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1. Executive Summary

This report outlines the results of an investigation of the flood susceptibility of the proposed Pacific Reef Fisheries Pty Ltd Guthalungra Prawn Farm site. It includes conclusions with regard to:

- The potential for the site to be flooded due to overflows from the Elliot River, and the likely extent of flooding.
- The potential for the site to be flooded as a result of storm surge.
- Runoff characteristics from local areas outside the Elliot River catchment.
- The implication of the above types of flooding, including the magnitude of the risks involved, and the design requirements of the development to accommodate flood risks.

Elliot River Flooding
Partial flooding of the site is likely to occur under both the 1 in 50 and 1 in 100 year recurrence interval events. This flooding is a result of overflows over the left bank of the river. Flooding would be limited mainly to the area east of the Coventry Road, with the depth of flooding typically 0.5m to 1.0m for the 1 in 100 year event.

Storm Surge Flooding
There is limited recent data on storm surge characteristics for the Bowen Area. An investigation undertaken for the Beach Protection Authority in 1985 indicated that the 1 in 500 year storm surge level at the Elliot River would be approximately 2.5m AHD. The 1 in 100 year level would be less than Highest Astronomical Tide (2.0m AHD). Given the relatively low storm surge estimates, and the fact that most of the development is located several kilometres from the ocean, the risk posed by storm surge appears to be minimal.

Local Catchment Flooding
Surface runoff passes through the proposed site at a number of locations. The area west of Coventry Road is that which is most likely to effect these runoff patterns as a consequence of construction of prawn growout ponds. Limited topographical information makes in this area makes accurate identification of upstream catchments difficult, however an assessment using stereoscopic photo imaging and field observations indicate that the catchment concerned areas are not large. Water passes through the proposed site largely as sheet flows and there are no clearly defined waterways. Provision will be necessary within the proposed development to allow these flows to continue to pass downstream without causing undue effects upstream.

Implications of Flooding For The Proposed Development
Storm surge and local catchment runoff do not appear to pose a significant risk to the proposed project. Adequate provision will need to be made in the design of the project to allow for runoff from the local catchment areas.

Whilst a significant proportion of the proposed site east of the Coventry Road is at risk of flooding from the Elliot River under very large floods, the expected depths of flooding are such that the risk to the development can be managed. This would involve the siting of infrastructure such as processing facilities, offices, workshops etc. outside the flood-prone area or about the flood level. Embankment levels for growout ponds, storage areas and sedimentation basins in the flood-prone area will need to be above the 1 in 100 year level. These requirements can be readily incorporated into the design of the development.

2. Objectives

The objectives of this investigation were to assess the nature and magnitude of risks posed by the flooding of the site from all likely sources of flood risk. This information provides a basis for assessing whether the feasibility of the project is jeopardised due to unacceptable flood risk.

To satisfy these objectives, it was necessary to consider the different types of flooding, ie:

- Flooding from the Elliot River,
- Flooding as a result of storm surge or,
- Flooding from local catchment runoff.

The likelihood of flooding from these three sources, and the potential consequences in terms of infrastructure damage, potential environmental impacts and crop loss, are important aspects of the feasibility of the project.

3. Site Description

The proposed site lies immediately to the west of the mouth of the Elliot River, as shown in **Figure 1**. It covers a total of approximately 800ha.

- **Figure 1: Locality Plan**

The Elliot River catchment area is approximately 29,000 ha rising near Mt Aberdeen to the south. The catchment is moderately steep, falling 200m over approximately 35km. Land use is predominantly cattle grazing.

The northern part of the site also receives rainfall run-off from local catchments that are separate from the Elliot River catchment. These areas drain via a number of relatively indistinct drainage lines, discharging into the salt pan flats immediately to the east of the proposed site.

There is only limited topographic information available for the catchment (1:2500 topographic maps with 5m contours). Topographic survey has been completed for the proposed prawn farm site, and cross section survey of the Elliot River was undertaken to allow hydraulic modelling (refer **Section 4.0**).

A Department of Natural Resources and Mines hydrographic station is located on the Elliot River at Guthalungra. Data from this station was used to determine the flood frequency characteristics of the river. The catchment area at the gauging site is 273 km^2.

