APPENDIX 6

Summary of Biodiversity Offset Strategy for the West Culburra Part 3A project, letter from Ecological Australia dated 18 May 2017

Mr John Toon
C-/ The Halloran Trust

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17SYD 6840

18/05/17

Dear John

Summary of Biodiversity Offset Strategy Summary for the West Culburra Part 3A project

The purpose of this summary report is to describe the methodology and results of a biodiversity offset assessment for the proposed West Culburra Part 3A residential/industrial subdivision on land owned by the Halloran Trust on the NSW South Coast. This summary report also provides a brief overview of the biodiversity offset assessment process for the Halloran Trust planning proposal.

Background:

An ecological and riparian assessment report for the West Culburra Part 3A residential/industrial subdivision was prepared by SLR Consultants in 2013 (*West Culburra Ecological & Riparian Issues & Assessment Report SLR March 2013*).

The Office of Environment and Heritage (OEH) advised the applicant in letters dated June 2013 and May 2014 that the Office was "*satisfied that the development is unlikely to have a significant impact on threatened species and their habitats*" and that "*the development should only proceed if suitable offsets can be located and secured to ensure overall biodiversity values are maintained*". OEH stated its position that an offset parcel should be located in the Lake Wollumboola catchments in accordance with the South Coast Regional Strategy 2007.

The Planning Proposal – brief description

Eco logical Australia (ELA) was employed by the Halloran Trust in 2015 to undertake an extensive ecological survey across approximately 2,500 ha of Trust owned land at Jervis Bay and Sussex Inlet. The survey included detailed mapping of 32 different biometric vegetation zones, the collection of over 220 biometric vegetation plots and targeted surveys for a range of threatened flora and fauna species. The ecological survey phase concluded in May 2017 and the results will feed into a biocertification assessment of lands impacted by vegetation clearance for proposed development areas in the planning proposal and biobank assessments of four proposed biobank sites used to offset the impact of the West Culburra Part 3A subdivision and proposed development areas in the Halloran planning proposal.

The biobank site assessments including credit calculations and report preparation are currently in progress to be submitted to OEH around the end of the 2016/17 financial year. After a period of five to seven years of management as biobank sites, one of the biobank sites will be transferred to Jervis Bay National Park, another site will be transferred to Lake Conjola National Park and the remaining two will continue to be managed as private biobanks site at Sussex Inlet.

Figure 1: Halloran Trust Planning Proposal

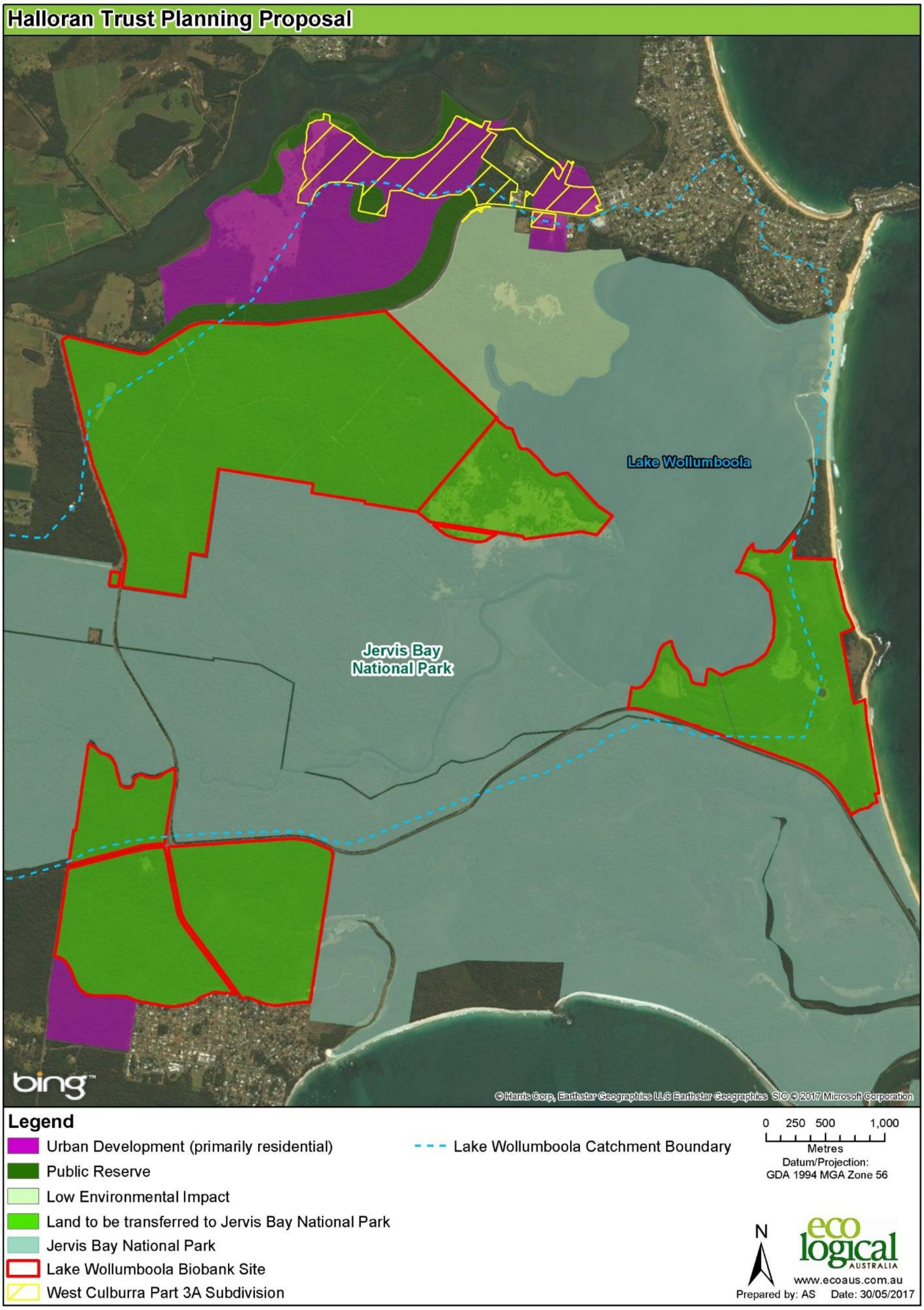
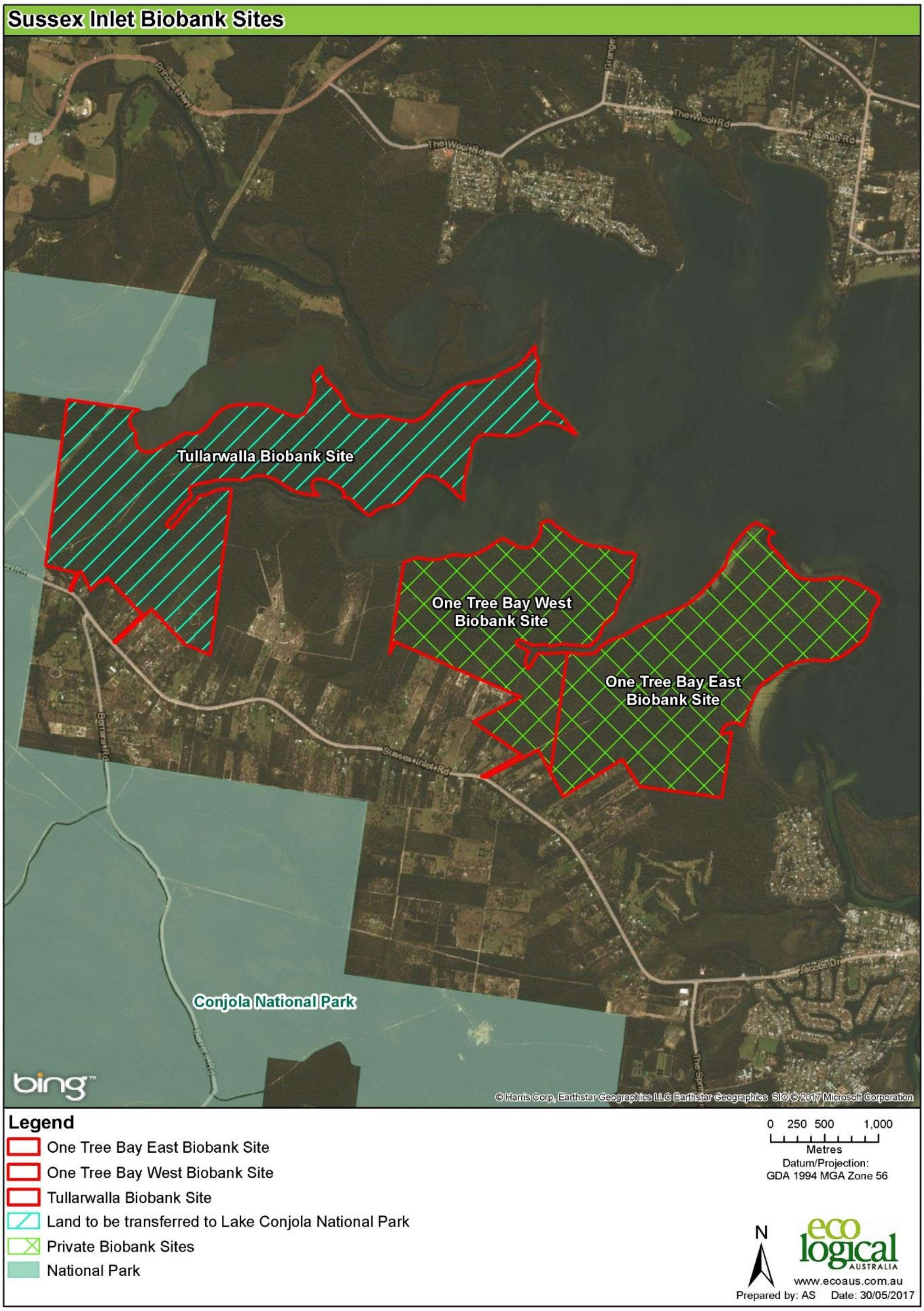


Figure 2: Sussex Inlet Biobank Sites



Biodiversity offset requirement for the West Culburra Part 3A residential/industrial subdivision:

The applicant was advised by OEH that the biodiversity offset for the West Culburra Part 3A subdivision should be determined using the Framework for Biodiversity Assessment (FBA) methodology 2014. An assessment for an impact site determines the number of 'ecosystem credits' (a measurement of threatened vegetation types and threatened habitat types that can be reliably predicted to occur within a vegetation type) and 'species credits' (all threatened plants and threatened fauna species that cannot be reliably predicted to use a vegetation type) that must be retired to offset the impact of the development..

The *West Culburra Ecological & Riparian Issues & Assessment Report SLR March 2013* did not identify an impact on species credit species; this was confirmed and agreed to in an email from OEH, accordingly, the FBA assessment was for ecosystem credits only.

The FBA credit calculator was used to calculate ecosystem credits required to offset impacts from the West Culburra subdivision. Data from 23 vegetation plots (exceeding the minimum plot number required in accordance with the FBA) for ten vegetation zones representing eight vegetation types and a landscape analysis was used in the credit calculation. The credit calculation was submitted for OEH review on Friday 4th November 2016 and then following an initial review and modification to the landscape score was re-submitted on Thursday 22nd December 2016. OEH has inspected the site with the lead ELA field ecologist and advised that they were satisfied with the vegetation mapping and credit calculations. The eight biometric vegetation types are shown in **Figure 3** and the biometric vegetation types for the entire area of subject Halloran Lands (including the Halloran Planning Proposal, Sussex Inlet Biobank and the West Culburra Part 3A subdivision) are shown in

The number of ecosystem credits required to offset the West Culburra Part 3A subdivision for eight biometric vegetation types is shown in **Table 1.** The table includes the vegetation formation, class and % cleared status in the southern rivers catchment management area because this information is relevant when matching credit profiles under the offsetting rules established in the FBA.

A total of 5,472 credits are required for the clearance of 91.65 ha of native vegetation at the West Culburra subdivision. A total of 9.57 ha comprising of four endangered ecological communities (EEC) listed under the NSW *Threatened Species Conservation Act 1997* (TSC Act) and 1.11 ha comprising of one critically endangered ecological community (CECC) listed under the *Commonwealth Environment Protection and Biodiversity Protection Act 1999* (EPBC) will be impacted. Note: two biometric types, SR650 Swamp Oak swamp forest fringing estuaries and SR649 Swamp Oak Floodplain swamp forest belong to one EEC.

SR592 Red Bloodwood - Blackbutt - Spotted Gum shrubby open forest requires by far the greatest number of credits (4,542) for offset. This is followed by SR516 Blackbutt - Turpentine - Bangalay moist open forest on sheltered slopes and gullies (340) and SR512 Bangalay - Old-man Banksia open forest on coastal sands (327). SR 592 Red Bloodwood - Blackbutt - Spotted Gum shrubby open forest known as the local vegetation type, Currambene-Batemans Lowlands Forest dominates Halloran Trust lands included in this assessment. Blackbutt - Turpentine - Bangalay moist open forest and Bangalay - Old-man Banksia open forest also occur extensively on the lands proposed for offset as well as the other impacted vegetation types.

OEH has advised both the applicant and Shoalhaven City Council that the credit requirement for West Culburra Part 3A subdivision may be recalculated in accordance with the Biocertification methodology (BCAM 2011) post approval which will result in a reduction of credits required in the vicinity of 1500 - 2000 credits. The excess credits may then be used to offset development in the Halloran Trust Planning proposal.

Table 1: No of ecosystem credits required to offset the West Culburra subdivision

BVT	Formation	Sub - formation	Class	TSC and EPBC	% cleared in SRCMA	Ha impacted	Credits Required	Source of Credits for offset
SR592 Red Bloodwood - Blackbutt - Spotted Gum shrubby open forest	Wet Sclerophyll Forests	Grassy	Southern Lowland Wet Sclerophyll forests	N/A	45	**76.66**	**4,542**	**LWB**
SR516 Blackbutt - Turpentine - Bangalay moist open forest on sheltered slopes and gullies		Shrubby	North Coast Wet Sclerophyll Forests	N/A	50	**5.28**	**340**	**LWB and Sussex Inlet**
SR650 Swamp Oak swamp forest fringing estuaries	Forested Wetlands		Coastal Floodplain Wetlands	EEC N/A	95	**0.35**	**18**	**LWB**
SR648 Swamp Mahogany swamp sclerophyll forest			Coastal Swamp Forests	EEC N/A	50	**1.25**	**93**	**LWB**
SR649 Swamp Oak Floodplain swamp forest				EEC N/A	95	**1.66**	**88**	**LWB and Sussex Inlet**
SR512 Bangalay - Old-man Banksia open forest on coastal sands	Dry Sclerophyll Forests	Shrubby	South Coast Sands Dry Sclerophyll Forests	EEC N/A	50	**5.2**	**327**	**LWB and Sussex Inlet**
SR669 Woollybutt - White Stringybark - Forest Red Gum grassy woodland	Grassy Woodlands		Coastal Valley Grassy Woodlands	EEC CEEC	95	**1.11**	**53**	**LWB**
SR575 Mangrove Forests in estuaries	Saline Wetlands		Mangrove Swamps		50	**0.14**	**11**	**Sussex Inlet**
Total						**91.65**	**5472**	

LWB: Lake Wollumboola Biobank Site

Sussex Inlet: Any or a combination of Tullarwalla, One Tree Bay East and One Tree Bay West Biobank Sites

Figure 3: Biometric vegetation types mapped in the West Culburra Part 3A subdivision

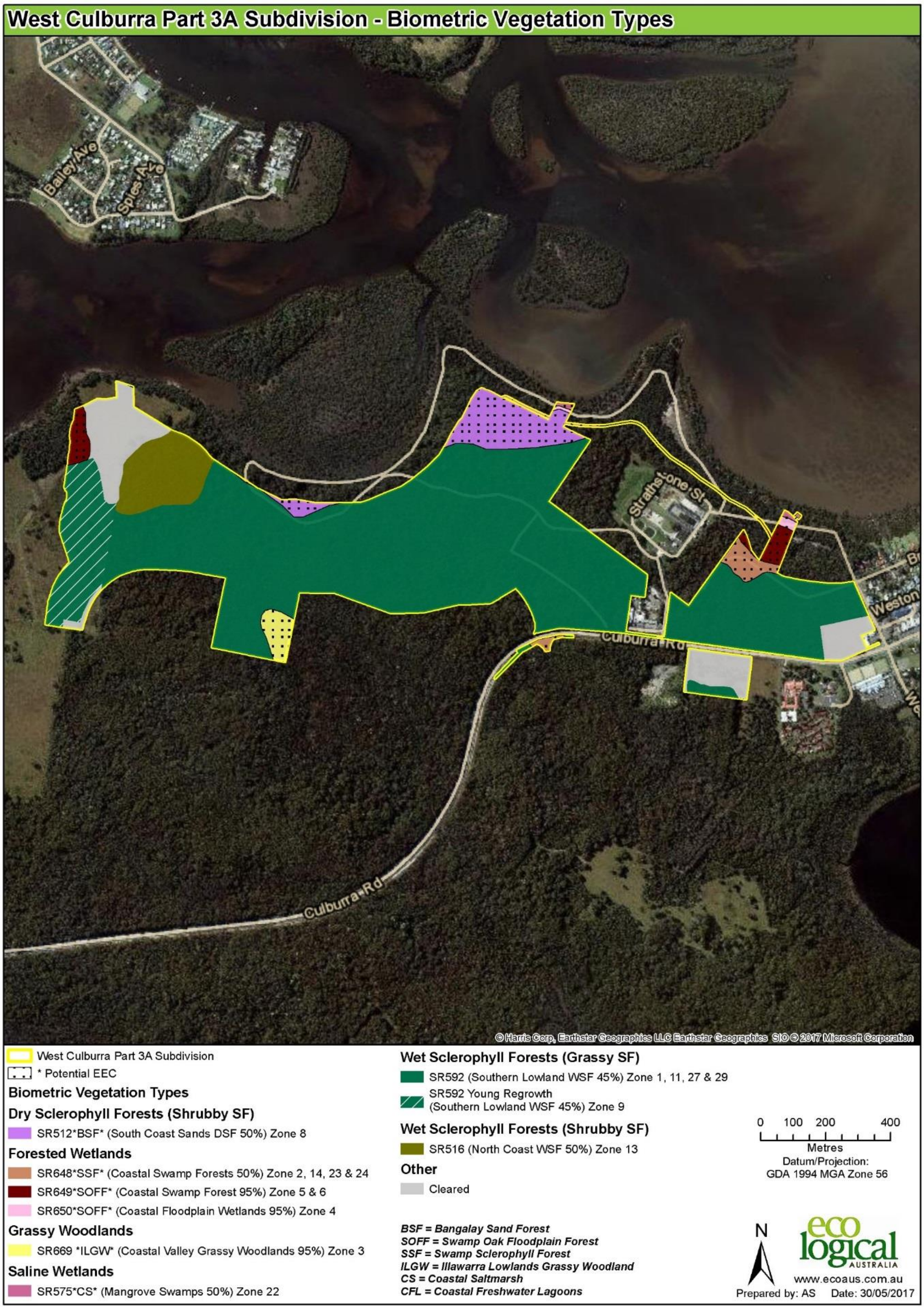
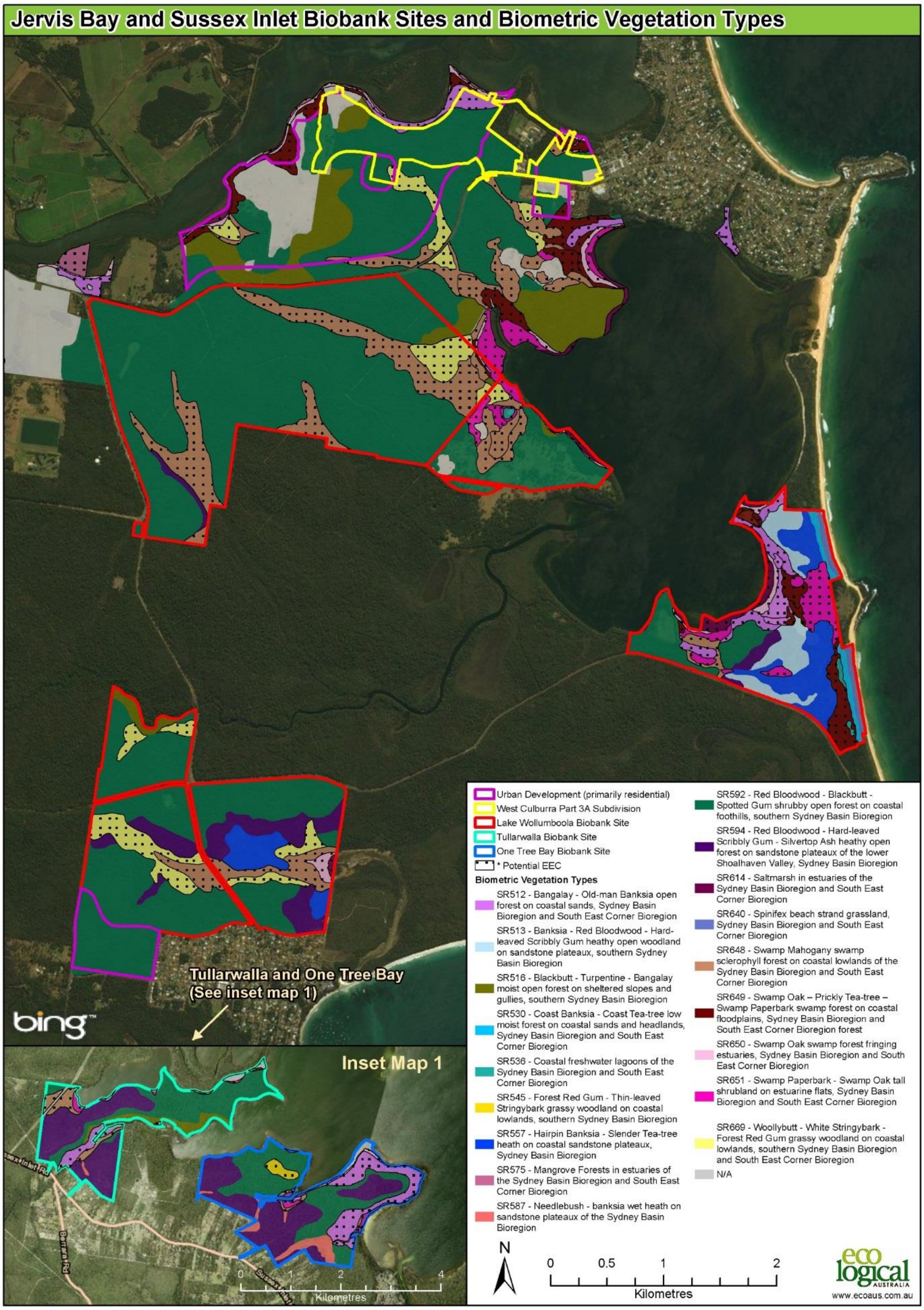


Figure 4: Biometric vegetation types mapped on the subject Halloran Lands



Biodiversity Offset Sites

Four biobank sites on lands owned by the Halloran Trust are currently being assessed for registration by ELA. The four proposed biobanking sites are “stand alone” biobank sites i.e. they are not part of the offset lands included in the Jervis Bay Biocertification assessment area. As well as providing the source of credits to offset the West Culburra Part 3A subdivision they will be used to provide credits for the Halloran Trust planning proposal assessed in the Jervis Bay Biocertification assessment. The biobanking site names and approximate areas are as follows:

- Lake Wollumboola Biobank Site (Jervis Bay): 1,057 ha
- Tullarwalla Biobank Site (Sussex Inlet): 477 ha
- One Tree Bay – East (Sussex Inlet): 361 ha
- One Tree Bay – West (Sussex Inlet): 260 ha

Lake Wollumboola Biobank Site is extensive and comprises of three separate areas of diverse intact vegetation which are contiguous with Jervis Bay National Park (Culburra, Kinghorne and Woods Estate). The majority of the site is within the catchment of Lake Wollumboola and it protects foreshore areas of this significant estuary. Tullarwalla and One Tree Bay Biobank Sites protect foreshore areas of St Georges Basin and are also in excellent condition and have high ecological values. The four biobank sites are shown in **Figure 1** and **Figure 2**.

