Why salmon farming should be removed from Long Bay

A MULTIPLE LINES OF EVIDENCE SCIENCE REVIEW

July 2023

Long Bay is not a suitable location for salmon or other finfish farming. It is strongly recommended that the current operations be removed from the bay, that the current Environmental and Marine Farming Licenses not be renewed, and that the Tasman Marine Farm Development Plan be modified to exclude finfish aquaculture as a permissible use at this lease.

ABOUT THE TASMANIAN INDEPENDENT SCIENCE COUNCIL

The Tasmanian Independent Science Council (TISC) is dedicated to science-based policy reform to ensure the long-term health of Tasmania's environment. The Council includes scientists and professionals who provide independent, non-government advice, focusing on policy reforms of significant State interest. We seek to inform public debate and influence legislative reform to improve outcomes for terrestrial, freshwater and marine ecosystems.

This report was prepared by Christine Coughanowr with input from and on behalf of the TISC.

SUMMARY

Of all the nearshore salmon aquaculture operations in Tasmania, Tassal's lease at Long Bay (#055) is one of the worst-situated with respect to the risk of environmental impacts.

Long Bay is not a suitable place for salmon aquaculture for the following reasons:

- Long Bay is a narrow, shallow, poorly flushed embayment.
- Long Bay is an area of high biodiversity, including seagrass beds and fringing temperate reefs.
- Long Bay is an important area for recreational fishing and other community uses with diverse habitats, good shelter and ease of access.

If the current IMAS Marine Spatial Planning tool (LaCharite et al, 2021) were applied to this lease, it would not be considered suitable for finfish aquaculture based on multiple physical, ecological and socio-economic criteria.

Intensive open-pen salmon farming commenced in Long Bay starting in 2017/18 and has resulted in serious eutrophication, as demonstrated by severe and persistent algal blooms, water pollution (including low oxygen levels), seagrass loss, and degradation of temperate reefs. This damage has been repeatedly highlighted by the community and the media, and further evidence is documented in over a dozen studies of the system by consultants, the EPA and IMAS. The primary source of nutrient pollution is clearly the salmon farm, as demonstrated by a basic nutrient loading assessment, provided in this report.

This report reviews the various research and monitoring reports published to date and confirms both the presence and source of eutrophication in Long Bay based on multiple lines of evidence. The salmon farm is clearly the primary source, accounting for over 90% of the bioavailable nitrogen to the Bay. The salmon farm has also experienced various disease incidents, elevated mortalities and fish escapes over the past five years and has been the subject of noise and light complaints. In October 2022, a petition signed by nearly 1300 people was tabled in Parliament asking that salmon farming operations be removed from Long Bay.

On 30 November 2023, the current Environmental License (9959/3) for the Long Bay finfish lease is due to expire. Based on the evidence of environmental harm and nuisance presented in this report, this License should not be renewed.

In summary, as demonstrated by multiple lines of evidence detailed in the following pages, Long Bay is not a suitable location for salmon or other finfish farming. It is strongly recommended that the current operations be removed from the bay, that the current Environmental and Marine Farming Licenses <u>not</u> be renewed, and that the Tasman Marine Farm Development Plan be modified to exclude finfish aquaculture as a permissible use at this lease.



The problem with open-pen salmon farming in Tasmania's nearshore waters

- Installation of nets and other infrastructure reduces water circulation, particularly where the bases of salmon pens are located near the sea bed.
- Fish excretia, uneaten food and net-cleaning operations (removal of biofouling) pollute coastal waters with organic and nutrient pollution.
- When too many salmon are grown in areas with limited flushing, this pollutes sediments in the vicinity of the pens and also causes algal blooms that reduce water clarity and smother nearby seagrass beds and reefs.
- Pens have become larger over time and there is no regulatory limit on the number of pens or tonnage of fish that can be grown on a given lease.

A short history of salmon farming in Long Bay

Starting in 1986, small-scale salmon farming was carried out in Long Bay using relatively small pens. This was controversial even at that time, with concerns raised about pollution, and the pens were removed in 2005.

Twelve years later, Tassal re-commenced operations in Long Bay at a much larger scale. Pre-development surveys largely focused on the presence/absence of EPBC-listed species, and baseline water quality surveys did not include sites in poorly flushed areas to the north of the lease. No detailed habitat mapping, environmental impact studies or carrying capacity assessment were done.

Tassal installed 14 large pens in the bay in 2017/18 and proceeded to grow salmon to full harvest size. In 2018/19 the number of pens increased to 16 and operations shifted to smolt grow-out, with the intermediate-sized fish transferred on to the Okehampton lease. Massive filamentous algal blooms occurred in the bay starting in 2018 and have persisted since then. Degradation and loss of seagrass beds have also been observed during this time.

Salmon are grown in the bay during spring and summer months, when the bay is most vulnerable to eutrophication. There is no public information provided about the tonnage of fish grown in the bay, and there are no biomass, feed or nitrogen limits set in the environmental license. The Tasman Marine Farm Development Plan allows for a stocking density of up to 15 kg of salmon/cubic meter.

Tassal also operate a desalination plant to produce freshwater for bathing, to augment local supplies. This plant produces a concentrated brine that is discharged directly to the bay. The volume, quality and impacts of this effluent is not monitored and is unknown. The large volumes of freshwater water used to bathe fish for disease control are also released to the bay with no monitoring or regulation.

The lease has experienced at least one significant fish escape (2018) and at least one significant episode of disease and mortality (2021); others may have also occurred but are not required to be publicly reported. The cause of these mortality events and the possible use of antibiotics have not been reported.

IMPACTS OF SALMON FARMING IN LONG BAY:
A Multiple Lines of Evidence review

1. Reduced water circulation and flushing

The double row of 16 large pens installed at the head of Long Bay extend across nearly half of the bay entrance and act as a barrier to water circulation. These nets also extend to a depth of more than 10 metres (in an area with water depths of 10 to 20 m) and thus have a further baffling effect on tidal flushing. The reduction in current speeds increases sedimentation and reduces the ability of the bay to clean itself out, even without the added pollution from the salmon operations. See ***Appendix A*** for a map and photo showing the lease extent.