The proposed prawn farm site drains to large areas of salt pan immediately to the east of the main farm area. This salt pan area is subject to inundation to varying degrees depending on tide levels and recent rainfall history. Anecdotal evidence, and comparison of surface levels with tide data, suggests significant ingress of seawater onto the salt pans only occurs during exceptionally high tides.

The salt pans extend across the full width of the peninsula separating Abbott Bay from Upstart Bay. It is likely that the direction of water flow in these pans would depend on the relative magnitude of rainfall runoff in the various parts of the catchment areas draining to these areas, the prevailing wind direction (under extreme events) and tidal conditions.

Overflows from the Elliot River are only likely to effect the southern part of the proposed site, given that much of the northern part of the site is located on high ground. Further away from the river, storm surge is most likely to be the dominant flood risk factor.

4. Elliot River Flooding

4.1 Flood Hydrology

Estimates of flood frequency for the Elliot River were determined using data from the stream gauging station at Guthalungra (Station No. 121002A). Data on flow level and flow rate were available on a continuous basis from 1973.

A frequency analysis was undertaken using 28 years of data of annual maxima from 1973/74 to 2000/01, resulting in estimates being produced for peak flow rates for different recurrence intervals (probabilities). These are show in **Table 4-1.**

- **Table 4-1 Peak Flow Rates Estimates (m^3/s) for the Elliot River at Guthalungra**

Recurrence Interval (years)	2	5	10	20	50	100
Peak Flow Rate (m^3/s)	415	815	1 100	1 375	1 725	1 975

The peak flow rate recorded during period of record was 1 430 m^3/s, which corresponds to approximately a 1 in 25 event. The most likely estimate for the 1 in 100 year peak flow rate estimate is 1 975 m^3/s with 90% confidence interval spanning the range from 1 125 m^3/s to 3 480 m^3/s (ie. there is a 90% probability that the 1 in 100 year peak flow rate will be between 1 125 and 3 480 m^3/s, and a 95% probability that the 1 in 100 year peak exceeds 1 125 m^3/s).

The peak flow rates determined by the frequency analysis were increased to include rainfall runoff from 1700ha Elliot River catchment area downstream of Guthalungra. This involved application of a simple algorithm (Myers formula) to the catchment area. **Figure 2** shows the approximate boundary of the Elliot catchment downstream of the highway. Resultant estimates of peak discharges in the vicinity of the proposed site are shown in **Table 4-2**.

- **Table 4-2 Peak Flow Rate Estimates (m^3/s) for the Mouth of the Elliot River**

Recurrence Interval (years)	2	5	10	20	50	100
Peak Flow Rate (m^3/s)	430	850	1 150	1 435	1 800	2 060

These estimates were used in the hydraulic modelling to determine flood levels.

4.2 Hydraulic Modelling

Hydraulic modelling of the lower Elliot River was undertaken using the MIKE11 computer package. Cross-sections of the Elliot River were surveyed at selected locations as shown in **Figure 3**, together with a layout of the MIKE 11 model structure.

- **Figure 2: Approximate Catchment area downstream of Guthalungra**

- **Figure 3: Elliot River Cross Section Survey Locations and MIKE11 Model Layout**

This information, together with topographic survey available for the proposed site and 1:25000 topographic information was used to establish a model that extended approximately 3.0 km upstream of the mouth.

In order to model the complex nature of flooding within the Elliot River, a series of link channels and floodplain cross sections were used to model the flooding behaviour of the river. During the 100year ARI flood event, river breakouts occur across the proposed site along the left bank of the river. Link branches were developed along the eastern and western sides of the river to model the flooding within the reach and the breakouts into the floodplain. Roughness values adopted for the modelling were taken from published data for these types of watercourses. A Manning's "n" of 0.03 was applied to the channel sections and 0.08 was adopted for overbank flows.

