fish might require vision for vertical migration and predator avoidance, whereas adult fish may rely on their eyesight for navigation, foraging, mate selection, spatial vision and communication (Nguyen and Winger, 2019). Exposure to ALAN along routes used by migrating fish may interrupt movement, increase predation on migrating fish and reduce the number of successful migrants (Nightingale, 2006).

The behaviour of light in water is complex, mediated by plankton, total suspended solids, and coloured dissolved organic matter in the water column (Hughes et al, 2015). Light is both scattered and absorbed by particulate matter and water molecules removing short wavelength light (dissolved organic matter) and long wavelength red light (attenuation by water molecules) and together this controls the amount of light that penetrates to the water column (Wetzel, 2001).

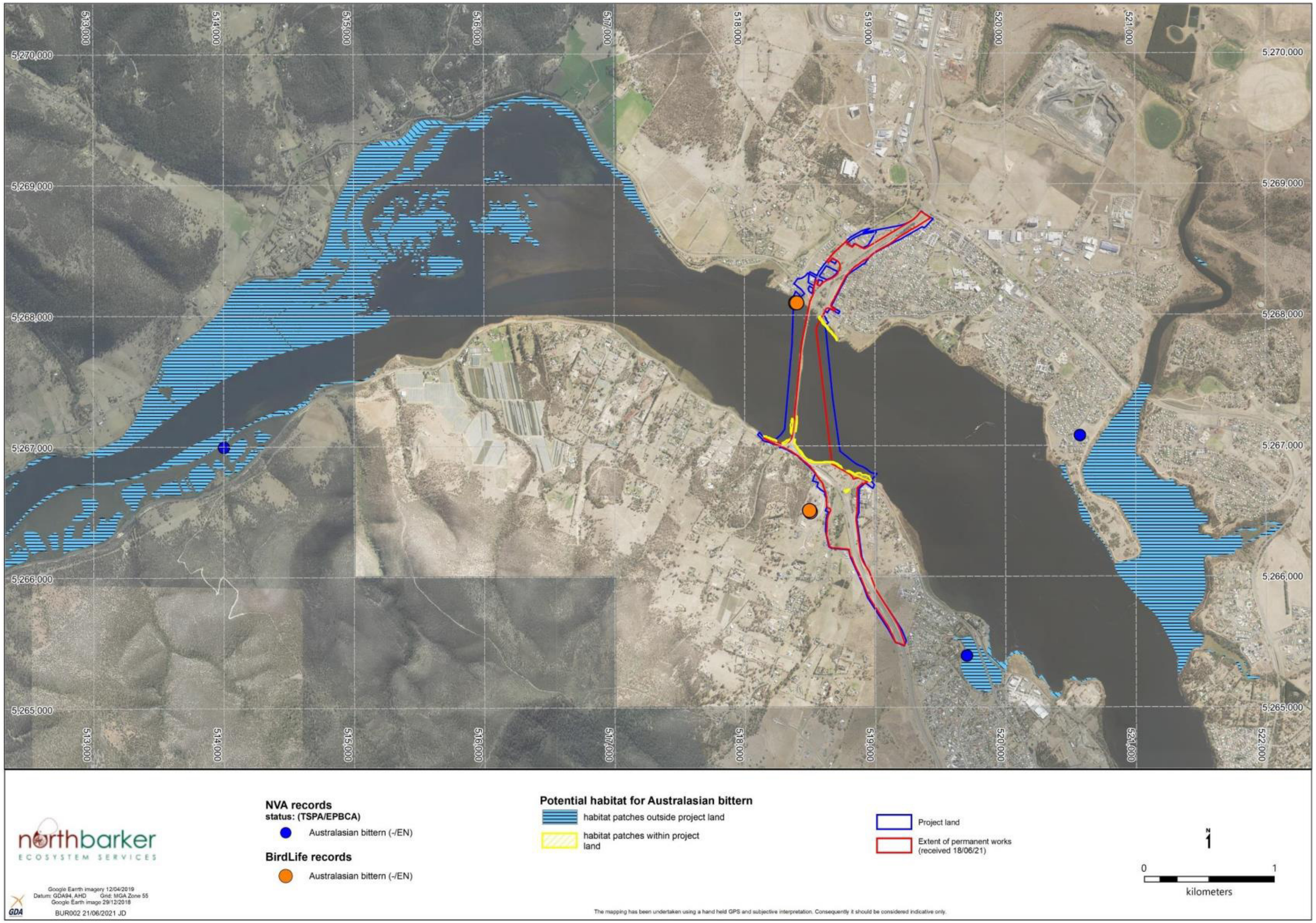

Figure 1: Distribution of potential Australian Bittern habitat within 5 km of the project area (blue shading, Source NBES 2021b)

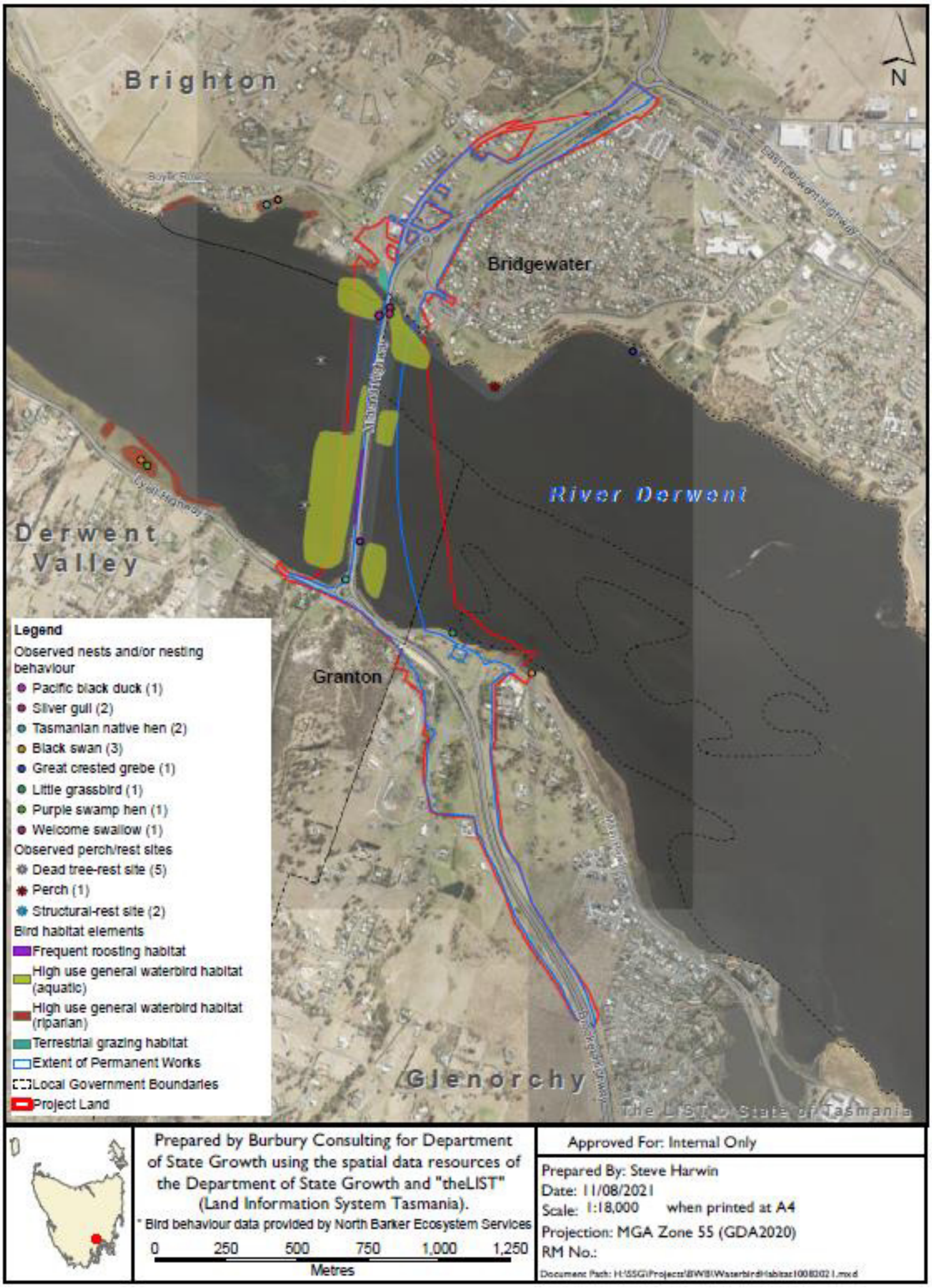

Figure 2: Key locations for waterbird use.

2.2 Humans

Evidence to show exposure to light at night impacts humans is growing. Specifically street lights, commercial lights and residential floodlighting are recognised as obtrusive when they intrude into residential living areas. The literature linking night-time exposure to artificial light to medical conditions (including insomnia, cancers, heart disease, obesity, depression etc.) is growing (Cho et al, 2015; Davies et al 2018). ALAN sources can include both external obtrusive light from street lights, commercial lighting and neighbours and internal light from electrical devices including computers, phones, televisions etc. Because the impact of exposure to ALAN on humans (and wildlife) is difficult to measure, the impacts are still not well defined, and trigger limits for impact have not been agreed upon. A precautionary approach to exposure to ALAN is therefore recommended.

The MPIS Assessment Criteria has recognised the potential for light impacting on local residents in *S2.2.7 a) Identification of potential sources of light pollution and **sensitive human** and wildlife **receptors** for both the construction and operational phases of the project.* In the absence of any published literature, or any regulatory guidance on how this should be done the risk assessment has been carried out based on the number and location of local residents who would potentially be exposed to direct lighting from the new crossing during the Visual Impact Assessment studies conducted by Inspiring Places (2021b). The risk assessment outcomes from the Visual Impact Assessment study have been used as a basis for the light impact assessment here, together with consequence rankings specific to humans that have been developed by the authors for this project (see **Section 4**) recognising that human perception, preferences and responses are personal and difficult to quantify.

2.3 Dark Sky Conservation

Dark Sky Conservation is a relatively new concept that is gaining recognition globally. Poorly installed and managed light can impact on human health, disrupt wildlife, increase greenhouse gases, cost money, prevent astronomy observing, impact on cultural and heritage storytelling relationships with the sky and shield our everyday view and enjoyment of the stars.

The work started by volunteer organisations to raise the awareness of light pollution (International Dark Sky Association (IDA), Commission for Dark Skies, Stars4All, Loss of the Night etc) is now being recognised in legislation globally (CMS 2021).

Currently there are no certified Dark Sky Places in Tasmania however Dark Sky Tasmania (https://www.darkskytasmania.org/) is actively engaged in preserving and protecting Tasmania's dark sky environment and is working with local partners to identify good quality candidate locations for dark sky certification under the IDA Dark Sky Places program. The economic benefits of dark sky places to local communities are recognised in the growth of Astrotourism both nationally and internationally.

The City of Hobart not only acknowledges light pollution as an issue but is committed to conserving the quality of its dark skies; in the *City of Hobart, Capital City Strategic Plan 2019-29*, it states that "the city will support and run initiatives to reduce light pollution and enhance the quality of Hobart's night sky" (Pillar 6, Strategy 6.1.7).

Finally, University of Tasmania (UTAS) has also adopted a 'wildlife sensitive lighting' strategy at their Burnie Campus to help protect the local penguin populations. This strategy is based on using light appropriate for penguins (orange-coloured PC Amber fixtures) and reducing light mounting heights around the colony areas.

3 DESCRIBE THE PROJECT RELATED LIGHTING

This section addresses the following component of the MPIS Assessment Criteria:

S2.2.7 a) Identification of potential sources of light pollution and sensitive human and wildlife receptors for both the construction and operational phases of the project.

3.1 Scoping Study Guidelines on light

The report *New Bridgewater Bridge Urban Design Guidelines* (2021*)* was prepared by Inspiring Place to provide input to the urban design process for ECI (Early Contractor Involvement) tenderers. Whilst the report is not a formal requirement. for assessment, aspects of the urban design guidelines pertinent to lighting design are included here.

Section 4.5.4 of the Inspiring Place Scoping Study described the recommended lighting design philosophy recommended for the project. Acknowledging that the lighting of the new crossing must facilitate safe movement for vehicles, cyclists and pedestrians the document also recognises that road safety depends on the wise use of lighting rather than simply more brightness of light.

The basis for the design philosophy recognises the growing awareness of light spill and its impacts on human health and wildlife and consequently it references the need to comply with the National Light Pollution Guidelines for Wildlife (Commonwealth of Australia 2020) and the need to protect this dark area on the Lyell Highway as an Environmental Zone A2 (low district brightness area, i.e. sparsely inhabited rural and semi-rural area), designation under AS/NZS 4282 Control of Obtrusive outdoor Lighting (AS/NZS 4282) 2019).

The urban designers describe the project as an opportunity to demonstrate best practice in dark sky protection and using Best Practice Lighting Principles they recommend that:

- *all lighting should have a clear purpose – decorative lighting, or architectural floodlighting of the new bridge should be avoided with the focus instead on road safety and/or way-finding for those using the shared path;*
- *light should be directed only where it is needed – shielding should be used to direct light downwards to avoid light spill (i.e. zero upward waste light) and avoiding discomforting glare;*
- *lighting should be no brighter than necessary – use the lowest light level allowable for the road conditions;*
- *control – consider use of motion sensors for the lighting of the shared path;*
- *colour – use warm coloured light (i.e. colour temperature ≤2700K); and*
- *integration – where possible lighting should be integrated with structural elements or other components of the bridge to reduce visual clutter.*

The design suggests alternatives to lighting, including the use of luminous markers for signs, kerbs and the use of reflective paints or materials and addresses visual clutter by recommending any light poles, if they are used, be distributed with a logical relationship with the structural elements such as piers, major joints, railing posts, etc. and all supporting infrastructure should be integrated into the bridge design.

3.2 Proposed construction and development lighting

The underside of the bridge deck will be 16.2 m above the water at its highest point, with up to 5 m thick road deck on top and gantries for signs and lighting on top of this. Consequently, streetlights on 6 – 8 m tall poles will potentially be elevated up to 27 – 29 m in the air above the River Derwent. The crossing will support 4 lanes of traffic with a minimum speed limit of 80km/hr as well as a shared cyclist and pedestrian access. The total construction period is expected to take up to 36 months.

The new crossing will operate 24/7 year-round. The design life of the new crossing is expected to be 100 years.

Appendix 29 of *State Growth, New Bridgewater Bridge Project*, *Exhibit A Initial Project Scope, Requirements for Lighting Roadways, Pedestrian Facilities and Bicycle Facilities, 11 June 2021, Revision 4* defines the requirements for the lighting on roadways, bridges, pedestrian facilities and bicycle facilities included in the Project Works. Specifically, it requires all lighting comply with AS/NZS 1158, with two exceptions:

29.2 Performance Standards (a)

(viii) lamps must be generally 4000K LED, to ensure colour rendering and to prevent confusion with other lamps used for traffic control, and

(x) lamps for carparks must be LED.

Project lighting has been addressed in the New Bridgewater Bridge Major Project Impact Statement. (Sections 3.3.2.12 Lighting and 3.3.3.10.2 Temporary Lighting) which describes project lighting as “generally all in accordance with AS 1158.1” and that operational lighting is to be provided from light poles located on the crossing and under structure lighting as required.

The Proposal Description concludes *that the design of the lighting will include consideration of the potential for light spill to the interfacing community and any sensitive receptors with the detailed design to include mitigation measures such as shielding of lights, and/or special lenses and luminaires as required to minimise glare and light spill.*

Temporary construction lighting could be required intermittently and could include:

- Mobile light towers during night works;
- Construction vehicles and plant with flashing beacons;
- Security lighting at site compounds;
- Variable message signs and temporary traffic lights to assist new traffic set ups and traffic management;
- Emergency lighting; and
- Site, risk and task specific lighting such as crossing points on traffic routes. Table 1 of Code of Practice (CoP), Tasmania, “Managing the work environment and facilities” will be used

for guidance on the recommended illumination levels for various types of tasks, activities or interiors.

