Pacific Reef Fisheries Pty Ltd

Alva Beach Sediment EIMP Report 2020

December 2020

WILD environmental consultants

(07) 4410 9000 | www.wildenvironmental.com | 75 Denham St, Townsville

Document Control

Alva Beach Sediment EIMP Report 2020

Project Ref:	JW201321
Document Title	Alva Beach Sediment EIMP Report 2020
Client Name	Pacific Reef Fisheries (Australia) Pty Ltd
Project Manager	Dr James Sadler

www.wildenvironmental.com

Wild Environmental Consultants Pty Ltd

Cite as:

Wild Environmental Consultants, 2020, Alva Beach Sediment EIMP Report 2020, prepared by Wild Environmental Consultants for Pacific Reef Fisheries (Australia) Pty Ltd.

Copyright:

Disclaimer

This report has been prepared by Wild Environmental Consultants on behalf of and for the exclusive use of Wild Environmental Consultants Pty Ltd's Client, and is subject to and issued in connection with the provisions of the agreement between Wild Environmental Consultants Pty Ltd and its Client.

While reasonable effort has been made to ensure that the contents of this publication are factually correct, Wild Environmental Consultants Pty Ltd does not accept responsibility for the accuracy or completeness of the contents, and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this publication.

Document history and status

Revision	Date	Description	By	Review
V0.1	11/11/2020	Draft for interval review	Michelle Barker Matthew Ayre	Nicholas Baker
V0.2	26/11/2020	Draft for client review	James Sadler	
V1.0	17/12/2020	Final submitted to client	James Sadler	

Approval for Issue

Name and position	Signature	Date
Nicholas Baker, Director		17/12/2020

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

Wildlife Authority (Rehabilitation Permit) (*Nature Conservation (Administration) Regulation 2017 – WA0002733*

Wildlife Authority (Damage Mitigation Permit) (*Nature Conservation (Administration) Regulation 2017 – WA0005146*

Executive summary

Sediment and benthic macroinvertebrate monitoring for the Alva Beach Aquaculture facility's Environmental Impact Monitoring Program (EIMP) was completed on 15 October 2020. Sediment samples were collected by a benthic grab for identification of the macroinvertebrate community composition, sediment-associated total organic carbon content and particle size distribution.

Sediments across the receiving environment were classified as being predominately comprised of sand sized particles, with the highest concentration of fine particles observed at the mouth of the potentially impacted watercourse, Little Alva Creek. Elevated concentrations of total organic carbon were also recorded at this location, with fine particles providing a larger surface area for the concentration of organics. However, total organic carbon content measurements from the site between 2018 and 2020 indicate a long-term increase at the mouth of Little Alva Creek that was not mirrored in the sediment fine particle composition. This discrepancy may be an indicator of eutrophication (nutrient enrichment) of Little Alva Creek. However, an assessment of the water quality data collected as part of the EIMP did not indicate that the operation of the aquaculture facility has resulted in localised eutrophication of Little Alva Creek.

Following the collection of limited benthic macroinvertebrate individuals during previous monitoring events, the methodology associated with sample collection was altered in 2020 to incorporate a reduced sieve mesh size (from 1 cm to 500 µm). These changes resulted in an increase in the identified macroinvertebrate abundance across all four (4) monitoring locations, with a concomitant increase in taxonomic diversity as a reflection of the increased sample size. It is, however, important to note that this variation is an artefact of the amended sampling, rather than an indication of large-scale ecological change within the receiving environment. Consistent with previous monitoring events, limited benthic macroinvertebrates were identified from the control watercourse Alva Creek. In contrast, a large number of individuals were identified from Little Alva Creek, which may be a reflection of increased food availably as evidenced by elevated total organic carbon content. Further assessment of benthic macroinvertebrates using the updated sampling methodology in 2021 will be beneficial in determining potential changes to the local macroinvertebrate community.

Contents

Figures

Tables

1. Introduction

1.1 Background

Pacific Reef Fisheries (Australia) Pty Ltd (PRF) operate an aquaculture facility in Alva Beach (Ayr, Queensland) for the production of Black Tiger Prawns (*Panaeus monodon*). The facility (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). Wild Environmental Consultants (Wild Environmental) was commissioned to complete the sediment and macroinvertebrate components of the Project's Environmental Impact Monitoring Program (EIMP) for the spring 2020 event.

1.2 Purpose

This sediment-based EIMP report is designed to assist PRF in the identification of any environmental effects induced by aquaculture operations at the Project. Physical (particle size distribution) and chemical (total organic carbon concentration) analyses provide an indication as to whether changes to the physical receiving environment have occurred following the approved release of wastewaters into Little Alva Creek. Analysis of macroinvertebrates recovered from the sediments provide an integrated indicator of the potential effects on the receiving environment through the local biological systems.

1.3 Project location and description

The Project is located at Lot 1, Trent Road, 15 km east of Ayr, North Queensland (Figure 1) and consists of 98 hectares of grow-out ponds (approximately 1.5 m deep[1]) for the production of Black Tiger Prawns (*Penaeus monodon*). In addition, the Project consists of a processing facility, 10.3 hectares of settlement-treatment ponds and 23 hectares of constructed mangrove wetland[2], which has been implemented to reduce the concentration of contaminants (nutrient and sediments) in the discharge waters prior to release into the receiving environment.

Saltwater required by the Project is sourced from Kalamia Creek, located to the east of the Project, with surplus wastewaters discharged via an approved discharge structure into Little Alva Creek. As per Condition SMR12 of EA EPPR00864913, PRF are required to *develop and undertake an Environmental Impact*

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

[2] Gassman Development Perspectives. 2017. Environmental Impact Monitoring Program – Spring 2017. Pacific Reef Fisheries, Alva Beach. 44 pp.

Monitoring Program, in relevant creeks and along the western shoreline of the Pacific Ocean adjacent to the licensed premises, to determine:

c) *presence of water quality disturbances; and*

d) *any changes to representative natural biological communities, with an 80% certainty of detecting any such changes should any be present*.

The design of the EIMP for the Project, prepared by Gassman Development Perspectives Pty Ltd (Gassman), requires that sediment and macroinvertebrate monitoring is conducted on an annual basis. This report provides a summary of sediment and macroinvertebrate monitoring conducted during October 2020.

