ARTIFICIAL LIGHTING IMPACT ASSESSMENT REPORT

Port Hedland Marina

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Artificial lighting impact assessment report
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ACKNOWLEDGEMENTS

This Artificial Lighting Impact Assessment Report has been prepared by RPS Australia West Pty Ltd for DevelopmentWA and has been based upon the following key subconsultant deliverables:

1. Preliminary Lighting Design and Line of Site analysis prepared JDSi Consulting Engineers
2. Benchmark Artificial Light at Night Survey prepared by Pendoley Environmental.

A technical review of the draft Artificial Lighting Impact Assessment Report was undertaken by Dr. Kellie Pendoley and Adam Mitchell of Pendoley Environmental. Reference sources were not read in conjunction with the review, which focused specifically on the content contained with the draft Artificial Lighting Impact Assessment Report.

Kellie was a co-author of and Adam a co-contributor to the draft document upon which the draft National Light Pollution Guidelines for Wildlife including marine turtles, seabirds and migratory shorebirds (Department of the Environment and Energy 2019a) are based.

SUMMARY

Location and land use

The Port Hedland marina (the marina) is proposed to be constructed on the spoilbank and is approximately 1.5 kilometres (km) north-east of the Port Hedland town centre (Figure A).

The spoilbank consists of both naturally occurring coastal land and reclaimed (man-made) land formed from the deposition of dredge spoil from the Port Hedland harbour and adjoining navigation channel. The spoilbank is predominantly vacant land with the only significant development on the spoilbank is a yacht club and dry dock area.

The spoilbank is primarily reserved for 'Parks and Recreation' under the Town of Port Hedland's (ToPH) Local Planning Scheme No. 5 (Figure B). The spoilbank is managed by the ToPH for informal recreation purposes, including fishing, four-wheel driving and general recreation.

Proposed marina development

The marine and terrestrial components of the proposed marina development include:

- Four-lane boat ramp
- Two breakwaters and internal revetment walls
- A separate access channel to exit into deeper water, plus long-term capacity up to 80 boat pens
- Public open recreational space and improved public access
- Parking
- Toilet facilities
- Areas for pop-up stalls.

The concept design for the Port Hedland marina is presented in Figure 1.

Flatback turtle context

Of the regionally important flatback turtle nesting areas for the Pilbara coast flatback turtle genetic stock, Mundabullangana Station and Cemetery Beach are proximate to Port Hedland (Figure D).

Mundabullangana Station is a major flatback turtle nesting rookery, situated approximately 60 km southwest of Port Hedland. Mundabullangana Station supports a substantial reproductive flatback turtle population, with an estimated 1,861 female turtles nesting annually (Pendoley et al 2014).

Cemetery Beach is a minor flatback turtle nesting rookery, with the nesting area situated approximately 1.7 km to the east of the marina. Females nest between mid-October and January, with a peak in late November (Imbricata Environmental 2016). The population of nesting turtles appears to be relatively stable between 148 to 202 females/year (Pendoley Environmental (PENV) 2019).

Flatback turtles are protected species under both the Western Australian *Biodiversity Conservation Act 2016* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Purpose of this report

The purpose of this Artificial Light Impact Assessment report is to demonstrate that artificial light generated by the operation of the proposed marina development can be managed so that flatback turtles are:

- Not disrupted within, nor displaced from, important habitat
- Able to undertake critical behaviours such as reproduction and dispersal.

This Artificial Light Impact Assessment report addresses:

- Potential artificial light impacts from the operational marina only

- The first three steps in the Commonwealth's recently released draft National Light Pollution Guidelines for Wildlife including marine turtles, seabirds and migratory shorebirds (draft Light Pollution Guidelines; Department of the Environment and Energy (DEE) 2019a) only. It is anticipated that an artificial light management plan, inclusive of biological and artificial light monitoring and auditing requirements, would be prepared for the proposed marina development to accord with steps four and five of the draft Light Pollution Guidelines (DEE 2019a) framework.

Benchmark artificial light at night survey

A benchmark artificial light at night survey (PENV 2020; Appendix B) was undertaken by PENV in late September – early October 2019 to obtain a qualitative set of benchmark data for the existing Cemetery Beach night environment, with specific reference to the Cemetery Beach flatback turtle nesting area (Cemetery Beach nesting area), to inform the likely effect of the proposed marina development.

The port operations, inclusive of loading, processing and stockpiling activities, was identified as the most dominant source of skyglow in Port Hedland (Figure F; PENV 2020). Point sources of artificial light that were directly visible from the Cemetery Beach nesting area included the Port Hedland Community Park, water tower, streetlighting, Port Hedland council building, Ibis Styles Port Hedland hotel and offshore vessels (Figure F; PENV 2020).

Existing artificial light impacts to flatback turtles at Cemetery Beach

Nesting female turtles

The relative stability of the nesting population suggests that existing artificial light impacts are not deterring adult females from nesting at Cemetery Beach. However, the relative density of nests between 2004 to 2013 does indicate that the nesting turtles prefer the eastern side of Cemetery Beach, where the dunes are higher providing a taller darker horizon cue behind the beach for orientation and some shielding from onshore artificial light sources (Figure E; Imbricata Environmental 2016).

Hatchlings

The Care for Hedland Environmental Association's hatchling orientation data for the 2018/2019 and 2019/2020 nesting seasons shows a wide spread of tracks with a minor bias towards western sources of artificial light (PENV 2020), which include the Port Hedland Community Park, Sutherland Street streetlights and skyglow from the port operations.

Key impact and proposed mitigation measures

Pole mounted lighting along the main access road and within the parking and hardstand areas of the proposed marina development is visible to hatchlings from the Cemetery Beach nesting area. The visible pole mounted lights could increase hatchling disorientation towards the west of Cemetery Beach.

The preliminary lighting design (JDSi Consulting Engineers; Appendix A) for the marina has been prepared to accord with the draft Light Pollution Guidelines (DEE 2019a), and the Environmental Protection Authority's (EPA) Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts (EAG 5; EPA 2010), while meeting legislative and regulatory requirements for human safety. In respect to the visible pole mounted lights, the preliminary lighting design uses:

- Minimum number and intensity of lights required to safely light the main access road and parking and hardstand areas to accord with road and outdoor public space requirements
- Amber LED lights (i.e. primarily long wavelength emitting lighting). The use of amber LED lights is considered suitable for use proximate to marine turtle habitat by DEE (2019a).

Given that artificial light pollution in Port Hedland is moderated by distance to the port operations, and together with the low lumen outputs of the proposed lighting, it is considered unlikely that the implementation of the proposed marina development would cumulatively add to the existing skyglow levels (Pendoley Environmental 2020).

To further reduce the potential for increased hatchling disorientation:

- Shielding should be installed on the east facing side (i.e. side facing towards the Cemetery Beach nesting area) of the pole mounted lights along the main access road to assist in reducing the line of sight visibility of these lights to hatchlings within the Cemetery Beach nesting area
- As part of the preparation of the artificial light management plan, consideration should also be provided to
  - Switching off the pole-mounted lighting during turtle hatching (early December to mid-February) when use is not required. Alternatively, a curfew time could be implemented for marina operations with the pole mounted lights being switched off from a particular time during turtle hatching
  - Planting screening vegetation along the eastern side of the main access road. The planted vegetation may assist in reducing the number of lights visible to hatchlings from the Cemetery Beach nesting area. Further, hatchlings are known to orient away from the elevated darker silhouettes of the dunes and / or vegetation, toward the lower, brighter seaward horizon. The planting of screening vegetation may assist in creating a less homogenous, more elevated horizon between the proposed marina development and the Cemetery Beach nesting area
  - Shielding on the eastern facing side of the pole mounted lights located within the parking and hardstand areas to the extent that compliance with AS/NZS 1158.3.1:2018 is not unreasonably compromised.

After the implementation of the best practice lighting design principles identified in the draft Light Pollution Guidelines (DEE 2019a), and EAG 5 (EPA 2010) key principles for lighting management:

- The residual risk to hatchling disorientation towards the west of Cemetery Beach being increased from the implementation of the proposed marina development is anticipated to be minimal in the context the existing artificial light impacts from point sources including the Port Hedland Community Park and Sutherland Street streetlights as well as skyglow from the port operations.
- The lighting design for the proposed marina development will meet legislative and regulatory requirements for human safety whilst addressing the biological diversity and ecological integrity of flatback turtles.

1 BACKGROUND

Artificial light at night provides for human safety, amenity and increased productivity, the provision of which is regulated by Australian legislation, regulation and standards for the purpose of human safety. Where there are competing objectives for lighting, creative solutions need to be employed which address both human safety requirements for artificial light and critical behaviours and physiology of conservation significant fauna species, such as marine turtles (Department of the Environment and Energy (DEE) 2019a).

1.1 Port Hedland artificial lighting

The industrialised landscape of Port Hedland's West End is home to the world's largest bulk export port, which primarily facilitates the export of iron ore. The port is comprised of 19 shipping berths including Utah Point, Nelson Point, Finucane Island, Anderson Point and Stanley Point, which provide for the continuous shipping operations (24 hours a day). Shipping operations, coupled processing, stockpiling and loading activities surrounding and servicing the port collectively contribute a significant amount of artificial light to the existing Port Hedland night environment. Other residential and commercial sources of artificial light include public open space lighting, sporting oval lights, and streetlights.

Artificial light from existing development in Port Hedland represents a significant increase in light levels that would otherwise be present from natural sources (stars and the moon). Due to the proximity of the port and associated industrial activities, the night environment in the West End is substantially more illuminated (from artificial light) when compared to the undeveloped rural areas around Port Hedland.

1.2 Port Hedland marina

1.2.1 Background

The Port Hedland marina (the marina) has been the subject of numerous environmental and planning studies over recent years in response to a recognised need for marina facilities in the community, including boat launching facilities.

The Port Hedland Land Use Masterplan (Town of Port Hedland (ToPH) 2007) identified that planning for the development of a new marina on the western side of the spoilbank was underway. In 2011 the ToPH appointed a "Port Hedland Spoil Bank Marina Stakeholder Committee" to work with the project managers (then LandCorp)[1] in the development of the spoilbank into a waterfront tourist attraction.

In 2012, LandCorp prepared a State Government submission for the development of marina infrastructure, land for marina associated uses (including hardstand including provision for a boat lifter, boat repair and service, outboard / diesel mechanic chandler, fibreglass and shipwright, marine electronic, refuelling jetty facility and tank farm) and a caravan park site on the spoilbank. The concept plan also proposed high density permanent residential development surrounding the marina as well as other retail and commercial uses. The ToPH also committed $40 million of funding towards development projects on the spoilbank. The marina subsequently received State Government approval for the allocation of $112 million of State funding in July 2012, with LandCorp assigned the role of project manager.

The scale and land use of the marina was to be confirmed via a scheme amendment seeking to rezone the land to include permanent residential development. LandCorp and the ToPH commenced the rezoning process for the proposed residential land use in August 2012. The process included extensive consultation with the respective government agencies. In February 2014, the Environmental Protection Authority (EPA) formally advised the environmental issues pertaining to the Scheme Amendment could not be resolved prior to the publication of the health risk assessment for particulate matter by the Department of Health.

[1] Now DevelopmentWA

In May 2014, the ToPH, BHP Billiton and the state government agreed to a joint funding arrangement to investigate Cooke Point in greater detail as an alternative marina location to the government approved spoilbank location. In June 2014, the Port Hedland Waterfront Place Plan (Village Well 2014) was finalised to assist with site selection as well as briefs for future design works and to communicate the project vision to the community and potential partners. The completion of this additional due diligence was considered at the ToPH's 13 May 2015 Special Council meeting where Council resolved as follows:

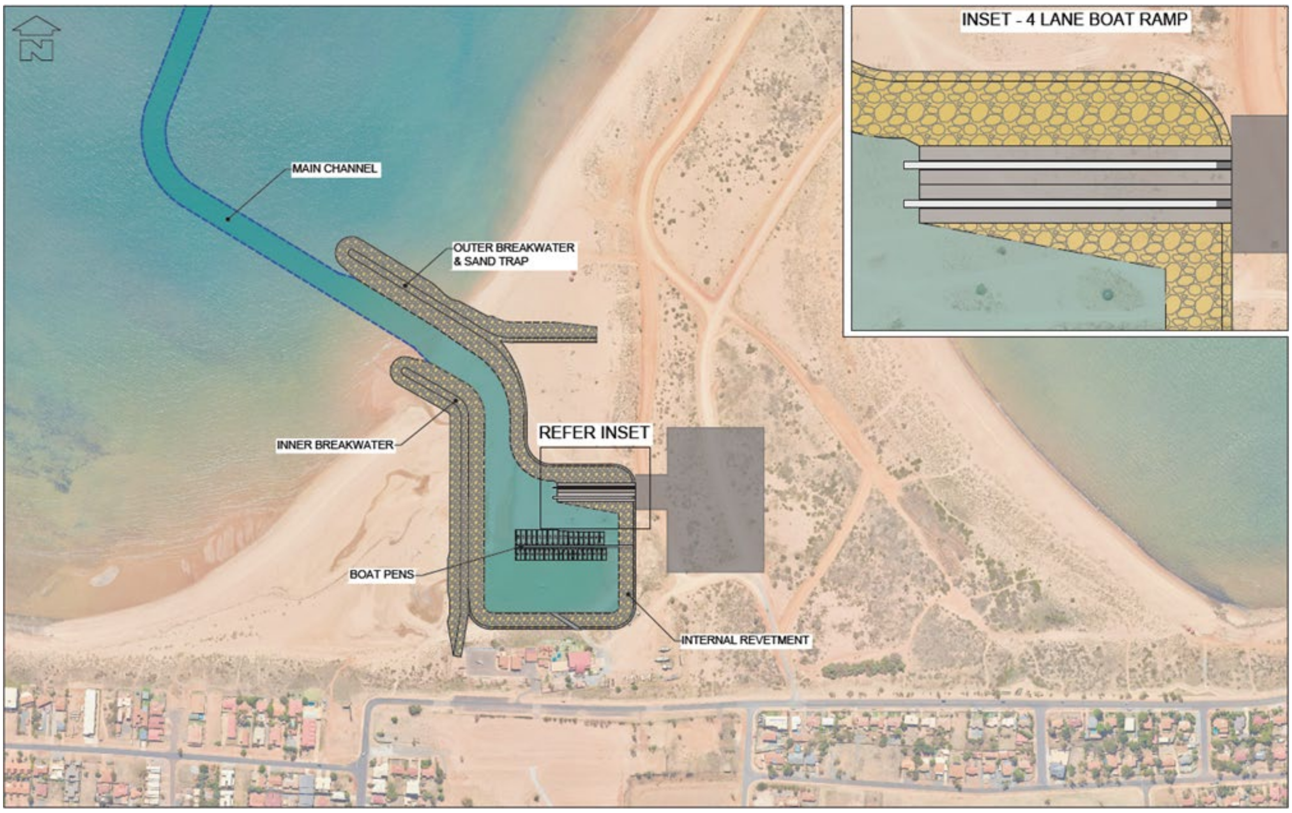
1. Reconfirms its commitment to the spoilbank as its preferred location for the development of a Marina Waterfront Development (Stage 1) as part of the ToPH's Waterfront Precinct Development Plan.
2. Endorses the Marina Waterfront Development (Stage 1) containing, but not limited to the following key components:
    a. Marina development with a maximum of 100 boat pens together with 4 boat launching ramps in Stage 1
    b. There being no residential development in the Marina Waterfront Development (Stage 1)
    c. A lagoon style swimming facility
    d. A community events space
    e. Commercial/retail space
    f. Continued public access to the balance of the spoilbank
    g. A suitable site being identified for an eco-tourism/caravan park development
3. Note that the following issues are supported:
    a. At the completion of the Marina Waterfront Development project that the existing Richardson Street boat ramp be removed
    b. Continued support for the development on the hospital site (proposed Finbar development) for a residential development
    c. The investigation of a suitable Town Planning instrument to be applied across the West End to restrict future densification of residential development
    d. The ToPH pursue the granting of the current Gratwick Aquatic Centre site in freehold title to assist in funding community amenities such as a new waterfront lagoon swimming facility after the completion of the Marina Waterfront Development project
4. Requests the Chief Executive Officer to review all works to-date and finalise a detailed Business Case for the Spoilbank Marina Waterfront Development (Stage 1) to be presented to Council for consideration at a later date.
5. Notes that further reports on a risk assessment (including shipping channel) and economic analysis of the Spoilbank Marina Waterfront Development (Stage 1) will be presented to Council for consideration at a later date as part of the Business Case.
6. Commence negotiations towards a funding agreement with the Western Australian Government for $112 million for the Marina Waterfront Development (Stage 1), while at the same time exploring further grant and/or partnership funding opportunities to further support the development of the project.
7. Continues to engage and inform the community and stakeholders on the Marina Waterfront Development Plan.

The ToPH and LandCorp have progressed further investigations to confirm the scope, demand and ongoing operational feasibility of the marina including:

- Community consultation and engagement to confirm demand for community space and for take-up of boat pens
- Needs analysis and preliminary feasibility of a proposed cultural and community centre building
- Design and costing for the development of a recreation swimming facility within the precinct
- Demand, feasibility and economic impact assessments of a caravan park/ transit park.

The Spoilbank Boating Facilities Taskforce was established in October 2017, with its membership including the Pilbara Development Commission, Department of Primary Industries and Regional Development, LandCorp and the Department of Transport (DoT).

Two concept plans were developed, with preference being given to the design which included a separate channel from the main Port Hedland shipping channel. On 15 October 2018 the State Government approved the preferred concept for the marina (Figure 1), confirmed a $94 million contribution to the delivery of the marina and endorsed the DoT progressing the proposal to the detailed design phase.



(Source: DoT 2019)

Figure 1: Preferred marina concept

Concurrently the ToPH allocated $13 million to prepare a masterplan and associated feasibility, with the balance utilised for landside public and civil infrastructure works. The draft Port Hedland Marina and Waterfront Masterplan (Taylor Burrell Barnett 2019) was subsequently prepared to explore the transformation of the spoilbank into a vibrant waterfront development, focusing on exploring an appropriate structure of recreation spaces, infrastructure and amenities and the inter-relationship with the public realm.

1.2.2 Location and land use

The marina is located approximately 1.5 km north-east of the Port Hedland town centre (Figure A) and is situated on two parcels of Crown Land that make up the spoilbank (Crown Reserve 30768):

1. Lot 5550 on Deposited Plan 240246 on Certificate of Crown Land Title Volume LR3060 Folio 414
2. Lot 5751 on Deposited Plan 91579 on Certificate of Crown Land Title Volume LR3060 Folio 422.

Lot 370 on Deposited Plan 35619 on Certificate of Crown Land Title Volume LR3118 Folio 753 includes the marine portion of the marina footprint and is managed by Pilbara Ports Authority.

The spoilbank consists of both naturally occurring coastal land and reclaimed (man-made) land formed from the deposition of dredge spoil from the West End port and adjoining navigation channel. The spoilbank is predominantly vacant land with the only significant development on it being a yacht club and dry dock area. The spoilbank is managed by the ToPH for informal recreation purposes, including fishing, four-wheel driving and general recreation.

1.2.3 Zoning

The spoilbank is primarily reserved for 'Parks and Recreation' under the ToPH's Local Planning Scheme (LPS) No. 5. A small portion of the spoilbank is also reserved for 'Waterways' under LPS No. 5 (Figure B).

1.2.4 Description

Development of the marina will assist in facilitating the planning outcomes envisioned for the West End precinct by the ToPH's Pilbara's Port City Growth Plan (ToPH 2011), Waterfront Place Plan (Village Well 2014) and draft Port Hedland Marina and Waterfront Masterplan (Taylor Burrell Barnett 2019).

The marina includes the following marine and terrestrial components:

- Four-lane boat ramp
- Two breakwaters and internal revetment walls
- A separate access channel to exit into deeper water, plus long-term capacity up to 80 boat pens
- Public open recreational space and improved public access
- Parking
- Toilet facilities
- Areas for pop-up stalls.

1.2.5 Flatback turtles

The marina is situated approximately 1.7 km from the Cemetery Beach flatback turtle nesting area (Cemetery Beach nesting area). The flatback turtle is a protected species under the Western Australian *Biodiversity Conservation Act 2016* (BC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Flatback turtles are also recognised in the EPA's Environmental Assessment Guideline for Protecting Marine Turtles from Light Impacts (EAG 5; EPA 2010), which identifies Cemetery Beach as being exposed to significant lighting from existing and planned residential development and iron ore shipping.

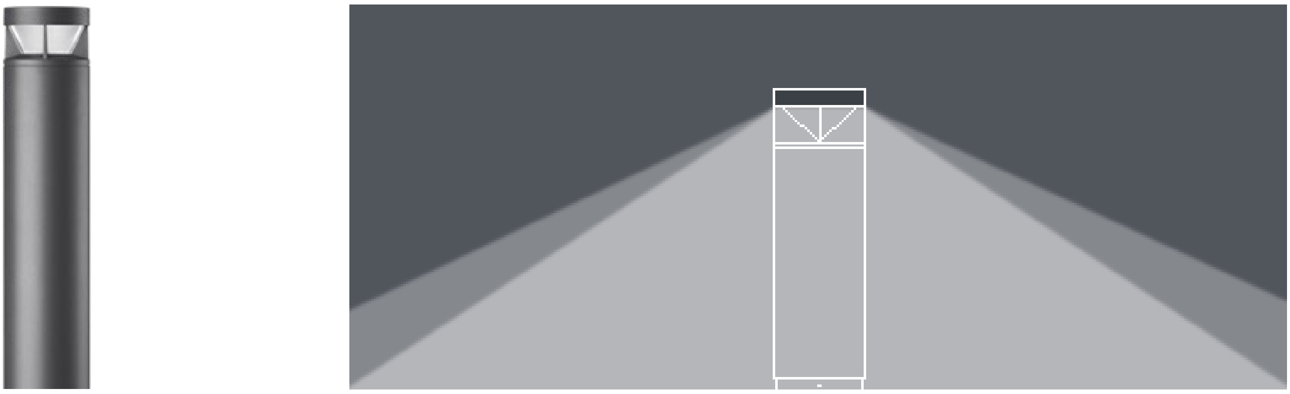
1.2.6 Lighting requirements

Artificial light is required for the proposed marina development to comply with Australian legislation, regulation and standards for human safety.

A preliminary lighting design for the marina has been developed by JDSi Consulting Engineers (JDSi; Appendix A). Bollard lighting is proposed to be implemented within the marina's basin, with pole mounted lighting required along the main access road and within the adjacent parking and hardstand areas. Amber LED lights (i.e. primarily long wavelength emitting lighting) are proposed to be used.

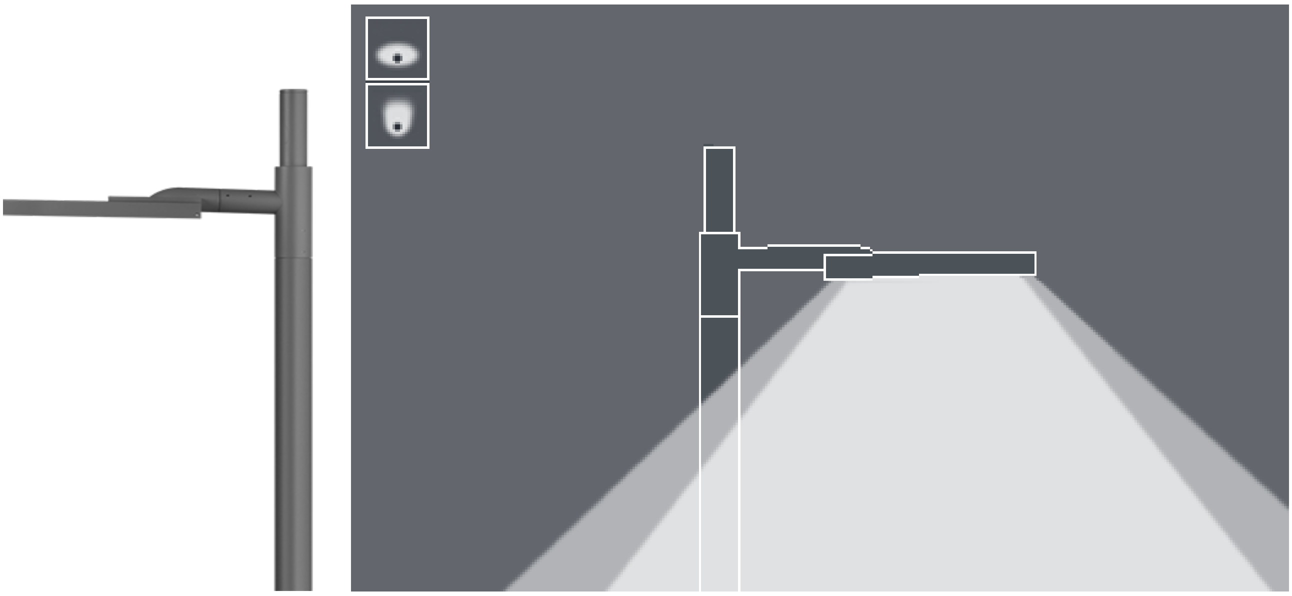
The bollard lights (we-ef KTY234) are approximately one metre high (Figure 2). The pole mounted lights (we-ef VFL530-SE, we-ef VFL530 and we-ef VFL540) vary in height between approximately four and eight metres (Figure 3 and Figure 4).