3.3 Viewshed/line of sight analysis

A GIS viewshed analysis was carried out by Inspiring Place (2021b). The study identified all surrounding terrestrial and aquatic areas that could be viewed from the Bridgewater Bridge, its northern and southern approaches as well as locations of the supporting piers. The analysis assumed that if a viewer can see a location from any given point, then that point can be seen by a viewer looking back at it from the surrounding landscape. This approach was then used to risk assess the visual impact of the New Bridgewater Bridge on surrounding areas.

The assessment was based on the magnitude of visibility (viewing distance, duration and expectations of viewer) and the sensitivity of the landscape to change in order to determine a significance of visual impact that ranged from high, medium to low/minor. Where inherent risk was high, mitigation actions including design responses and enhanced mitigation measures are recommended to reduce the residual risk. An inherent risk of a moderate impact will require basic mitigation measures to reduce the residual risk while the inherent risk from a low/minor impact will only require mitigation actions "where the magnitude of impact or sensitivity is greater than for the larger viewing opportunity". The mitigation initiatives recommended include consideration of the urban design elements, particularly those relating to the form of the New Bridgewater Bridge, landscaping, earthworks and lighting (Inspiring Places 2021a).

The results of the visual risk assessment shown in **Table 1** indicate three areas will receive the highest level of visual impact: Bridgewater central, Bridgewater west and Granton (**Figure 3**). All are located within 1 km of the new bridge. Five locations will be exposed to a moderate risk of visual impact while 4 locations will be exposed to a low/minor impact. Visibility of the crossing from facilities, roads and walking trails was ranked as low/minor to moderate and overall, the study concluded the Bridgewater Bridge will have a moderate impact to residents of the suburbs that make up the study area (**Table 1**).

Table 1: Summary of the New Bridgewater Bridge visibility risk assessment (Source: Inspiring Places, 2021b).

Location	Total dwellings	Dwellings visible from bridge structure		Visual impact
		Without vegetation	With vegetation	
Austins Ferry	1,473	503	230	Moderate
Bridgewater Central	680	479	456	High
Bridgewater East	742	354	362	Moderate
Bridgewater West	81	53	45	High
Brighton	1,688	53	51	Minor
Claremont	2,784	22	18	Minor
Dromedary	45	5	4	Minor
Gagebrook/Herdsmans Cove	1,438	701	625	Moderate
Granton	150	93	40	High
Mt Faulkner	62	15	5	Moderate
Old Beach	870	161	104	Minor
River Derwent	70	43	40	Moderate

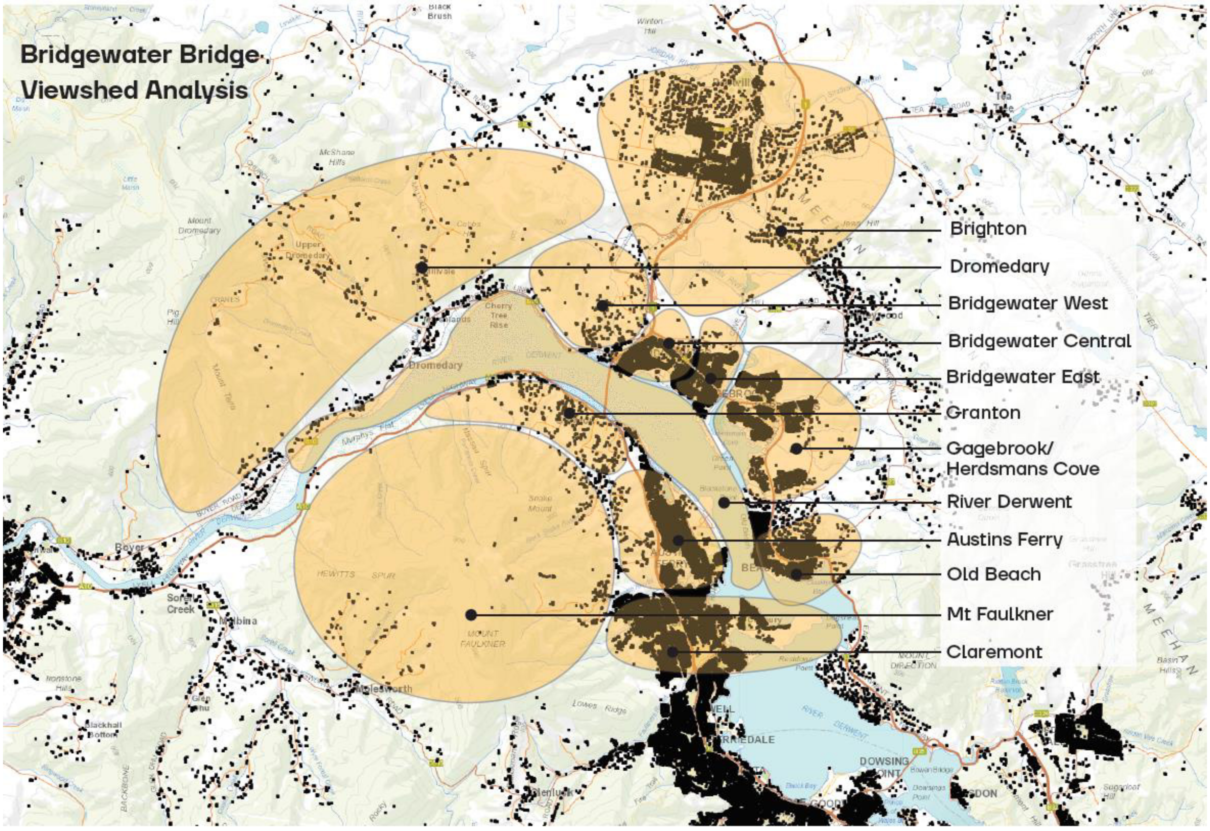

Figure 3: Line of sight viewshed analysis of the New Bridgewater Bridge, (Source: Inspiring Place, 2021).

3.4 Benchmark ALAN monitoring

A benchmark light monitoring survey was conducted in June 2021 with the aim to collect data from the project footprint as follows:

- Artificial Light at Night (ALAN) data from wildlife habitat and residential areas using Sky42 cameras to capture existing light and sky glow on a landscape scale.
- Capture data on zenith sky quality along regional residential streets to map current sky quality at a local scale.
- Collect luminance data on residential streets and from property boundaries to establish benchmark luminance values from residential areas potentially impacted by obtrusive lighting (to meet AS/NZS 4282 requirements).

Logistical and weather (cloud and rain) limitations impacted on the planned program reducing the amount and quality of data that could be collected. The survey results are summarised in the following section.

3.4.1 Regional Light

Light may appear as either a direct light source from an unshielded lamp with direct line of sight to the observer or through sky glow. Where direct light falls upon a surface, be it land or water, this area of light is referred to as light spill.

Visible Infrared Imaging Radiometer Suite (VIIRS) satellite sensor data from 2020 (available through www.lightpollutionmap.info) was used to identify existing light sources within the project area (**Figures 4 and 5**). Regionally significant light sources potentially visible from the project site as sky glow include; Hobart, New Norfolk, Bridgewater and Pontville.

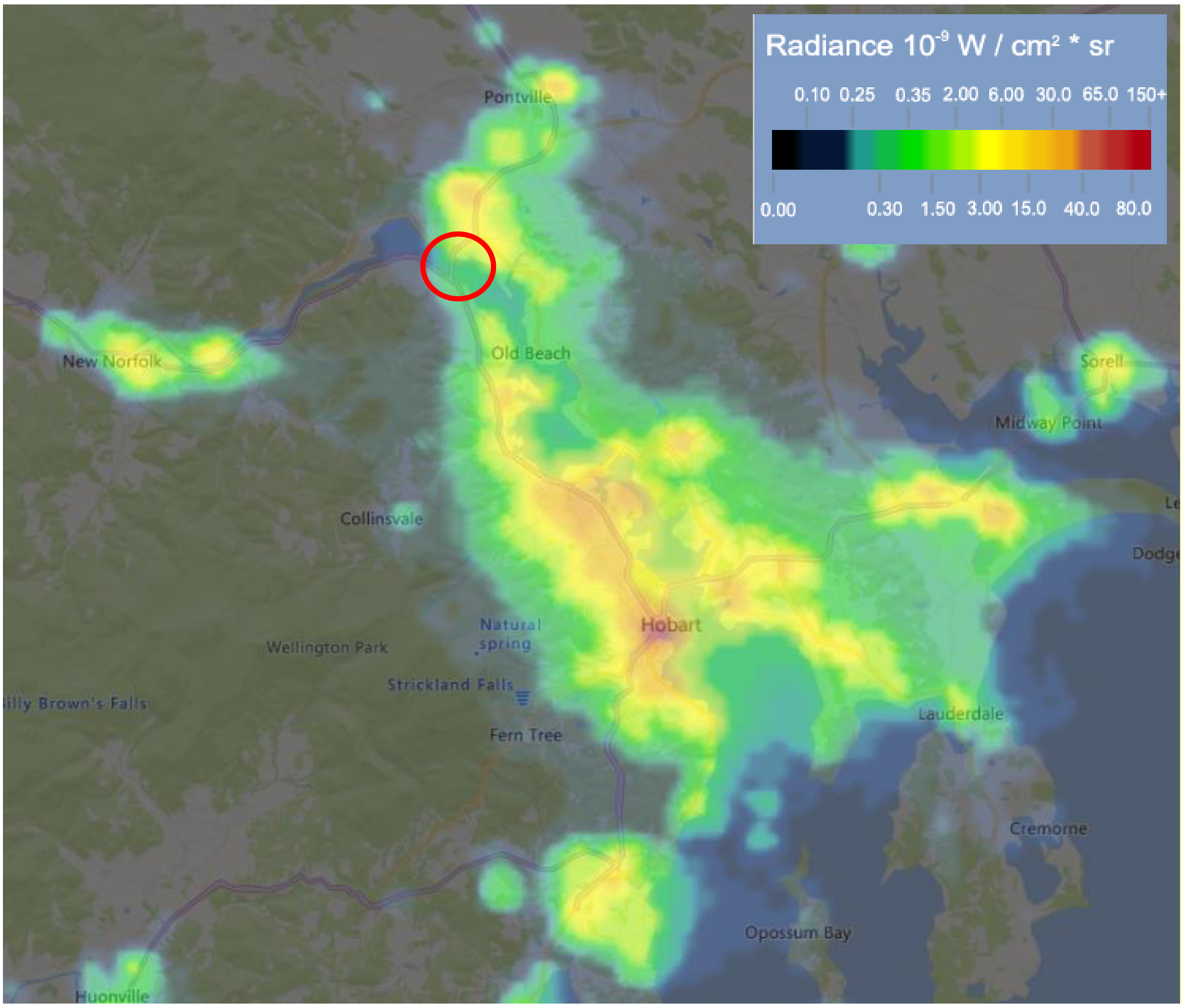

Figure 4: VIIRS 2020 satellite image of light in the Hobart area. Red circle denotes Bridgewater Bridge (Source lightpollutionmap, 2021)

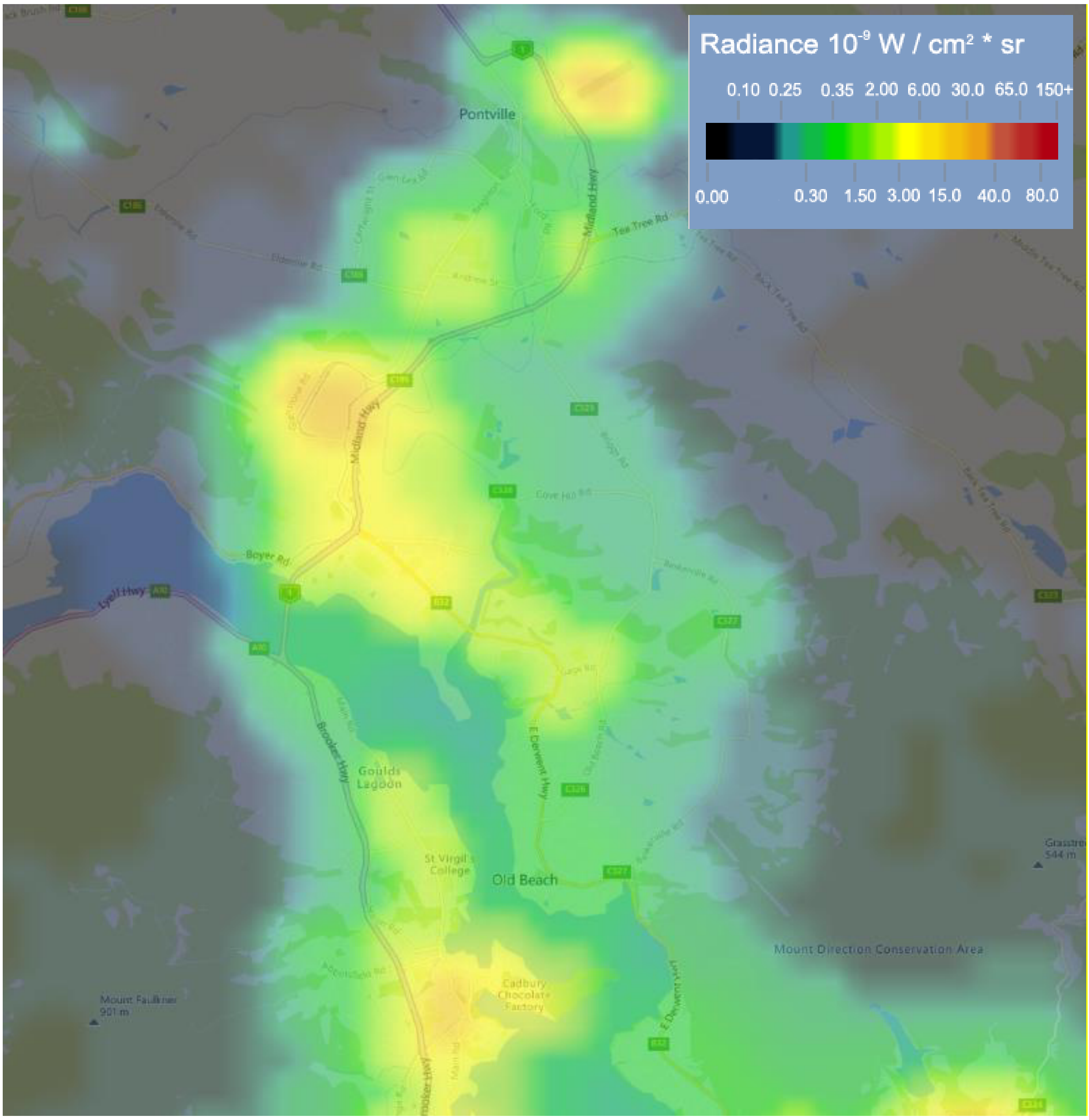

Figure 5: Local scale image of VIIRS satellite light pollution data

3.4.2 Local Scale

The ALAN survey of the existing bridge and causeway (**Appendix A**) identified a total of nine lights, comprising two cool green (likely mercury vapour) and two cool white (likely metal halide) pole mounted lights. Four warm orange lights (likely high-pressure sodium) and one cool white are mounted overhead on the underside of the existing bridge support structure. A red navigation light is mounted on the river side of the existing bridge deck (**Figure 6**). The relatively dark area of the causeway and existing bridge as the Lyell Highway crosses the River Derwent is demonstrated in **Figure 7.** The contribution of local and regional lighting to landscape scale sky glow is demonstrated in **Figure 8** where the lights from Hobart and intervening suburbs is very visible as it reflects from clouds.