Pacific Reef Fisheries (Aust) Pty Ltd

Alva Beach Sediment EIMP Report 2020

Figure 1: Project location

Legend

- Populated places

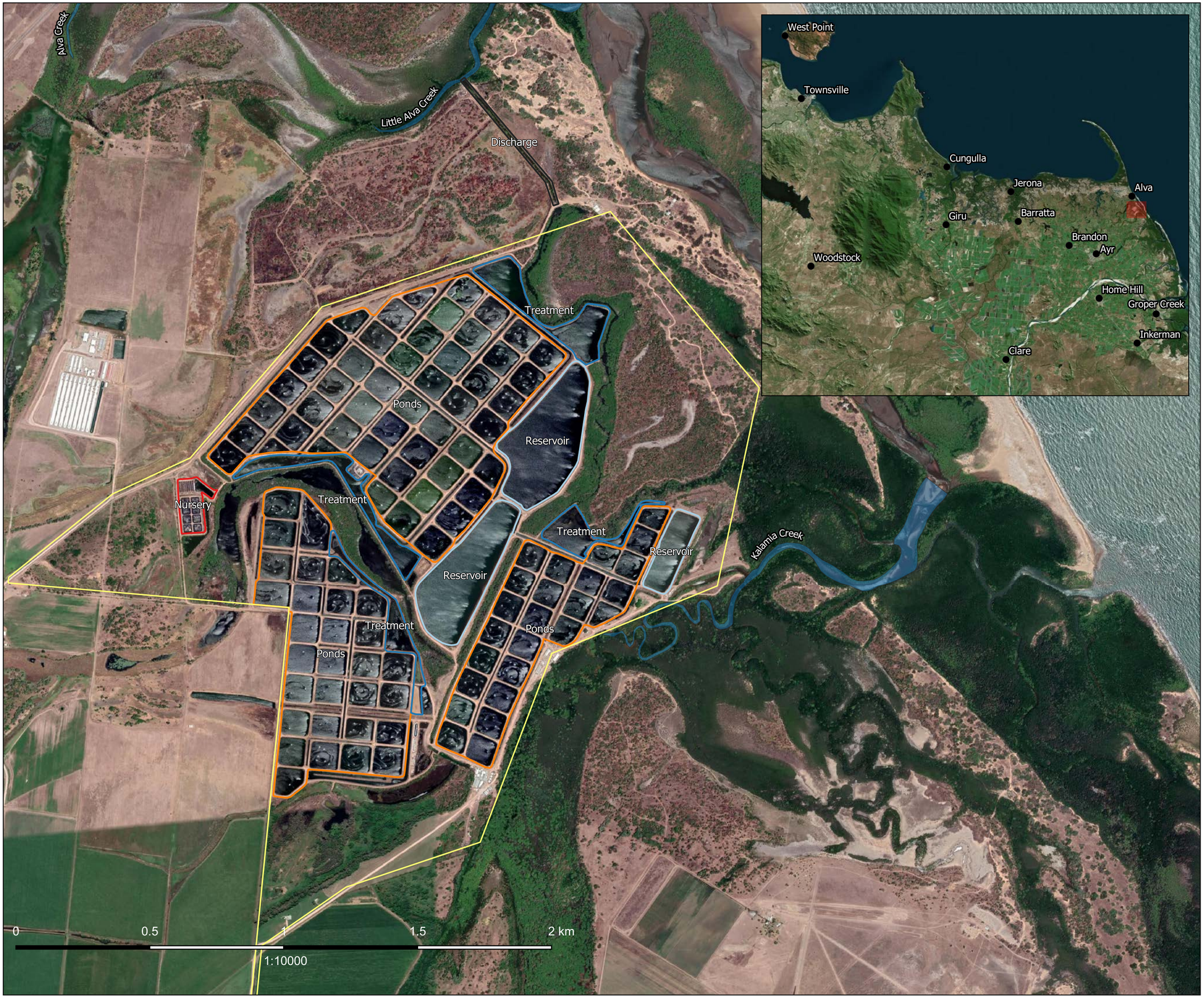
Land parcel

Project layout

- Discharge
- Nursery
- Ponds
- Reservoir
- Treatment

Job Number: JW201321
Coordinate reference system: WGS 84
Date: November 2020

WILD environmental



2. Methodology

Sediment and macroinvertebrate monitoring was conducted around the daytime high tide on 15 October 2020, two (2) days before a new moon. The Alva Beach weather station (Station 033295) did not record any precipitation on 15 October; however, a total of 4.6 mm was recorded between 12 and 14 October, inclusive. Wind speeds during the sampling event were low, with 15 km/h winds from the southeast recorded at 9 am.

Sampling was conducted in accordance with the approved EIMP prepared by Gassman at two (2) control sites associated with Little Alva Creek (B and C), and two (2) potentially impacted sites associated with Alva Creek (E and F) (Table 1, Figure 2). At each location, three (3) subsamples were collected in a line transect across the mouth of the creek, i.e. two (2) subsamples from each bank and one (1) subsample from the middle of the channel. Numerical nomenclature of the subsamples progressed from 1 to 3 in an east to west direction at each sampling location specified within the EIMP design documentation. Sediment samples were collected by a 1 litre stainless steel Ponar gab that was deployed twice at each subsampling location. Samples were collected for the analysis of:

- total organic carbon;
- particle size distribution;
- species composition of macroinvertebrates; and
- abundance of macroinvertebrates.

Table 1. Sampling locations

Site	Description	Latitude	Longitude
Potential Impact			
B	Little Alva Creek mouth	19.46540° S	147.49000° E
	B1	*19.46598° S*	*147.49019° E*
	B2	*19.46593° S*	*147.49002° E*
	B3	*19.46586° S*	*147.48992° E*
C	Little Alva Creek mixing zone	19.46510° S	147.49160° E
	C1	*19.46516° S*	*147.49174° E*
	C2	*19.46523° S*	*147.49145° E*
	C3	*19.46535° S*	*147.49215° E*
Control			
E	Alva Creek mouth	19.46320° S	147.48700° E
	E1	*19.46298° S*	*147.48753° E*
	E2	*19.46304° S*	*147.48737° E*
	E3	*19.46275° S*	*147.48720° E*
F	Alva Creek mouth mixing zone	19.46160° S	147.49000° E
	F1	*19.46236° S*	*147.48858° E*
	F2	*19.46179° S*	*147.48911° E*
	F3	*19.46208° S*	*147.49048° E*

Sediment samples for physicochemical parameter analysis were stored on ice in the appropriate containers provided by the National Association of Testing Authorities (NATA) certified analysing laboratory (Australian Laboratory Services (ALS) Environmental) (Table 2).

