Report for Taronga Conservation Society Australia

Ecologically Sustainable Development (ESD) Statement

2 July 2020

EDGE

Project Delivered for:

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Revision	Revision Details	Author	Approved by	Date Approved
V0.1	Draft Issued to Client	Ken Lunty, Vaibhav Gaikwad, Ben Hale & Elizabeth Cuan	Ken Lunty	23rd June 2020
FINAL	FINAL Issued to Client	Ken Lunty, Vaibhav Gaikwad, Ben Hale & Elizabeth Cuan	Ken Lunty	2nd July 2020

Client Signed off

Edge Signed off

Contents

1 Introduction

The Taronga Zoo Conservation Society ("the Zoo") is submitting a State Significant Development Application (SSDA) to the Minister for Planning and Public Spaces pursuant to Part 4 of the Environment Planning and Assessment Act 1979 (EP&A Act).

The Zoo is seeking to secure concept approval for development of the "Upper Australia Precinct". The precinct will showcase Australia's unique flora and fauna in their natural habitat. The objective for the precinct is to showcase native Australian wildlife and landscapes in an unobtrusive manner, whilst conveying an educational message of conservation through minimal intervention. This will be achieved through working with the existing mature landscape and topography align with the integration of multi-layered cultural messaging throughout the precinct.

Sustainability and Ecologically Sustainable Development (ESD) forms a core part of the Zoo operations and is key to their current and future strategic plan. The current (2016-2020) strategic plan commits the Zoo as a leader in conservation, securing a shared future for wildlife and people. A key enabler of the strategic plan is Financial and Environmental Sustainability- committing to consider environmental sustainability targets in all business planning processes. The Zoo's Sustainability Strategy (2016-2020) includes targets such as:

- 90% waste diversion from landfill
- 20% reduction in energy consumption
- Engage 100% of staff to participate in sustainable work practices
- Integrate environmental risk into Taronga's Enterprise Risk Framework

Going forward, the Zoo continues to value the following strategic priorities:

- Meaningful engagement with the supply chain
- Support for the United Nations Sustainable Development Goals
- Retaining carbon neutral status
- Climate change resilience

The Zoo has engaged Edge Environment (Edge) to facilitate the development of an Ecologically Sustainable Development (ESD) statement to respond to the Secretary's Environmental Assessment Requirements (SEARs) issued for the concept stage SSDA addressing the requirements under ESD. These are outlined in Section 1.2.

The Zoo will undertake a whole of life approach to addressing the SEARs. This approach considers the impacts of the development across all stages through a life cycle assessment (LCA) methodology detailed in Section 2.2.

1.1 Proposed development

The new Upper Australia Precinct will occupy an area of 7,900sqm with a focus on building upon Taronga's contribution to conservation, science, education and enhancing visitor experiences. The project is multi-layered, dealing with a number of issues, such as:

- Re-routing of existing underground services
- Heritage and cultural considerations
- Existing topography and landscape integration
- Engagement and consultation with a number of stakeholders
- State of the art keeper facilities to allow for continued care and conservation of animals
- Visitor and staff safety
- Animal welfare
- Providing an enhanced and educational visitor experience.

The proposed precinct areas are focused around education, inviting visitors to engage with the landscape and animals. Some key strategies to achieve this are:

- To create an experience where the barriers between the animal and the visitor are removed or the perception of barrierless viewing is achieved
- To develop world class, iconic and immersive animal precincts that provides for meaningful animal and human connection
- Retain and re-use key heritage components pre-existing to provide a connection to Taronga Zoo's history and context
- Integrate cultural and interpretive messaging into the precincts and buildings to communicate ESD aspects of the precinct, to provide conservation education and connection to country and land.

The proposed buildings and structures are designed to sit within the landscape to create an immersive experience for guests. The site sits within a dense tree canopy and structures will not be visible from Sydney Harbour or from lower down the hill of Taronga Zoo. The main street frontage on Bradleys Head road will have a large timber fence/screen to provide the animals with visual and acoustic privacy. The scale of this screen will be lessened by pulling the top edge down where possible reducing the overall scale. The screen will also be softened by the use of natural timbers and with a landscaping strip in front of the screen to help break up the scale and soften the appearance from the street. The site location is presented in Figure 1.

Figure 1: Proposed site location

1.2 Secretary's Environmental Assessment Requirements (SEARs)

The SEARs for the SSDA require a response for the following:

- Detail how ESD principles (as defined in clause 7(4) of Schedule 2 of the Environmental Planning and Assessment Regulation) will be incorporated in the design, construction and ongoing operation of the development.
- Demonstrate how the proposed development responds to sustainable building principles and best practice, and improves environmental performance through energy efficient design, technology and opportunities for renewable energy.
- Provide an integrated water management plan that considers water, wastewater and stormwater, including an assessment of water demand, alternative water supply, proposed end uses of potable and non-potable water, water sensitive urban design and water conservation measures.

The principles of ecologically sustainable development as defined in clause 7(4) of Schedule 2 of the Regulation are as follows:

- The precautionary principle, namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:
    - careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment, and
    - an assessment of the risk-weighted consequences of various options,
- inter-generational equity, namely, that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations,
- conservation of biological diversity and ecological integrity, namely, that conservation of biological diversity and ecological integrity should be a fundamental consideration,
- improved valuation, pricing and incentive mechanisms, namely, that environmental factors should be included in the valuation of assets and services, such as:
    - polluter pays, that is, those who generate pollution and waste should bear the cost of containment, avoidance or abatement,
    - the users of goods and services should pay prices based on the full life cycle of costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste,
    - environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, that enable those best placed to maximise benefits or minimise costs to develop their own solutions and responses to environmental

This statement responds to the SEARs using an LCA approach which considers the principles of ESD as follows:

The Precautionary Principle

The precautionary principle is used to manage uncertainty around environmental and social impact associated with decision making and/or project delivery. It is used when there are threats of serious or irreversible environmental damage. In such cases, a lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. The precautionary principle facilitates the careful evaluation of potential environmental impacts to avoid serious and irreversible damage to the environment. The LCA approach used in this statement considers potential uncertainty across all stages of the development by taking a whole of life view of potential impacts. The statement has been delivered and the approach designed to reduce uncertainty as much as feasibly possible and the precautionary principle has been applied throughout design development.

Intergenerational Equity

Intergenerational equity is commonly associated with Our Common Future's definition of sustainable development, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs". When considering that the asset life of this development could be between 50-100 years, it is important to understand the intergenerational impacts that may occur throughout its life cycle. This LCA methodology used in the development of this statement will provide a framework for design development and delivery that considers the impact of the asset throughout operation and in end of life. Consideration of all stages of the project life will manage impacts across generations. This is in line with the approach to sustainability adopted by the Zoo in its organisational strategy. The project will enable memorable experiences for all generations that visit the precinct. It will provide opportunity to educate visitors in sustainable practices, natural habitats and the intrinsic value of native Australian species.

Conservation of biological diversity and ecological integrity

Conservation of biological diversity and ecological integrity is a core strategic focus area for the Zoo. This will be integrated into the delivery of the Upper Australia Precinct. The Zoo Actively participates in wildlife conservation initiatives that ensure the long-term security of wildlife in sustainable ecosystems and habitats. This objective is supported by the following goals:

- Support conservation initiatives that demonstrate positive impact for wildlife habitats and communities
- Investigate, communicate and implement collaborative scientific programs that inform key environmental issues, improve conservation planning and optimise wildlife management
- Develop and carry out community conservation campaigns that achieve positive outcomes for wildlife
- All species in Zoocare have a clear role that contributes to conservation or education outcomes
- Expand habitat for native wildlife at both Zoos.

The Upper Australia Precinct will be delivered under these goals and strategic objective and therefore will align with the intent of the EP&A regulation.

Improved valuation, pricing and incentive mechanisms

Improved valuation, pricing and incentive mechanisms require the consideration of all environmental resources which may be affected by the development. This statement includes an understanding of the life cycle impacts of the development through analysis of the supply chain, operational impacts and end of life considerations. The proposed development will be delivered in line with the Zoo's Sustainability Strategy with additional actions summarised in this statement. The use of LCA is not typical in SSDAs and represents an improved valuation of whole of life environmental impacts to be considered through design development.

2 Ecologically Sustainable Development (ESD) Approach

The ESD approach used in the development of this Statement uses LCA as a core framework to identify whole of life impacts associated with the development. The concept design LCA was considered in context with the wider Zoo sustainability activities and proposed sustainability initiatives were developed in consultation with the Zoo stakeholders and the project design and delivery team. The Zoo has implemented the following sustainability initiatives which are relevant to the delivery of the Upper Australia Precinct and addressing the SEARs:

- **Carbon Neutral Operations**: In 2019, the Zoo achieved Carbon Neutral Status under Climate Active, 6 years ahead of its commitment schedule. To become Carbon Neutral under the Climate Active Scheme, organisations must show that they are committed to take action on climate change by reducing carbon emissions on a continual basis and offset remaining emissions by investing in carbon reduction projects. Key contributions to the Zoos certification include investment in on-site renewable energy including more than 450 kW of photovoltaics to date and incorporation of ESD principles in all new developments
- **Water Treatment Facility**: Taronga Zoo operates a wastewater treatment plant to treat and recycle water on site. The plant includes a stormwater tank and a micro filtration unit to reclaim up to 100 million litres of water per year. The recycled water is used for:
    - Hosing down of animal exhibits
    - Exhibit moat filling
    - Toilet flushing
    - Lawn and garden irrigation

  The benefits of using recycled water on site include the following:
    - Reduction of dry weather discharge into Sydney Harbour
    - Reduce reliance on Sydney Water's fresh water supply, particularly during water restriction periods
    - Support the principles of waste avoidance and resource recovery
    - Demonstrate effective water recycling resulting in educational benefits and technology sharing.