The pole mounted lights are proposed to be mounted horizontally relative to the ground to prevent light from shining above the horizontal plane and contributing to skyglow (Figure 3 and Figure 4). The pole mounted lights have been certified by independent assessors as meeting the Australian Dark Sky Alliance's (ADSA) night light criteria (ADSA 2019).



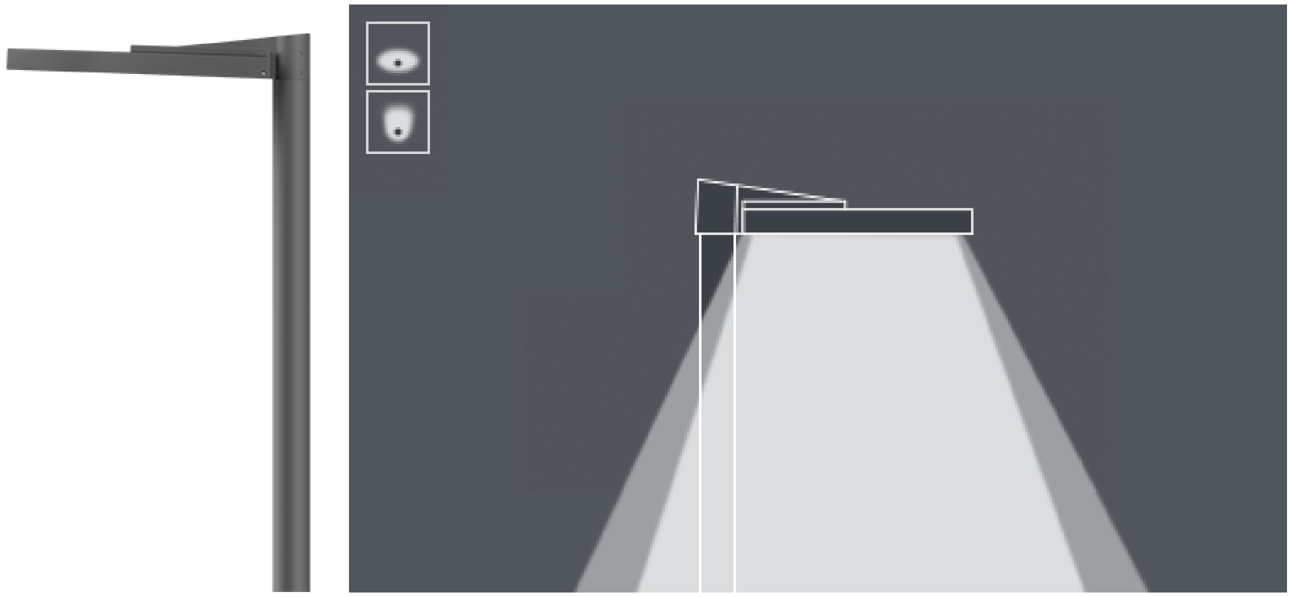
(Source: we-ef 2020a)

Figure 2: we-ef KTY234, light is approximately one metre high



(Source: we-ef 2020b)

Figure 3: we-ef VFL530-SE, light to be mounted on a four metre pole



(Source: we-ef 2020b)

Figure 4: we-ef VFL530 / we-ef VFL540, light to be mounted on a six / eight metre pole

1.3 Purpose of this report

The purpose of this Artificial Light Impact Assessment report is to demonstrate that artificial light generated by the operation of the proposed marina development can be managed so that flatback turtles, and other species of marine turtles, are:

- Not disrupted within, nor displaced from, important habitat
- Able to undertake critical behaviours such as reproduction and dispersal.

This Artificial Lighting Impact Assessment Report addresses potential artificial light impacts from the operational marina only. Other potential impacts to marine turtles during the construction and operation of the marina, such as entrainment during dredging and boat strike, will be addressed as part of a holistic environmental impact assessment for the proposed marina development.

1.4 Structure of this report

This Artificial Light Impact Assessment Report reviews the existing night environment at Cemetery Beach, with specific reference to the Cemetery Beach nesting area, to inform the significance of the potential artificial light impacts of the proposed marina development upon flatback turtles. Specifically, this outcome has been achieved through:

- Providing a description and overview of lighting requirements for the proposed marina development (Section 1.2.6)
- Detailing the legislative and regulatory context relating to flatback turtles (Section 2)
- Reviewing the key biological attributes of flatback turtle (Section 3)
- Identifying the potential artificial light impacts to marine turtles (Section 4)
- Describing the local and regional significance of the Cemetery Beach nesting area (Section 5)
- Reviewing the existing artificial light sources proximate to Cemetery Beach (Section 6)
- Identifying and assessing potential artificial light impacts from the proposed marina development to flatback turtles (Section 7)
- Providing design outcomes to reduce potential artificial light impacts to flatback turtles from the proposed marina development (Section 8)
- Reviewing the residual impacts to flatback turtles from the proposed marina development after the implementation of the preliminary lighting design (Section 9).

This Artificial Light Impact Assessment Report addresses the first three steps in the Commonwealth's draft National Light Pollution Guidelines for Wildlife including marine turtles, seabirds and migratory shorebirds (draft Light Pollution Guidelines; DEE) 2019a):

1. Describe the project lighting
2. Describe wildlife
3. Risk assessment
4. Artificial light management plan
5. Biological and artificial light monitoring and auditing.

It is anticipated that an artificial light management plan, inclusive of biological and artificial light monitoring and auditing requirements, would be prepared for the proposed marina development to accord with steps four and five of the draft Light Pollution Guidelines (DEE 2019a) framework.

2 LEGISLATIVE AND REGULATORY CONTEXT

2.1 State legislation and guidance

2.1.1 *Biodiversity Conservation Act 2016* (BC Act)

The objectives of the BC Act are to provide for the conservation and protection of biodiversity and biodiversity components; and promote the ecologically sustainable use of biodiversity components. The BC Act is administered by the Director General of the Department of Biodiversity Conservation and Attractions (DBCA) under the direction and control of the Minister for the Environment.

The BC Act provides for taxa of fauna to be listed as specially protected, Threatened (Critically Endangered, Endangered or Vulnerable) or Extinct in Western Australia.

The BC Act affords seven levels of special protection:

- Schedule 1 – being fauna that is rare or likely to become extinct, as critically endangered fauna, are declared to be fauna that needs special protection
- Schedule 2 – being fauna that is rare or likely to become extinct, as endangered fauna, are declared to be fauna that needs special protection
- Schedule 3 – being fauna that is rare or likely to become extinct, as vulnerable fauna, are declared to be fauna that needs special protection
- Schedule 4 – being fauna that is presumed to be extinct, are declared to be fauna that needs special protection
- Schedule 5 - being birds that are subject to international agreements relating to the protection of migratory birds, are declared to be fauna that needs special protection
- Schedule 6 - being fauna that are of special conservation need being species dependent on ongoing conservation intervention, are declared to be fauna that needs special protection
- Schedule 7 - are declared to be fauna that needs special protection otherwise than for the reasons mentioned in Schedules 1 to 6.

The flatback turtle is listed in Schedule 3 under the BC Act as Vulnerable.

2.1.2 Environmental protection authority guidance

2.1.2.1 Environmental factor guideline marine fauna

The EPA's environmental factor guideline for marine fauna:

- Describes the factor Marine Fauna and explains the associated objective
- Describes environmental impact assessment considerations for this factor
- Discusses the environmental values of marine fauna, and their significance
- Describes issues commonly encountered by the EPA during environmental impact assessment of this factor
- Identifies activities that can impact on marine fauna
- Provides a summary of the type of information that may be required by the EPA to undertake environmental impact assessment related to this factor.

2.1.2.2 Environmental assessment guideline for protecting marine turtles from light impacts

The EPA developed EAG 5 to specifically address approaches to proposal design and implementation to protect marine turtles from the adverse impacts of light. EAG 5 sets out:

- Guidance on an array of approaches available for avoiding, reducing, managing and mitigating light impacts on marine turtles to be considered when preparing documentation relevant to the environmental impact assessment process and during the implementation of proposals or planning schemes
- Alternative methods for the avoidance and management of light impacts that can be applied using a risk-based approach and by applying best practice methods.

Specifically, EAG 5 identifies the following key principles for light management applicable to coastal development projects from Shark Bay northwards:

- Keep it OFF (keep light off the beach and lights off when not needed)
- Keep it LOW (mount lights low down with the lowest intensity for the job)
- Keep it SHIELDED (stop all light escaping upwards and outwards)
- Keep it LONG (use long wavelength lights).

2.2 Commonwealth legislation and guidance

2.2.1 *Environmental Protection and Biodiversity Conservation Act 1999*

The objectives of the EPBC Act are to:

- Provide for the protection of the environment, especially Matters of National Environmental Significance (MNES)
- Conserve Australian biodiversity.
- Provide a streamlined national environmental assessment and approvals process.
- Enhance the protection and management of important natural and cultural places.
- Control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife.
- Promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources.
- Recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity.
- Promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

The EPBC Act protects MNES, with state legislation providing for the protection of matters of state and local significance. MNES that relate to native fauna are:

- Listed threatened species
- Migratory species protected under international agreements.

The flatback turtle is listed as Vulnerable under the EPBC Act indicating that the species is not critically endangered or endangered but is facing a high (10%) risk of extinction in the wild in the medium-term future (DEE 2019b).

2.2.1.1 Recovery Plan for Marine Turtles in Australia

The Recovery Plan for Marine Turtles in Australia (DEE 2017) identifies that habitat critical to the survival of a species for marine turtle stocks has been identified by consensus of a panel of experts in marine turtle biology. Specifically, regarding flatback turtles nesting and inter-nesting habitat has been identified based on the following criteria:

- Nesting habitat critical to the survival of flatback turtles includes at least 70% of nesting for the stock.
- Nesting habitat critical to survival of marine turtles is of a geographically relevant scale.
- Where relevant, nesting habitat determined to be critical to the survival of marine turtles includes areas that are: geographically dispersed; major and minor rookeries; mainland and island beaches; and winter or summer nesting.
- To ensure the validity of long-term monitoring programs for assessing trends in nesting turtle abundance, all index beaches are considered habitat critical to survival of marine turtles.
- Inter-nesting habitat critical to the survival of marine turtles is located immediately seaward of designated nesting habitat critical to the survival of marine turtles. The inter-nesting habitat critical buffer for flatback turtles is 60 km.

Cemetery Beach is identified as minor nesting rookery and an index beach, as it has monitored by the Care for Hedland Environmental Association's (CHEA) Community Volunteer Turtle Monitoring Program monitoring program since 2004/05 and is representative of the Pilbara Coast stock (Imbricata Environmental 2016; DEE 2017). Cemetery Beach and a 60km inter-nesting buffer area are designated as habitat critical to the survival of the flatback turtle (Figure C; DEE 2017).

2.2.1.2 Draft national Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds

Light pollution was identified as a high-risk threat in the Recovery Plan for Marine Turtles in Australia (DEE 2017) because artificial light can disrupt critical behaviours such adult nesting and hatchling orientation, sea finding and dispersal, and can reduce the reproductive viability of turtle stocks. A key action identified in the Recovery Plan was the development of guidelines for the management of light pollution in areas adjacent to biologically sensitive turtle habitat.

The draft Light Pollution Guidelines for Wildlife (DEE 2019a) have been developed to address potential impacts to critical behaviours in wildlife from artificial light. The aim of the draft Light Pollution Guidelines for Wildlife is that artificial light will be managed so wildlife is:

1. Not disrupted within, nor displaced from, important habitat[2]
2. Able to undertake critical behaviours such as reproduction and dispersal.

The draft Light Pollution Guidelines for Wildlife (DEE 2019a) recommend:

1. Always using best practice lighting design to reduce light pollution and minimise the effect on wildlife. Best practice lighting design principles that can be used to reduce light pollution, including:
    a. Start with natural darkness and only add light for specific purposes.
    b. Use adaptive light controls to manage light timing, intensity and colour.
    c. Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill.
    d. Use the lowest intensity lighting appropriate for the task.
    e. Use non-reflective, dark-coloured surfaces.
    f. Use lights with reduced or filtered blue, violet and ultra-violet wavelengths.

[2] Important habitat for marine turtles includes all areas that have been designated as habitat critical to survival of marine turtles and biologically important areas (DEE 2019a).

2. Undertaking an environmental impact assessment for effects of artificial light on wildlife for listed species for which artificial light has been demonstrated to affect behaviour, survivorship or reproduction.

This Artificial Lighting Impact Assessment Report addresses these two key recommendations for potential artificial light impacts to flatback turtles, and other species of marine turtles, from the proposed marina development.

3 FLATBACK TURTLE BIOLOGICAL ATTRIBUTES

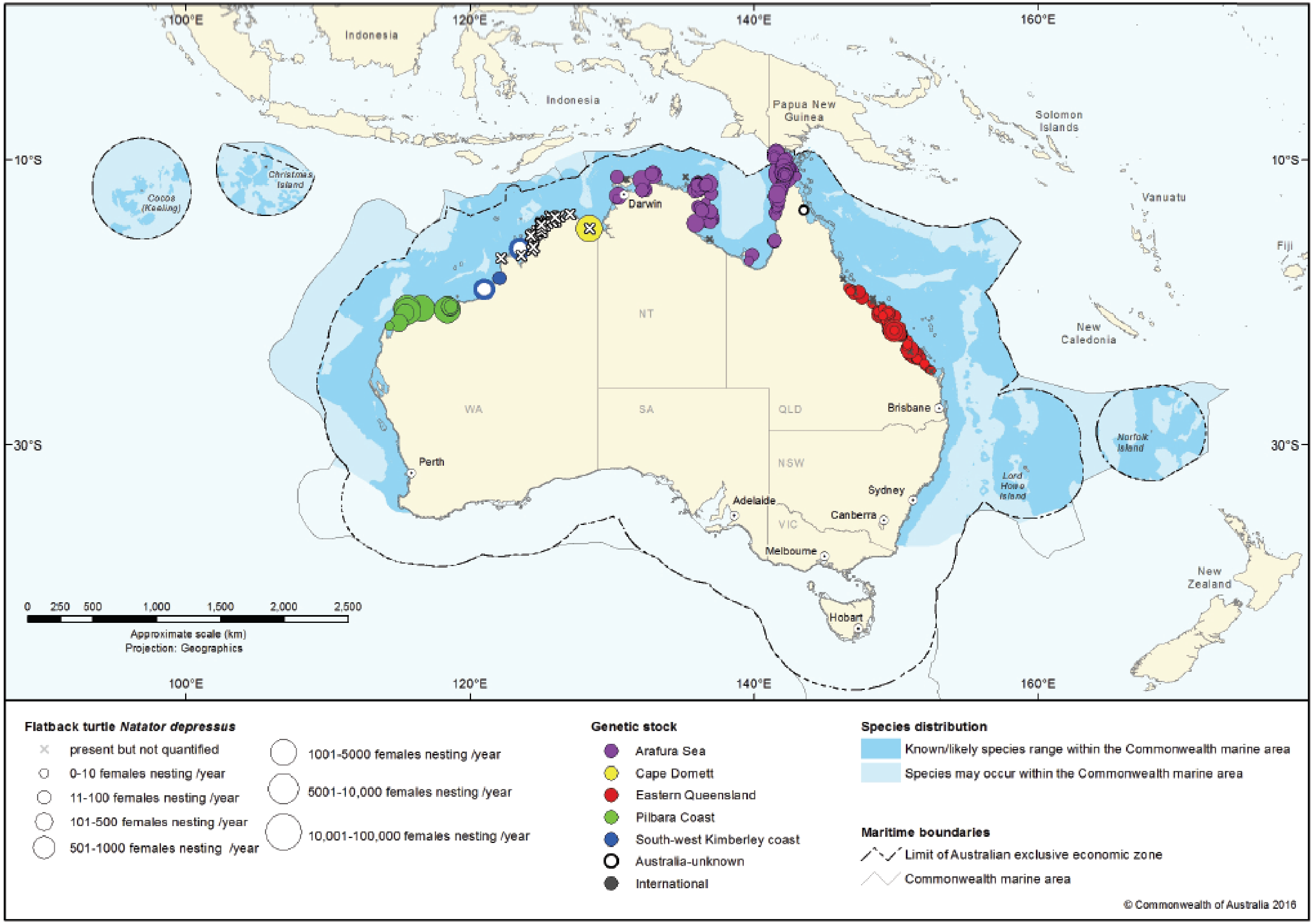
3.1 Distribution

Flatback turtles are widely distributed across northern Australian continental shelf (Limpus et al. 1989; Limpus 2007), Gulf of Papua New Guinea (Spring 1982), coastal waters of West Papua in Indonesia (Samertian and Noija 1994) and Kei in Eastern Indonesia (Suarez 2000). Their nesting distribution is restricted to tropical and subtropical Australian beaches (Limpus et al. 1981; 1983a; 1983b; Parmenter 1990; Schauble et al. 2006; Whiting and Guinea 2006; Limpus 2007; Whiting et al. 2008 and Waayers and Fitzpatrick 2013). Genetic studies have demonstrated that this restricted distribution is attributed to large distances between rookeries, lack of trans-oceanic migrations (Limpus 2007), and high nest site fidelity between nesting seasons.

The Recovery Plan for Marine Turtles in Australia (DEE 2017) identifies that five genetically distinct flatback turtle stocks have been established around Australia, however a recently published study by Fitzsimmons et al (2020) have identified seven distinct flatback turtle stocks. For the purpose of providing a general overview of flatback turtle distribution the DEE (2017) identified flatback turtle stocks have been referenced. These are:

1. Eastern Queensland
2. Arafura Sea
3. Cape Dommett
4. South-west Kimberly
5. Pilbara Coast.

Nesting sites for the Pilbara Coast genetic stock extend between Exmouth to the Lacepede Islands and across the Pilbara coast (Figure 5). Key nesting areas include Barrow Island, Mundabullangana Station and Delambre Island. Minor nesting areas are Thevenard, Varanus, Murion Islands, Montebello Group, Cemetery Beach and the Dampier Archipelago (DEE 2017). Post migration satellite tracking indicates that the Pilbara Coast stock is likely to forage along the coast of Western Australia and north to the Gulf of Carpentaria, and several likely important foraging grounds have been identified (Figure C; DEE 2017).



(Source: DEE 2017)

Figure 5: Flatback turtle nesting sites in Australia and surrounding regions

3.2 Biology

The flatback turtle belongs to the cheloniid family of turtles and is the only extant species in the genus. The flatback turtle has a low domed, fleshy carapace with reflexed margins and is grey, pale grey–green or olive in colour (Bustard 1972; Cogger 1996, Limpus 1971).

Flatback turtles appear to be primarily carnivorous throughout their lives, feeding on a variety of soft bodied invertebrates (DEE 2017). Juveniles eat gastropod molluscs, squid, siphonophores (Zangerl et al. 1988). Limited data indicate that cuttlefish (Chatto et al. 1995) and crinoids (Zangerl et al. 1988) and are also eaten. This combination of benthic and pelagic prey means they can forage in a range of habitats.

3.3 Habitat

Post-hatchling and young juvenile flatback turtles do not have the wide dispersal phase in the oceanic environment like other sea turtles and are thought to remain in waters over the Australian continental shelf (Walker and Parmenter 1990; DEE 2017). Juvenile to adult flatback turtles are known to favour soft bottom habitats that support benthic invertebrates.

Post-nesting satellite tracking indicates foraging occurs along the Western Australian coast in water shallower than 130 m and within 315 km of shore. High use areas include waters around Thevenard Island, adjacent to Eighty Mile Beach and Quondong Point, Lynher Banks and the Holothuria Banks (DEE 2017). Figure 6 shows the indicative dispersal for the Pilbara Coast as well as the four other genetic stocks.

3.4 Nesting and inter-nesting

Flatback turtles are believed to reach sexual maturity after 21 years of age (Limpus 2007) with reproductive half-life estimated at 10.1 years (Parmenter and Limpus 1995). Flatback turtles breed at intervals between one to five years (i.e. remigration interval) with a mean of 2.7 years (Limpus et al. 1983a; 1983b).

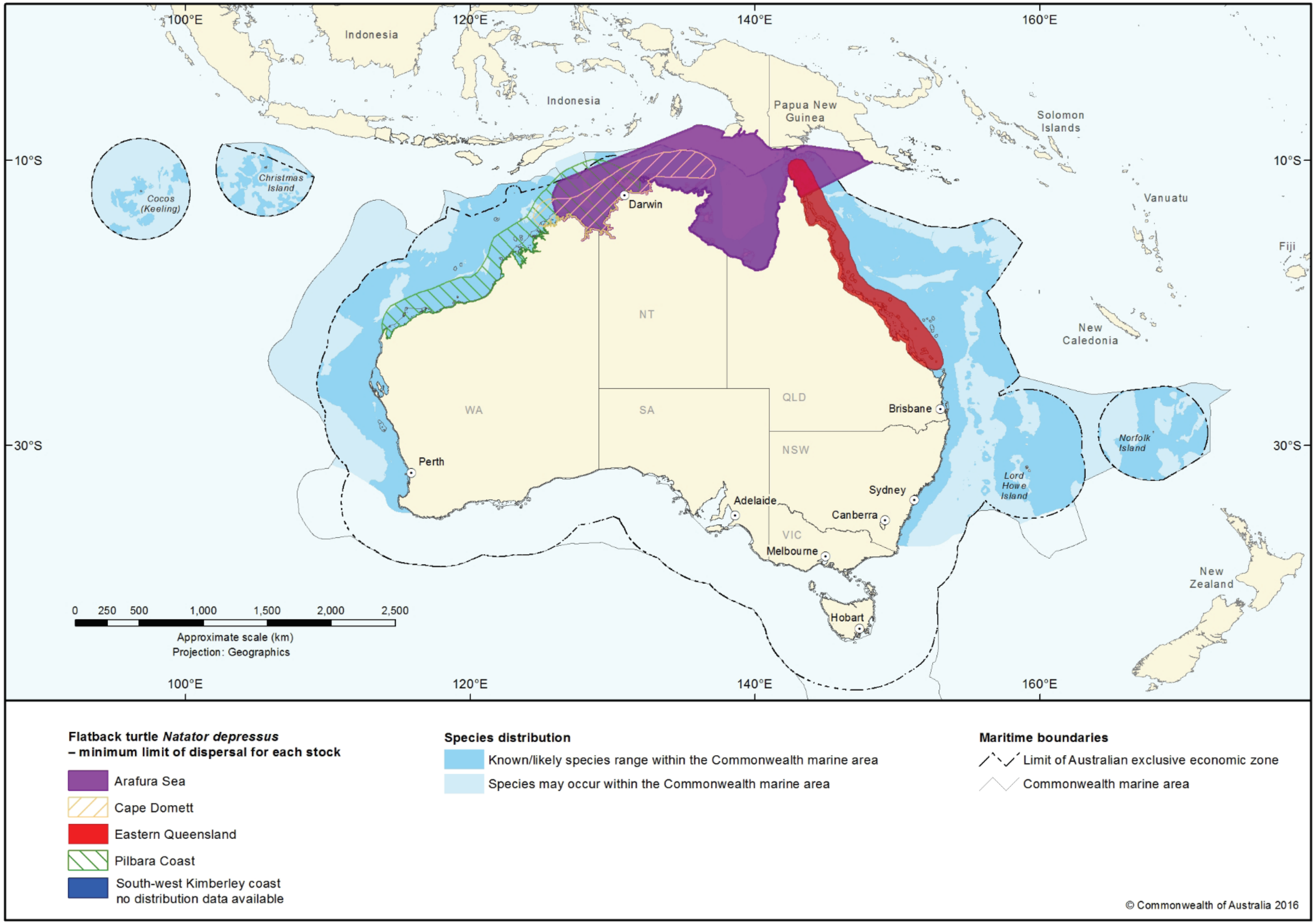
Females lay an average of 2.8 clutches per season on sandy beaches at an inter-nesting interval (i.e. time taken between laying successive egg clutches) of approximately 15 days. Clutches contain approximately 50 eggs with an average size of 5.2 centimetres (cm) in diameter and 78 grams in weight. Clutches are laid at a depth of 55 cm (Limpus 1971). The temperature of the sand around the nest is thought to determine the sex ratio of the hatchlings with more females hatching from warmer nests (> 29 °C) (Limpus 1995).

Successful incubation of eggs requires temperatures within the nest of between 25 ºC and 33 ºC, good ventilation, low salinity, high humidity and no disturbance (such as rotation) of the egg (Limpus 2007). Eggs incubate for around six weeks before hatchlings emerge from the nest and enter the sea.

