Methodology for the identification and selection of terrestrial aquaculture development areas in the coastal zone

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Queensland Government

This publication has been compiled by Fisheries Queensland, Department of Agriculture and Fisheries.

Contents

Introduction

The Queensland Government supports the future development and growth of an ecologically sustainable, diverse and innovative aquaculture industry.

In 2016, the Queensland Government released its response to the Queensland Competition Authority's review on aquaculture regulation in Queensland. The following recommendation was endorsed by government to facilitate the expansion of aquaculture in Queensland:

> … the creation of terrestrial aquaculture development areas (ADAs), including the identification of 450 hectares (ha) suitable for aquaculture operations.

This document outlines the process for identifying aquaculture areas that are appropriately located and suitable for designation as terrestrial aquaculture development areas (ADAs). The process of identifying terrestrial ADAs focuses on coastal areas that are suitable for culturing a range of marine species in earthen ponds that require access to seawater. This is often referred to as 'land-based marine aquaculture'. Cultured species might include prawns and marine fin fish, such as barramundi, cobia, groper and cod. The project has a target of identifying and selecting at least 450 ha of coastal land designated as ADAs, comprised of areas that possess:

- optimum physical, socio-economic and supporting infrastructure characteristics that would support large-scale aquaculture operations
- attractive investment qualities
- an acceptably low level of environmental and planning constraints to development and, therefore,
- a high likelihood for successfully obtaining government approvals for development.

Selection criteria for identifying investigation areas

The first step in locating potential ADAs involved identifying the selection criteria, representing both opportunities and constraints, to be considered in the site selection process. These criteria include relevant attributes for locating and operating an aquaculture operation as well as factors that are considered in acquiring the relevant government approvals.

Selection criteria include physical, environmental, government planning, socio-economic, and supporting infrastructure attributes or themes:

- Physical themes include necessary features for the construction or location of aquaculture infrastructure, such as land with suitable elevation, topography, soil characteristics and access to good quality seawater.
- Environmental themes include potential ecological impacts that may be a consequence of the construction and operation of the aquaculture facility, such as impacts on terrestrial habitats, water quality, coastal processes or agricultural land use.
- Planning themes address tenure issues and compatibility with regional plans and local planning schemes.
- Socio-economic themes include the impacts on existing uses, cultural heritage, financial return on investment, and employment opportunities.
- Supporting infrastructure, such as access to services, power, labour and transport, is also considered for selecting appropriate areas to develop.

GIS modelling

GIS desktop modelling incorporates spatial data that appropriately represent the site selection criteria. Datasets were compiled, scoring protocol applied, and overlayed to produce a mosaic of land polygons along the coast. Each polygon represents an area of land with a particular set of characteristics (selection criteria) and a cumulative score made up from all overlying dataset layers.

Polygons with the highest scores are of most interest, representing areas with desirable physical attributes for locating and operating an aquaculture operation and with fewer constraints to obtaining development approvals. This section briefly describes the spatial data incorporated, scoring protocol applied, and process used to date for identifying areas for further investigation.

Coastal land lying within 5 km of accessible seawater (coastal beach or estuarine creek/river) serves as the area of interest (AOI) for ADA selection. Within this AOI, several data layers were derived and scored (Appendix1) to describe a number of land attributes that would be important in determining the suitability of an area to construct aquaculture ponds:

- land elevation (height above sea level)
- topography (slope of land)
- distance of land to water source
- land tenure/local government area (LGA) zoning
- land subject to tidal influence
- water quality/quantity (surrogate) accessible for intake.

The above data layers were scored (see Table 1) and merged to form a mosaic of polygons within the AOI, with each polygon assigned a total score derived by the sum of scores from all overlying layers (x/50). Any polygon that contained a score of ‘0’ in any of the six overlying layers was deemed to be incompatible for aquaculture development and was assigned a total score of ‘0’. All polygons with a score > ‘0’ were deemed to have the minimum acceptable characteristics for development. These areas were extracted and formed the base layer for further consideration of aquaculture development potential (termed ‘Potential Aquaculture Land’).

Table 1. Scoring protocol for six base data layers to identify areas with minimum requirements for further consideration of land-based aquaculture development potential.