The above sustainability initiatives are applied across the Taronga Zoo through operations and will be applied to the Upper Australia Exhibit in delivery and operation. Project specific sustainability initiatives were developed through the following activities:

- Initial materiality assessment
- Sustainability ideation session
- Sustainability initiative prioritisation
- Concept level life cycle assessment.

2.1 Materiality assessment

An initial materiality assessment was undertaken through a workshop with the Zoo stakeholder group made up of the following stakeholders:

- Simon Duffy: Director
- Kristine Marshall: Project Manager
- Michael Head: Project Manager
- Belinda Fairbrother: Community Engagement Manager
- Bridget Corcoran: Environmental Sustainability Manager

- Rod Stapley: Head of Asset Management
- Dane O'Donoghue: Capital works and asset management
- Elio Bombonato: Precinct Manager

The materiality assessment helps to identify the most important areas of sustainability for investment. It also informs the development of initiatives, goals and targets in line with priority sustainability themes. The following sustainability themes were ranked according to relative importance to internal (Zoo investors, managers, operations staff) and external stakeholders (customers, community):

- Natural Land Transformation
- Tree retention
- Operational water efficiency
- Water sensitive urban design
- Off-site renewable energy
- Climate change resilience
- Operational energy efficiency
- Locally sourced materials
- Interpretation of initiatives
- Life cycle carbon
- On-site renewable energy
- Material re-use

The results of the materiality assessment are presented in Figure 2. Natural land transformation, tree retention, water efficiency and climate change resilience were outlines as having the highest relative materiality.

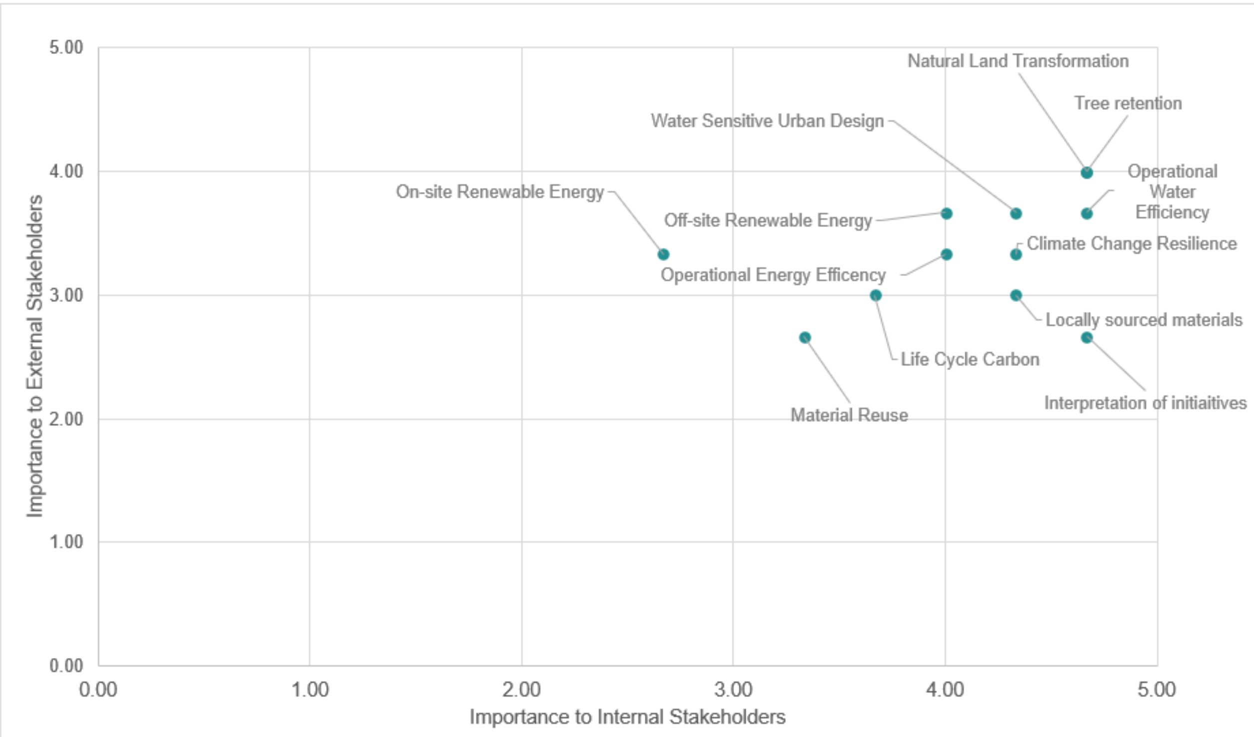

Figure 2: Sustainability materiality assessment for Upper Australia Exhibit

2.2 Life Cycle Assessment Approach

LCA can be used to guide decisions and optimise material selection, design and operations of a building's life cycle.

By overlaying calculated quantities with verified environmental impact factors, the cumulative effects of each building material considering whole of life cycle stage (Figure 3) strategies to design a low-impact precinct can be developed and implemented.

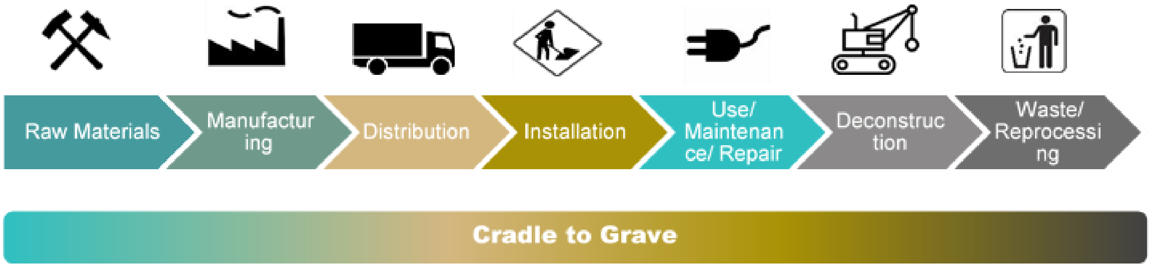

Figure 3: Asset life cycle stages

2.2.1 Approach

Taronga Zoo's environmentally sustainable development (ESD) initiatives follow an LCA based approach. Edge Environment undertook LCA of the SSDA Proposed Upper Australia Precinct at concept design stage (Figure 4) considering 50-year project life. The LCA identified environmental impact hotspots across the whole life cycle of the building elements within the precinct, from sourcing raw materials, through choice of building products, to deconstruction and waste disposal. By understanding these hotspots and their causes, strategies to design a low-impact precinct were developed.

Figure 4: SSDA Proposed Upper Australia Precinct – Concept Design

The assessment complied with the following standards using the module structure shown in Figure 5:

- ISO 14040 – Life cycle assessment – Principles and procedures
- ISO 14044 – Life cycle assessment – Requirements and guidelines

- Building LCA standard EN15978

The approach included estimating the embodied carbon of different materials within the Proposed Upper Australia Precinct using SimaPro v9.0. The cumulative effects of the building products within the precinct have been calculated and presented.

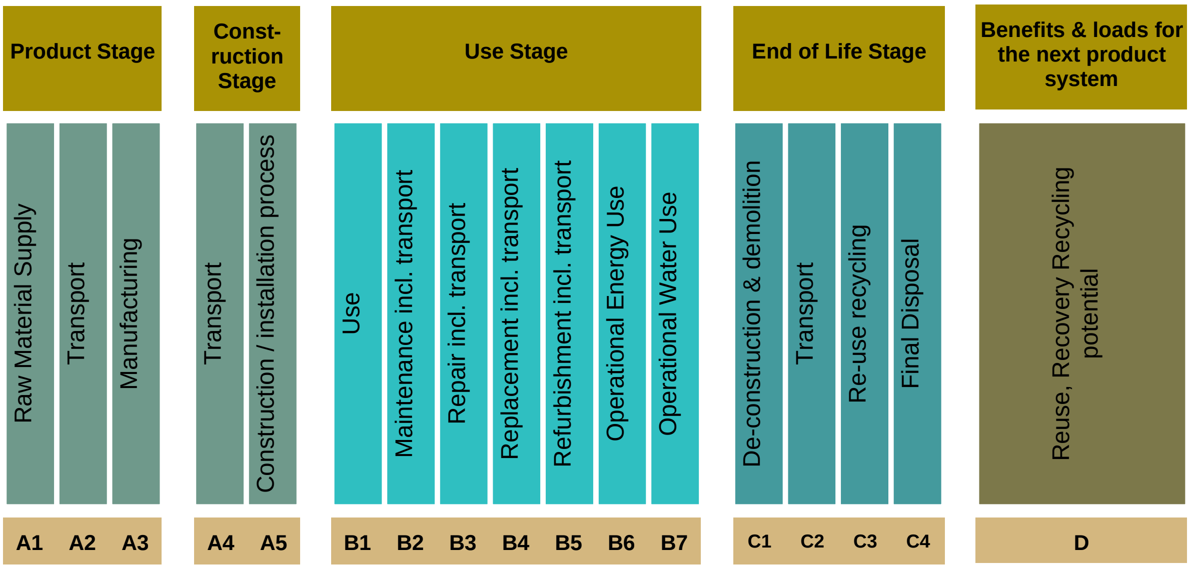

Figure 5: LCA Modules

3 Projected Life Cycle Impacts for Upper Australia Precinct

This section provides an estimate of the impacts for climate change, natural land transformation and water stress indicators for the Upper Australia Precinct. All impacts presented in this and subsequent sections are for a 50-year project life. The project footprint is based on the materials and processes included in the study and assume business-as-usual scenario. Negative impacts indicate emissions reductions (benefits) due to recycling or carbon sequestration in case of timber related materials.