Flatback turtle hatchlings are the largest of the marine turtle hatchlings and are strong swimmers. Once the hatchlings reach the water they swim away from the beach and begin their juvenile life, presumably in the coastal zone around their natal beach. Post-hatchlings are surface-water dwelling, feeding on macroplankton (Limpus 2007).

Little is known of the habits of juvenile flatback turtles, but after several decades they mature, return to the nearshore waters to breed and thus complete the lifecycle. Survivorship from hatchling emergent to maturity is estimated at less than 0.0026 (Parmenter and Limpus 1995).

The female flatback turtle displays a high degree of fidelity to her chosen nesting beach, with most females returning to the same beach within a nesting season and in successive nesting seasons (Limpus 2007). It is not known, however, whether this fidelity is the result of imprinting to the natal beach during the egg or hatchling phase (Limpus 2007). Flatback turtles show a preference for nesting in sand dunes or the steep seaward slope of beaches and rarely come ashore to nest on beaches fronted by intertidal coral reef flats (Limpus 2007).



(Source: DEE 2017)

Figure 6: Indicative dispersal for the flatback turtle stocks

4 LIGHTING AND MARINE TURTLES

4.1 Threats to turtles

The Recovery Plan for Marine Turtles in Australia (DEE 2017) identifies that the key threats to the Pilbara Coast flatback turtle stocks are:

- Climate change and variability is anticipated to cause changes in dispersal patterns, food webs, species range, primary sex ratios, habitat availability, reproductive success and survivorship.
- Acute chemical and terrestrial discharge refers to any release of pollutants and/or sediment into marine turtle habitat, including spills from land sources, vessels, drilling operations, and natural sources.
- Light pollution can inhibit nesting by females and disrupt hatchling orientation and sea finding behaviour.
- Coastal development around nesting beaches has the potential to reduce the reproductive success of a stock by direct mortality where nests are destroyed, reducing availability of suitable nesting habitat and impacting the quality of the nesting habitat.
- Coastal infrastructure, such as marinas, can reduce the availability of important marine turtle habitat.

4.1.1 Life stages considered to be at risk

Marine turtles are long-lived animals and therefore, changes to reproductive success and/or mortality rates can potentially exert substantial long-term demographic effects. Based on the findings of previous studies in the region, the marine turtle life stages considered to be at potential risk from artificial lighting from the marina include:

- Nesting female flatback turtles during the summer breeding season (mid-October to late January)
- Post-hatchling flatback turtles emerging from the nest and crawling across Cemetery Beach (early December to mid-February)
- Post-hatchling flatback turtles swimming from Cemetery Beach in the nearshore waters (early December to mid-February).

4.1.1.1 Effect of light on marine turtles

Artificial lighting has the potential to reduce the reproductive success of marine turtles by deterring adult females from approaching nesting beaches or nesting; and disorienting and / or misorienting hatchlings on the beach and in the nearshore environments (DEE 2019a).

The physical aspects of light that have the greatest effect on marine turtles include intensity, colour (wavelength), and elevation above beach. Management of these aspects assist in reducing potential artificial light impacts to marine turtles (DEE 2019a).

4.1.1.1.1 Nesting

Artificial lighting on or near nesting beaches has been shown to disrupt the nesting behaviour of marine turtles (Witherington and Martin 2003). Although lighting may not be the primary cause, nesting densities are typically lower at beaches exposed to artificial light than dark beaches (Salmon 2003). Artificial light may also mediate variations in adult female turtle nesting behaviours, such as the location of beach emergence, nest construction and whether nesting is abandoned, success of egg deposition, hatchling production and seaward return of adults (Witherington and Martin 1996).

Light types which exclude shorter wavelengths (i.e. blue to green light) do not appear to adversely affect nesting densities (Pennell 2000). On beaches exposed to light, higher nesting densities have been found in areas that are shadowed (e.g. from dunes and buildings), compared with illuminated areas (Salmon and Witherington 1995). Moving sources of artificial light may also deter nesting or cause disturbance to nesting females (e.g. flash photography) (Salmon 2006).

4.1.1.1.2 Beach environment

Artificial lighting may adversely affect hatchling sea-finding behaviour in two ways:

1. Disorientation – where hatchlings crawl on circuitous paths
2. Misorientation – where they move in the wrong direction, possibly attracted to artificial lights.

The consequence of this disruption to sea finding is often mortality, resulting from increased exposure to predation, dehydration and exhaustion (Witherington and Martin 1996; Salmon 2006). Table 1 provides a list of key environmental cues shown to inform hatchling sea-finding behaviour and identifies hatchling response to alteration of these cues by artificial light.

Table 1: Environmental cues and observed behaviour

Environmental cue	Observed hatchling behaviour
Light wavelength	Short wavelength light (i.e. blue to green and white light) is highly attractive to hatchlings. Long wavelength light (i.e. orange to red light) is relatively less attractive to hatchlings
Light intensity	• High intensity light is more attractive than low intensity light • High intensity long wavelength light may be more attractive than low intensity short wavelength light
Beach silhouettes (shape and form)	Hatchlings orient away from the elevated darker silhouettes of the dunes and / or vegetation, toward the lower, brighter seaward horizon
Light directivity	• Hatchlings integrate light over a broad area (~180°). They often ignore bright point sources of light • Broad skyglow may be more attractive than a single bright point source of light
Trapping effect of light	Hatchlings that enter a bright pool of light may be trapped within the spill of light and be unable to crawl away from the light spill area, both onshore and in the sea
Moon light	Bright moonlight may override the effects of artificial light
Clouds	Artificial light reflected off clouds creates a broad area of skyglow that may be attractive to hatchlings

(Sources: Pendoley 2005; Lohmann et al. 1997; Tuxbury and Salmon 2005; Limpus and Kamrowski 2013; Pendoley and Kamrowski 2016)

Hatchlings have a strong tendency to orient towards the brightest direction, with brightness being a function of light intensity, wavelength and hatchling spectral sensitivity (Witherington and Martin 2003). Hatchlings are notably more responsive to light of shorter wavelengths (i.e. blue to green light) than to lights of longer wavelengths (i.e. orange to red light) (Pendoley 2005; Fritches 2012). Flatback turtles are attracted to light <600 nanometers (nm), with a preference for ultra-violet (365 -400 nm) and blue light (400 – 450 nm) over longer wavelength light (Pendoley 2005; Fritches 2012). Although longer wavelengths of light are less attractive than shorter wavelengths, they can still disrupt sea finding behaviour, and if bright enough can elicit a similar response to shorter wavelength light. Hence, the disruptive effect of light on hatchlings is also strongly correlated with intensity (Pendoley 2005; Pendoley and Kamrowski 2016; Roberson et al 2016).

Based on the variable responses of turtles to lights of different wavelengths, several light types have been trialled with the aim of reducing hatchling attractions to lights. Lights emitting large proportions of short wavelength light are the most disruptive to sea finding behaviour, while lights which emit large proportions of longer wavelength light are only weakly attractive to hatchlings and are therefore less disruptive (Witherington and Bjorndal 1991a; Witherington and Bjorndal 1991b; Witherington and Martin 1996).

Studies have shown that hatchlings respond to shape cues during sea finding (Limpus 1971; Salmon et al. 1992). Hatchlings crawl away from higher dark silhouettes and toward the lower bright horizon (Mrosovsky 1972; Salmon et al. 1992). However, in situations where both cues are present, hatchlings are more responsive to the effects of silhouettes and darkened horizon elevation than to differences in brightness. On a natural beach this behaviour would direct the hatchlings away from dunes and vegetation and towards the more open horizon over the ocean (DEE 2019a). Hatchlings are most influenced by skyglow when it is situated low in the horizon relative to the hatchling (Limpus 1971; Salmon et al. 1992, Pendoley and Kamrowski 2015). Maintaining a dark, high dune or vegetation silhouette behind nesting beaches is therefore an effective management strategy for inland light sources (Tuxbury and Salmon 2005).

4.1.1.1.3 Nearshore environment

Artificial cues, such as light, may override or disrupt the dispersal process. The presence of artificial light has been shown to disrupt flatback hatchling dispersal, causing them to linger, become disoriented in the nearshore and expend energy swimming against ocean currents towards the light source (Wilson et al 2018). In addition to interfering with swimming it can influence predation rates, where hatchlings were predated more in areas with significant skyglow. Since the nearshore area tends to be predator-rich, hatchling survival may depend on them rapidly leaving this area (Gyuris 1994).

Hatchlings have also been anecdotally reported swimming around lights on boats at seas and in laboratory studies lights have attracted swimming hatchlings (Salmon and Wyneken 1990; White and Gill 2007). Metal halide light was shown by Wilson et al (2018) to be more attractive to flatback hatchlings than high pressure sodium light (80% attracted compared to 63%) and could have a trapping effect on hatchlings. This could become an issue when light sources are associated with coastal structures that also attract fish (e.g. jetties and marinas) as there is likely to be an increase in predation levels (Wilson et al 2018).

5 FLATBACK TURTLES IN PORT HEDLAND

Numerous flatback turtle studies have been undertaken in Port Hedland to support development projects including BHP Billiton's Outer Harbour Development (PENV 2009, 2010, 2011a, 2011b) and DevelopmentWA 's Pretty Pool Development (RPS 2009; 2010a, 2010b, 2012a, 2012b and 2013). A review of potential impacts to flatback turtles was also completed by PENV for the marina (PENV 2019).

Baseline data on the breeding biology of flatback turtles at three rookeries (Barrow Island, Mundabullangana Station and Cemetery Beach) of the Pilbara Coast genetic stock has been documented by Pendoley et al (2014). Inter-nesting behaviours of flatback turtles from four rookeries (Barrow Island, Thevenard Island, Mundabullangana Station and Cemetery Beach) have been recorded using satellite tracking by Whittock et al 2014). The findings of CHEA's Community Volunteer Turtle Monitoring Program monitoring program at Cemetery Beach and Pretty Pool have been documented by Conservation Volunteers Australia (2013) and Imbricata Environmental (2016).

5.1 Adult flatback turtles

5.1.1 Nesting

5.1.1.1 Regional significance

The nesting period for the Pilbara Coast stock occurs during the summer months, primarily between October and February (Pendoley et al 2014). Of the regionally important flatback turtle nesting areas identified by DEE (2017), Mundabullangana Station and Cemetery Beach are proximate to Port Hedland (Figure D).

Mundabullangana Station is a major flatback turtle nesting rookery, approximately 60 km southwest of Port Hedland (DEE 2017). The primary nesting site is Cowrie Beach, a 3.3 km long, narrow, low energy beach bounded by a mangrove creek to the northeast and a rocky headland to the southwest (Pendoley et al 2014). Mundabullangana Station is index beach which has been monitored since 1992 and is also used by PENV as a reference site for Barrow Island to assist with quantifying potential impacts of constructing and operating a gas facility proximate to turtle nesting beaches (DEE 2017; Pendoley et al 2014). Mundabullangana Station supports a substantial reproductive flatback turtle population with an estimated 1,861 female turtles nesting annually (Pendoley et al 2014).

Cemetery Beach is a minor flatback turtle nesting rookery, approximately 1.7 km east of the marina site and 3.3 km from the Port Hedland town centre (Figure E). Female turtles nest at Cemetery Beach between mid-October and January, with a peak in late November (Imbricata Environmental 2016). The population of nesting turtles appears to be relatively stable between 148 to 202 females/year (PENV 2019).

5.1.1.2 Local significance

Nesting sites within the Port Hedland townsite are Cemetery Beach and Pretty Pool Beach (other flatback turtle nesting rookery) (Figure D).

Pretty Pool Beach is a north-east facing marine embayment, sheltered by Cooke Point, on the eastern side of Port Hedland. The flatback turtle nesting area is situated approximately 6 km east of the marina and over 7 km from the Port Hedland town centre. The population of female turtles nesting on Pretty Pool Beach ranges between 31 to 222 females/year (PENV 2019).

Other nesting sites proximate to Port Hedland include Reefs Island, Downes Island, Paradise Beach, Spit Point and various unnamed beaches (PENV 2009; Figure D). The relative abundance of turtle tracks attained from snap-shot aerial track count surveys during the peak nesting period in December 2009 indicate that these other nesting sites support low nesting densities with approximately 6.7 tracks/km recorded at Paradise Beach and 1.4 tracks/km recorded at Downes Island (PENV 2009).

A comparison of the population size of the Port Hedland nesting sites (i.e. Cemetery and Pretty Pool beaches) to the major flatback turtle nesting rookeries in the Pilbara Coast genetic stock (i.e. Barrow Island and Mundabullangana Station) identifies that the Port Hedland nesting sites support significantly smaller numbers of nesting turtles (Table 2).

Table 2: Size of Pilbara Coast genetic stock major nesting rookeries and Port Hedland nesting sites

Nesting site	Estimated annual population size (females/year)
Barrow Island	1,512
Mundabullangana Station	1,861
Cemetery Beach	148 to 202
Pretty Pool Beach	31 to 222

(Sources: Pendoley et al 2014, PENV 2019)

Due to the spatial separation of Pretty Pool Beach from the marina it is not considered that the operation of the marina would result in artificial light impacts to flatback turtles at Pretty Pool Beach.

5.1.2 Offshore

5.1.2.1 Mating

Mating for Cemetery Beach flatback turtles is likely to occur from September and continue over the duration of the nesting period until January (PENV 2019). A flatback turtle breeding ground is located approximately 7 km offshore, in an area 33 km north-west of Port Hedland (PENV 2019). Flatback turtle mating has not been reported proximate to the marina.

5.1.2.2 Inter-nesting

Inter-nesting for Cemetery Beach flatback turtles is likely to occur over the same timeframe as the nesting period (i.e. between mid-October and January) (PENV 2019). Flatback turtle inter-nesting periods at Cemetery Beach have been recorded as 12 days (Whittock et al. 2014; Imbricata Environmental 2016).

The offshore movements of flatback turtles fitted with satellite tags from Cemetery Beach has been reviewed by PENV (2010) and Whittock et al. (2014).The most important inter-nesting habitat for flatback turtles nesting at Cemetery Beach appears to be the nearshore zone within 50 km stretching north-east along the coast which mostly consists of bare sediment or bare sediment over hard substrate (PENV 2010; Figure C), however habitat to the north-west of Cemetery Beach is also utilised by inter-nesting turtles (Whittock et al. 2014).

Cemetery Beach turtles show a high level of nest site fidelity, primarily returning to same beach where the transmitter was applied for subsequent clutches (Whittock et al. 2014). Although one turtle was recorded traveling approximately 60 km south–west of Cemetery Beach to nest at Mundabullangana Station (Whittock et al. 2014). Inter-nesting turtles have also been recorded within the existing shipping channel (BHP Billiton 2011).

5.1.2.3 Foraging

After the cessation of the mating and nesting periods, adult flatback turtles migrate to their Kimberly and Gulf of Carpentaria foraging grounds (PENV 2019).

Juvenile flatback turtles are known to use the shallow nearshore waters of the Pilbara coast for foraging (PENV 2009). Anecdotal reports indicate that juvenile flatback turtles are present within the tidal creeks of the inner harbour (PENV 2009). Biota Environmental Services (2004) also identified that flatback turtles are known to utilise habitats within the tidal creeks of the inner harbour, although no contextual information on age class is provided.

5.1.2.3.1 Other marine turtles

Adult green turtles are commonly observed in the inner harbour (BHP Billiton 2011). While mangroves are not considered a primary food source for adult green turtles, they are probably used as a supplemental or opportunistic food source along the Pilbara coast (PENV 2009; Pendoley and Fitzpatrick 1999). Juvenile green turtles have also been reported to shelter in the tidal creeks of the inner harbour (Biota Environmental

Services 2004; PENV 2009) suggesting that they may be foraging on green algal mats and *Sargassum* species within the surrounding creeks (Fortescue Metals Group 2008). An adult loggerhead turtle was also reported in the inner harbour to the south of Finucane Island in 2007, therefore loggerhead turtles may also use the area for foraging (PENV 2009).

5.2 Hatchling flatback turtles

5.2.1 Reproductive output

The average number of eggs laid by nesting flatback turtles at Cemetery Beach is similar to the Pilbara Coast genetic stock major nesting rookeries (Table 3). The average hatch success at Barrow Island is comparable to other flatback turtle rookeries, however the average hatch success recorded for Mundabullangana Station and Cemetery Beach are very low for flatback rookeries (Pendoley et al 2014). The low hatch success at Mundabullangana Station and Cemetery Beach is most likely due to the elevated natural sand temperature experienced during egg incubation compared to the more southerly populations within the Pilbara Coast genetic stock (PENV 2019). Alternatively, storm surges associated with high cyclonic activity in the region affecting the embryonic development may also be a factor (DEE 2017).

Table 3: Reproductive outputs of Pilbara Coast genetic stock major nesting rookeries and Port Hedland nesting sites

Nesting site	Average clutch size (number of eggs)	Average hatch success (%)
Barrow Island	46.6	83.4
Mundabullangana Station	46.6	68.2
Cemetery Beach	46.6	57.3

(Source: Pendoley et al 2014)

5.2.2 Nest emergence

Hatchlings start emerging from the nests at Cemetery Beach in early December, with a peak in early January, and continue until mid-February (Imbricata Environmental 2016).

After emerging from nests hatchlings crawl directly towards the sea, a behaviour known as sea finding. The sea finding process is directed by several cues including light wavelength, light intensity and shape and form (Lohmann et al. 1997; Tuxbury and Salmon 2005). Beach slope and sound are considered secondary cues relative to vision and are overruled by light (Lohmann et al. 1997).

5.2.3 Nearshore disbursal

The disbursal of flatback hatchlings entering the water have been shown to be primarily influenced by ocean currents under natural conditions (Wilson et al 2018). Nearshore currents in the Port Hedland region are primarily driven by astronomical tides, which causes a periodic inflow (flood tide) and outflow (ebb tide) of oceanic water to/from the Northwest shelf region (Cardno 2011). On an incoming flood tide currents generally flow in a south-southeast easterly direction, whilst on an outgoing ebb tide currents generally flow in a north-northwest direction (Cardno 2011).

6 ARTIFICIAL LIGHT ON CEMETERY BEACH

There are two ways by which artificial light may influence the Cemetery Beach night environment:

- Direct light – sources of artificial light that can be seen directly from the beach or from the nearshore waters (i.e. point source lighting)
- Indirect light or skyglow – artificial light illuminates water vapour, dust or any other airborne particles suspended in the night sky which indirectly scatters light into the surrounding environment.

Imbricata Environmental (2016) reported that the following management actions have been implemented to reduce direct light levels at Cemetery Beach:

- Turning the water tower off during turtle nesting and hatching periods
- Installation of orange LED lights along Sutherland Street and the footpath connecting the Civic Centre to the Port Hedland Community Park, including Ibis Styles Port Hedland hotel
- Installation of turtle friendly dual lighting system at the Port Hedland Community Park and the back of the Civic Centre.

6.1 Previous artificial light assessments

6.1.1 Stage 3 investigation area, Pretty Pool development

A light monitoring survey was undertaken at Cemetery Beach on 18 April 2013, in conjunction with light surveys for DevelopmentWA's Stage 3 Investigation Area, Pretty Pool Development, to identify and assess the influence of artificial light from direct sources and skyglow. The light survey identified that the existing Cemetery Beach night environment is dominated by skyglow produced by the port operations and to a lesser extent the Colin Matheson Oval lights, when in use. Skyglow from the port operations was found to be the dominant source of artificial light influencing the Cemetery Beach night environment (RPS 2013).

Direct artificial light sources detected by the RPS (2013) survey included:

- Sutherland Street streetlights
- Ibis Styles Port Hedland hotel
- Port Hedland Community Park[3]
- Water tower[4].
- Port Hedland council building
- Offshore lighting such as navigational markers and ships.

Figure F shows the key direct artificial light and skyglow sources proximate to the Cemetery Beach nesting area and the marina.

6.2 Port Hedland Marina – Benchmark Artificial Light Survey

Due to the period of time that has elapsed since the previous light study (RPS 2013), limited amount of monitoring data derived for the Cemetery Beach night environment and advancements in the quantification techniques for artificial light, it was considered that a contemporary set of light data was required to inform this artificial lighting impact assessment for the marina proposal.

In recognition of the inherent limitations of the previous investigations and their derived data sets leading marine turtle and light monitoring consultancy, PENV, were commissioned to undertake a benchmark artificial light at night survey for Cemetery Beach (PENV 2020; Appendix B).

[3] Port Hedland Community Park switches to turtle friendly lighting during turtle nesting and hatching periods

[4] Water tower is turned off during turtle nesting and hatching periods

6.2.1 Objective

The objective of the benchmark artificial light at night survey was to obtain a qualitative set of benchmark data for the existing Cemetery Beach light at night t environment, with specific reference to the Cemetery Beach nesting area, to inform the likely effect of the development of the marina.

6.2.2 Scope of works

The survey involved the collection of light data from the Cemetery Beach nesting area using PENV's Sky42™ cameras, which are globally recognised as a leading tool in artificial light measurement and management. These calibrated cameras capture high resolution, non-attenuated, full 360º images of the horizon every 15 minutes.

6.2.3 Methodology

To date no standard protocols, methodologies or accepted practices have been established for the measurement of artificial light emissions in Australia. To address the lack of a standardised method to quantify light emissions from point sources (i.e. streetlights, buildings) and diffuse sources (i.e. skyglow) PENV and RPS met with officers from the DBCA on 12 September 2019 to confirm the proposed approach for the implementation of the light survey.

The key outcome of the meeting was that the proposed approach for the implementation of the light survey was acceptable. The DBCA also recommended that in addition to the proposed monitoring sites at Cemetery and Pretty Pool Beaches a third site be established on the spoilbank. Consultation was also undertaken with Kelly Howlett (CHEA) to confirm the proposed light survey approach.

6.2.3.1 Timing of the light survey

The light survey was undertaken between 30 September and 03 October 2019 to coincide with the September new moon phase thereby avoiding ambient light generated by the full moon. Moore (2001) identifies the following additional environmental factors are known affect the amount of direct and scattered light visible in the sky at a particular point in time:

- Presence of clouds
- Pollutants
- Airborne particulates (dust)
- Humidity.

There were no adverse weather conditions encountered during the survey, with all nights free of rain and cloud cover (PENV 2020).

6.2.3.2 Field program

6.2.3.2.1 Monitoring locations

Four monitoring locations were selected for the light survey:

1. Cemetery Beach East was located within the Cemetery Beach nesting area.
2. Cemetery Beach West was located was located within the Cemetery Beach nesting area.
3. Pretty Pool Beach was used to compare the night environments of the two known turtle nesting beaches in Port Hedland.
4. Spoilbank was monitored to accord with DBCA advice.

Cameras were deployed at the two Cemetery Beach monitoring locations for three nights between 30 September and 02 October, with Pretty Pool Beach monitored on 30 September and the spoilbank monitored on 02 October (Figure 7).

(Source: PENV 2020)

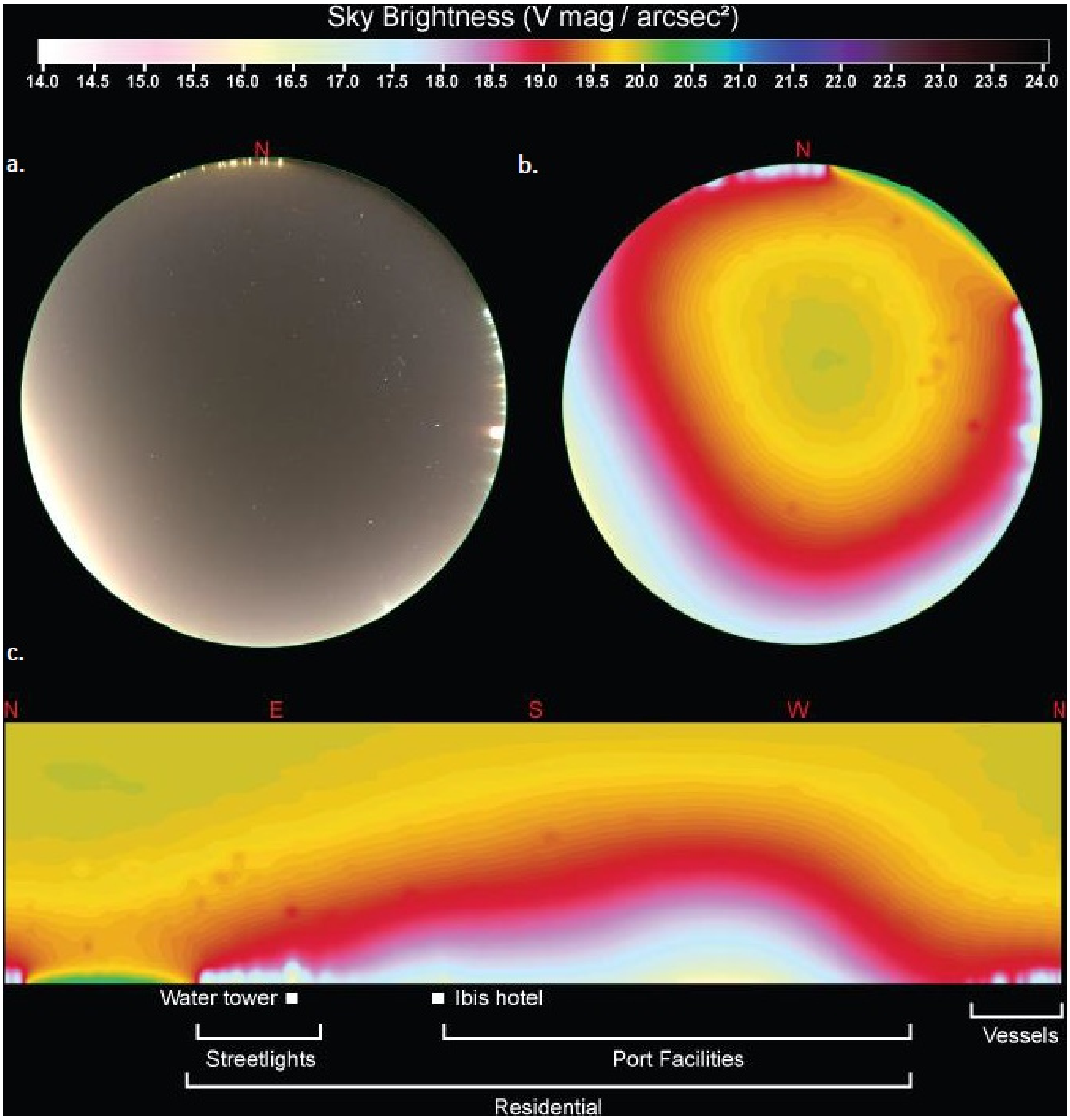
Figure 7: Light survey monitoring location

6.2.3.2.2 Image capture

Images were captured using automated Sky42™ light monitoring cameras that feature a Canon EOS 700D camera and fish-eye lens with custom built hardware to acquire low light night sky images of the entire sky (PENV 2020). The cameras are built into a rigid housing with a protective lid that automatically opens during image capture and closes between capture intervals (PENV 2020). The cameras were deployed at each survey location and were programmed to automatically begin taking photos in 15-minute intervals between sunset and sunrise. Images were downloaded from the cameras each day. processing and data analysis (PENV 2020).