After a period of five to seven years of management by the Halloran Trust as biobank sites, Lake Wollumboola Biobank Site will be transferred to Jervis Bay National Park and Tullarwalla Biobank Site will be transferred to Lake Conjola National Park. The National Parks and Wildlife Service advised that they were not interested in One Tree Bay site because it is not contiguous with a national park. The One Tree Bay site has been split into two biobank sites and it is envisaged that ownership will be transferred from the Trust to private individual(s) who will manage the sites into the future in accordance with the registered BioBank Agreements once the in perpetuity BioBank Management Trust account has been fully met by the Halloran Trust.

Although formal calculations (i.e. using the biobanking credit calculator) of the credits generated by the biobank sites are yet to occur, based on a conservative estimate of 10 credits/ha generated for vegetation in moderate to good condition with a high landscape value score (e.g. protecting buffers of an estuary such as Lake Wollumboola and St Georges Basin), there are sufficient credits available to offset the credits required by the West Culburra subdivision.

Table 1 shows that the majority of the credits required by the West Culburra subdivision can be sourced within the catchment of Lake Wollumboola with the Lake Wollumboola Biobank site supplying all of the 4,542 credits for SR592 Red Bloodwood - Blackbutt - Spotted Gum shrubby open forest and all of the credits required for five other biometric vegetation types. There with be a moderate credit shortfall for the two remaining BVTs, SR516 Blackbutt - Turpentine - Bangalay moist open forest on sheltered slopes and gullies and SR512 Bangalay - Old-man Banksia open forest on coastal sands which can be supplied by the Sussex Inlet Biobank Sites.

Yours sincerely,

Jennie Powell.

Jennie Powell

Senior Consultant

APPENDIX 7

Addendum to Water Cycle Management Report, Mixed Use Subdivision, West Culburra (SSD 3846).
Martens, 8 June 2017

'Posted
Faxed
Emailed Robert.Byrne@planning.nsw.gov.au
Courier
By Hand
Contact: Megan Kovelis / Andrew Norris
Our Ref: P1203365JC49V01
Pages: 3
cc. John Toon

June 08, 2017

NSW Department of Planning and
Environment
Att: Robert Byrne
By Email

Dear Robert,

RE: WATER CYCLE MANAGEMENT REPORT ADDENDUM; MIXED USE SUBDIVISION, WEST CULBURRA (SSD 3846)

1.0 Introduction

We understand that following review of the most recent version of the Water Cycle Management Report (November, 2016) and associated water quality (MUSIC) modelling, the Department's Peer Reviewer maintains their concern with the water quality modelling approach and the specified stormwater treatment solution. Specifically, the Peer Reviewer does not support modelling which includes approach which includes nutrient assimilation with the vegetation in the 7(a) protection zone between the development and the Crookhaven River.

To address the Peer Reviewer's concern, water quality modelling has been revised to achieve NorBe *without* the treatment of infiltrated water. The specific performance standard adopted is that NorBe be achieved at the 7(a) protection zone boundary. In order to achieve this objective, the proponent has made substantial modifications to the development proposal and footprint.

This addendum outlines:

1. Modifications to the development proposal and subsequently to the water quality model in order to achieve revised water quality objectives.

2. Results of water quality modelling.

3. Final proposed treatment train.

2.0 Development Proposal Modifications

In order to achieve water quality objectives without reliance on the assimilation of nutrients in the 100+ m buffer vegetated zone in the 7(a) land, the proponent has made substantial modifications to the development footprint and proposal:

1. Most significantly, the proponent has removed 50% of the proposed industrial area. The area previously proposed as industrial is now to be retained with existing forest vegetation. Within the water quality model, the industrial zone was contributing a significant proportion of nutrients generated by the development to seagrass areas and the Crookhaven River. By removal of 50% of this area, water quality objectives are more easily achieved.

2. Project planners (Allen Price & Scarratts - AP&S) completed a detailed assessment of subdivision design based on similar residential land releases in the Shoalhaven region. Through this assessment, the following project modelling assumptions were refined:

    a. Road areas: Impervious road area assumptions were modified from the previously assumed 50% to an impervious percentage calculated for each road, based on its intended use. AP&S confirmed paved width required was generally 6m with wider widths of 9m along future bus roads and 10m in the industrial zone.

    b. Roof areas: Previously a roof area of 40% of lot area was applied to the entire site, regardless of location or lot size. Based AP&S's specification, roof areas have been adjusted to range from 200m^2 (smaller lots) – 275m^2 (larger lots). It is anticipated that final roof area shall be confirmed at detailed design stage once a final lot layout and extent is prepared.

3.0 Water Quality Model Modifications

The MUSIC water quality model was amended as follows to reflect development proposal modifications and achieve NorBe objectives:

1. Vegetation uptake node (treating infiltrated water) was removed from the pre and post development models and infiltration from treatment devices (e.g. bioswales) was discharged directly to the model outlet, untreated, as required by Peer Reviewer.

2. All base flow 'secondary routing' was deleted from pre and post development model as is normal modelling practice. MUSIC manages and routes the baseflow by its inbuilt routines.

3. Terminal wetland/infiltration systems were removed from the model (excluding catchment O6 which discharges to Lake Wollumboola). These areas are to be left undeveloped.

4. 50% of the industrial area was removed from the model and replaced with forest.

5. Roof areas were refined to 200 - 275 m^2 as discussed in Section 2.0. Pervious residential areas were increased by an equivalent area.

6. Road reserve percentage impervious is specified on a **sub-catchment basis** based on required pavement width rather than a model-wide assumption.

7. The wetland in catchment O6 (Lake Wollumboola catchment) was increased in size and permanent pool volume in order to increase water storage available to better meet reuse demands. This improved the treatment efficiency of the wetland.

4.0 Results

Results of iterative modelling conclude that NorBe objectives, as prescribed in Section 1.0 are achieved as a result of the development proposal modifications. Results are tabled below (Table 1 and Table 2) for each required receiving environment as previously reported in Table 10 – Table 14 of Marten and Associates, November 2016.

Table 1: MUSIC results – Pre Development catchment pollutant load.

Parameter	Pre Development Loads					
	SEPP 14 /O2	Curleys/O5	Lake	Seagrass	River	Total
TSS (kg/year)	1580.0	9140.0	293.0	12000.0	13600.0	13900.0
TP (kg/year)	4.7	18.0	0.9	28.9	33.6	34.5
TN (kg/year)	50.5	115.0	9.3	203.0	253.0	263.0
Gross Pollutants	0.0	899.0	0.0	899.0	899.0	899.0

Table 2: MUSIC results – Post Development catchment pollutant load and NORBE assessment

Parameter	Post Development Loads					
	SEPP 14 /O2	Curleys/O5	Lake	Seagrass	River	Total
TSS (kg/year)	587	6960	136	8110	8670	8810
Change (%)	-62.8	-23.9	-53.6	-32.6	-36.3	-36.6
TP (kg/year)	4.3	14.2	0.8	22.7	27.0	27.8
Change (%)	-8.3	-21.1	-4.8	-21.5	-19.6	-19.4
TN (kg/year)	49.6	102.0	8.5	190.0	240.0	248.0
Change (%)	-1.8	-11.3	-9.1	-6.4	-5.1	-5.7
Gross Pollutants	0.0	782.0	0.0	782.0	782.0	782.0
Change (%)	0.0	-13.0	0.0	-13.0	-13.0	-13.0

Note: Change is difference/predevelopment. Zero or negative values indicate NorBE test is met.

5.0 Implications on Estuarine Process Modelling

Estuarine Process Modelling (EPM) completed to date assessed the impact of the development on water quality within the Crookhaven Estuary. Two scenarios, each using different landside pollutant generation profiles, were considered:

1. Land-side stormwater quality using MUSIC modelling with treatment of infiltrated water by downslope vegetation (i.e. inclusion of vegetation uptake node).

2. Land-side stormwater quality using MUSIC modelling without treatment of infiltrated water by downslope vegetation.

Modelling scenario 1 achieved NorBe at the receiving environment, while scenario 2 did not. EPM results indicated that under both modelling scenarios, the impact on change in water quality within the Crookhaven Estuary was negligible.

Given the results of water quality modelling for the modified development as documented in Section 4.0 are between Scenario 1 and Scenario 2 above, and much nearer to the lower load of scenario 1, no impact on water quality within the Crookhaven Estuary would be expected. It is therefore unnecessary to re-run EPM in light of these latest modifications.

6.0 Revised Treatment Train

The treatment train developed to achieve NorBE water quality objectives is:

- Roofs discharge to 5KL rainwater tanks on each dwelling.
- Roofs of medium density residential discharge to rainwater tanks of 3KL – 5KL per unit.
- Tank overflows, remaining lot areas and road runoff is treated by roadside bioswales.
- Bioswales discharge into Enviropods and Stormfilters.
- Stormfilters discharge to the outlet.

In the Lake Wollumboola catchment, the treatment train for runoff from the small area of road and oval includes:

- Road areas treated by roadside swales.
- Roadside swale and oval discharge into a wetland of 3,200 m^2 with a permanent pond volume of 3.2 ML.
- Stored water is available for reuse to irrigate the oval.
- Overflow discharges to the Lake.

7.0 Conclusion

To address the Department's Peer Reviewer's concerns regarding the modelling of stormwater, the MUSIC water quality model has been amended to incorporate changes requested by the Peer Reviewer related to the treatment of infiltrated water. The water quality objective has been revised to require that NorBe be achieved at the 7(a) protection zone boundary. This mean no modelling allowance for the treatment of infiltrated water by the vegetation buffer between the development and the estuary is made. By implementing this change, the revised model addresses the Peer Reviewer's concerns.

To achieve the modified performance objective the application has modified, most notably by removing half the proposed industrial area. This, along with additional model refinements, achieves revised water quality objectives.

The revised water quality model confirms that the proposed development will have a neutral or beneficial effect on stormwater quality at the boundary of the development at the 7(a) zone, and therefore on the downslope receiving environments. This performance objective is achieved using the treatment train as outlined in Section 4.0. Further refinement of the model at the detailed design stage may alter the sizes of the proposed treatment structures and may allow substitution of elements of the treatment train provided the final treatment train achieves water quality performance objectives as specified in this document.

If you have any queries please contact the undersigned.

For and on behalf of

MARTENS & ASSOCIATES PTY LTD

MEGAN KOVELIS

Environmental Scientist/Planner

APPENDIX 8

West Culburra Aquatic Ecology Impact Assessment; Proposed Mixed Use Subdivision. Ecological Australia, May 2017.

ecological AUSTRALIA

West Culburra Aquatic Ecology Impact Assessment: Proposed Mixed Use Subdivision

Aquatic Ecology Assessment

Prepared for
The Halloran Trust

04 May 2017

DOCUMENT TRACKING

Item	Detail
Project Name	West Culburra Aquatic Ecology Impact Assessment: Proposed Mixed Use Subdivision
Project Number	16WOL-5719
Project Manager	Ian Dixon 02 4201 2208 Suite 204, Level 2, 62 Moore Street, Austinmer NSW 2515
Prepared by	Ian Dixon
Reviewed by	Miles Yeates (v1 and v3) and Peter Hancock (v2)
Approved by	Miles Yeates (v1 and v3) and Peter Hancock (v2)
Status	24/03/17 - 1st Draft for comment (v1)
	07/04/17 – 2nd Draft for comment (v2)
	02/05/17 – Version 3 (v3)
Version Number	v3
Last saved on	4 May 2017
Cover photo	Waterside edge of mangrove forest. Photo by Ian Dixon, December 2016

This report should be cited as 'Eco Logical Australia 2016. *West Culburra Aquatic Ecology Impact Assessment: Proposed Mixed Use Subdivision*. Prepared for The Halloran Trust.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from John Toon and Martens and Associates Pty Ltd.

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Abbreviations

Abbreviation	Description
Council	Shoalhaven City Council
DPI	NSW Department of Primary Industries
ELA	Eco Logical Australia Pty Ltd
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FM Act	NSW *Fisheries Management Act 1994*
TSC Act	NSW *Threatened Species Conservation Act 1995*

Executive summary

This assessment provides an overview of the existing health and predicted impacts to estuarine habitats near a proposed subdivision at West Culburra.

In response to stakeholder consultation on the project, Martens and Associates (Consulting Engineers) assessed the estuarine hydrodynamics and changes in water quality variables in the Crookhaven River using a Tuflow Advection Dispersion (TAD) model. The TAD model was used to evaluate the estuarine impacts of the development using the outputs of the surface water quality impact assessment (MUSIC modelling) undertaken for the project. Target variables considered in the TAD model include:

- Salinity
- Total Nitrogen
- Total Phosphorus
- Total Suspended Solids

The independent peer reviewed model is well calibrated and has been used to assess estuarine hydrodynamics and pollutant transport in 32 scenarios, as documented in the *Estuarine Processes Modelling Report.* The 32 model scenarios address two development scenarios for pre- and post-development, two infiltration scenarios (with and without vegetated buffer uptake), four meteorological scenarios (rainfall) and three dispersion sensitivity scenarios (fate of discharged water).

Eco Logical Australia (ELA) conducted a review of environmental tolerances for dominant key fish habitat in the estuary (seagrass, mangroves and saltmarsh). To assess development impacts on these habitats, data was extracted from the MUSIC and TAD models.

On review of these modelling results we conclude that:

- Salinity concentrations at each seagrass sample point and for each assessed scenario match very closely and the proposed development does not increase the duration of salinity concentrations being below 20 g/L and 10 g/L at any seagrass location.
- There are no annual increases in total suspended solids concentrations at the seagrass sample points due to the proposed development.
- Changes to nutrient concentrations at seagrass sample points due to the proposed development throughout the year are negligible.
- Processes favouring mangrove survival would be maintained.
- The development would not have any direct or indirect impact to saltmarsh patches near the development.

In summary, we conclude there is **not** likely to be a significant impact on threatened species, populations, ecological communities or their habitats; and a Species Impact Statement is **not** required, nor is a referral to a Commonwealth body.

The healthy condition of marine vegetation indicates it is tolerant of numerous existing catchment pressures (e.g. dairy farming, residential use). Modelled changes in salinity, nutrients and suspended solids demonstrate an insignificant change between existing and proposed land use. This is the case irrespective of the inclusion of infiltration in the MUSIC model. Our review of the ecology of the estuary and of the model outputs concludes that the proposed subdivision would not alter the health, extent or values of the estuarine ecology.

1 Introduction

The Halloran Trust has engaged Eco Logical Australia (ELA) Pty Ltd to provide an aquatic ecology impact assessment for the proposed development at Culburra Road, West Culburra (Lot 61 DP 755971, Part Lot 5 DP 1065111, Part Lot 6 DP 1065111 and Part Lot 7 DP 1065111) (herein referred to as the site). The aquatic assessment addresses potential impacts to any threatened or protected aquatic species listed under the NSW *Fisheries Management Act 1994* (FM Act), NSW *Threatened Species Conservation Act 1995* (TSC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It also addresses broader impacts to estuarine ecology, especially to ‘key fish habitat’ defined by DPI Fisheries.

1.1 Description of works

The proposed works involve the subdivision and subsequent development of predominantly forested land in the Crookhaven River catchment. The site is located on the northern side of Culburra Road, West Culburra. The proposed development consists of numerous allotments across 93 ha. The proposed land uses include (**Figure 1**):

- residential
- commercial
- industrial
- tourist facilities
- conservation areas of ecological and cultural significance

1.2 Previous studies

In response to stakeholder consultation on the project, Martens and Associates (Consulting Engineers) assessed the estuarine hydrodynamics and changes in water quality variables in the Crookhaven River using a Tuflow Advection Dispersion (TAD) model. The TAD model was used to evaluate the estuarine impacts of the development using the outputs of the surface water quality impact assessment (MUSIC modelling) undertaken for the project. Target variables considered in the TAD model include:

- Salinity
- Total Nitrogen
- Total Phosphorus
- Total Suspended Solids

A comprehensive monitoring regime was undertaken to collect data on water level, flow and salinity in the Crookhaven River to calibrate the model. The independent peer reviewed model is well calibrated and has been used to assess estuarine hydrodynamics and pollutant transport in 32 scenarios, as documented in the *Estuarine Processes Modelling Report.* The 32 model scenarios address two development scenarios for pre and post-development, two infiltration scenarios (with and without vegetated buffer uptake), four meteorological scenarios (rainfall) and three dispersion sensitivity scenarios (fate of discharged water) (**Table 1**).

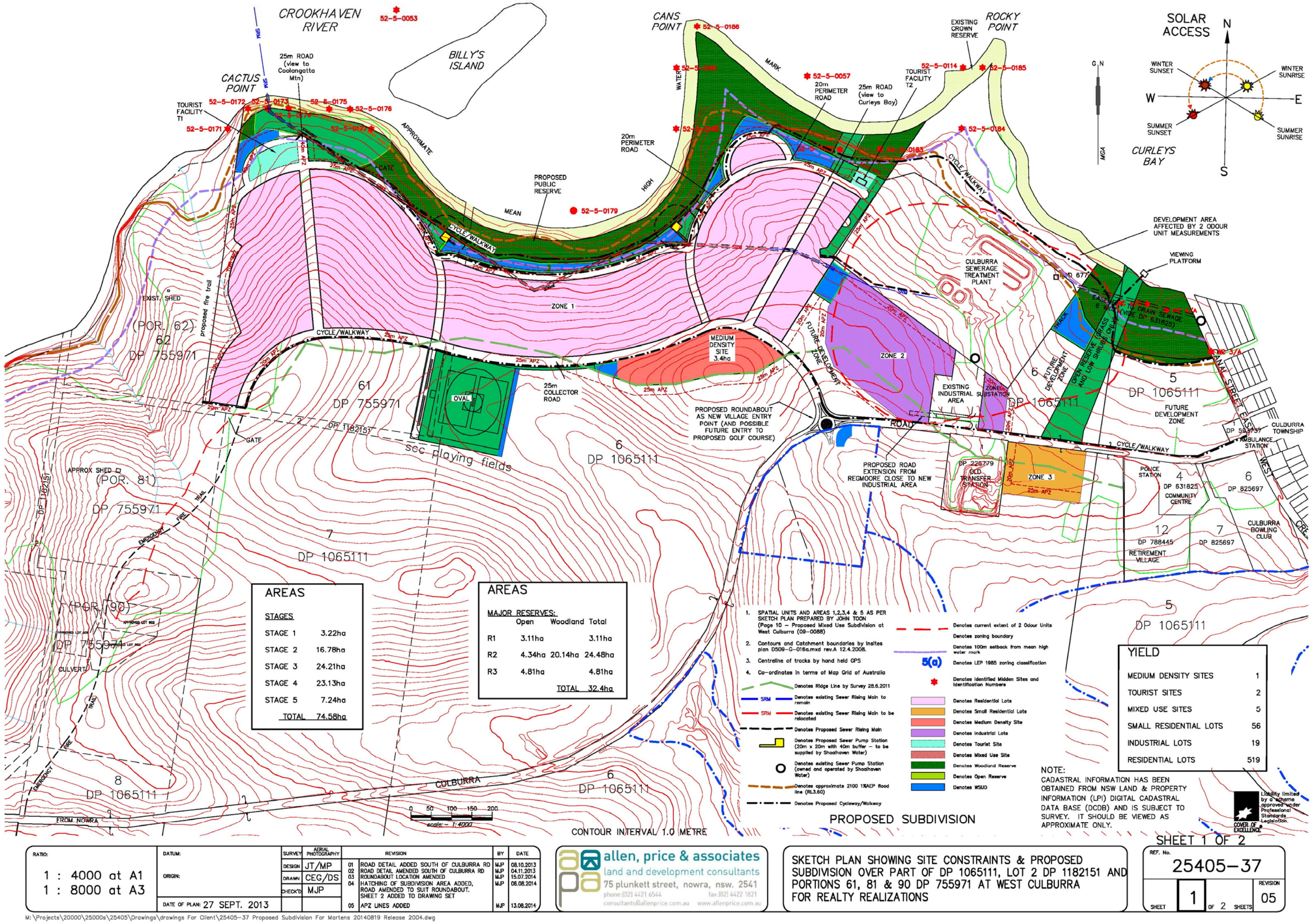


Figure 1: Concept design of proposed development (Water Sensitive Urban Design (WSUD) in blue shade)

Table 1: Development scenarios and Tuflow model naming (provided by Martens & Associates).

