

A photograph of a mangrove forest with dense, tangled tree trunks and roots. The top half shows the canopy with sunlight filtering through, while the bottom half shows a close-up of the complex root system.

Pacific Reef Fisheries (Australia) Pty Ltd

Alva Beach EIMP Report — Mangroves 2020

May 2020



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Permits and approvals

Wild Environmental Consultants operate in accordance with the following permits and approvals:

Scientific Use Registration Certificate (*Animal Care and Protection Act 2001*) – Registration Number 600

Scientific Purposes Permit (*Nature Conservation (Administration) Regulation 2006*) – Permit number WISP17791316

Animal Ethics Approval (Animal Ethics Committee) – AEC Application Reference Number CA 2016/08/997

Marine Parks Permit (*Great Barrier Reef Marine Park Regulations 1983 and Marine Park Regulation 2006*) – G16/38539.1

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Executive summary

Mangrove health monitoring for the Alva Beach aquaculture facility (the Project) Environmental Impact Monitoring Program (EIMP) was completed on 17 and 20 April 2020. In accordance with the existing EIMP design, three (3) sites were surveyed within the potentially impacted Little Alva Creek with an additional three (3) control sites within Alva Creek. Unfortunately, the previous EIMP reports only provide one (1) GPS location for each established quadrat at the six monitoring sites. No physical markers could be identified on site in the vicinity of the provided location. In light of this, six (6) new mangrove monitoring transects, 20 m in length, were established in close proximity to the previously reported GPS locations.

The establishment of new transects prevents a quantitative determination of any potential impacts to the mangrove communities of Little Alva Creek that may be attributed to the discharge of wastewaters from the Project. However, this adjustment provided an opportunity to update the monitoring methodology to align more closely with the mangrove monitoring techniques suggested within the Department of Environment and Science Monitoring and Sampling Manual. These methods included identifying mangrove species within the surveyed area; measuring canopy cover; calculating the leaf area index and determining mangrove recruitment.

In addition to the characterisation of each new monitoring transect, incidental observations suggested that the mangrove communities along both Alva Creek and Little Alva Creek were in a healthy state, with no evidence of significant leaf discolouration or defoliation. These qualitative observations suggest that the discharge of the Project's wastewater has not resulted in any negative impacts to the mangrove communities of the receiving environment. Conclusions that are consistent with the previously completed monitoring reports detailing the original quadrats.



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1. Introduction

1.1 Background

Pacific Reef Fisheries (Australia) Pty Ltd (PRF) operate an aquaculture facility in Alva Beach (Ayr, Queensland) producing Black Tiger Prawns (*Penaeus monodon*). The prawn farm (the Project) has been operating since 1994 in accordance with Environmental Authority (EA) EPPR00864913 and EPBC approval 2001/402, with PRF conducting regular monitoring of their activities and the receiving environment to ensure compliance with the limits and regulations set by the Department of Environment and Science (DES) and Department of Agriculture, Water and the Environment (DAWE). Wild Environmental Consultants (Wild) was commissioned to complete the mangrove components of the Environmental Impact Monitoring Program (EIMP) for 2020.

1.2 Purpose

This mangrove-based Environmental Impact Monitoring Program (EIMP) report is designed to assist PRF in the identification of any environmental effects induced by aquaculture operations at the Alva Beach facility. Changes in the mangrove community composition, juvenile recruitment to mangrove systems and canopy coverage can all indicate whether the discharge of wastewaters from the Project has an impact on biological receptors of the receiving environment. This monitoring is particularly important around areas mapped as Matters of State Environmental Significance (MSES) high ecological significance wetlands.

1.3 Project location and description

The PRF Alva Beach aquaculture facility is located at Lot 1, Trent Road, 15 km east of Ayr, North Queensland (Figure 1). The Project consists of 98 hectares of grow-out ponds (approximately 1.5 m deep¹) for the production of Black Tiger Prawns (*Penaeus monodon*). In addition, the facility consists of a processing facility, 10.3 hectares of settlement-treatment ponds and 23 hectares of constructed mangrove wetland; which has been implemented to reduce the concentration of contaminants (nutrients and sediments) in the discharge waters prior to release into the receiving environment.

¹ Gassman Development Perspectives. 2017. Alva Beach Aquaculture Facility Draft Biodiversity and Environmental Impact Assessment. Prepared for Pacific Reef Fisheries. 124 pp.