Particle size distribution analysis was conducted by ALS Environmental in Townsville using an in-house methodology referenced to AS 1289.3.6.1 – 2009. Determination of the particle size of distribution of a soil – Standard method of analysis by sieving. Analysis of the total organic carbon content incorporated with the collected sediments was also determined by ALS Environmental in Townsville using the in-house methodology C-IR17. Samples were dried, pulverised, reacted with acid to remove inorganic carbonates and combusted in a furnace with strong oxidants/ catalysts. Carbon dioxide, formed by the organic carbon present in the sample, was then quantified by an infra-red detector.

Sediments collected for benthic macroinvertebrate identification were transferred through a 500 µm sieve and gently rinsed with site water at the Alva Beach foreshore. The retained material was composited and preserved in 70% ethanol for laboratory-based identification of macroinvertebrate species by a taxonomic specialist. Removal of macroinvertebrates from any remaining sediment matrix (i.e. sediment particles >500 µm in diameter) was conducted through a 20-minute timed pick. This methodology is adapted from that associated with freshwater macroinvertebrate monitoring and is designed to ensure that sufficient individuals are captured for identification when a large ratio of sediment to biota is retained following sieving.

Table 2. Sample containers

Analyte	Container
Total organic carbon	250 ml solvent washed, acid rinsed glass jar with a Teflon lined lid.
Particle size distribution	Plastic bag to hold a minimum of 500 g sample.
Macroinvertebrates species composition and abundance	Plastic bag/ plastic jar containing 70% ethanol.

Pacific Reef Fisheries (Aust) Pty Ltd

Alva Beach Sediment EIMP Report 2020

Figure 2: Sampling locations

Legend

- Populated places
- Land parcel

Sediment sampling sites

- Control
- Potential impact

Job Number: JW201321
Coordinate reference system: WGS 84
Date: November 2020

WILD environmental

3. Results

3.1 Particle size distribution

No sites were identified to contain sediment particles greater than 9.5 mm (Table 3), with only two (2) subsamples at Site B (B2 and B3, located at the mouth of Little Alva Creek), containing sediments greater than 4.75 mm in diameter. All sites indicated a trend of decreased percentage abundance with increasing particle size (Table 3).

Sediments collected from the three (3) subsamples at Site B contained the highest concentration of fine particles, classified as <75 µm, with percentage compositions reported at greater than 10% (Table 4). However, all sites were dominated by sand particles (75 µm–2 mm) with gravel (2 mm–6 cm) comprising less than 5% of the sediment analysed (Table 4).

Table 3. Sediment particle size distribution

Particle Sizing	B1 (%)	B2 (%)	B3 (%)	C1 (%)	C2 (%)	C3 (%)	E1 (%)	E2 (%)	E3 (%)	F1 (%)	F2 (%)	F3 (%)
+75 µm	55	89	86	97	95	98	98	98	94	98	94	97
+150 µm	50	85	84	97	94	98	97	98	91	97	86	96
+300 µm	41	74	73	77	76	78	70	77	64	75	63	82
+425 µm	24	54	51	30	30	30	34	36	35	33	29	46
+600 µm	11	31	26	6	6	6	11	11	11	11	9	14
+1180 µm	2	7	6	<1	<1	<1	<1	<1	<1	<1	2	2
+2.36 mm	<1	3	2	<1	<1	<1	<1	<1	<1	<1	1	<1
+4.75 mm	<1	1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1
+9.5 mm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
+19.0 mm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
+37.5 mm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
+75.0 mm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table 4. Sediment classification

Particle Sizing	B1 (%)	B2 (%)	B3 (%)	C1 (%)	C2 (%)	C3 (%)	E1 (%)	E2 (%)	E3 (%)	F1 (%)	F2 (%)	F3 (%)
Fines (<75 µm)	45	11	14	3	5	2	2	2	6	2	6	3
Sand (75 µm – 2 mm)	54	85	82	97	95	98	98	98	94	98	93	96
Gravel (2 mm – 6 cm)	1	4	3	<1	<1	<1	<1	<1	<1	<1	1	1
Cobbles (>6 cm)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

3.2 Total organic carbon

Total organic carbon (TOC) concentrations ranged from below laboratory detection limits (i.e. <0.02%, subsample E1) to 1.28% recorded at subsample B1 (Table 5). The highest concentrations of organic carbon were consistently recorded at Site B (0.24–1.28%), located at the mouth of Little Alva Creek. However, these concentrations were reduced within the downstream mixing zone characterised at Site C (0.02–0.07%). Concentrations at the relative control locations within Alva Creek were comparable between the creek mouth (Site E, <0.02–0.09%) and downstream mixing zone (Site F, 0.03–0.13%).

Table 5. Total organic carbon

Particle Sizing	B1	B2	B3	C1	C2	C3	E1	E2	E3	F1	F2	F3
TOC (%)	1.28	0.24	0.70	0.04	0.07	0.02	<0.02	0.03	0.09	0.03	0.13	0.07

3.3 Benthic macroinvertebrates

Following the identification of benthic macroinvertebrates for each subsample, the results were composited to provide a representation of each of the four (4) sites assessed (Table 6). Overall, 500 individuals were identified belonging to 30 different taxa: nine (9) Gastropoda families; seven (7) Bivalvia families; six (6) Polychaeta families; two (2) Amphipoda families; one (1) Decopoda family; one (1) Isopoda family; one (1) Tanaidacea family; one (1) Echinoidea family; one (1) Brachiopoda family and one (1) Nemertinea family.