6.2.4 Results

All suitable raw images captured by the Sky42™ light monitoring cameras were processed by PENV using custom built software to determine sky brightness levels. As an example, Figure 8 presents the raw image captured by the Sky42™ camera (a), processed image (b), and panorama showing location of visible light sources (c) for the Cemetery Beach West monitoring site on 30 September 2019.



(Source: PENV 2020)

Figure 8: Light survey results at Cemetery Beach West on 30 September 2019

Sky brightness was quantified in units of visual magnitudes/arcsec^2 (vmag/arcsec^2; a standard unit used in astronomical measurements and emerging as a standard for skyglow monitoring globally) (PENV 2020). The vmag/arcsec^2 unit quantifies light intensity on an inverted logarithmic scale (i.e. higher values represent lower intensity light, while lower values represent higher intensity light) (PENV 2020). Values between 21-22 vmag/arcsec^2 represent an ideal natural dark sky and values between 17 -18 vmag/arcsec2 are representative of a poor urban night sky (PENV 2020).

The spoilbank monitoring location recorded the brightest mean values (Whole-of-sky18.12, Zenith 19.57 and Horizon 18.12 vmag/arcsec^2), which is typical of an urban night sky and considered to be a high (artificial light impacted) recording (PENV 2020). Pretty Pool Beach recorded the darkest mean values (Whole-of-sky 19.49, Zenith 20.43 and Horizon 19.09) which is typical of a suburban night sky and considered to be a moderate (artificial light impacted) recording (PENV 2020). This finding indicates that sky brightness levels are influenced by proximity to the port operations and artificial light sources in the townsite (i.e. the brightest mean values were recorded at the spoilbank which is the closest monitoring location to the port operations and townsite whilst the darkest mean values were recorded at Pretty Pool Beach which is the furthest monitoring location from these light sources).

The port operations, inclusive of loading, processing and stockpiling activities, was identified as the most dominant source of skyglow in Port Hedland and was visible from all four monitoring locations (PENV 2020). Point sources of artificial light that were directly visible from the Cemetery Beach nesting area included the Port Hedland Community Park, water tower, streetlighting, Port Hedland council building, Ibis Styles Port Hedland hotel and offshore vessels (Figure F; PENV 2020). These findings are consistent with outcomes of the RPS (2013) light monitoring survey at Cemetery Beach (Section 6.1.2).

7 ARTIFICIAL LIGHT IMPACTS

Artificial lighting has the potential to reduce the reproductive success of marine turtles by deterring adult females from approaching nesting beaches or nesting; and disorienting and / or misorienting hatchlings on the beach and in the nearshore environments (DEE 2019a). The Cemetery Beach nesting area is approximately 1.7 km to the east of the marina. Over this distance, artificial light sources are considered unlikely to be bright enough to deter experienced flatback turtles from nesting (PENV 2019). Hatchlings are considered to be more sensitive to light, with impacts recorded at nesting habitat situated over 18 km away from a light source (Hodge et al 2007).

7.1 Existing artificial light impacts to flatback turtles at Cemetery Beach

7.1.1 Adult flatback turtles

7.1.1.1 Nesting

CHEA's Community Volunteer Turtle Monitoring Program has monitored the number of nesting turtles at Cemetery Beach since 2004. CHEA's population estimates identify that Cemetery Beach supports a stable nesting population. This finding is underpinned by a less than 30% variation between consecutive nesting seasons, which is characteristic of flatback turtle populations elsewhere in Australia (Imbricata Environmental 2016). Minor fluctuation in seasonal abundance is attributed to relatively short (1-2 year) remigration intervals, which is likely influenced by ecological change, sea surface temperatures, remigration rates and the health of foraging grounds that are outside the Port Hedland area (Figure C; Imbricata Environmental 2016).

The relative stability of the nesting population suggests that existing artificial light impacts are not deterring experienced adult females from nesting at Cemetery Beach. However, the relative density of nests between 2004 to 2013 does indicate that the nesting turtles prefer the eastern side of Cemetery Beach, where the dunes are higher providing a taller darker horizon cue behind the beach for orientation and some shielding from onshore artificial light sources (Figure E; Imbricata Environmental 2016).

7.1.2 Hatchling flatback turtles

7.1.2.1 Hatchling orientation

7.1.2.1.1 Previous hatchling orientation assessments

Imbricata Environmental (2016) reported that artificial light visible from Cemetery Beach appears to have an impact on hatchling orientation. The mean spread (112.4º) and offset (24.4º) angles recorded in 2013 for 124 fan maps were higher than those previously reported by PENV (2011b), which were 62.5º and 9.2º, respectively (Imbricata Environmental 2016). Anecdotal records of hatchlings being misoriented (PENV 2009) and disorientated (Limpus 2007; Imbricata Environmental 2016) by artificial light on Cemetery Beach have also been reported.

7.1.2.1.2 Benchmark artificial light at night survey

Hatchling orientation data recorded over the 2018/2019 and 2019/2020 nesting seasons by CHEA was reviewed and cross checked for errors by PENV. Records where confidence in data accuracy was high where used to provide an indicative benchmark for hatchling orientation, prior to the implementation of the proposed marina development. Records where confidence in data accuracy was low where removed from the CHEA dataset.

The hatchling orientation data shows a wide spread of tracks with a minor bias towards western sources of artificial light (PENV 2020), which include the Port Hedland Community Park, Sutherland Street streetlights and skyglow from the port operations.

8 PROPOSED MARINA DEVELOPMENT LIGHTING DESIGN

New sources of artificial light visible to flatback turtles within the Cemetery Beach nesting area were considered by PENV (2020) as having the potential to increase hatchling disorientation in a westerly direction along Cemetery Beach.

The siting of the marina and approach to the reduction of artificial light emissions implemented by the preliminary lighting design has sought to limit the introduction of new sources of artificial light visible to flatback turtles within the Cemetery Beach nesting area.

The physical aspects of light that have the greatest effect on marine turtles include intensity, colour (wavelength), and elevation above beach (DEE 2019a). In addition to limiting the introduction of new sources of artificial light, these aspects have been considered holistically across the entire development footprint to assist in reducing any potential increase in hatchling disorientation as a result of the proposed marina development.

8.1 Development siting

The proposed marina development is sited in the same westerly alignment from the Cemetery Beach nesting area as the port operations, which are the dominant source of skyglow at Cemetery Beach. Skyglow from the port operations was found to be the dominant source of artificial light influencing the Cemetery Beach night environment (RPS 2013). Situating the marina on the western side of the spoilbank maximises the separation distance between the marina and the Cemetery Beach nesting area, when compared to situating the marina on the eastern side of the spoilbank. The western siting of the marina also provides the opportunity for the existing topography of the spoilbank to be used to shield the new point sources of artificial light.

8.1.1 Line of sight analysis

A line of sight analysis was undertaken by JDSi to determine the proposed lighting features likely to be visible to flatback turtles within the Cemetery Beach nesting area (Appendix C).

The area of highest density flatback turtle nests, as identified by Imbricata Environmental (2016), was used as the reference point for the assessment, with the ground level (i.e. hatchling height) used to indicate the projected hatchling line of sight. A recent drone survey undertaken by MP Rogers and Associates in May 2019 was used to inform the Cemetery Beach topographic levels (Figure E).

The outcomes of this investigation, for which three indicative sections (i.e. most seaward light, through the car park and to yacht club) have been taken through the development, are presented in Appendix C.

The line of site analysis indicates that the pole mounted lighting along the main access road and within the parking and hardstand areas will be directly visible to flatback turtles. The bollard lighting within the marina's basin will either be shielded by the existing topography or the future breakwaters / internal revetment walls and will not be directly visible to flatback turtles from the Cemetery Beach nesting area.

8.2 Approach to reduction of light emissions

The preliminary lighting design (Appendix A) for the marina has been prepared to accord with the draft Light Pollution Guidelines (DEE 2019a) while meeting legislative and regulatory requirements for human safety. This has been achieved through implementing the following the draft Light Pollution Guidelines (DEE 2019a) best practice lighting design principles:

1. Start with natural darkness and only add light for specific purposes.
2. Use adaptive light controls to manage light timing, intensity and colour.
3. Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill.
4. Use the lowest intensity lighting appropriate for the task.
5. Use non-reflective, dark-coloured surfaces.
6. Use lights with reduced or filtered blue, violet and ultra-violet wavelengths.

The implementation of the draft Light Pollution Guidelines (DEE 2019a) best practice lighting design principles provide a contemporary framework to address the four key principles for lighting management identified in EAG 5 (EPA 2010):

- Keep it OFF (keep light off the beach and lights off when not needed)
- Keep it LOW (mount lights low down with lowest intensity for the job)
- Keep it SHEILDED (stop all light escaping upwards and outwards)
- Keep it LONG (use long wavelength lights).

The following sections detail the application of the draft Light Pollution Guidelines (DEE 2019a) best practice lighting design principles, and the EPA (2010) key principles for lighting management, in respect to the preliminary lighting design for the marina.

8.2.1 Start with natural darkness and only add light for specific purposes

The preliminary lighting design has been prepared to accord with Australian / New Zealand Standard, Lighting for Roads and Public Spaces (AS/NZS 1158.3.1:2018) thereby meeting minimum human safety requirements.

This principle has been addressed by the preliminary lighting design through using the minimum number of lights required to safely light the proposed marina development to accord with road and outdoor public space requirements detailed in AS/NZS 1158.3.1:2018 in situations where the visual requirements of pedestrians are the primary consideration (e.g. local roads, outdoor car parks).

8.2.2 Use adaptive light controls to manage light timing, intensity and colour

The use of LED lighting provides the opportunity for lighting controls to be fitted allowing for:

- Remotely managed lights (computer controls)
- Instant on and off switching of lights
- Control of light colour
- Dimming, timers, flashing rate, motion sensors
- Well defined directivity of light.

Although lighting controls have not been proposed to be implemented at the proposed marina development, the intent of this principle has been addressed by the preliminary lighting design through:

- Maintaining a permanent amber light colour
- Permanently shielding bollard lighting (i.e. we-ef KTY234; Figure 2) and permanently directing pole mounted lighting downwards (i.e. we-ef VFL530-SE; Figure 3, we-ef VFL530 and we-ef VFL54; Figure 4) reduces light trespass to the Cemetery Beach nesting area.

As part of the preparation of the artificial light management plan, consideration should also be provided to switching off the pole-mounted lighting during turtle hatching (early December to mid-February) when use is not required. Alternatively, a curfew time could be implemented for marina operations with the pole mounted lights being switched off from a particular time during turtle hatching.

8.2.3 Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill

To mitigate the potential for light spill to occur (i.e. light that falls outside the area intended to be lit) and ensure that only the target area is lit, the following actions have been implemented by the preliminary lighting design to address this principle:

- Keeping lights as close to the ground as possible

- Pole mounted lights are proposed to be mounted horizontally relative to the ground to prevent light from shining above the horizontal plane and contributing to skyglow (Figure 3 and Figure 4)
- Permanently shielding bollard lighting (i.e. we-ef kty234; Figure 3) and permanently directing pole mounted lighting downwards (i.e. we-ef vfl530-se; Figure 4, we-ef vfl530 and we-ef vfl54; Figure 5) reduces light trespass to the Cemetery Beach Nesting Area
- Installing the pole mounted lighting (i.e. we-ef VFL530) on the eastern side of the main access road so that the lights face to the west away from the Cemetery Beach nesting area.

Shielding should be installed on the east facing side (i.e. side facing towards the Cemetery Beach nesting area) of the pole mounted lights along the main access road to assist in reducing the line of sight visibility of these lights to hatchlings within the Cemetery Beach nesting area.

As part of the preparation of the artificial light management plan, consideration should also be provided to:

- planting screening vegetation along the eastern side of the main access road. The planted vegetation may assist in reducing the number of lights visible to hatchlings from the Cemetery Beach nesting area. Further, hatchlings are known to orient away from the elevated darker silhouettes of the dunes and / or vegetation, toward the lower, brighter seaward horizon (Table 1). The planting of screening vegetation may assist in creating a less homogenous, more elevated horizon between the proposed marina development and the Cemetery Beach nesting area.
- shielding on the eastern facing side of the pole mounted lights located within the parking and hardstand areas to the extent that compliance with AS/NZS 1158.3.1:2018 is not unreasonably compromised.

8.2.4 Use the lowest intensity lighting appropriate for the task

The preliminary lighting design has used only the minimum number and intensity of lights required to safely light the proposed marina development to accord with road and outdoor public space requirements detailed in AS/NZS 1158.3.1:2018, in situations where the visual requirements of pedestrians are the primary consideration (e.g. local roads, outdoor car parks). The pole mounted lights have also been certified by independent assessors as meeting the ADSA night light criteria (ADSA 2019).

Due to the low lumen outputs of the proposed lighting, it is not considered that the implementation of the proposed marina development would cumulatively add to the existing skyglow levels (PENV 2020).

8.2.5 Use non-reflective, dark-coloured surfaces

This principle has been addressed by the preliminary lighting design by using bollard housings, pole mounted fixtures and masts that are dark in colour. The use of reflective or white infrastructure within the lighting area also is proposed to be avoided.

8.2.6 Use lights with reduced or filtered blue, violet and ultra-violet wavelengths

This principle has been addressed by the preliminary lighting design through the use amber LED lights (i.e. primarily long wavelength emitting lighting) for the proposed marina development. The use of amber LED lights is considered suitable for use proximate to marine turtle habitat by DEE (2019a).

The use of lights containing ultra-violet, violet and blue light (i.e. short wavelength emitting lighting) to which hatchlings are more attracted has been avoided.

9 POTENTIAL IMPACTS AND PROPOSED MITIGATION MEASURES

The benchmark artificial light at night survey (PENV 2020; Appendix B) and line of sight analysis (JDSi; Appendix C) identify that pole mounted lighting along the main access road and within the parking and hardstand areas is visible to hatchlings from the Cemetery Beach nesting area. The visible pole mounted lights could increase hatchling disorientation towards the west of Cemetery Beach.

The preliminary lighting design (JDSi; Appendix A) for the marina has been prepared to accord with the draft Light Pollution Guidelines (DEE 2019a) best practice lighting design principles, and EAG 5 (EPA 2010), while meeting legislative and regulatory requirements for human safety (Section 8.2 demonstrates how this has been achieved). In respect to the visible pole mounted lights, the preliminary lighting design uses:

- Minimum number and intensity of lights required to safely light the main access road and parking and hardstand areas to accord with road and outdoor public space requirements
- Amber LED lights (i.e. primarily long wavelength emitting lighting). The use of amber LED lights is considered suitable for use proximate to marine turtle habitat by DEE (2019a).

Given that artificial light pollution in Port Hedland is moderated by distance to the port operations, and together with the low lumen outputs of the proposed lighting, it is considered unlikely that the implementation of the proposed marina development would cumulatively add to the existing skyglow levels (PENV 2020).

To further reduce the potential for increased hatchling disorientation:

- Shielding should be installed on the east facing side (i.e. side facing towards the Cemetery Beach nesting area) of the pole mounted lights along the main access road to assist in reducing the line of sight visibility of these lights to hatchlings within the Cemetery Beach nesting area
- As part of the preparation of the artificial light management plan, consideration should also be provided to
  - switching off the pole-mounted lighting during turtle hatching (early December to mid-February) when use is not required. Alternatively, a curfew time could be implemented for marina operations with the pole mounted lights being switched off from a particular time during turtle hatching
  - planting screening vegetation along the eastern side of the main access road
  - shielding on the eastern facing side of the pole mounted lights located within the parking and hardstand areas to the extent that compliance with AS/NZS 1158.3.1:2018 is not unreasonably compromised.

After the implementation of the best practice lighting design principles identified in the draft Light Pollution Guidelines (DEE 2019a), and EAG 5 (EPA 2010) key principles for lighting management:

- The residual risk to hatchling disorientation towards the west of Cemetery Beach being increased from the implementation of the proposed marina development is anticipated to be minimal in the context the existing artificial light impacts from point sources including the Port Hedland Community Park and Sutherland Street streetlights as well as skyglow from the port operations.
- The lighting design for the proposed marina development will meet legislative and regulatory requirements for human safety whilst addressing the biological diversity and ecological integrity of flatback turtles.

Table 4 summarises the key potential impacts to flatback turtles from artificial light from the proposed marina development, identified by the PENV (2019) review, and proposes mitigation measures to address the potential impacts consistent with the EPA's mitigation hierarchy, the draft Light Pollution Guidelines (DEE 2019a) and EAG 5 (EPA 2010) for the environmental factor of Marine Fauna.

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Table 4: Key potential impacts to flatback turtles from artificial light emitted from the proposed marina development

<table>
<tr><th colspan="2">Marine fauna</th></tr>
<tr><td>EPA objective</td><td>To protect marine fauna so that biological diversity and ecological integrity are maintained.</td></tr>
<tr><td>Policy and guidance</td><td>Environment Protection and Biodiversity Conservation Act 1999
Draft national light pollution guidelines for wildlife, including marine turtles, seabirds and migratory shorebirds (DEE 2019a)
Biodiversity Conservation Act 2016
Environmental Factor Guideline: Marine Fauna (EPA 2016)
EAG 5 for Protecting Marine Turtles from Light Impacts (EPA 2010)</td></tr>
<tr><td>Potential impacts</td><td>Adult flatback turtles
The relative stability of the nesting population suggests that existing artificial light impacts are not deterring experienced adult females from nesting at Cemetery Beach. Informed by the separation distance between the marina and the Cemetery Beach nesting area (approximately 1.7 km), the findings of the benchmark artificial light at night survey (PENV 2020; Appendix B) and the proposed approach adopted for reducing light emissions by the preliminary lighting design it is not considered likely that experienced adult females would be deterred from nesting at Cemetery Beach as a result of the implementation of the proposed marina development.
Artificial light from the proposed marina development is not considered likely to significantly impact turtles when in the ocean. Some studies suggest that marine turtles may be attracted to lights when foraging, however inter-nesting flatback turtles are not considered to feed during the breeding season (Limpus et al. 2013) meaning they are unlikely to move to well-lit areas, with their foraging grounds situated away from Port Hedland (Figure C; PEV 2019).
Hatchling flatback turtles
Pole mounted lighting along the main access road and within the parking and hardstand areas is visible to hatchlings from the Cemetery Beach nesting area. The visible pole mounted lights could increase hatchling disorientation towards the west of Cemetery Beach.
Artificial light from the marina is not considered likely to significantly impact hatchlings when in the ocean. Hatchlings entering the water will orient into the waves and will be swept along with local currents resulting in the hatchlings moving offshore and away from the marina (PENV 2019). In the event that a hatchling turtle situated offshore was attracted to artificial light sources, the presence of the spoilbank would act as a physical barrier and inhibit any further movement in a westerly direction (PENV 2019). The lack of any reported or anecdotal evidence from this extremely well monitored rookery showing that hatchlings crawl back ashore at Cemetery Beach towards the highly illuminated landward horizon suggests that the local oceanographic conditions and strong in- water cues used by hatchlings migrating offshore are sufficient to prevent hatchlings crawling back ashore.</td></tr>
<tr><td>Mitigation</td><td>Preliminary lighting design for the proposed marina development has been prepared to accord with the best practice lighting design principles identified in the draft Light Pollution Guidelines (DEE 2019a), and EAG 5 (EPA 2010) key principles for lighting management, while meeting legislative and regulatory requirements for human safety.
Avoid
Bollard lighting within the marina will either be shielded by the existing topography or the future breakwaters / internal revetment walls and will not be directly visible to turtles from the Cemetery Beach nesting area
Minimise
Pole mounted lighting along the main access road and within the parking and hardstand areas will be directly visible to hatchlings. To minimise the potential for increased hatchling disorientation from light sources which are directly visible to hatchlings, whist also reducing skyglow, the following management actions have been implemented:
Minimising the number of lights needed
Keeping lights as close to the ground as possible
Permanently shielding all bollard lighting
Permanently directing all pole mounted lighting downwards to reduces light trespass to the Cemetery Beach nesting area
Using pole mounted lights which are mounted horizontally relative to the ground prevents light from shining above the horizontal plane and contributing to skyglow
Using lowest intensity lighting to meet human safety requirements
Using bollard housings, pole mounted fixtures and masts that are dark in colour only
Using amber LED lighting (i.e. primarily long wavelength emitting lighting) only.
To further reduce the potential for increased hatchling disorientation:
Shielding should be installed on the east facing side (i.e. side facing towards the Cemetery Beach nesting area) of the pole mounted lights along the main access road to assist in reducing the line of sight visibility of these lights to hatchlings within the Cemetery Beach nesting area
As part of the preparation of the artificial light management plan, consideration should be provided to switching off the pole-mounted lighting during turtle hatching (early December to mid-February) when use is not required. Alternatively, a curfew time could be implemented for marina operations with the pole mounted lights being switched off from a particular time during turtle hatching
As part of the preparation of the artificial light management plan, consideration should be provided to shielding on the eastern facing side of the pole mounted lights located within the parking and hardstand areas to the extent that compliance with AS/NZS 1158.3.1:2018 is not unreasonably compromised.
Rehabilitate
As part of the preparation of the artificial light management plan, consideration should be provided to planting screening vegetation along the eastern side of the main access road.</td></tr>
<tr><td>Outcome</td><td>After the implementation of the best practice lighting design principles identified in the draft Light Pollution Guidelines (DEE 2019a), and EAG 5 (EPA 2010) key principles for lighting management:
the residual risk to hatchling disorientation towards the west of Cemetery Beach being increased from the implementation of the proposed marina development is anticipated to be minimal in the context the existing artificial light impacts from point sources including the Port Hedland Community Park and Sutherland Street streetlights as well as skyglow from the port operations
the lighting design for the proposed marina development will meet legislative and regulatory requirements for human safety whilst addressing the biological diversity and ecological integrity of flatback turtles.</td></tr>
</table>

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FIGURES

Figure A

Site Location

GDA 1994 MGA Zone 50

0 200 400 800 m

Scale: Map 1:15,000 Overview 1:8,000,000 @ A4

Job Number: L19121.001
Doc Number: 001
Date: 22.01.20
Created by: RL
Source: Imagery - Landgate