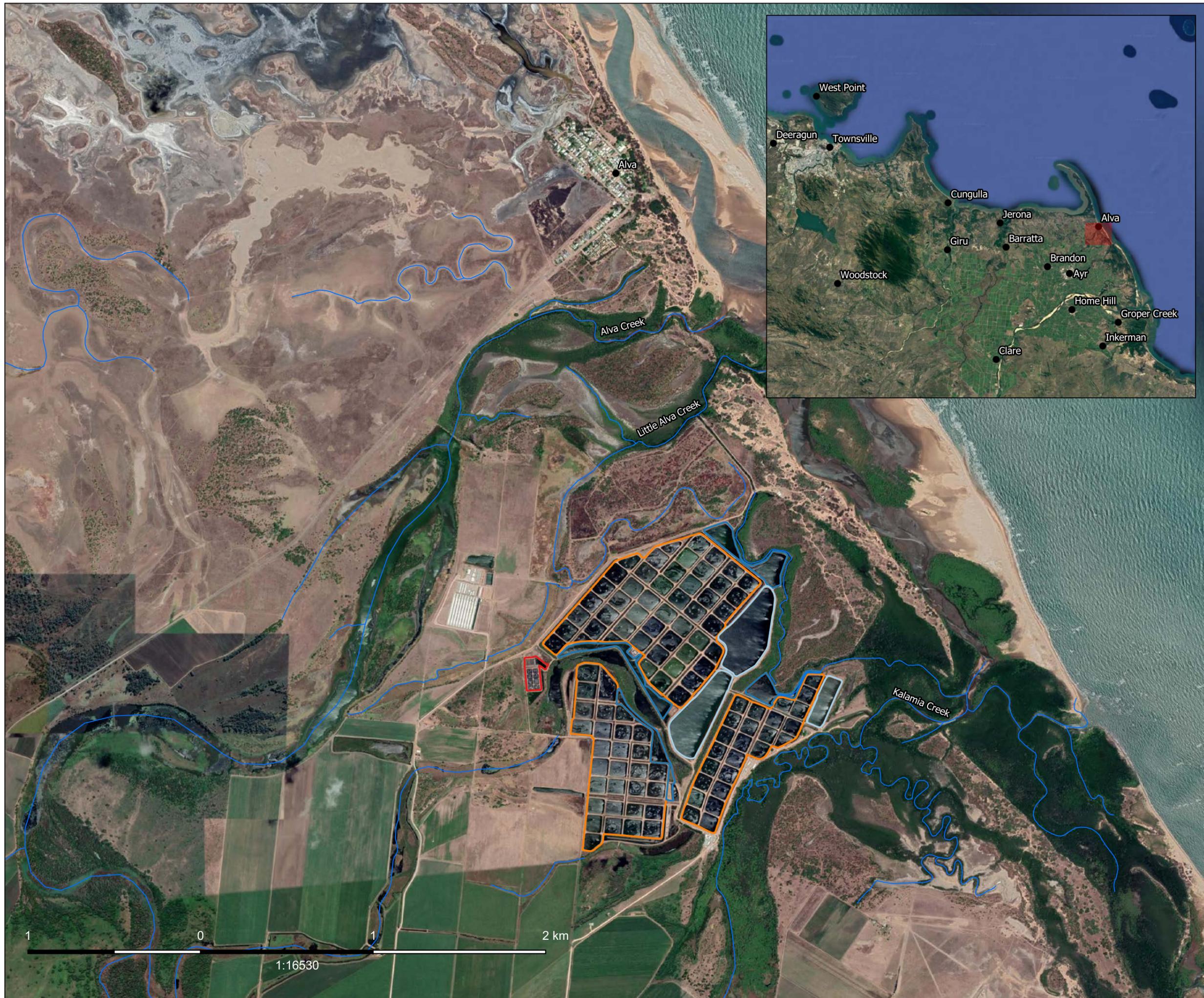
Pacific Reef Fisheries (Australia) Pty Ltd

Environmental Impact Monitoring Program – Mangrove Health

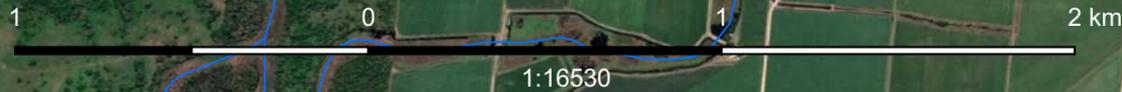
Figure 1: Project location

Legend

- Populated places
- Watercourse
- Alva Beach Facility
 - Production Ponds
 - Treatment Sytem
 - Nursery
 - Reservoir



Job Number: JW201304
Coordinate reference system: GDA2020
Date: 06 May 2020





1.3.1 Previous monitoring results

Mangrove health monitoring under the Project’s previous EIMP has been collected at six (6) locations; three (3) within Little Alva Creek (sites A, B, G) and three (3) within Alva Creek (sites E, F and H) at an annual frequency. The original EIMP design documentation² indicates that mangrove monitoring was originally to be conducted biannually for the first two (2) years, annually for the following two (2) years and then reduced to biennially (one every two years) thereafter. The EIMP methodology required that 20 m x 20 m quadrats were established at each site with the following parameters recorded:

- species composition;
- density of mature trees (i.e. over 3 m, of each species); and
- density of sapling and small trees (i.e. less than 3 m, of each species).