3.1 Operational energy

Based on the assumption that the Upper Australia Precinct accounts for 2% of Taronga zoo's electricity consumption, it is estimated that the precinct will emit 159 t CO2 eq per year or 7,969 t CO2 eq. over 50 years.

Taronga zoo is certified as carbon neutral by Climate Active and offsets its emissions by purchasing carbon credits. In addition to on-site solar energy, the zoo is also exploring sourcing of off-site renewable energy.

Figure 6 depicts the potential emissions reduction which can be achieved at various levels of Solar PPA coverage over the 50-year life of the project.

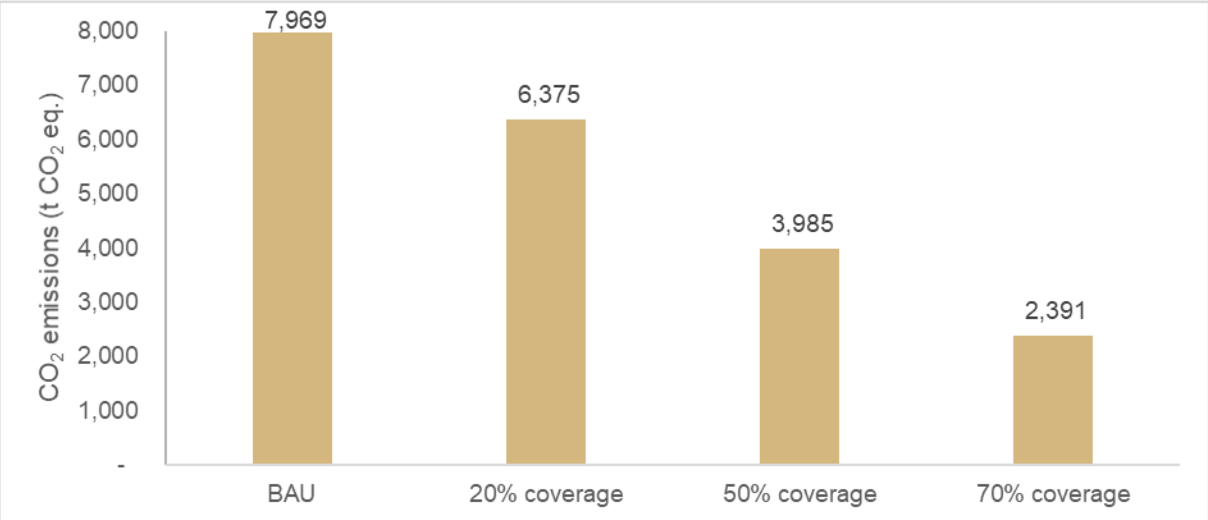

Figure 6: Potential emissions offset due to PPA coverage

3.2 Operational Water

While the zoo does not currently have a site-wide integrated water management plan, significant and concerted efforts are made across the zoo's whole footprint to ensure that water management and water practices are relevant, innovative, and sustainable.

3.2.1 Water Treatment Plant

Taronga Zoo has put significant, time, thought, and resource into water management initiatives, in an effort to identify and implement water savings opportunities, through recycling and reusing water, and through reducing the use of fresh, potable water, wherever feasible.

Chief among the zoo's investment is the on-site water treatment plant, built in 1996. The plant treats captured rain and storm water for recycling and reuse. The primary aims of the plant is to keep Sydney Harbour free of unnecessary particulates and pollutants, while simultaneously reducing the on-site demand for municipal potable water.

With recent upgrades, the plant has an annual capacity of 100 million litres of treated, recycled water. The major uses of this recycled water at the zoo are:

- Hosing down of animal exhibits

- Exhibit moat filling
- Toilet flushing
- Lawn and garden irrigation

Given that these uses form the majority of the demand for the new precinct, it can be assumed that outside of the drinking water provided through on-site drinking fountains and bubblers, the site's demand can be met through rain water, backed up through use of the zoo's recycled water.

3.2.2 Reducing Potable Water Demand

The capture and reuse of recycled water across the zoo (and inclusive of the current site) will reduce the demand on municipal, potable supply, with potable water consumption reductions also forming part of the initiatives described.

As shown in the 'Proposed ESD Initiatives' section, these standard practices are to be continued through the design and construction of the new precinct. Following the calculation of a more detailed precinct water balance, the designers will be able to examine any remaining water demands with the view to reduce any material and feasible aspects, as required.

3.3 Material Use – Overall life cycle impacts

3.3.1 Climate change impact

Based on the materials included in this study, the estimated carbon footprint of the Upper Australia precinct is 460,085 kg CO_2 eq. over the life of the project i.e. 50 years (see Table 1).

Table 1: Estimated carbon footprint of the Upper Australia precinct (kg CO_2 eq.)

Category	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)	Recycling Benefit (D)	Total
Pathways	15,178	1,311	763	5,466	712	0.0	23,431
Structural materials (Building construction)	285,453	11,317	16,792	0.0	115,273	-98,970	329,865
Utilities fitout (ceramic toilets)	1,400	3.0	5.0	106,635	3.0	-42,963	65,083
Hydraulics (concrete pipes)	28,658	482	5,189	0.0	7,376	0.0	41,706
Climate change impact							**460,085**

The production stage of life cycle (A1-A3) is the most material stage in terms of carbon emissions and accounts for 55% of the total emissions (see Table 2)

Table 2: Distribution of carbon emissions across life cycle stages for Upper Australia precinct (excluding benefits)

Category	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)
Pathways	3%	0%	0%	1%	0%
Structural materials (Building construction)	47%	2%	3%	0%	19%
Utilities fitout (ceramic toilets)	0%	0%	0%	18%	0%
Hydraulics (concrete pipes)	5%	0%	1%	0%	1%
Total	**55%**	**2%**	**4%**	**19%**	**20%**

3.3.2 Natural land transformation impact

The estimated natural land transformation impact due to the construction materials used in the upper Australia precinct is 25.6 m^2.

Table 3: Estimated land transformation impacts for Upper Australia precinct (m^2)

Category	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)	Recycling Benefit (D)	Total
Pathways	2.3	0.0	0.0	2.1	0.0	0.0	4.6
Structural materials (Building construction)	20.8	0.3	0.1	0.0	1.8	-5.0	18.1
Utilities fitout (ceramic toilets)	0.1	0.0	0.0	3.4	0.0	-6.0	-2.5
Hydraulics (concrete pipes)	1.6	0.0	1.9	0.0	2.0	0.0	5.5
Natural land transformation impact							**25.6**

Similar to the climate change, majority of the impacts for land transformation are from the production stage (see Table 4).

Table 4: Distribution of land transformation impacts across life cycle stages for Upper Australia precinct (excluding benefits)

Category	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)
Pathways	6%	0%	0%	6%	0%
Structural materials (Building construction)	57%	1%	0%	0%	5%
Utilities fitout (ceramic toilets)	0%	0%	0%	9%	0%
Hydraulics (concrete pipes)	4%	0%	5%	0%	5%
Total	**68%**	**1%**	**5%**	**15%**	**10%**

3.3.3 Water stress impacts

The overall impact of water stress is negative i.e. – 15,217 m^3 eq. (savings), mainly due to the use of recycled water for activities such as toilet flushing (see Table 5). Taronga zoo's onsite water treatment plant provides this recycled water.

Table 5: Estimated water stress impacts for Upper Australia Precinct (m^3 eq.)

Category	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)	Recycling Benefit (D)	Total
Pathways	197	4.3	2.3	212	4	0.0	420
Structural materials (Building construction)	2,329	33	6	0.0	248	-693	1,923
Utilities fitout (ceramic toilets)	9	0.0	0.0	724	0.0	-18,509	-17,775
Hydraulics (concrete pipes)	192	1.7	7.1	0.0	14	0.0	215
Water stress impacts							**-15,217**

In this case too, the most material life cycle stage for water stress impacts is the production stage, accounting for 68 % of the impacts (see Table 6).

Table 6: Distribution of water stress impacts across life cycle stages for Upper Australia precinct (excluding benefits)

Category	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)
Pathways	5%	0%	0%	5%	0%
Structural materials (Building construction)	58%	1%	0%	0%	6%
Utilities fitout (ceramic toilets)	0%	0%	0%	18%	0%
Hydraulics (concrete pipes)	5%	0%	0%	0%	0%
Total	**68%**	**1%**	**0%**	**24%**	**7%**

The subsequent section explores materials alternatives for different aspects of this project such as pathways, structural materials, utilities fitout and hydraulics. The life cycle impacts presented there are based on per functional unit as defined for each material in the calculations.

3.4 Life cycle impacts for project components: Pathways

3.4.1 Key findings

Table 7: Summary of impacts for pathway materials

Category	Item	Functional unit	Climate change (kg CO_2 eq.)	Natural land transformation (m^2)	Water stress (m^3 eq.)
Pathways	Exposed aggregate concrete - no fly ash	per m^2	46	0.004	0.36
	Exposed aggregate concrete - 30% fly ash		41	0.004	0.34
	Timber decking		-16	0.001	0.10
	Wood plastic composite		46	0.004	0.59
	Decomposed granite/ gravel		16	0.009	0.78
	Mulch		-270	-0.021	-0.18

- The zoo will be retaining some concrete pathways and retaining walls, which will result in emissions savings or reductions due to avoided materials production and construction.
- Addition of 30% fly ash to concrete mix could reduce the carbon footprint of the pathways by 12%.
- Decomposed granite/ gravel has a significantly lower carbon footprint (65%) than concrete. However, it has a higher land transformation and water stress impact – which is mainly due to maintenance or replenishment of decomposed granite/ gravel during the project's life. Overall, it has the highest land transformation and water stress impacts of all materials considered for pathways.
- Although, production of wood plastic composite (WPC) has a much lower carbon (50%) than exposed aggregate concrete on a standalone basis, its life cycle impact is almost similar to concrete. This is because WPCs have a shorter service life (30 years) compared to concrete and hence will need replacement over the life of the project. The shorter service life coupled with use of plastics in the WPC also increases the water stress compared to concrete.
- Overall, timber and mulch are the most sustainable alternatives for pathways. Since mulch is a non-rigid form of pathway, it may limit its use compared to timber decking. The negative values for the climate change indicator are due to consideration of carbon sequestration in wood.