		Meteorological Scenario [3]											
		Average Year 1967			Dry Year 1968			Wet Year 1969			Local Wet Month 20 Oct – 20 Nov 1969		
Infiltration Scenario [1]	Development Scenarios [2]	Dispersion Sensitivity Scenario [4]											
		D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
With Infiltration	Pre Dev	M01	M02	M03	M04	–	–	M05	–	–	M06	M07	M08
	Post Dev	M09	M10	M11	M12	–	–	M13	–	–	M14	M15	M16
Without Infiltration	Pre Dev	M17	M18	M19	M20	–	–	M21	–	–	M22	M23	M24
	Post Dev	M25	M26	M27	M28	–	–	M29	–	–	M30	M31	M32

Notes

1. Infiltration scenarios defined in Section 2 of the EPMR (2016).
2. Development scenarios defined in Section 12.5.2 of the EPMR (2016).
3. Meteorological scenarios defined in Section 12.5.3 of the EPMR (2016).
4. Dispersion sensitivity scenarios defined in Section 12.5.4 of the EPMR (2016).

1.3 Study aims

The aims of this aquatic assessment are to:

- gain an understanding of the biota and habitat occurring near the proposed development
- evaluate the predicted changes to environmental conditions due to the development
- assess if the development is likely to cause a significant impact to threatened species, communities or populations and the general estuarine fish habitat.

This report does not consider impacts to oyster farming, as this is addressed by a separate monitoring program (Martens and Associates 2016b, *Water Quality Monitoring Plan*). The following tasks were undertaken to address the project aims:

- a desktop review of species and habitats likely to occur on or adjacent to the site
- literature review of environmental tolerances of key fish habitat, especially seagrass, mangroves and saltmarsh
- an aquatic survey during optimum conditions (high tide with calm swells and high water clarity) to verify and photograph aquatic flora and key fish habitats
- develop criteria for the estuary model to predict environmental changes that have the potential to impact seagrass, mangroves, and saltmarsh
- interpret water quality and estuary model results to allow an assessment of potential aquatic flora and fauna impacts.

2 Legislative context

2.1 NSW Fisheries Management Act 1994 (FM Act)

Under s205, Part 7 of the FM Act, a permit is required to harm (cut, remove, damage, destroy, shade etc.) marine vegetation (saltmarsh, mangroves, seagrass and macroalgae) on public 'water land' or the foreshore of public 'water land' up to the level of Highest Astronomical Tide. This includes indirect impacts if a development alters tidal movement, shades vegetation or is expected to cause dieback from other means. DPI Fisheries does not support clearing of mangroves to provide vistas, but may approve small areas of pruning or removal for infrastructure that benefits the broader community (e.g. a community jetty compared with numerous private jetties).

Future development stages may require specific Part 7 permits, such as and *dredging and/or reclamation* for foreshore structures (e.g. viewing platform). This report only addresses the broader concept plan and does not cover future Development Applications lodged with Council, which may require separate Aquatic Ecology Impact Assessments for foreshore structures (e.g. construction of the viewing platform or other proposed activities that may cause harm to key fish habitat).

Species, communities or populations that are listed as threatened under the FM Act require assessment according to Section 5A of the NSW *Environmental Planning and Assessment Act 1979*, which lists factors that must be taken into account through the preparation of an Assessment of Significance (7-Part Test).

2.2 NSW Threatened Species Conservation Act 1995 (TSC Act)

The TSC Act aims to protect and encourage the recovery of threatened species, populations and communities. The interactions between the TSC Act and the *Environmental Planning and Assessment Act 1979* (EP&A Act) require consideration of whether a development (Part 4 of the EP&A Act) is likely to significantly affect threatened species, populations, ecological communities or their habitats. This is achieved through the preparation of an Assessment of Significance (7-Part Test).

2.3 NSW Water Management Act 2000 (WM Act)

A controlled activity approval under the WM Act is required for certain types of developments and activities that are carried out in or near a river, lake or estuary. The WM Act defines waterfront land as the bed of any river, lake or estuary and any land within 40 meters of the river banks, lake shore or estuary mean high water mark.

2.4 Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

Under the EPBC Act, the Commonwealth Environment Minister needs to approve any development that is likely to have a significant impact on Matters of National Environmental Significance (MNES). Should such an impact be likely, the preparation and submission of a referral is required. MNES relevant to this study include threatened ecological communities, flora and fauna species and migratory species listed under The Act.

3 Methods

3.1 Desktop study

Publicly available databases and reports were reviewed for potential impacts resulting from the proposed development. This included a literature review to determine if marine vegetation has specific condition thresholds, such as tolerance limits to freshwater inflows or excessive nutrients causing severe epiphyte growth. The outcomes of the literature review are provided in **Appendix A**. Online databases were accessed to determine if threatened species, communities and populations were likely to occur in the region. The search covered a 10 km radius from the point -34.920755, 150.739165 in the Crookhaven River (central point just east of Billys Island). Only aquatic species known to use estuarine/marine water were considered in this assessment. Databases include:

- Commonwealth EPBC Act – Protected Matters Search Tool
- NSW TSC Act – Threatened Species Search Tool (BioNet)
- NSW FM Act – Listed protected and threatened species and populations, including species profiles, 'Primefact' publications and expected distribution maps (Riches et al 2016)
- Online Zoological Collections of Australian Museums (OZCAM) – individual species searches to determine likelihood of occurrence of threatened species.

3.2 Field survey

The site was visited between 7:00 am and 2:30 pm on 13th December 2016 by two ELA aquatic ecologists. The survey targeted seagrass, mangrove and saltmarsh habitat at eight locations, with additional general observations of environmental condition made between locations (**Figure 2**). The survey was conducted using a canoe mounted with a colour / infrared underwater video camera linked by a 30 m cable to an on-board monitor. This method allows viewing and recording of substrate and sub-tidal flora in shallow and deep water (even in low light conditions by switching to infrared spectrum) without the risks associated with snorkelling or diving. Conditions were reasonably calm leading up to and during the survey (**Table 2**).

Table 2: Weather conditions leading up to the aquatic survey on 13th Dec 2016

Date	Min temperature (°C)	Max temperature (°C)	Rainfall (mm)	Wind Direction	Wind speed (km/h)
6/12/2016	17.4	23	18.8	SW	7
7/12/2016	17.1	22.2	4.8	NNE	7
8/12/2016	16.8	26.1	3	NNE	30
9/12/2016	16.5	21	0	SSE	13
10/12/2016	15.9	21	0	NE	6
11/12/2016	17.2	22.3	1	SSE	13
12/12/2016	17.9	28.2	0.2	NNE	17
13/12/2016	19.2	35.3	0	NNE	13

Observations from BOM – Jervis Bay (Station 068151)

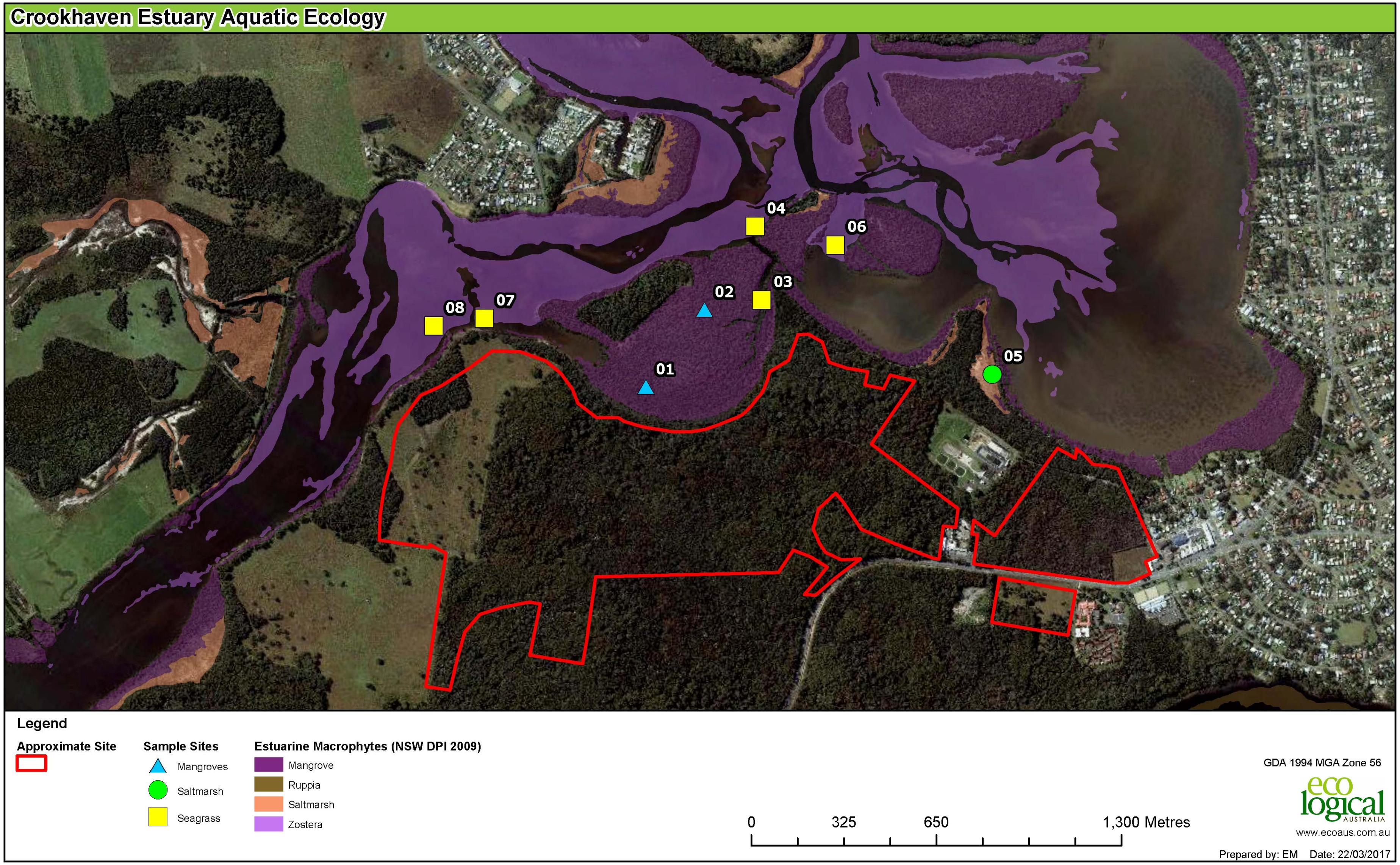


Figure 2: Sample locations during aquatic ecology survey

3.3 Water Quality Sampling

Water samples were taken near the base of the water column to compliment the field observations. Samples were either measured in-situ using a Horiba U-50 multi-parameter meter, or collected using appropriate protocols, and sent to a registered NATA laboratory (ALS) for analysis. Parameters measured include:

Field measurement

- Dissolved oxygen
- Temperature
- Oxygen-reduction (redox) potential
- Salinity
- Total suspended solids

Lab measurement

- Biological oxygen demand (BOD)
- Nutrients (nitrogen and phosphorus: NO_3, NO_2, Total N, Total P, Filtered Reactive P, Ammonia).

Water quality results are provided in **Appendix B**.

3.4 Modelling impacts using habitat thresholds

Condition thresholds of marine vegetation were derived from a review of publicly accessible literature (**Appendix A**). Our review identified several hypothetical issues that could impact the estuary, which led to a series of questions that could be answered by reviewing the estuary model results (Martens and Associates). Potential sources of impacts to each habitat and recommended tests are:

Seagrass

- stormwater discharged on or adjacent to seagrass
  - **TEST → Is a stormwater outlet/channel proposed in or adjacent to the seagrass?**
- prolonged discharge of freshwater in a concentrated area near seagrass
  - **TEST → will salinity near seagrass fall below 10 and 20 ppt, and for what duration?**
- increased suspended solids discharged into the estuary
  - **TEST → will suspended solids increase during rain events, especially in spring-summer?**
- erosion leading to sediment deposits in the estuary, especially during construction
  - **TEST → will suspended solids increase during construction and operation?**
- increased nutrients discharged into the estuary
  - **TEST → will nutrient concentrations be higher than normal, especially in spring-summer, and for how long?**

Mangroves

- foreshore earthworks or structures that effect tidal movement
  - **TEST → Does the proposal inhibit tidal movement to the mangroves?**
- sedimentation of the estuary during construction and operation, including suspended solids such as fine sediment released during earthworks (if mitigation measures fail)
  - **TEST → Does the proposal result in an increase in suspended solids and/or sediment and would this be deposited in the mangroves?**
- diversion of overland flows that currently diffuse water across the bushland to the mangroves

  - **TEST → Is the natural overland flow to the mangroves across a vegetated surface, or otherwise treated to avoid impacts from runoff?**
- stormwater discharged on mangroves
  - **TEST → Is a stormwater outlet/channel proposed in the mangroves?**
- roads, earthworks and development that prevents mangrove retreat over decades
  - **TEST → Will predicted sea level rise reach artificially raised areas of development (http://coastalrisk.com.au/viewer)?**

Saltmarsh

- foreshore earthworks or structures that effect tidal movement
  - **TEST → Does the proposal inhibit any tidal movement to the saltmarsh?**
- diversion of overland flows that currently diffuse water across the bushland to the saltmarsh
  - **TEST → Is the natural overland flow to the saltmarsh across a vegetated surface, or otherwise treated to avoid impacts from runoff?**
- stormwater discharged on or adjacent to the saltmarsh
  - **TEST → Is a stormwater outlet/channel proposed in or adjacent to the saltmarsh?**
- roads, earthworks and development that prevents saltmarsh retreat over decades
  - **TEST → Will predicted sea level rise reach artificially raised areas of development (http://coastalrisk.com.au/viewer)?**

4 Results and impact assessment

4.1 Aquatic habitat

The Crookhaven River estuary is a disturbed ecosystem in a mixed use catchment, but is abundant in healthy marine vegetation comprised of saltmarsh, mangroves and seagrass. These habitats are protected under the FM Act. Additionally, saltmarsh is listed as a threatened ecological community under the TSC Act and EPBC Act. Other marine vegetation (macroalgae and seaweeds) may occur, but was not an abundant habitat type in the surveyed area.

Seagrass

The estuary has an extensive seagrass community, dominated by *Zostera capricorni* (Ribbonweed). A survey at **Sites 03, 04, 06, 07 and 08** (**Figure 2**) showed that meadows appear reasonably healthy, due to high density (cover), large extent, long leaf length, and minor-moderate epiphyte cover. Bioturbation from benthic infauna was evident at all sites, indicating sediment quality suitable to support aquatic organisms. Seagrass is dynamic in its seasonal growth and adaption to sediment movement. Mapping by DPI Fisheries (**Figure 2**) was correct at the time of survey, but meadows may contract or expand over years. For example, the estuary arm surrounding **Site 03** is currently a healthy seagrass bed, but was not evident in the 2009 mapping by DPI Fisheries. In other estuaries ELA has observed disappearance of seagrass beds due to sand deposition after large storms (e.g. between Holts Point and Tom Uglys Bridge, Sylvania).

The seagrass beds at **Sites 03, 04, 07 and 08** (**Figure 2**) were similar in appearance:

- leaf length typically 40+ cm
- dense cover (50-70%)
- minor to moderate epiphyte cover across entire leaf blade

The seagrass at **Site 06** was notably different to other sites:

- leaf length typically 20-30 cm
- sparse cover (10 %)
- minor to moderate epiphyte cover across entire leaf blade

Water quality tests in the seagrass were taken at high tide, mostly in calm conditions but wind and waves increased throughout the day (**Sites 03, 04, 06, 07** and **08**, **Figure 2**). Water was sampled from the bottom without disturbing the substrate. Water salinity was high (35-36 ppt) and similar to sea water. Biological Oxygen Demand (BOD) was low (<2 mg/L), indicating little organic matter breakdown on the bottom. Suspended solid concentrations were variable but high (27-139 mg/L), although the high reading at **Site 08** could have been caused by sediment disturbance by strong winds affecting the boat. Ammonia concentration was high at all sites (0.16-0.18 mg/L) and greatly exceeded ANZECC Guideline trigger values for South-east Australian estuaries. Total phosphorus concentration was also above guidelines at three sites, **Sites 04, 07** and **08** (0.12-0.22 mg/L). Complete water quality results are in **Appendix B**.

Site photos for seagrass beds are in **Appendix C**. An impact assessment for seagrass is provided below in **Section 4.5**.

Mangroves

Mangroves are abundant across the entire foreshore of the study area, with forests ranging in width between 10 – 500 m (**Figure 2**). Two sites (**Site 01** and **Site 02**) were selected in the largest mangrove forest (between the proposed development and Billy's Island). Other locations were observed via canoe at high tide. Mangroves in the surveyed area are a monoculture of *Avicennia marina* (Grey Mangrove), although *Aegiceras corniculatum* (River Mangrove) may occupy landward areas. However, River Mangrove may have been historically harvested for 'oyster sticks', resulting in a dominance of Grey Mangrove (Dwyer 2014).

Mangroves observed during the survey are in good condition, because:

- regeneration appears successful, with abundant seedling/juveniles and a variety of trunk girths (diameter at breast height) with no obvious gaps in recruitment events caused by disturbance
- canopy cover is dense and extensive, covering all available habitat.

Water quality tests at mangrove sites were conducted when most of the mangrove forest was tidally inundated (**Site 01 and Site 02**, **Figure 2**). Water salinity was high (35-36 ppt) and similar to sea water. Biological Oxygen Demand (BOD) was low (<u><</u>2 mg/L), indicating little organic matter. Suspended solids was variable but high (14-60 mg/L). Ammonia concentration was high at both sites (0.16-0.20 mg/L) and greatly exceeded ANZECC Guideline trigger values for South-east Australian estuaries. Total phosphorus concentration was also above guidelines at Site 01 (0.07 mg/L). Complete water quality results are in **Appendix B**.

Site photos for mangroves are in **Appendix C**. An impact assessment for mangroves is provided below in **Section 4.5**.

Saltmarsh

Saltmarsh is uncommon along the southern shore of the estuary. It occurs in two locations near the Culburra Wastewater Treatment Plant. The larger of the two patches (**Site 05**) is mostly bare sediment with *Sporobolus virginicus* (Saltwater Couch) and scattered *Avicennia marina* (Grey Mangrove) in the tidal inundation zone; and *Juncus kraussii* subsp. *australiensis* (Sea Rush) and *Casuarina glauca* (Swamp Oak) along the fringes. This mix of species forms a 'Low Saltmarsh' community (as described in Sainty et al. 2012). The bare sediment has abundant crab burrows, an indicator of a healthy environment. 'Low Saltmarsh' depends on a mix of tidal inundation for its competitive advantage, plus freshwater input to promote germination. Saltmarsh communities may be influenced by complex groundwater interaction and local soil chemistry, which is beyond the scope of this study.

Water quality tests at the saltmarsh site were conducted while it was tidally inundated (**Site 05**, **Figure 2**). Water salinity was high (35 ppt) and similar to sea water. Biological Oxygen Demand (BOD) was low (3 mg/L), indicating little organic matter. Suspended solids was high (48 mg/L). Ammonia concentration was high (0.22 mg/L) and greatly exceeded ANZECC Guideline trigger values for South-east Australian estuaries. Total phosphorus concentration was also above guidelines (0.06 mg/L). Unlike the other seven sites in mangroves and seagrass, nitrate (0.04 mg/L) and total nitrogen (0.5 mg/L) concentrations were high and above guidelines. Complete water quality results are in **Appendix B**.