Table 6. Macroinvertebrate taxonomic composition and abundance

Phylum/Subclass	Order/Class	Family/Order	B	C	E	F
Annelida	Polychaeta	Capitellidae		1		
Annelida	Polychaeta	Magelonidae				1
Annelida	Polychaeta	Nephtyidae	4			1
Annelida	Polychaeta	Nereididae				2
Annelida	Polychaeta	Paraonidae				1
Annelida	Polychaeta	Polychaeta*	4			
Crustacean	Amphipoda	Corophiidae	1			
Crustacean	Amphipoda	Melitidae				1
Crustacean	Decopoda	Alpheidae				2
Crustacean	Isopoda	Corallanidae		4	15	5
Crustacean	Tanaidacea	Tanaid				1
Echinodermata	Echinoidea	Echinoidea				1
Mollusca	Bivalvia	Arcidae	1			
Mollusca	Bivalvia	Cardiidae	1			
Mollusca	Bivalvia	Mactridae	5	18	4	51
Mollusca	Bivalvia	Mytilidae	1			2
Mollusca	Bivalvia	Pharidae	1			
Mollusca	Bivalvia	Tellinidae	141	114	32	21
Mollusca	Bivalvia	Veneridae	2			

Phylum/Subclass	Order/Class	Family/Order	B	C	E	F
Mollusca	Brachiopoda	Linguloidea				1
Mollusca	Gastropoda	Cerithiidae	3	1		1
Mollusca	Gastropoda	Conidae				1
Mollusca	Gastropoda	Gastropod*	1			
Mollusca	Gastropoda	Haminoeidae				1
Mollusca	Gastropoda	Littorinidae	4	1		5
Mollusca	Gastropoda	Nassaridae		1		2
Mollusca	Gastropoda	Neritidae	2		1	24
Mollusca	Gastropoda	Olividae		1		
Mollusca	Gastropoda	Turritellidae	1	2	2	
Nemertea	Nemertinea	Nemertinea	7			

*Polychaeta and Gastropod damaged and excluded from richness counts.

Tellinidae were observed to be the most abundant Family across the four (4) sampling sites (308 individuals in total, equating to 61.6% of the total individuals identified). The greatest abundances were recorded at Site B at the mouth of Little Alva Creek (141 individuals) and the downstream mixing zone at Site C (114 individuals). Notably fewer individuals were associated with the Alva Creek control sampling at sites E and F, with 32 and 21 individuals recorded, respectively (Table 6). Mactridae were observed to be the second most abundant Family present, displaying a notable spatial distribution. Sampling sites associated with the mouths of Little Alva and Alva creeks contained low abundance, 5 and 4 individuals, respectively. However, within the downstream mixing zones associated with both watercourses, abundance was notably increased at 18 and 51 individuals, respectively (Table 6). Both families were the only consistent benthic macroinvertebrates to be recorded at all three (3) monitoring locations.

Table 7. Macroinvertebrate abundance and diversity 2020

Site	Abundance	Taxonomic Diversity
B	179	15
C	143	9
E	54	5
F	124	19

Abundance of individuals ranged from 54 to 179 between the four (4) sampling sites, with the greatest number of individuals observed at the mouth of Little Alva Creek (Site B), and the lowest abundance recorded at the mouth of Alva Creek (Sites E) (Table 7). Relatively similar numbers of individuals were recorded in the downstream mixing zones of both watercourses, with 143 individuals recorded at site C and 124 individuals recorded at Site F. Taxonomic diversity did not display an apparent spatial correlation, with the greatest diversity recorded at the downstream mixing zone of Alva Creek (Site F, 19 families), followed by the mouth of Little Alva Creek (Site B, 15 families). Relatively low taxonomic diversity was recorded at both sites C and E, with 9 and 5 families identified, respectively.

It should be noted that where individuals could not be identified to the Family level, they were included within the total abundance count but not within the calculation of taxonomic diversity. One (1) Polychaeta and one (1) Gastropoda specimen could not be identified down to Family level due to damage.

4. Discussion

4.1 Sediment physicochemical parameters

4.1.1 Spatial variations

Variations in sediment particle size distribution observed across the four (4) monitoring locations can be largely explained by the physical environmental conditions experienced within the receiving environment. Sites C and F are located in the downstream mixing zone of Little Alva and Alva creeks, respectively. As such, they are relatively exposed to both wind and tidal forces that provide sufficient energy to the system to maintain particle suspension within the water column. Similarly, satellite imagery of the local area suggests that Alva Creek experiences a greater flow volume and velocity when compared to Little Alva Creek, which will also aid in sediment resuspension. These higher energy sampling sites are characterised by low proportions (<10%) of fine particles within the analysed sediments, resulting in dominant composition of sand sized particles (≥93%).

Within the relatively narrow and protected mouth of Little Alva Creek, sediments collected at Site B contained the highest proportion of fine particles within the benthos (11–45%). This compositional difference from the remaining three (3) sampling locations is likely a result of reduced flow velocities associated with the relatively small watercourse of Little Alva Creek and increased shear forces associated with the interaction of riverine flow with the watercourse banks. These attributes reduce the energy of the local environment and allow finer particles to settle out of the water column into the underlying sediments. These effects were particularly apparent at the northern subsample collected from B1, which was comprised of 45% fine particles. Flow velocities are typically reduced on the inside of a meander, such as observed at B1 (Figure 2), resulting in a zone that is characterised by sediment deposition.

Spatial variability in sediment total organic carbon content mirrored the reported concentrations of fines (Figure 3), with low organic carbon concentrations recorded at sites that were characterised by low compositions of fines/ high concentrations of sand sized particles. The highest organic carbon content was recorded at the subsample site B1, at 1.28%. This location was also characterised as containing the greatest percentage of fine particles within the sediment (45%). An inverse relationship between particle size and

organic matter content has been previously documented[3,4] and is likely attributed to the larger surface area associated with smaller particles that allows for the concentration of contaminants.

The low energy environment associated with monitoring Site B may support the continued deposition of fine particles and associated elevated concentration of total organic carbon, however consideration should be given to the release of aquaculture wastewaters associated with the Project into Little Alva Creek. Within sediments associated with the mouth of the control watercourse, Alva Creek (Site E), concentrations of total organic carbon ranged between below laboratory detection limits (i.e. <0.02%) to 0.09%. These concentrations are notably lower than those observed at the mouth of Little Alva Creek (Site B), however, are consistent with the reduced proportion of fine particles within the sediments. Water quality results will be required to identify whether the release of surplus wastewaters associated with the Project's operation are impacting nutrient and fine particle concentrations within Little Alva Creek, which may then be contributing to an anthropogenic impact on the sediments.