2. High nutrient loading

Poorly flushed coastal bays are highly sensitive to nutrient pollution. Each of the 120m circumference pens at the Long Bay lease is permitted to hold up to 15 kg of fish per cubic meter. If fully stocked, each pen could produce the equivalent bioavailable nitrogen pollution (DIN) as the sewage from a town of about 5000 people. As such, 16 fully stocked pens could potentially discharge the equivalent nutrient pollution of up to 80,000 people. While this stocking rate may be unlikely, it is nonetheless permitted under current license conditions. Even using a lower stocking rate (10 kg/m3) over a period of 6 months could generate the equivalent nitrogen pollution of more than 25,000 people. See ***Appendix B*** for calculations.

While claims have been made that aquaculture is just one of multiple sources of nutrient pollution, the salmon pens in Long Bay lease are by far the largest source. A catchment-based analysis of the full range of nutrient inputs was undertaken, including fish farming, sewage from domestic and commercial sources (including the Port Arthur Historic Site), forestry and other land use activities. The resulting nitrogen budget indicates that the Long Bay fish farm contributes at least 90% of the annual bioavailable nitrogen load. See ***Appendix C*** for details.

3. Severe and persistent nuisance algal blooms

The first grow-out cycle in 2017/18 grew salmon to full size and resulted in severe filamentous algal blooms across large areas of the bay. Despite the shift to smolt grow-out in subsequent years, the algal blooms have persisted as documented by photos collected by concerned community members over the past 5 years. These blooms have fouled both fringing reefs and seagrass beds, blocking sunlight and entangling seaweed. At times, huge rafts of rotting algae have also washed up along the foreshore. See ***Appendix D*** for photos.

In response to community complaints, the EPA commissioned IMAS scientists to investigate the nuisance algal blooms in Long Bay (White et al, 2022). Rapid Visual Assessment (RVA) surveys were undertaken at 15 sites on reef ecosystems across the bay, as well as at reference sites at Fortescue Bay and Port Arthur in January and June of 2021. This survey was repeated in 2022, with similar findings (pers comm C White, 2022). The studies confirmed that reefs adjacent to the lease, and in the poorly flushed areas of Long Bay to the north of the lease. showed extensive signs of eutrophication, including the proliferation of nuisance, epiphytic and filamentous algae and a lower reef canopy cover. These impacts were shown to be persistent, without the typical seasonal recovery that normally occurs in other regions. The report attributed the blooms to a combination of nutrient inputs and differential wave exposure. While the salmon farm was identified as an important source, the study did not undertake an assessment of other nutrient sources, nor did it consider the likely reduction in wave exposure associated with the double row of salmon cages installed at the head of the bay.

Samples of macroalgae were also collected for stable isotope analysis, to help identify the likely sources of nutrients. The analysis of nitrogen isotopic ratios confirmed that aquaculture inputs were an important source of nitrogen enrichment to Long Bay, with a clear gradient observed between the lease and more distant sites during January, when the lease was stocked. This gradient was not observed in June after the lease had been fallowed. The report concludes with the statement: '*…the patterns observed highlight the susceptibility of low-exposure sites to nutrients, regardless of the source*', confirming that Long Bay is a poor choice for activities with high nutrient discharges such as finfish aquaculture.

4. Degradation and loss of seagrass beds

Concerns about visible degradation of seagrass beds in Long Bay have been regularly raised by the community since salmon farming recommenced in 2017. Seagrass stabilises sediments, releases oxygen and provides essential shelter and nursery areas for recreational and commercial fisheries, including flathead and calamari. Excess nutrients, including those from aquaculture, are a well-documented cause of seagrass decline, as they stimulate both micro- and macroscopic algal growth (phytoplankton, epiphytes and macroalgae) that can reduce light availability and/or overgrow seagrass directly (e.g. Thomsen et al, 2020).

Starting in 2019, Tassal commissioned annual seagrass surveys along four transects; three in Long Bay and one at a reference site in Carnarvon Bay. The EPA subsequently added this as a condition of the Environmental License and BEMP reporting. The most recent BEMP report (Aquenal, 2022) demonstrates that seagrass cover has declined significantly along 2 of the 3 transects in Long Bay, in parallel with an increase in epiphyte fouling. This decline is most evident in the areas further from shore, suggesting that the nutrient sources is not from adjacent land areas.

5. Reduced water quality

There have been over a dozen water quality monitoring programs carried out in the Long Bay/Port Arthur region over the past 9 years, initially by Tassal and more recently (4+ years) by the EPA as well. These include:

- The Tassal monthly Tasman Region Broadscale Environmental Monitoring Program (BEMP), including 4 (now 5) sites in the Long Bay/Port Arthur region (annual, 2013 to present)
- The EPA monthly water quality monitoring (seasonal, starting in Dec 2019)
- A targeted EPA water quality study during stocked and fallow periods (24 Feb and 12 April 2022)
- EPA water quality monitoring using sensors (dissolved oxygen and phytoplankton) 2021 to 2023
- Citizen science monitoring by the Tasman Peninsula Marine Protection (occasional surveys of water clarity based on Secchi depth)

While monthly monitoring programs can provide useful baseline and regional information about water quality, this depends on the location of the sampling sites, the timing and frequency of sampling, and the parameters measured. Water quality results should be considered as one of multiple lines of evidence. Unfortunately, much of the previous monitoring was not well designed to document impacts of salmon farming operations on Long Bay for the following reasons:

- The majority of the BEMP sites are too far away to provide meaningful data particularly with respect to bioactive nutrients, which are rapidly taken up by algae and/or diluted to below standard lab detection limits. In particular, the original BEMP did not include any monitoring sites in the poorly-flushed, northern part of the Long Bay, so there is no baseline data for this area. In response to meetings with concerned local residents about the subsequent severe algal blooms, Tassal agreed to add additional monitoring sites in this area, but this data was not made public. Finally, the EPA required an additional northern site to be added to the BEMP in 2019. The EPA monthly monitoring design does include four sites in the northern Bay, but this work commenced well after the fish farm was reactivated so does not provide the necessary baseline for comparison.
- Water quality can vary widely over time scales of hours, days, seasons and years, particularly in dynamic coastal environments. As such, monthly grab samples may not be representative. For example, samples

collected on a flood tide when clean seawater is entering the system may show no evidence of pollution, and oxygen levels are typically lowest at night.