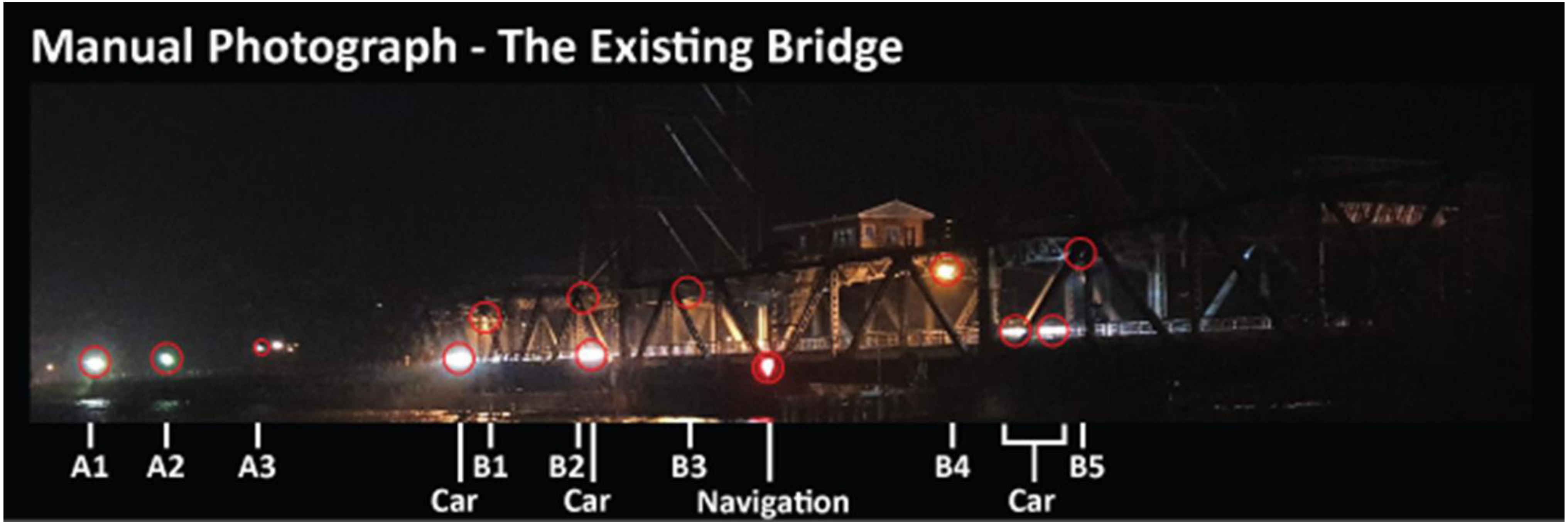

Figure 6: Manual camera image captured from the bank near the existing bridge on 9th June 2021. Note lights have been circled in red and labelled, these are described further in **Table 3.**

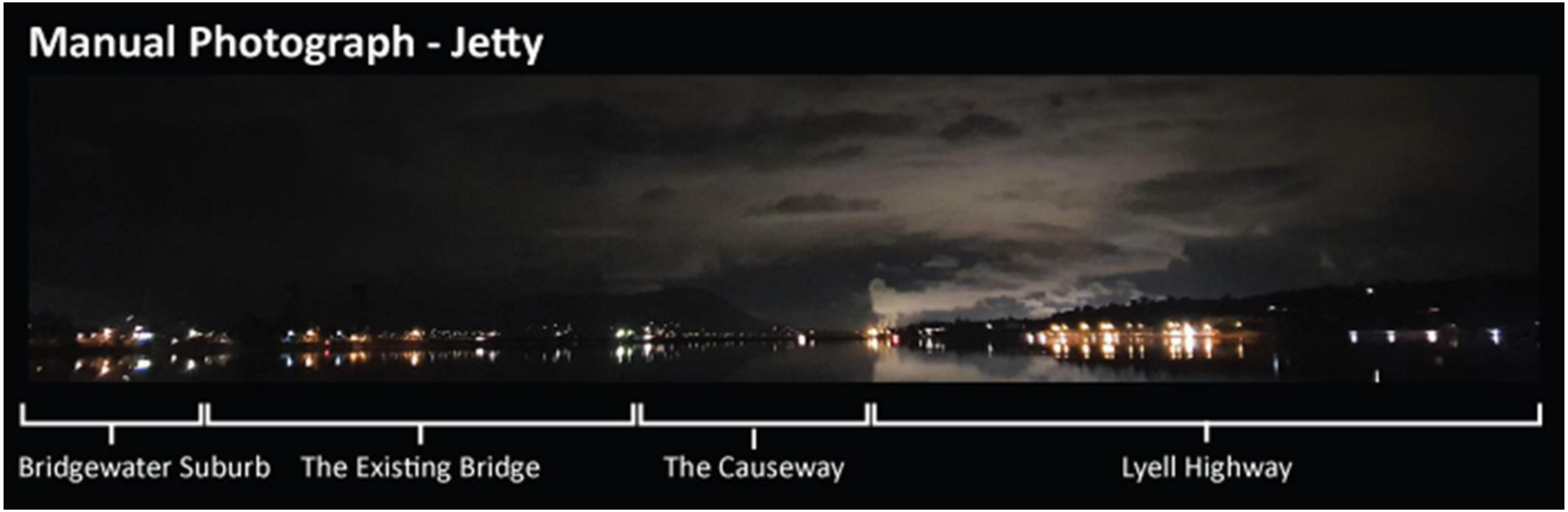

Figure 7: Manual camera image captured from the Jetty location on 8th June 2021. Note that the image includes car headlights on the causeway and existing bridge.

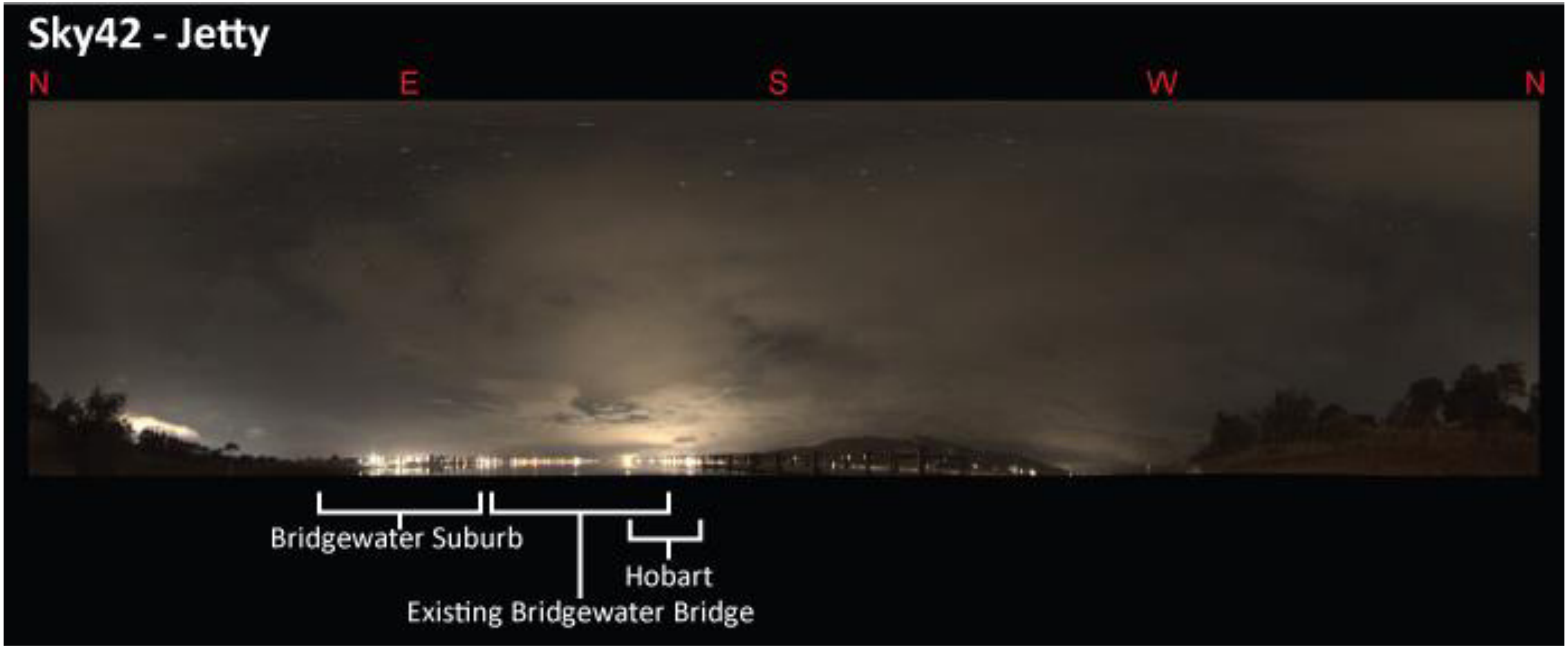

Figure 8: Sky42 camera image captured from the Jetty monitoring location on 8th June 2021.

Poor weather and cloud cover during the survey prevented the collection of reliable Sky 42 all sky images or zenith SQM measurements, so no quantitative data is available to assess the current dark sky quality.

Benchmark obtrusive lighting measurements were taken on the residential boundary lines of residential areas adjacent to the project site in Bridgewater. The values recorded ranged from 0 - 25.94 Lux, with some sites located near residences exceeding the illumination criteria for a curfew area, as described in the AS/NZS 4282:2019 standard (**Appendix A**).

4 IMPACT ASSESSMENT

This section addresses the following component of the MPIS Assessment Criteria:

S2.2.7 b) Assessment of construction and operational light pollution should include:

i) Consideration of existing levels of light.

ii) Consideration of different types of light pollution, and potential impact on human and wildlife receptors, with reference to any relevant guidelines or standards.

The potential sensitive receptors (human and wildlife) in the vicinity of the project have been identified using the line-of-sight analysis of both the proposed construction footprint area and of the existing crossing. The results of the benchmark artificial light at night (ALAN) and the Obtrusive Lighting benchmark monitoring program are used with the line-of-sight mapping to conduct an impact assessment from construction and operational lighting. Sensitive receptors will include residential areas and local sensitive wildlife receptors. The impact assessment on the dark sky quality will be based on the results of the benchmark ALAN survey conducted in June 2021 and Environmental Zones described in AS/NZS 4282.

Guidelines and standards used include the Commonwealth guidelines (wildlife), AS4282 Control of Obtrusive Lighting (humans and environment), and the Unihedron sky quality guide (dark sky quality).

4.1 Methods

The potential impacts on wildlife associated with the project during both construction and operational phase are assessed utilising an impact assessment matrix. The impact assessment process is modified from the Great Barrier Reef Marine Park Authority Environmental Assessment and Management Risk Management Framework (GBRMPA 2009). The impact assessment matrix is described in **Table 2** with descriptions of the likelihood and consequence definitions provided in **Tables 3 and 4**, respectively. In this section we assess the impacts before (inherent) and after (residual) mitigation measures outlined in **Section 3** and **Section 5** are applied.

Table 2: Impact assessment matrix.

Likelihood (See **Table 3** for definition)		**Consequence** (See **Table 4** for definitions)				
		Insignificant 1	*Minor* 2	*Moderate* 3	*Major* 4	*Catastrophic* 5
Almost certain	5	**Medium**	**High**	**High**	**Extreme**	**Extreme**
Likely	4	**Medium**	**Medium**	**High**	**High**	**Extreme**
Possible	3	**Low**	**Medium**	**Medium**	**High**	**High**
Unlikely	2	**Low**	**Low**	**Medium**	**Medium**	**High**
Rare	1	**Low**	**Low**	**Low**	**Medium**	**Medium**

Table 3: Definition of likelihood.

Description	Frequency
Almost certain	• Expected to occur more or less continuously throughout a year (e.g. more than 250 days per year) • All lights are directly visible to a human/bird viewer within 5 km
Likely	• Expected to occur once or many times in a year (e.g. 1 to 250 days per year) • All lights are directly visible to the human/bird viewer within 1 km
Possible	• Expected to occur once or more in the period of 1 to 10 years • Some lights are directly visible to a human/bird viewer from within 1 km
Unlikely	• Expected to occur more than once in the period of 10 or more years • Some lights are directly visible to a human/bird viewer from within 5 km
Rare	• Expected to occur once or less over project life • No lights are directly visible to a human/bird viewer within 5 km

Table 4: Definition of consequence. (SQM = Unihedron Sky Quality Meter), the definitions are used as a guide for context and will vary depending on location and scale of the impact factor

Description	Definition
Insignificant	Birds/fish: Little/no impact on individuals. Humans: Little/no impact on humans, no construction lighting Lighting: No commercial or street lighting Dark sky quality: Not impacted and representative of an excellent natural dark sky, SQM range 21 – 22 Vmag/arcsec^2, AS/NZS 4282 Zone A0, intrinsically dark – example UNESCO Starlight Reserve, IDA Dark Sky Park, Major optical observatory, no road lighting unless specifically required by the road controlling authority
Minor	Birds/fish: Impacts are present, but not to the extent that the overall condition of the populations are impaired in the long term. Low levels of mortality of individuals. Humans: Residents not affected/disturbed by visibility of lights and sky glow. No light trespass inside the boundary of the property is occurring, little/no lights directly visible inside the property boundary or house. Short term duration of impact (e.g. Construction, 1 – 3 years) Lighting: Local commercial or street lighting very low density (i.e. one every 1 km+), warm colour temperature (<2000K), low lumen output (XX) and well shielded (0 ULR) with no sky glow. Directly visible lights appear as a small pinpoint of light in the field or view.

Description	Definition
	Dark sky quality: Minor impact on dark sky quality, representative of a typical rural night sky, SQM range 20 – 21 Vmag/arcsec^2 AS/NZS 4282 Zone A1 Dark **–** example Relatively uninhabited rural area, no road lighting unless specifically required by the controlling authority, and AS/NZS 4282 Zone A2 Low district darkness, sparsely inhabited rural and semirural suburban areas in towns and cities
Moderate	Birds/fish: Significantly affected, Recovery of populations taking several decades. Humans: Residents are mildly disturbed by the visibility of lights and sky glow; some lights are directly visible inside the property boundary but not enough to cause discomfort to residents. Moderate term duration of impact, (e.g., construction, 3 – 5 years) Lighting: Local Street or commercial lighting is typical of a suburban area with a minimum number of widely spaced streetlights (i.e. every 500m – 1 km) warm colour temperature (<2700 K), and low lumen output. Commercial lighting restricted to local shops, illuminated signage and little or no parking lot lighting and has lower population density relative to urban areas. Light curfews may be present with lights dimmed or switch off late at some time in the night (ie streetlights, sporting fields, commercial facilities) Dark sky quality: Moderate impact on dark sky quality, representative of a typical suburban night sky, SQM range 19 – 20 Vmag/arcsec^2 AS/NZS 4282 Zone A3 Medium district darkness, Suburban areas in towns and cities
Major	Birds/fish: Significant impact on populations with high level of mortality. Recovery of populations taking several decades. Humans: Residents are notably disturbed by visible lights and are likely to file complaints with the local council, obtrusive light trespass and glare are present inside the boundary of the private residence and sleep quality may be affected without window coverings. Long term duration of impact, (e.g. construction, 5 – 10 years) Lighting: Local Street and commercial lighting is typical of a densely populated urban area, streetlights are closely spaced and lighting is brighter and cooler (> 3000 K) than in suburban areas. Commercial areas more brightly illuminated, car yards and parking lots brightly lit all, often all night, large and bright LED signage more common. Dark sky quality: High impact on dark sky quality, representative of a typical urban night sky, SQM range 18 – 19 Vmag/arcsec^2 AS/NZS 4282 Zone A3 Medium district darkness, Suburban areas in towns and cities
Catastrophic	Birds/fish: Populations are irretrievably compromised. Mass mortality individuals, and local extinction of species. Recovery over several centuries for populations.