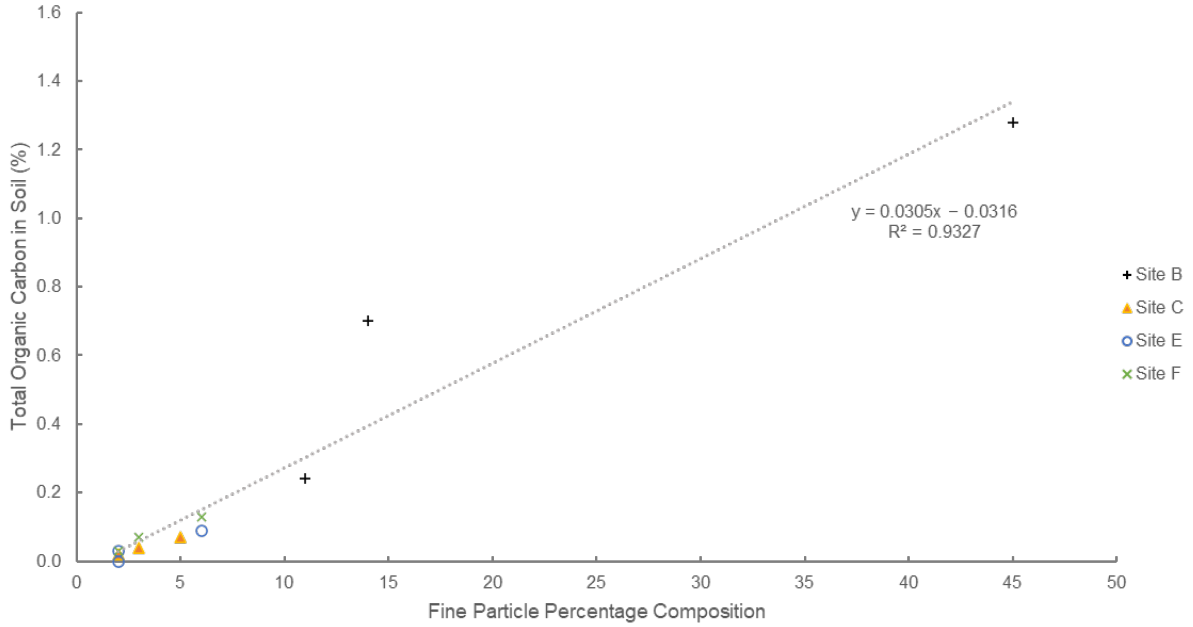


Figure 3: Total organic carbon and sediment fines composition

[3] Longbottom, M. R. 1970. The distribution of *Areicola marina* (L.) with particular reference to the effects of particle size and organic matter of the sediments. Journal of Experimental Marine Biology and Ecology. 5(2). 138–157.

[4] Thomson-Becker, E. A and Luoma, S. N. 1985. Temporal fluctuations in grain size, organic materials and iron concentrations in intertidal surface sediment of San Francisco Bay, Hydrobiologia. 129(1), 91–107.

4.1.2 Temporal variations

Wild Environmental have conducted the Project's annual EIMP sampling of sediment physicochemical parameters and macroinvertebrate community assessments for 2018, 2019 and 2020. During this timeseries, the composition of fine particles within benthic sediments at the two (2) downstream mixing zones associated with Little Alva Creek (Site C) and Alva Creek (Site F) remained relatively consistent, at ≤5% of the benthic substrate. Within Little Alva Creek, samples collected from the potentially impacted watercourse indicate a slight increase in fine sediments between 2018 and 2019, with a smaller reduction in composition from 2019 to 2020 (Figure 4). This variability was not observed within the control site (Site E) associated with Alva Creek, with the composition of fine particles displaying a decline from 16.3% in 2018 to 3.3% in 2020 (Figure 4). Such different trends between the control (Alva Creek Site E) and potentially impacted (Little Alva Creek Site B) watercourses raise questions regarding the suitability of the location of the monitoring sites associated with the Project's EIMP. A significant volume of sediments released from the Project would be required to both counteract a natural decline in fine sediment composition (as observed within Alva Creek) and result in the observed slight increase in Little Alva Creek. These volumes would be identified within the water quality monitoring component of the EIMP, and therefore it is likely that the differing patterns in sediment contribution are a result of different watercourse dynamics between Alva Creek and Little Alva Creek.

Changes in sediment-associated total organic carbon content within the control watercourse Alva Creek display a decline in concentration between 2018 and 2020 (Figure 5), consistent with observed trends in fine particle percentage composition. A reduction in the abundance of fine particles within the benthos reduces the total surface area available for the absorption of organic carbon. However, an opposing increase in sedimentary total organic carbon has been identified for the potentially impacted watercourse Little Alva Creek (Figure 5), that is not supported by a corresponding increase in fine particles (Figure 4). This discrepancy indicates that there may be a long-term increase in sediment-associated total organic carbon that cannot be explained by a natural increase in the abundance of fine particles.

Potential eutrophication of Little Alva Creek was assessed through the EIMP collected water quality data acquired from Site B (Little Alva Creek) and Site E (Alva Creek). Increases in the concentration of total nitrogen and total phosphorous within watercourses may result in increased algal growth, which upon death would settle to the sediments and increase the concentration of sedimentary organic carbon, similar to that observed in Little Alva Creek (Figure 5). However, concentrations of total nitrogen within Little Alva Creek remained relatively consistent between August 2019 and October 2020 (Figure 6). Variability in recorded total phosphorous was slightly greater, however, a similar range of concentrations was observed within the control watercourse Alva Creek (Figure 7). Based off the available data, there is little evidence to suggest that the operation of the Project is resulting in increased nutrient concentrations—and subsequent increases in organic matter—within the potentially impacted watercourse Little Alva Creek.

Despite consistent trends of increasing sediment-associated total organic carbon concentrations within Little Alva Creek, and decreasing concentrations within Alva Creek, analysis of the downstream mixing zones associated with both watercourses indicated relatively consistent organic carbon content between 2018 and 2020 (Figure 5). If wastewater release associated with the Project's operations is attributing to increased total organic carbon concentrations within the sediments of Little Alva Creek, the impact to the receiving environment is likely restricted to the potentially impacted watercourse with minimal extent into the coastline.