Eight (8) separate species were identified within the receiving environment during surveys in 2015³, 2016⁴ and 2017⁵, with no apparent declines in the density of adult or sapling/ juvenile mangrove trees (Table 1).

Table 1: REMP mangrove density data 2015 to 2017

Date	Site A Density		Site B Density		Site G Density		Site D Density		Site E Density		Site H Density	
	(>3 m)	(<3 m)	(>3 m)	(>3 m)	(>3 m)	(<3 m)						
2015	0.0625	0.72	0.02	0.16	0.8	0.75	0.4	0.8	0.04	0.8	0.45	0.04
2016	0.0625	0.72	0.02	0.16	0.8	0.75	0.4	1.0	0.04	1.0	0.45	0.03
2017	0.0625	0.72	0.02	0.16	0.8	0.75	0.4	1.2	0.04	1.2	0.45	0.1

² Gassman Development Perspectives. 2013. Environmental Impact Monitoring Program Alva Beach Prawn Farm. Prepared for Pacific Reef Fisheries. 15 pp.

³ Gassman Development Perspectives. 2015. Environmental Impact Monitoring Program (EIMP) – Spring 2015. Prepared for Pacific Reef Fisheries (Australia) Pty Ltd. 38 pp.

⁴ Gassman Development Perspectives. 2016. Environmental Impact Monitoring Program (EIMP) – Spring 2016. Prepared for Pacific Reef Fisheries (Australia) Pty Ltd. 38 pp.

⁵ Gassman Development Perspectives. 2017. Environmental Impact Monitoring Program (EIMP) – Spring 2017. Prepared for Pacific Reef Fisheries (Australia) Pty Ltd. 38 pp.



2. Methodology

Mangrove monitoring was conducted around the daytime low tides on 17 and 20 April 2020. The Alva Beach weather station (Station 033295) measured 0.6 mm of rainfall on 17 April, with no rain recorded on 20 April. However, 16.2 mm of rainfall was recorded on 19 April, which was the highest amount recorded during the month. Wind speeds during sampling were low with a slight increase observed in the afternoon of both sampling days.

Sampling was planned to be conducted in accordance with the approved EIMP prepared by Gassman Development Perspectives⁶ at the six (6) permanent quadrat locations with Alva Creek and Little Alva Creek; sites A, B, D, E, G and H. Unfortunately, only one GPS location per site was provided within the earlier EIMP reports, and no physical markers of the quadrats could be identified at any of the marked locations following an extensive search. In light of this, new permanent transect locations were established (Table 2, Figure 2) at the sites marked within the previous EIMP reports. Given the monitoring inconsistencies that would arise from the spatial differences between the current and previous (unknown) monitoring locations, a new monitoring methodology was developed, which was consistent with the methods detailed within the Department of Environment and Science Monitoring and Sampling Manual⁷. Not all of the methods described in the Manual were utilised due to accessibility and repeatability. Access to the sites was primarily by foot during low tides; only site D was accessed by boat. Site access was time restricted, requiring the crossing of creek channels at the lowest point in the tidal cycle. Therefore, only methods that could be reliably reproduced were utilised.

Table 2: Sampling locations

Site	Description	Transect Start		Transect Finish	
		Latitude (°S)	Longitude (°E)	Latitude (°S)	Longitude (°E)
Little Alva Creek Impact Monitoring					
G	Upstream of wastewater discharge	19.47056	147.48367	19.47060	147.48349
A	Confluence with wastewater discharge	19.46866	147.48615	19.46869	147.48604
B	Downstream of wastewater discharge	19.46518	147.48978	19.46519	147.48959
Alva Creek Control Monitoring					
H	Upstream site comparable with impact Site G	19.46552	147.47323	19.46567	147.47316
D	Midstream site comparable with impact Site A	19.46439	147.48043	19.46454	147.48037
E	Downstream site comparable with impact Site B	19.46265	147.48716	19.46281	147.48709

⁶ Gassman Development Perspectives, 2013. Environmental Impact Monitoring Program. Alva Beach Prawn Farm. Prepared for Pacific Reef Fisheries. 15 pp.

⁷ DES. 2018. Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane. Department of Environment and Science Government.



2.1 Site selection

At each location, 20 m transects were set up and marked on a GPS. Under thick mangrove growth, satellite accuracy for the GPS was observed to be limited—as likely experienced with the previous sites—therefore transects were also physically identified with flagging tape and/or wooden stakes with pink tips. Ideally, transects were set perpendicular to the watercourse, however, where mangrove communities were <20 m wide or were characterised by marked vegetation changes, transects were aligned parallel to the watercourse.