Description	Definition
	Humans: Residents are greatly disturbed by visible lights and sky glow, the enjoyment of their private space within the property boundary (including inside and outside the home) is severely impacted by obtrusive light trespass and glare, lights directly visible inside any room in the house, sleep quality compromised without substantial window coverings. High likelihood that residents will regularly complain to council or regulators about light. Lighting: Local Street and commercial lighting is typical of a very densely populated inner-city area, streetlights are very closely spaced and lighting is brighter and cooler (e.g. > 5000 K) than in suburban areas. Commercial districts are brightly illuminated all night, very large and brightly lit LED signage the norm. Very long-term duration of impact, (e.g., construction, 10+ years) Dark sky quality: Very high impact on dark sky quality, representative of a typical poor urban night sky, SQM range 17 – 18 Vmag/arcsec^2 AS/NZS 4282 Zone A4 High district darkness, Town and city centres and other commercial areas, residential areas abutting commercial area

4.2 Limitations and Assumptions

This assessment was carried out in the absence of a detailed lighting design for construction or operational lighting, (e.g. the amount, type, colour, intensity, positioning or management of the lighting). Consequently, a number of assumptions have been made:

1. This assessment did not take into account other existing non-project related sources of stressors within the same project area that may have the potential to negatively influence humans and wildlife (i.e. light from the residential and commercial sources in Bridgewater and Granton). This is important to note because the impact of some stressors on wildlife, humans and dark sky value will be cumulative.
2. Inherent risk is assessed without mitigation measures to reduce the impact of light.
3. Residual risk considers mitigation and management activities.

The recommendations on light mitigation and management provided in this Artificial Light Management Plan (ALMP) do not infringe on human safety obligations. The ALMP recognises that Australian Standards, for example AS/NZS 1158.3.1:2018 *Lighting for roads and public spaces pedestrian area (Category P) lighting,* provide agreed limits for various lighting scenarios, generally for the purposes of human safety. This ALMP therefore provides advice and recommendations on how to manage and mitigate the project lighting to protect the wildlife, human receptors and dark sky values, while recognising the needs of human safety.

4.3 Birds

As described in Section 2.1, there are five listed bird species which could potentially be exposed to the project works; Australian bittern, great crested grebe, Tasmanian wedge tailed eagle, white-bellied sea eagle and swift parrot. As these species are likely to respond to ALAN in a similar way as the more common waterbirds, they have all been risk assessed as a group and the management and mitigation actions recommended will provide the same level of protection to all of the birds.

4.3.1 Construction

Based on the research outlined in Section 2.1, bird species from several orders have been shown to experience detrimental impacts from artificial lighting, even when they are urban-tolerant. These detrimental impacts can be physiological (in terms of wavelength sensitivity for each species and their circadian clock), behavioural (in terms of habitat usage, nocturnal flight patterns and evasion of, or attraction to, artificial light sources) as well as ecological (in terms of impacts upon prey species and foraging activity). While night-time construction is not expected to be frequent within a 3-year construction time-frame, there will be lighting associated with illuminating roadwork areas and project infrastructure. Waterbird habitat adjacent to the project works associated with the new crossing is likely to be exposed intermittently to direct visibility of the temporary construction lighting towers and infrastructure light from the crossing. As this is for a short time (1-3 years), the consequences are assessed as Minor and the likelihood as Possible, resulting in a Medium inherent risk ranking. While mitigation measures to manage construction lighting outlined in Section 5.1 will not alter the duration of the impact, the mitigation measures will decrease the amount of light spill to an Insignificant level with an Unlikely likelihood, resulting in a Low residual risk ranking.

The likelihood of disturbance is further reduced when additional control measures are applied (outlined in **Section 5**). Outcomes of the risk assessment is provided in **Table 5**.

Table 5: Summary of light impact assessment for waterbirds during construction

Impact	Consequence	Likelihood	Ranking
Inherent	Minor (2)	Possible (3)	Medium (5)
Residual	Insignificant (1)	Unlikely (2)	Low (3)

4.3.2 Operations

The streetlights associated with the new crossing will introduce substantially more sources of light into the local waterbird habitat. The waterbirds roosting near the project location are likely to be impacted by the elevation of the bridge lighting ~ 25m above the current level of the existing bridge, together with an expected increase in the number, pole height, colour and brightness (4000K LED) of the streetlights.

The current lighting on the existing bridge is modest and limited to 9 widely spaced lights, with low lumen output (intensity), and are low on the visual horizon relative to the new crossing (Section 3.4). The new crossing lighting will introduce substantially more sources of light into the local environment.

Recognising that different waterbirds have different sensitivity to visible light (short vs long wavelength) we believe the cumulative impact of short wavelength blue and white light has a greater impact on wildlife in general as well as human receptors and dark sky values. Consequently, we recommend the use of long wavelength lighting to provide the best protection to the most sensitive receptors.

The inherent impact of an increased number of bright white (4000K) LED lights permanently elevated into the field of view of waterbird habitat with no specific shielding is ranked as having a Minor consequence and a Possible likelihood, resulting in a Medium inherent impact.

The residual risk could be substantially reduced to Low, for waterbirds in the area if the light mitigation and management actions outlined in **Section 5.1** are implemented with a specific focus on;

- Reduce the CCT of the project street lights to 2000K CCT (or at least 2700K CCT as recommended in Inspiring Places 2021a) to replicate the existing low intensity high pressure sodium and metal halide lights, install shielding on all lights.
- Consider additional shielding on lights in the approaches to the bridge to shield the direct visibility of the lights to waterbird habitat.
- Aim the lights carefully to prevent lights shining into adjacent habitat areas.
- Dim the intensity of the light.

By doing the above the consequence would be reduced to Insignificant and the likelihood of waterbirds being impacted will be reduced to Rare, with Low residual impact.

Outcomes of the risk assessment is provided in **Table 6.**

Table 6: Summary of light impact assessment for waterbirds during operations

Impact	Consequence	Likelihood	Ranking
Inherent	Minor (2)	Possible (3)	Medium (5)
Residual	Insignificant (1)	Rare (1)	Low (2)

4.4 Fish

4.4.1 Construction

Based on the research outlined in Section 2.1, freshwater fish have been shown to experience detrimental impacts from artificial lighting during hatching and migration. While night-time construction is not expected to be frequent within a 3-year construction time-frame, there will be lighting associated with illuminating roadwork areas and project infrastructure. The age classes potentially exposed to construction lighting include larval graylings that are carried to the sea by the Derwent River and the returning juveniles migrating back up the river 4-6 months later. These age classes may be exposed intermittently to direct visibility of the temporary construction lighting towers and infrastructure light from the crossing. This assessment recognises but has not accounted for the existing cumulative impacts of light from other bridge crossings, ports, roads, and urban areas in the lower reaches of the River Derwent that the grayling larvae and juveniles will be exposed to as they move between the Bridgewater Bridge area and the ocean.

As construction is of short duration (1-3 years) the potential exposure of individuals to light is Possible, however it will be intermittent and of limited duration. The consequences are assessed as Minor, resulting in a Medium inherent risk ranking. While mitigation measures to manage construction lighting outlined in **Section 5.1** will not alter the duration of the impact, the mitigation measures will decrease the amount of light spill to an Insignificant consequence level with an Unlikely likelihood, resulting in a Low residual risk ranking.

Outcomes of the risk assessment is provided in **Table 7**.

Table 7: Summary of light impact assessment for juvenile graylings during construction

Impact	Consequence	Likelihood	Ranking
Inherent	Minor (2)	Possible (3)	Medium (5)
Residual	Insignificant (1)	Unlikely (2)	Low (3)

4.4.2 Operations

The age classes potentially exposed to operation lighting include larval graylings that are carried to the sea by the Derwent River and the returning juveniles migrating back up the river 4-6 months later. These age classes may be exposed to direct visibility of the street lights associated with the crossing for decades.

The permanent nature of the street lighting over the projects' 100-year life, means that there is a potential exposure of individual larvae and juveniles to light during every annual spawning and migration season. The likelihood of exposure is therefore assessed as Likely. Since the exposure of larvae will be of short duration as they are swept downstream on the river currents, the consequences are assessed as Minor, resulting in a Medium inherent risk ranking.

The impact of light on the returning juveniles is unknown however since they can swim purposefully, they may be attracted to light spill in the water exposing them to an increased risk of predation and interrupting their natural migration patterns (Nightingale, 2006). The likelihood of juvenile fish being exposed to permanent street light spill into the water is expected to occur more than once a year and therefore assessed as Likely, the consequences of this long-term impact on juvenile fish is Moderate resulting in a High risk ranking.

The impact of crossing light spill on graylings can by substantially reduced by preventing light spill from reaching the river water below the bridge and by using lights with little or no blue wavelengths. Any minor light spill that reaches the water will be absorbed and scattered by the water reducing the spatial extent of light influence. The residual risk to juvenile fish could be substantially reduced if the mitigation and management actions outlined in Section 5.1 are implemented with specific focus on;

- Reducing the CCT of the project streetlights to 2000K CCT (or at least 2700K CCT as recommended in Inspiring Places 2021a). In clear water short wavelengths penetrate further than long wavelengths so using lights with little short wavelength light will reduce the penetration of the light through the water column, long wavelength light is absorbed by water molecules and will be rapidly attenuated once it reaches the river;

- Installing shielding on all lights to confine all light to the footprint of the roadway and to prevent any light spill from reaching the river beneath the crossing.

Implementing these management actions will reduce the likelihood of exposure of grayling juveniles to light to Unlikely with a consequence of Minor resulting in a residual risk of Low.

Outcomes of the operations risk assessment for the more sensitive juvenile age class, is provided in **Table 8**.

Table 8: Summary of light impact assessment for juvenile graylings during operations

Impact	Consequence	Likelihood	Ranking
Inherent	Moderate (3)	Likely (4)	High (7)
Residual	Minor (2)	Unlikely (2)	Low (4)

4.5 Humans

The results of the Visual Impact Assessment are used here to assess the impact of the project on human receptors. That assessment concluded the areas with highest level of visual impact were Bridgewater central, Bridgewater west and Granton and all are located within 1 km of the crossing. These areas have been risk assessed for operations as the worst-case scenario due to their proximity to the project site. Other sites within 1 – 5 km are assessed separately.

4.5.1 Construction

Night-time construction is expected to be infrequent within a 3-year construction timeframe however there will be lighting associated with illuminating roadwork areas and project infrastructure. The Bridgewater central, Bridgewater west and Granton areas are likely to be exposed intermittently to direct visibility of the temporary construction lighting towers and infrastructure light from the crossing. As this is for a short time (1-3 years) the consequences are assessed as Minor. While mitigation measures to manage construction lighting outlined in **Section 5.1** will not alter the duration of the impact, the mitigation measures will reduce the visibility of the construction light to the viewer to an Insignificant level and results in a Low residual risk ranking.

Table 9: Summary of impact assessment for human receptors during construction.

Impact	Consequence	Likelihood	Ranking
Inherent	Minor (2)	Likely (4)	Medium (6)
Residual	Insignificant (1)	Possible (3)	Low (4)

4.5.2 Operations

The Visual impact Assessment (Inspiring Places, 2021b) found that for the 100-year life of the project, the areas shown in **Table 1** will be exposed to a high, medium or low level of visual impact. The visibility of the crossing from facilities, roads and walking trails was ranked as low/minor to moderate. Overall, the study concluded the Bridgewater Bridge will have a moderate impact to residents of the suburbs that make up the study area (**Table 1**).

The streetlights associated with new approach road system and alignment together with the new crossing lighting will introduce substantially more sources of light into the local environment than the local residents are currently accustomed to. The visual amenity of the humans residing near the project location are likely to be impacted by the lights on the approach roads, elevation of the crossing and the associated lighting ~ 25m above the current level of the causeway and existing bridge together with an expected increase in the number, pole height, colour and brightness (4000K LED) of the streetlights.

The current lighting on the causeway and existing bridge is modest and limited to 9 widely spaced lights, with low lumen output (intensity), which are low on the visual horizon relative to the proposed bridge (**Section 3.4)**. Local residents are therefore accustomed to little light in the direction of the project site.

The inherent impact of an increased number of bright white (4000K) LED lights permanently elevated into the field of view of local human residents, and with no specific shielding, is likely to cause a Moderate impact on some residents who may be disturbed by the visibility of the lights that are directly visible inside their property boundaries > 1km from the project site (**Table 10**). While the lights may be visible it is likely that over the distances involved the lights are unlikely to cause discomfort to residents. Alternatively, for some residents living adjacent to the approaches to the crossing in Granton and Bridgewater the inherent impact of poorly managed bright white 4000K LED streetlights could be Major resulting in an Extreme risk ranking (**Table 11**).

The residual risk could be substantially reduced to Low for residents located within 5 km of the crossing (i.e. both <1 km and > 1 km) if the mitigation and management actions outlined in **Section 5.1** are implemented with specific focus on;

- Reducing the CCT of the project streetlights to 2000K CCT (or at least 2700K CCT as recommended in Inspiring Places 2021a) to replicate the existing low intensity high pressure sodium and metal halide lights;
- Installing shielding on all lights and consider additional shielding on lights in the approaches to the crossing to shield the direct visibility of the lights to residents whose homes are immediately adjacent to the new road alignment;
- Aiming the lights carefully to prevent lights shining in resident homes and dim the intensity.

By doing this the likelihood of the resident seeing the lights will be reduced to unlikely with only a limited number of lights potentially directly visible to the human viewer and the consequences are a minor disturbance to residents.

Table 10: Summary of impact assessment for human receptors >1km from the crossing during operations.

Impact	Consequence	Likelihood	Ranking
Inherent	Moderate (3)	Almost certain (5)	High (8)
Residual	Minor (2)	Unlikely (2)	Low (4)

Table 11: Summary of impact assessment for human receptors <1km from the crossing during operations.

Impact	Consequence	Likelihood	Ranking
Inherent	Major (4)	Almost certain (5)	Extreme (9)
Residual	Minor (2)	Unlikely (2)	Low (4)

4.6 Dark Sky values

The results of the benchmark ALAN survey (**Section 3.4** and **Appendix A**) are used to assess the impacts of the project on dark sky values. The existing lighting across the project site ranges from suburban (as defined by Zone A3 under AS/NZS 4282 and SQM range), to rural (as defined by Zone A2 under AS/NZS 4280 and SQM range). Introducing additional bright white unmitigated streetlights into the environment is likely to substantially brighten the sky, increasing light visibility and sky glow particularly under the influence of clouds which, depending on cloud height and thickness, scatter and reflect light across broad landscape scales (Kyba et al. 2011).

4.6.1 Construction

Night construction is not expected to be frequent within a 3-year construction timeframe however there will be lighting associated with illuminating roadwork areas and project infrastructure. These light sources will include mobile lighting towers and infrastructure. Poorly managed mobile lighting towers will likely contribute to sky glow, however this is for a short time (1-3 years) and therefore the consequences are assessed as minor. While mitigation measures to manage construction lighting outlined in **Section 5.1** will not alter the duration of the impact, the mitigation measures will reduce the visibility of the construction light to the viewer to an insignificant level and results in a low residual risk ranking.

Table 12: Summary of impact assessment for dark sky values.

Impact	Consequence	Likelihood	Ranking
Inherent	Insignificant (1)	Likely (4)	Medium (5)
Residual	Insignificant (1)	Unlikely (2)	Low (3)

4.6.2 Operations

For the 100-year life of the project, the sky above the project area will potentially be exposed to sky glow from project related street and infrastructure lighting.

As addressed in **Section 4.4.2**, the streetlights associated with new approach road system and alignment together with the new crossing lighting will introduce substantially more sources of light into the local environment than has previously existed. The quality of the sky near the project location is likely to be impacted by the lights on the approach roads and crossing due to an expected increase in the number, brightness and colour temperature (4000K LED) of the streetlights.

The current lighting on the causeway and existing bridge contributes a relatively small amount of light to the local sky glow, which is dominated by lighting from suburban and urban areas at Bridgewater as well as the urban areas between the existing bridge and Hobart (see **Section 3.4.2, Figures 4, 5, 7 and 8**) with the light from these urban areas substantially reducing sky quality under the influence of cloud. The existing bridge and causeway is a relatively dark region on the Lyell Highway and is consistent with the Environmental Zone A2 (low district brightness area, i.e. sparsely inhabited rural and semi-rural area, *AS/NZS 4282)* recommended in the Scoping Study (section 3.1). Lights should be mitigated to maintain this zoning with no reduction in sky quality.

The inherent impact of an increased number of bright white (4000K) LED lights permanently illuminated, with no control on light spill into the night sky (likelihood almost certain), and with no specific mitigation is likely to cause a Moderate impact on sky quality immediately above the project site increasing the sky glow to that of an Environmental ranking of A3 (AS4282) typical suburban night sky (Moderate) with an overall High impact.