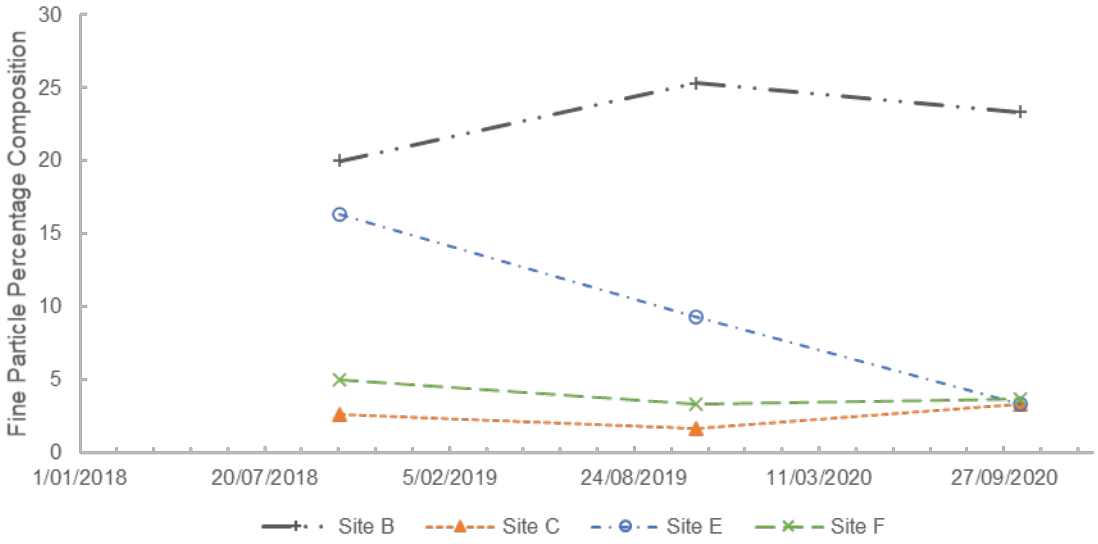


Figure 4: Fine particle percentage composition 2018–2020

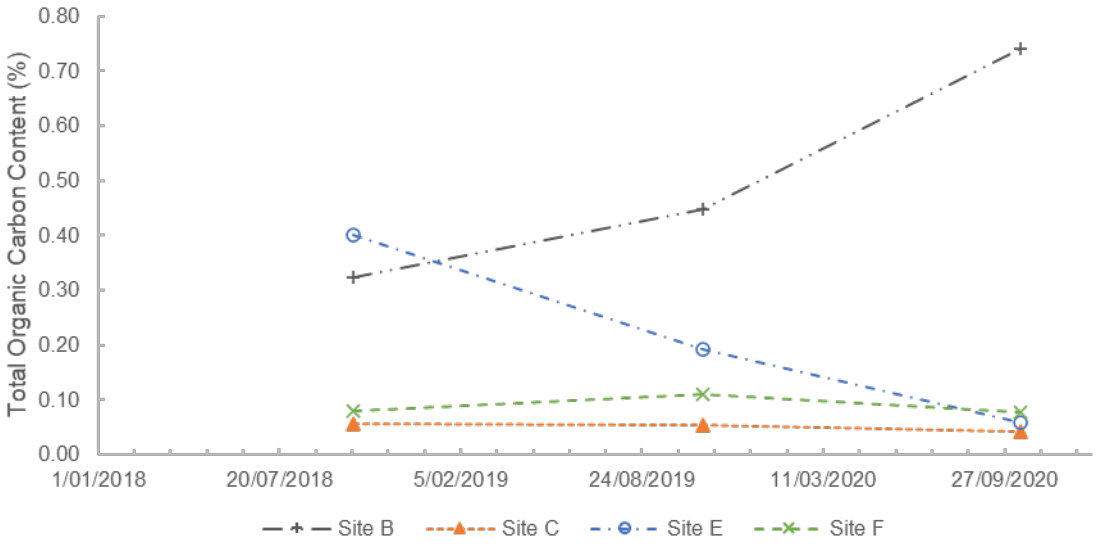


Figure 5: Total organic carbon content in sediments 2018–2020

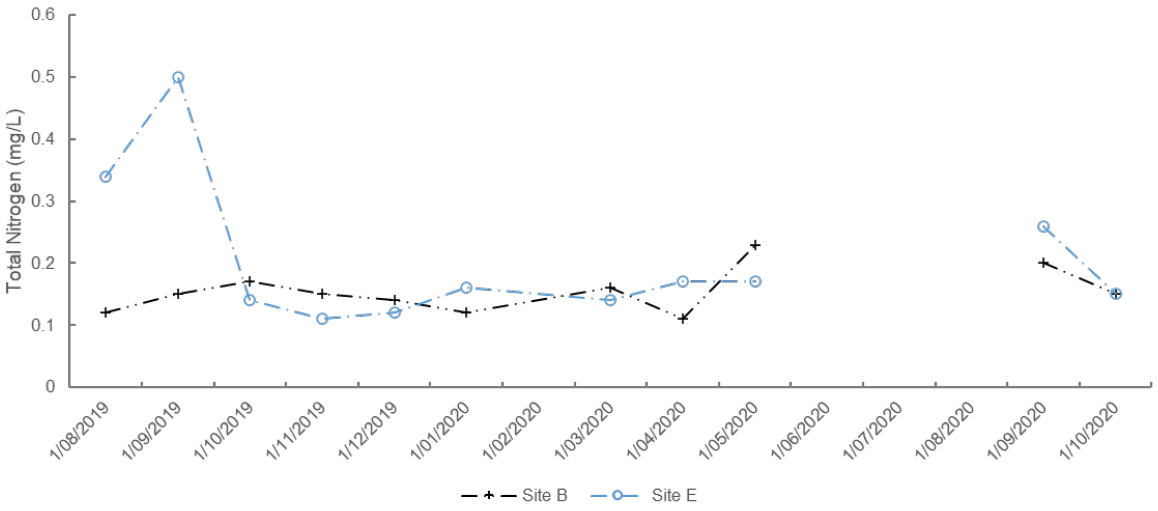


Figure 6: Total nitrogen concentrations within Little Alva Creek and Alva Creek

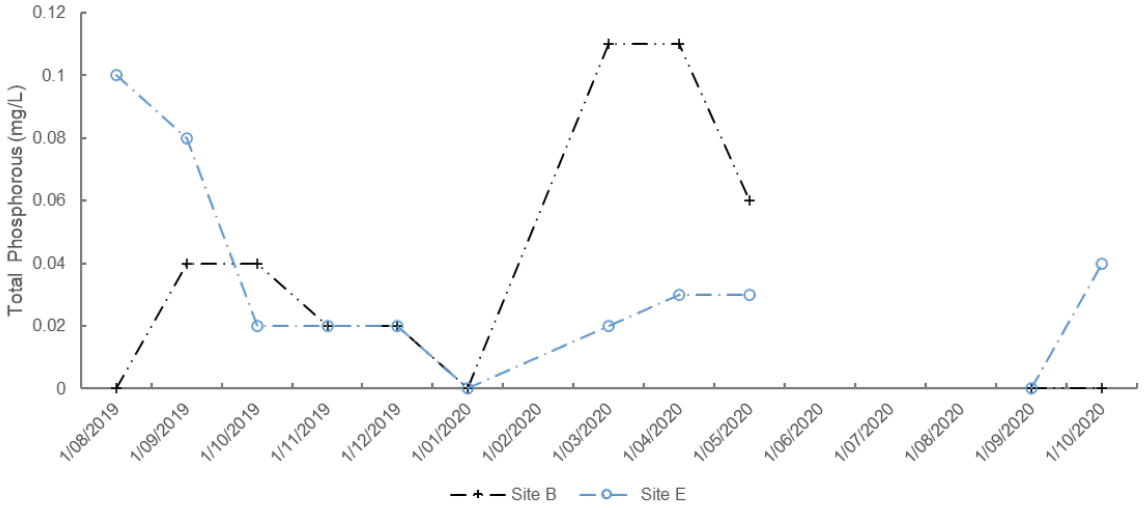


Figure 7: Total phosphorous concentrations within Little Alva Creek and Alva Creek

4.2 Benthic macroinvertebrates

Following the identification of low benthic macroinvertebrate abundance during the 2018 and 2019 assessments conducted by Wild Environmental, the sampling methodology provided by the initial EIMP design document was reviewed. Following advice from macroinvertebrate taxonomists and the identification of standardised procedures[5], the sieve size was reduced to 500 µm during the 2020 sampling (i.e. Section 2). The reduced sieve size permitted the retention of smaller individuals than during previous monitoring events, and gentle sieving within the Alva Beach foreshore enabled delicate individuals to remain in an identifiable condition. Unfortunately, this change in sampling technique does not allow a direct temporal comparison of macroinvertebrate data (Table 8). However, it should be noted that previous monitoring had not identified a spatial trend in benthic macroinvertebrate communities associated with the release of wastewater from the Project[6].

Updated sampling methods associated with benthic macroinvertebrate collection associated with the 2020 EIMP monitoring resulted in a significantly greater number of individuals collected; 500 in 2020 c.f. 69 individuals in 2019. In a similar manner, greater taxonomic diversity within the Project's receiving environment was also reported in 2020, with 30 different families identified c.f. nine (9) families in 2019. It should be stressed that these changes are likely a result of the corrected sampling technique, rather than an indication of large-scale alteration within the receiving environment.

Consistent with previous monitoring, the greatest number of individuals were collected at Site B, located at the mouth of Little Alva Creek. Relatively comparable macroinvertebrate abundance data were recorded at both downstream mixing zone monitoring sites associated with Little Alva Creek (Site C, 143 individuals) and Alva Creek (Site F, 124 individuals) suggesting a lack of impact associated with the Project's operations. Abundance was low within the control site in Alva Creek (Site E, 54 individuals), consistent with previous monitoring events.