2.2 Mangrove species composition

Adult mangrove trees within 10 m of the transect were identified to the species level where possible; however, the seasonal absence of key identifying features limited the identification of some individuals to the genus level.

2.3 Tree canopy cover

Canopy cover was estimated using the line intercept method along the 20 m transect through measurement of the vertical projection of the tree canopy cover for each species. The total length of the projected canopy was then divided by the total transect length (20 m) to give an estimate of percentage canopy cover on the site. If the canopy cover consists of more than one species of mangrove, the percentage that each species contributes to the total canopy cover was estimated.

In addition to tree canopy cover, the leaf area index (LAI) was calculated by collecting light intensity measurements from within the mangrove canopy, outside the mangrove canopy and measuring the zenith angle of the sun. Light measurements were collected using an Apogee Instruments MQ-200 Quantum Light Meter (measuring photosynthetic photon flux density) and the LAI was calculated using the following formula:

$$LAI = \frac{\ln\left(\frac{I_b}{I_0}\right)}{-k \times \cos\left(\frac{\infty\pi}{180}\right)}$$

where:

Ln = natural logarithm;

I_b = mean values of light below the canopy;

I_0 = mean value of light above the canopy (i.e. ambient light intensity);

k = extinction coefficient that accounts for the angle and orientation of the foliage. Selected at 0.55 for mangroves;

∞ = zenith angle of the sun; and π = 3.14



2.4 Mangrove recruitment

Mangrove seedlings were monitored along the transect at intervals of 4 m within 1 m x 1 m quadrats. The height and stem diameter of each seedling within the quadrat was using the following method⁸:

1. Count the number of seedlings within each 1 m x 1 m quadrat. Record species type.
2. Using a measuring stick, record the height of the seedling by measuring from the ground to the base of the uppermost apical shoot.
3. Measure the stem diameters of seedlings at the same height above soil level each time. This height will be determined by the height of the seedlings but 5 cm above ground height would in most cases be an appropriate height.
4. For species that propagate using an elongated propagule rather than a seed (e.g. *Rhizophora spp.*) take the measurement at the base of the stem, just above the swelling of where the propagule meets the emerging stem.
5. Record density (number of stems per m²).

Given the relatively high proportion of mangrove shrubs present and the majority of sites, mangrove seedlings were defined as single stemmed individuals less than 1 m in height.

⁸ DES. 2018. Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane. Department of Environment and Science Government.

Environmental Impact
Monitoring Program –
Mangrove Health

Figure 2: Mangrove
monitoring sites

Legend

- Populated places
- ◆ Mangrove transects
- GBR wetland of high ecological significance
- Wetland of high ecological significance
- Watercourse



Job Number: JW201304
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Date: 06 May 2020



3. Results

3.1 Site A (impact)

Mangroves communities associated with the confluence of outflow water from the Project with Little Alva Creek were characterised as a closed forest of Red Mangrove *Rhizophora stylosa* (dominant) and Grey Mangrove *Avicennia marina* and River Mangrove *Aegialitis annulata* being sub-dominant and emergent in the canopy layer (Table 3). No shrub layer was present. This narrow community transitions to one dominated by Yellow Mangrove *Ceriops spp.* (likely either *Ceriops tagal* or *Ceriops australis*) and Orange Mangrove *Bruguiera exaristata*, which were observed on the higher land to the south (i.e. shoreward) which is likely to be subject to less frequent salt water inundation. Fringing salt couch and marine grasses were observed along the edge of the *Ceriops* communities.

Canopy cover was dominated by the Red Mangrove (100% of the transect), however, the Grey Mangrove and Orange Mangrove were also observed to contribute to the canopy at 8.5% and 0.7%, respectively. Supporting the indication of a dense canopy cover, the calculated LAI was 8.10, the second highest value recorded at all of the monitoring sites in 2020.

No seedlings were observed along the transect at this monitoring location.

Table 3: Site A mangrove transect characteristics

Characteristic	Observations	
Date Time	11:40 20/04/2020	
Transect Start	-19.46866°S ,147.48615°E	
Transect Finish	-19.46869°S ,147.48604°E	
Species Present	<i>Rhizophora stylosa</i>	100 % canopy cover
	<i>Avicennia marina</i>	8.5 % canopy cover
	<i>Bruguiera exaristata</i>	0.7 % canopy cover
Leaf Area Index	8.10	
Seedlings	None observed	



Figure 3: Site A *Rhizophora stylosa*. closed forest



Figure 4: Site A *Ceriops* spp. +/- *Avicennia marina* open shrubland



3.2 Site B (impact)

Located at the mouth of Little Alva Creek, downstream of the confluence of outflow wastewater from the Project, the mangroves of Site B comprise a high ecological significance wetland that has been designated a Matter of State Environmental Significance (MSES) (Figure 2). Moreover, this community is described as low open forest of Grey Mangrove *Avicennia marina* (dominant), with occasional Red Mangrove *Rhizophora stylosa* also present (Table 4). The dominance of the Grey Mangrove resulted in a more open ground layer, given the single trunk with peg type above ground roots (pneumatophores) as opposed to the prop roots associated with the Red Mangrove.