3.4.2 Climate change impacts

Figure 7 and Table 8 provide a breakdown of climate change impacts for different materials considered for pathways. Table 8 also provides a split between the fossil based and biogenic carbon emissions for the materials.

Overall, the production stage i.e. A1-A3 is the most significant contributor to fossil-based carbon emissions for all materials. However, in case of decomposed material used for maintenance in the use stage i.e.B1-B7 is the most significant contributor. As mentioned earlier, exposed aggregate concrete (no fly ash) and WPC have the highest net carbon footprint of all materials considered for pathways.

For wood-based materials, the end-of-life stage has some negative emissions or savings associated with it – these are due to recovery and utilisation of a small quantity of methane resulting from landfilling of these materials. However, these savings are insignificant compared to the carbon released in the atmosphere due to landfilling.

It is assumed that mulch is replaced every three years and hence the biogenic carbon involved in its life cycle is significantly higher compared to timber or WPC. Also, it is assumed that mulch is produced onsite using tree/ plant waste and hence there is recycling benefit allotted to its footprint.

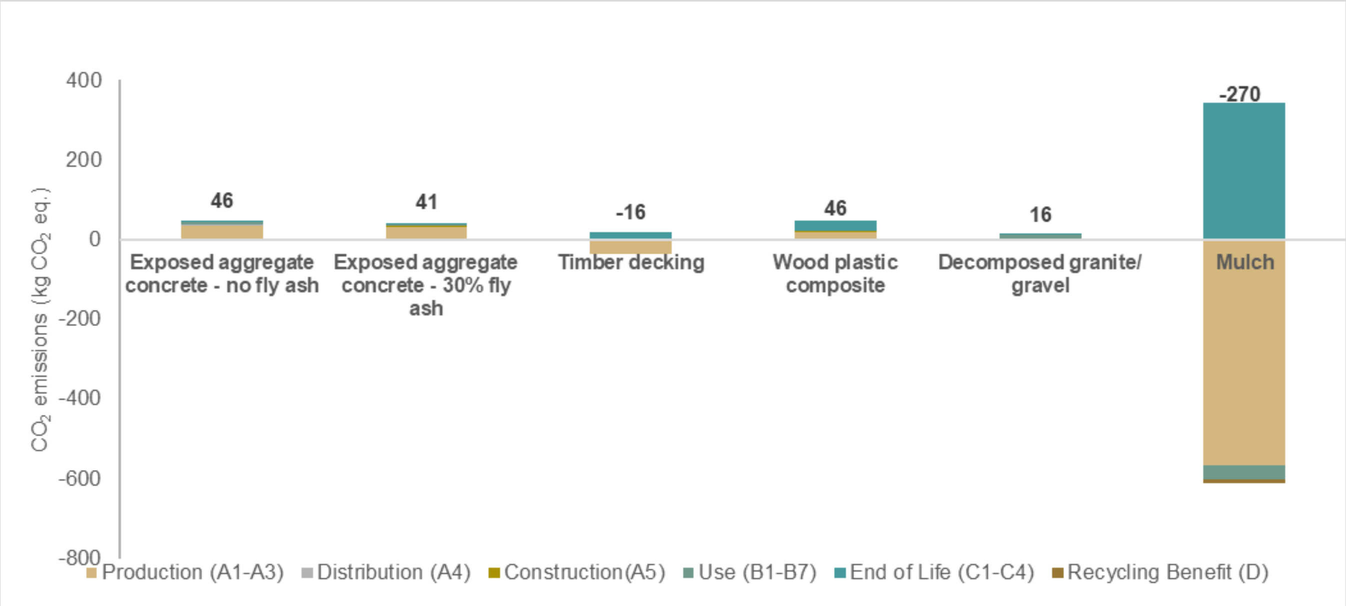

Figure 7: Climate change impact per life cycle stage for pathways

Table 8: Detailed breakdown of climate change impacts per life cycle stage for pathways (kg CO_2 eq./m^2)

Item (CO2)	Emissions category	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)	Recycling Benefit (D)	Total
Exposed aggregate concrete - no fly ash	**Net**	36	2.2	1.1	5.5	1.7	0.0	**46**
Exposed aggregate concrete - 30% fly ash	**Net**	30	2.2	1.1	5.5	1.7	0.0	**41**
Timber decking	Fossil	7.4	0.1	1.2	1.7	-3.8	0.0	7
	Biogenic	-42	0.0	0.1	-1.5	21.2	0.0	-23
	Net	-35	0.1	1.2	0.2	17.4	0.0	**-16**
Wood plastic composite	Fossil	55	0.3	2.0	3.2	-4.4	0.0	56
	Biogenic	-37	0.0	0.1	-0.1	27.3	0.0	-10
	Net	18	0.3	2.1	3.2	22.8	0.0	**46**
Decomposed granite/ gravel	**Net**	2.0	1.6	0.0	8.8	3.9	0.0	**16**
Mulch	Fossil	4.7	0.0	0.0	0.3	-78.8	-12.2	-86
	Biogenic	-571	0.0	0.0	-34.3	420.9	0.0	-184
	Net	-566	0.0	0.0	-34.0	342.1	-12.2	**-270**

3.4.3 Natural land transformation and water stress impacts

Figure 8 and Figure 9 depict the breakdown of land transformation and water stress impacts for pathway materials for each life cycle stage.

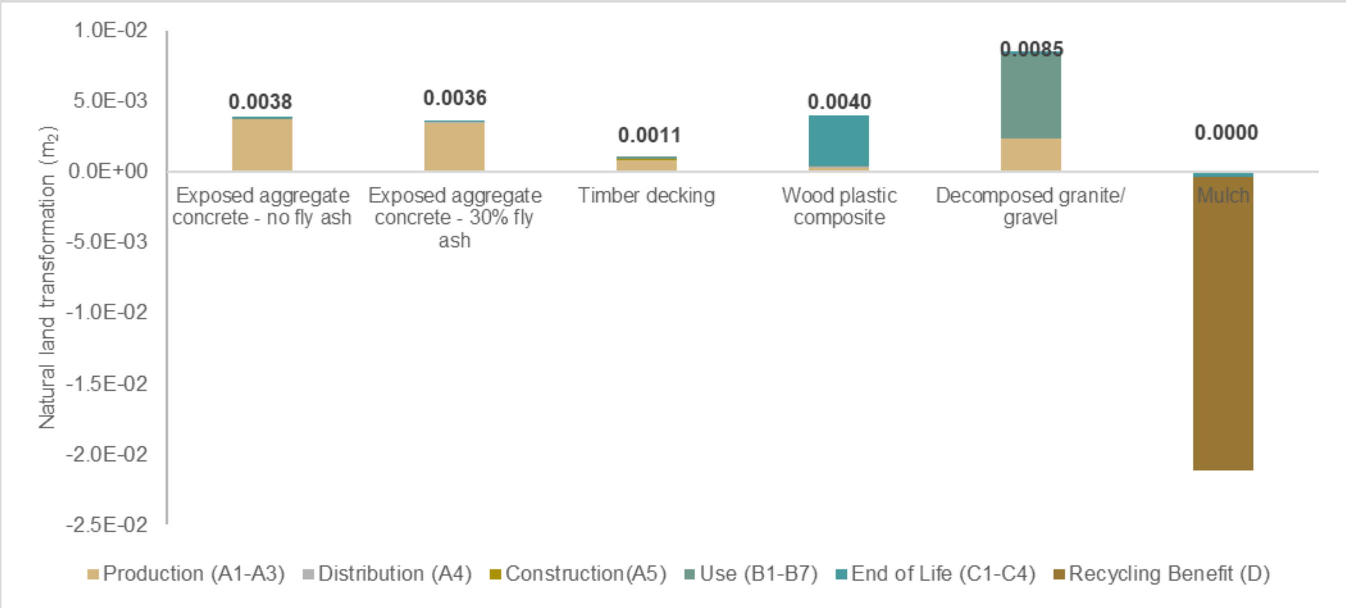

Figure 8: Natural land transformation impact per life cycle stage for pathways

Decomposed granite / gravel has the highest impact in both indicators, followed by WPCs and concrete. The use of additional material for maintenance of decomposed gravel/ granite contributes to a higher impact compared to its concrete counterpart. Since mulch is assumed to be produced from waste, it has a negative impact for both indicators.