The residual risk could be substantially reduced to Low if mitigation actions are implemented as outlined in **Section 5.1** with specific focus on the following.

- The CCT of the project streetlights are reduced to <2700 CCT and preferably 2000K CCT;
- Shield and orient the lights to prevent upward light and horizontal scattering; and
- Dim the intensity of the lights.

Good lighting management will reduce the likelihood of the light spill into the night sky to Unlikely and the consequences to Minor. The residual risk would be reduced to Low.

Table 13: Summary of impact assessment for dark sky values.

Impact	Consequence	Likelihood	Ranking
Inherent	Moderate (3)	Almost certain (5)	High (8)
Residual	Minor (2)	Unlikely (2)	Low (4)

5 LIGHT MANAGEMENT PLAN

This section addresses the following component of the MPIS Assessment Criteria,

S2.2.7 b) Assessment of construction and operational light pollution should include:

iii) Identify the need or otherwise for construction and operational mitigation measures and strategies.

iv) Development of construction and operational phase design, management and mitigation strategies if required.

The objectives of this Management Plan are to reduce the impacts from the project area to as low as reasonably practicable.

The following section provides guidance for how best to achieve this objective and applies to impacts associated with the construction and operation of the New Bridgewater Bridge on birds, humans and dark sky values.

5.1 Light

Best practice light design principles for external light sources should be implemented for any light associated with the project, i.e. for streetlighting and any required pedestrian or security lighting (Commonwealth of Australia 2020). The project specific recommendations for light management in the Urban Design Guidelines which were provided to tenderers to inform design are presented in **Section 3.1** (and listed again below) are consistent with Best Practice Lighting Principles

- *all lighting should have a clear purpose – decorative lighting, or architectural floodlighting of the new bridge should be avoided with the focus instead on road safety and/or way-finding for those using the shared path;*
- *light should be directed only where it is needed – shielding should be used to direct light downwards to avoid light spill (i.e. zero upward waste light) and avoiding discomforting glare;*
- *lighting should be no brighter than necessary – use the lowest light level allowable for the road conditions;*
- *control – consider use of motion sensors for the lighting of the shared path;*
- *colour – use warm coloured light (i.e. colour temperature ≤2700K); and*
- *integration – where possible lighting should be integrated with structural elements or other components of the bridge to reduce visual clutter.*

In addition to these principles, it is recommended the lighting design consider the following additional mitigation measures.

Mitigation recommendations specific to construction lighting:

- Use the minimum number of lighting towers necessary for the task.
- Consider curfews, i.e. turn unnecessary lights off late at night (i.e. after 11 pm).

- Aim the towers so as to reduce light spill into the river and nearby bird habitat and away from the direction of residential areas.
- Use warm colour temperature, < 3000K.

Mitigation measures for operational lighting:

- Start with natural darkness and only add light for specific purposes. The lighting design for the New Bridgewater Bridge should start with a base case of no lights and any street or pedestrian light be added only if and when they are needed.
- Use 2000K LEDs (Amber or PC Amber) on the approach roadways and crossing to replicate the warm dim high pressure sodium lighting that drivers and residents are currently accustomed to.
- Streetlights should be mounted horizontal to the ground with no upward tilt angle to prevent glare and upward sky glow.
- Keep the pole heights as low as possible, integrate pedestrian lighting into handrails or other bridge structures and ensure pedestrians are not subject to glare from light at eye level.
- Use the lowest intensity lighting necessary for safe movement of vehicles, marine vessels or pedestrians.
- Use non-reflective, dark-coloured surfaces in the crossing structure.
- Ensure the street and pedestrian lighting is not rich in short wavelength blue light, use Amber or PC Amber LED lights for street lighting and ensure the LEDs have reduced or filtered blue.
- Lights containing violet and ultra-violet wavelengths must not be used.
- Install additional shielding on lights on the approach roads to the crossing to prevent direct visibility of lights from residential homes immediately adjacent to the Lyell Highway in Granton and Bridgewater.
- Ensure the street lights on the crossing are contained entirely withing the footprint of the roadway and no light spill reaches the water below.

The plan to use 4000K LED streetlights (see **Section 3.2**) on the crossing is not supported by this assessment. These lights will introduce a substantial increase in short wavelength blue light (~450 nm) into the landscape relative to the current levels**.** This is demonstrated in **Figure 9** which shows the relative amount of short wavelength blue light in 2700, 3000 and 4000 K LEDs.

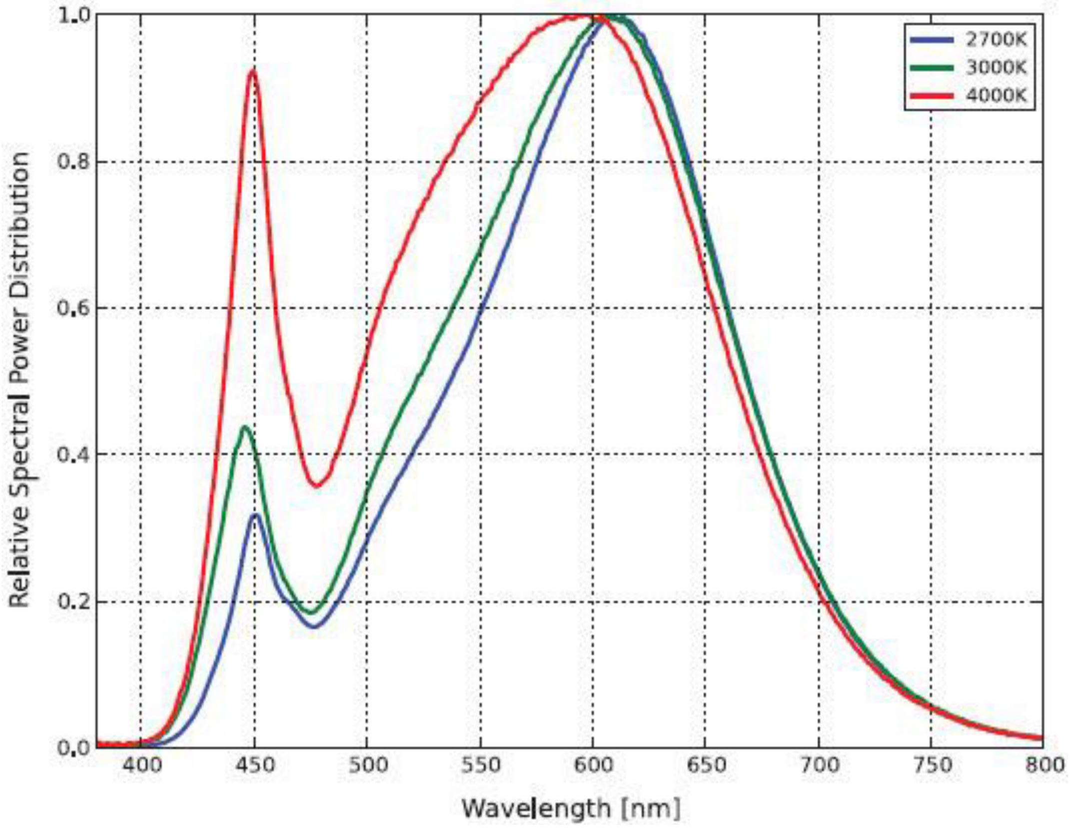

Figure 9: example of different short wavelength blue content in 2700, 3000 and 4000 K LED lights. Note the large blue peak at 450 nm in the 4000 K LED relative to the 2700 and 3000 K LEDs.

6 MONITORING AND AUDITING

An ongoing ALAN monitoring program is recommended during construction operations to inform an adaptive management framework to support continuous improvement in light management for this project. Post construction auditing and reporting is recommended to confirm compliance with light management and mitigation activities.

No additional bird monitoring is recommended beyond that required for other project related requirements.

6.1 Artificial light Monitoring

6.1.1 Obtrusive lights

A survey of post construction obtrusive lighting impacts on residents in the immediate vicinity of the project is recommended. In addition to a follow-up of the AS/NZS 4282 obtrusive lighting monitoring at residential boundaries using a handheld lux meter (see **Appendix A** for benchmark survey), an on-the-ground survey of light visibility from selected locations should be conducted in person to assess visually if the project lighting is obtrusive since AS/NZS 4282 does not account for this. For example, the streetlight in **Figure 10** is not considered obtrusive under AS/NZS 4282.

The sites to be surveyed should also include locations where residents have submitted formal complaints to the council, contractor or road authority about project related obtrusive lighting. This inspection should be done in person and the nuisance factor of the light assessed visually, and not only by calculation as outlined in AS/NZS 4282.

6.1.2 Sky Quality

Because the June 2021 ALAN survey was impacted by weather there is no quantitative data on the sky quality at the existing bridge. It is recommended a pre-construction survey be conducted to gather benchmark data that can be used when assessing sky quality post construction. This survey should be targeted for a period of clear weather on a new moon and repeat the survey as outlined in **Appendix A**.

A follow-up post construction survey is also recommended to assess the success of the mitigation actions in minimising sky glow and protecting the sky quality at the project site.

6.2 Auditing/inspections

The project should be audited both during construction and after commissioning to ensure all commitments regarding light management have been met. The audit outcomes should be used for adaptive management if additional risks are identified, or it is discovered that risks have not been assessed correctly.

As outlined in the National Light Pollution Guidelines for Wildlife, audits should be undertaken by personnel experienced in environmental auditing and considered in consultation with an appropriately qualified biologist or ecologist.

Auditing schedules should be developed outlining the frequency of audits to ensure:

- Compliance with control measures; and
- Identification of any new information regarding potential impact pathways between project related impacts and biological receptors, and any adaptive management measures that could further reduce potential impacts.

Figure 10: Example of a streetlight that was measured at 0 Lux (both on the horizontal and the vertical plane) from the photographer/viewer location, so would not be considered obtrusive under AS/NZS 4282 conditions (either measured or calculated)

7 CONCLUSIONS

This assessment has addressed the potential impacts of the New Bridgewater Bridge on wildlife, human receptors, and dark sky values. The assessment focussed on listed species with credible impact pathways, i.e. species that can reasonably expected to be at risk from exposure to and impact from light, including birds and the Australian grayling fish as well as locally important waterbird species. It is the first formal environmental risk assessment in Australia to assess the impacts of development project lighting on human receptors and on dark sky values.

The risk assessment summaries are collated in **Table 14**. The risk assessment generally found that all sensitive receptors are at a Medium to High inherent risk from exposure to artificial light associated with the project when the light is not managed. An Extreme risk is predicted for human receptors living within 1 km of the project site under these conditions. However once recommended light management and mitigation actions are implemented the risks will be substantially reduced to Low in all cases.

The three management actions that will be most influential in mitigating the bulk of the identified risk include shielding, light colour and intensity. The streetlights on the approaches to and on the crossing should be shielded to stop upward sky glow, to prevent light spill directly onto the water, and to prevent direct visibility of light from residential areas. The street lights selected should have little or no blue wavelengths, e.g. Amber, PC Amber or filtered LEDS (aim for 2000 – 2700 K CCT). Finally, the lights should be operated at the lowest intensity possible while still accounting for the safety of human users moving around the area.

Table 14: Collated risk assessment summaries.

		Impact	Consequence	Likelihood	Ranking
Birds	Construction	Inherent	Minor (2)	Possible (3)	Medium (5)
		Residual	Insignificant (1)	Unlikely (2)	Low (3)
	Operation	Inherent	Minor (2)	Possible (3)	Medium (5)
		Residual	Insignificant (1)	Rare (1)	Low (2)
Grayling juvenile	Construction	Inherent	Minor (2)	Possible (3)	Medium (5)
		Residual	Insignificant (1)	Unlikely (2)	Low (3)
	Operation	Inherent	Moderate (3)	Likely (4)	High (7)
		Residual	Minor (2)	Unlikely (2)	Low (4)
Human receptors	Construction	Inherent	Minor (2)	Likely (4)	Medium (6)
		Residual	Insignificant (1)	Possible (3)	Low (4)
Human receptors >1 km from crossing	Operation	Inherent	Moderate (3)	Almost certain (5)	High (8)
		Residual	Minor (2)	Unlikely (2)	Low (4)
Human receptors <1 km from crossing		Inherent	Major (4)	Almost certain (5)	Extreme (9)
		Residual	Minor (2)	Unlikely (2)	Low (4)
Dark sky values	Construction	Inherent	Insignificant (1)	Likely (4)	Medium (5)
		Residual	Insignificant (1)	Unlikely (2)	Low (3)
	Operation	Inherent	Moderate (3)	Almost certain (5)	High (8)
		Residual	Minor (2)	Unlikely (2)	Low (4)

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Appendix A:ARTIFICIAL LIGHT AT NIGHT SURVEY REPORT.

BURBURY CONSULTING

NEW BRIDGEWATER BRIDGE: BENCHMARK ARTIFICAL LIGHT AT NIGHT SURVEY

Prepared by

Pendoley Environmental Pty Ltd

For

Burbury Consulting

15 September 2021

ARTIFICIAL LIGHT ASSESSMENT SERVICES

PENDOLEY ENVIRONMENTAL

PENDOLEY ENVIRONMENTAL

DOCUMENT CONTROL INFORMATION

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1 INTRODUCTION

1.1 Project Background

The New Bridgewater Bridge Project (the Project) involves the construction and operation of a new bridge across the River Derwent in Hobart Tasmania. The Project is supported by a $576 million commitment from the Australian and Tasmanian Governments as part of the Hobart City Deal. This commitment represents the largest ever investment in a single transport infrastructure project in Tasmania's history. The Bridgewater Bridge is a critical part of the transport and freight link between the northern and southern regions of Tasmania.

A condition of the project assessment was related to light pollution; Assessment Criteria, Schedule 2:

S2.2.7 Light pollution

The following Information requirements and matters to be addressed for clause 5.1.7 Light pollution:

a) Identification of potential sources of light pollution and sensitive human and wildlife receptors for both the construction and operational phases of the project.

b) Assessment of construction and operational light pollution should include:

- *i) Consideration of existing levels of light.*
- *ii) Consideration of different types of light pollution, and potential impact on human and wildlife receptors, with reference to any relevant guidelines or standards.*
- *iii) Identify the need or otherwise for construction and operational mitigation measures and strategies.*
- iv) *Development of construction and operational phase design, management and mitigation strategies if required*.

This study has been conducted to meet the above Development Assessment Criteria condition a) and b) i) and is required for the preparation of an Artificial Light Management Plan which will satisfy conditions a) and b) i) to iv).

1.2 Objectives and Scope

The objective of this lighting survey was to establish the benchmark level of artificial light in the vicinity of the existing bridge prior to construction of the new crossing which will allow comparison with future construction or operational light surveys. This survey is consistent with the National Light Pollution Guidelines for Wildlife ("the guidelines"; Commonwealth of Australia 2020), the principles of Dark Sky protection promoted by locally based Australasian Dark Sky Alliance (ADSA), and the International Dark Sky Association (IDA). The design requirements AS4282 Control of Obtrusive Outdoor Lighting are also addressed.

Burbury Consulting on behalf of The Department of State Growth therefore requested PENV to conduct a benchmark artificial light survey and prepare an Artificial Lighting Management Plan (ALMP) to meet address the assessment criteria.

This report presents the results of the benchmark artificial light at night survey. These results will be used to conduct an impact assessment as part of the ALMP.