The canopy was dominated by the Grey Mangrove, which covered approximately 83% of the transect, with an additional 11.5% cover attributed to the Red Mangrove. This lower percentage canopy cover observed at Site B when compared with Site A was further supported by a reduced LAI of 3.39.

Quadrats interspaced along the transect intercepted 12 seedlings at Site B. The majority (7) were identified as the Grey Mangrove, with two (2) additionally identified as the Red Mangrove. Three additional seedlings were identified and measured, however, could not be reliably identified due to a limited number of leaves.

Table 4: Site B mangrove transect characteristics

Characteristic	Observations	
Date Time	13:40 20/04/2020	
Transect Start	19.46518°S, 147.48978°E	
Transect Finish	19.46519°S, 147.48959°E	
Species Present	<i>Avicennia marina</i>	83 % canopy cover
	<i>Rhizophora stylosa</i>	11.5 % canopy cover
Leaf Area Index	3.39	
Seedlings	Density: 2.4 seedlings/m ² Mean height: 422 mm. Mean diameter: 5 mm.	



Figure 5: Site B *Avicennia marina* low open forest



3.3 Site D (control)

Mangroves midway downstream of Alva Creek were monitored at Site D, providing a control site ideally representative of the Impact Site A at the confluence of the discharged wastewaters with Little Alva Creek. Site D is a low open forest with a variety of species. Within the tree layer, the Grey Mangrove *Avicennia marina* was the most dominant with sub-dominant Red Mangrove *Rhizophora stylosa* also present. The Club Mangrove *Aegialitis annulata* and the River Mangrove *Aegiceras corniculatum* make up the shrub layer with the former being more dominant. Immature Red, Grey and Club Mangroves along with additional individuals of the Myrtle Mangrove *Osbornia octodonta* also occur within the shrub layer. A large number of Red Mangrove seedlings were observed at the shoreline edge of the mangrove community.

Canopy cover was dominated by the Grey Mangrove, accounting for approximately 68% of the transect. Similar to the impact site B, the Red Mangrove also contributed to approximately 7% of the observed canopy cover along the transect line. Leaf area index for Site D was calculated at 6.07, supporting the transect observations of less than 100% canopy cover.

Seedling density was recorded at 2.4 seedlings/ m². The majority (8) were identified as the Club Mangrove, with four (4) additionally identified as the Red Mangrove. Three additional seedlings were identified and measured, however, could not be reliably identified due to a limited number of morphological features required for a positive identification.

Table 5: Site D mangrove transect characteristics

Characteristic	Observations	
Date Time	09:53 20/04/2020	
Transect Start	19.46439°S, 147.48043°E	
Transect Finish	19.46454°S, 147.48037°E	
Species Present	<i>Avicennia marina</i>	67.5% canopy cover
	<i>Rhizophora stylosa</i>	6.5% canopy cover
	<i>Aegialitis annulata</i>	Incidental observation
	<i>Aegiceras corniculatum</i>	Incidental observation
	<i>Osbornia octodonta</i>	Incidental observation
Leaf Area Index	6.07	
Seedlings	Density: 2.4 seedlings/ m ² . Mean height: 298 mm. Mean diameter: 5 mm.	



Figure 6: Site D *Avicennia marina* low open forest with *Rhizophora stylosa*



3.4 Site E (control)

Mangrove monitoring at Site E was completed at the mouth of Alva Creek, downstream (further north) of the high ecological significance wetlands at Site B. Classified as a low open forest, the site was dominated by Grey Mangrove *Avicennia marina* in the tree layer and Yellow Mangrove *Ceriops spp.* in the shrub layer, with occasional Orange Mangrove *Bruguiera exaristata* individuals (Table 6). Seedlings of the Red Mangrove *Rhizophora stylosa* were observed to be dominant along the waterline, providing a relatively dense community with increasing size (remaining <2 m) in a landwards direction.

Canopy cover at Site E was relatively low, at 42.5% of the transect length. Several patches of open space were observed within the vicinity of the survey area, suggesting that transect was representative of the site. Leaf area index values were not determined for Site E. This was the first location completed during the 2020 monitoring, and the inability to locate the original transect markers necessitated a variation to the sampling methodology in the field. Mangrove seedlings were recorded at a density of 3 seedlings/ m² along the transect, eight (8) individuals were identified as the Yellow Mangrove and seven (7) as the Red Mangrove.