- There is too much reliance on ephemeral water quality parameters such as total ammonia nitrogen (TAN) that is rapidly removed from the water column by plants, or chlorophyll a that varies widely from day to day. Nutrient concentrations must be interpreted within the context of both phytoplankton and macroalgae dynamics. In a macroalgae- and seagrass- dominated system such as Long Bay, bioavailable nutrients are likely to be rapidly removed from the water column – particularly by opportunistic green algae. It is entirely possible to have low water column nutrient concentrations in a highly eutrophic system, particularly where there is prolific growth of opportunistic macroalgae – as is the case with Long Bay.
- There is rarely any information provided in the EPA or Tassal water quality monitoring reports about aquaculture operations at the time of monitoring (e.g. biomass, feed inputs or even stocked vs fallow periods). This makes interpretation of the data very difficult.
- The sediment monitoring design – at large distances from the leases and often several months after peak biomass – is particularly uninformative.

Even with these limitations –the **Tassal BEMP monitoring** programs has shown clear evidence of water quality degradation in the vicinity of the Long Bay lease on multiple occasions, particularly at the monitoring site closest to the lease (PA-1). High levels of TAN are frequently measured at this site when the lease is stocked, confirming that nutrient pollution extends well beyond the 30m compliance zone. Chlorophyll a has also increased at sites PA-1 and more so at PA-5, as compared to more seaward sites. This reflects increased growth of phytoplankton in response to nutrient loading. See Aquenal 2022, and previous BEMPs for details.

In response to community concerns, the **EPA** commenced independent **water quality monitoring** of Long Bay in 2019 at the sites shown in Figure 1, including surveys that spanned the salmon grow-out periods in 2020/21 and 2021/22 (the 2022/23 report has not yet been released). These surveys have also documented persistent high TAN levels in the vicinity of the lease (particularly in surface waters), as well as high chlorophyll a levels at multiple sites in the poorly flushed areas to the north of the lease. See EPA reports 2020, 2021 and 2022 for details.

In March/April 2022, the **EPA** conducted a **more intensive water quality survey** – before and after the lease was destocked. This survey found clear evidence of nutrient enrichment (TAN) in the vicinity of the lease when stocked, along with elevated microscopic algae. These nutrient indicators dissipated after the lease had been fallowed. See EPA 2022 for details.

Prompted by extreme high and low oxygen fluctuations in the bay observed during routine monitoring, the **EPA** installed **automated sensors** in the northern part of Long Bay to better understand the variation in dissolved oxygen (DO) and phytoplankton levels, and how these changed with salmon production. The sensor was located 1 km to the north of the lease at a depth of 9m (about half-way to the bottom). DO values in 2020/21 exhibited high variation with maximum values in summer of up to 160% saturation for 3 weeks in February, followed by a 10-day period in April where values dropped to about 10% saturation (see Figure 2). The high DO levels likely coincide with the rapid growth of micro and macro-algae in the bay in response to nutrient emissions, while the low levels may reflect the rapid decline and decomposition of the algae, once the source of excess nutrients has been removed. The observed low oxygen levels of <20% are particularly concerning as this could have serious impacts on bottom-dwelling fauna, particularly as DO levels are likely to have been even lower at depth. Furthermore, salmon are highly sensitive to oxygen levels, with poor feeding, increased mortality and disease likely at levels below about 50%. It is unclear if the salmon mortality events reported in 2021 were related to low oxygen levels.

Figure 1: EPA Water Quality Monitoring Locations (yellow pins= water quality; red star= DO sensor location); The Tassal BEMP has monitored Sites PA-1, PA-2,PA-3 and PA-4 (PA-5 was added in 2019**)** *Source: after EPA*