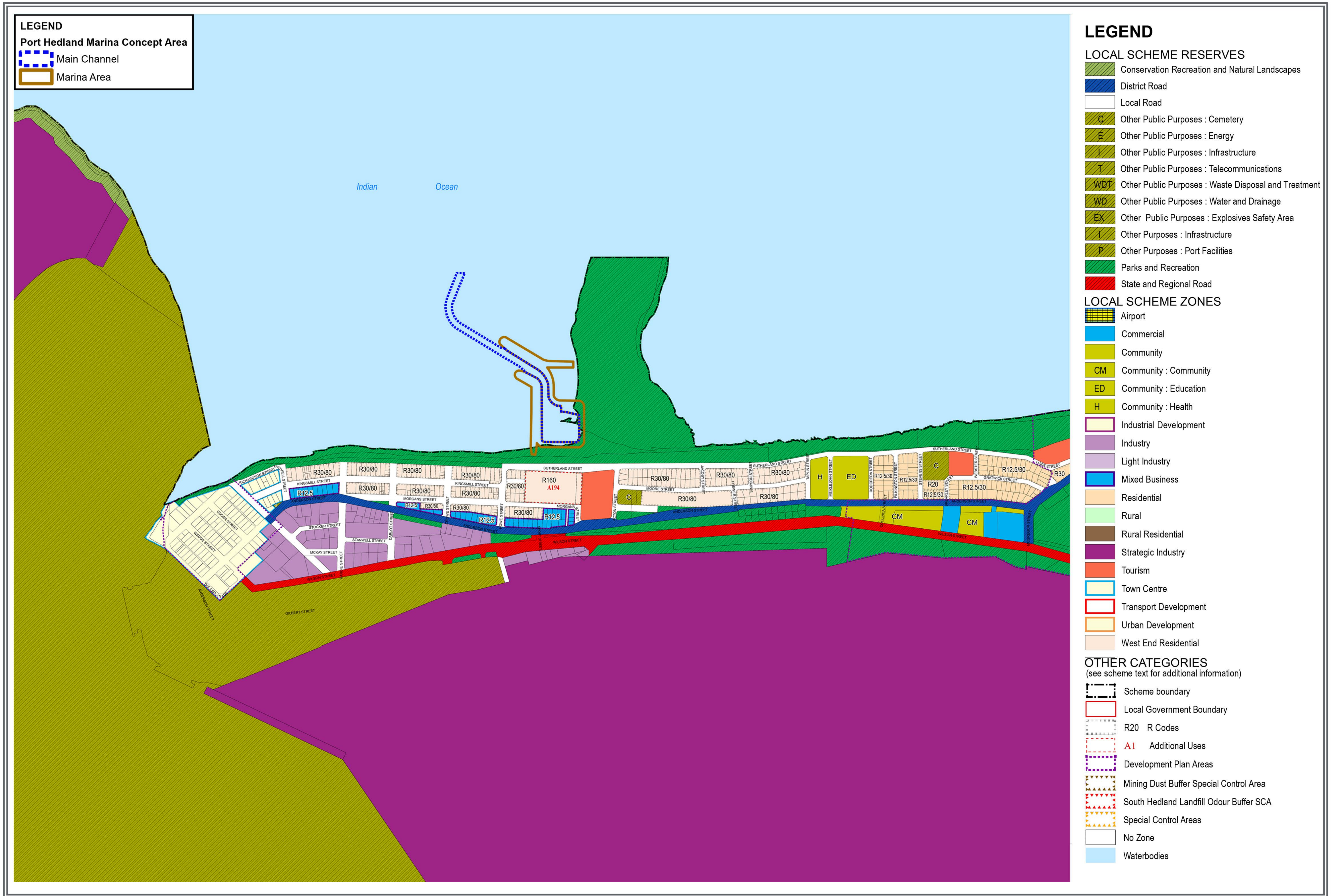


Figure B

Local Planning Scheme No. 5 mapping

Job Number: L19121.001
Doc Number: 002
Date: 22.01.20
Scale: NTS @ A3
Created by: RL
Source: DoP, Town Planning Scheme No.5, Map No. 4 - 31.08.2001

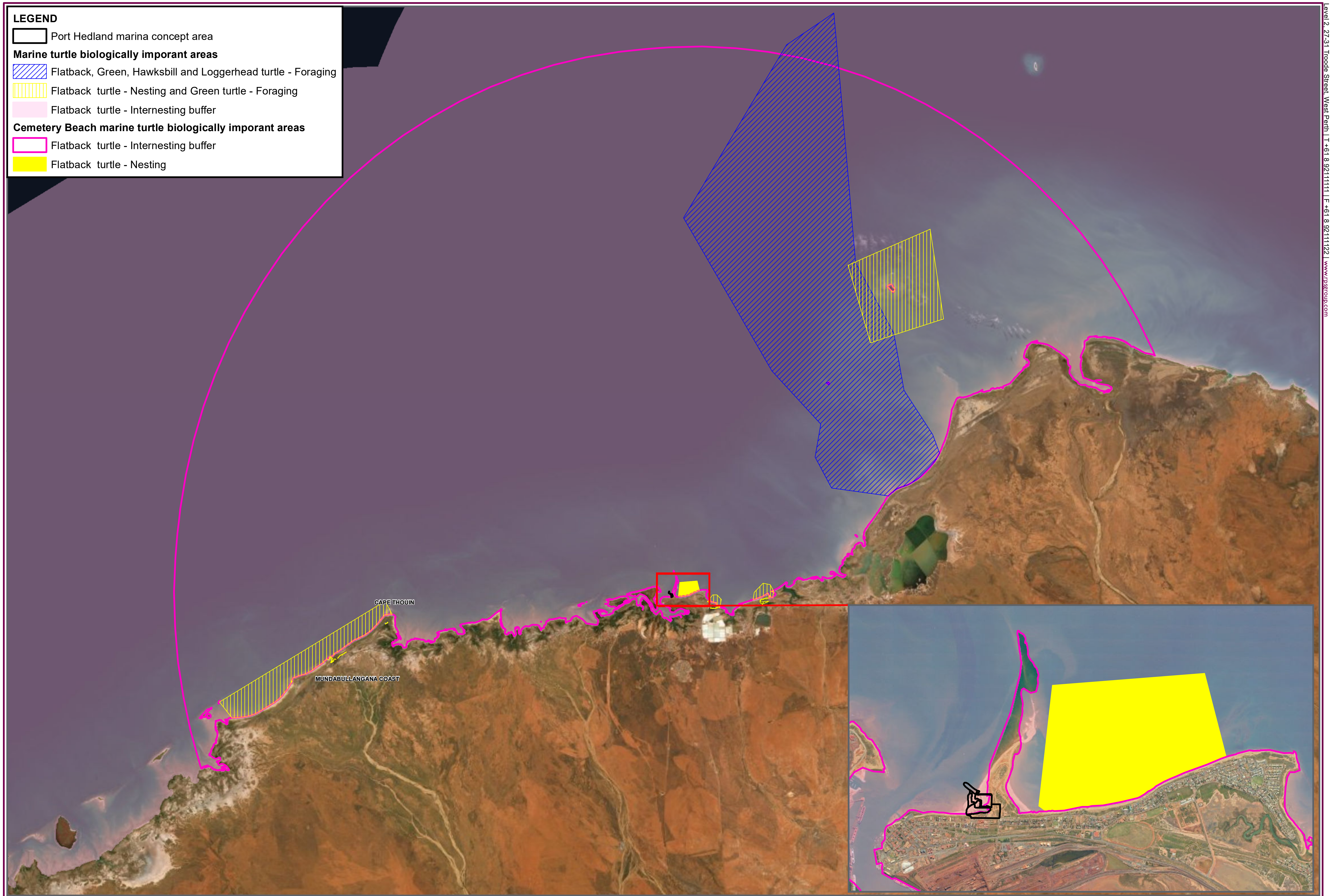


Figure C

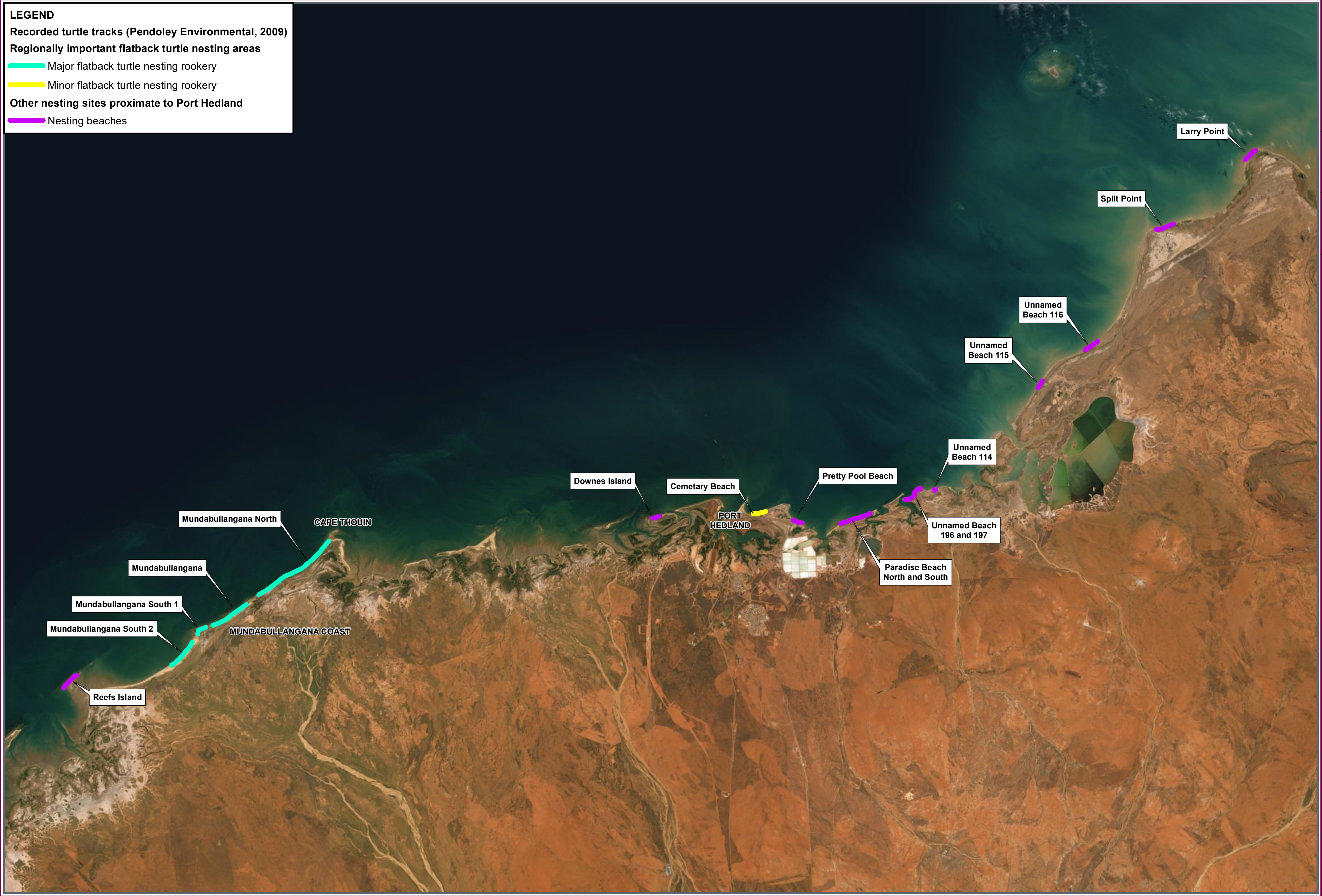
Marine turtle biologically important areas

GDA 1994 MGA Zone 50

0 5 10 20 km

Job Number: L19121-001
Doc Number: 003
Date: 05.02.20
Scale: 1:56,522 @ A3
Created by: MA
Source: Cadastre - Landgate, 2019 Orthophoto - Landgate, 2018

Level 2, 27-31 Troode Street, West Perth | T +61 8 92111111 | F +61 8 92111122 | www.rpsgroup.com



Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122 | www.rpsgroup.com

Figure D

Marine turtle nesting sites proximate to Port Hedland

GDA 1994 MGA Zone 50

0 2.5 5 10 km

Job Number: L19121-001
Doc Number: 004
Date: 05.02.20
Scale: 1:350,000 @ A3
Created by: MA

Source: Cadastre - Landgate, 2019 Orthophoto - Landgate, 2018

Document Path: G:\Jobs\L_Jobs\L19121 - Spoil Bank Marina Status\Figures L19121-001\L19121-001_G_004_FigD Marine turtle nesting sites proximate to Port Hedland_200205.mxd

Figure E

Cemetery Beach flatback turtle nesting area

Job Number: L19121-001
Doc Number: 005
Date: 02.05.20
Scale: 1:4,613 @ A3
Created by: MA
Source: Cadastre - Landgate, 2019 Orthophoto - Landgate, 2018

Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122 | www.rpsgroup.com

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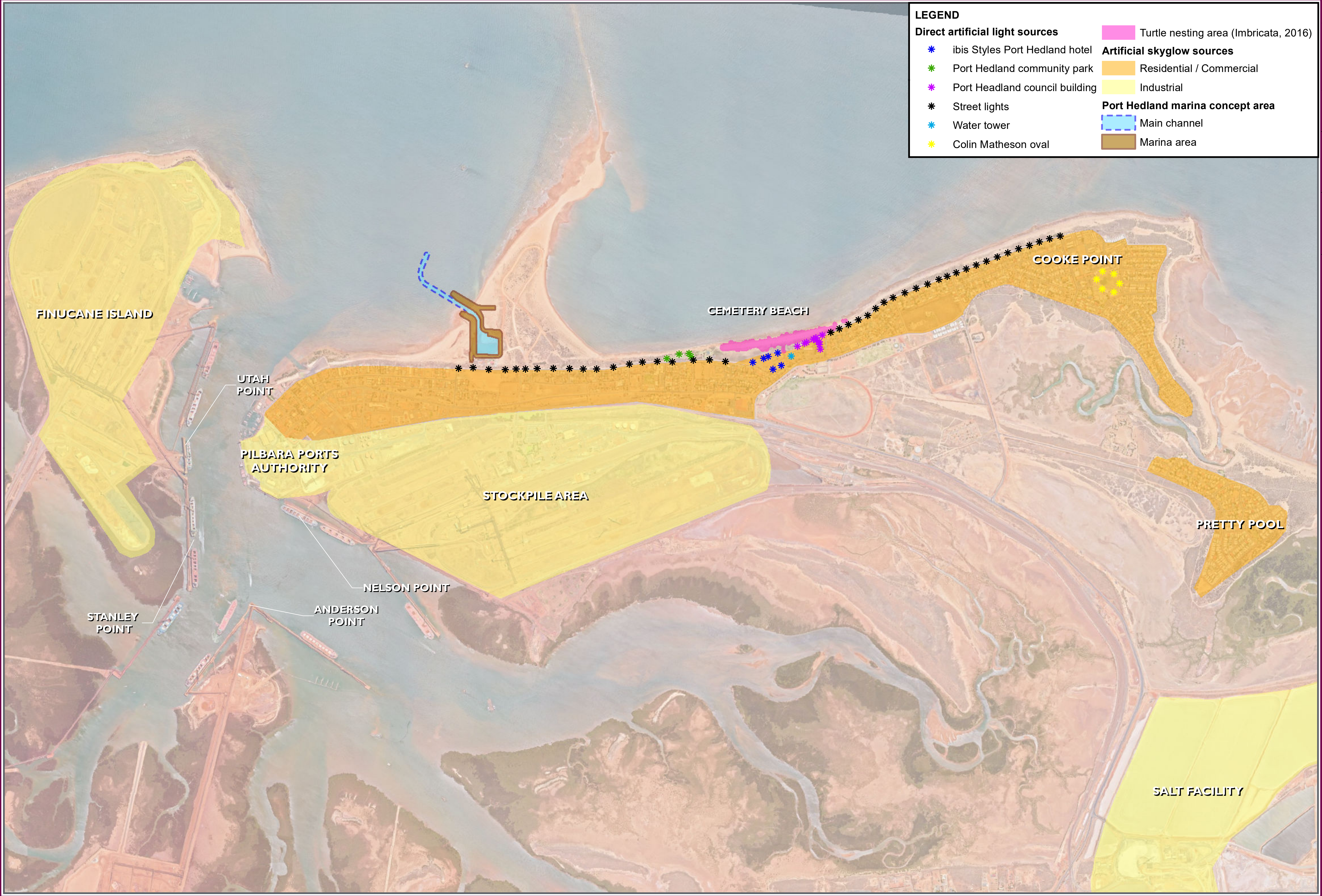

Level 2, 27-31 Troode Street, West Perth | T +61 8 9211 1111 | F +61 8 9211 1122 | www.rpsgroup.com

Figure F

Key artificial light sources proximate to Cemetery Beach

GDA 1994 MGA Zone 50

0 250 500 1,000 m

Job Number: L19121-001
Doc Number: 006
Date: 02.05.20
Scale: 1:25,000 @ A3
Created by: MA
Source: Cadastre - Landgate, 2019 Orthophoto - Landgate, 2018

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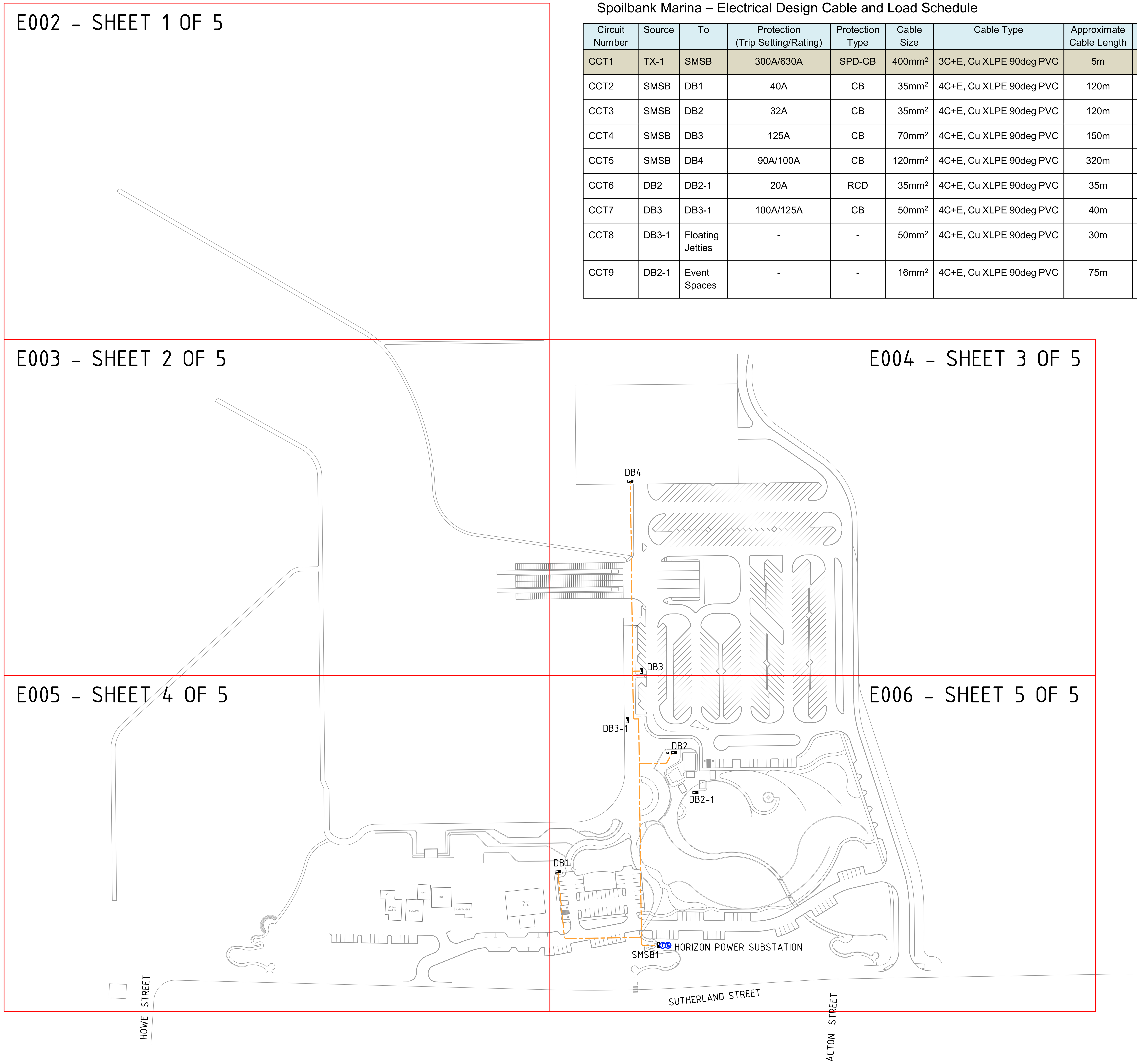
Appendix A

Preliminary lighting design



Spoilbank Marina – Electrical Design Cable and Load Schedule

Circuit Number	Source	To	Protection (Trip Setting/Rating)	Protection Type	Cable Size	Cable Type	Approximate Cable Length	Load (AS3000)	Comments
CCT1	TX-1	SMSB	300A/630A	SPD-CB	400mm²	3C+E, Cu XLPE 90deg PVC	5m	297A	
CCT2	SMSB	DB1	40A	CB	35mm²	4C+E, Cu XLPE 90deg PVC	120m	40A	
CCT3	SMSB	DB2	32A	CB	35mm²	4C+E, Cu XLPE 90deg PVC	120m	32A	
CCT4	SMSB	DB3	125A	CB	70mm²	4C+E, Cu XLPE 90deg PVC	150m	125A	
CCT5	SMSB	DB4	90A/100A	CB	120mm²	4C+E, Cu XLPE 90deg PVC	320m	100A	
CCT6	DB2	DB2-1	20A	RCD	35mm²	4C+E, Cu XLPE 90deg PVC	35m	20A	
CCT7	DB3	DB3-1	100A/125A	CB	50mm²	4C+E, Cu XLPE 90deg PVC	40m	100A	
CCT8	DB3-1	Floating Jetties	-	-	50mm²	4C+E, Cu XLPE 90deg PVC	30m	100A	
CCT9	DB2-1	Event Spaces	-	-	16mm²	4C+E, Cu XLPE 90deg PVC	75m	20A	

LEGEND

CONDUIT
- POWER - DISTRIBUTION
- POWER - RETICULATION
- POWER - LIGHTING
- POWER - 4x150mm SPARE

POWER INFRASTRUCTURE
- TRANSFORMER
- SWITCHGEAR
- SWITCHBOARD

Dimensions and scales to be checked prior to measuring cable lengths.
(Scale bar only valid for sections of drawing that are as per specified scale)

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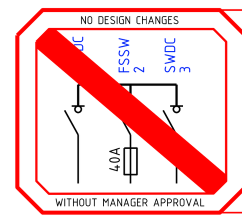
SCALE 1:1500 @ ORIGINAL SHEET SIZE A1



NO CHANGES TO DESIGN UNLESS APPROVED BY DESIGN MANAGER

PRELIMINARY ISSUE ONLY

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REV	DATE	DRAWN	PROJECT REVIEW	CHECKED	APPROVED	REVISION DESCRIPTION
B	-	LC	-	-	-	-
A	08.01.19	LC	BT	NMcK	NMcK	ISSUED TO CLIENT FOR COMMENT

PRELIMINARY ISSUE ONLY

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JDSi CONSULTING ENGINEERS
Workzone, Level 6, 1 Nash Street, Perth WA 6000
P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

PROJECT: SPOILBANK MARINA

DRAWING TITLE: PRIVATE POWER AND LIGHTING SITE OVERVIEW

DRAWN	L.CONTEMPRATO
DESIGNED	L.CONTEMPRATO
PROJECT MANAGER	D.HELLMUTH
WAPC No.	
SCALE @ A1	1:1500
DATUM/COORD	AHD/PHG94
HP REFERENCE	NA
JDSi PROJECT No.	JDS14736.0
DRAWING No.	E001
REVISION	B

N

LIGHTING SCHEDULE								
SYMBOL	LABEL	ARRANGEMENT	DESCRIPTION	LUM. WATTS	LUM. LUMENS	LLF	MH (m)	QTY
	Bxx	SINGLE	114-XXXX KTY234 R65.BEAM 3 LED 6W/700mA PC AMBER BOLLARD IP66 ALU LEC	6	198	0.800	1	
	S1-xx	SINGLE	108-XXXX VFL530 P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1A-xx	SINGLE	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1B-xx	BACK-BACK	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S3-xx	SINGLE	108-XXXX VFL530 R65.BEAM 24 LED 700mA PC AMBER IP66 ALU LEC	55	3312	0.800	6	
	S5-xx	SINGLE	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	6	
	S5A-xx	BACK-BACK	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	8	