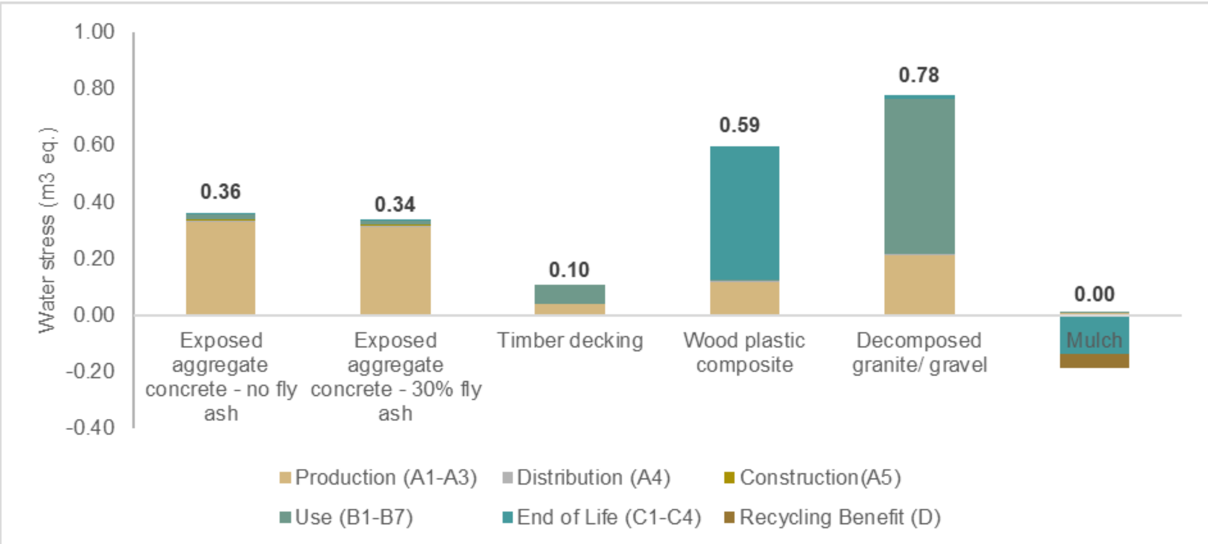

Figure 9: Water stress impact per life cycle stage for pathways

3.5 Life cycle impacts for project components: Structural materials

3.5.1 Key findings

- Substituting concrete with 30% fly ash could reduce the carbon footprint of structural columns by 16% and could also lower the land transformation and water stress impacts by 5% and 4% respectively.
- On a per m^3 basis, the timber column could have a significantly lower carbon and water stress footprint compared to concrete and steel (see Table 9). However, the design of a structure has a strong influence the quantity of timber needed to replace concrete and thereby the footprint.
- Similarly, although steel columns (Circular Hollow Section - CHS) have higher impact per m^3 of material compared to reinforced concrete columns, several design factors such as the amount of steel vs concrete required to attain the same functionality and structural integrity need to be considered during the detailed design stage.
- The land transformation impact could be slightly higher for timber columns compared to concrete and steel columns, which might be due to a very conservative estimate of the quantity of steel needed to install timber columns. Benefit due to recycling of steel contributes to a lower land transformation and water stress impacts for the steel column made from 100% scarp metal inputs.

Table 9: Summary of impacts for structural materials

Category	Item	Functional unit	Climate change (kg CO_2 eq.)	Natural land transformation (m^2)	Water stress (m^3 eq.)
Structural	Steel column (CHS) - made with primary materials	per m^3	1763	0.025	9.25
	Steel column (CHS) - made with 100 % scrap		869	-0.011	-1.35
	Concrete column - no fly ash		649	0.036	3.85
	Concrete column - 30% fly ash		543	0.034	3.70
	Timber column		-1154	0.039	2.37

3.5.2 Climate change impacts

Figure 10 and

Table 10 provides a breakdown of climate change impacts for different materials considered for

Item	Emissions type	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)	Recycling Benefit (D)	Total
Steel column (CHS) - made with primary materials	**Fossil**	**1,715**	**8**	**33**	**0**	**1,291**	**-1,284**	**1,763**
Steel column (CHS) - made with 100 % scrap	**Fossil**	**821**	**8**	**33**	**0**	**1,291**	**-1,284**	**869**
Concrete column - no fly ash	**Fossil**	**561**	**23**	**33**	**0**	**217**	**-184**	**649**
Concrete column - 30% fly ash	**Fossil**	**455**	**23**	**33**	**0**	**217**	**-184**	**543**
Timber column	Fossil	532	7	33	0	-19	-184	370
	Biogenic	-2,505	0	0	0	981	1.1	-1,523
	Net	**-1,974**	**7**	**33**	**0**	**963**	**-183**	**-1,154**

structural elements.

Table 10 also provides a split between the fossil based and biogenic carbon emissions for the

Item	Emissions type	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)	Recycling Benefit (D)	Total
Steel column (CHS) - made with primary materials	**Fossil**	**1,715**	**8**	**33**	**0**	**1,291**	**-1,284**	**1,763**
Steel column (CHS) - made with 100 % scrap	**Fossil**	**821**	**8**	**33**	**0**	**1,291**	**-1,284**	**869**
Concrete column - no fly ash	**Fossil**	**561**	**23**	**33**	**0**	**217**	**-184**	**649**
Concrete column - 30% fly ash	**Fossil**	**455**	**23**	**33**	**0**	**217**	**-184**	**543**
	Fossil	532	7	33	0	-19	-184	370
Timber column	Biogenic	-2,505	0	0	0	981	1.1	-1,523
	Net	**-1,974**	**7**	**33**	**0**	**963**	**-183**	**-1,154**

structural materials.

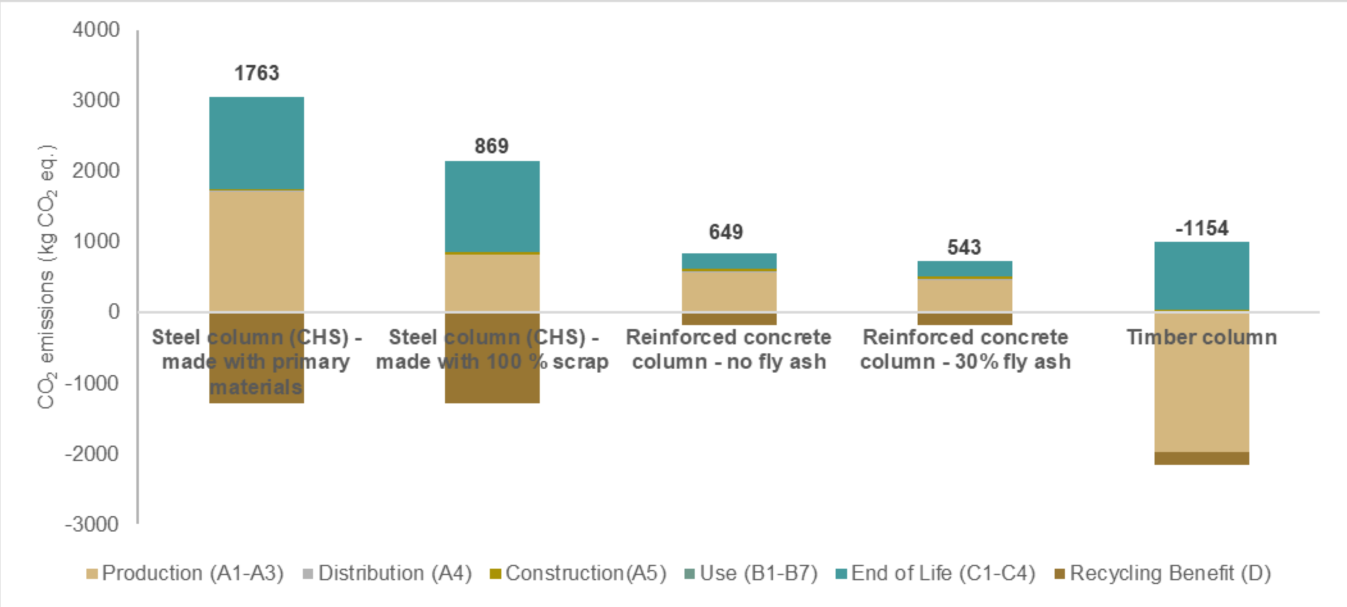

Figure 10: Climate change impact per life cycle stage for structural materials

The production stage i.e. A1-A3 is the most significant contributor to fossil-based carbon emissions for all structural materials. There is little or no maintenance required for these structural elements

Item	Emissions type	Production (A1-A3)	Distribution (A4)	Construction (A5)	Use (B1-B7)	End of Life (C1-C4)	Recycling Benefit (D)	Total
Steel column (CHS) - made with primary materials	**Fossil**	**1,715**	**8**	**33**	**0**	**1,291**	**-1,284**	**1,763**
Steel column (CHS) - made with 100 % scrap	**Fossil**	**821**	**8**	**33**	**0**	**1,291**	**-1,284**	**869**
Concrete column - no fly ash	**Fossil**	**561**	**23**	**33**	**0**	**217**	**-184**	**649**
Concrete column - 30% fly ash	**Fossil**	**455**	**23**	**33**	**0**	**217**	**-184**	**543**

Timber column	Fossil	532	7	33	0	-19	-184	370
	Biogenic	-2,505	0	0	0	981	1.1	-1,523
	Net	**-1,974**	**7**	**33**	**0**	**963**	**-183**	**-1,154**

Table 10: Breakdown of climate change impacts for structural materials (kg CO_2 eq./m^3)

For the timber column, the end-of-life stage could have some emission savings (negative impacts) associated with it, which are due to recovery and utilisation of a small quantity of methane resulting from landfilling the timber. However, these savings could be insignificant compared to the carbon released in the atmosphere due to landfilling. Overall, as a column material, timber could sequester a significant amount of carbon over its life cycle and could be carbon negative. The recycling benefit is mainly due to recycling of steel at the end-of-life of the column.

3.5.3 Natural land transformation and water stress impacts

Figure 11 and Figure 12 depict the breakdown of land transformation and water stress impacts for structural materials for each life cycle stage.