Map 1: Port Arthur monitoring locations

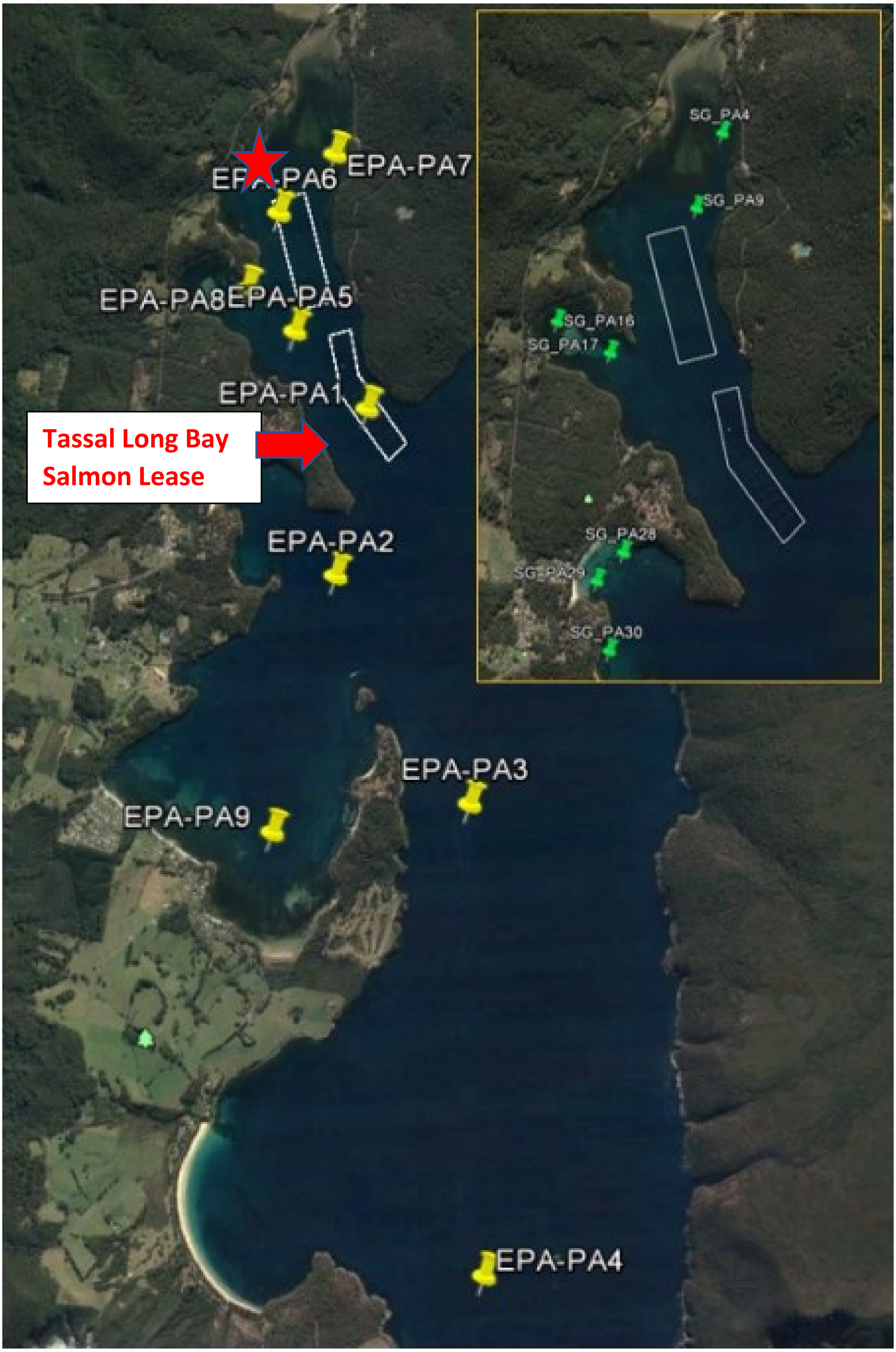

Figure 2: EPA sensor monitoring 2020 to 2021 – Dissolved Oxygen *Source: EPA 2023*

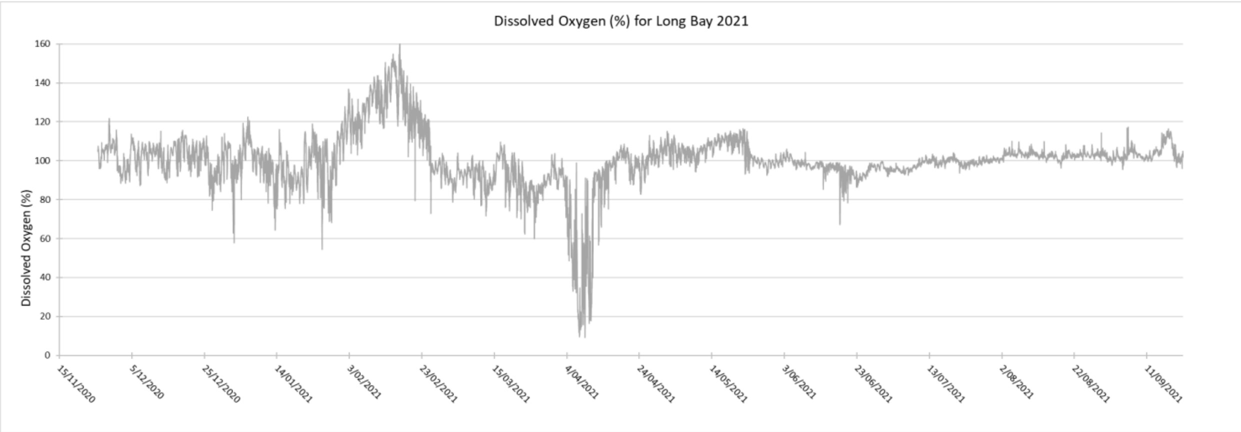

Fig 1: Dissolved oxygen in Long Bay for 2021

(Source EPA, 2023)

Unusual DO patterns were also observed in 2021-23, while the added fluorometer showed a strong phytoplankton signal associated with fish production, with chlorophyll a levels increasing above previously observed levels, in Jan/Feb 2023. This apparent trend towards eutrophication was confirmed by heavy nuisance algal growth observed by the EPA adjacent to the lease in early summer of 2022. See EPA 2023 for details.

Figure 3: EPA sensor monitoring 2021 to 2023 – Dissolved Oxygen and Chlorophyll a *Source: EPA 2023*

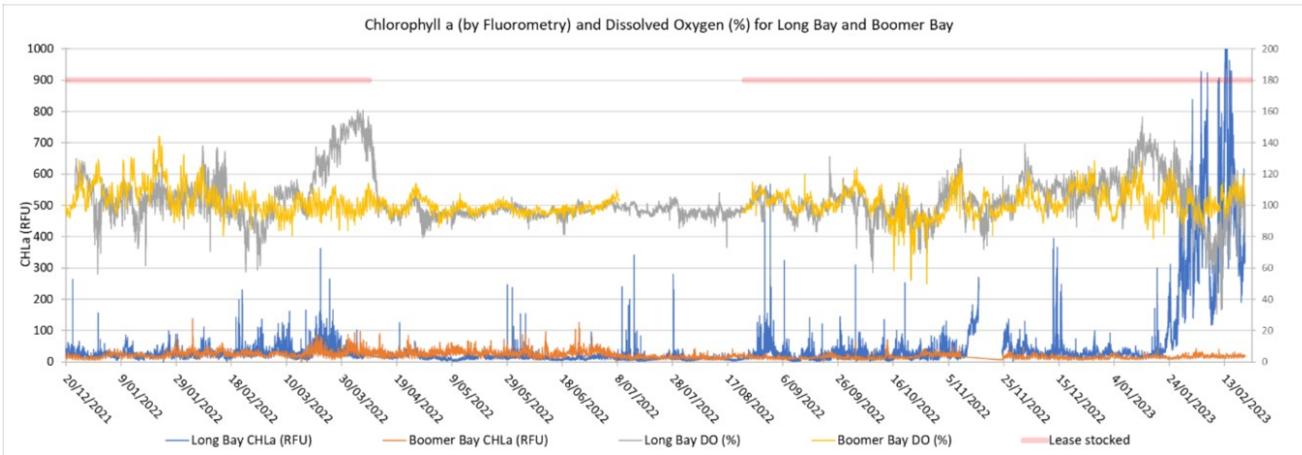

Fig 2: Dissolved oxygen and CHLa (by fluorometry) for Long Bay and Boomer Bay 2021-2022

(Source EPA, 2023)

In addition to the studies outlined above, periodic **citizen science** surveys by TPMP have also documented periods of reduced water clarity in Long Bay over the past 4 years. On multiple occasions, Secchi depth readings to the north of the lease were approximately half of the readings to the south when the pens were stocked, while there was little difference observed when the lease was fallowed.