Table 6: Site E mangrove transect characteristics

Characteristic	Observations	
Date Time	10:26 17/04/2020	
Transect Start	19.46265°S, 147.48716°E	
Transect Finish	19.46281°S, 147.48709°E	
Species Present	<i>Avicennia marina</i>	42.5% canopy cover
	<i>Rhizophora stylosa</i>	Incidental observation
	<i>Ceriops spp.</i>	Incidental observation
	<i>Bruguiera exaristata</i>	Incidental observation
Leaf Area Index	—	
Seedlings	Density: 3 seedlings/ m ² . Mean height: 317 mm. Mean diameter: 6 mm.	



Figure 7: Site E *Avicennia marina* low open forest



3.5 Site G (impact)

Mangroves at Site G were comprised of two distinct communities. Firstly, a narrow band of very dense closed forest dominated by Red Mangrove *Rhizophora stylosa* lining the banks of Little Alva Creek, extending approximately 5–7 m from the watercourse. No shrub layer was present. An extremely high density of prop roots associated with the Red Mangrove growth form inhibited ecologists' movement towards the water's edge and within the forest structure. Secondly, landward of the Red Mangrove community lay a low open shrubland dominated by immature multi-stemmed Yellow Mangroves *Ceriops spp.* less than two metres in height. Occasional Grey Mangrove *Avicennia marina* was also interspersed within the community. Further inland on the drier substrate individuals of the Myrtle Mangrove *Osbornia octodonta* were observed. The landward edge of the mangrove habitat contained the Black Mangrove *Lumnitzera sp.* and Blind Your Eye Mangrove *Excoecaria agallocha* (Table 7).

Old hypocotyls (partially developed seedlings from the fruits) were observed to be approximately 13 cm long on several individuals, which combined with horizontal striations on the trunk bark is an indicator of *Ceriops australis*.

Following consideration of the dense Red Mangrove growth along the waterfront, only LAI was measured for the Red Mangrove community. LAI measurements were taken within an approximate 5 m by 5 m quadrat. A high LAI of 14.57 was calculated, the highest value of all the monitored sites, suggesting a healthy mangrove community with a dense canopy.

Canopy cover was assessed along a 20 m transect within the *Ceriops spp.* open shrubland, parallel to the watercourse. Assessment of the canopy cover provided low values, with only 27% of the transect covered by *Ceriops spp.* canopy; with an additional 5% from the Myrtle Mangrove and 2.5% from the Grey Mangrove. This is consistent with the observation of an immature shrubland with *Ceriops spp.* individuals being predominately less than two meters in height, and therefore comprising the understorey rather than canopy.

Seedling density within the surveyed area was 1.4 seedlings/ m². Three (3) of which appeared to be *Ceriops spp.* and an additional four (4) were estimated to be the Club Mangrove *Aegialitis annulata*. It should, however, be noted that a limited number of leaves on these individuals prevented an accurate and reliable identification to a species level.



Table 7: Site G mangrove transect characteristics

Characteristic	Observations	
Date Time	14:14 17/04/2020	
Transect Start	19.47056°S, 147.48367°E	
Transect Finish	19.47060°S, 147.48349°E	
Species Present	<i>Rhizophora stylosa</i>	100% canopy cover (riverine)
	<i>Ceriops spp.</i>	27% canopy cover (inland)
	<i>Osbornia octodonta</i>	5% canopy cover (inland)
	<i>Avicennia marina</i>	2.5% canopy cover (inland)
	<i>Lumnitzera sp.</i>	Incidental observation
	<i>Excoecaria agallocha</i>	Incidental observation
Leaf Area Index	14.57 (<i>Rhizophora stylosa</i>)	
Seedlings	Density: 1.4 seedlings/ m ² . Mean height: 686 mm. Mean diameter: 17 mm.	



Figure 8: Site G *Rhizophora stylosa* closed forest



Figure 9: Site G *Ceriops spp.* low open shrubland



3.6 Site H (control)

Mangroves within control site H were located in close proximity to the Alva Creek boat ramp, and therefore may be susceptible to anthropogenic impacts associated with the ramp use and maintenance. The site was characterised as a mixed association of mangrove species over a range of heights. Red Mangrove *Rhizophora stylosa* dominated the waterfront edge, with Grey Mangrove *Avicennia marina* as emergents, and subdominant Orange Mangrove *Bruguiera exaristata*. Yellow Mangrove *Ceriops spp.* dominated the shrub layer further from the creek edge where less inundation occurs. Individuals of the Orange Mangrove *Bruguiera exaristata* and the Grey Mangrove *Avicennia marina* were also observed away from the water’s edge (Table 8).