Site photos for saltmarsh are in **Appendix C**. An impact assessment for saltmarsh is provided below in **Section 4.5**.

4.2 Key fish habitat

DPI Fisheries identify three types of 'key fish habitat' in their *Policy and Guidelines for Fish Habitat Conservation and Management* (Fairfull 2013) (**Appendix D**): **TYPE 1** (highly sensitive aquatic habitat); **TYPE 2** (moderately sensitive key fish habitat); and **TYPE 3** (minimally sensitive key fish habitat). All three key fish habitats are present in the study area:

- **TYPE 1**
  - *Zostera seagrass bed (>5 m^2)*
  - *Coastal saltmarsh (>5 m^2)*
  - *SEPP 14 coastal wetland*
- **TYPE 2**
  - *Zostera seagrass bed (<5 m^2)*
  - *Mangroves*
  - *Stable intertidal sand/mud flats with large populations of infauna*
- **TYPE 3**
  - *Unvegetated sand or mud substrate with minimal or no infauna*

4.3 Threatened species, communities and populations

Database searches for threatened species, communities and populations within the study area are listed in **Appendix E**. Of the species known in the region, many are unlikely to use the estuary due to unsuitable habitat (e.g. shallow marine water not suitable for large mammals). While other species may opportunistically and infrequently pass through the study area whilst exploring or grazing (e.g. turtles), their habitat is unlikely to be adversely impacted by the development. Likelihood of the main groups of **threatened** aquatic fauna to occur in the area are:

- Fish – unlikely as no suitable habitat, or no records in catchment
- Sharks & rays – sharks unlikely to come this close to shore in shallow water; rays may pass through, but there is ample foraging habitat throughout the estuary
- Turtles – may briefly explore area, especially in seagrass beds
- Whales & dolphins – too shallow, unlikely this close to shore.

One threatened ecological community occurs in the study area. Two patches of "Subtropical and Temperate Coastal Saltmarsh" occur near the Culburra Wastewater Treatment Plant. Saltmarsh will not be directly impacted by the proposed development.

No threatened plant species were observed in the study area.

4.4 Comments on the 'Estuarine Processes Modelling Report'

Existing conditions

The *Estuarine Processes Modelling Report* (EPMR) (Martens and Associates 2016a) describes the existing conditions in the estuary based on the modelled results:

- For the average rainfall year the Crookhaven River is frequently above ANZECC (2000) trigger criteria for TN and TP in estuaries (0.300 mg/L and 0.030 mg/L respectively), and is therefore considered a disturbed ecosystem with compromised health in existing conditions
- Significant freshening and high nutrient / solids concentrations occur during infrequent storm events. The 1st percentile salinity concentrations and 99th percentile TN, TP and TSS

concentrations (i.e. levels for approximately 3 days per year) in impact assessment scenarios show:

- o 1st percentile salinity concentrations falling below 2500 mg/L in an average year and falling as low as 1000 mg/L in a wet year
- o 99th percentile TN concentrations of up to 0.70 mg/L in an average year and over 1.00 mg/L in a local wet month
- o 99th percentile TP concentrations of up to 0.135 mg/L in an average year
- o 99th percentile TSS concentrations of over 40 mg/L in an average year and over 60 mg/L in a local wet month.

- The estuary quickly recovers from stormwater runoff impacts due to tidal flushing and natural concentration fluctuation within the system.

ELA agrees with Martens and Associates' findings and concludes the overarching status is that the Crookhaven River is a disturbed ecosystem with compromised health in existing conditions. ELA's water quality sampling is in line with the modelled findings and confirms the Crookhaven River is above ANZECC trigger criteria at most sample locations. Modelled and observed background concentrations are high, and the model demonstrates extreme short duration runoff events increase estuarine concentrations of nutrients and TSS even further past ANZECC criteria. Despite this, the system still supports commercial aquaculture and reasonably healthy marine vegetation as validated in this study. This demonstrates the resilience of the marine vegetation in surviving despite the pressures of stormwater runoff from the developed catchment, which includes dairy farming and residential use, and can likely be attributed to the large degree of tidal flushing.

Proposed conditions

The EPMR assessed the potential impacts to water quality under 16 developed case scenarios. Statistical analyses and review of maximum spatial concentrations were used by Martens and Associates to develop an impact assessment. Their assessment identified that:

- Changes to estuarine concentrations due to the proposed development are negligible, even in infrequent storm events.
- The magnitudes of changes to estuarine concentrations due to the proposed development are insignificant compared to the large degree of natural concentration fluctuation which occurs under existing conditions.
- The pollutant masses from the proposed development are minor compared to those from the existing Culburra village (suburbs of Culburra Beach and Orient Point), where development often includes seawalls and clearing along the foreshore (unlike the proposed subdivision which aims to protect marine vegetation).
- The vast majority of site impact plumes are limited to foreshore areas immediately adjacent to site outlet locations.
- There are many instances of positive changes to estuarine concentrations which are consequences of the effectiveness of proposed treatment measures and the controlled discharge of stormwater.

Martens and Associates produced impact plots which show the change in minimum / maximum concentration for one hour out of the simulated year / month. Threshold triggers were applied to each variable (100 mg/L change in salinity, 1 µg/L for TN / TP, and 100 µg/L for TSS). The plots represent changes at very low thresholds in extreme, short term events (i.e. one hour out of the year), resulting in a limited assessment over a longer term. It is unlikely such short sporadic changes in water quality would impact an aquatic ecosystem evolved to respond to dynamic fluctuations in environmental conditions (i.e. tides, temperature, light, salinity and sedimentation). For example, changed discharge regimes due to the proposed development may slightly increase the absolute maximum concentration over a single hour, but the results of the statistical analysis demonstrate developed scenarios have no change to mean / median concentrations, and no material long-term sustained changes in 90^{th}, 95^{th} and 99^{th} percentile conditions.

Given the large range of 'pollutant' concentrations the estuary experiences over the course of a year and even over a single tidal cycle, the magnitude of localised changes to minimum / maximum concentrations in one hour per year is insignificant to the processes supporting a healthy aquatic ecology. In such dynamic systems, persistence of a 'pollutant' in unacceptable concentrations may compound to a negative impact over the long term. Results showing a sporadic spike across a year does not correlate to a threat to ecological health. This is pertinent to estuarine vegetation that has evolved to have a competitive advantage in dynamic environmental conditions, and is somewhat resilient to short-term extreme pressures. The dominant species found in this estuary are typically robust, reasonably healthy and are not likely to be impacted by short-term changes in water quality: *Zostera capricorni* (Ribbonweed), *Avicennia marina* (Grey Mangrove), *Sporobolus virginicus* (Saltwater Couch), *Juncus kraussii* subsp. *australiensis* (Sea Rush) and *Casuarina glauca*.

ELA concludes the minimum / maximum impact plots do not represent a valid assessment of potential impacts to aquatic ecology. Rather, the statistical analysis should be used as the primary impact assessment tool, and for this reason ELA requested Martens and Associates extract additional data from the models to inform a further statistical analysis specific to ELA's study.

The EPMR concludes that there will be no detrimental impacts on estuarine health due to the proposed development. The following section tests that conclusion, specifically addressing environmental tolerances of marine vegetation.

4.5 Model results

ELA has considered the development layout and results of MUSIC and TAD models provided by Martens and Associates. Based on these, ELA has assessed the 'tests' outlined in **Section 3.4** as follows:

Seagrass tests

Is a stormwater outlet/channel proposed in/adjacent to the seagrass?

> There is no direct discharge of stormwater into the estuary. All stormwater discharged from proposed infiltration basins shall be via a level spreader/energy dissipater with outflow into the retained 100 m vegetated buffer zone adjacent to the estuary.

Will salinity near seagrass fall below 10 and 20 ppt, and for what duration?

> Modelled salinity concentrations at the five seagrass sample points (**Figure 2**) have been extracted from the estuarine processes model for each of the 32 scenarios (**Appendix F**). Detailed results from four of the modelled scenarios are presented to address this question:
>
> - [M01] – Existing conditions with infiltration
> - [M09] – Proposed conditions with infiltration
> - [M17] – Existing conditions without infiltration
> - [M25] – Proposed conditions without infiltration

These four scenarios are for an 'average' rainfall year (1967 data) and use calibrated dispersion coefficients (D1), as detailed in the EPMR (Martens and Associates 2016a). **Appendix F** - **Figure 1** plots salinity concentrations for each of the five sample points and each of the four models, and demonstrates that predicted salinity concentrations at each sample point and for each scenario match very closely. Salinity concentrations in all scenarios fall below 20 g/L during seven 'events', and fall below 10 g/L during four 'events'. **Appendix F** - **Figure 2** shows a detailed view of salinity concentrations at one sample point (SG08) for one event ('event 3') and demonstrates there are practically no differences between the four modelled scenario results.

Appendix F - **Table 1** summarises durations below 20 g/L and 10 g/L for each event, using the approximate average duration for all sample points. Durations of salinity concentration <20 g/L range from 6 to 28 days, with a total of 110 days over the modelled average year (i.e. 30% of the year). Durations of salinity concentration <10 g/L range from 1.5 to 12.5 days, with a total of 37 days over the modelled average year (i.e. 10% of the year). The proposed development is not predicted to increase the duration of salinity concentrations being below 20 g/L and 10 g/L at any seagrass location.

Will suspended solids increase during rain events, especially in spring-summer?

Detailed MUSIC modelling indicates average annual load of total suspended solids (TSS) delivered to mapped seagrass areas will be reduced by 14%, from 11,139 kg/year to 9,557 kg/year.

Throughout the consultation process, the Department of Planning's peer reviewer has suggested that water quality modelling should bypass any infiltration, untreated, to the model outlet node – thereby ignoring the natural processes that will occur within the 100 m wide vegetated buffer zone. MUSIC sensitivity analysis indicates that a reduction in suspended solids load to seagrass areas is still achieved under the scenarios suggested by the reviewer, with a reduction from 12,089 kg/year to 11,163 kg/year (8%) when comparing pre and post-development scenarios.

TSS concentrations at the five seagrass sample points have been extracted from each of the 32 models, with statistical analyses summarised in **Appendix F - Table 3 to Table 18**. Results of all 32 model scenarios indicate there are no significant annual increases (<0.5% change) in TSS concentrations at the seagrass sample points due to the proposed development. This annual result does not warrant further tests into variation among months or seasons.

Will suspended solids increase during construction and operation?

Detailed MUSIC modelling indicates that during operation the proposed stormwater management treatment train achieves a 14% reduction of suspended solids discharged to seagrass areas and an 18% reduction (12,319 kg/year to 10,067 kg/year) in suspended solids discharged to the Crookhaven River.

In accordance with industry best practice, Landcom (2004) is the criteria for site management and water quality treatment during the construction phase of development. Sediment and erosion control measures for the site have been designed in accordance with these guidelines. Construction shall be staged and each stage shall include sedimentation basins, energy dissipaters, earth diversion bunds, sediment fences, stabilised site entry and revegetation. Suspended solids will increase during construction within the developed land, however, runoff would be treated by these onsite measures prior to discharge into the vegetated buffer strip and thence to the estuary and seagrass areas.

Regular monitoring and maintenance of construction and operational phase water quality treatment structures would be in accordance with Martens and Associates (2016c) *Water Quality Monitoring Plan*. Monitoring shall assist in mitigating failure and potential impact to seagrass areas

Will nutrient concentrations be higher than normal, especially in spring-summer, and for how long?

Predicted total nitrogen (TN) and total phosphorous (TP) concentrations at each of the five seagrass sample points have been extracted from each of the 32 model scenarios, with statistical analyses summarised in **Appendix F - Table 3 to Table 18**. Results indicate the changes to TN or TP concentrations at the seagrass sample points due to the proposed development throughout the year are negligible (see discussion below). This annual result does not warrant further tests into variation among months or seasons.

Seagrass discussion

For each of the 32 model scenarios tested for change in TSS, TN, TP and salinity at the five seagrass locations, five concentration statistics were used (median, mean and 90th / 95th / 99th percentile concentrations). This gives a total of 1,600 impact statistics. Of the 1,600 impact statistics, the maximum impact due to the proposed development is a 1.5% (0.4 µg/L) increase to the median TP concentration at seagrass Site 03 over the course of a month. This occurs when comparing [M23] and [M31] (**Appendix F - Table 17**), which are modelled 'without infiltration' and with D2 (lower bound) dispersion coefficients, in conjunction with an extreme wet month over Culburra and the site with no other catchment inflows. This is the most unlikely combination of scenarios assessed, and the scenario most likely to 'model' adverse impacts. The EPMR describes the improbability/impracticality of these conditions occurring simultaneously (if ever). Despite this being the most extreme change to model variables assessed, changes to estuarine concentrations due to the proposed development are of immaterial significance and do not push concentrations over ANZECC Guideline triggers for estuarine waters (ANZECC & ARMCANZ 2000).

Of the 1,600 impact statistics for TSS, TN, TP and salinity, there are two instances of concentration impacts between 1 - 2% change, and eight instances of impacts between 0.5 - 1.0% change, which are also considered negligible.

The majority of statistics demonstrate no impact (<0.5% change), with many changes demonstrating improvement of estuarine concentrations (slightly increasing salinity and slightly decreasing TN / TP / TSS) due to:

- The effectiveness of the proposed treatment measures in reducing the concentrations of stormwater pollutants from the development site.
- The reduced peak stormwater runoff flow rates due to discharge control measures incorporated into the proposed treatment train.

There are no significant changes to mean / median concentrations or extreme concentrations (90th / 95th / 99th percentile). The inclusion or exclusion of infiltration in the MUSIC assessment has no significant impact on the estuary water quality outcome predicted by the model. Modelling concludes that the proposed development will not affect long-term concentrations or short-term discharge concentrations near seagrass.

The magnitudes of changes to estuarine concentrations due to the proposed development are considered insignificant compared to the large degree of fluctuation in natural concentrations. Regardless of the combination of scenarios assessed, there would not be any material impacts on seagrass health due to the proposed development, as concentration changes in TSS, TN, TP and salinity are negligible.

Mangrove tests

Does the proposal inhibit tidal movement to the mangroves?

No foreshore earthworks or structures are proposed that would affect tidal movement or exchange. A single viewing platform is proposed in the foreshore area east of the Culburra Sewage Treatment Plant (**Figure 1**), but this is outside the current SEPP 14 wetland areas and is not considered to be a structure that would affect tidal movements.

Does the proposal result in an increase in suspended solids and/or sediment and would this be deposited in the mangrove?

Detailed MUSIC modelling indicates average annual load of suspended solids delivered to the Billys Island inlet (area of SEPP 14 wetlands and mangroves) will be reduced by 57%, from 1,180 kg/year to 510 kg/year. Mangroves often occur in areas where natural sedimentation occurs, and they may be dependent on some sediment deposition. TAD modelling presented in the EPMR shows that mean / median TSS concentrations at the mangroves across the 32 scenarios do not reduce by more than 1% (0.3 mg/L) due to the proposed development, which indicates that changes to sediment deposition from the immediate upslope catchment are negligible compared to the natural estuary depositions. The change in surface runoff loads modelled for the development change is therefore not significant in the context of the requirements of the community.

In accordance with industry best practice, Landcom (2004) is the criteria for site management and water quality treatment during construction phase of development. Sediment and erosion control measures for the site have been designed in accordance with these guidelines. Construction shall be staged and each stage shall include sedimentation basins, energy dissipaters, earth diversion bunds, sediment fences, stabilised site entry and revegetation. Suspended solids will increase during construction, however, overland flows shall be treated by these onsite measures prior to any discharge into the estuary.

Regular monitoring and maintenance of construction and operational phase water quality treatment structures would be in accordance with Martens and Associates (2016c) *Water Quality Monitoring Plan*. Monitoring shall assist in mitigating failure and potential sedimentation of mangrove areas.

Is the natural overland flow to the mangroves across a vegetated surface, or otherwise treated to avoid impacts from runoff?

The development has been designed to ensure pre-development flow rates discharging into the wetlands are maintained. Iterative hydrological modelling has been used to determine the post development catchment area required to achieve this for the 1 in 2, 10, 20 and 100 year ARI storm events. A 100 m wide vegetated buffer zone shall be retained between the development and the estuary (and mangroves) to further maintain natural overland flow.

Is a stormwater outlet/channel proposed in the mangroves?

There is no direct discharge of stormwater into the estuary. All stormwater discharged from proposed end-of-line infiltration basins shall be via a level spreader/energy dissipater into the retained 100 m wide vegetated buffer zone before entering the estuary. In the vicinity of the SEPP 14 wetlands, the infiltration basin has been designed to have an elongated outlet weir to ensure even dispersal of discharged flow.

Will predicted sea level rise reach artificially raised areas of the development?

Using the suggested website (http://coastalrisk.com.au/viewer), the model predicts that maximum sea level rise predictions for 2100 plus highest tide does not reach the development **Figure 3**.

Figure 3: Sea level rise predictions for 2100 plus high tide (http://coastalrisk.com.au/viewer)

Mangrove discussion

The development would continue to allow freshwater flows across a vegetated buffer before entering the mangroves, whilst preventing excessive sedimentation of the mangrove flats. This design feature is preferable to diverting water through centralised outfalls (stormwater channels). As discussed in the seagrass tests, salinity in the estuary will resemble natural fluctuations under any modelled scenario. Therefore, the models produced by Martens and Associates demonstrate that processes favouring mangrove survival would be maintained, and the proposed development would not cause a negative impact to the mangrove forest.

DPI Fisheries commented on a draft planning proposal and raised concerns that sediment plumes may enter the estuary during earthworks. Fine sediment (especially disturbed clay) would pass through sediment fences erected around the construction site, however this is a tertiary treatment measure which would be minimised due to the proposed controlled capture and treatment of all runoff via sedimentation basins and flocculation (if necessary) before being released to the vegetated buffer zone. Assuming the measures detailed in the Water Quality Monitoring Plan (Martens and Associates, 2016c) are implemented, the construction phase works are unlikely to release fine sediments to the estuary. This is especially important for protection of not only mangroves, but the broader aquatic ecology where filter feeders (oysters), benthic biota and fish all rely on clean estuary water.

Saltmarsh tests

Does the proposal inhibit tidal movement to the saltmarsh?

A proposed viewing platform is located in the vicinity of mapped saltmarsh. However, the ramp is unlikely to inhibit tidal movement.

Is the natural overland flow to the saltmarsh across a vegetated surface, or otherwise treated to avoid impacts from runoff?

Given the location of the existing STP, development as part of this project is limited in the vicinity of the mapped saltmarsh. Overland flow from developed areas shall be treated within the proposed stormwater treatment train and the 100 m wide vegetated zone before discharging into the estuary. Modelling indicates a neutral or beneficial effect on water quality is achieved. Overflow from proposed infiltration basins shall be via a level spreader/energy dissipater across the buffer vegetation before entering the estuary.

Is a stormwater outlet/channel proposed in or adjacent to the saltmarsh?

There is no direct discharge of stormwater into the estuary. No stormwater outlets/channels are proposed in or adjacent to the saltmarsh.

Will predicted sea level rise reach artificially raised areas of the development?

As per response under *Mangroves* the model predicts that maximum sea level rise predictions for 2100 plus highest tide does not reach the development (**Figure 3**).

Saltmarsh discussion

The proposed development design and modelling indicates a neutral or beneficial effect on water quality is achieved. No works are proposed in the saltmarsh or influence the natural processes for survival (tidal movement and freshwater inflows). Therefore, <u>the development would not have any direct or indirect impact to saltmarsh patches near the development.</u>

4.6 Legislation compliance

The above impact assessment demonstrates there is unlikely to be a significant impact to threatened species, populations or communities listed under the FM, TSC and EPBC Acts. As such, a Species Impact Statement is not required.

The modelling demonstrates that under any tested scenario, there would be very little change between pre and post-development. Marine vegetation appears reasonably healthy and has established under numerous catchment pressures. The modelled post-development scenarios would not alter essential environmental conditions those species currently depend on, nor would it compound existing catchment pressures regarding TP, TN, TSS and salinity concentrations. As such, there would be no significant harm (directly, indirectly or cumulatively) to marine vegetation or other key fish habitat in the estuary.

Based on the review of applicable legislation and the impact assessment undertaken, we conclude the proposed development meets the legislation criteria and is not expected to cause impacts to estuarine ecology.

5 Conclusion

There is **not** likely to be a significant impact on threatened species, populations, ecological communities or their habitats; and a Species Impact Statement is **not** required, nor is a referral to a Commonwealth body. Future Development Applications to Council would require further assessment if foreshore structures require permits under 7 of the FM Act (e.g. *Harm Marine Vegetation* or *Dredging and/or Reclamation* for the viewing platform).

The water quality and estuary model results provided by Martens and Associates indicate that natural processes supporting marine vegetation will be maintained and would replicate natural conditions under any tested development scenario. By protecting the key fish habitats in the estuary (discussed in **Section 4.2**) there is minimal anticipated impact to aquatic fauna.

The healthy condition of marine vegetation indicates it is tolerant to numerous existing catchment pressures (e.g. dairy farming, residential use). Modelled changes in salinity, nutrients and suspended solids demonstrate an insignificant change between existing and proposed land use. This is the case irrespective of the inclusion of infiltration in the MUSIC model. Our review of the ecology of the estuary and of the model outputs concludes that the proposed subdivision would not alter the health, extent or values of the estuarine aquatic ecology.