6. Fish escapees, disease and use of antibiotics

There has been at least one significant escape of farmed salmon into Long Bay in late November 2018. This was not publicly reported by Tassal. When the issue was raised by concerned locals due to the quantity of large salmon being seen and caught, Tassal stated the number of escapees was less than 200 and was thus not reportable. Regardless of the precise number of escaped fish, the release of farmed salmon to the environment is considered to be poor practice and carries heavy fines and other consequences in most countries.

Disease outbreaks are not publicly reported and are only reported to the EPA when mortalities reach a certain level. In the summer of 2021 (Jan, Feb and possibly beyond) the Long Bay lease experienced a period of disease outbreaks and mortalities that eventually came to light by way of a media investigation (ABC, 2021) and FTI submissions (NRE, 2021). To date no information has been provided as to the disease in question, the overall mortalities, the likelihood or recurrence, and whether it could have affected native species. No information has also been provided as to whether antibiotics were used on the lease. Public information on fish escapes, disease and mortalities and use of antibiotics in public waterways is routinely provided in other salmon-farming countries and should also be standard practice in Tasmania.

7. High use of freshwater for bathing fish, and pollution by desalination brine

At most Tasmanian salmon leases, large volumes of freshwater are required to bathe fish during marine grow-out to combat amoebic gill disease. Based on net size and frequency of bathing, it is estimated that approximately 147 to 218 ML of freshwater is required for the Long Bay operations each year (see ***Appendix E*** for calculations). Of this, a maximum of 14.5ML can be provided by the existing surface water allocation (LIST Tasmania). Due to limited freshwater supplies at Long Bay, a desalination plant has been constructed on the foreshore to convert saltwater to fresh. This process also produces a hypersaline brine along with other potentially toxic chemicals, that are discharged directly to Long Bay. This activity is not regulated by the EPA and no monitoring or other information has been provided on the effluent quantity, quality or impacts on the Bay. In addition to the hypersaline and potentially toxic discharges, the desalination process filters out and destroys large numbers of larval/juvenile fish, molluscs and invertebrates, potentially reducing the productivity of Long Bay. Further assessment of the desalination operations is strongly recommended.

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APPENDIX A

LONG BAY LEASE: PHOTO, WATER DEPTHS AND PEN DIMENSIONS

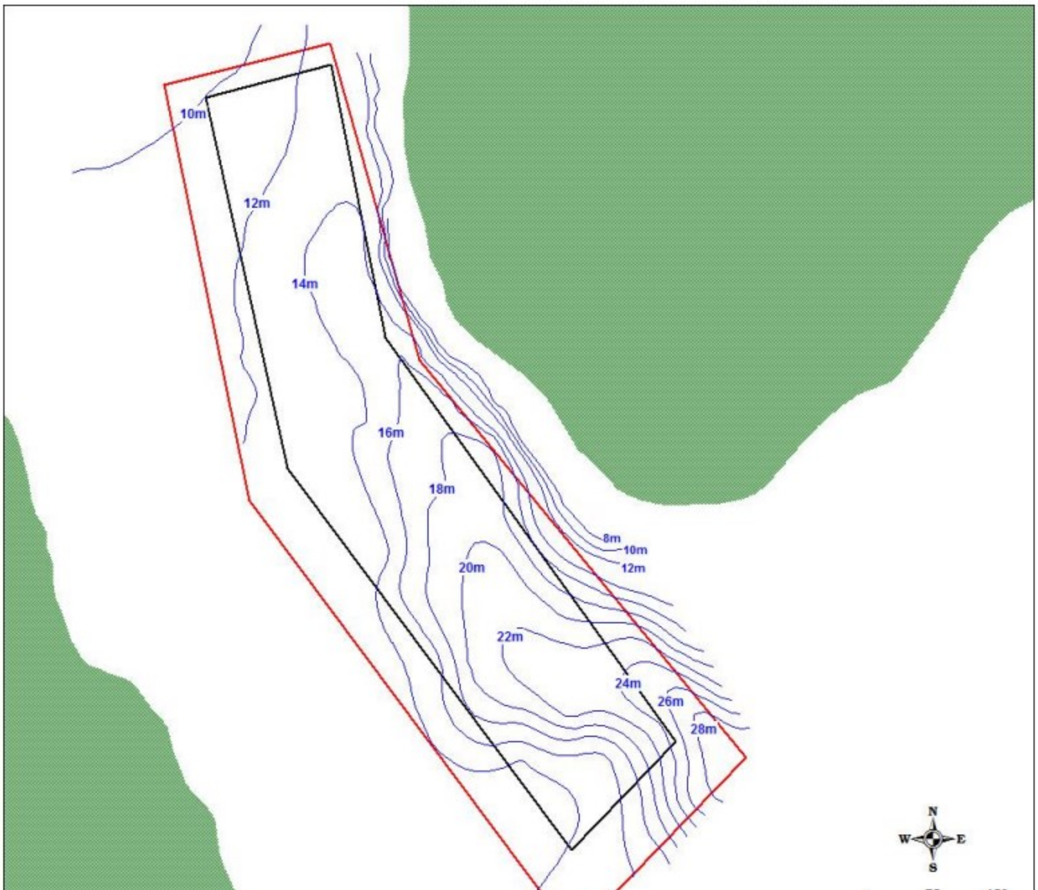


Figure 5 Bathymetric map. Contour interval = 2 m.

Source[1]: Aquenal, 2017

PEN DIMENSIONS

The estimated depth of a 120m circumference pen is assumed to be approximately 10 to 15 metres based on net dimensions and volumes as published by Tassal[2], along with specification for similar-sized infrastructure published by Huon Aquaculture[3].