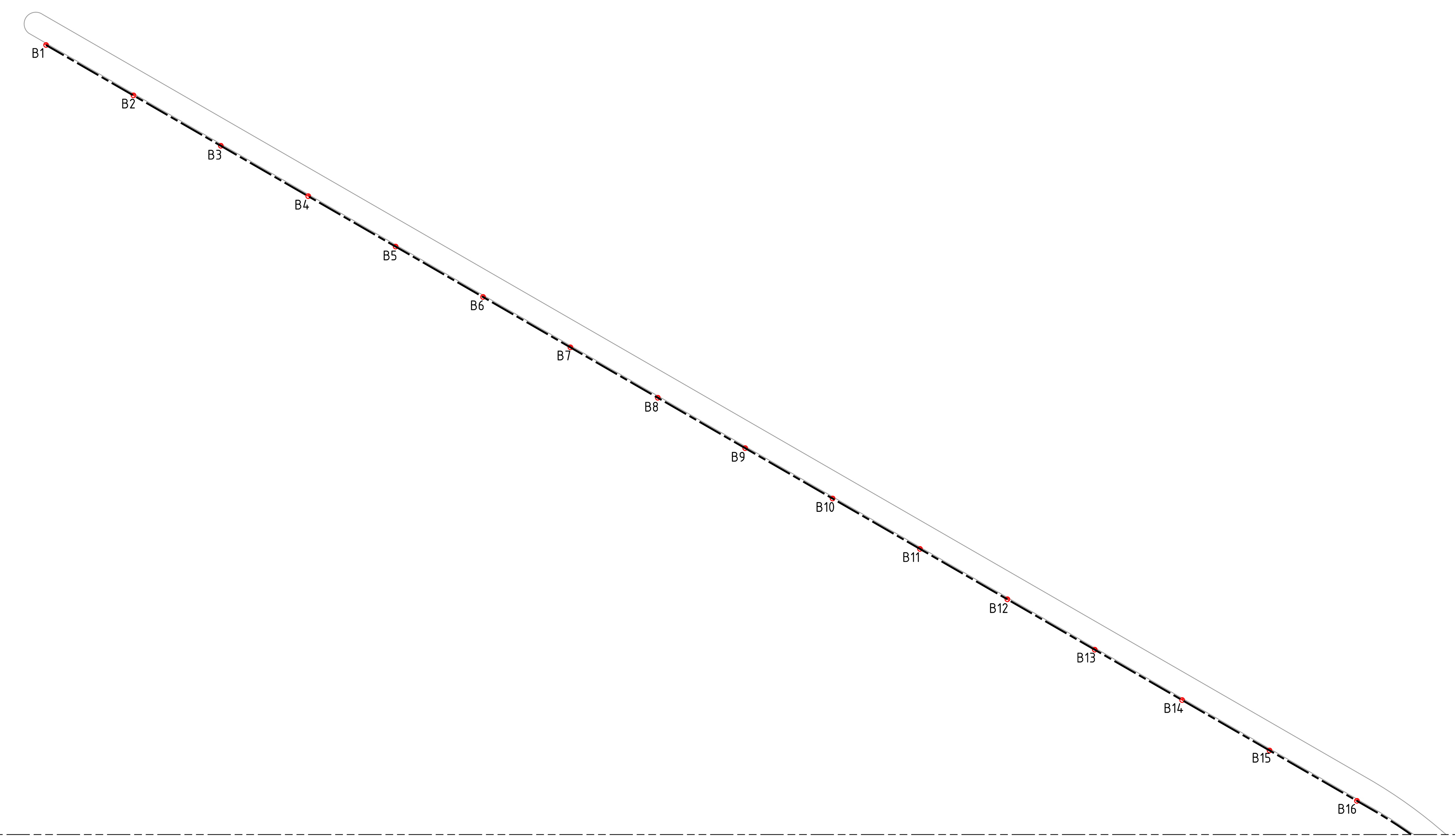
LEGEND

CONDUIT

- POWER - DISTRIBUTION
- POWER - RETICULATION
- POWER - LIGHTING
- POWER - 4x150mm SPARE

POWER INFRASTRUCTURE

- TRANSFORMER
- SWITCHGEAR
- SWITCHBOARD



MATCHLINE A REFER DRG E003

Dimensions and scales to be checked prior to measuring cable lengths.
(Scale bar only valid for sections of drawing that are as per specified scale)

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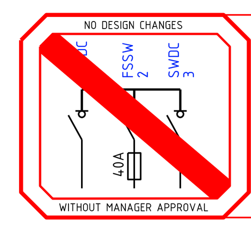
SCALE 1:500 @ ORIGINAL SHEET SIZE A1



NO CHANGES TO DESIGN UNLESS APPROVED BY DESIGN MANAGER

PRELIMINARY ISSUE ONLY

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PRELIMINARY ISSUE ONLY

REV	DATE	DRAWN	PROJECT REVIEW	CHECKED	APPROVED	REVISION DESCRIPTION
A	08.01.19	LC	BT	NMcK	NMcK	ISSUED TO CLIENT FOR COMMENT

NOTE
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Certified Quality System to ISO 9001

JDSi
CONSULTING ENGINEERS
Workzone, Level 6, 1 Nash Street, Perth WA 6000
P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

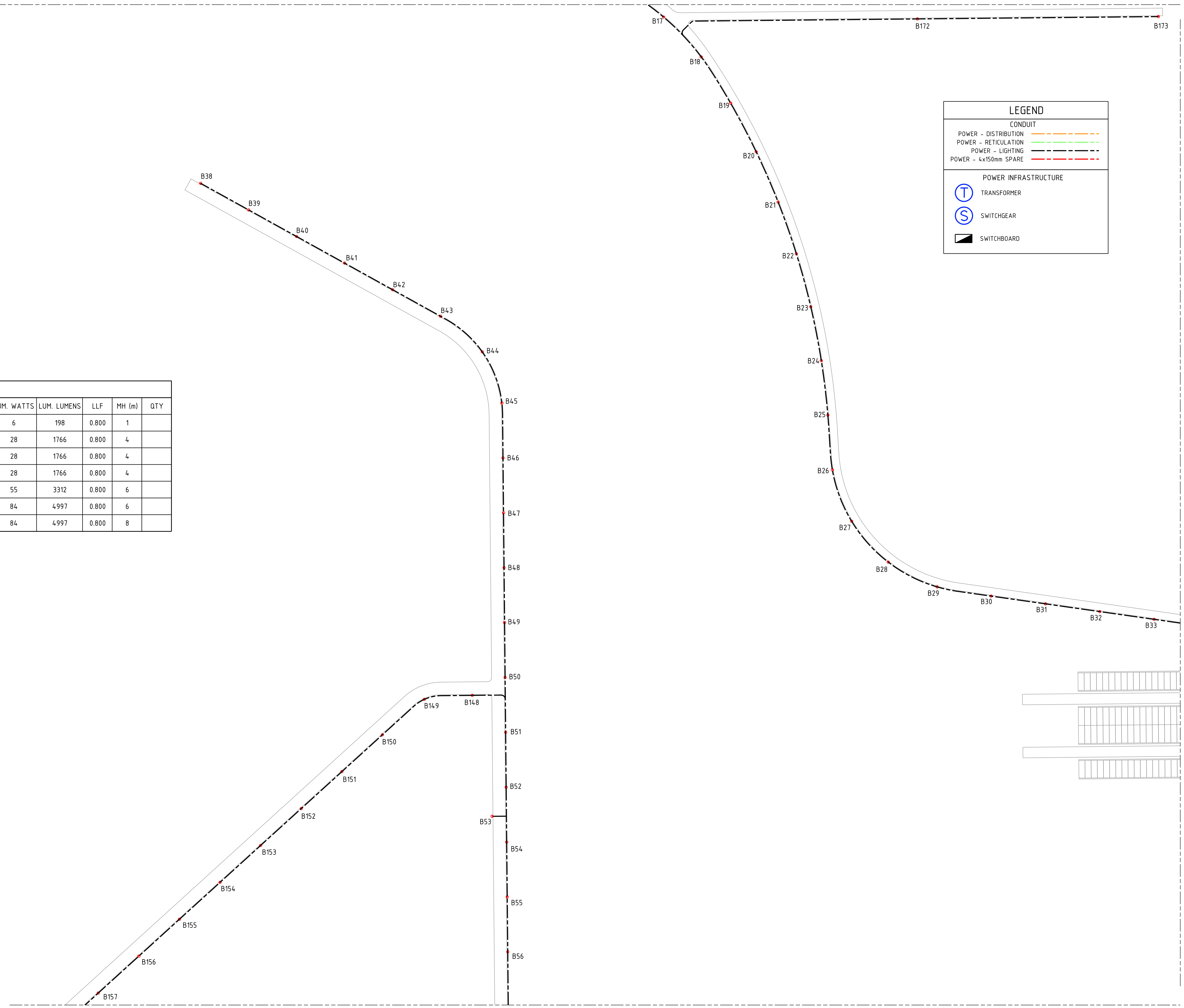
PROJECT: SPOILBANK MARINA

DRAWING TITLE: PRIVATE POWER AND LIGHTING DESIGN LAYOUT SHEET 1 OF 5

DRAWN	L.CONTEMPRATO
DESIGNED	L.CONTEMPRATO
PROJECT MANAGER	D.HELLMUTH
WAPC No.	
SCALE @ A1	1:500
DATUM/COORD	AHD/PHG94
HP REFERENCE	NA
JDSi PROJECT No.	JDS14736.0
DRAWING No.	E002
REVISION	B

N

MATCHLINE A REFER DRG E002



MATCHLINE B REFER DRG E004

MATCHLINE C REFER DRG E005

LIGHTING SCHEDULE								
SYMBOL	LABEL	ARRANGEMENT	DESCRIPTION	LUM. WATTS	LUM. LUMENS	LLF	MH (m)	QTY
	Bxx	SINGLE	114-XXXX KTY234 R65.BEAM 3 LED 6W/700mA PC AMBER BOLLARD IP66 ALU LEC	6	198	0.800	1	
	S1-xx	SINGLE	108-XXXX VFL530 P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1A-xx	SINGLE	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1B-xx	BACK-BACK	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S3-xx	SINGLE	108-XXXX VFL530 R65.BEAM 24 LED 700mA PC AMBER IP66 ALU LEC	55	3312	0.800	6	
	S5-xx	SINGLE	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	6	
	S5A-xx	BACK-BACK	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	8	

Dimensions and scales to be checked prior to measuring cable lengths.
(Scale bar only valid for sections of drawing that are as per specified scale)

0 5 10 20 30m
SCALE 1:500 @ ORIGINAL SHEET SIZE A1

NO DESIGN CHANGES WITHOUT MANAGER APPROVAL

NO CHANGES TO DESIGN UNLESS APPROVED BY DESIGN MANAGER

PRELIMINARY ISSUE ONLY

NOT FOR CONSTRUCTION

PRELIMINARY ISSUE ONLY

REV	DATE	DRAWN	PROJECT REVIEW	CHECKED	APPROVED	REVISION DESCRIPTION
A	08.01.19	LC	BT	NMcK	NMcK	ISSUED TO CLIENT FOR COMMENT

NOTE
This drawing shall be preliminary only until it is Issued for Construction.

Certified Quality System to ISO 9001

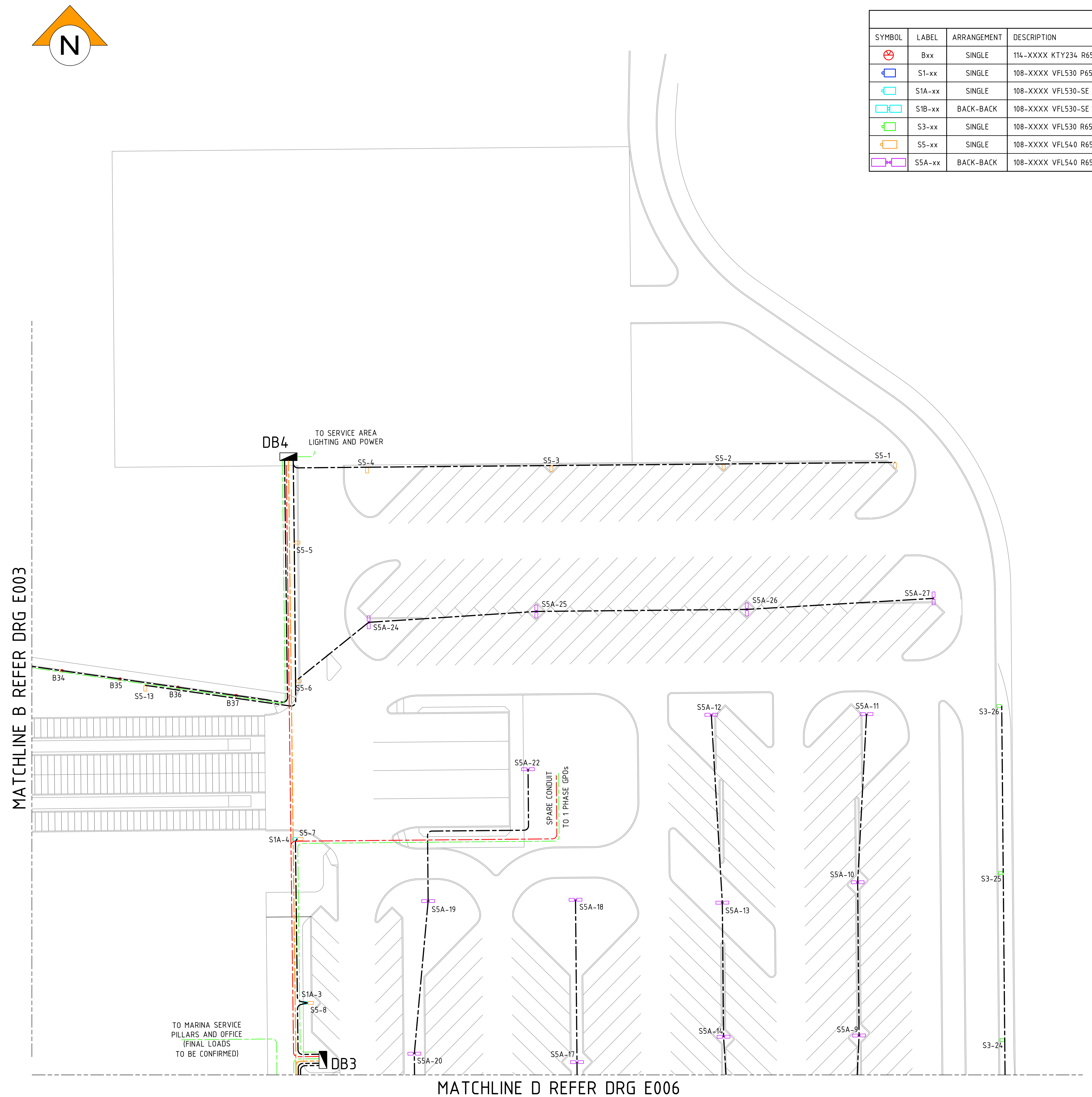
JDSi CONSULTING ENGINEERS
Workzone, Level 6, 1 Nash Street, Perth WA 6000
P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

PROJECT: SPOILBANK MARINA

DRAWING TITLE: PRIVATE POWER AND LIGHTING DESIGN LAYOUT SHEET 2 OF 5

DRAWN: L.CONTEMPRATO
DESIGNED: L.CONTEMPRATO
PROJECT MANAGER: D.HELLMUTH
WAPC No.:
SCALE @ A1: 1:500
DATUM/COORD: AHD/PHG94
HP REFERENCE: NA
JDSi PROJECT No.: JDS14736.0
DRAWING No.: E003
REVISION: B



LIGHTING SCHEDULE

SYMBOL	LABEL	ARRANGEMENT	DESCRIPTION	LUM. WATTS	LUM. LUMENS	LLF	MH (m)	QTY
	Bxx	SINGLE	114-XXXX KTY234 R65.BEAM 3 LED 6W/700mA PC AMBER BOLLARD IP66 ALU LEC	6	198	0.800	1	
	S1-xx	SINGLE	108-XXXX VFL530 P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1A-xx	SINGLE	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1B-xx	BACK-BACK	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S3-xx	SINGLE	108-XXXX VFL530 R65.BEAM 24 LED 700mA PC AMBER IP66 ALU LEC	55	3312	0.800	6	
	S5-xx	SINGLE	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	6	
	S5A-xx	BACK-BACK	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	8	

LEGEND

CONDUIT

- POWER - DISTRIBUTION
- POWER - RETICULATION
- POWER - LIGHTING
- POWER - 4x150mm SPARE

POWER INFRASTRUCTURE

- T TRANSFORMER
- S SWITCHGEAR
- SWITCHBOARD

NOTES:

1. DB3-1 AT TOP OF REVETMENT WALL WILL PROVIDE MARINA SERVICE PILLAR RETICULATION TO FINAL CIRCUITS.

Dimensions and scales to be checked prior to measuring cable lengths.
(Scale bar only valid for sections of drawing that are as per specified scale)

0 5 10 20 30m
SCALE 1:500 @ ORIGINAL SHEET SIZE A1

NO DESIGN CHANGES ... WITHOUT MANAGER APPROVAL

NO CHANGES TO DESIGN UNLESS APPROVED BY DESIGN MANAGER

PRELIMINARY ISSUE ONLY

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PRELIMINARY ISSUE ONLY

REV	DATE	DRAWN	PROJECT REVIEW	CHECKED	APPROVED	REVISION DESCRIPTION
A	08.01.19	LC	BT	NMcK	NMcK	ISSUED TO CLIENT FOR COMMENT

NOTE
This drawing shall be preliminary only until it is Issued for Construction.
Certified Quality System to ISO 9001

JDSi CONSULTING ENGINEERS
Workzone, Level 6, 1 Nash Street, Perth WA 6000
P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

PROJECT: SPOILBANK MARINA

DRAWING TITLE: PRIVATE POWER AND LIGHTING DESIGN LAYOUT SHEET 3 OF 5

DRAWN	L.CONTEMPRATO
DESIGNED	L.CONTEMPRATO
PROJECT MANAGER	D.HELLMUTH
WAPC No.	
SCALE @ A1	1:500
DATUM/COORD	AHD/PHG94
HP REFERENCE	NA
JDSi PROJECT No.	JDS14736.0
DRAWING No.	E004
REVISION	B

N

LEGEND	
CONDUIT	
POWER - DISTRIBUTION	
POWER - RETICULATION	
POWER - LIGHTING	
POWER - 4x150mm SPARE	
POWER INFRASTRUCTURE	
T	TRANSFORMER
S	SWITCHGEAR
	SWITCHBOARD

Dimensions and scales to be checked prior to measuring cable lengths.
(Scale bar only valid for sections of drawing that are as per specified scale)

0 5 10 20 30m
SCALE 1:500 @ ORIGINAL SHEET SIZE A1

NO CHANGES TO DESIGN UNLESS APPROVED BY DESIGN MANAGER

PRELIMINARY ISSUE ONLY

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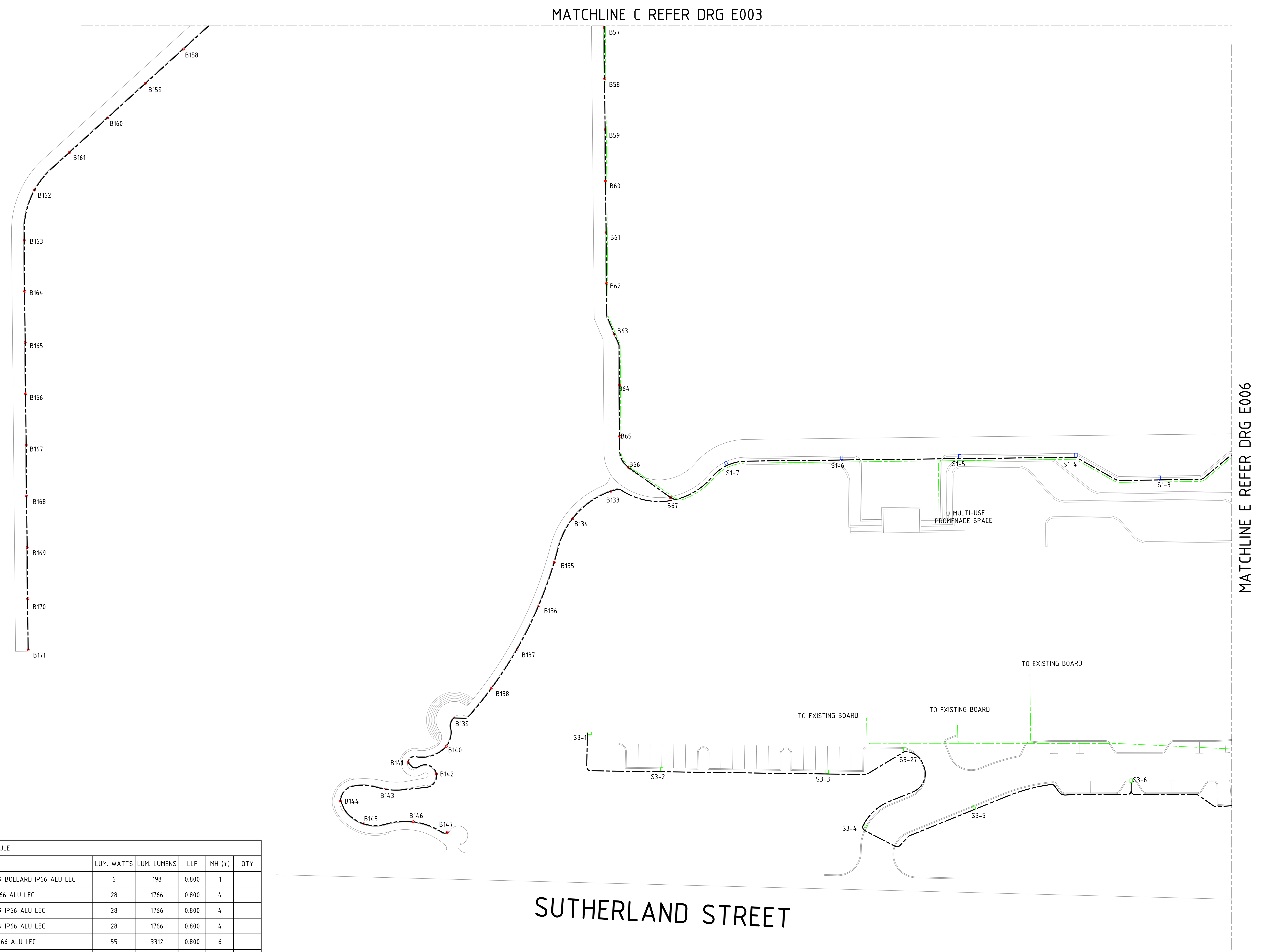

LIGHTING SCHEDULE								
SYMBOL	LABEL	ARRANGEMENT	DESCRIPTION	LUM. WATTS	LUM. LUMENS	LLF	MH (m)	QTY
	Bxx	SINGLE	114-XXXX KTY234 R65.BEAM 3 LED 6W/700mA PC AMBER BOLLARD IP66 ALU LEC	6	198	0.800	1	
	S1-xx	SINGLE	108-XXXX VFL530 P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1A-xx	SINGLE	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1B-xx	BACK-BACK	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S3-xx	SINGLE	108-XXXX VFL530 R65.BEAM 24 LED 700mA PC AMBER IP66 ALU LEC	55	3312	0.800	6	
	S5-xx	SINGLE	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	6	
	S5A-xx	BACK-BACK	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	8	

PRELIMINARY ISSUE ONLY

REV	DATE	DRAWN	PROJECT REVIEW	CHECKED	APPROVED	REVISION DESCRIPTION
A	08.01.19	LC	BT	NMcK	NMcK	ISSUED TO CLIENT FOR COMMENT

NOTE
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Certified Quality System to ISO 9001

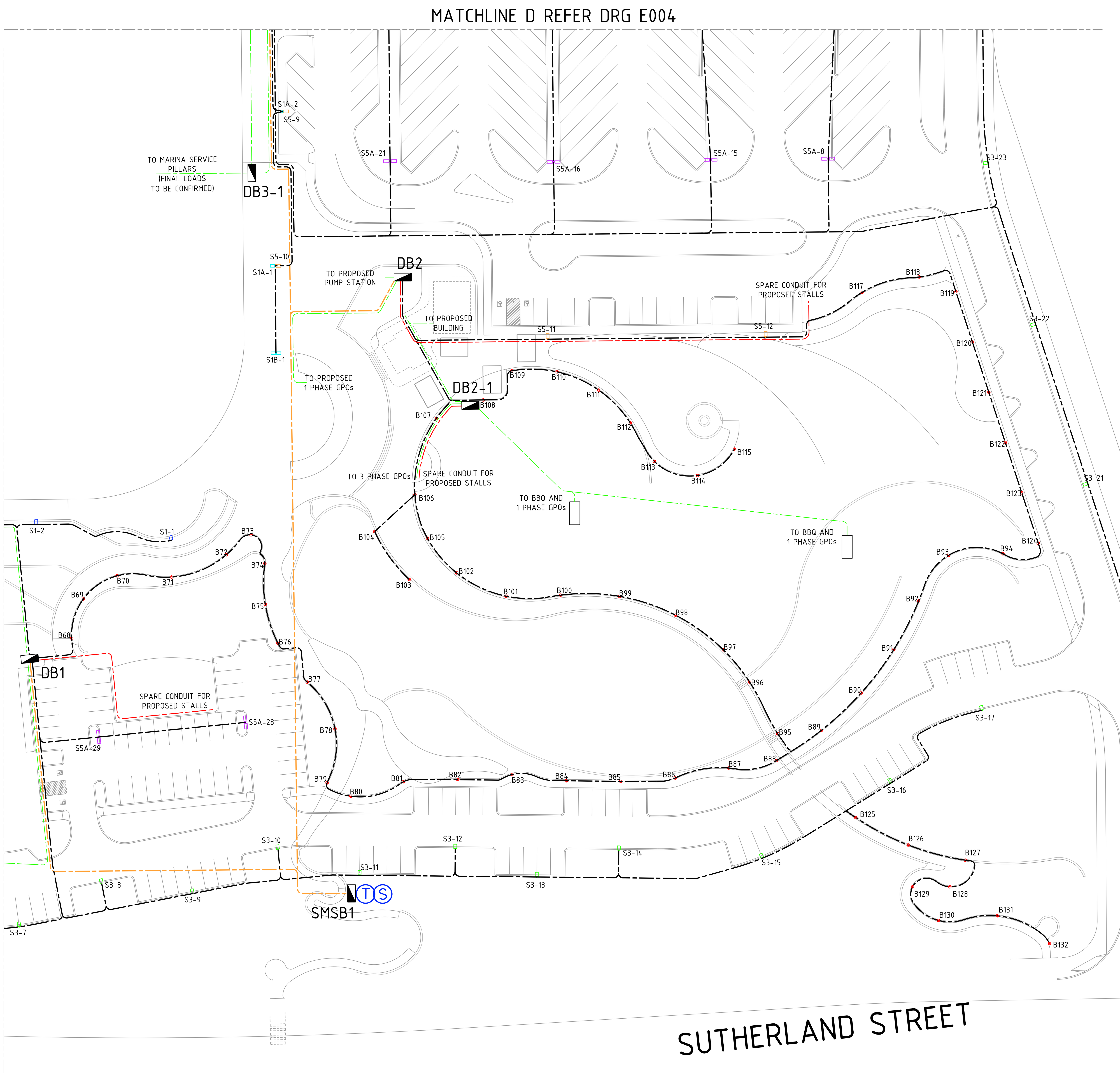
JDSi CONSULTING ENGINEERS
Workzone, Level 6, 1 Nash Street, Perth WA 6000
P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