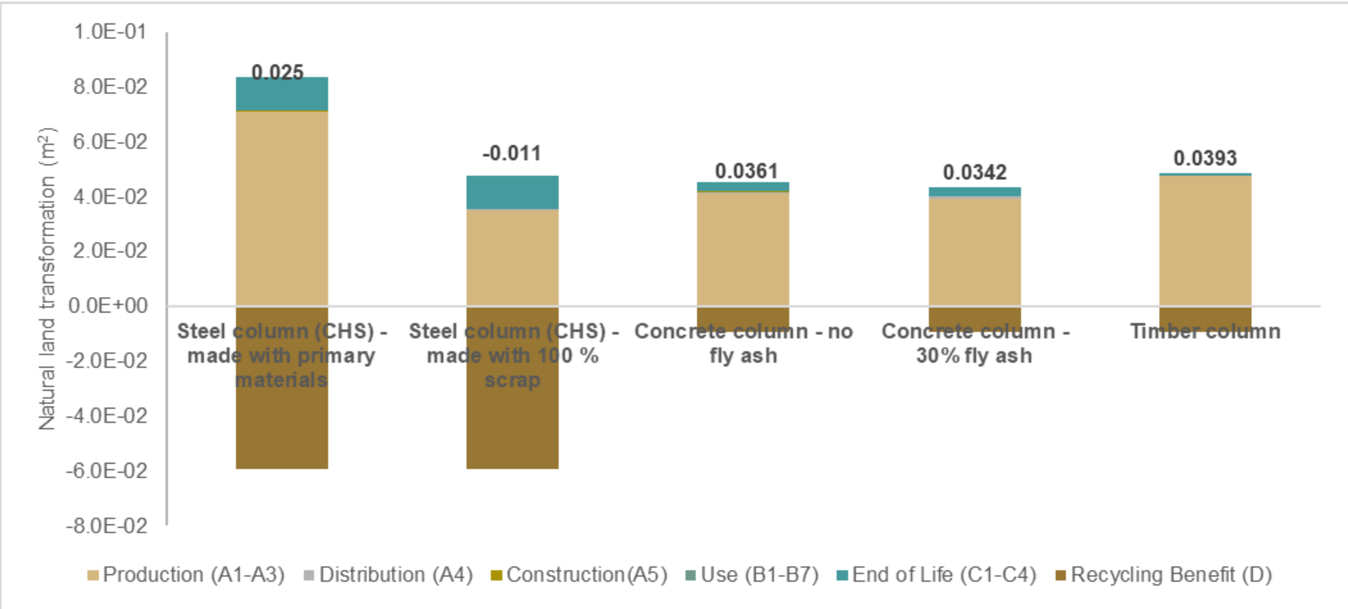

Figure 11: Land transformation impacts per life cycle stage for structural materials

The timber column could have a lower water stress impact when compared to its concrete and steel counterparts and a marginally higher land transformation impact. The higher impact could be due to conservative estimation of steel used to install or anchor the timber columns.

Figure 12: Water stress impacts per life cycle stage for structural materials (per m^3)

Similar to the climate change indicator, majority of impacts are associated with the production stage i.e. A1-A3 for the land transformation and water stress indicators.

3.6 Life cycle impacts for project components: Materials for hydraulic elements

3.6.1 Key findings

Virgin PVC pipes could have a 10% higher carbon footprint than concrete pipes (see Table 11)**.** This is could be mainly due to the raw material and production process for PVC pipes.

Using 20% recycled PVC in the mix could lower its carbon footprint by~10% and make it slightly lower than concrete

Concrete pipes are substantially heavier than PVC pipes and hence when they are landfilled at the end-of-life they could result in a higher land transformation and water stress impact when compared to PVC.

Table 11: Summary of impacts for materials for hydraulic elements

Category	Item	Functional unit	Climate change (kg CO_2 eq.)	Natural land transformation (m^2)	Water stress (m^3 eq.)
Hydraulics	Concrete pipe	per m	42	0.005	0.22
	PVC Pipe - virgin		46	0.002	0.11
	PVC pipe - 20% recycled content		41	0.002	0.09

3.6.2 Climate change impacts

Figure 13 depicts the breakdown of potential climate change impacts for structural materials for each life cycle stage. As observed, the production stage is the most significant contributor to the emissions for all materials.

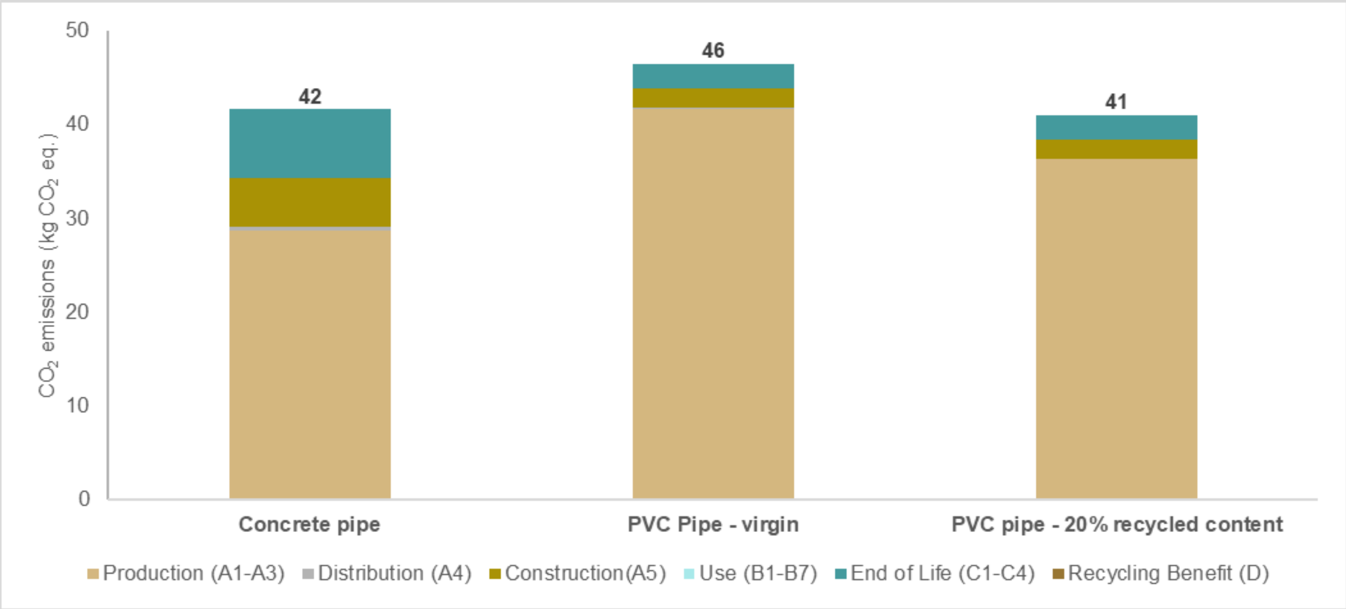

Figure 13: Climate change impacts per life cycle stage for hydraulic elements

3.6.3 Natural land transformation and water stress impacts

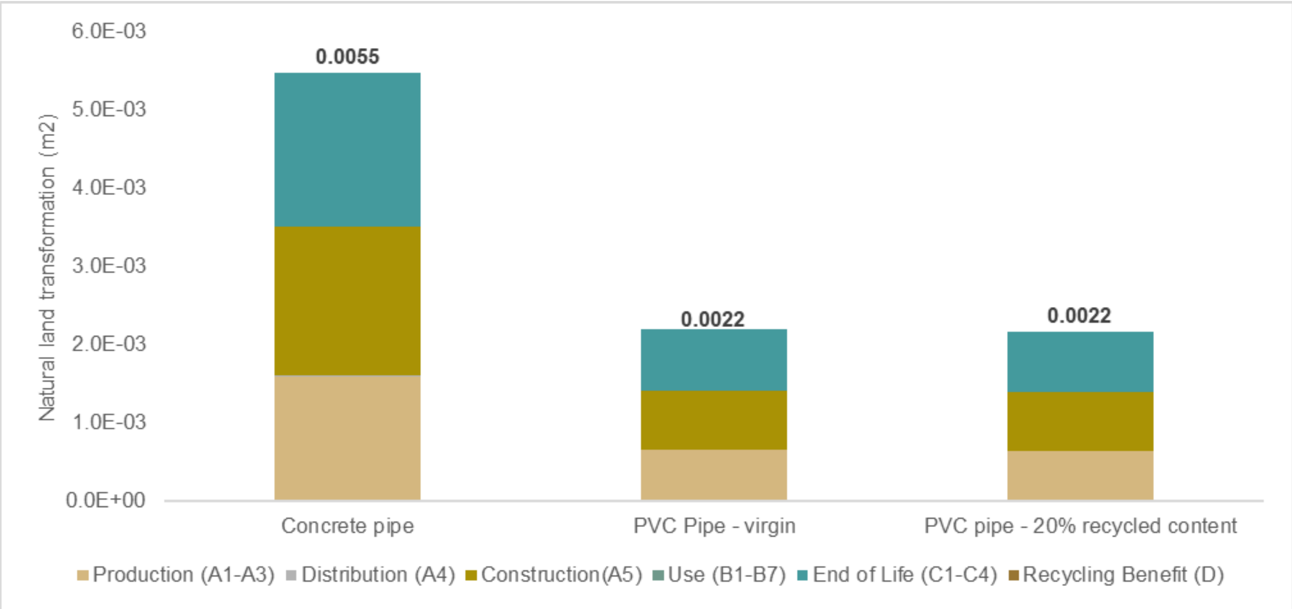

Figure 14: Land transformation impacts per life cycle stage for materials for hydraulic elements

Figure 14 and Figure 15 depict the breakdown of the potential land transformation and water stress impacts for structural materials for each life cycle stage.