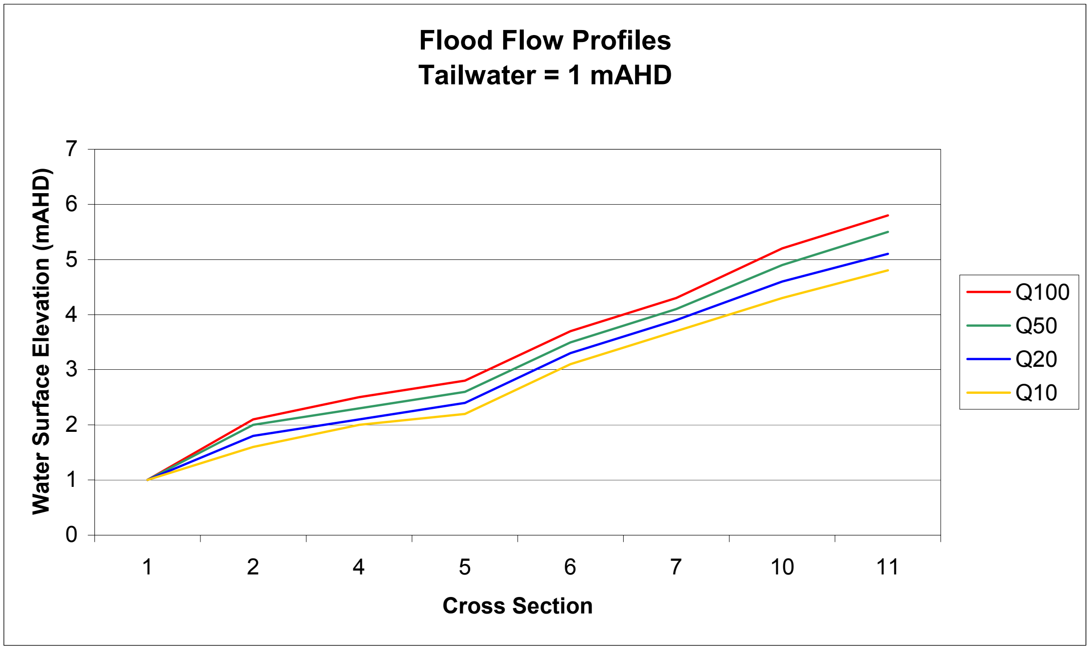
Two separate tailwater conditions were adopted as part of the hydraulic analysis. A constant tailwater level of 2m AHD was assumed to approximate the conditions established under the Highest Astronomical Tide (calculated as approximately 2.0m AHD). The second tailwater condition (a constant 1m AHD) was chosen as an arbitrary level. This level is 0.96m above the mean sea level (0.04m AHD) but approximates the Mean High Water Springs level (1.064m AHD) at the downstream boundary.

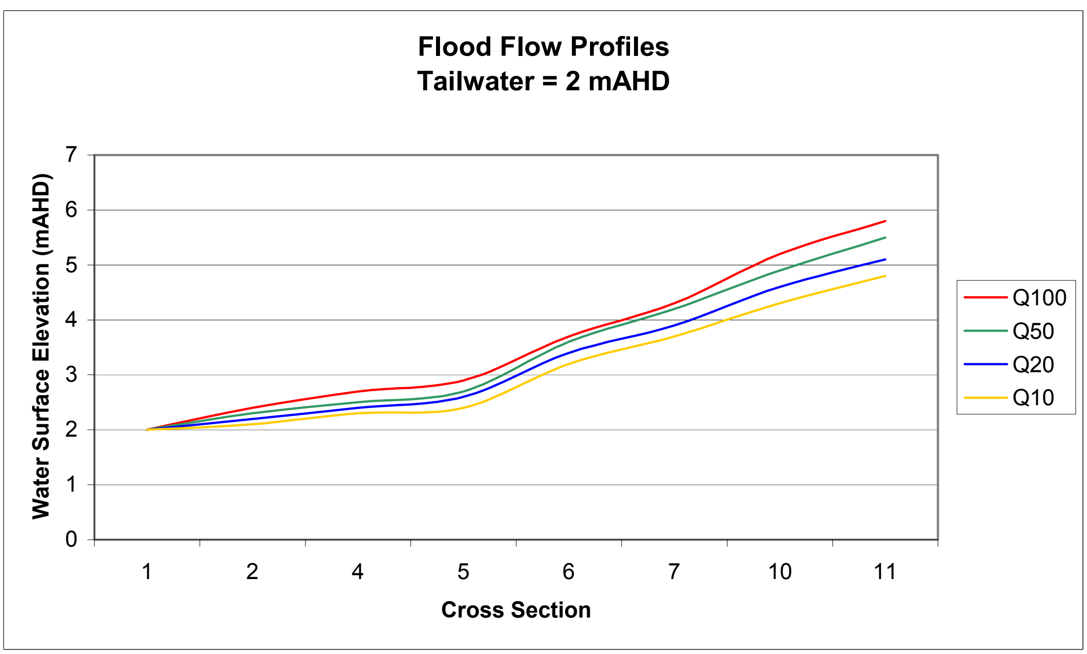
The impact of the tailwater level can be seen in the flood profiles in **Figure 4**. It can be seen that the effects of the assumed tailwater level extends approximately 1.5km upstream for most of the events considered. In the river reach adjacent to the proposed farm the impact of the assumed tailwater is not significant, increasing the 1:50 year flood level from 3.80m AHD for an assumed tailwater of 1.0m to 4.0m AHD for a tailwater of 2.0m. There is virtually no difference for the 1:100 year event.