PROJECT: SPOILBANK MARINA

DRAWING TITLE: PRIVATE POWER AND LIGHTING DESIGN LAYOUT SHEET 4 OF 5

DRAWN	L.CONTEMPRATO
DESIGNED	L.CONTEMPRATO
PROJECT MANAGER	D.HELLMUTH
JDSi PROJECT No.	JDS14736.0
WAPC No.	
SCALE @ A1	1:500
DATUM/COORD	AHD/PHG94
HP REFERENCE	NA
DRAWING No.	E005
REVISION	B



LEGEND

CONDUIT

- POWER - DISTRIBUTION
- POWER - RETICULATION
- POWER - LIGHTING
- POWER - 4x150mm SPARE

POWER INFRASTRUCTURE

- T — TRANSFORMER
- S — SWITCHGEAR
- SWITCHBOARD

LIGHTING SCHEDULE

SYMBOL	LABEL	ARRANGEMENT	DESCRIPTION	LUM. WATTS	LUM. LUMENS	LLF	MH (m)	QTY
	Bxx	SINGLE	114-XXXX KTY234 R65.BEAM 3 LED 6W/700mA PC AMBER BOLLARD IP66 ALU LEC	6	198	0.800	1	
	S1-xx	SINGLE	108-XXXX VFL530 P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1A-xx	SINGLE	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S1B-xx	BACK-BACK	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S3-xx	SINGLE	108-XXXX VFL530 R65.BEAM 24 LED 700mA PC AMBER IP66 ALU LEC	55	3312	0.800	6	
	S5-xx	SINGLE	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	6	
	S5A-xx	BACK-BACK	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	8	

Dimensions and scales to be checked prior to measuring cable lengths.
(Scale bar only valid for sections of drawing that are as per specified scale)

0 5 10 20 30m
SCALE 1:500 @ ORIGINAL SHEET SIZE A1

PRELIMINARY ISSUE ONLY

NOT FOR CONSTRUCTION

NO CHANGES TO DESIGN UNLESS APPROVED BY DESIGN MANAGER

PRELIMINARY ISSUE ONLY

REV	DATE	DRAWN	PROJECT REVIEW	CHECKED	APPROVED	REVISION DESCRIPTION
A	08.01.19	LC	BT	NMcK	NMcK	ISSUED TO CLIENT FOR COMMENT

NOTE
This drawing shall be preliminary only until it is Issued for Construction.
Certified Quality System to ISO 9001

JDSi CONSULTING ENGINEERS
Workzone, Level 6, 1 Nash Street, Perth WA 6000
P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

PROJECT: SPOILBANK MARINA

DRAWING TITLE: PRIVATE POWER AND LIGHTING DESIGN LAYOUT SHEET 5 OF 5

DRAWN	L.CONTEMPRATO
DESIGNED	L.CONTEMPRATO
PROJECT MANAGER	D.HELLMUTH
WAPC No.	
SCALE @ A1	1:500
DATUM/COORD	AHD/PHG94
HP REFERENCE	NA
JDSi PROJECT No.	JDS14736.0
DRAWING No.	E006
REVISION	B

BOLLARD LIGHTING

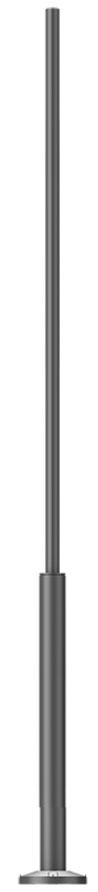
WE-EF
KTY234

POLE TOP LIGHTING

WE-EF
VFL530 & VFL540

POLE TOP LIGHTING

WE-EF
VFL530-SE



LIGHTING POLE

WE-EF
AMF-S
270-9388 4.0m
270-9320 6.0m
270-9324 8.0m

LIGHTING DESIGN TO AUSTRALIAN STANDARD AS/NZS1158.3.1
LIGHTING FOR PEDESTRIAN AREAS - CATEGORY P4
GENERAL STREET LIGHTING - CATEGORY P4
CAR PARK LIGHTING - CATEGORY P11C

LIGHTING SCHEDULE

SYMBOL	LABEL	ARRANGEMENT	DESCRIPTION	LUM. WATTS	LUM. LUMENS	LLF	MH (m)	QTY
	Bxx	SINGLE	114-XXXX KTY234 R65.BEAM 3 LED 6W/700mA PC AMBER BOLLARD IP66 ALU LEC	6	198	0.800	1	
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	S1B-xx	BACK-BACK	108-XXXX VFL530-SE P65.BEAM 12 LED 700mA PC AMBER IP66 ALU LEC	28	1766	0.800	4	
	S3-xx	SINGLE	108-XXXX VFL530 R65.BEAM 24 LED 700mA PC AMBER IP66 ALU LEC	55	3312	0.800	6	
	S5-xx	SINGLE	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	6	
	S5A-xx	BACK-BACK	108-XXXX VFL540 R65.BEAM 36 LED 700mA PC AMBER IP66 ALU LEC	84	4997	0.800	8	

NOT FOR CONSTRUCTION

PRELIMINARY ISSUE ONLY

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PRELIMINARY ISSUE ONLY

REV	DATE	DRAWN	PROJECT REVIEW	CHECKED	APPROVED	REVISION DESCRIPTION
A	08.01.19	LC	BT	NMcK	NMcK	ISSUED TO CLIENT FOR COMMENT

NOTE
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JDSi
CONSULTING ENGINEERS
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P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

PROJECT: SPOILBANK MARINA

DRAWING TITLE: PRIVATE POWER AND LIGHTING DESIGN DETAILS

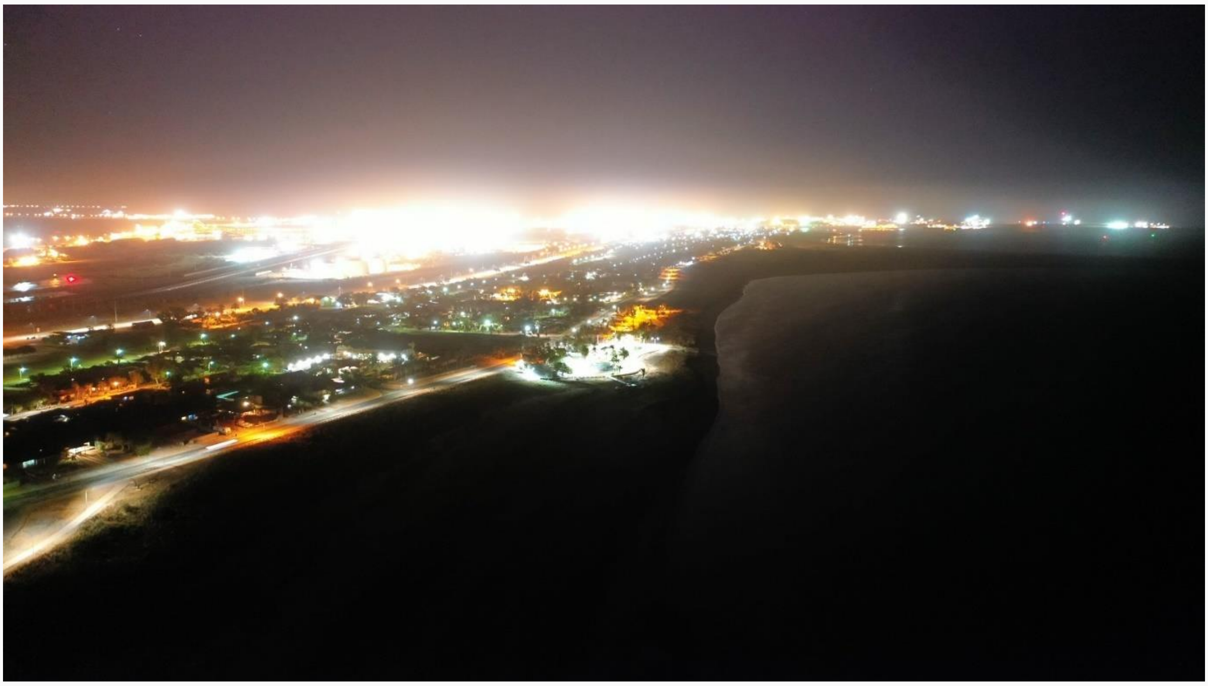
DRAWN: L.CONTEMPRATO
DESIGNED: L.CONTEMPRATO
PROJECT MANAGER: D.HELLMUTH
WAPC No.:
SCALE @ A1: N/A
DATUM/COORD: AHD/PHG94
HP REFERENCE: NA
JDSi PROJECT No.: JDS14736.0
DRAWING No.: E007
REVISION: B

Appendix B

Port Hedland Marina ‑ Benchmark Artificial Light Survey

RPS AUSTRALIA WEST

PORT HEDLAND MARINA – BENCHMARK ARTIFICIAL LIGHT AT NIGHT SURVEY



Prepared by

Pendoley Environmental Pty Ltd

For

RPS Australia West

15th November 2019

PENDOLEY ENVIRONMENTAL

MARINE CONSERVATION
ENVIRONMENTAL SERVICES

DOCUMENT CONTROL INFORMATION

TITLE: PORT HEDLAND MARINA - BENCHMARK ARTIFICIAL LIGHT AT NIGHT SURVEY

Disclaimer and Limitation

Document History

Revision	Description	Date received	Date issued	Personnel
Draft	Report Draft		14/11/2019	A. Mitchell
Rev A	Internal Review	14/11/2019	14/11/2019	K. Pendoley
Rev B	Client review	17/12/2019	17/12/2019	G. Glasson
Rev 0	Final report issued		06/02/2019	A. Mitchell

Printed:	6 February 2020
Last saved:	6 February 2020 10:35 AM
File name:	J69001_Port Hedland Spoilbank_Benchmark Light Monitoring_Rev0.docx
Author:	Adam Mitchell
Project manager:	Dr Kellie Pendoley
Name of organisation:	Pendoley Environmental Pty Ltd
Name of project:	Port Hedland Marina – Benchmark ALAN Survey
Client	RPS Australia West
Client representative:	Giles Glasson
Report number:	J69001
Cover photo:	Drone footage of Port Hedland at night – Paul Whittock

TABLE OF CONTENTS

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1 INTRODUCTION

1.1 Project Background

The Western Australia (WA) Department of Transport (DoT) and LandCorp are proposing to construct a marina on the western side of a man-made spoilbank in Port Hedland. The proposed marina is located immediately west of Cemetery Beach, which is a known nesting site for flatback turtles (*Natator depressus*). Flatback turtles are a threatened species, listed as Vulnerable under the WA *Biodiversity Conservation Act 2016* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

One of the potential impacts to flatback turtles is from new lighting installed as part of the proposed marina development. RPS Australia West (RPS) partnered with Pendoley Environmental (PENV) to assist with delivering an artificial lighting impact assessment for the Port Hedland marina with specific reference to the Cemetery Beach flatback turtle rookery.

The approach adopted to address the potential impact of the marina development's artificial light to nesting adult turtles and emergent hatchlings included early engagement with key project stakeholders, a benchmark light monitoring survey, and this survey report.

The stakeholder engagement included consultations with:

- Michelle Corobellini and David Pickles of the Environmental Management Branch, and Dr Scott Whiting of the Department of Biodiversity Conservation and Attractions (DBCA) were consulted on 13th September 2019 by Kellie Pendoley (PENV) and John Halleen (RPS) to confirm the proposed lighting impact assessment methodology. DBCA were satisfied with the proposed approach and asked only that an additional survey location on the spoilbank be included.

- Kelly Howlett (Care for Hedland) was contacted by Kellie Pendoley on 23rd September to discuss the marina proposal, lighting impact assessment methods, and proposed light monitoring locations in respect to the turtle nesting data held by Care for Hedland. She offered to provide her hatchling orientation data for Cemetery Beach and this data has been requested.

The results of the benchmark light monitoring survey of Cemetery Beach is provided in this report.

1.2 Deliverables

The DBCA and Care for Hedland confirmed the scope of works for the benchmark light survey included:

1. Overview of benchmark light monitoring methodology;
2. Identification of the existing Cemetery Beach night light environment;
3. Provide an estimation of light outputs from the marina in respect to the existing surrounding light levels recorded by the benchmark light monitoring; and
4. Liaison with the consulting engineer group (JDSi) to review the outputs of the final lighting design to inform preparation of this report.

Figure 1: Artificial light survey locations in Port Hedland.

2 METHODOLOGY

2.1 Survey Locations and Schedule

Two survey locations were selected on Cemetery Beach (see **Figure 1**); one situated at the east end of the beach and the second at the western end of the beach. The exact survey locations at Cemetery Beach were refined on site following:

- Daytime and night-time site reconnaissance of potential locations to ascertain ease-of-access to specific geographic locations and line of sight visibility of the light dome over Port Hedland.
- Assessment of survey location security (with regards to leaving equipment on site overnight unattended).

Cameras were deployed at these survey locations for each of the three monitoring nights.

Two additional survey locations (Spoilbank and Pretty Pool) were monitored for several hours on one night each (see **Figure 1**). These survey locations were included following consultation with Care for Hedland (K. Howlett) and DBCA (S. Whiting).

GPS coordinates of each survey location were recorded to enable comparison with future lighting surveys if required. The survey sites and GPS positions for the cameras are shown in **Table 1** and the monitoring schedule and camera locations are shown in **Table 2**.

Table 1: Survey locations and GPS positions.

Survey location	Latitude	Longitude
CB East	-20.307010	118.612659
CB West	-20.307670	118.608730
Pretty Pool	-20.314001	118.644642
Spoilbank	-20.307220	118.593262

Table 2: Monitoring schedule.

Date	Survey location: Overnight Deployment	Survey location: Short-term Deployment
30/09/2019	CB East, CB West	Pretty Pool
01/10/2019	CB East, CB West	NA
02/10/2019	CB East, CB West	Spoilbank

2.2 Data Capture

Sky brightness data was gathered using automated Sky42™ light monitoring cameras that feature a Canon EOS 700D camera and fish-eye lens with custom built hardware to acquire low light night sky images of the entire sky. The cameras are built into a rigid housing with a protective lid that automatically opens during image capture and closes between capture intervals. The cameras were deployed at each survey location and were programmed to automatically begin taking photos in 15-minute intervals between sunset and sunrise. Images were downloaded from the cameras each day.

Flatback hatchling fan data was captured by Care For Hedland (CFH) over the 2018/19 and 2019/20 nesting seasons and then quality checked for errors by PENV. However, as no information on CFH data collection methods is currently available to PENV, this was only a high-level check looking for obvious errors. Records with uncertainty around their validity were completely removed from the dataset (approximately 30 records).

2.3 Data Analysis

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 or dust 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.

All suitable images were processed to determine "whole-of-sky", "zenith", and "horizon" sky brightness levels. Zenith is the mean value of sky glow in magnitudes within 0° – 30° field of view directly overhead, whole-of-sky (WOS) is the mean value of sky glow in the entire image, and horizon is the mean value of sky glow within the 60° – 90° outer band (**Figure 2**).

Sky brightness was quantified in units of visual magnitudes/arcsec^2 (a standard unit used in astronomical measurements and emerging as a standard for sky glow monitoring globally). The visual magnitudes/arcsec^2 unit quantifies light intensity on an inverted logarithmic scale, i.e. higher values represent lower intensity light, while lower values represent higher intensity light (**Table 3**). The image with the median value of sky brightness for each site on a clear night was selected for complete analysis and presentation in this report.

Table 3: Qualitative interpretation of magnitude band values (source: Unihedron Sky Quality Meter). Use as guide only. **Values <17 Vmag/arcsec^2 not provided by source (considered to represent light level greater than 'very high' and representative of skies brighter than an urban night sky horizon).

Magnitude (Vmag/arcsec^2)	Qualitative Intepretation	Qualitative Example of Interpretation
21 – 22	Very low	Ideal natural dark night sky horizon
20 – 21	Low	Typical rural night sky horizon
19 – 20	Moderate	Typical suburban night sky horizon
18 – 19	High	Typical urban night sky horizon
17 – 18	Very High**	Poor urban night sky horizon

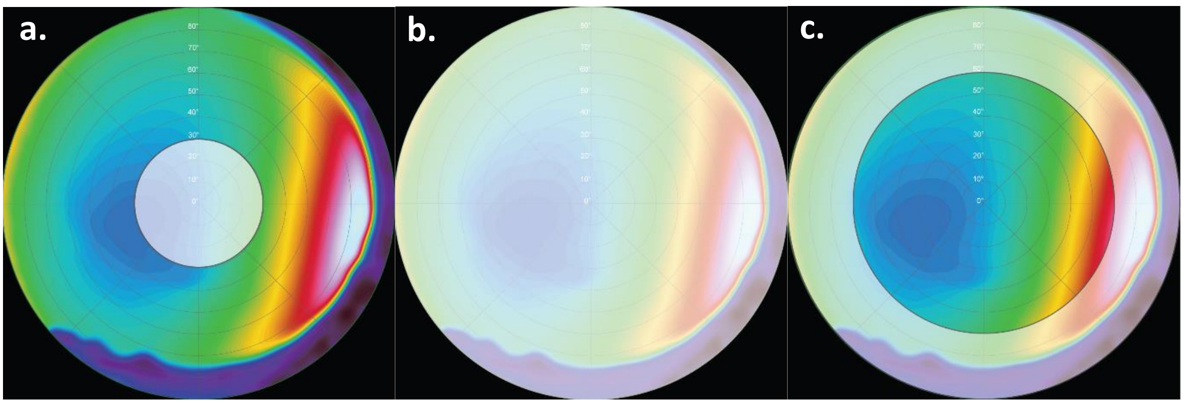


Figure 2: Measurement of mean pixel values; a. Zenith brightness (0° – 30°); b. WOS brightness (full image); c. Horizon brightness (60° – 90°). White shaded areas denote the region of the sky being measured.

Note that the colour coding used in the isophote map represents the scale of intensity of light and is not representative of the colour of light as perceived by a human/turtle eye or Sky42 camera.

3 RESULTS

Data was successfully collected from the four survey locations during three nights between 31st September and 2nd October 2019. There was no adverse weather and all nights were free of rain and cloud cover. The m sky brightness from each median image at each survey site are shown in **Table 4** and **Figure 3**. The Spoilbank survey location recorded the brightest WOS, zenith, and horizon values, and the Pretty Pool survey location recorded the darkest WOS, zenith, and horizon values (**Table 4**).

Table 4: Mean sky brightness (Vmag/arcsec^2) for zenith, whole-of-sky, and horizon brightness from a median image captured on a clear night at each survey location. Note survey locations are ordered by closest distance from the proposed marina development.

Survey location	Sky Brightness (Vmag/arcsec^2)		
	Whole-of-sky	Zenith	Horizon
Spoilbank	18.55	19.57	18.12
CB West	18.73	19.80	18.28
CB East	18.99	19.85	18.63
Pretty Pool	19.49	20.43	19.09

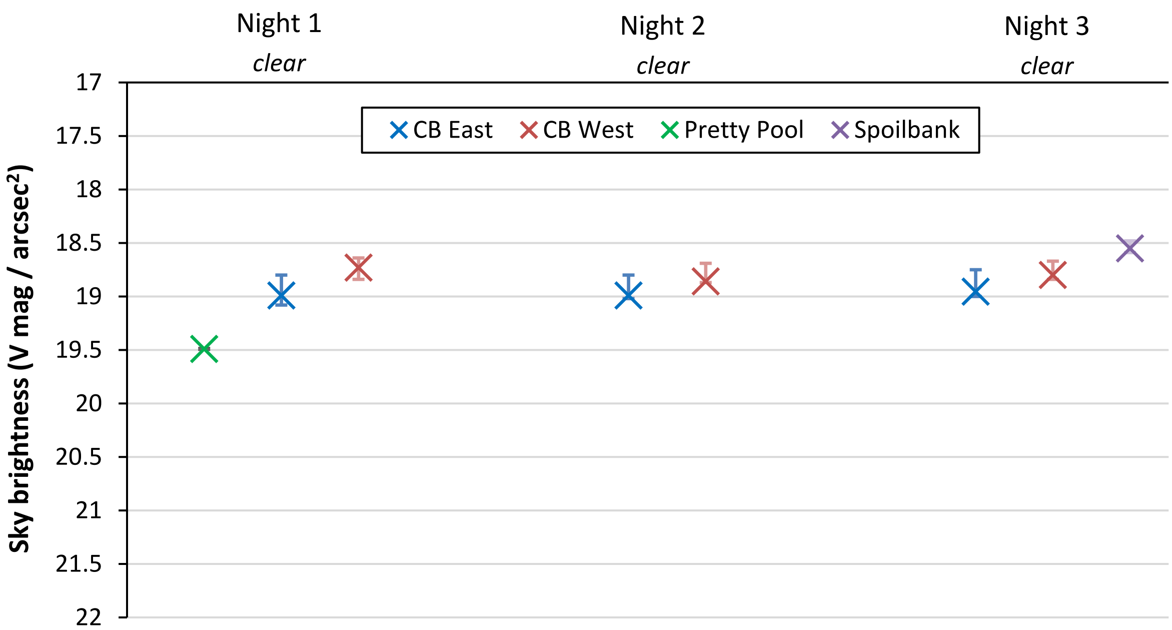


Figure 3: Whole-of-sky brightness at all sites over the survey period. An 'X' represents the median value for that site on a particular night, with the error bars indicating the range. The y-axis has been reversed to show brighter values towards the top and darker values towards the bottom of the graph.

The port facilities were the most dominant source of sky glow in Port Hedland and were visible from each survey location (see **Figures 4 – 7**). This was closely followed by Port Hedland residential and commercial lighting. Point sources of light that were directly visible from each survey location have been identified and are summarised in **Table 5**. Hatchling fan data collected on Cemetery Beach during the 2018/19 and 2019/20 nesting season shows a wide spread of tracks with minor bias towards the western light sources (**Figure 8**).

Table 5: Bearing to visible point sources of light from each survey location.