- Circumference 120m
- Radius 19.1m
- Area 1146
- Volume[2] 11,600 cubic metres
- Estimated depth [2, 3] 10 to 15m 10.1m (from volume/area) (HAC brochure: 13 to 16m)

References:

1 Aquenal, 2017. MF55 Long Bay Port Arthur – Baseline Environmental Assessment
2 Tassal website – Our Operations. https://tassalgroup.com.au/our-planet/our-operations/
3 Calculated on basis of circumference and volume (above)
4 HAC – Brochure for 120m Fortress pen specifications give a depth of 13 (fish net) 16m (predator net)
https://www.huonaqua.com.au/wp-content/uploads/2017/08/Huon-Fortress-Brochure.pdf

APPENDIX B

ESTIMATED NITROGEN RELEASES FROM THE LONG BAY SALMON LEASE AS COMPARED TO EQUIVALENT NITROGEN IN HUMAN SEWAGE

Estimated Dissolved Inorganic Nitrogen (DIN) load from the Long Bay salmon farm

- There are currently sixteen 120m circumference pens located on the Long Bay lease.
- Each pen has a reported volume of 11,600 cubic meters.
- The maximum allowed stocking density in the Tasman Marine Farm region is 15 kg/cubic meter
  Thus, the maximum allowed salmon biomass per pen would be 174 tonnes/pen
- Using a conversion factor of 0.0574 tonnes of Dissolved Inorganic Nitrogen per tonne of fish, yields 10 tons of DIN per fully stocked cage.
- So the maximum DIN load for the lease, at maximum permitted capacity, would be 16 cages x 10t/cage = 160t

This is almost certainly an overestimate, since the lease shifted from 12-month full grow-out, to intermediate sized fish over a 6 to 8-month period starting in about 2018/19.

As discussed in Appendix C, a more realistic loading scenario may be a 10 kg/m3 density over a period of 6 months. This would yield 58 tonnes of fish/cage or 3.3 tonnes DIN/cage, or about 53 tonnes for the lease as a whole. See Appendix C for further discussion and references.

Estimated DIN load from human sewage

The DIN load from human sewage depends on the level of treatment. For urban populations with centralised sewerage systems and using standard sewage treatment technologies (e.g. secondary treatment) typical per capita DIN loads are about 1 kg/person/year. For rural areas that rely on septic systems, per capita DIN loads may range from 1.3 to 2.7 kg/pp/yr. See Appendix C for further discussion and references.

For the purposes of this analysis a per capita DIN loading rate of 2 kg/person/yr was used.

Human sewage equivalent DIN loading from the Long Bay lease

In summary, the human sewage equivalent of a fully stocked 120m pen at 15 kg/m3 could be as much as 5000 people, assuming a relatively poor level of sewage treatment (i.e. septic systems).

However, at Long Bay, assuming a lower stocking density of 10 kg/m3 and a 6 to 8-month production period**, the *human equivalent DIN load would probably in the order of 1650 to 2000 people per cage***.

Given that there are 16 cages on the lease, ***the DIN released from the Long Bay salmon lease could be the equivalent to the nitrogen released in sewage from a town of more than 26,400 people***.

APPENDIX C

ANALYSIS OF ANTHROPOGENIC NITROGEN INPUTS TO LONG BAY

The Long Bay catchment is relatively small, covering an area of approximately 17.5 km2[1]. The catchment is largely forested (~85%), with smaller areas of residential, commercial, conservation and agricultural uses[2]. There are several minor creeks discharging to Long Bay, the largest of which is Long Bay Creek that discharges to the head of the bay. Freshwater inputs are typically low and tend to be ephemeral.

Population densities are relatively low in this region and tend to be seasonal, dominated by holiday homes and tourism operations. There are approximately 20 dwellings located within the catchment and four main tourism venues (the Lavender Farm, Fox and Hounds Inn, Port Arthur Caravan Park, Stewarts Bay Lodge), as well as the land-based operations for Tassal - Long Bay. The Port Arthur Historic Site is located about 2 km to the south[3].

Anthropogenic Dissolved Inorganic Nitrogen (DIN) inputs to Long Bay have been calculated as follows:

1. Residential and commercial wastewater (468 kg/yr)

1.1 Residential dwellings: 50 kg/yr

There are approximately 15 to 20 private residences within the catchment [3], all of which are presumed to use septic systems for wastewater disposal. The Stewarts Bay Lodge complex includes another 35 to 40 units, however the wastewater from this site is pumped to the Port Arthur treatment system.

- It is assumed that 100% of the nitrogen discharged by septic systems to groundwater is in dissolved form.
- A typical occupancy rate of 2.5 people/dwelling was used, which is slightly higher than recent census data[4]
- It is assumed that residences are occupied a maximum of six months/year due to seasonal use

Published values for nitrogen loading from septic systems range from 1.3 to 2.7 kg per person per year. See, for example, Costa 2022[5] (1.3 to 2.7 kg per person per year), Wood, 2020[6] (citing Lerner 2000[7] (1.64 kg/p/yr) and Chilton[8] (1.75 kg/p/yr). For the purposes of this analysis, an annual per capita DIN load of 2 kg was used.

Based on the assumptions and references noted above, **the estimated annual load per dwelling is** (2 kg DIN per person x 2.5 people per dwelling, divided by 2 for seasonal use) = **2.5 kg/dwelling**

*Thus, **the estimated DIN load for residential dwellings*** in the Long Bay catchment is 20 dwellings x 2.5 kg/dwelling = **or *50 kg/yea*r**.

This figure is likely to be an over-estimate as it is based on a relatively high occupancy rate and assumes that all visible structures are habitable dwellings (some are probably sheds).

1.2 Commercial operations: 235 kg/yr

There are four major businesses located within the Long Bay catchment (the Lavender Farm, Fox and Hounds Inn, Port Arthur Caravan Park and Stewarts Bay Lodge). Wastewater from the Caravan Park and Lodge is pumped to/treated at the Port Arthur Wastewater Treatment facility, for which the DIN loads have been calculated in Section 1.3. According to the Tasman Council EHO, both the Lavender Farm and the Fox and Hounds Inn have a higher level of sewage treatment than septic systems (package treatment system and sewage treatment lagoon, respectively), however details were not readily available.