The canopy cover at Site H was moderate, with 47.5% cover provided by the Yellow Mangrove and 9% cover by the Grey Mangrove. An additional 6% canopy cover was generated by the Orange Mangrove and 5.5% from the Red Mangrove. Light intensity measurements along the transect indicated a LAI of 3.92. Seedling density was 2.6 seedlings/ m², with all individuals identified as the Yellow Mangrove.

Table 8: Site H mangrove transect characteristics

Characteristic	Observations
Date Time	08:52 20/04/2020
Transect Start	19.46552°S, 147.47323°E
Transect Finish	19.46567°S, 147.47316°E
Species Present	<i>Ceriops spp.</i> 47.5% canopy cover
	<i>Avicennia marina</i> 9% canopy cover
	<i>Bruguiera exaristata</i> 6% canopy cover
	<i>Rhizophora stylosa</i> 5.5% canopy cover
Leaf Area Index	3.92
Seedlings	Density: 2.6 seedlings/ m ² . Mean height: 320 mm. Mean diameter: 4 mm.



Figure 10: Site H *Rhizophora stylosa* open forest



4. Discussion

Previous mangrove monitoring events completed by Gassman Development Perspectives between 2015 and 2017 (inclusive) did not indicate any deterioration in mangrove health following the discharge of wastewater from the Project into Little Alva Creek. Unfortunately, only one GPS location per site was detailed within previous EIMP monitoring reports, limiting the ability to exactly reproduce the previous monitoring techniques. Following an inability to locate any physical markers associated with the monitoring quadrats, updated transects were installed within close proximity to the singular location provided for each site. Given that altered sampling locations prevents the continuation of the data collected under previous monitoring rounds; the survey design was updated to incorporate the methodologies detailed within the Department of Environment and Science Monitoring and Sampling Manual⁹. These methods included identifying mangrove species within the surveyed area; measuring canopy cover; calculating the leaf area index and determining mangrove recruitment.

Incidental observations did not indicate any signs of poor health or distress such as significant defoliation or leaf discolouration; suggesting that the observed communities were relatively healthy. A full quantitative assessment of potential impacts to the mangrove community of Little Alva Creek could not be determined from these surveys due to the establishment of new monitoring locations and associated baseline characterisation.

Downstream control and impact monitoring sites (E and B, respectively) contained relatively similar mangrove communities that were dominated by the Red Mangrove *Rhizophora stylosa* and the Grey Mangrove *Avicennia marina*. Differences in mangrove community composition was, however, observed between the corresponding midstream monitoring locations A and D. In close vicinity to the Project's discharge channel, Site A was characterised by dense growth of the Red Mangrove with fringing salt couch and marine grasses on the disturbed edge line. In contrast, Site D within Alva Creek contained an open structured community of Red Mangroves, which graded into a Grey Mangrove dominated region further inland. Differences between the control and impact mangrove communities were more distinct at the upstream sites G and H. Mangroves along Little Alva Creek (Site G) were observed to occur in two distinctive communities, very dense growth of Red Mangrove along the watercourse with a landward region dominated by shrub forms of the Yellow Mangrove *Ceriops spp.* In contrast, within Alva Creek (Site H) a relatively thin community of Red Mangrove lined the watercourse that graded into more widely spaced Yellow Mangroves when compared to Site G. While the communities at corresponding impact and control sites were similar, it should be considered that

⁹ DES. 2018. Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane. Department of Environment and Science Government.



the more open structure of mangroves associated with the control sites may impede the reliability of any conclusions of Project related impacts.



5. Conclusions

Environmental impact monitoring for the mangrove communities of Little Alva Creek was conducted on 17 and 20 April 2020, following on from previous monitoring rounds completed by Gassman Development Perspectives in 2015, 2016 and 2017. Unfortunately, only one GPS location per site was provided within the previous EIMP reports and no physical markers could be identified to locate the position of the previously monitored quadrats.

New monitoring transects were set up at each of the six (6) sites identified within the previous EIMP reports, in close proximity to the singular location provided. The commencement of a 'new' monitoring program through the establishment of new sites additionally provided an opportunity to update the monitoring methods for alignment with the Department of Environment and Science Monitoring and Sampling Manual¹⁰. These methods included identifying mangrove species within the surveyed area; measuring canopy cover; calculating the leaf area index and determining mangrove recruitment.

Each new monitoring site was characterised to provide an updated baseline for the mangrove monitoring component of the EIMP. However, given the initial stage of these sites, no quantitative assessment of potential impacts could be conducted. Incidental observations while completing the surveys suggested healthy mangrove communities at all locations, with no evidence of defoliation or leaf discolouration. This qualitative assessment is in accordance with the conclusions of the three previous monitoring rounds completed by Gassman Development Perspectives.