Survey location	Point source of light	Bearing from survey location
Spoilbank (Figure 4)	Street lighting	280° – 320°
	CB Turtle Park	90°
CB West (Figure 5)	Water tower	95°
	CB Turtle Park	260°
	Street lighting	60° - 100°
	Ibis hotel	140°
	Offshore vessels on moorings	330° - 10°
CB East (Figure 6)	Water tower	200°
	Council building	180°
	Aquatic centre	90°
	Street lighting	70° - 85°, 240° - 280°
	Offshore vessels on moorings	330° - 10°
	CB Turtle Park	260°
Pretty Pool (Figure 7)	Street lighting	300° - 340°
	Offshore vessels on moorings	350° - 360°

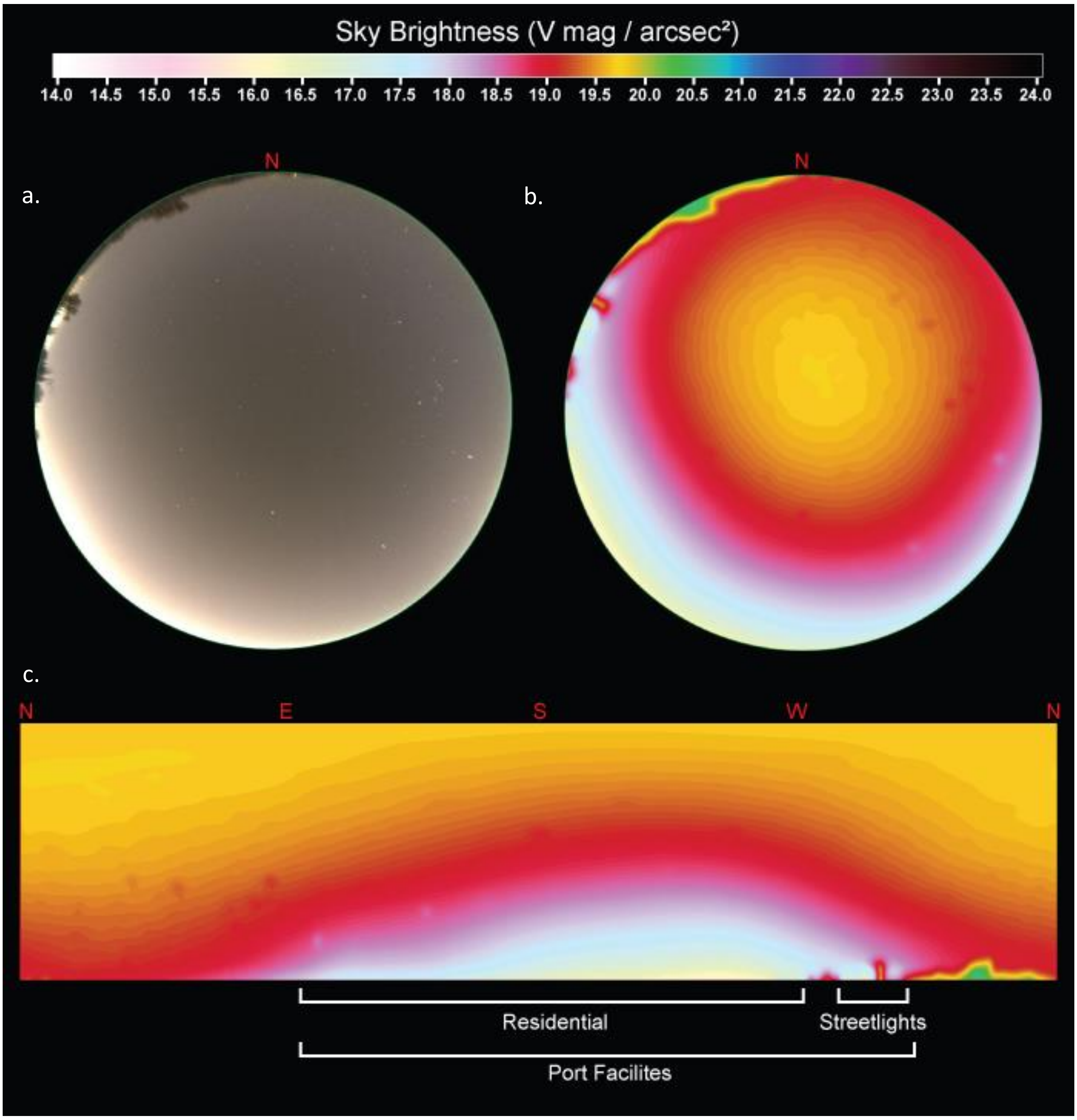


Figure 4: Artificial light monitoring results at Spoilbank on 2nd October 2019; a. Median raw image; b. Processed isophote image; c. Processed equirectangular panorama showing location of visible light sources.

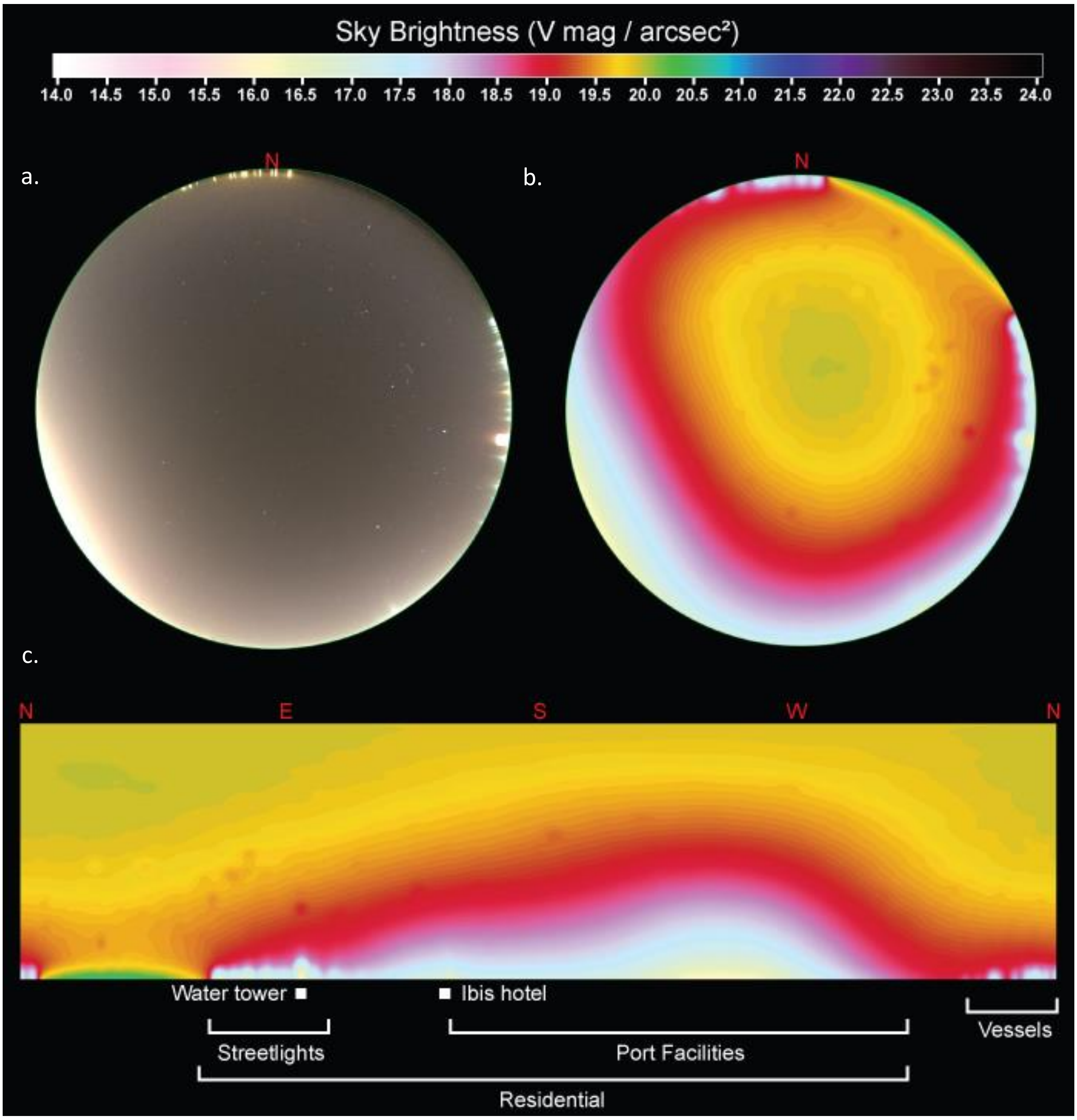


Figure 5: Artificial light monitoring results at CB West on 30th September 2019; a. Median raw image; b. Processed isophote image; c. Processed equirectangular panorama showing location of visible light sources.

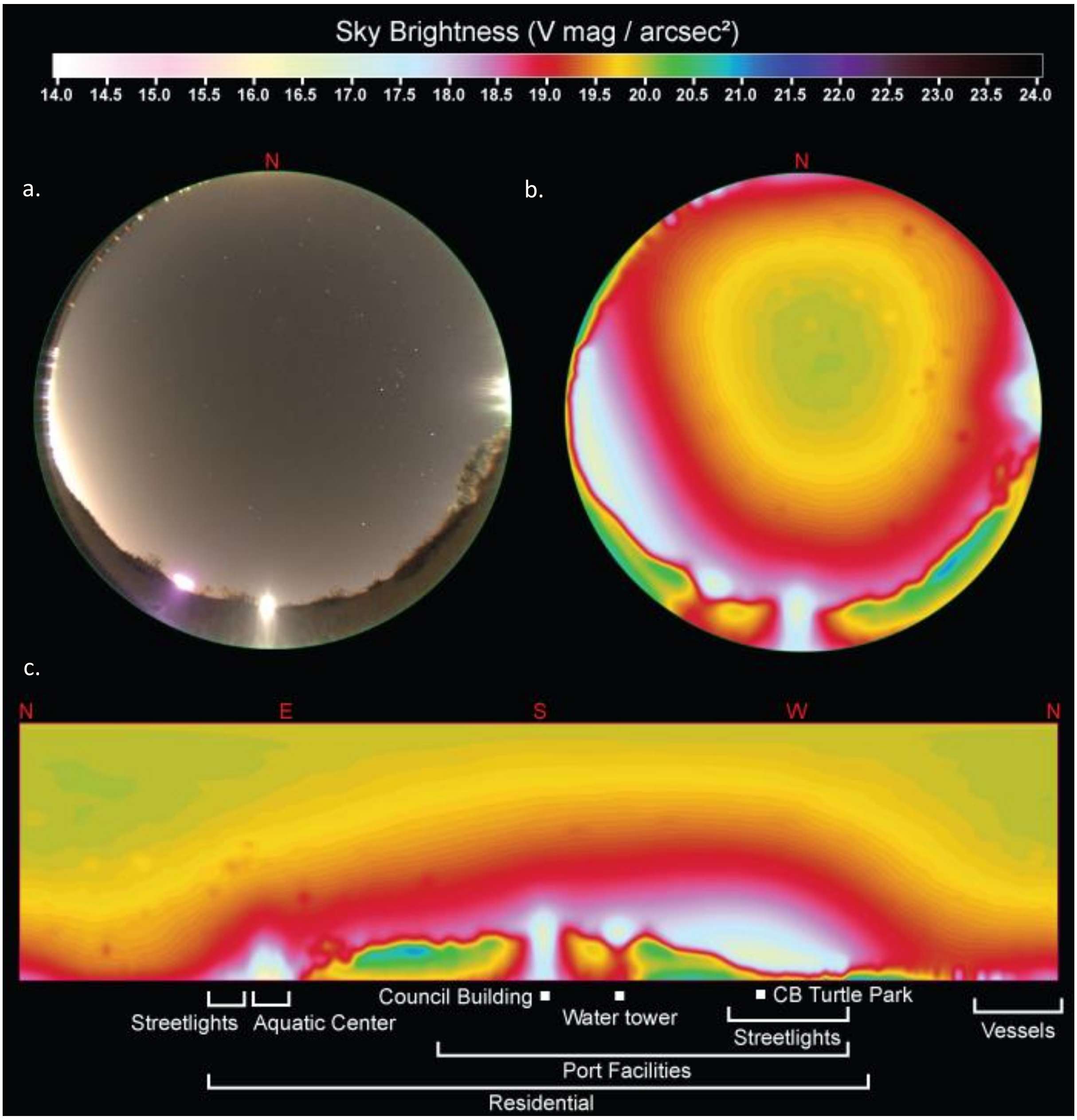


Figure 6: Artificial light monitoring results at CB East on 30th September 2019; a. Median raw image; b. Processed isophote image; c. Processed equirectangular panorama showing location of visible light sources.

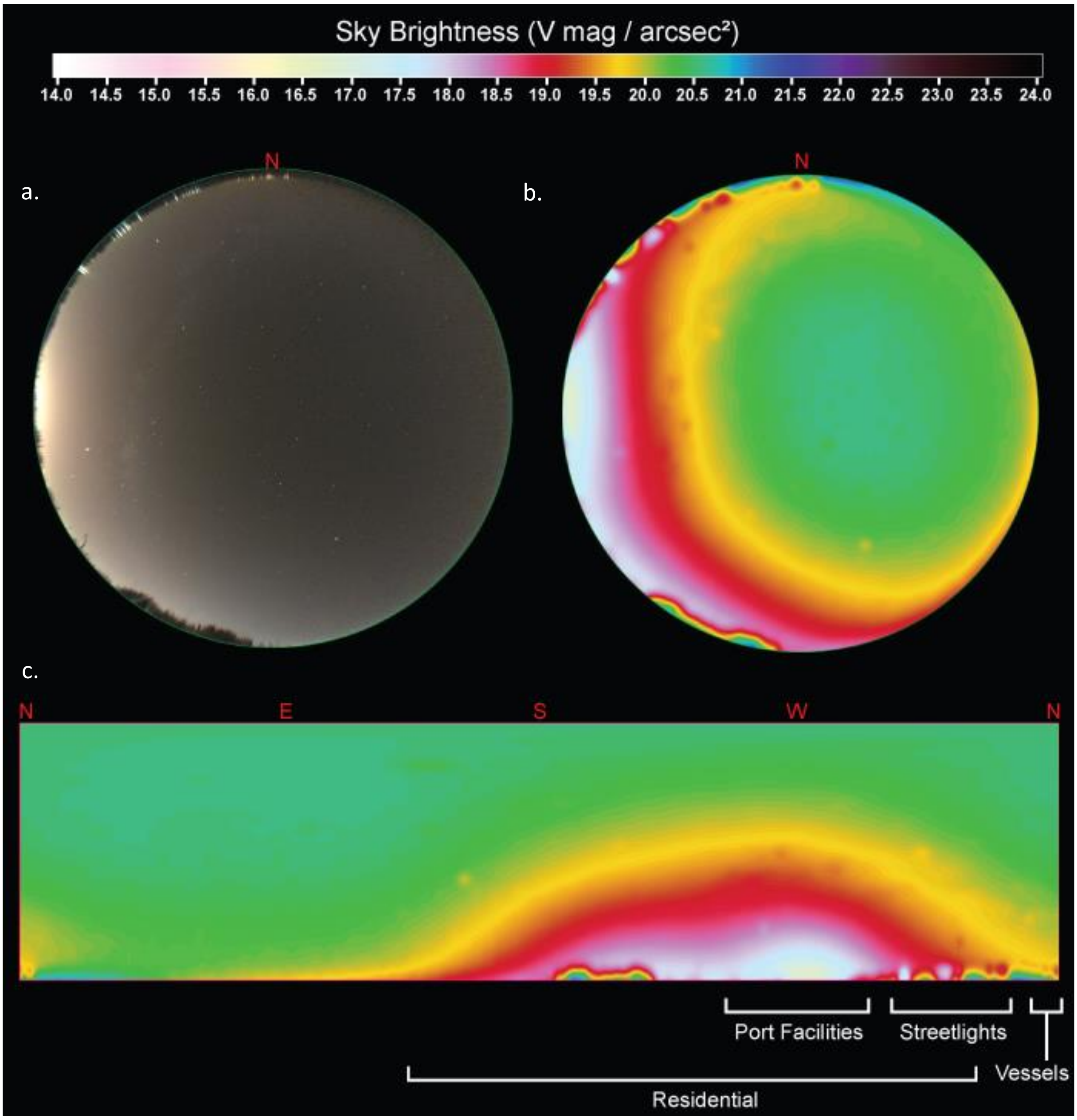


Figure 7: Artificial light monitoring results at Pretty Pool on 30th September 2019; a. Median raw image; b. Processed isophote image; c. Processed equirectangular panorama showing location of visible light sources.

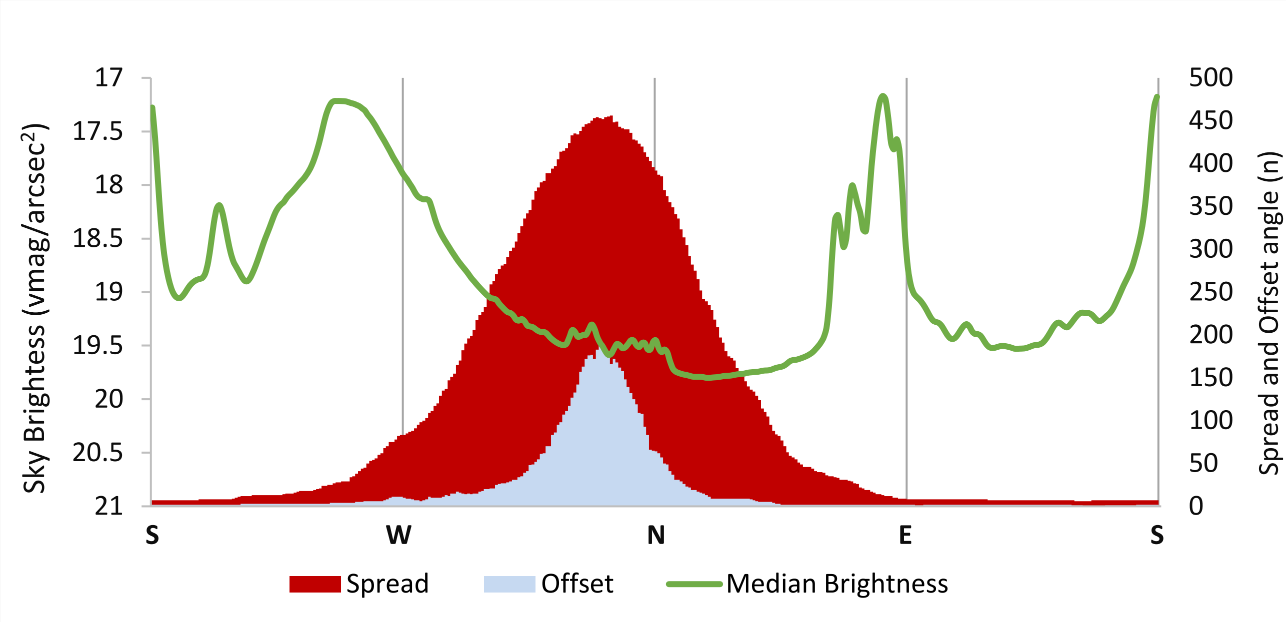


Figure 8: CFH hatchling fan data from Cemetery Beach in relation to brightness levels on the horizon (0° – 30°). Red: Histogram of hatchling fan spread angles; Blue: Histogram of hatchling fan angles offset from the ocean; Green: Horizon sky brightness levels from the CB East Sky42 camera location on cemetery beach.

4 DISCUSSION

The sky glow visible from all four survey locations was dominated by the port loading, processing and stockpiling facilities followed by urban residential and commercial lighting. The benchmark study results found a spatial relationship with distance from the proposed marina site with the brightest values recorded at the Spoilbank survey location, closest to the port light sources, and the darkest values recorded at Pretty Pool, furthest away from the light sources (**Table 4**). The two survey locations on Cemetery Beach showed that there is currently significant sky glow originating primarily from the port facilities, and residential lighting on a lesser scale, in the direction of the proposed marina site (approximately 260° – 290° bearing). A highly visible, bright source of unshielded bright white light (the light frequency considered most disruptive to sea turtles) originates from the Turtle Centre facility situated at the western end of Cemetery Beach (**Figures 5** and **6**), and is a potential cause of minor hatchling disorientation (**Figure 8**). Other unshielded point sources of light visible from the beach include commercial and council facilities and streetlights adjacent to Cemetery Beach.

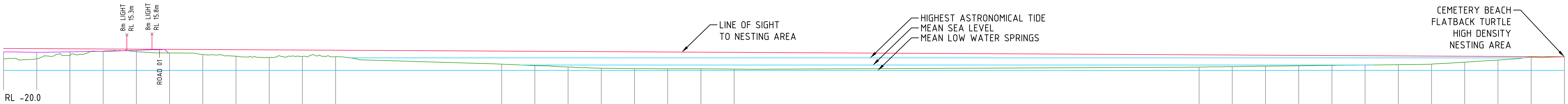
Lighting design plans from JDSi indicate the intent for lowered bollard-style walkway lighting throughout the site, and taller pole-mounted street lighting on the access road and parking areas. The bollard-style lighting will not be directly visible from the beach and have a negligible effect on sky glow due to the low lumen output and low height above ground. The pole-mounted lighting, while unlikely to increase sky glow more than the current measured levels, will be directly visible from the beach in some locations. As this has the potential to further increase hatchling disorientation towards the west end of Cemetery Beach, it is recommended that shielding be placed on these east-facing side of these lights to prevent or reduce line-of-sight visibility from Cemetery Beach.

5 REFERENCES

DEPARTMENT ENERGY AND ENVIRONMENT (*in review*) DRAFT National Light Pollution Guidelines for Wildlife - including Marine Turtles, Seabirds and Migratory Shorebirds.

Appendix C

Line of sight analysis



DATUM RL -20.0

CENTRE LINE CHAINAGE	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00
EXISTING SURFACE LEVEL	4.92	7.05	6.82	6.16	5.39	4.51	3.83	4.36	4.25			

CENTRE LINE CHAINAGE	700.00	750.00	800.00	850.00	900.00	950.00	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00
EXISTING SURFACE LEVEL		0.53	-0.19	-0.93	-1.52	-1.72	-1.80	-1.82	-1.92			

CENTRE LINE CHAINAGE	1300.00	1350.00	1400.00	1450.00	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00
EXISTING SURFACE LEVEL											-0.92

CENTRE LINE CHAINAGE	1850.00	1900.00	1950.00	2000.00	2050.00	2100.00	2150.00	2200.00	2250.00	2300.00	2350.00
EXISTING SURFACE LEVEL	-0.73	-0.48	-0.27	-0.08	0.13	0.28	0.56	1.55	2.59	4.01	4.26

SECTION TO MOST SEAWARD LIGHT

DATUM RL -20.0

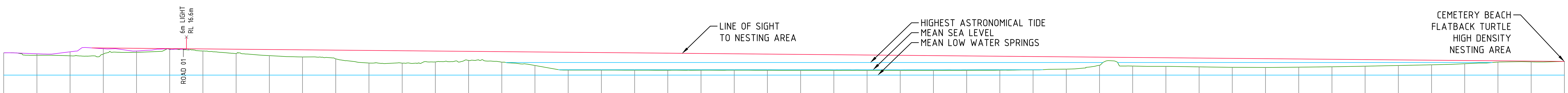
CENTRE LINE CHAINAGE	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00
EXISTING SURFACE LEVEL	4.81	7.05	9.39	8.86	7.99	6.24	5.41	5.72	4.07	4.52	4.68	2.69

CENTRE LINE CHAINAGE	700.00	750.00	800.00	850.00	900.00	950.00	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00
EXISTING SURFACE LEVEL	1.99	1.14	0.07	-1.03	-1.20	-1.47	-1.54	-1.55	-1.58	-1.61	-1.64	-1.68

CENTRE LINE CHAINAGE	1300.00	1350.00	1400.00	1450.00	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00
EXISTING SURFACE LEVEL	-1.60	-1.48	-1.41				-0.92	-0.76	-0.56	-0.29	-0.28

CENTRE LINE CHAINAGE	1850.00	1900.00	1950.00	2000.00	2050.00	2100.00	2150.00	2200.00	2250.00	2300.00	2350.00
EXISTING SURFACE LEVEL	-0.22	-0.16	0.03	0.28	0.42	0.86	1.53	2.25	3.12	4.06	4.26

SECTION THROUGH CARPARK



DATUM RL -20.0

CENTRE LINE CHAINAGE	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00
EXISTING SURFACE LEVEL	7.11	7.99	8.87	10.34	9.57	8.28	7.20	6.54	5.58	3.47	3.42	4.02

CENTRE LINE CHAINAGE	700.00	750.00	800.00	850.00	900.00	950.00	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00
EXISTING SURFACE LEVEL	4.80	3.93	2.22	-0.07	-0.07	-0.13	-0.15	-0.12	-0.14	-0.16	-0.21	-0.22

CENTRE LINE CHAINAGE	1300.00	1350.00	1400.00	1450.00	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00
EXISTING SURFACE LEVEL	-0.23	-0.27	-0.26	-0.20	-0.12	-0.01	0.39	2.38	1.93	1.80	1.55

CENTRE LINE CHAINAGE	1850.00	1900.00	1950.00	2000.00	2050.00	2100.00	2150.00	2200.00	2250.00	2300.00	2350.00
EXISTING SURFACE LEVEL	1.30	1.25	1.40	1.59	1.89	2.23	2.57	3.11	3.96	4.06	4.26

SECTION TO YACHT CLUB

PRELIMINARY

REV	DATE	DRAWN	CHECKED	APPROVED

NOTE
This drawing shall be preliminary only until it is issued for Construction.

Certified Quality System to ISO 9001

JDSi CONSULTING ENGINEERS
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P: (08) 9227 0595 F: (08) 9227 8617

CLIENT: TOWN OF PORT HEDLAND

PROJECT: SPOILBANK MARINA

DRAWING TITLE: SECTIONS TOWARDS CEMETERY BEACH WITH EXTENDED SURVEY SHOWING TURTLE NESTING AREAS

DRAWN	STEVE PARK
DESIGNED	STEVE PARK
PROJECT MANAGER	D HELLMUTH
JDSi PROJECT No.	JDS14736.0
WAPC No.	
SCALE @ A1	1:3000
DATUM	AHD
CO-ORDS	PHG94
DRAWING No.	SK503
REVISION	A

Plotted By: drullo Plot Date: 29/11/19 - 17:02 Cad File: I:\JDS14736\Drawings\DWG\Sketches\JDS14736.0_SK500.dwg