Although virgin PVC pipes may have a higher carbon footprint, they could have 60% lower land transformation impact and 50% lower water stress impact when compared to their concrete counterpart. This could be attributed to the end-of-life stage, where the disposal of concrete pipes results in a higher amount of material being landfilled compared to PVC.

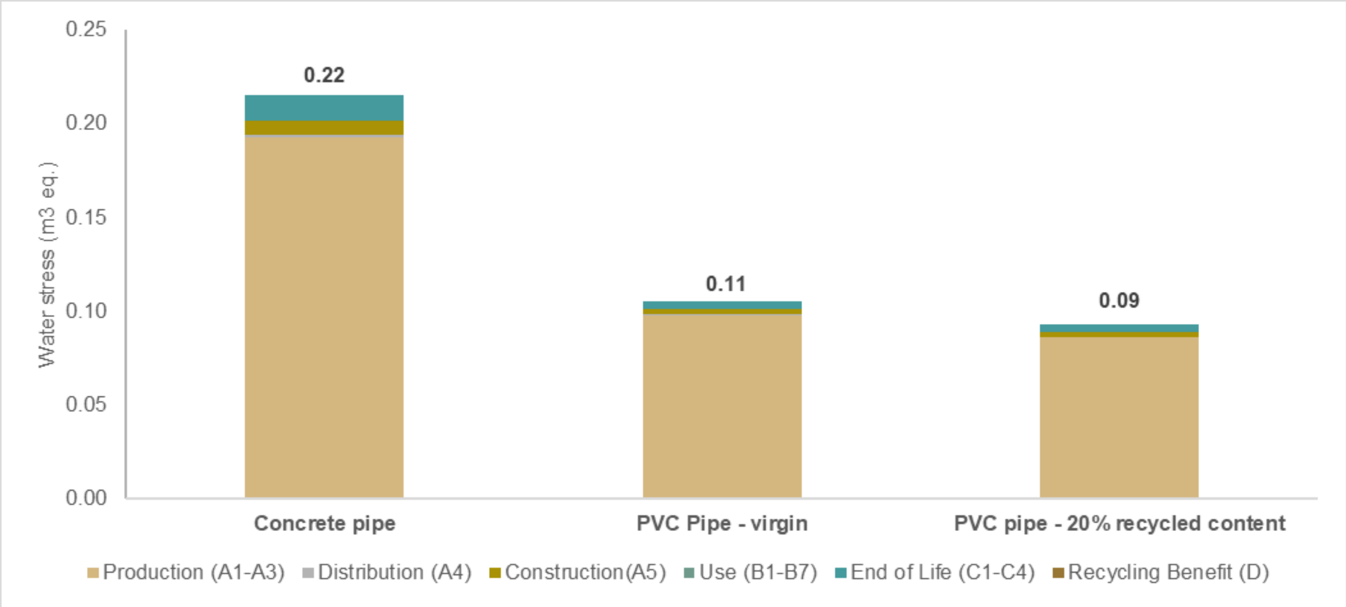

Figure 15: Water stress impacts per life cycle stage for materials for hydraulic elements

PVC pipes with recycled content could potentially have lower impact for both indicators.

3.7 Life cycle impacts for project components: Utilities fitout

3.7.1 Key findings

The zoo has an on-site water treatment plant which captures rain and storm water for recycling and reuse. The primary aims of the plant is to keep Sydney Harbour free of unnecessary particulates and pollutants, while simultaneously reducing the on-site demand for municipal potable water. One of the major uses of this recycled water at the zoo is toilet flushing.

This was included in the LCA and resulted in potential significant reductions in carbon impacts i.e. ~40% compared to a scenario where tap water would have been used.

Although, the steel toilet could have has slightly higher impact in the production stage for all indicators, the difference is insignificant in terms of overall impact and both toilets could have almost similar impacts for all indicators. Both toilets were assumed to have similar flush volume (5L).

Table 12: Summary of impacts for materials for utilities fitout

Category	Item	Functional unit	Climate change (kg CO_2 eq.)	Natural land transformation (m^2)	Water stress (m^3 eq.)
Fitout - Utilities	Ceramic toilets	per piece	13,017	-0.491	-3,555
	Steel toilets		13,032	-0.484	-3,555

Also, unlike other items explored in this project, the use stage could be the most significant contributor to emissions. A major component of the use stage impact is operation of the on-site water treatment plant.

Figures 16, 17 and 18 provide a breakdown of the potential impacts for each life cycle stage for climate change, land transformation and water stress indicators.

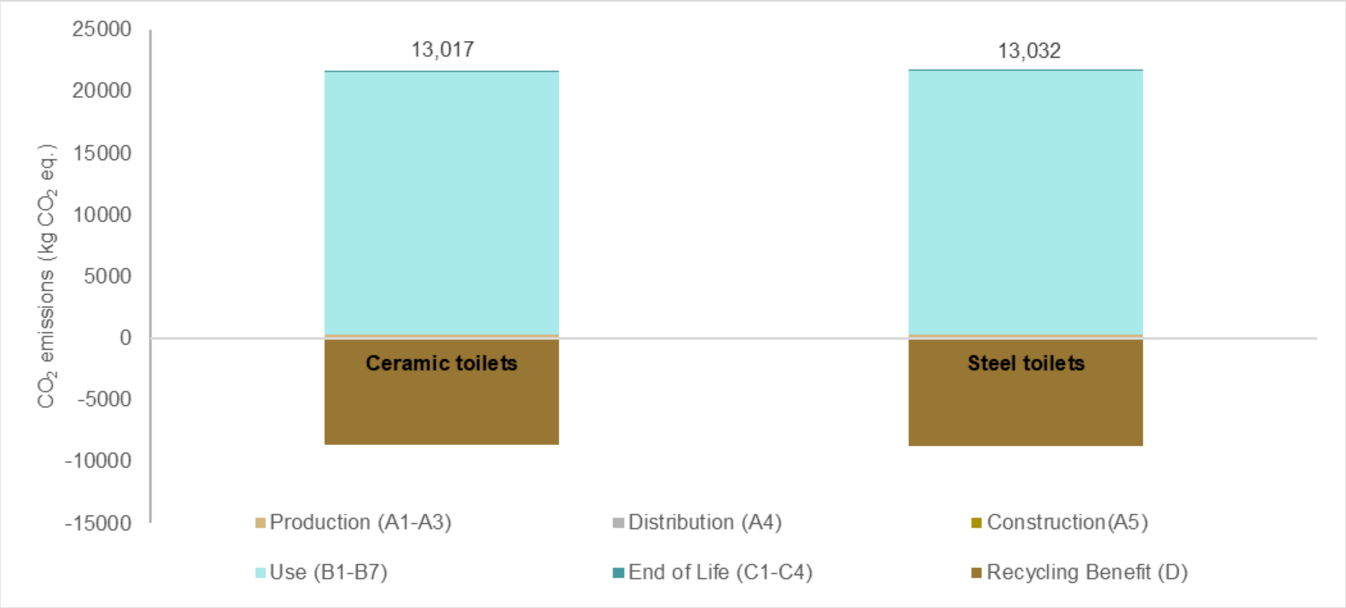

Figure 16: Climate change impacts per life cycle stage for materials for utilities fitout

Figure 17: Natural land transformation impacts per life cycle stage for materials for utilities fitout

Figure 18: Water stress transformation impacts per life cycle stage for utilities fitout

4 Proposed ESD Initiatives

Table 13 provides a summary of proposed ESD initiatives to be considered through design development to meet the SEARs. Initiatives have been prioritised based on a qualitative rating of economic, environmental and social benefits along with costs. The initiatives have been developed in consultation with the design team using the outcomes of the ESD approach.

Table 13: Proposed ESD initiatives for the Upper Australia Exhibit

Materials									
#	**Initiative**	**Description**	**Estimated Capex**	**Economic Benefit**	**Social Benefit**	**Env. Benefit**	**Overall score**	**Overall Feasibility**	**Comments / Notes**
1	LCA-informed design	Use LCA to specify low carbon materials for use in construction	Low	Medium	Medium	High	10	High	Use of LCA-informed design forms part of the current undertaking. The ease of implementation of this initiative would lift its overall feasibility.
2	Carbon sequestration and tree retention	Retention of trees and tree cover, installation of living structures and use of wood. This is best achieved through engagement with designers, contractors, architects, and other stakeholders early. One mechanism suggested is the use of contractual obligations.	Low	Medium	High	High	11	High	This is part of the standard practice in design.
3	Locally Sourced Materials	Through ensuring that locally-sourced materials are prioritised, the project would seek to reduce transport impacts, ensure that materials are geographically appropriate, and keep economic benefits in the local economy.	Low	High	High	High	12	High	

4	Lessons Learned	Incorporation of maintenance lessons learnt from existing developments ensures a more effective and efficient project.	Low	Medium	Medium	Medium	9	Medium	Embodied carbon in the project's materials will have a high proportional impact. Reduction in maintenance and replacement requirements will reduce this over the asset's life-cycle, as well as assisting the zoo through lowered maintenance requirements.
5	Low Impact Materials: Secondary/Low Carbon Materials	Incorporating low-impact materials, secondary materials, and recycled materials into the project's design to reduce overall emissions. These could include re-used timber products, fly ash in concrete, or green-waste derived mulch.	Low	Medium	High	High	11	High	The use of materials with recycled content like recycled PVC pipes could potentially reduce overall emissions. The use of this or other material options could be evaluated considering whole of life impacts.
7	Material Reuse and Repurposing	Reuse/Repurpose of existing materials on site to reduce virgin material requirements	Low	High	High	High	12	High	Plans exist to retain some concrete and brick paving and to reuse as raw materials and pavement materials. Heritage materials and retaining walls will also likely be reused. Potential to expand this idea to import re-useable materials to site from other local projects. Identification of finalised materials needs will be required.
Energy									
#		**Initiatives**	**Capex**	**Economic Benefit**	**Social Benefit**	**Env. Benefit**	**Overall score**	**Overall Feasibility**	**Comments / Notes**