For this study, an estimate of sewage loading from commercial premises was based on the number of advertised rooms (Fox and Hounds only), plus the maximum legal seating numbers permitted in Fox and Hounds and Lavender Farm restaurants. This information was used to estimate the number of people using these commercial facilities each year, and then multiplied by the same per capita DIN loading rates used above (2 kg/pers/yr), divided by 2 for seasonal use. Further details are provided below.

Commercial premise	# Restaurant seats	# Rental units or campsites
Lavender Farm	100	0
Fox & Hounds Inn	65	28
Port Arthur Caravan Park*	na	na
Stewarts Bay Lodge*	na	na

*Wastewater treated at Port Arthur WWTP

- ***Restaurant DIN loads*** based were calculated using the maximum permitted seating number and assumed seasonal use of 6 months/year. While the total number of daily customers may exceed permitted seating limits, the wastewater produced is unlikely to exceed that of household users. As such, the estimated DIN load for restaurants is 100 + 65 = 165 people x 2 kg/pp/yr, divided by 2= ***165 kg DIN/year***.
- ***DIN loads from commercial hotel rooms*** used the same assumptions as those used for residential dwellings (i.e. 2.5 kg DIN/unit/year based on 6 months seasonal use) So 28 x 2.5 kg/dwelling/year = ***70 kg DIN/year***

The above calculations are likely to over-estimate commercial DIN loads, as activities such as bathing and laundry are not normally part of restaurant use. Also, package treatment plants and sewage lagoons would result in substantively lower DIN loads than septic systems. For example, Wood, 2020[6] reports a typical loading rate of 1.1 kg/per/year for sewage discharged from package treatment plants, and the per capita loading rate for treated sewage from the Hobart Metropolitan Area is about 1 kg/pp/yr (DEP, 2015[9]).

1.3 Port Arthur Historic Site wastewater treatment system: 113 kg/yr

The Port Arthur Historic site is by far the largest operation in the region, receiving well over 300,000 visitors in a typical year. (e.g. 357,411 visitors/year in 2018/19; PAHS Annual Report[10]). Sewage from the site, along with a number of other commercial and residential properties in the vicinity, is treated in a small-scale treatment system (sewage lagoon) that discharges treated effluent to nearshore waters, about 1.5 km to the south of the Long Bay lease. This treatment system is regulated by the EPA, and the permit details are available on the LIST website[11]. While the discharge point is relatively well-mixed, it is possible that some of the effluent plume could enter Long Bay. As such, the estimated load from the Historic Site has been calculated below, based on effluent flows and concentrations data provided by the EPA (G Napthali, EPA, 2020[11]). Specifically:

- Flows are typically less than 2ML/month
- Median ammonia and NOx concentrations were 0.92 and 8.4 mg/L, respectively (for a total DIN = 9.3 mg/L) in 2019/2020

Based on this effluent volume and concentration data, monthly DIN loading from the Historic Site WWTP was calculated as 18.6 kg/mo or 223 kg/year. If we assume that up to half of this nutrient load enters Long Bay, this would contribute **113 kg/year to the annual DIN load**.

2. Long Bay catchment (1635 kg/yr)

The Long Bay catchment is relatively small (approximately 17.5 km2) and largely occupied by forested land (~85%), with smaller areas of residential, commercial, conservation and agricultural uses[2]. A review of remote sensing imagery[3] indicates that there has been no visible forestry harvesting operations in the catchment since at least 2006. During the period from 2008 – 2011, a pasture area of ~75 ha was converted to plantation forest. Nutrient loads from the catchment were estimated using nutrient generation rates derived from relevant land uses, based on Tasmanian studies[12], as follows:

Land use	Area km	TN kg/ha	N-load kg
Forestry	8	0.89	712
Wilderness area	7	2.68	1876
Plantation	0.75	5.49	412
Mixed rural/urban	1.75	14	2450
Total	**17.5**		**5450**

It was estimated that the DIN load is 30% of the total nitrogen load, yielding an **estimated catchment DIN load of 1635 kg/year**. This is likely a conservative estimate, based on water quality monitoring data from other Tasmanian rivers. For example, the proportional DIN load in the River Derwent at New Norfolk is about 18%, on average[9].

3. Salmon aquaculture: 53,000 to 184,000 kg/year

Calculations of DIN loading from the salmon lease at Long Bay can be estimated in a number of different ways. The most accurate method would be based on the actual amount of feed used, the nitrogen content of the feed, an accurate feed conversion rate (FCR), and a number of other factors – as outlined in reports published by CSIRO[13] and IMAS[14]. However, in the absence of this information, DIN loads have been calculated based on the estimated or reported biomass of salmon grown on the lease, a feed conversion rate (FCR) of 1.35 and previously published conversion factors. Specifically, it is estimated 5% of the feed enters the environment as nitrogen, of which 85% is in dissolved form [13, 14].

Many of the criteria above date back to the early 2000s, or before, and are in urgent need of a detailed scientific review. While the EPA has recently published a document outlining the compliance methodology for compiling and allocating DIN loads[15], there is little discussion of the criteria used to calculate DIN, other than that N is taken to be 16% of the protein present in feed.

Neither the feed input nor recent biomass information for the Long Bay lease has been made publicly available. In the absence of this information, estimated DIN inputs have been calculated using several alternative methods:

Method 1: The maximum permitted loading can be calculated based on the volume of each pen, the maximum permitted stocking density and the number of pens on the lease, and the estimated DIN loading per tonne of fish. Specifically:

- The volume of a 120m circumference pen is 11,600 m3[16]
- The permitted stocking density for leases in Tasman Marine Farm Development Plan is 15 kg/m3[17]
- Based on this, the maximum biomass of salmon allowed per pen would be 174 t
- The conversion rate from salmon biomass to DIN is 0.574 t DIN per tonne of fish, based on a FCR of 1.35
- Estimated DIN produced per pen is 174 t fish x 0.574 t DIN per t of fish = 10 t DIN/cage
- Thus, the maximum estimated DIN load for the entire lease would be 10 t/cage x 16 cages = 160 t

While the above calculations are theoretically allowed under current regulations, this is almost certainly an overestimate for a site that farms smolt to intermediate-sized fish over a period of 6 to 8 months. Young fish are unlikely to be stocked at such a high density and are likely to suffer some level of mortality.