Data collected in 2019 indicated relatively consistent taxonomic diversity (4–6 families) across all four (4) monitoring locations. Following the updated sampling techniques, taxonomic diversity increased at all monitoring locations, although this is likely an artefact of the increased number of individuals collected. No spatial relationship was observed between macroinvertebrate diversity and proximity to control/ reference watercourses. However, Site B, which contained the greatest abundance and high diversity of macroinvertebrates, was also characterised by the greatest total organic carbon content. This relationship

[5] Przeslawski, R., Berents, P., Clark, M., Edgar, G., Frid, C., Hughes, L., Ingleton T., Kennedy, D., Nichol, S., and Smith, J. Marine sampling field manual for grabs and box corers. In *Field Manuals for Marine Sampling to Monitor Australian Waters*, Przeslawski, R., Foster, S. (Eds). National Environmental Science Programme (NESP). pp. 172–195.

[6] Wild Environmental Consultants. 2019. Alva Beach Sediment EIMP Report 2019. Prepared by Wild Environmental Consultants for Pacific Reef Fisheries (Australia) Pty Ltd.

may indicate localised increased availability of food (i.e. organic material) for benthic macroinvertebrates. No apparent relationship between total organic carbon content and benthic macroinvertebrate abundance/ diversity was observed across all four (4) monitoring locations. Therefore, physicochemical parameters such as flow velocity and dissolved oxygen concentration may play a greater role in determining distributions of benthic macroinvertebrates within the Project's receiving environment.

Table 8. Long-term macroinvertebrate abundance and diversity

	1 cm Sieve				500 µm Sieve	
	2018		2019		2020	
	Abundance	Richness	Abundance	Richness	Abundance	Richness
B	40	8	17	4	179	15
C	19	6	11	4	143	9
E	21	13	6	4	54	5
F	50	13	35	6	124	19

5. Conclusions

Sediment-based environmental monitoring, as part of the Project's EIMP, was completed during October 2020. Sediment samples were collected with a 1 litre stainless steel benthic Ponar grab deployed from a vessel at four (4) monitoring sites. Samples were collected for the determination of total organic carbon content, particle size distribution and macroinvertebrate abundance and composition analyses. Within each monitoring location, three (3) replicate samples were collected progressing from bank to bank across each watercourse.