2 METHODOLOGY

2.1 Survey Locations

The survey locations (**Figure 1**) were selected following a desktop review of the topography of the study area and further refined on site following;

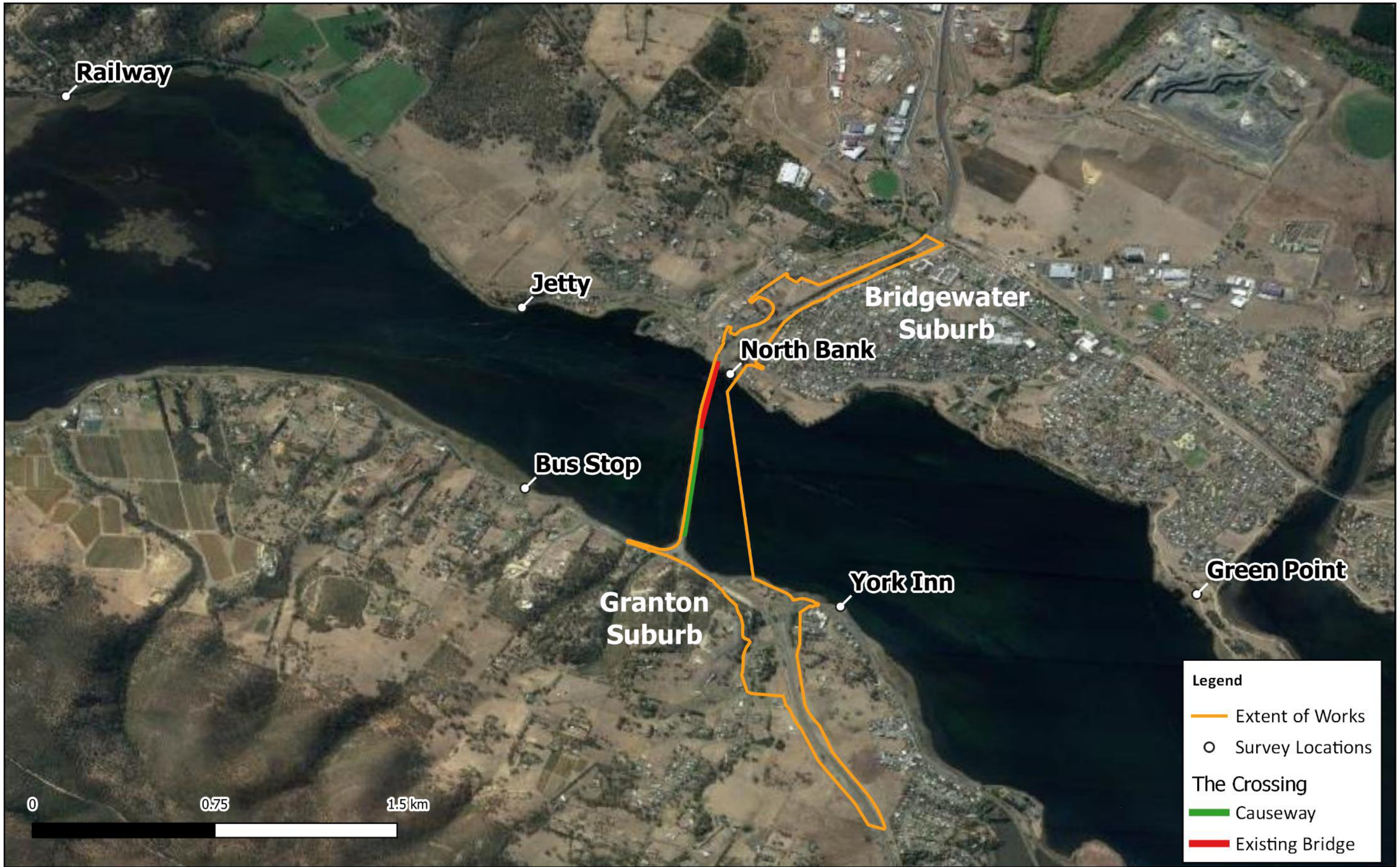
- discussions with representatives of Burbury Consulting;
- day-time and night-time site reconnaissance of potential locations to ascertain ease-of-access to specific geographic locations and line-of-sight visibility of the existing bridge and causeway;
- proximity to water bird habitat (North Barker Ecosystem Services 2021);
- assessment of monitoring site security (with regards to personnel and equipment); and
- assessment of weather conditions, with the aim to avoid rain, cloud, and fog.

The five locations selected for the survey included representative locations for densely populated areas, low density rural areas, and areas of high conservation value for wildlife.

Camera deployment locations and lux meter recordings were marked with GPS positions for comparison with future lighting surveys. The survey sites and GPS positions for the camera are shown in **Table 1**, and lux meter measurements are detailed in **Appendix A**.

Table 1: Survey sites and GPS positions of locations shown in Figure 1.

Survey site	Latitude	Longitude	Height (m)
Railway	-42.726899	147.193122	1.46
Jetty	-42.737112	147.216228	0.00
Bus Stop	-42.746195	147.216540	1.13
York Inn	-42.751885	147.232504	0.83
Green Point Nature Reserve	-42.750917	147.250366	1.30
North Bank	-42.740270	147.226763	1.00



J91001 Burbury New Bridgewater Bridge Project

Figure 1: Location of survey sites, The Project Land Extents, and The Crossing.

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2.2 Data Capture

Benchmark light data was collected over the course of the survey between the 7th – 11th June 2021. Detail on the instruments used to collect data, including a lux meter, Sky42 camera and a hand-held camera are provided below.

2.2.1 Lux/Light Meter

A handheld lux meter (manufacturer: TENMARS; model: TM-208) was used to measure the light levels (unit: lux) falling on vertical surfaces at residences situated the vicinity of the project footprint (if present/accessible). The meter can detect light levels between 0 and 400,000 lux, at a resolution of 0.01 lux. The data collection methods were consistent with those outlined in AS/NZS 4282 Control of the Obtrusive Effects of Outdoor Lighting.

2.2.2 Manual Photographs

Data was captured using a Samsung Galaxy S10e (SM-G970F) to gather qualitative information on pre-existing lighting conditions from the Jetty and North Bank locations.

2.2.3 Sky42 Camera

PENV has developed a unique, innovative monitoring tool (Sky42™ camera) for recording ambient night-time light emissions (**Figure 2**). The Sky42 camera measures light on a landscape scale including the light at the horizon which is most pertinent to local bird and human residents. The Sky42 cameras are stand-alone and rugged, encased within all-weather housing, and can be transported by hand in the field. Cameras were deployed, retrieved, and had their data downloaded every day.

Figure 2: Deployed Sky42 light monitoring camera.

The cameras can be operated automatically or manually and feature custom-written software to capture multiple low light night sky images of night-time light emissions visible from the survey location, on a full 360° horizon. The images allow for:

- All visible, individual light sources to be identified and monitored across a complete survey period; and
- comparison against future monitoring surveys.

The quality of an image captured by a Sky42 light monitoring camera can be influenced by atmospheric factors such as the presence of the moon, twilight, cloud, rain, dust, humidity, or physical factors such as accumulation of sand on the lens. Any images that were affected by physical factors were removed from the analysis, as well as any images that were affected by the moon or twilight.

Images are then batch processed using specialised software (Sky Quality Camera, Euromix Pty Ltd). The processing involved converting each image into an isophote (light level) contour map and calculating the mean whole-of-sky brightness value (Vmag/arcsec^2) for all pixels in the map. The isophote maps are then converted to an equirectangular panorama.

3 RESULTS

Sky42 camera data was successfully captured from five survey locations (**Figure 1)**. However, adverse weather conditions for the entire duration of the 3-day survey limited the data that could be processed from the images. Extensive cloud cover was experienced during every night of the survey which impacted on the accuracy of the image processing and consequently could not be used to confidently quantify visual brightness of the existing light sources or overhead sky glow.

The Sky42 images are however useful for qualitative assessment of the light in the project area. The 15-second exposure raw images are used to qualitatively identify existing lights. Further, manual photographs were also captured from the Jetty and North Bank locations to aid in the determination of existing light levels.

Lux meter readings were captured at key points around the Project extent where potential impact on human receptors, from obtrusive light, was deemed greatest.

3.1 Lux Meter

The lux meter was used to determine current light levels at key points around the Project Land extents. The maximum value recorded was 25.94 lux under a streetlight (-42.7400001 , 147.228076) while a minimum of 0 lux was commonly measured. The vertical illumination limits as described in AS/NZS 4282:2019 (**Table 2**) are exceeded (under light curfew) at several positions along roadways.

Table 2: Maximum values of light based on lighting subcategory as per AS/NZS 4282:2019.

Lighting Subcategory	Description	Vertical Lux (lx)	
		Non-curfew	Curfew
A3	Medium District Brightness.	5	2
V	Residences near traffic routes.	NA	4
R1	Residences near local roads with significant setback.	NA	1
R2	Residence near local roads.	NA	2
R3	Residences near a roundabout or local area traffic management device.	NA	4
RX	Residences near a pedestrian crossing.	NA	4

The full list of lux readings and corresponding GPS locations can be found in **Appendix A**, and maps of the data recorded can be seen in **Figure 3**. Note that GPS locations included in the maps are accurate to within 5 metres. While all points were measured on public land, a GPS location may occasionally display a point as measured inside a residence boundary due to the 5-meter variance.

3.2 Manual Photographs

Manual photographs were captured from the Jetty and North Bank locations (**Figure 1**) . Existing lights on the bridge have been noted in **Table 3** and **Figure 5**.

Table 3: Lights on the existing Bridgewater Bridge.

Label	Mounting	Temperature	Latitude	Longitude
A1	Pole	Cool Green	-42.74283858	147.2253768
A2	Pole	Cool Green	-42.74282469	147.225207
A3	Pole	Cool White	-42.74188227	147.2255975
B1	Bridge	Warm Orange	-42.74138984	147.2256562
B2	Bridge	Warm Orange	-42.74101473	147.2257473
B3	Bridge	Warm Orange	-42.74086654	147.2257781
B4	Bridge	Warm Orange	-42.74069365	147.2258275
B5	Bridge	Cool White	-42.74058868	147.2258584
B6	Bridge	Warm White	-42.74021819	147.2259449

3.2.1 North Bank

The existing Bridgewater Bridge has nine lights on it, eight of which are visible in **Figure 5**. At the causeway adjoining side are two cooler green (A1 and A2) and one cool white (A3) pole mounted lights (likely metal halide) (**Table 3**). Four warm orange lights (likely high-pressure sodium, B1-4) and one cool white (B5) are mounted overhead on the underside of the existing bridge support structure. A red navigation light is mounted on the river side of the existing bridge deck.

3.2.2 Jetty

Figure 6 shows both the existing Bridgewater Bridge and the causeway. The only lights on the causeway are two streetlights at the Granton traffic interchange, the remainder of the lights seen are car headlights. Street and residential lights can be seen from the Bridgewater suburb. In addition, several of the point sources included in **Table 3** can be seen, with a mixture of warm orange and cooler white light sources in addition to the single red navigation light.

3.3 Sky42 Artificial Light Monitoring

Sky42 data was captured from five locations at various heights as detailed in **Table 1**. The images presented are 15-second exposure in a cylindrical projection, with key locations on the horizon noted (**Figure 7** – **11**). Images that featured the least amount of cloud cover and car headlights were selected for inclusion within this report.

3.3.1 Bus Stop

This site was selected due to its proximity to the water bird habitat, clear line of sight to the west side of the existing bridge and causeway from the Granton side of the River Derwent, and accessibility (**Figure 7**).

Street and residential lights in Bridgewater are visible as point sources in the bearing range 356° - 45° (**Figure 6).** Most of the lighting visible in the direction of the bridge (bearing 47° - 117°) can be attributed to residential lighting and car headlights. Scattered light from Hobart and intervening suburbs appears as glow on the horizon between bearing 120° and 160°. Note the orange colour of the sky glow in the direction of Hobart is likely produced by warm colour temperature high pressure sodium streetlights with reduced blue content.

3.3.2 Jetty

This site was selected due to its proximity to water bird habitat, clear line of sight to the west side of the existing bridge and causeway from the Bridgewater side of the River Derwent, and accessibility (**Figure 8**).

Street and residential lights in Bridgewater are visible as point sources in the bearing range 75° - 108° Lights are visible in the direction of the existing structure (bearing 110° - 154°), the majority of which can be attributed to car headlights. Hobart appears as glow on the horizon, overlapping the existing structure from bearing 147° - 157°.

3.3.3 Green Point Nature Reserve

This site was selected due to its clear line of sight to the east side of the existing bridge and causeway, representativeness of human resident visibility of the project site from the Bridgewater side of the River Derwent, and accessibility (**Figure 9**).

Street and residential lights in Bridgewater are visible as point sources in the bearing range 300° – 30°, further lights from southern suburbs can also be seen in the bearing 168° - 270°. Very few sources of light are visible in the direction of the existing structure (bearing 275° - 302°), sources closer to the bearing of 300° can be attributed to suburban street and residential lights. Minimal glow can be seen in the direction of Hobart in the bearing 154° - 165°.

3.3.4 Railway

This site was selected due to its clear line of sight to the west side of the existing bridge and causeway, proximity to water bird habitat, sufficient distance to optimise post construction data collection (i.e. avoid over exposure of images in the event that the new lighting design is significantly brighter than the existing light scheme on the causeway and bridge), and accessibility (**Figure 10**).

Streetlights are visible as point sources from both Lyell Highway (bearing 135° - 200°) and Boyer Road (bearing 230° - 280°). Large amounts of glow can be seen in the bearing 70° - 115°, this is the direction of the Bridgewater suburb, Rogerville train station, and an industrial area. Very few sources of light are visible in the direction of the existing structure (bearing 117° - 134°). Bright glow can be seen in the direction of Hobart in the bearing 145° - 160°.

3.3.5 York Inn

This site was selected due to its clear line of sight to the east side of the existing bridge and causeway on the Granton side of the River Derwent, and accessibility (**Figure 11**).

Street and residential lights along Main Road can be seen in the bearing 130° - 300°, further lights from Bridgewater suburb are seen in the bearing 342° - 90°. Some point sources are seen in direction of the bridge (bearing 295° - 340°).

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Figure 3: Lux meter recordings in the Bridgewater suburb, captured on the 9th of June 2021.

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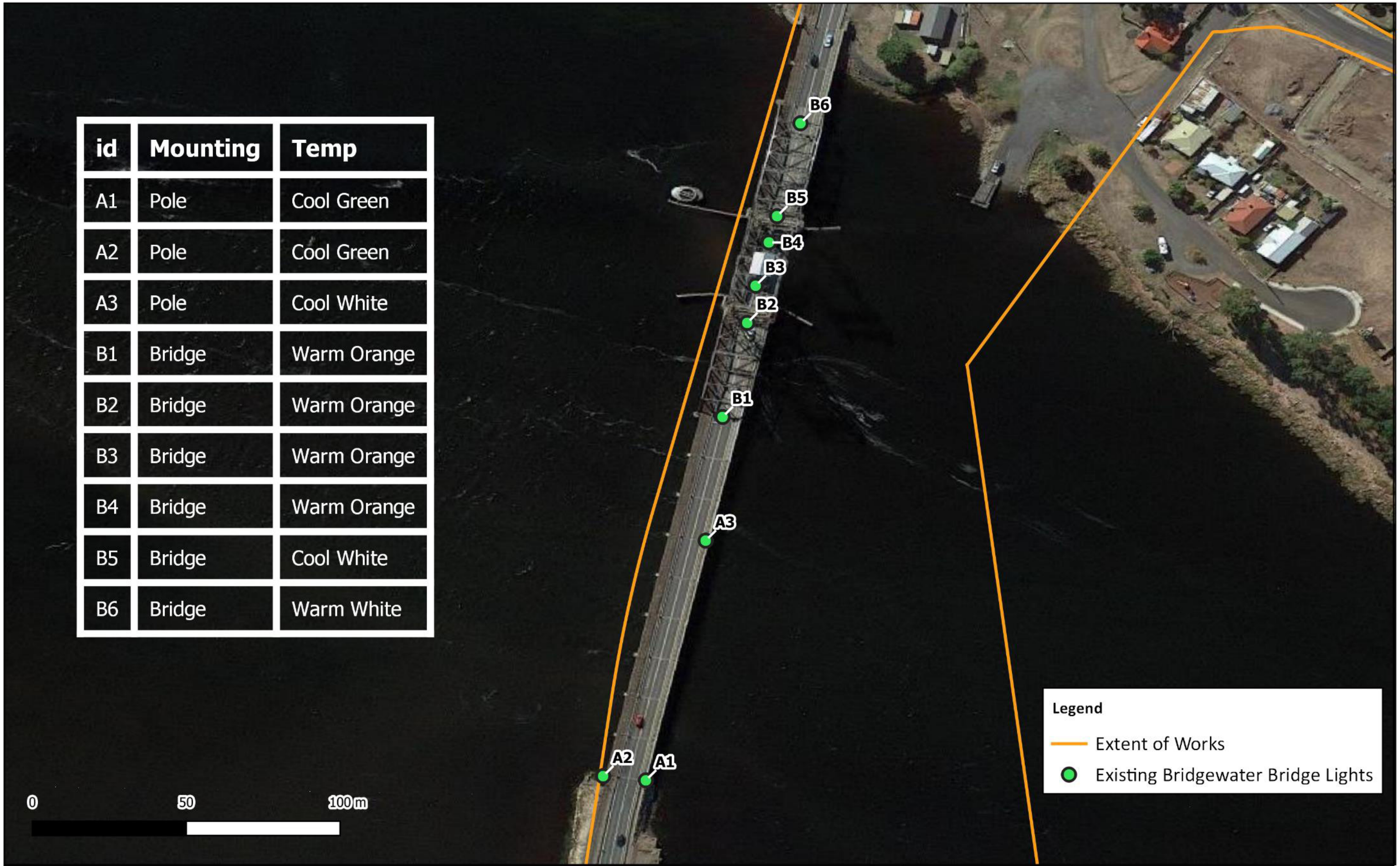

id	Mounting	Temp
A1	Pole	Cool Green
A2	Pole	Cool Green
A3	Pole	Cool White
B1	Bridge	Warm Orange
B2	Bridge	Warm Orange
B3	Bridge	Warm Orange
B4	Bridge	Warm Orange
B5	Bridge	Cool White
B6	Bridge	Warm White

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Figure 4: Lights on the existing Bridgewater Bridge. Labels described in **Table 3**.