ELEVATION (m AHD)	SCORE
< 0m	0
0 - 5m	8
5 - 10m	10
10 - 15m	5
15 - 20m	3
> 20m	0

Distance to Water (km):	SCORE
1	10
2	8
3	6
4	4
5	2
>5	0

SLOPE(%)	SCORE
> 5%	0
3 - 5%	2
2 - 3%	5
1 - 2%	7
0 - 1%	10
0 (flat)	6

Water Source (km from coast)	SCORE
1	5
2	4.5
3	4
4	3.5
5	3
6	2.5
7	2
8	1.5
9	1
>10	0.5

TENURE:	SCORE
XX	0
AB	10
FH	10
LL	6
SL	3

Tidal Influence:	SCORE
> HAT line	5
>TI but < HAT	1
<Tidal Influence	0

The objective of the modelling process is to identify areas that not only have desirable physical attributes for land-based aquaculture but also have minimal constraints in obtaining government approvals for development. To identify these areas of least constraints, The 'Potential Aquaculture Land' data was subjected to a series of refinements to eliminate those areas in which the approvals process might impose significant and/or costly obstacles.

The ‘Potential Aquaculture Land’ data was progressively whittled down by eliminating areas that were within the following areas of land (Appendix 2):

- World Heritage Areas
- Commonwealth Heritage Places
- Protected Areas – Collaborative Australian Protected Areas Database (CAPAD, 2014; excluding Indigenous Protected Areas that are freehold (FH), leasehold land (LL) or State Land (SL) tenures)
- Fish Habitat Areas
- Matters of State Environmental Significance (MSES Version 4.1, 2014)
- Regulated Vegetation (Category A, B, C and R not included in MSES layer)
- Agricultural Land Classification (ALC Class ‘A’ and ‘B’).

This derived a new data layer ‘Potential Aquaculture Land – less constraints’ (PALLC).

The PALLC layer was then visually scrutinised and subjected to a cleaning process. The following cases are examples of where polygons were manually eliminated:

- small isolated areas
- adjacent to residential zones
- wetlands not included in MSES
- polygons not in updated LGA rural zones (visual comparisons with online LGA mapping where available)
- incompatible current land use (e.g. fruit/nut plantations)
- areas containing numerous small lots with residences
- priority development areas
- areas that are separated from water source/discharge area by large areas of MSES, residential areas, major highways/rail, high elevation, numerous lots.

This produced a new layer, ‘Potential Aquaculture Land less constraints – refined’ (PALLCR), of approximately 50 000 ha of land. To reduce the ‘busy’ nature of the resulting data (e.g. numerous polygons within larger polygons), larger polygons were assigned a weighted score according to the score and percentage area of all smaller polygons that were contained within the larger polygons (spatial join).

These larger polygons were ranked according to their weighted scores with the new data layer termed ‘Potential Aquaculture Land – weighted score’ (PALWS). These larger polygons were then grouped according to their localised proximity into 44 clusters. Clusters were assigned a weighted score according to the score and percentage area of the grouped polygons (spatial join). These clusters were then ranked according to their weighted scores. This new layer is ‘Potential Aquaculture Land – clusters’ (PALC) (figures 1–3).

Figure 1. 'Potential Aquaculture Land less constraints – refined': Illustrates large polygons containing numerous smaller polygons, each with its own score derived by the sum of the six overlaying base datasets. Areas where no polygons are shown would have received a score of '0' for at least one of the overlaying datasets (e.g. not rural, >20 m elevation, slope >5%, <HAT, not FH/LL/SL).

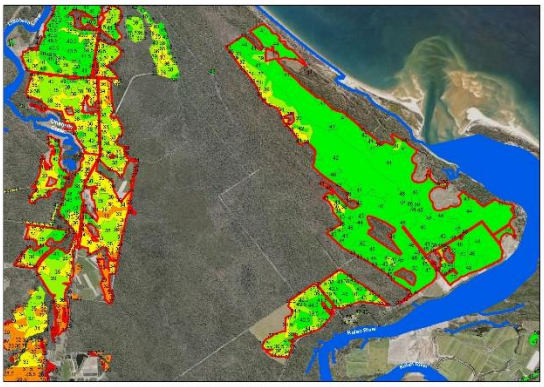


Figure 2. 'Potential Aquaculture Land – weighted score': Illustrates the merge of polygons within larger polygons to produce weighted scores of larger polygons.