Four flood events were modelled, 100, 50, 20, and 10year ARI events. It was assumed that a steady discharge entered the upstream boundary of the model (cross section 11). These discharges were taken from the estimates shown in **Table 4-2** above, derived from the flood frequency analysis.

Profiles of river flow levels were generated using the technique described above for all events, as shown in **Figure 4.** The 1 in 100 year recurrence interval is typically used as the benchmark by which the flood susceptibility of aquaculture developments are assessed in Queensland ie. developments are required to demonstrate that they are immune to the impacts of a 1 in 100 year flood. It can be seen from **Figure 4** that the peak water surface elevation in the 100year ARI event is between 3.7 and 4.3m AHD along the reach immediately adjacent to the farm location (Cross Sections 6 and 7).

■ **Figure 4: Flood Flow Profiles**





4.3 Flood Mapping

To assess the extent of inundation likely to be caused by flood overflows from the river, flood maps were prepared using the topographic survey available for the site.

In the absence of a full 2 dimensional model for this site, an approximate method was used to estimate flood levels across the site. This involved linear interpolation of levels between the river overflow point and the salt pan area. For this purpose the flood level in the salt pan area was taken to be the same as the level in the river at the point where the salt pan drains to the river (Cross Section 3 on **Figure 3**). This is considered a reasonable assumption on the grounds that the salt pan area would constitute a very large, flat storage area, and as such there would be minimal flood gradient across this area.

Flood maps for the 1 in 100 and 1 in 20 year recurrence interval floods are shown in **Figure 5** and **Figure 6**. Modelled river flood levels are shown at strategic cross-section locations.

These results indicate that whilst substantial areas of the site near the river are likely to be inundated under the 1 in 100 year event, the depth of inundation would be limited. Maximum flood levels of approximately 4.0m AHD would occur at the upstream end of the site, immediately adjacent to the river. Natural surface levels at this location are typically 3.0m to 3.5m AHD, suggesting a flooding depth of 1.0 to 1.5m. More typically across the flood-prone area, flooding depth would be 0.5 to 1.0m.

Adjacent to the area proposed to be developed for water treatment ponds and the administration/processing area east of Coventry Road, the flood levels are approximately 4.0m AHD and 3.5m AHD for the 1:100 and 1:20 year events respectively. Natural surface levels in this area range from 2.0 to 4.5m AHD. Any infrastructure in this area would need to be raised above a level of 4.0m to ensure immunity form the 1:100 year flood event.

Implications of Findings

The modelling and flood mapping approach adopted is relatively conservative, and is constrained by the amount and detail of topographic information available for the lower Elliot River floodplain as a whole. With the conservative nature of the analysis in mind the flood mapping should be interpreted as a guide to those areas expected to be at risk, rather than an accurate definition of flooding extent. Based on the modelling, it can be expected that the areas shown in **Figure 5** are likely to flood under the 1 in 100 year storm event. The maximum depth of flooding across the site has been conservatively estimated to be 1.0 to 1.5m under the 1 in 100 year event. In terms of aquaculture development, this is an issue in terms of:

a) The top of the banks around growout ponds and sedimentation areas must be greater than the nominated flood level to ensure that overtopping does not occur, and potential loss of stock to the environment.

- **Figure 5: 100 year ARI Flood Inundation**

- **Figure 6: 20 year ARI Flood Inundation**

b) Other infrastructure as processing facilities, offices and workshops will need to be located so they are above the nominated flood level, or site foundations raised above this level.

The investigations undertaken indicate that although flooding of part of the site is likely to occur under extreme events, the depth and lateral extent of flooding are not such that it would jeopardise the feasibility of the project. Provision would however required during design to ensure the works in the flood prone area are immune to the impacts of flooding.