References

Adam, P. 1981. Saltmarsh plants of NSW. *Wetlands (Australia)* **1,** 11-19.

ANZECC & ARMCANZ. 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Benjamina, K. J., Walker, D. I., McComb, A. J., & Kuo, J. 1999. Structural response of marine and estuarine plants of Halophila ovalis (R. Br.) Hook. f. to long-term hyposalinity. *Aquatic Botany*, *64*(1), 1-17.

Burchett, M. D., Clarke, C. J., Field, C. D., & Pulkownik, A. 1989. Growth and respiration in two mangrove species at a range of salinities. *Physiologia Plantarum*, *75*(2), 299-303.

Chevron 2010. Technical Appendices N3 to N10. *Draft Environmental Impact Statement/ Review and Management Programme for the Proposed Wheatstone Project*. Available: https://www.chevronaustralia.com/docs/default-source/default-document-library/wheatstone_draft_eis_ermp_technical_appendices_n3_to_n10_web-pdf-sflb.pdf?sfvrsn=0 (19 January 2017).

Creese, R.G., Glasby, T.M, West, G. and Galen, C. 2009. *Mapping the habitats of NSW estuaries. Industry & Investment NSW Fisheries Final Report Series 113.* Port Stephens, NSW, Australia.

CSIRO 2002. *Simple Estuarine Response Model*. Available: http://www.per.marine.csiro.au/serm/indicators.htm (19 January 2017).

Doorn-Groen, S. M., & Foster, T. M. 2007. Environmental monitoring and management of reclamations works close to sensitive habitats. *Terra et Aqua*, *108*, 3.

Dwyer, P. 2014. *Historical harvesting of River Mangrove for use as 'oyster sticks' in NSW* (Video file). Retrieved from http://sydney.edu.au/environment-institute/videos/patrick-dwyer-historical-harvesting-of-river-mangrove-for-use-as-oyster-sticks-in-nsw/ (19 January 2017).

Department of Agriculture and Fisheries 2010. *Grey Mangrove.* Available: https://www.daf.qld.gov.au/fisheries/habitats/marine-plants-including-mangroves/common-mangroves/grey-mangrove (19 January 2017).

Fairfull 2013. *Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management (2013 update).* NSW Department of Primary Industries.

Hillman, K., McComb, A. J., & Walker, D. I. 1995. The distribution, biomass and primary production of the seagrass Halophila ovalis in the Swan/Canning Estuary, Western Australia. *Aquatic Botany*, *51*(1), 1-54.

Landcom 2004. *Managing Urban Stormwater: Soils and Construction*. New South Wales Government.

Lee, K. S., Park, S. R., & Kim, Y. K. 2007. Effects of irradiance, temperature, and nutrients on growth dynamics of seagrasses: a review. *Journal of Experimental Marine Biology and Ecology*, *350*(1), 144-175.

Martens & Associates Pty Ltd 2016a. *Estuarine Processes Modelling Report: Proposed Mixed Use Subdivision West Culburra, NSW*. Martens & Associates Pty Ltd.

Martens & Associates Pty Ltd 2016b. *Water Quality Monitoring Plan – Mixed Use Subdivision, West Culburra, NSW*. Martens & Associates Pty Ltd.

Naidoo, G., & Naidoo, S. 1992. Waterlogging responses of Sporobolus virginicus (L.) Kunth. *Oecologia*, *90(3),* 445-450.

Nelson, W. G. 2017. Development of an epiphyte indicator of nutrient enrichment: Threshold values for seagrass epiphyte load. *Ecological Indicators*, *74*, 343-356.

Riches, M., Gilligan, D., Danaher, K. and Pursey, J. 2016. *Fish Communities and Threatened Species Distributions of NSW*. NSW Department of Primary Industries.

Saintilan, N. 2009. *Australian saltmarsh ecology*. CSIRO publishing.

Sainty, G. 2012. *Estuary Plants and What's Happening to them in South-East Australia.* Sainty Books.

Ye, Y., Tam, N. F. Y., Lu, C. Y., & Wong, Y. S. 2005. Effects of salinity on germination, seedling growth and physiology of three salt-secreting mangrove species*. Aquatic Botany*, 83(3), 193-205.

Appendix A: Environmental tolerances

This section outlines a literature review of environmental tolerances for marine vegetation identified in the Crookhaven River and the potential impacts of urban development on these vegetation types. From this review a number of questions were formed in order to assess the impacts of the West Culburra proposed mixed use subdivision. These questions are provided in **Section 3.4** and answers are provided in **Section 4.5**.

Seagrass

Zostera marina (Ribbonweed) is a seagrass common in estuaries because of their ideal conditions for growth, such as nutrient loads, tidal flushing and calm conditions. This species generally grows on soft sediment up to depths of 4 m if adequate light is available (low turbidity). Seagrass is best adapted to seawater salinity (35 ppt) but can tolerate and grow for short periods in brackish (near fresh) or hypersaline (60 ppt) waters (Sainty et al 2012). Most seagrasses cannot withstand long periods of those extreme salinity conditions. *Halophila ovalis* (Paddleweed) is likely to occur in the estuary, and can grow in salinities between 10 to 40 ppt (Hillman et al 1995). This species has been observed to become stressed after four weeks at 10 ppt (Benjamina et al. 1999).

Seagrasses provide many functions in the ecosystem (nutrient cycling, shelter, food, etc) and also support small plants and sessile animals that grow on their leaves and stems, called epiphytes. These epiphytes are also important as a food source for other animal and for uptaking nutrients from the water. However, a higher than normal nutrient load may cause excessive growth of epiphytes, causing dense shade to the leaf they are attached to. Seagrasses are more tolerant to shading in winter than in summer or spring. But, once the shading kills the seagrass leaf, it detaches and decomposes on the sea floor. This decomposition causes an increase in aerobic bacteria, and hence oxygen use. Consequently, when oxygen is depleted, anaerobic bacteria (bacteria that do not require oxygen) take over and kill other benthic animals as the bottom becomes bare with a thick black anaerobic layer containing hydrogen sulphide (Sainty et al. 2012; Lee et al. 2007; Nelson 2017). We have observed this black ooze in other estuaries at stormwater channel outlets, large near-shore areas and where seagrass wrack has sunken if steep banks prevent it from being washed ashore (e.g. Tuggerah Lakes). Excessive leaf litter discharged from the catchment can also cause anoxic conditions, especially if deciduous street trees release a large volume of leaves over a short period.

Impacts to seagrass as a result of urbanisation are commonly attributed to erosion and siltation (smothering beds or causing turbid water), and high nutrient concentrations causing excessive epiphyte growth (especially inorganic nitrogen – sum of nitrate and ammonia). The Simple Estuarine Response Model (CSIRO 2002 - http://www.per.marine.csiro.au/serm/indicators.htm) uses 22 indicators that reflect the state of an estuary. Those indicators relevant to this assessment are shown in **Table 3**.

In an unrelated study in tropical water, Doorn-Groen & Foster (2007) developed impact guidelines based on concentration and duration of suspended sediment and sedimentation in high background environments (i.e. those already with high sediment) (**Table 4**). We have not found similar threshold guidelines for temperate seagrass.

Seagrass requires specific depth and light conditions to survive. *Zostera marina* is tolerant of a range of environmental conditions, but may become stressed under prolonged changes (e.g. weeks at very low salinity, turbid water, or after higher than usual nutrient loads). In regards to impacts of urban development to estuary seagrass, the most foreseeable issues are related to turbidity (suspended solids), polluted water, freshwater inflows and high nutrient concentrations. If development does not increase turbidity, sedimentation and nutrients for extended periods of time, then seagrass quantity and quality within should be retained.

Table 3: Six of the twenty two indicators that define the state of an estuary (CSIRO 2002)

Limits	Dissolved inorganic nitrogen (mg/m³)	Dissolved inorganic phosphorus (mg/m³)	Total nitrogen (mg/m³)	Total phosphorus (mg/m³)	Total suspended solids (g/m³)	Salinity (PSU)
Very Low	1-30	3-10	100-200	10-30	0.1-0.5	0-10
Low	30-60	10-20	200-400	30-60	-	10-20
Moderate	60-180	20-60	400-1200	60-180	0.5-10	20-30
High	180-3000	60-1000	1200-3000	180-1000	10-100	30-40

Table 4: Sediment thresholds used in a tropical seagrass monitoring study (Doorn-Groen & Foster 2007)

Table III. Impact severity matrix for suspended sediment impact on Seagrass in high background environments

Severity	Definition (excess concentrations)
No Impact	Excess Suspended Sediment Concentration > 5 mg/l for less than 20% of the time
Slight Impact	Excess Suspended Sediment Concentration > 5 mg/l for more than 20% of the time Excess Suspended Sediment Concentration > 10 mg/l for less than 20% of the time
Minor Impact	Excess Suspended Sediment Concentration > 25 mg/l for less than 5% of the time
Moderate Impact	Excess Suspended Sediment Concentration > 25 mg/l for more than 20% of the time Excess Suspended Sediment Concentration > 75 mg/l for less than 1% of the time
Major Impact	Excess Suspended Sediment Concentration > 75mg/l for more than 20% of the time

Table IV. Impact severity matrix for sedimentation impact on Seagrass in high background environments

Severity	Definition (Excess sedimentation)
No Impact	Sedimentation < 0.1 kg/m²/day (<0.25 mm/day)
Slight Impact	Sedimentation < 0.25 kg/m²/day (<0.63 mm/day)
Minor Impact	Sedimentation < 0.5 kg/m²/day (<1.25 mm/day)
Moderate Impact	Sedimentation < 1.0 kg/m²/day (<2.5 mm/day)
Major Impact	Sedimentation > 1.0 kg/m²/day (>2.5 mm/day)

Mangroves

Avicennia marina (Grey Mangrove) is one of the most tolerant mangroves to changes (or temporary extremes) in salinity, aridity, water temperature and frost frequency (Nguyen 2015). Environmental tolerances of *A. marina* and other mangroves are documented in several articles, but with notable variance in some results (possibly due to difference in local environmental character):

- *A. marina* can withstand short periods of inundation by freshwater or hypersaline water (salinity exceeding that of seawater). However, they are susceptible to extended periods of waterlogging, with death occurring within 14 days (DAF Qld 2017).
- Mangrove seedlings were successfully established in experiments at salinities of 0, 5, 15, 25 and 35 ppt for *A. marina*, while salinities over 25 ppt significantly reduced the values of *Aegiceras corniculatum* (River Mangrove) (Ye et al. 2005).
- Growth of established *A. marina* in 0-2 ppt salinity was so poor that plants were unlikely to reach reproductive maturity; and *A. marina* seedlings failed to grow in 0-2 ppt salinity. Growth was maximal in 18-26 ppt saline water (Nguyen et al. 2015).
- *A. marina* growth was similar in freshwater and 100% seawater (35 ppt). *A. corniculatum* growth was significantly lower in 35 ppt seawater than in tap water (Burchett et al. 1989).
- Mangroves are able to withstand gradual sediment accumulation, as part of their natural dynamic state. However, acute increases in sedimentation due to natural or anthropogenic dumping of material can result in burial of pneumatophores (aerial roots), reducing their ability to supply oxygen to the root system. The most sensitive components to sedimentation impacts are seedlings and pneumatophores, as both have a relatively small vertical extent and therefore may be partially or fully buried by high sedimentation rates within a short period of time (Chevron 2010).
- Mangroves with pneumatophore root systems are only likely to be stressed when prolonged sedimentation reaches levels from 10-30 cm (Doorn-Groen & Foster 2007).
- Sedimentation impact on *A. marina* varied from stressed (5 cm sediment deposition) to death (20 cm sediment deposition), with various impacts at greater sediment depths in different locations (Chevron 2010).

In regards to sea level rise, a notable constraint to mangrove survival is whether mangrove assemblages can retreat landwards. Potential retreat is determined by numerous factors, including upslope topography (adjacent low gradient terrain required) and barriers to propagule and tidal movement (such as road batters, houses and fill).

Mangroves occupy a specific niche in the aquatic ecosystem, and are highly dependent on substrate type and grade, and intertidal movement. *A. marina* is tolerant to a range of water conditions, but is susceptible to impacts from sediment deposition and changed hydrology. *A. corniculatum* has a lower tolerance to salinity, and relies on freshwater input from the adjacent land (overland flows and groundwater).

In regards to impacts of urban development to estuary mangroves, the most foreseeable issues are related to hydrology, stormwater, contaminants and litter. If development does not alter the tidal regime or freshwater inflows, or release large volumes of sediment (and suspended solids) during construction and operation, then mangroves are unlikely to be impacted.

Saltmarsh

Saltmarsh consists of many species adapted to micro-topography in the high intertidal zone. Only those species known to occur in the study are included in this review. Environmental tolerances of *Sporobolus virginicus* (Saltwater Couch) are wide ranging, surviving between low-to-high waterlogging and low-to-high salinity (Sainty et al. 2012). The species is also tolerant of waterlogged acidic soils (Naidoo & Naidoo 1992). *Juncus kraussii* subsp. *australiensis* (Sea Rush) is also reported to tolerate low-to-high salinity levels; and waterlogging is rated as low-to-moderate/high (Sainty et al. 2012). However, the species is described in Saintalin (2009) as being able to withstand several months of continuous inundation around margins of lagoons (Adam 1981).

A shift in environmental factors may not directly harm these species (and generally other 'Low Saltmarsh' species), but may favour other wetland plants that outcompete saltmarsh. For example, increased waterlogging from sea level rise or continuous stormwater discharge may increase mangrove establishment in the saltmarsh. Also, increased depth from a constructed discharge channel, along with more regular freshwater inflows may favour brackish species such as *Phragmites australis* (Common Reed) and other reeds and rushes, including invasive species (Saintilan 2009). The resulting shift in species and physical structure can then influence local hydrology and deposition through trapping sediment and organic plant material. If saltmarsh can't establish in the new hydrology/topography and loses its competitive advantage, then the saltmarsh community may not survive.

In regards to sea level rise, a notable constraint to saltmarsh survival is whether it can retreat landwards. Potential retreat is determined by numerous factors, including upslope topography (adjacent low gradient terrain required) and barriers to propagule and tidal movement (such as road batters, houses and fill).

Saltmarsh occupies a specific niche in the aquatic ecosystem, and is the closest marine vegetation to the terrestrial interface. It is tolerant to a range of environmental conditions (salinity, waterlogging) and relies on a mix of tidal inundation and freshwater input. It is, however, susceptible to pressures from landside and waterside. In regards to impacts of urban development to estuary saltmarsh, the most foreseeable issues are related to hydrology, stormwater, contaminants, litter and weeds. If development does not alter the tidal regime of the saltmarsh, and does not intercept the current overland freshwater input, then the saltmarsh will retain its essential processes.

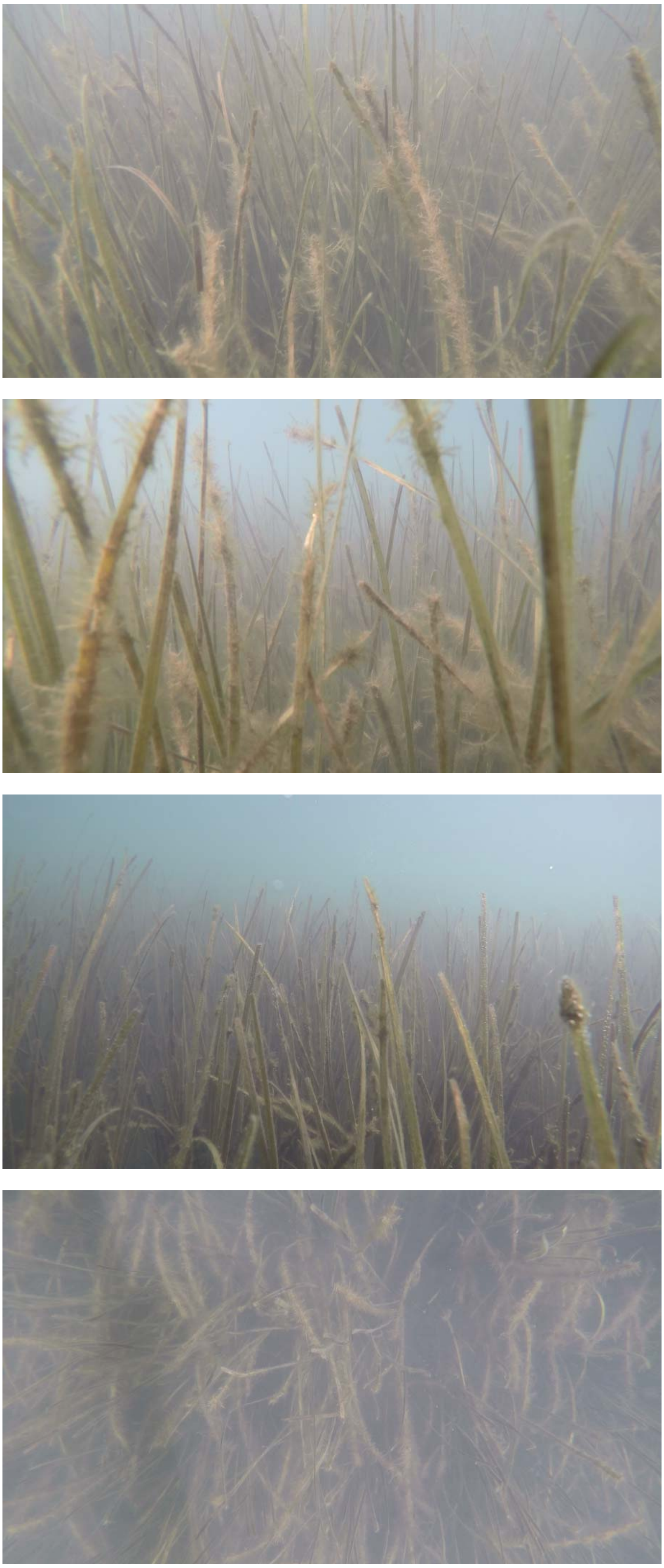
Appendix B: Water quality results

	Unit	Limit of reporting	ANZECC	Site 01	Site 02	Site 03	Site 04	Site 05	Site 06	Site 07	Site 08
Date				13/12/16	13/12/16	13/12/16	13/12/16	13/12/16	13/12/16	13/12/16	13/12/16
Time				8:46	9:25	9:43	9:58	10:29	11:08	12:26	12:36
Habitat MG = Mangrove SM = Saltmarsh SG = Seagrass				**MG**	**MG**	**SG**	**SG**	**SM**	**SG**	**SG**	**SG**
Physiochemical											
Temperature	°C			22.72	22.23	22.48	22.07	24	23.48	24.51	24.53
pH	pH		7-8.5	7.59	8.02	8.06	8.08	7.73	7.95	7.93	7.9
Oxidation reduction potential	mV			92	97	110	118	121	170	133	148
pHmV	mV			-58	-83	-85	-87	-66	-79	-78	-77
Conductivity	mS/cm			53.5	54.8	54.5	55.1	53.7	54.1	53.7	53.3
Turbidity	NTU		0.5-10	8.7	5.2	6	9.4	16.5	16.1	21.2	34.8
Dissolved Oxygen	mg/L			3.66	5.58	6.06	6.64	5.45	6.15	5.76	5.71
Dissolved Oxygen	%		80-110	53.6	81.6	88.9	96.9	81.6	91.5	87	86
TDS	g/L			32.1	32.9	32.7	33.1	32.2	32.5	32.2	32
Salinity	ppt			35.3	36.2	36	36.5	35.4	35.8	35.5	35.2
Suspended Solids											
Suspended Solids	mg/L	5		**60**	**14**	**27**	**58**	**48**	**32**	**42**	**139**
Nutrients											
Ammonia as N	mg/L	0.01	0.005	**0.20**	**0.16**	**0.17**	**0.18**	**0.22**	**0.17**	**0.16**	**0.16**
Nitrite as N	mg/L	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01		<0.01	<0.01	<0.01	<0.01	**0.04**	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	mg/L	0.01	0.005	<0.01	<0.01	<0.01	<0.01	**0.04**	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1		<0.5	<0.5	<0.5	<0.5	**0.5**	<0.5	<0.5	<0.5
Total Nitrogen as N	mg/L	0.1	0.3	<0.5	<0.5	<0.5	<0.5	**0.5**	<0.5	<0.5	<0.5
Total Phosphorus as P	mg/L	0.01	0.03	**0.07**	<0.05	<0.05	**0.14**	**0.06**	**0.12**	<0.05	**0.22**
Reactive Phosphorus as P	mg/L	0.01	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Biochemical Oxygen Demand (BOD)											
BOD	mg/L	2		**2**	<2	<2	<2	**3**	<2	<2	<2