¹⁰ DES. 2018. Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane. Department of Environment and Science Government.



6. Appendix A Field Data

	Site A	Site B	Site D
Time and Date	11:40 20/04/2020	13:40 20/04/2020	09:53 20/04/2020
Species Present	<i>Rhizophora stylosa</i> ; <i>Avicennia marina</i> ; <i>Bruguiera exaristata</i> ; <i>Aegialitis annulata</i> .	<i>Rhizophora stylosa</i> ; <i>Avicennia marina</i> ;	<i>Rhizophora stylosa</i> <i>Avicennia marina</i> <i>Aegialitis annulata</i> <i>Osbornia octodonta</i> <i>Aegiceras corniculatum</i>
Sun Angle (degrees)	32	41	46
Ambient PAR	1869; 1756; 1741; 1776, 1801.	1478; 1531; 1694; 1560; 1491.	1590; 1615; 1606; 1582; 1561.
Canopy PAR	64; 31; 21; 29; 33; 25; 18; 19; 14; 18; 12; 11; 16; 312; 34; 26; 111; 15; 25; 49; 24; 15; 17; 26.	25; 39; 63; 29; 66; 647; 1269; 591; 77; 652; 53; 58; 278; 215; 1098; 63; 82; 157; 111; 398; 1546; 1518; 151; 107; 206.	71; 76; 70; 61; 79; 279; 283; 255; 284; 275; 111; 243; 103; 197; 113; 96; 225; 61; 92; 116; 97; 54; 91; 75; 501.
Leaf Area Index	8.10	3.39	6.07
Canopy Cover (length of 20 m transect)	<i>Rhizophora stylosa</i> : 20 m; <i>Avicennia marina</i> : 1.7 m; <i>Bruguiera exaristata</i> : 0.14 m.	<i>Rhizophora stylosa</i> : 2.3 m; <i>Avicennia marina</i> : 16.6 m;	<i>Rhizophora stylosa</i> : 1.3 m; <i>Avicennia marina</i> : 13.5 m;
Seedling Height (mm)	None observed.	800; 300; 370; 190; 530; 580; 370; 350; 750; 290; 310; 220	170; 230; 810; 190; 90; 230; 220; 180; 450; 490; 100; 410
Seedling diameter (mm)	None observed.	5; 4; 4; 5; 5; 6; 4; 4; 8; 4; 3; 3	4; 5; 4; 3; 4; 12; 4; 3; 7; 5; 3; 5



	Site E	Site G	Site H
Time and Date	10:26 17/04/2020	14:14 17/04/2020	08:52 20/04/2020
Species Present	<i>Avicennia marina</i> <i>Bruguiera exaristata</i> <i>Ceriops spp.</i>	<i>Avicennia marina</i> <i>Ceriops spp.</i> <i>Lumnitzera sp.</i> <i>Osbornia octodonta</i> <i>Rhizophora stylosa</i> <i>Excoecaria agallocha</i> <i>Aegialitis annulata</i>	<i>Avicennia marina</i> <i>Ceriops spp.</i> <i>Rhizophora stylosa</i> <i>Bruguiera exaristata</i>
Sun Angle (degrees)	–	52	40
Ambient PAR	–	1474; 1370; 1345; 1763; 1294	1702; 1556; 1782; 1689; 1635
Canopy PAR	–	16; 12; 9; 8; 7; 8; 11; 16; 8; 14; 16; 10; 4; 8; 10; 9; 10; 13; 15; 6; 7; 13; 14; 9; 7	1412; 210; 104; 52; 26; 61; 77; 140; 97; 1425; 141; 794; 582; 126; 73; 64; 70; 79; 70; 810
Leaf Area Index	–	14.57	3.92
Canopy Cover (length of 20 m transect)	<i>Avicennia marina</i> : 8.5 m	<i>Avicennia marina</i> : 0.5 m <i>Ceriops spp.</i> : 5.4 m <i>Osbornia octodonta</i> : 1 m	<i>Avicennia marina</i> : 1.8 m <i>Ceriops spp.</i> : 9.5 m <i>Rhizophora stylosa</i> : 1.1 m <i>Bruguiera exaristata</i> : 1.2 m
Seedling Height (mm)	770; 250; 200; 20; 670; 450; 400; 380; 110; 170; 220; 200; 230; 100; 590	480; 650; 370; 830; 790; 890; 790	410; 240; 150; 250; 310; 240; 270; 230; 230; 220; 230; 940; 440
Seedling diameter (mm)	10; 5; 5; 8; 5; 7; 5; 7; 4; 5; 4; 5; 3; 2; 16	15; 20; 4; 25; 20; 20; 16	5; 4; 4; 3; 3; 3; 4; 3; 3; 3; 5; 8; 4