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Coordinate System: EPSG:4326 - WGS 83

PENDOLEY ENVIRONMENTAL

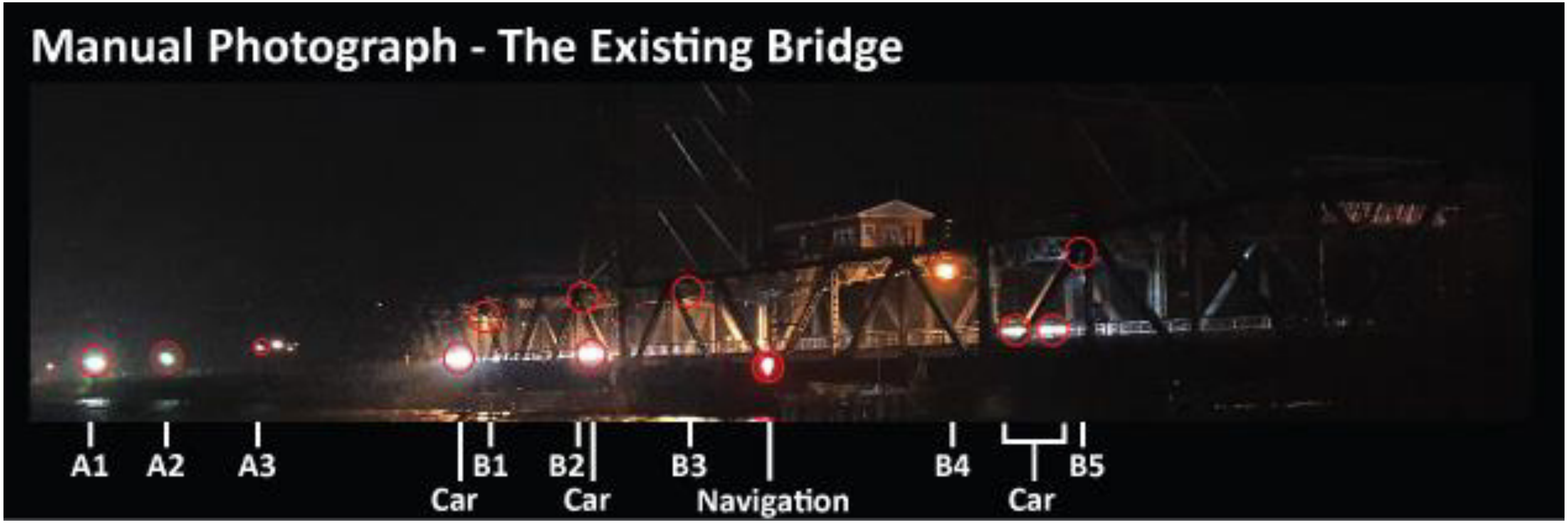

Figure 5: Manual camera image captured from the bank near the existing bridge on 9th June 2021. Note lights have been circled in red and labelled, these are described further in **Table 3.**

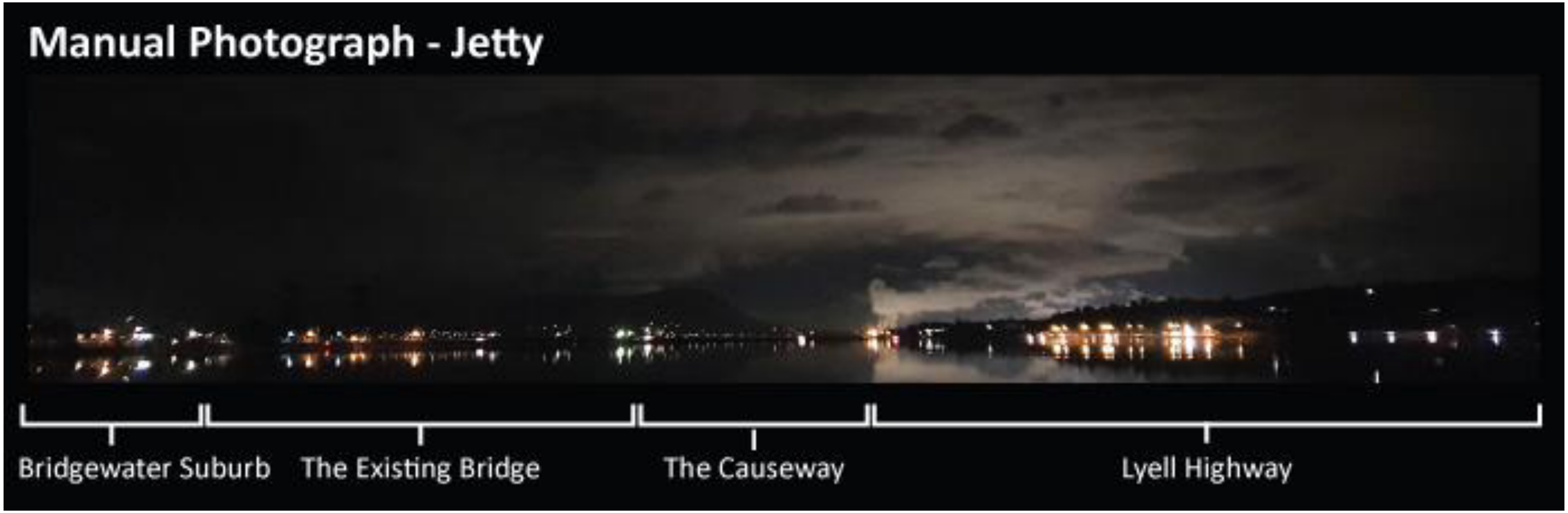

Figure 6: Manual camera image captured from the Jetty location on 8th June 2021.

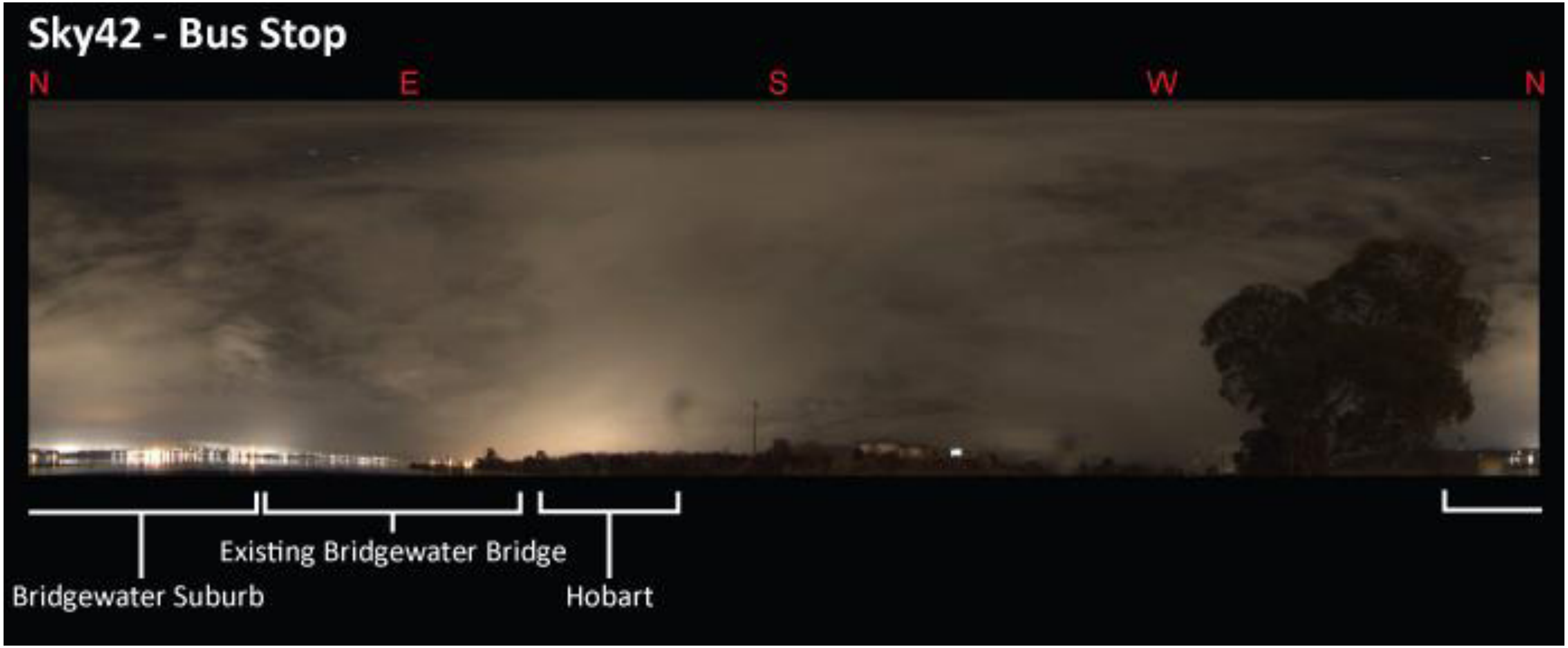

Figure 7: Sky42 camera image captured from the Bus Stop monitoring location on 8th June 2021.

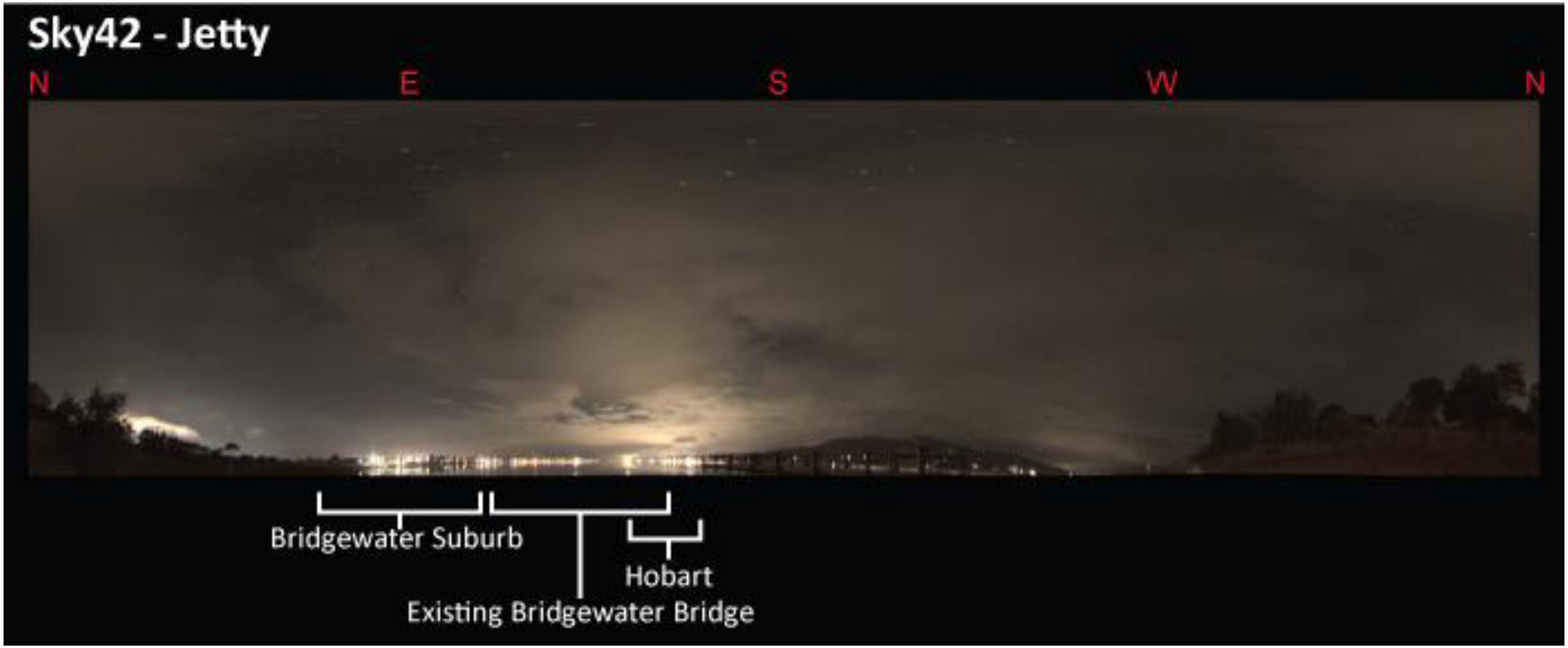

Figure 8: Sky42 camera image captured from the Jetty monitoring location on 8th June 2021.

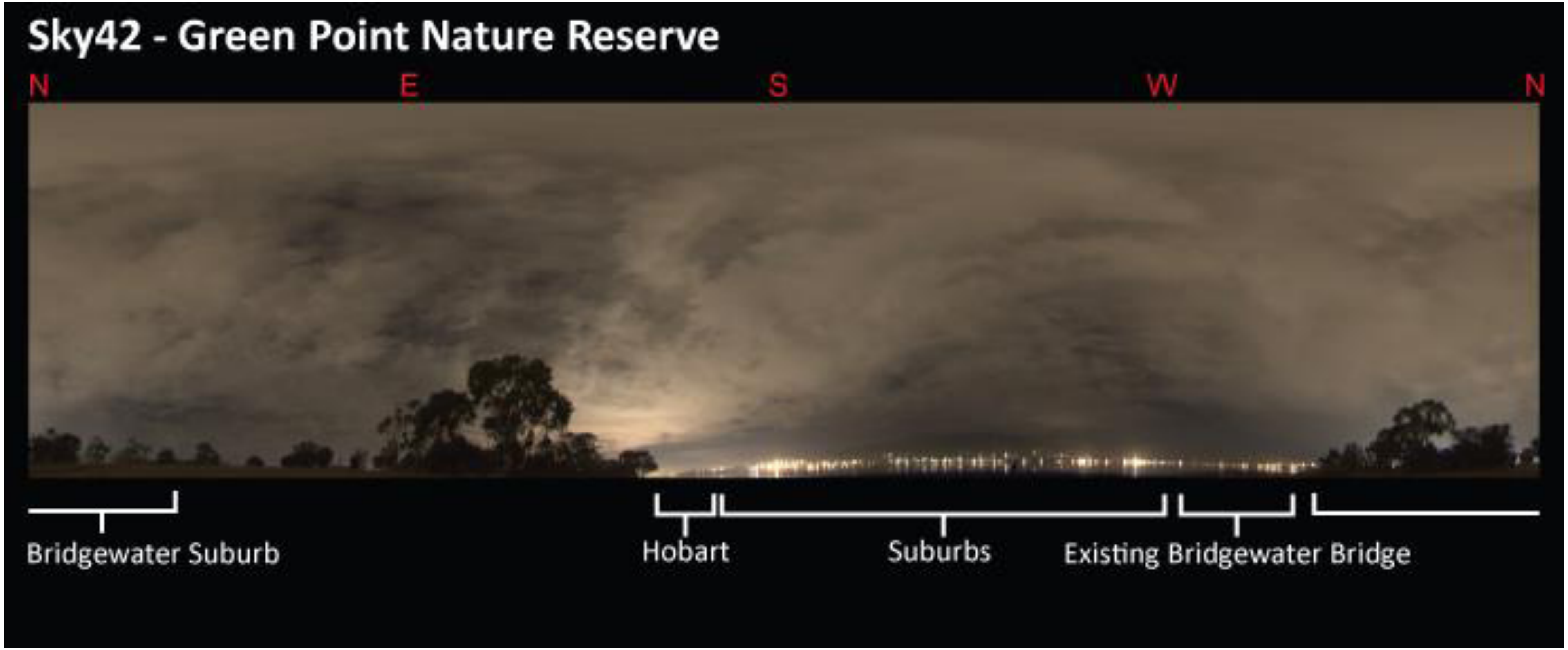

Figure 9: Sky42 camera image captured from the Green Point Nature Reserve monitoring location on 8th June 2021.