1	Renewable Energy Feasibility Study	Undertake feasibility study for provision of off and onsite renewable energy	Low	High	High	High	12	High	Taronga Zoo's strategic direction is toward the off-site procurement of renewables-produced energy due to perceived constraint. Considering a feasibility study has been undertaken for Taronga Zoos as a whole, a simple business case for renewable energy could be undertaken for the Upper Australia Precinct.
2	Passive Design	Use of non-mechanical design elements (i.e. passive design), where possible. Principally suggested for animal exhibits (energy use for animal needs) and buildings.	Medium	Medium	Low	High	8	Medium	In the design's Nocturnal House, mixed mode principles are being used to reduce operational energy demand through the use of natural ventilation. However, some areas will still have specific requirements.
3	Construction Energy Requirements	Reduction in construction energy consumption through use of energy use targets in construction services contracts.	Low	Low	Medium	Medium	8	Medium	Suggestion is to mandate or encourage the use of electric or hybridised plant through the construction phase of the project.
4	Lessons Learned	Incorporation of energy requirement lessons learnt from existing developments	Low	High	Low	High	10	High	The ease of implementation of this initiative gives it a high technical feasibility.
5	Energy efficiency	Use of energy efficient lighting opportunities	Low	Medium	Low	High	9	Medium	The design's Nocturnal house will feature low level lighting and focused light in guest areas. Exhibits will only be lit to a level that is useable to ensure the correct balance between visitor amenity and animal comfort. The rest of the site will have natural lighting or high spec lighting for high energy efficiency and low light pollution.

6	Energy efficiency	Use of energy efficient heating opportunities	Low	Medium	Low	High	9	Medium	Animals will require spot heating/appliances. Investigations are ongoing relating to efficient technologies, but the equipment is specialised.
Water									
#		**Initiatives**	**Capex**	**Economic Benefit**	**Social Benefit**	**Env. Benefit**	**Overall score**	**Overall Feasibility**	**Comments / Notes**
1	Harnessing Natural Waterways	Improved use of natural waterways for better landscape management - more natural systems for irrigation	Low	Low	Low	Medium	7	Medium	Site irrigation has not been designed in detail as yet. Standard practice for the zoo's irrigation is the use of recycled water from the zoo's treatment plant.
2	Cleaning Requirements	Reduction in the site's hard surfaces which require cleaning to reduce the asset's water consumption.	Low	Medium	Low	Medium	8	Medium	
3	Lessons Learned	Incorporation of maintenance lessons learnt from existing developments	Low	High	Low	High	10	High	The ease of implementation of this initiative gives it a high technical feasibility.
4	Efficient Facilities and Fittings	Selection of efficient facilities, fixtures, and fittings such as low and dual flush toilets and other fittings with high WELS ratings.	Low	Low	Low	High	8	Medium	
5	Drinking Water	Provision of fountains and bubblers for drinking water to reduce waste through bottles.	Low	Low	Medium	High	9	Medium	This forms part of the zoo's standard practice design procedures and environmental policy.
6	Flushless (composting) toilets	Installation of composting toilets to reduce the asset's water demand.	Medium	Low	Low	Low	5	Low	Composting toilets are not likely to be technically feasible on this site. Additionally, as toilet flushing uses recycled water, the positive impact would not be sufficient to overcome the required design and compliance issues.

7	Maintenance and cleaning methods	Ensure that maintenance manual encourage brushing over power-washing	Low	Low	Low	Medium	7	Medium	Operational and maintenance portions of the zoo's personnel will be consulted on this issue.
8	Cleaning Water Capture	Capture and re-use of sprayed cleaning (as well as drainage) water	Low	Low	Low	Medium	7	Medium	Cleaning water will run into the site's stormwater capture system.
9	Mulch Layers	Installation of mulch layers to reduce soil evaporation	Low	Medium	Low	Medium	8	Medium	While this has been agreed in concept, details regarding the type and sizing of mulch will require further discussions due to a precedence of bush turkeys disturbing the mulch layers in other parts of the zoo.
10	Irrigation Systems Scheduling	Ensure that irrigation (particularly sprayed irrigation) is undertaken at times of the day with low evaporation rates (i.e. pre-dawn) to reduce overall water demand.	Low	Low	Low	Medium	7	Medium	Operational and maintenance portions of the zoo's personnel will be consulted on this issue. It is understood that the use of recycled water in irrigation may make this issue less relevant and impactful.
11	Low Evaporation Irrigation	Installation of buried water diffusers or entrenched soaker hoses for irrigation with lower evaporation rates	Medium	Low	Low	Low	5	Low	Mechanisms to lower irrigation demand are to be considered in the further development of the asset design. The irrigation design has not yet been finalised.
12	Xeriscaping	Installation of landscape design which will not require additional irrigation.	Low	Medium	Low	Medium	8	Medium	Australian native plants will be chosen to reduce irrigation demand. Additionally, landscaping includes permeable surfaces to allow stormwater to be utilised by the vegetation as much as possible.
13	Water Capture	Rainwater and stormwater capture to reduce requirements for municipal water	Low	High	High	High	12	High	This already forms part of the zoo's standard practice design guidelines. Rain water is captured and treated prior to use on site.

14	Site-wide Integrated Water Management Plan	Business case for the development of a site-wide Integrated Water Management Plan	Medium	High	Low	High	9	Medium	While significant and concerted efforts are being undertaken to address water management across the zoo, with laudable initiatives already in place, a formalised approach to water management under an Integrated Water Management Plan for the whole zoo could be considered.
15	Water-related Education	Improved understanding from visitors of the critical importance of water sustainability and their role in that. Provide insights and inspiration on the Cultural significance and importance of water to Cammeraigal. Celebrate success through alignment with the story - reduction of biodiversity impact by material choices and leads to facilitation of action in everyday lives. Ensure we engage with Taronga's habitat committee and prioritise cultural heritage to ensure site is looked after.	Low	Low	High	Medium	9	Medium	Due to the use of recycled and rain water, the direct impact of water-related education would not be large on site. However, given the zoo's role in environmental education, education relating to water sensitivity, historically, culturally, and in relation to current conditions in the state should not be downplayed.

Appendix A

Item	Value	Unit	Source/ Comment
Excavation rate	22.7	m^3/h	http://www.methvin.org/construction-production-rates/excavation/trench-excavation
Amount of reinforcement steel in concrete	100	kg/m3	Edge assumption
Thickness of exposed aggregate pathway	100	mm	Edge assumption
Frequency of sealer spraying for exposed aggregate concrete	10	years	Edge assumption based on feedback from Taronga
Thickness of decomposed granite/ pathway	100	mm	Edge assumption
Time required to compact $1m^2$ of decomposed granite pathway	10	min	Edge assumption
Amount of granite/ gravel replenished every year	5	%	Edge assumption
Thickness of mulch layer	100	mm	
Mulch	-	-	Assumed to be made onsite from waste plants/trees
Concrete pathways area	342	m^2	From drawing
Decomposed granite/ gravel pathways area	342	m^2	From drawing
Timber pathway area	317	m^2	From drawing
Amount of concrete required	501	m^3	From drawing
Steel columns (circular hollow sections) required – total lineal meters	137	m	From drawing
Outer diameter of Steel columns (circular hollow sections)	219	mm	From drawing
Wall thickness of Steel columns (circular hollow sections)	6.4	mm	Edge assumption
Weight of Steel columns (circular hollow sections)	33.6	kg/m	https://www.libertygfg.com/media/164195/design-capacity-tables-for-structural-steel-hollow-sections.pdf
Crane operation to install 2.4 m of concrete pipe or 6 m of PVC pipe	5	min	Edge assumption
Weight per m of concrete pipe	0.09	t	Table 28 Humes EPD: https://epd-australasia.com/wp-content/uploads/2018/04/epd998-Reinforced-Concrete-Pipe-RCP.pdf
% of steel in concrete pipes	5	%	Table 2 Humes EPD: https://epd-australasia.com/wp-content/uploads/2018/04/epd998-Reinforced-Concrete-Pipe-RCP.pdf
Oil coverage for timber maintenance	10	m^2/L	
Energy use per m^2 of construction (Diesel)	150	MJ	Cole R J (1999) - 70% of total - for concrete slab, concrete column and concrete roof construction
Transport distance to supplier/ recycling/ landfilling site	50	km	Edge assumption
EoL scenario for all pathway materials	Landfilling	N/A	Assumption made to model worst case scenario
Actual service life of WPC	30	years	Impacts extrapolated to 50 years
Actual service life of toilets	15	years	Impacts extrapolated to 50 years
Water use – flushing (1 toilet)	750	L/day	3000 daily visitors. Assume 5% use the toilet. 5 L per flush
Number of toilets in Upper Australia Precinct	5	no.	Edge assumption
Weight of steel toilet (with cistern)	21	kg	https://www.delabie.com/our-products/stainless-steel-sanitary-ware/wc/110390-monobloco-s21-wc-pan-with-cistern
Weight of ceramic toilet (with cistern)	32.8	kg	https://www.armitageshanks-mena.com/fileadmin/resource/content/download/01_WC_s_BB_BB_2015.pdf
Service life of concrete and hardwood timber pathways	50	years	
Vegetation clearing impacts not included	-	-	-