Appendix C: Site photos

Site 01 - Mangroves

Site 02 - Mangroves

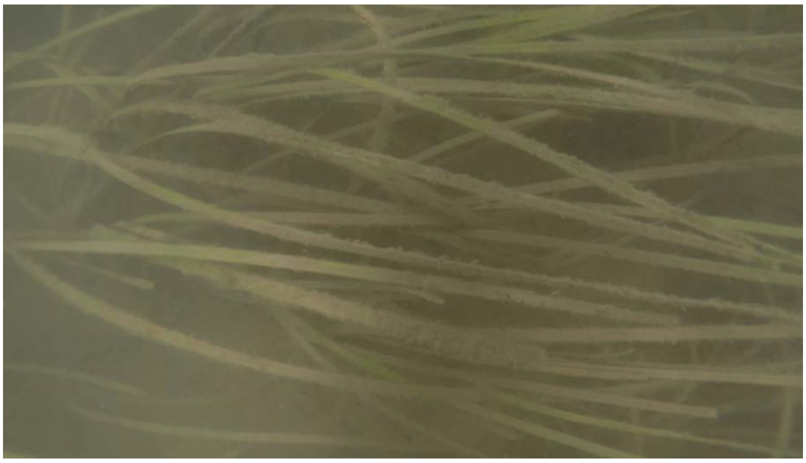


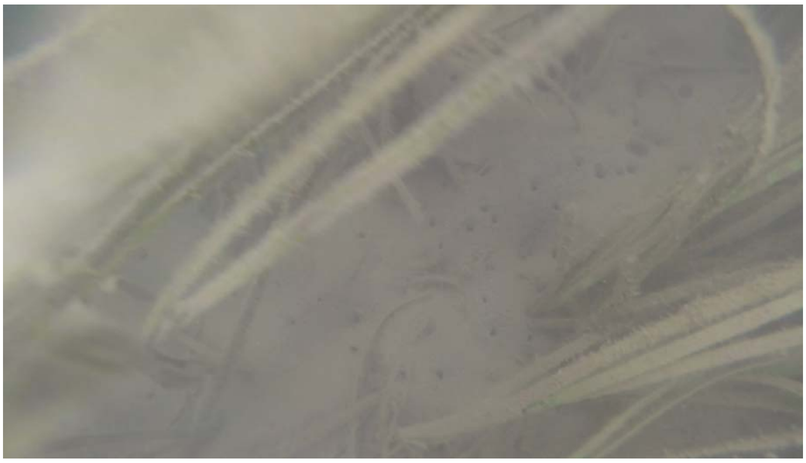
Site 03 – Seagrass

Site 04 – Seagrass

Site 05 – Saltmarsh

Site 06 – Seagrass





Site 07 – Seagrass

Site 08 – Seagrass

Appendix D: Key fish habitat types

TYPE 1 - Highly sensitive key fish habitat:	TYPE 2 – Moderately sensitive key fish habitat:
▪ *Posidonia australis* (strapweed) ▪ *Zostera, Heterozostera, Halophila and Ruppia* species of seagrass beds >$5m^2$ in area ▪ Coastal saltmarsh >$5m^2$ in area ▪ Coral communities ▪ Coastal lakes and lagoons that have a natural opening and closing regime (i.e. are not permanently open or artificially opened or are subject to one off unauthorised openings) ▪ Marine park, an aquatic reserve or intertidal protected area ▪ SEPP 14 coastal wetlands, wetlands recognised under international agreements (e.g. Ramsar, JAMBA, CAMBA, ROKAMBA wetlands), wetlands listed in the Directory of Important Wetlands of Australia[2] ▪ Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, or native aquatic plants ▪ Any known or expected protected or threatened species habitat or area of declared 'critical habitat' under the FM Act ▪ Mound springs	▪ *Zostera*, *Heterozostera, Halophila* and *Ruppia* species of seagrass beds <$5m^2$ in area ▪ Mangroves ▪ Coastal saltmarsh <$5m^2$ in area ▪ Marine macroalgae such as *Ecklonia* and *Sargassum* species ▪ Estuarine and marine rocky reefs ▪ Coastal lakes and lagoons that are permanently open or subject to artificial opening via agreed management arrangements (e.g. managed in line with an entrance management plan) ▪ Aquatic habitat within 100 m of a marine park, an aquatic reserve or intertidal protected area ▪ Stable intertidal sand/mud flats, coastal and estuarine sandy beaches with large populations of in-fauna ▪ Freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in TYPE 1 ▪ Weir pools and dams up to full supply level where the weir or dam is across a natural waterway **TYPE 3 – Minimally sensitive key fish habitat may include:** ▪ Unstable or unvegetated sand or mud substrate, coastal and estuarine sandy beaches with minimal or no in-fauna ▪ Coastal and freshwater habitats not included in TYPES 1 or 2 ▪ Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation

NSW key fish habitat types and associated sensitivity classification (from Fairfull 2013).

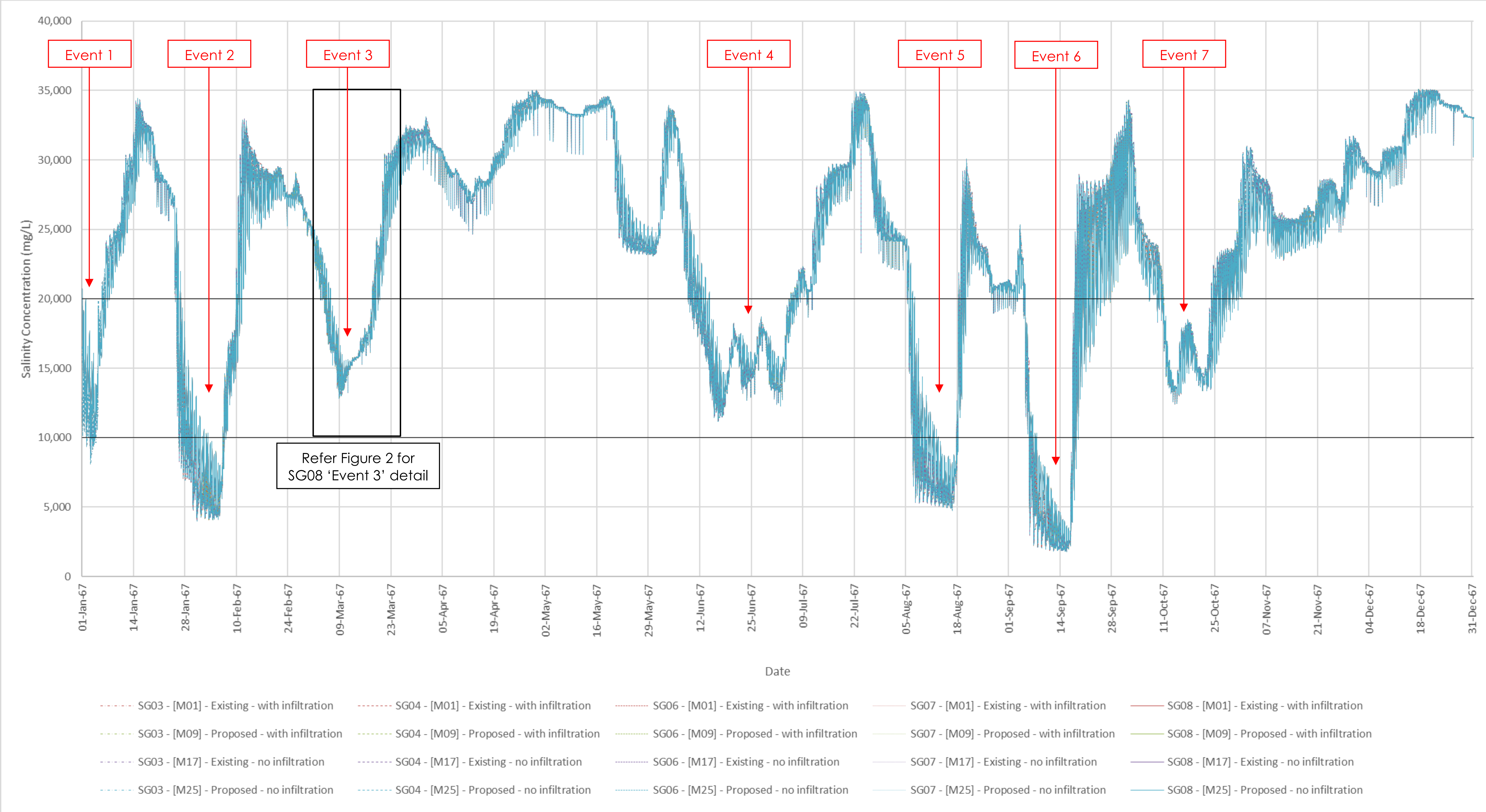
Appendix E: Threatened species likelihood of occurrence and impacts

If a species has suitable habitat present on site **AND** is likely to use this habitat **AND** the species or its habitat will be directly or indirect impacted, **THEN** an Assessment of Significance (7-part test) is required. Such species, if any, are highlighted in the table below. This list excludes terrestrial fauna, such as shorebirds and amphibians.

Species name	Common Name	FM Act Status	EPBC Act Status	Distribution overlaps	Habitat present	Species known to occur in region	Species known to occur on site	Likelihood of occurrence	Habitat on site directly or indirectly impacted	Impact Assessment Required?
Carcharias taurus	Grey Nurse Shark	E4A	CE	Yes	None	No	No	No	No	No
Carcharodon carcharias	Great White Shark	V	V, M	Yes	None	No	No	No	No	No
Epinephelus daemelii	Black Rockcod	V	V	Yes	None	No	No	No	No	No
Macquaria australasica	Macquarie Perch	E1	E	Yes	None	No	No	No	No	No
Prototroctes maraena	Australian Grayling	E1	V	Yes	None	No	No	No	No	No
Rhincodon typus	Whale Shark		V, M	Yes	None	Yes	No	No	No	No
Balaenoptera musculus	Blue Whale	E1	E, M	Yes	None	No	No	No	No	No
Caretta caretta	Loggerhead Turtle	E1	E, M	Yes	None	Yes	No	No	No	No
Chelonia mydas	Green Turtle	V	V, M	Yes	Marginal	Yes	No	Potential	No	No
Dermochelys coriacea	Leatherback Turtle	E1	E, M	Yes	Marginal	Yes	No	Potential	No	No
Eubalaena australis	Southern Right Whale	E1	E, M	Yes	None	Yes	No	No	No	No
Megaptera novaeangliae	Humpback Whale	V	V, M	Yes	None	Yes	No	No	No	No
Coastal saltmarsh	Saltmarsh	E1 (TSC)	V	Yes	Yes	Yes	Yes	Present	No	No

TSC Act: E1 = Endangered, E2 = Endangered Population, E4 = Extinct, E4A = Critically Endangered, V = Vulnerable
FM Act: E1 = Endangered, E2 = Endangered Population, E4 = Extinct, E4A = Critically Endangered, V = Vulnerable
EPBC Act: Bonn = Listed migratory species under Bonn Convention, CD = Conservation Dependent, CE = Critically Endangered, E = Endangered, V = Vulnerable, X = Extinct

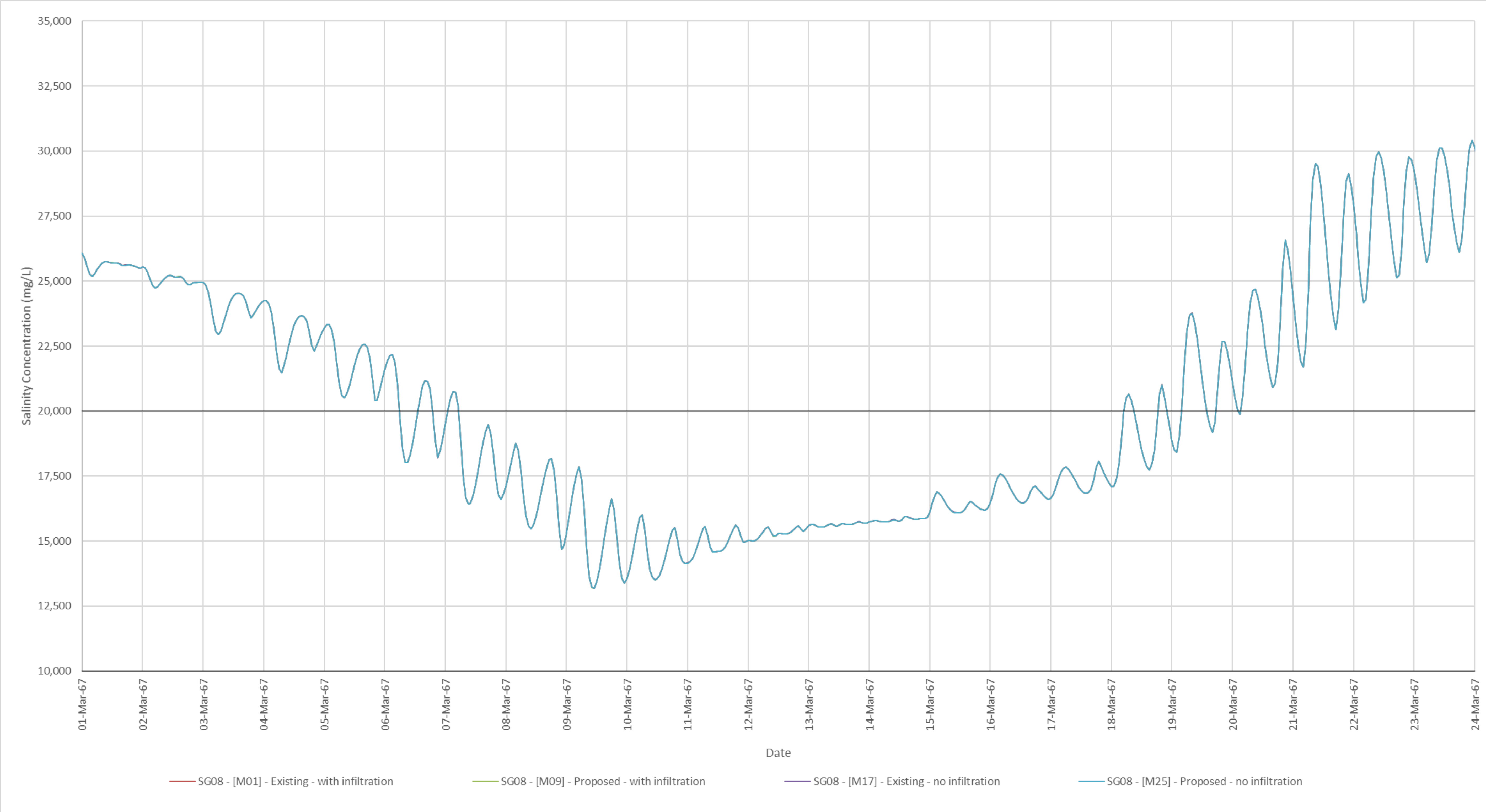
Appendix F: Modelled results



Notes

1. All results shown are for the 'average' year (1967) using calibrated (D1) dispersion coefficients.
2. The 4 models used for this assessment use parameters for existing / proposed conditions and with / without infiltration. Each model is displayed with the same colour.
3. Each Eco Logical seagrass sample point (SG03-SG08) is displayed with the same style.
4. 'Events' are defined by salinity concentrations falling below 20,000 mg/L.

Martens & Associates Pty Ltd	ABN 85 070 240 890	**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**MODELLED SALINITY CONCENTRATIONS VS TIME AT ECO LOGICAL SEAGRASS SAMPLE POINTS OVER FULL SIMULATION PERIOD**	Drawing No: **FIGURE 1**
Approved:	AN		
Date:	02.03.2017		
Scale:	NA		Job No: P1203365



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Notes

1. All results shown are for the 'average' year (1967) using calibrated (D1) dispersion coefficients.
2. The 4 models used for this assessment use parameters for existing / proposed conditions and with / without infiltration.
3. Only the Eco Logical seagrass sample point SG08 is displayed in this figure.
4. 'Events' are defined by salinity concentrations falling below 20,000 mg/L.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**MODELLED SALINITY CONCENTRATIONS VS TIME AT ECO LOGICAL SEAGRASS SAMPLE POINT 08 OVER 'EVENT 3'**	Drawing No: **FIGURE 2**
Approved:	AN		
Date:	02.03.2017		
Scale:	NA		Job No: P1203365

Table 1: Modelled durations (days) for salinity falling below 20 g/L and 10 g/L at Eco Logical seagrass sample points.

		Threshold											
		Salinity Concentration < 20 g/L						Salinity Concentration < 10 g/L					
		Scenario [1]											
		With Infiltration			Without Infiltration			With Infiltration			Without Infiltration		
		Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
		[M01]	[M09]	[M09] – [M01]	[M17]	[M25]	[M17] – [M25]	[M01]	[M09]	[M09] – [M01]	[M17]	[M25]	[M17] – [M25]
Event [2]	**Date**	**Duration (days) [3]**											
1	Jan 1967	6.1	6.1	0.0	6.1	6.1	0.0	1.6	1.6	0.0	1.6	1.6	0.0
2	Feb 1967	16.0	16.0	0.0	16.0	16.0	0.0	11.3	11.3	0.0	11.3	11.3	0.0
3	Mar 1967	13.4	13.4	0.0	13.4	13.4	0.0	– [4]	– [4]	– [4]	– [4]	– [4]	– [4]
4	Jun 1967	28.0	28.0	0.0	28.0	28.0	0.0	– [4]	– [4]	– [4]	– [4]	– [4]	– [4]
5	Aug 1967	14.5	14.5	0.0	14.5	14.5	0.0	11.9	11.9	0.0	11.9	11.9	0.0
6	Sep 1967	16.5	16.5	0.0	16.5	16.5	0.0	12.4	12.4	0.0	12.4	12.4	0.0
7	Oct 1967	15.3	15.3	0.0	15.3	15.3	0.0	– [4]	– [4]	– [4]	– [4]	– [4]	– [4]
	Total	109.8	109.8		109.8	109.8		37.2	37.2		37.2	37.2	

Notes

1. The 4 models used for this assessment use parameters for existing / proposed conditions and with / without infiltration. All 4 models are for the 'average' year (1967) using calibrated (D1) dispersion coefficients.
2. 'Events' are defined by salinity concentrations falling below 20 g/L and are displayed in Figure 2.
3. Approximate average duration for all Eco Logical seagrass sample points having a modelled concentration below 20 g/L and 10 g/L.
4. Salinity concentrations do not fall below 10 g/L for these 'events'.