Total organic carbon and particle size distribution were analysed at the NATA accredited laboratory ALS Environmental. Sediments across the sampling area were predominately defined as sand, i.e., 75 µm–2 mm. The highest concentration of fine particles (<75 µm diameter) was observed at the mouth of Little Alva Creek, which is likely a reflection of the relatively protected location of the site and expected low flow velocities that allow fine particles to settle out of the water column. Elevated concentrations of total organic carbon were also recorded at Little Alva Creek, indicating a long-term increase over the 2018, 2019 and 2020 monitoring events. This pattern was not apparent within particle size data, and as such cannot be attributed to an increased composition of fine particles within the local sediments. A comparison against water quality data associated with the Project's EIMP did not identify potential eutrophication (nutrient enrichment) of Little Alva Creek associated with the release of wastewaters associated with the Project.

Following the identification of limited numbers of benthic macroinvertebrates during previous EIMP assessments, the sampling was updated to reflect the current 'best practice' methodology. A reduction in the sieve mesh size from 1 cm to 500 µm resulted in a significant increase in both the number of individuals collected and the determined taxonomic diversity. These apparent increases should be considered a reflection of improved sampling practices rather than a large-scale ecological change across the receiving environment. However, despite these updates, a similar relationship of high macroinvertebrate abundance within Little Alva Creek and limited abundance within the control watercourse Alva Creek was once again observed. Further assessment of benthic macroinvertebrates using the updated sampling methodology in 2021 will be beneficial in determining changes to the local macroinvertebrate community.

6. ALS Laboratory Data

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ET2004040**	Page	: 1 of 5
Client	: **WILD ENVIRONMENTAL**	Laboratory	: Environmental Division Townsville
Contact	: JAMES SADLER	Contact	: Joy Morgan
Address	: Suite 1, Level 4 75 Denham Street TOWNSVILLE QLD 4810	Address	: 13 Carlton Street, Kirwan Townsville QLD Australia 4814
Telephone	: ----	Telephone	: +61 7 4773 0030
Project	: JW191257 Alva Beach Sediments	Date Samples Received	: 15-Oct-2020 14:10
Order number	: -	Date Analysis Commenced	: 26-Oct-2020
C-O-C number	: 14909	Issue Date	: 27-Oct-2020 17:09
Sampler	: JAMES SADLER		
Site	: PRF Alva Beach 2020		
Quote number	: TV/111/19		
No. of samples received	: 12		
No. of samples analysed	: 12		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Methods EA150 & EP003 conducted by ALS Brisbane, NATA Site No. 818.
- All analysis will be conducted by ALS Environmental, Brisbane, NATA accreditation no. 825, Site No. 818.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results.

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	Site B 1	Site B 2	Site B 3	Site C 1	Site C 2
			Client sampling date / time	15-Oct-2020 08:40	15-Oct-2020 08:40	15-Oct-2020 08:40	15-Oct-2020 08:50	15-Oct-2020 08:50
Compound	CAS Number	LOR	Unit	ET2004040-001	ET2004040-002	ET2004040-003	ET2004040-004	ET2004040-005
				Result	Result	Result	Result	Result
EA150: Particle Sizing								
+75µm	----	1	%	55	89	86	97	95
+150µm	----	1	%	50	85	84	97	94
+300µm	----	1	%	41	74	73	77	76
+425µm	----	1	%	24	54	51	30	30
+600µm	----	1	%	11	31	26	6	6
+1180µm	----	1	%	2	7	6	<1	<1
+2.36mm	----	1	%	<1	3	2	<1	<1
+4.75mm	----	1	%	<1	1	2	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	45	11	14	3	5
Sand (>75 µm)	----	1	%	54	85	82	97	95
Gravel (>2mm)	----	1	%	1	4	3	<1	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	1.28	0.24	0.70	0.04	0.07

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	Site C 3	Site E 1	Site E 2	Site E 3	Site F 1
			Client sampling date / time	15-Oct-2020 08:50	15-Oct-2020 08:20	15-Oct-2020 08:20	15-Oct-2020 08:20	15-Oct-2020 11:39
Compound	CAS Number	LOR	Unit	ET2004040-006	ET2004040-007	ET2004040-008	ET2004040-009	ET2004040-010
				Result	Result	Result	Result	Result
EA150: Particle Sizing								
+75µm	----	1	%	98	98	98	94	98
+150µm	----	1	%	98	97	98	91	97
+300µm	----	1	%	78	70	77	64	75
+425µm	----	1	%	30	34	36	35	33
+600µm	----	1	%	6	11	11	11	11
+1180µm	----	1	%	<1	<1	<1	<1	<1
+2.36mm	----	1	%	<1	<1	<1	<1	<1
+4.75mm	----	1	%	<1	<1	<1	<1	<1
+9.5mm	----	1	%	<1	<1	<1	<1	<1
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	2	2	2	6	2
Sand (>75 µm)	----	1	%	98	98	98	94	98
Gravel (>2mm)	----	1	%	<1	<1	<1	<1	<1
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.02	<0.02	0.03	0.09	0.03

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Client sample ID	Site F 2	Site F 3	----	----	----
			Client sampling date / time	15-Oct-2020 08:02	15-Oct-2020 08:02	----	----	----
Compound	CAS Number	LOR	Unit	ET2004040-011	ET2004040-012	--------	--------	--------
				Result	Result	----	----	----
EA150: Particle Sizing								
+75µm	----	1	%	94	97	----	----	----
+150µm	----	1	%	86	96	----	----	----
+300µm	----	1	%	63	82	----	----	----
+425µm	----	1	%	29	46	----	----	----
+600µm	----	1	%	9	14	----	----	----
+1180µm	----	1	%	2	2	----	----	----
+2.36mm	----	1	%	1	<1	----	----	----
+4.75mm	----	1	%	<1	<1	----	----	----
+9.5mm	----	1	%	<1	<1	----	----	----
+19.0mm	----	1	%	<1	<1	----	----	----
+37.5mm	----	1	%	<1	<1	----	----	----
+75.0mm	----	1	%	<1	<1	----	----	----
EA150: Soil Classification based on Particle Size								
Fines (<75 µm)	----	1	%	6	3	----	----	----
Sand (>75 µm)	----	1	%	93	96	----	----	----
Gravel (>2mm)	----	1	%	1	1	----	----	----
Cobbles (>6cm)	----	1	%	<1	<1	----	----	----
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.13	0.07	----	----	----