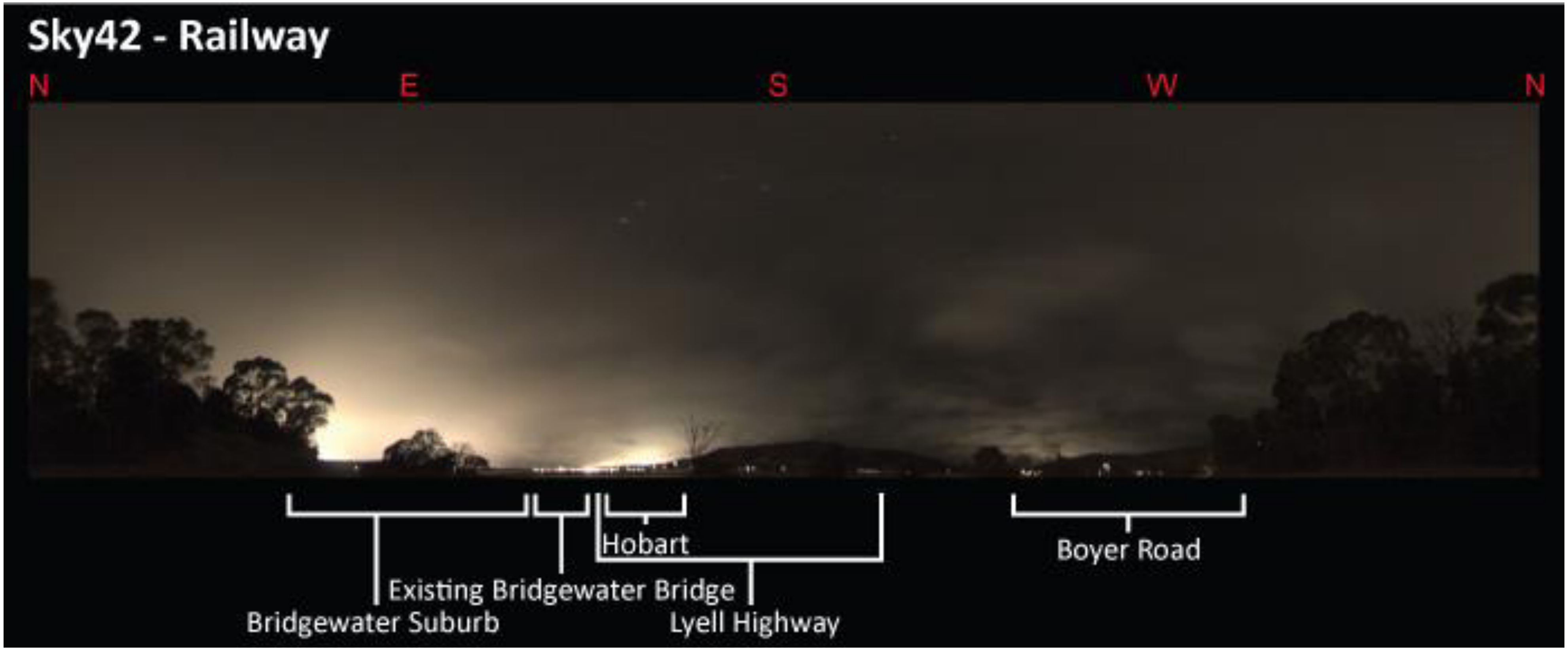

Figure 10: Sky42 camera image captured from the Railway monitoring location on 9th June 2021.

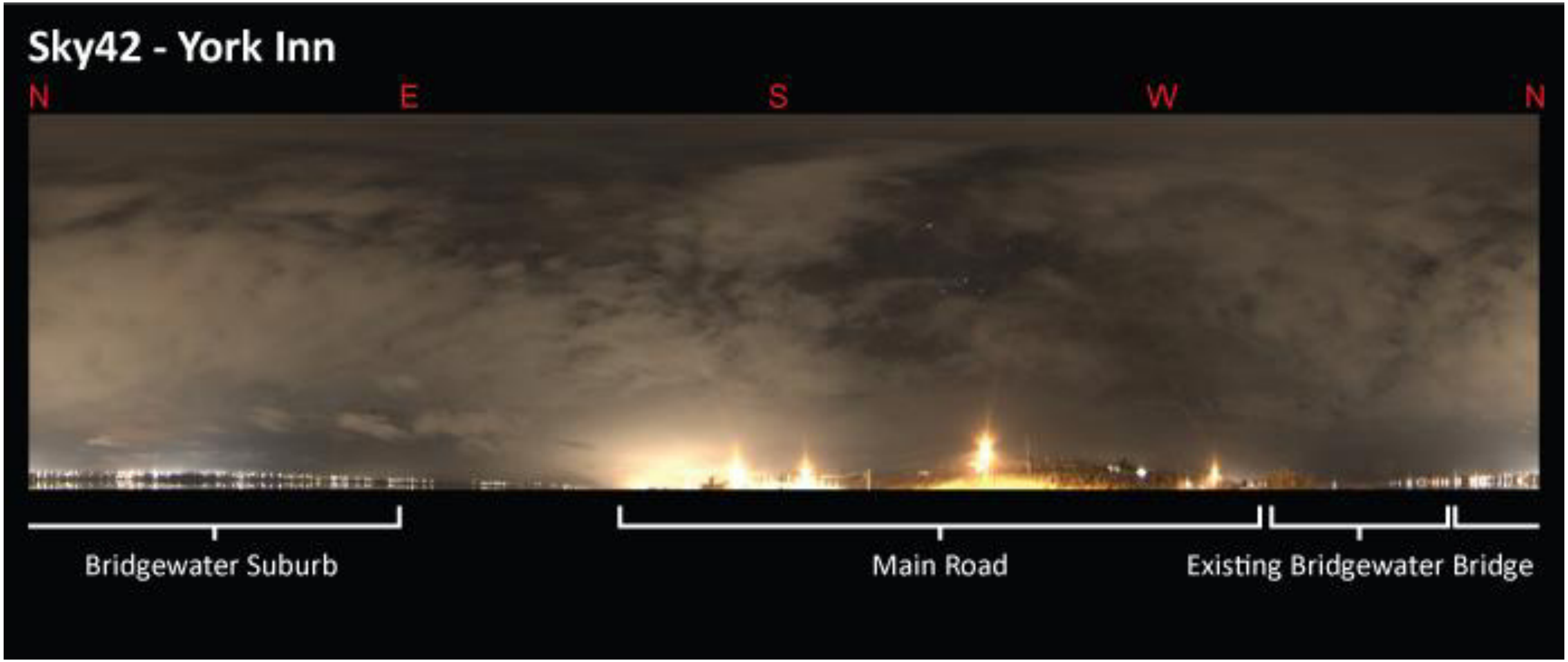

Figure 11: Sky42 camera image captured from the York Inn monitoring location on 8th June 2021.

4 CONCLUSION

The benchmark ALAN survey was completed successfully despite the weather limitations preventing the quantification of project area lighting. The survey data can be used for construction and post-construction monitoring to qualitatively assess the changes in the area lighting.

The existing Bridgewater Bridge was monitored from five locations to determine current light levels and create a baseline if future studies are required. Observations from both Sky42 and manual photographs show that the existing bridge is quite dark, featuring only nine lights (**Figure 4** and **Table 3**) and several streetlights at either end at the adjoining intersections.

Illumination measurements were also taken in Bridgewater, the range of lux measurements recorded were 0 - 25.94 Lux. Some locations located near residences exceeded the illumination limits if these regions were under curfew, as described in the AS/NZS 4282:2019 standard and **Table 2**.

It is recommended any future surveys (if required) replicate this survey design to allow for accurate conclusions to be made regarding impacts of ALAN on sensitive receptors in close proximity to the surveyed sites.

5 REFERENCES

AUSTRALIAN/NEW ZEALAND STANDARD (2019) Control of the obtrusive effects of outdoor lighting (AS/NZS 4282:2019). SAI Global.

NORTH BARKER ECOSYSTEM SERVICES (2021) Bridgewater Bridge Replacement Natural Values Assessment. Unpublished report for Burbury Consulting, Version 1.0, 12th January 2021.

Appendix A: Lux Measurements

Table A1: Lux readings and GPS locations

Lux	Latitude	Longitude
0	-42.7386	147.2256
0	-42.7382	147.2253
0	-42.7382	147.2252
0	-42.7384	147.2252
0	-42.7383	147.2253
0	-42.7385	147.2252
0	-42.7385	147.2253
0	-42.7386	147.2253
0	-42.7387	147.2254
0	-42.7387	147.2255
0	-42.7388	147.2256
0	-42.7387	147.2255
0	-42.7386	147.2255
0	-42.7386	147.2254
0	-42.7385	147.2253
0	-42.7385	147.2252
0	-42.7384	147.2251
0	-42.7384	147.225
0.01	-42.7383	147.2249
1.52	-42.7382	147.2248
3.45	-42.7382	147.2247
0.24	-42.7381	147.2246
0.04	-42.7381	147.2245
0	-42.7382	147.2243
0	-42.7382	147.2242
0	-42.7381	147.2241
0	-42.7381	147.2242
0	-42.7381	147.2244
2.66	-42.7381	147.2245
1.54	-42.7381	147.2246
0.24	-42.7382	147.2247
0.04	-42.7382	147.2248
0	-42.7383	147.2249
0	-42.7383	147.225
0	-42.7384	147.2251
0	-42.7383	147.2252
0	-42.7382	147.2253
0	-42.7383	147.2254
0	-42.7382	147.2255
0	-42.7383	147.2257
0	-42.7383	147.2258
0	-42.7383	147.2259

Lux	Latitude	Longitude
0	-42.7384	147.2259
0.55	-42.7385	147.2259
0.74	-42.7386	147.2259
0.26	-42.7386	147.226
0	-42.7387	147.2261
0.05	-42.7387	147.2262
1.42	-42.7387	147.2263
0.16	-42.7386	147.2263
0	-42.7385	147.2264
0	-42.7384	147.2264
0.11	-42.7383	147.2264
0.34	-42.7382	147.2264
0.62	-42.7381	147.2265
1.2	-42.738	147.2265
0.55	-42.7379	147.2265
1.34	-42.7379	147.2266
12.08	-42.7378	147.2266
19.36	-42.7378	147.2267
4.41	-42.7379	147.2268
3.02	-42.738	147.2268
1	-42.738	147.2267
0.85	-42.7381	147.2267
0.21	-42.7382	147.2268
0.53	-42.7381	147.2267
0	-42.7381	147.2267
3.24	-42.738	147.2269
2.23	-42.738	147.227
2.1	-42.7381	147.2271
11.62	-42.7382	147.227
9.61	-42.7383	147.227
8.61	-42.7382	147.2271
6.18	-42.7381	147.2271
0	-42.7377	147.2252
0	-42.7376	147.2252
0	-42.7375	147.2252
0	-42.7378	147.2251
0	-42.7377	147.225
0	-42.7377	147.2249
0	-42.7377	147.2248
0	-42.7377	147.2247
0	-42.7376	147.2245
0	-42.7376	147.2244
0	-42.74	147.2284
0	-42.74	147.2278
0	-42.7397	147.2281

Lux	Latitude	Longitude
2.89	-42.7397	147.228
3.87	-42.7396	147.2281
1.51	-42.7395	147.2282
0.37	-42.7394	147.2282
0.05	-42.7393	147.2283
0	-42.7392	147.2283
0	-42.7392	147.2284
0	-42.7391	147.2285
0	-42.739	147.2285
0	-42.7389	147.2286
0	-42.7388	147.2287
0	-42.7387	147.2287
0	-42.7386	147.2288
0	-42.7386	147.2288
0	-42.7385	147.2289
0	-42.7384	147.229
0	-42.7383	147.229
0	-42.7382	147.2291
0	-42.7381	147.2292
0	-42.7381	147.2292
0	-42.738	147.2293
0	-42.7379	147.2293
0	-42.7378	147.2294
0	-42.7377	147.2294
0	-42.7376	147.2295
0	-42.7375	147.2296
0	-42.7375	147.2297
0	-42.7374	147.2297
0	-42.7375	147.2298
0	-42.7376	147.2298
0	-42.7377	147.2298
0	-42.7378	147.2299
0	-42.7378	147.23
0	-42.7379	147.2299
0	-42.7381	147.2298
0	-42.7381	147.2297
0	-42.7382	147.2297
0	-42.7383	147.2296
0	-42.7384	147.2296
0	-42.7386	147.2295
0	-42.7387	147.2295
0	-42.7388	147.2295
0	-42.739	147.2295
0	-42.7391	147.2294
0	-42.7392	147.2294

Lux	Latitude	Longitude
0	-42.7394	147.2294
0	-42.7395	147.2293
0	-42.7397	147.2293
0	-42.7398	147.2292
0	-42.74	147.2291
0	-42.74	147.229
0	-42.7401	147.229
0	-42.7402	147.2289
0	-42.7401	147.2287
0	-42.7401	147.2286
0	-42.74	147.2285
0	-42.74	147.2284
0	-42.7399	147.2282
0	-42.7398	147.228
0	-42.7398	147.2279
0	-42.7397	147.2278
0	-42.7397	147.2277
0	-42.7398	147.2275
0	-42.7399	147.2275
0	-42.74	147.2274
0	-42.74	147.2273
0	-42.7401	147.2273
0	-42.7402	147.2272
0	-42.7403	147.2272
0	-42.7404	147.2273
0	-42.7405	147.2274
0	-42.7406	147.2275
0	-42.7407	147.2276
0	-42.7408	147.2277
0	-42.7408	147.2278
0	-42.7408	147.2279
0	-42.7409	147.228
0	-42.7409	147.2281
0	-42.741	147.2281
0	-42.741	147.228
0	-42.7411	147.2281
0	-42.7412	147.2281
0	-42.7411	147.2281
0	-42.741	147.228
0	-42.7409	147.228
0	-42.7408	147.2278
0	-42.7408	147.2277
0	-42.7407	147.2276
0	-42.7406	147.2276
0	-42.7406	147.2275

Lux	Latitude	Longitude
0	-42.7405	147.2274
0	-42.7404	147.2273
0	-42.7403	147.2273
0.42	-42.7402	147.2273
0.65	-42.7401	147.2274
0.92	-42.74	147.2275
0	-42.74	147.2275
0.09	-42.7399	147.2276
0.98	-42.7399	147.2278
3.15	-42.7398	147.2279
6.46	-42.7398	147.228
1.29	-42.7399	147.2281
25.94	-42.74	147.2281
0.29	-42.7401	147.228
0.62	-42.7402	147.228
1.96	-42.7401	147.228