Table 3: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – average year (1967), with infiltration, using D1 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M01] Existing Conditions	Median	26489	25760	26036	25199	25092	0.272	0.274	0.272	0.279	0.281	0.026	0.027	0.026	0.028	0.028	25.0	25.1	25.1	25.3	25.3
	Mean	24038	23846	23865	23618	23559	0.277	0.290	0.277	0.309	0.314	0.027	0.030	0.028	0.034	0.035	25.2	25.6	25.1	26.2	26.3
	90th Percentile [3]	10344	11311	10946	12533	12789	0.288	0.316	0.291	0.380	0.395	0.030	0.035	0.031	0.048	0.051	25.4	26.2	25.6	27.5	27.9
Model Summary (mg/L)	95th Percentile [3]	5387	5951	5495	7491	7756	0.301	0.376	0.308	0.482	0.508	0.033	0.048	0.035	0.071	0.078	25.9	27.9	26.1	31.0	31.8
	99th Percentile [3]	2317	2480	2238	3294	3491	0.347	0.535	0.380	0.710	0.751	0.044	0.093	0.052	0.137	0.148	28.0	35.4	29.5	42.6	44.0
[M09] Proposed Conditions	Median	26488	25760	26033	25197	25090	0.272	0.274	0.272	0.279	0.281	0.026	0.027	0.026	0.028	0.028	25.0	25.1	25.1	25.3	25.3
	Mean	24034	23846	23861	23618	23559	0.277	0.290	0.277	0.309	0.314	0.027	0.030	0.028	0.034	0.035	25.2	25.6	25.1	26.2	26.3
	90th Percentile [3]	10343	11312	10946	12534	12771	0.288	0.316	0.291	0.380	0.395	0.030	0.035	0.031	0.048	0.051	25.4	26.2	25.6	27.5	27.9
Model Summary (mg/L)	95th Percentile [3]	5382	5954	5482	7494	7758	0.300	0.376	0.308	0.482	0.507	0.033	0.048	0.035	0.071	0.078	25.9	27.9	26.1	31.0	31.8
	99th Percentile [3]	2319	2477	2237	3294	3491	0.344	0.536	0.380	0.711	0.751	0.044	0.093	0.052	0.138	0.148	27.9	35.4	29.5	42.6	44.0
Change from Existing [M01] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	-0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	95th Percentile [3]	-0.1%	0.0%	-0.2%	0.0%	0.0%	-0.1%	0.0%	0.1%	0.0%	-0.2%	0.0%	-0.3%	0.0%	0.1%	-0.2%	0.0%	0.0%	0.0%	-0.1%	-0.1%
	99th Percentile [3]	0.1%	-0.1%	-0.1%	0.0%	0.0%	-0.9%	0.2%	0.1%	0.1%	0.0%	-0.2%	0.0%	0.2%	0.2%	0.1%	-0.3%	0.0%	-0.1%	0.2%	0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 4: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – average year (1967), with infiltration, using D2 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M02] Existing Conditions	Median	26205	25348	25679	24315	24103	0.273	0.276	0.274	0.288	0.291	0.027	0.028	0.027	0.031	0.032	25.2	25.3	25.2	26.1	26.3
	Mean	23987	23632	23767	23055	22921	0.283	0.308	0.288	0.354	0.364	0.029	0.034	0.030	0.045	0.047	25.4	26.3	25.5	27.9	28.2
Model Summary (mg/L)	90th Percentile [3]	11113	11556	11657	12388	12391	0.307	0.372	0.323	0.536	0.569	0.034	0.047	0.037	0.081	0.088	26.1	27.8	26.4	31.8	32.8
	95th Percentile [3]	5985	6813	6254	9371	9701	0.328	0.487	0.354	0.727	0.776	0.040	0.072	0.046	0.129	0.140	27.0	31.5	27.8	39.6	41.3
	99th Percentile [3]	2739	2752	2599	4515	4910	0.393	0.727	0.468	0.982	1.034	0.053	0.137	0.073	0.207	0.222	29.6	42.9	33.0	53.7	56.0
[M10] Proposed Conditions	Median	26189	25346	25671	24316	24106	0.274	0.277	0.274	0.288	0.291	0.027	0.028	0.027	0.031	0.032	25.2	25.3	25.2	26.1	26.3
	Mean	23981	23631	23759	23055	22922	0.283	0.308	0.287	0.354	0.364	0.029	0.034	0.030	0.045	0.047	25.4	26.3	25.5	27.9	28.2
Model Summary (mg/L)	90th Percentile [3]	11180	11565	11647	12388	12395	0.307	0.372	0.323	0.534	0.568	0.034	0.047	0.037	0.080	0.088	26.1	27.8	26.4	31.7	32.8
	95th Percentile [3]	6016	6815	6239	9367	9710	0.328	0.486	0.354	0.726	0.774	0.039	0.072	0.046	0.129	0.140	26.9	31.4	27.8	39.6	41.3
	99th Percentile [3]	2751	2751	2597	4513	4912	0.384	0.725	0.468	0.982	1.033	0.052	0.137	0.073	0.207	0.222	29.5	42.8	33.0	53.7	56.1
Change from Existing [M02] (%)	Median	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.6%	0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.4%	-0.1%	-0.1%	-0.1%	0.0%	-0.6%	-0.2%	-0.1%	0.0%	0.0%	-0.1%	-0.1%
	95th Percentile [3]	0.5%	0.0%	-0.2%	0.0%	0.1%	-0.1%	-0.2%	-0.2%	-0.1%	-0.2%	-0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%
	99th Percentile [3]	0.4%	0.0%	-0.1%	0.0%	0.0%	-2.3%	-0.3%	-0.1%	0.0%	-0.2%	-1.1%	0.0%	-0.2%	0.2%	0.3%	-0.6%	-0.1%	0.0%	0.0%	0.0%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 5: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – <u>average</u> year (1967), <u>with</u> infiltration, using <u>D3</u> dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M03] Existing Conditions	Median	26591	26435	26197	26211	26180	0.271	0.271	0.271	0.273	0.273	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	24040	24003	23891	23963	23952	0.274	0.276	0.272	0.281	0.282	0.027	0.027	0.027	0.028	0.029	25.1	25.2	25.0	25.3	25.4
	90th Percentile [3]	10211	10510	10144	11398	11399	0.276	0.280	0.275	0.287	0.289	0.027	0.027	0.027	0.029	0.029	25.1	25.2	25.1	25.3	25.4
Model Summary (mg/L)	95th Percentile [3]	5071	5148	5055	5558	5662	0.282	0.289	0.280	0.304	0.307	0.029	0.030	0.028	0.033	0.034	25.3	25.5	25.3	25.9	26.0
	99th Percentile [3]	1961	2074	1942	2283	2336	0.334	0.378	0.334	0.459	0.479	0.044	0.055	0.044	0.078	0.084	27.7	29.5	27.7	32.9	33.9
[M11] Proposed Conditions	Median	26593	26434	26195	26212	26182	0.271	0.271	0.271	0.273	0.273	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	24040	24003	23891	23964	23953	0.274	0.276	0.272	0.281	0.282	0.027	0.027	0.027	0.028	0.029	25.1	25.2	25.0	25.3	25.4
	90th Percentile [3]	10211	10511	10144	11405	11400	0.276	0.280	0.275	0.287	0.289	0.027	0.027	0.027	0.029	0.029	25.1	25.2	25.1	25.3	25.4
Model Summary (mg/L)	95th Percentile [3]	5071	5148	5055	5560	5667	0.282	0.288	0.280	0.303	0.307	0.028	0.030	0.028	0.033	0.034	25.3	25.5	25.3	25.9	26.0
	99th Percentile [3]	1974	2076	1943	2291	2343	0.334	0.378	0.333	0.459	0.478	0.044	0.055	0.044	0.078	0.084	27.7	29.4	27.7	32.8	33.9
Change from Existing [M03] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	95th Percentile [3]	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	-0.1%	-0.1%	0.0%	-0.1%	0.0%	-0.1%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
	99th Percentile [3]	0.7%	0.1%	0.0%	0.4%	0.3%	0.0%	-0.1%	-0.1%	-0.1%	-0.3%	0.0%	-0.3%	-0.1%	-0.2%	-0.2%	0.0%	-0.1%	0.0%	-0.1%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 6: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – dry year (1968), with infiltration, using D1 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M04] Existing Conditions	Median	29048	28973	28815	28782	28761	0.270	0.271	0.270	0.272	0.272	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.0	25.1
	Mean	26471	26481	26352	26518	26526	0.271	0.272	0.270	0.274	0.274	0.026	0.026	0.026	0.027	0.027	25.0	25.1	24.9	25.1	25.1
	90th Percentile [3]	13861	14068	13895	14831	15023	0.272	0.275	0.272	0.280	0.282	0.026	0.027	0.026	0.028	0.028	25.1	25.1	25.1	25.3	25.3
Model Summary (mg/L)	95th Percentile [3]	11462	11829	11589	12434	12607	0.273	0.278	0.273	0.286	0.288	0.026	0.027	0.026	0.028	0.029	25.1	25.2	25.1	25.5	25.5
	99th Percentile [3]	3723	4341	3917	5684	5992	0.276	0.287	0.278	0.299	0.302	0.027	0.029	0.027	0.031	0.032	25.3	25.7	25.4	26.3	26.5
[M12] Proposed Conditions	Median	29048	28973	28817	28782	28762	0.270	0.271	0.270	0.272	0.272	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	26470	26481	26351	26519	26526	0.271	0.272	0.270	0.274	0.274	0.026	0.026	0.026	0.027	0.027	25.0	25.1	24.9	25.1	25.1
	90th Percentile [3]	13861	14066	13895	14832	15024	0.272	0.275	0.272	0.280	0.282	0.026	0.027	0.026	0.027	0.028	25.1	25.1	25.1	25.3	25.3
Model Summary (mg/L)	95th Percentile [3]	11462	11829	11589	12434	12605	0.273	0.278	0.273	0.286	0.288	0.026	0.027	0.026	0.028	0.029	25.1	25.2	25.1	25.5	25.5
	99th Percentile [3]	3720	4342	3915	5687	5992	0.276	0.287	0.278	0.299	0.302	0.027	0.029	0.027	0.031	0.032	25.3	25.7	25.4	26.3	26.5
Change from Existing [M04] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	95th Percentile [3]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	99th Percentile [3]	-0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 7: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – wet year (1969), with infiltration, using D1 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M05] Existing Conditions	Median	20801	20610	20678	20167	20091	0.277	0.286	0.278	0.312	0.318	0.027	0.028	0.027	0.032	0.033	25.1	25.3	25.2	25.9	26.0
	Mean	19629	19245	19382	18716	18586	0.283	0.310	0.284	0.349	0.359	0.028	0.032	0.028	0.038	0.040	25.4	26.1	25.3	27.1	27.3
Model Summary (mg/L)	90th Percentile [3]	3298	3739	3371	4869	5158	0.303	0.382	0.310	0.478	0.499	0.031	0.043	0.032	0.059	0.062	26.0	28.0	26.1	30.7	31.4
	95th Percentile [3]	1968	2343	2084	2966	3093	0.317	0.431	0.324	0.549	0.576	0.034	0.051	0.035	0.070	0.075	26.5	29.7	26.8	33.7	34.5
	99th Percentile [3]	947	1386	1009	1884	1982	0.344	0.543	0.362	0.696	0.732	0.039	0.070	0.041	0.095	0.102	28.0	33.7	28.7	39.1	40.2
[M13] Proposed Conditions	Median	20793	20610	20678	20168	20091	0.277	0.286	0.278	0.311	0.318	0.027	0.028	0.027	0.032	0.033	25.1	25.3	25.2	25.9	26.0
	Mean	19623	19245	19379	18717	18588	0.283	0.310	0.284	0.349	0.359	0.028	0.032	0.028	0.038	0.040	25.4	26.1	25.3	27.1	27.3
Model Summary (mg/L)	90th Percentile [3]	3297	3740	3377	4871	5160	0.303	0.382	0.309	0.477	0.497	0.031	0.043	0.032	0.058	0.062	26.0	27.9	26.1	30.7	31.4
	95th Percentile [3]	1974	2347	2084	2973	3099	0.316	0.431	0.324	0.549	0.576	0.034	0.051	0.035	0.070	0.074	26.5	29.7	26.7	33.6	34.5
	99th Percentile [3]	946	1386	1008	1886	1981	0.343	0.542	0.362	0.697	0.731	0.039	0.070	0.041	0.095	0.102	28.0	33.7	28.7	39.1	40.2
Change from Existing [M05] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	0.0%	-0.1%	0.0%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.2%	-0.2%	-0.1%	-0.2%	-0.1%	-0.2%	-0.1%	-0.1%	-0.1%	0.0%	-0.1%	0.0%
	95th Percentile [3]	0.3%	0.1%	0.0%	0.2%	0.2%	-0.2%	-0.1%	-0.1%	-0.1%	-0.1%	-0.2%	-0.1%	-0.2%	-0.2%	-0.4%	0.0%	0.0%	-0.1%	-0.2%	-0.1%
	99th Percentile [3]	-0.1%	0.0%	-0.1%	0.1%	0.0%	-0.2%	-0.1%	-0.1%	0.0%	-0.1%	-0.5%	-0.1%	-0.2%	0.0%	0.1%	-0.1%	0.0%	-0.1%	-0.1%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 8: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – local wet month (20 Oct – 20 Nov 1969), with infiltration, using D1 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	Statistic	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08
[M06] Existing Conditions	Median	28043	28010	28007	27900	27878	0.272	0.274	0.272	0.279	0.280	0.026	0.026	0.026	0.027	0.027	25.0	25.1	25.0	25.1	25.1
	Mean	27964	27972	27688	27885	27866	0.273	0.276	0.273	0.279	0.280	0.026	0.027	0.026	0.027	0.027	25.1	25.2	25.1	25.2	25.2
	90^{th} Percentile [3]	27775	27784	25674	27694	27671	0.278	0.283	0.285	0.287	0.289	0.027	0.028	0.028	0.028	0.028	25.4	25.6	25.9	25.6	25.7
Model Summary (mg/L)	95^{th} Percentile [3]	27580	27710	25603	27634	27605	0.281	0.285	0.289	0.290	0.292	0.027	0.028	0.029	0.028	0.028	25.6	25.8	26.5	25.8	25.8
	99^{th} Percentile [3]	27107	27586	25359	27522	27501	0.285	0.292	0.303	0.295	0.295	0.028	0.029	0.030	0.029	0.029	25.8	26.3	27.4	25.9	25.9
[M14] Proposed Conditions	Median	28030	28011	27991	27904	27882	0.272	0.274	0.272	0.279	0.280	0.026	0.026	0.026	0.027	0.027	25.0	25.1	25.0	25.1	25.1
	Mean	27982	27971	27678	27881	27863	0.273	0.276	0.273	0.279	0.280	0.026	0.027	0.026	0.027	0.027	25.1	25.2	25.0	25.2	25.2
	90^{th} Percentile [3]	27832	27793	25674	27691	27666	0.277	0.283	0.284	0.287	0.289	0.027	0.028	0.028	0.028	0.028	25.4	25.5	25.9	25.6	25.6
Model Summary (mg/L)	95^{th} Percentile [3]	27703	27713	25583	27599	27581	0.279	0.285	0.289	0.290	0.292	0.027	0.028	0.029	0.028	0.028	25.5	25.8	26.4	25.8	25.8
	99^{th} Percentile [3]	27408	27581	25320	27471	27472	0.282	0.292	0.302	0.294	0.295	0.028	0.029	0.030	0.029	0.029	25.7	26.2	27.3	25.9	25.9
	Median	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Change from Existing [M06] (%)	Mean	0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%
	90^{th} Percentile [3]	0.2%	0.0%	0.0%	0.0%	0.0%	-0.4%	0.0%	-0.1%	-0.1%	0.0%	-0.2%	-0.1%	0.0%	-0.2%	-0.1%	-0.2%	-0.1%	-0.1%	-0.1%	-0.1%
	95^{th} Percentile [3]	0.4%	0.0%	-0.1%	-0.1%	-0.1%	-0.5%	0.0%	0.0%	0.0%	0.0%	-0.3%	-0.2%	0.0%	-0.1%	-0.1%	-0.3%	-0.1%	-0.1%	-0.1%	-0.1%
	99^{th} Percentile [3]	1.1%	0.0%	-0.2%	-0.2%	-0.1%	-1.0%	-0.1%	-0.2%	-0.1%	0.0%	-1.3%	-0.3%	-0.1%	-0.2%	-0.1%	-0.2%	-0.1%	-0.1%	-0.1%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90^{th}, 95^{th} and 99^{th} percentile values are given for TN, TP and TSS. For salinity the 10^{th}, 5^{th} and 1^{st} percentile values are given (respectively) to assess the impact of freshening.