4.4 Storm Surge

Storm surge is a phenomenon whereby sea levels are raised through a combination of extreme winds and low barometric pressures. In north Queensland storm surge is most commonly associated with cyclones. The severity of storm surge impacts is determined by the severity of the cyclone, its speed and direction of movement relative to the coast, and most importantly, its timing relative to tides.

Prediction of storm surge magnitudes and probabilities is a complex process, and detailed recent estimates are scarce for much of the Queensland Coast.

The most detailed information available for the Bowen region was a report produced by consultants, Blain, Brenner & Williams for the Beach Protection Authority in 1985. This report was one of a series covering various parts of the Queensland Coast. The results quoted in the report suggest the 1 in 500 year storm surge level at Elliot River would be 2.5m AHD. The 1 in 100 year level would be less than Highest Astronomical Tide for the site (quoted as 2.2m AHD). These levels are relatively low compared to natural surface levels at the site, and based on these estimates storm surge flooding would be confined mainly to the salt pan area.

4.5 Local Catchment Runoff

Local catchment runoff passes through the site at a number of locations via a series of shallow depressions. East of Coventry Road, several dams exist across these depressions to store water for stock watering purposes. The proposal does not impact on these watercourses, and they have not been analysed in detail.

The locations of these depressions are marked in **Figure 7.** The extent of the catchments draining through the site is difficult to determine due to a lack of detailed topographic information, however the small size of the drainage lines across the site suggest that the catchments are not large.

A hydrological assessment of local catchment runoff has been conducted using RAFTS. Two catchments have been identified as contributing to runoff that flows through the site. **Table 4-3** below provides details on the characteristics of each of these catchments as they were modelled. Six storm events were included in the hydrologic modelling. These events were 100, 50, 20, 10, 5, and 2 year ARI events.

- **Table 4-3: Catchment characteristics.**

Catchment characteristic	Catchment A	Catchment B	Catchment C
Area (ha)	130.3	72.3	308.3
Slope (%)	0.2	0.2	0.2
Manning's n	0.08	0.08	0.08

Figure 7 indicates the extents of these local catchments and the drainage lines associated with each. A ridge running east-west below the site limits the amount of runoff entering the site. These boundaries were determined using aerial photography in stereopairs and topographic information for the site.

- **Figure 7: Local runoff catchment boundaries.**

The critical duration was determined for each of these storms. The resulting peak discharges are detailed in **Table 4-4**. It can be seen from these results that the volume of local catchment runoff is not large. The loss model used was the same as that used in other recent flood studies for the Burdekin area (Kinhill 1992), which in turn was based on work carried out by the Water Resources Commission in this region. The initial loss assumed was 40mm, and the continuing loss was 2.5mm/h for all events.

- **Table 4-4: Peak Discharges for local catchment runoff.**

Storm Event (ARI)	Peak Discharge Catchment A (m^3/s)	Peak Discharge Catchment B (m^3/s)	Total Discharge (A + B) (m^3/s)	Peak Discharge Catchment C (m^3/s)	Critical Duration
100	6.91	4.22	11.13	13.90	12 hrs*
50	5.62	3.37	8.99	11.09	12 hrs*
20	3.93	2.49	6.42	7.85	12 hrs
10	2.95	1.90	4.85	5.95	36 hrs
5	2.34	1.47	3.81	4.63	36 hrs
2	1.33	0.86	2.19	2.65	36 hrs

* 6 hours for Catchment C

The proposed farm development will need to include allowance for passing the flows shown above through the site without causing undue increases in flooding upstream.

5. Conclusions

5.1 Flood Susceptibility

The investigations undertaken indicate that the most likely cause of flooding at the site would be from the Elliot River. The storm surge estimates available suggest that for even a 1 in 500 year event, flooding would be minimal. Local catchment runoff is not significant, however allowance will have to be made in the design of the development to accommodate runoff from upstream catchments.

With regards to Elliot River flooding, flooding of much of the area east of the Cape Upstart Road could be expected. The extent and depth of flooding likely to occur is likely to be such, however, that it would not constitute a significant risk to the viability of the project.

6. References

- Kinhill, 1992, *"Brandon Flood Study"*
- Sinclair Knight Merz, 2001, *"Town of Ayr Flood Study"*