For example, at a stocking rate of 10 kg/m3 over a period of 6 months, the estimated biomass would be about 58t/cage or 928t for the lease, with a DIN load of 53t/yr

Method 2: In the past, Tassal has provided verbal information of the harvested biomass from the lease as follows.

2017/18 harvest	2682 to 3200 t *	14 cages	154 to 184 t DIN	full-sized fish
2018/19 harvest	1200 to 2000 t	14 cages	67 to 115 t DIN	mid-sized fish

**These values suggest the cages may have been stocked above the permitted density of 15 kg/m3*

Estimated DIN loads based on these figures range from 67 to 184t but would be proportionally higher with the current 16 cages. It is also unclear if these estimates were for live biomass on Heads-on-Gutted (HOG weigh approx. 15 to 20% less than live fish)

In summary, based on current permit regulations and the size and number of cages on the lease, together with previously reported biomass, ***DIN loads from the Long Bay salmon lease could range from about 53,000 to 184,000 kg/year.***

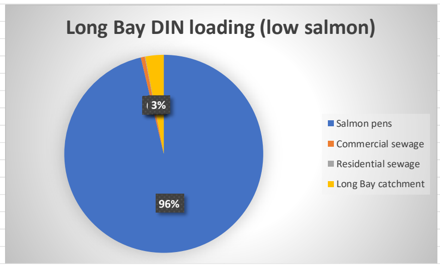
4. Summary and sensitivity analysis

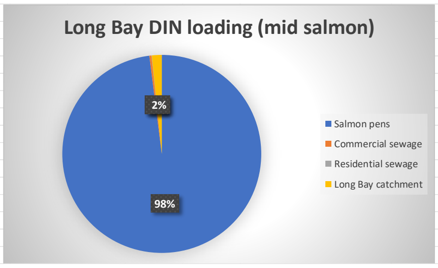
Based on the nutrient loading analysis above, the salmon lease at Long Bay is by far the largest source of anthropogenic DIN to the bay, regardless of the stocking scenario used. **The proportional load from the lease ranges from 95 to 98% of the combined inputs, with catchment loads coming a distant second at 1 to 3%.**

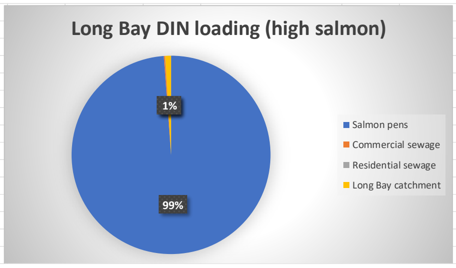
Even if DIN loads from the salmon lease are halved (equivalent to a stocking density of 5 kg/m3), the salmon lease would still contribute over 90% of the anthropogenic DIN to Long Bay.

Estimated DIN Loading to Long Bay using a range of estimated salmon loads (in tonnes/year)

	Low	mid/high	max
Salmon pens	53.0	100.0	174
Commercial sewage	0.35	0.35	0.35
Residential sewage	0.05	0.05	0.05
Long Bay catchment	1.6	1.6	1.6







5. References

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10 Port Arthur Historic Site Annual Report

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15 EPA Tasmania, 2022. TPDNO explanatory paper: compliance assessment methodology

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17. DPIPWE, 2018. Tasman Peninsula and Norfolk Bay Marine Farming Development Plan (Sec 3.3.1)

APPENDIX D

PHOTOS OF ALGAL BLOOMS AT LONG BAY

Long Bay/Port Arthur Dec 2018

Long Bay/Port Arthur Oct 2019

Long Bay/Port Arthur May 2020

APPENDIX E

ESTIMATED FRESHWATER USE, SOURCES AND POTENTIAL IMPACTS AT LONG BAY SALMON LEASE

Based on past discussions with Tassal, after salmon have been transferred to sea, they are typically bathed in freshwater approximately 7 times to control Amoebic Gill Disease (AGD). Typically, bathing would occur about 4 times early on (to a weight of 1.5kg), and 3 times later in the production cycle. During the bathing process, fish are transferred into a plastic liner filled with freshwater and held for about 2 hours. The liner is then removed and the bathing water is released onto the lease. (Pers Comm, Tassal)

The liners are filled to a depth of 2-3m, as freshwater is more buoyant than seawater. Thus, for a 120m circumference pen the estimated volume per bathe is 2.3 to 3.4 ML. This is based on a radius of 19.1m and freshwater depth of 2 to 3 meters. **Therefore, the estimated volume of freshwater required to bathe 16 pens of salmon on four occasions would be between 147 and 218 ML per growth cycle** (2.3 x 16 x 4 = 147 ML or 3.4 x 16 x 4 = 218 ML). In the event of a severe AGD outbreak where additional freshwater treatments are required, it could be considerably more.

Tassal has access to several sources of freshwater at Long Bay. These include two small dams, a groundwater bore as well as the desalination plant.

According to information available on the LIST, Tassal has a land-based freshwater allocation near Long Bay of 10ML (surety 5; 1 May through 31 Oct). This is associated with a dam permit of 10 ML capacity. In addition, there is a permit for a smaller dam (4.5 ML capacity) as well as a groundwater bore of unknown capacity.

Given the small size and seasonal limitations on the land-based allocation, it is presumed that the majority of freshwater is either produced through desalination and/or that the bore is used to top up the dam. Taking larger volumes of water, or taking freshwater out of season, is not permitted under the current permit.

If the fish were to be bathed on the Aquaspa wellboat, a smaller volume of freshwater would be required, as the vessel has the ability to treat and re-use bathing water up to four times. Used bathing water – possibly containing disinfectants – is also discharged on the lease, but would eventually enter adjacent waters. The source of water used on the Aquaspa may include allocations from the Huon/Channel region and/or freshwater produced by the desalination plant on the wellboat. However, the Aquaspa is frequently in use elsewhere and is rarely used for bathing operations in Long Bay.