Table 9: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – local wet month (20 Oct – 20 Nov 1969), with infiltration, using D2 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	Statistic	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08
[M07] Existing Conditions	Median	27956	28034	27941	27937	27909	0.272	0.273	0.273	0.280	0.281	0.026	0.026	0.026	0.027	0.027	25.0	25.0	25.0	25.1	25.1
	Mean	27802	27951	27546	27865	27851	0.274	0.276	0.276	0.280	0.281	0.026	0.027	0.027	0.027	0.027	25.1	25.2	25.2	25.3	25.3
Model Summary (mg/L)	90th Percentile [3]	27380	27661	25683	27551	27541	0.282	0.284	0.296	0.290	0.291	0.028	0.028	0.029	0.028	0.028	25.6	25.6	26.4	25.7	25.7
	95th Percentile [3]	27010	27531	25457	27465	27477	0.287	0.290	0.305	0.293	0.294	0.028	0.028	0.031	0.029	0.029	25.8	25.9	27.3	26.0	26.0
	99th Percentile [3]	26130	27275	24926	27300	27338	0.293	0.301	0.322	0.295	0.296	0.029	0.030	0.033	0.029	0.029	26.0	26.9	28.7	26.4	26.3
[M15] Proposed Conditions	Median	27891	28031	27914	27926	27896	0.272	0.273	0.273	0.280	0.281	0.026	0.026	0.026	0.027	0.027	25.0	25.0	25.0	25.1	25.1
	Mean	27823	27944	27506	27838	27831	0.274	0.276	0.276	0.280	0.281	0.026	0.026	0.027	0.027	0.027	25.0	25.2	25.2	25.2	25.2
Model Summary (mg/L)	90th Percentile [3]	27467	27626	25678	27503	27506	0.281	0.284	0.295	0.290	0.291	0.027	0.028	0.029	0.028	0.028	25.4	25.5	26.3	25.6	25.6
	95th Percentile [3]	27172	27520	25429	27436	27453	0.283	0.290	0.304	0.293	0.294	0.028	0.028	0.031	0.029	0.029	25.6	25.9	27.3	26.0	26.0
	99th Percentile [3]	26669	27225	24775	27058	27335	0.285	0.301	0.321	0.295	0.296	0.028	0.030	0.033	0.029	0.029	25.9	26.8	28.7	26.3	26.3
Change from Existing [M07] (%)	Median	-0.2%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.1%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%
	Mean	0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	-0.1%	-0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%	-0.2%	-0.1%
	90th Percentile [3]	0.3%	-0.1%	0.0%	-0.2%	-0.1%	-0.5%	-0.1%	-0.2%	-0.1%	-0.1%	-0.7%	-0.2%	-0.2%	-0.5%	-0.4%	-0.8%	-0.2%	-0.3%	-0.3%	-0.2%
	95th Percentile [3]	0.6%	0.0%	-0.1%	-0.1%	-0.1%	-1.2%	-0.2%	-0.4%	0.0%	-0.1%	-1.3%	-0.1%	-0.3%	-0.7%	-0.6%	-0.5%	-0.3%	-0.1%	-0.2%	-0.3%
	99th Percentile [3]	2.1%	-0.2%	-0.6%	-0.9%	0.0%	-2.6%	-0.1%	-0.3%	0.0%	-0.1%	-1.8%	-0.3%	-0.5%	-0.6%	-0.7%	-0.4%	-0.4%	-0.2%	-0.3%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 10: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – local wet month (20 Oct – 20 Nov 1969), with infiltration, using D3 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	Statistic	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08	SG03	SG04	SG06	SG07	SG08
[M08] Existing Conditions	Median	28052	28044	28043	28012	28004	0.272	0.272	0.272	0.274	0.274	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	28038	28017	27771	27973	27962	0.272	0.274	0.271	0.275	0.276	0.026	0.026	0.026	0.027	0.027	25.1	25.1	24.9	25.1	25.1
Model Summary (mg/L)	90th Percentile [3]	27976	27906	25664	27812	27785	0.275	0.279	0.277	0.283	0.284	0.027	0.027	0.027	0.027	0.027	25.3	25.3	25.4	25.3	25.3
	95th Percentile [3]	27927	27850	25629	27735	27705	0.277	0.282	0.279	0.287	0.288	0.027	0.027	0.027	0.028	0.028	25.5	25.5	25.7	25.5	25.5
	99th Percentile [3]	27787	27752	25592	27592	27546	0.283	0.288	0.291	0.292	0.294	0.028	0.028	0.029	0.028	0.028	25.7	25.9	26.5	25.7	25.6
[M16] Proposed Conditions	Median	28053	28044	28042	28012	28004	0.272	0.272	0.272	0.274	0.274	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	28042	28017	27770	27972	27962	0.272	0.274	0.271	0.275	0.276	0.026	0.026	0.026	0.027	0.027	25.1	25.1	24.9	25.1	25.1
Model Summary (mg/L)	90th Percentile [3]	27992	27901	25666	27805	27783	0.275	0.279	0.276	0.283	0.284	0.027	0.027	0.027	0.027	0.027	25.2	25.3	25.4	25.3	25.3
	95th Percentile [3]	27941	27854	25629	27722	27705	0.277	0.282	0.279	0.287	0.288	0.027	0.027	0.027	0.028	0.028	25.5	25.5	25.7	25.5	25.5
	99th Percentile [3]	27829	27739	25591	27591	27545	0.282	0.287	0.290	0.292	0.294	0.028	0.028	0.029	0.028	0.028	25.7	25.9	26.5	25.7	25.6
Change from Existing [M08] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	0.0%	-0.1%	-0.1%
	95th Percentile [3]	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.0%	-0.2%	-0.1%	-0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
	99th Percentile [3]	0.2%	0.0%	0.0%	0.0%	0.0%	-0.2%	-0.1%	-0.2%	0.0%	0.0%	-0.2%	-0.2%	-0.2%	-0.2%	0.0%	-0.3%	-0.1%	-0.1%	-0.1%	0.0%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 11: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – average year (1967), without infiltration, using D1 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M17] Existing Conditions	Median	26490	25762	26038	25199	25094	0.272	0.274	0.272	0.279	0.281	0.026	0.027	0.026	0.028	0.028	25.0	25.1	25.1	25.3	25.3
	Mean	24039	23847	23866	23618	23559	0.277	0.290	0.277	0.309	0.314	0.027	0.030	0.028	0.034	0.035	25.2	25.6	25.1	26.2	26.3
	90th Percentile [3]	10344	11311	10946	12535	12770	0.288	0.316	0.291	0.380	0.395	0.030	0.035	0.031	0.048	0.051	25.4	26.2	25.6	27.5	27.9
Model Summary (mg/L)	95th Percentile [3]	5389	5950	5493	7490	7758	0.301	0.376	0.308	0.482	0.509	0.033	0.048	0.035	0.071	0.078	25.9	27.9	26.1	31.1	31.8
	99th Percentile [3]	2320	2478	2237	3291	3489	0.348	0.537	0.380	0.712	0.752	0.044	0.093	0.052	0.138	0.149	28.0	35.4	29.6	42.7	44.1
[M25] Proposed Conditions	Median	26486	25760	26034	25196	25086	0.272	0.274	0.272	0.279	0.281	0.026	0.027	0.026	0.028	0.028	25.0	25.1	25.1	25.3	25.3
	Mean	24034	23846	23861	23618	23559	0.277	0.290	0.277	0.309	0.314	0.027	0.030	0.028	0.034	0.035	25.2	25.6	25.1	26.2	26.3
	90th Percentile [3]	10343	11311	10946	12534	12761	0.288	0.316	0.291	0.380	0.395	0.030	0.035	0.031	0.048	0.051	25.4	26.2	25.6	27.5	27.9
Model Summary (mg/L)	95th Percentile [3]	5376	5953	5484	7490	7759	0.301	0.376	0.309	0.482	0.507	0.033	0.048	0.035	0.071	0.078	25.9	27.9	26.1	31.0	31.8
	99th Percentile [3]	2320	2477	2236	3293	3492	0.344	0.536	0.380	0.711	0.750	0.044	0.093	0.052	0.137	0.148	27.9	35.3	29.5	42.5	43.9
Change from Existing [M17] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	-0.1%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
	95th Percentile [3]	-0.2%	0.1%	-0.2%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	-0.3%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	-0.1%	-0.1%	0.0%
	99th Percentile [3]	0.0%	0.0%	0.0%	0.1%	0.1%	-1.3%	-0.2%	0.0%	-0.2%	-0.3%	-0.6%	-0.5%	-0.2%	-0.5%	-0.4%	-0.3%	-0.3%	-0.2%	-0.4%	-0.3%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 12: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – average year (1967), without infiltration, using D2 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M18] Existing Conditions	Median	26202	25348	25682	24316	24116	0.274	0.277	0.274	0.288	0.291	0.027	0.028	0.027	0.031	0.032	25.2	25.3	25.2	26.1	26.3
	Mean	23990	23632	23769	23055	22921	0.283	0.308	0.288	0.354	0.364	0.029	0.034	0.030	0.045	0.047	25.5	26.3	25.5	27.9	28.2
	90th Percentile [3]	11182	11564	11659	12380	12387	0.308	0.372	0.323	0.535	0.569	0.034	0.047	0.037	0.080	0.088	26.1	27.8	26.4	31.8	32.8
Model Summary (mg/L)	95th Percentile [3]	6013	6807	6255	9362	9696	0.328	0.486	0.355	0.727	0.775	0.040	0.073	0.046	0.129	0.140	27.0	31.5	27.8	39.6	41.4
	99th Percentile [3]	2758	2757	2601	4514	4903	0.396	0.726	0.470	0.983	1.035	0.053	0.138	0.073	0.207	0.222	29.7	43.0	33.1	53.7	56.1
[M26] Proposed Conditions	Median	26194	25347	25667	24320	24110	0.274	0.277	0.274	0.288	0.291	0.027	0.028	0.027	0.031	0.032	25.2	25.3	25.2	26.1	26.3
	Mean	23981	23631	23759	23055	22921	0.284	0.308	0.288	0.354	0.364	0.029	0.034	0.030	0.045	0.047	25.4	26.3	25.5	27.9	28.2
	90th Percentile [3]	11203	11563	11643	12377	12386	0.308	0.372	0.323	0.535	0.569	0.034	0.047	0.037	0.080	0.088	26.1	27.8	26.4	31.8	32.8
Model Summary (mg/L)	95th Percentile [3]	6012	6804	6240	9370	9709	0.328	0.487	0.355	0.727	0.775	0.040	0.073	0.046	0.129	0.140	26.9	31.5	27.8	39.5	41.2
	99th Percentile [3]	2752	2752	2599	4515	4903	0.387	0.727	0.471	0.982	1.033	0.053	0.137	0.073	0.207	0.222	29.5	42.8	33.0	53.6	55.9
Change from Existing [M18] (%)	Median	0.0%	0.0%	-0.1%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.2%	0.0%	-0.1%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.0%	-0.4%	-0.2%	0.0%	0.0%	0.0%	-0.1%	-0.1%
	95th Percentile [3]	0.0%	0.0%	-0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	-0.1%	0.0%	0.1%	-0.1%	0.2%	0.2%	0.1%	-0.1%	0.0%	0.0%	0.0%	-0.3%
	99th Percentile [3]	-0.2%	-0.2%	-0.1%	0.0%	0.0%	-2.4%	0.1%	0.1%	-0.1%	-0.2%	-1.0%	-0.7%	-0.2%	-0.2%	-0.2%	-0.8%	-0.4%	-0.1%	-0.2%	-0.3%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 13: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – <u>average</u> year (1967), <u>without</u> infiltration, using <u>D3</u> dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M19] Existing Conditions	Median	26592	26434	26193	26211	26180	0.271	0.271	0.271	0.273	0.273	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	24040	24003	23891	23963	23952	0.274	0.276	0.272	0.281	0.282	0.027	0.027	0.027	0.028	0.029	25.1	25.2	25.0	25.3	25.4
Model Summary (mg/L)	90th Percentile [3]	10211	10511	10144	11392	11395	0.276	0.280	0.275	0.287	0.289	0.027	0.027	0.027	0.029	0.029	25.1	25.2	25.1	25.3	25.4
	95th Percentile [3]	5071	5148	5055	5558	5662	0.282	0.288	0.280	0.304	0.307	0.029	0.030	0.028	0.033	0.034	25.3	25.5	25.3	25.9	26.0
	99th Percentile [3]	1961	2075	1943	2287	2337	0.334	0.378	0.333	0.459	0.479	0.044	0.055	0.044	0.078	0.084	27.7	29.4	27.7	32.9	33.9
[M27] Proposed Conditions	Median	26590	26433	26193	26210	26180	0.271	0.271	0.271	0.273	0.273	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	24040	24003	23891	23963	23952	0.274	0.276	0.272	0.281	0.282	0.027	0.027	0.027	0.028	0.029	25.1	25.2	25.0	25.3	25.4
Model Summary (mg/L)	90th Percentile [3]	10211	10507	10144	11401	11400	0.276	0.280	0.275	0.287	0.289	0.027	0.027	0.027	0.029	0.029	25.1	25.2	25.1	25.3	25.4
	95th Percentile [3]	5071	5148	5056	5560	5662	0.282	0.289	0.280	0.304	0.308	0.029	0.030	0.028	0.033	0.034	25.3	25.5	25.3	25.9	26.0
	99th Percentile [3]	1974	2075	1943	2288	2339	0.334	0.378	0.334	0.460	0.479	0.044	0.055	0.044	0.078	0.084	27.7	29.5	27.7	32.9	33.9
Change from Existing [M19] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	95th Percentile [3]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	99th Percentile [3]	0.7%	0.0%	0.0%	0.0%	0.1%	0.0%	-0.1%	0.1%	0.3%	0.0%	-0.2%	-0.1%	0.2%	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 14: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – <u>dry</u> year (1968), <u>without</u> infiltration, using <u>D1</u> dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M20] Existing Conditions	Median	29048	28973	28817	28782	28760	0.270	0.271	0.270	0.272	0.272	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.0	25.1
	Mean	26471	26482	26352	26519	26526	0.271	0.272	0.270	0.274	0.274	0.026	0.026	0.026	0.027	0.027	25.0	25.1	24.9	25.1	25.1
	90th Percentile [3]	13861	14068	13895	14831	15024	0.272	0.275	0.272	0.280	0.282	0.026	0.027	0.026	0.028	0.028	25.1	25.1	25.1	25.3	25.3
Model Summary (mg/L)	95th Percentile [3]	11462	11829	11589	12435	12607	0.273	0.278	0.273	0.286	0.288	0.026	0.027	0.026	0.028	0.029	25.1	25.2	25.1	25.5	25.5
	99th Percentile [3]	3723	4340	3916	5685	5992	0.276	0.287	0.278	0.299	0.302	0.027	0.029	0.027	0.031	0.032	25.3	25.7	25.4	26.3	26.5
[M28] Proposed Conditions	Median	29048	28974	28816	28783	28762	0.270	0.271	0.270	0.272	0.272	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.0	25.1
	Mean	26470	26481	26351	26518	26526	0.271	0.272	0.270	0.274	0.274	0.026	0.026	0.026	0.027	0.027	25.0	25.1	24.9	25.1	25.1
	90th Percentile [3]	13861	14067	13895	14831	15023	0.272	0.275	0.272	0.280	0.282	0.026	0.027	0.026	0.027	0.028	25.1	25.1	25.1	25.3	25.3
Model Summary (mg/L)	95th Percentile [3]	11462	11829	11589	12434	12606	0.273	0.278	0.273	0.286	0.288	0.026	0.027	0.026	0.028	0.029	25.1	25.2	25.1	25.5	25.5
	99th Percentile [3]	3720	4343	3915	5684	5992	0.276	0.287	0.279	0.299	0.302	0.027	0.029	0.027	0.031	0.032	25.3	25.7	25.4	26.3	26.4
Change from Existing [M20] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	95th Percentile [3]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	99th Percentile [3]	-0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	-0.1%	0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 15: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – wet year (1969), without infiltration, using D1 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M21] Existing Conditions	Median	20802	20610	20678	20169	20092	0.277	0.286	0.278	0.312	0.318	0.027	0.028	0.027	0.032	0.033	25.1	25.3	25.2	25.9	26.0
	Mean	19628	19245	19383	18716	18587	0.283	0.310	0.285	0.349	0.359	0.028	0.032	0.028	0.038	0.040	25.4	26.1	25.3	27.1	27.3
	90th Percentile [3]	3299	3740	3369	4871	5157	0.303	0.382	0.310	0.478	0.498	0.031	0.043	0.032	0.058	0.062	26.0	28.0	26.1	30.7	31.4
Model Summary (mg/L)	95th Percentile [3]	1968	2345	2084	2972	3096	0.317	0.431	0.324	0.549	0.576	0.034	0.051	0.035	0.070	0.074	26.5	29.7	26.8	33.7	34.5
	99th Percentile [3]	946	1385	1009	1883	1982	0.345	0.543	0.362	0.697	0.731	0.039	0.070	0.041	0.095	0.102	28.0	33.8	28.7	39.1	40.2
[M29] Proposed Conditions	Median	20792	20610	20676	20166	20091	0.278	0.286	0.278	0.312	0.318	0.027	0.028	0.027	0.032	0.033	25.1	25.3	25.2	25.9	26.0
	Mean	19624	19244	19379	18716	18586	0.283	0.310	0.285	0.349	0.359	0.028	0.032	0.028	0.038	0.040	25.4	26.1	25.3	27.1	27.3
	90th Percentile [3]	3297	3741	3374	4871	5157	0.303	0.382	0.310	0.477	0.498	0.031	0.043	0.032	0.059	0.062	26.0	28.0	26.1	30.7	31.4
Model Summary (mg/L)	95th Percentile [3]	1974	2345	2085	2969	3094	0.317	0.431	0.324	0.549	0.575	0.034	0.051	0.035	0.070	0.074	26.5	29.7	26.8	33.6	34.5
	99th Percentile [3]	944	1386	1008	1886	1982	0.344	0.543	0.362	0.698	0.733	0.039	0.070	0.041	0.095	0.102	28.0	33.7	28.7	39.1	40.2
	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Change from Existing [M21] (%)	90th Percentile [3]	-0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	95th Percentile [3]	0.3%	0.0%	0.1%	-0.1%	-0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%
	99th Percentile [3]	-0.2%	0.0%	-0.1%	0.1%	0.0%	-0.2%	0.1%	0.1%	0.1%	0.3%	0.1%	0.0%	-0.1%	-0.2%	0.0%	0.0%	-0.1%	-0.1%	-0.2%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 16: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – local wet month (20 Oct – 20 Nov 1969), without infiltration, using D1 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M22] Existing Conditions	Median	28042	28010	28009	27901	27878	0.272	0.274	0.272	0.279	0.280	0.026	0.026	0.026	0.027	0.027	25.0	25.1	25.0	25.1	25.1
	Mean	27962	27971	27688	27885	27866	0.273	0.276	0.273	0.280	0.281	0.026	0.027	0.026	0.027	0.027	25.1	25.2	25.1	25.2	25.2
	90th Percentile [3]	27774	27785	25674	27693	27670	0.279	0.283	0.285	0.288	0.289	0.027	0.028	0.028	0.028	0.028	25.5	25.6	25.9	25.6	25.7
Model Summary (mg/L)	95th Percentile [3]	27593	27710	25600	27633	27605	0.281	0.286	0.289	0.290	0.292	0.027	0.028	0.029	0.028	0.028	25.6	25.8	26.5	25.8	25.8
	99th Percentile [3]	27083	27585	25365	27521	27501	0.289	0.293	0.303	0.295	0.295	0.028	0.029	0.030	0.029	0.029	25.8	26.3	27.4	26.0	25.9
[M30] Proposed Conditions	Median	28032	28011	27991	27903	27880	0.272	0.274	0.272	0.279	0.280	0.026	0.026	0.026	0.027	0.027	25.0	25.1	25.0	25.1	25.1
	Mean	27986	27971	27679	27881	27863	0.274	0.276	0.273	0.280	0.281	0.026	0.027	0.026	0.027	0.027	25.1	25.2	25.1	25.2	25.2
	90th Percentile [3]	27840	27792	25674	27691	27665	0.279	0.283	0.285	0.288	0.289	0.027	0.028	0.028	0.028	0.028	25.4	25.6	25.9	25.6	25.6
Model Summary (mg/L)	95th Percentile [3]	27712	27711	25582	27598	27581	0.281	0.286	0.290	0.290	0.292	0.027	0.028	0.029	0.028	0.028	25.5	25.8	26.5	25.8	25.8
	99th Percentile [3]	27402	27575	25325	27468	27472	0.285	0.292	0.302	0.294	0.296	0.028	0.029	0.030	0.029	0.029	25.7	26.3	27.4	25.9	25.9
Change from Existing [M22] (%)	Median	0.0%	0.0%	-0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%
	90th Percentile [3]	0.2%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.1%	-0.1%	-0.1%	-0.2%	-0.1%	-0.2%	-0.1%	-0.1%
	95th Percentile [3]	0.4%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	0.2%	0.0%	0.0%	-0.1%	0.0%	0.2%	-0.1%	-0.1%	-0.3%	-0.1%	-0.2%	-0.1%	-0.1%
	99th Percentile [3]	1.2%	0.0%	-0.2%	-0.2%	-0.1%	-1.1%	-0.1%	-0.1%	-0.1%	0.0%	-0.2%	-0.2%	-0.1%	-0.2%	-0.1%	-0.2%	-0.1%	-0.3%	-0.2%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 17: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – <u>local wet month</u> (20 Oct – 20 Nov 1969), <u>without</u> infiltration, using <u>D2</u> dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M23] Existing Conditions	Median	27956	28034	27935	27937	27909	0.272	0.274	0.273	0.280	0.281	0.026	0.026	0.026	0.027	0.027	25.0	25.0	25.0	25.1	25.1
	Mean	27801	27951	27547	27865	27851	0.275	0.276	0.277	0.281	0.282	0.026	0.027	0.027	0.027	0.027	25.1	25.2	25.2	25.3	25.3
Model Summary (mg/L)	90th Percentile [3]	27375	27661	25683	27551	27542	0.285	0.285	0.298	0.291	0.292	0.028	0.028	0.030	0.028	0.028	25.6	25.6	26.5	25.7	25.7
	95th Percentile [3]	27012	27531	25473	27466	27477	0.290	0.291	0.307	0.294	0.294	0.028	0.029	0.031	0.029	0.029	25.8	26.0	27.3	26.0	26.1
	99th Percentile [3]	26168	27275	24930	27301	27339	0.300	0.303	0.324	0.297	0.297	0.029	0.031	0.033	0.029	0.030	26.0	26.9	28.8	26.4	26.4
[M31] Proposed Conditions	Median	27896	28032	27917	27929	27896	0.275	0.274	0.273	0.280	0.281	0.027	0.026	0.026	0.027	0.027	25.0	25.0	25.0	25.1	25.1
	Mean	27825	27945	27512	27838	27832	0.277	0.276	0.277	0.281	0.282	0.027	0.027	0.027	0.027	0.027	25.1	25.2	25.2	25.2	25.3
Model Summary (mg/L)	90th Percentile [3]	27460	27628	25681	27500	27509	0.285	0.286	0.299	0.291	0.292	0.028	0.028	0.030	0.028	0.028	25.5	25.5	26.4	25.6	25.6
	95th Percentile [3]	27177	27521	25440	27437	27454	0.289	0.291	0.308	0.294	0.295	0.028	0.029	0.031	0.029	0.029	25.7	25.9	27.3	26.0	26.0
	99th Percentile [3]	26630	27228	24821	27055	27337	0.296	0.303	0.324	0.298	0.297	0.029	0.031	0.033	0.029	0.029	26.0	26.8	28.7	26.3	26.3
Change from Existing [M23] (%)	Median	-0.2%	0.0%	-0.1%	0.0%	0.0%	1.0%	0.1%	0.1%	0.1%	0.1%	1.5%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	-0.1%	-0.1%
	Mean	0.1%	0.0%	-0.1%	-0.1%	-0.1%	0.5%	0.0%	0.2%	0.1%	0.0%	0.7%	0.1%	0.2%	-0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
	90th Percentile [3]	0.3%	-0.1%	0.0%	-0.2%	-0.1%	0.1%	0.1%	0.3%	0.2%	0.0%	0.4%	0.0%	0.9%	-0.1%	-0.2%	-0.6%	-0.2%	-0.4%	-0.3%	-0.3%
	95th Percentile [3]	0.6%	0.0%	-0.1%	-0.1%	-0.1%	-0.3%	0.2%	0.2%	0.3%	0.2%	0.5%	0.0%	0.5%	-0.1%	-0.2%	-0.4%	-0.3%	-0.1%	-0.2%	-0.3%
	99th Percentile [3]	1.8%	-0.2%	-0.4%	-0.9%	0.0%	-1.4%	0.0%	0.0%	0.3%	0.0%	0.7%	0.0%	-0.1%	0.0%	-0.3%	-0.3%	-0.3%	-0.2%	-0.2%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90th, 95th and 99th percentile values are given for TN, TP and TSS. For salinity the 10th, 5th and 1st percentile values are given (respectively) to assess the impact of freshening.

Table 18: Modelled concentration statistics and impacts at Eco Logical seagrass sample points – local wet month (20 Oct – 20 Nov 1969), without infiltration, using D3 dispersion coefficients.

		Pollutant																			
		Salinity [1]					Total Nitrogen (TN)					Total Phosphorous (TP)					Total Suspended Solids (TSS)				
		Observation Point [2]																			
Scenario	**Statistic**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**	**SG03**	**SG04**	**SG06**	**SG07**	**SG08**
[M24] Existing Conditions	Median	28052	28044	28043	28012	28003	0.272	0.272	0.272	0.274	0.274	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	28038	28016	27771	27973	27962	0.273	0.274	0.271	0.275	0.276	0.026	0.026	0.026	0.027	0.027	25.1	25.1	24.9	25.1	25.1
Model Summary (mg/L)	90^{th} Percentile [3]	27976	27905	25663	27812	27785	0.275	0.279	0.277	0.283	0.284	0.027	0.027	0.027	0.027	0.027	25.3	25.3	25.4	25.3	25.3
	95^{th} Percentile [3]	27927	27850	25631	27735	27705	0.277	0.282	0.280	0.287	0.288	0.027	0.027	0.027	0.028	0.028	25.5	25.5	25.7	25.5	25.5
	99^{th} Percentile [3]	27786	27750	25592	27592	27546	0.283	0.288	0.291	0.292	0.294	0.028	0.028	0.029	0.028	0.028	25.8	25.9	26.5	25.7	25.7
[M32] Proposed Conditions	Median	28053	28044	28043	28012	28005	0.272	0.272	0.272	0.274	0.274	0.026	0.026	0.026	0.026	0.026	25.0	25.0	25.0	25.1	25.1
	Mean	28042	28017	27771	27971	27962	0.272	0.274	0.271	0.275	0.276	0.026	0.026	0.026	0.027	0.027	25.1	25.1	24.9	25.1	25.1
Model Summary (mg/L)	90^{th} Percentile [3]	27992	27901	25663	27805	27783	0.275	0.279	0.277	0.283	0.284	0.027	0.027	0.027	0.027	0.027	25.2	25.3	25.4	25.3	25.3
	95^{th} Percentile [3]	27941	27850	25630	27721	27705	0.277	0.282	0.280	0.287	0.288	0.027	0.027	0.027	0.028	0.028	25.5	25.5	25.7	25.5	25.5
	99^{th} Percentile [3]	27833	27739	25591	27591	27545	0.282	0.287	0.290	0.292	0.294	0.028	0.028	0.029	0.028	0.028	25.7	25.9	26.5	25.7	25.6
Change from Existing [M24] (%)	Median	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Mean	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	90^{th} Percentile [3]	0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%
	95^{th} Percentile [3]	0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	-0.2%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%
	99^{th} Percentile [3]	0.2%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.0%	-0.2%	-0.2%	-0.2%	-0.2%	0.0%	-0.3%	-0.1%	-0.1%	-0.1%	-0.1%

Notes

1. Negative changes for salinity represent a freshening effect due to a reduction in salinity concentration. Positive changes represent an increase in salinity concentration.
2. Observation points based on seagrass sample points as per Figure 1 of Eco Logical's *Culburra Estuarine Ecology Preliminary Assessment (Phase 1)* (2017).
3. The 90^{th}, 95^{th} and 99^{th} percentile values are given for TN, TP and TSS. For salinity the 10^{th}, 5^{th} and 1^{st} percentile values are given (respectively) to assess the impact of freshening.

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APPENDIX 9

Confirmation that the report by SLR Global Environmental Solutions would apply to the odour buffer zone around Culburra Wastewater Treatment Plant. Email from Ljupco Lazarevski, Shoalhaven Water, 30 June 2017.

From: Ljupco Lazarevski
Sent: Friday, June 30, 2017 10:31 AM
To: evjotoon@bigpond.com.au
Subject: West Culburra Expansion - 3A10/1003 - Odour Buffer Zone

John

Further to our conversation today, I advise that a meeting was held with representatives from Allen Price & Associates (on 24-7-2013) and it was agreed that the report by SLR Global Environmental Solutions (prepared on behalf of the applicant) would apply in relation to the odour buffer zone around the Culburra Wastewater Treatment Plant.

Regards

Ljupčo Lazarevski
Unit Manager – Project/Development
Shoalhaven Water – Shoalhaven City Council

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