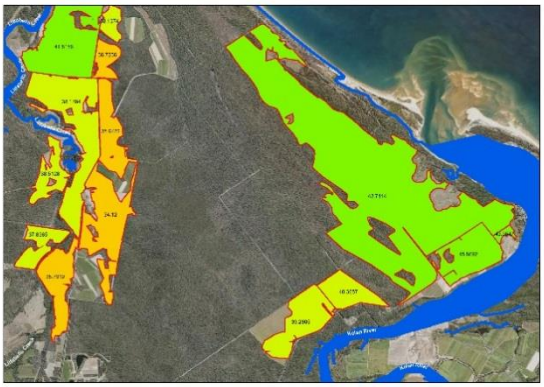
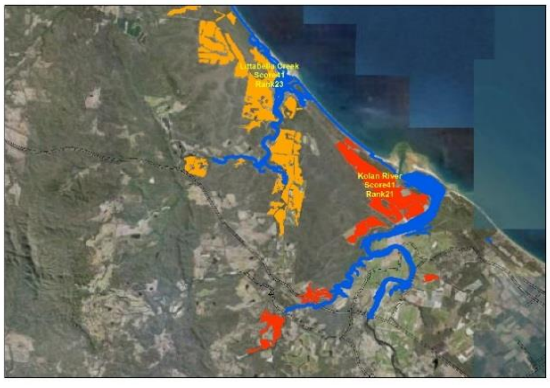
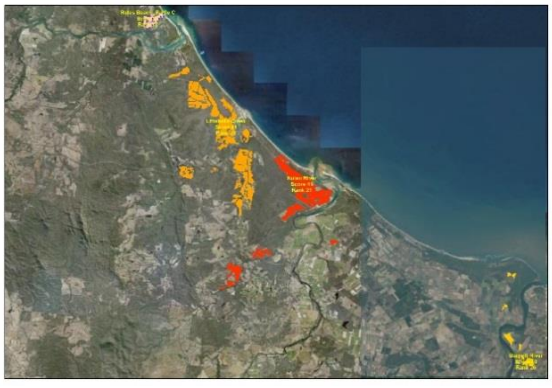


Figure 3. 'Potential Aquaculture Land – clusters': Illustrates the grouping of polygons into localised clusters with the weighted score for each cluster.





Weighted scores range from 34.8 (Caloundra) to 46.6 (Godwin Beach) out of a total possible score of 50 (Table 2).

Table 2. Location and rank of 44 clusters of 'Potential Aquaculture Land' possessing basic requirements for development and with minimal impacts on MSES, regulated vegetation and agricultural land. Within cluster scores, refer to weighted score from all polygons within the cluster. Among cluster scores, refer to weighted score of cluster relative to total area of all clusters.

		Within Cluster		Among Clusters	
Cluster Location	**Area (ha)**	**Wt Score**	**Rank**	**Wt Score**	**Rank 2**
Godwin Beach	61	46.6	1	0.06	44
Sleeper Log Creek	377	46.5	2	0.35	19
Bowen-Sandy Creek	225	45.8	3	0.21	30
Bluewater	357	45.6	4	0.33	21
Ayr	3221	44.8	5	2.91	4
Donnybrook	197	44.8	6	0.18	37
Abbott Point SDA	223	44.7	7	0.20	33
Beach Holm	591	44.7	8	0.53	16
Townsville	229	44.2	9	0.20	32
Home Hill	2890	43.7	10	2.54	5
Ingham-Victoria Creek	107	43.3	11	0.09	41
Toomulla	168	43.1	12	0.15	39
Gumlu	348	42.9	13	0.30	22
Keppel Sands	3770	42.7	14	3.24	3
Good Fortune Bay	775	42.6	15	0.66	14
Beachmere	299	42.5	16	0.26	26
Rules Beach Baffle Creek	243	42.3	17	0.21	31
Giru-Haughton River	87	42.3	18	0.07	43
Coolum-Maroochy River	224	42.2	19	0.19	35
Greenhill	107	41.8	20	0.09	42
Kolan River	1449	41.3	21	1.21	12
Logan	355	41.2	22	0.29	23
Littabella Creek	2197	41.0	23	1.81	10
Hervey Bay-GS Strait	452	40.8	24	0.37	18
Carmilla-Clairview	334	40.7	25	0.27	25
Burnett River	266	40.4	26	0.22	28
Rosslyn Bay	572	40.1	27	0.46	17
Howard-Cherwell River	123	39.7	28	0.10	40
Sarina	239	39.3	29	0.19	36
Bloomsbury	2366	39.1	30	1.86	9
Rockhampton-Fitzroy River	6418	38.7	31	5.00	1
Tannum Sands-Boyne River	326	38.7	32	0.25	27
Toogum-Beelbi Creek	199	38.6	33	0.15	38
Maryborough	2221	38.6	34	1.72	11
Starke River	447	38.4	35	0.35	20
Woodgate-Isis River	277	37.4	36	0.21	29
Howard-Burrum River	2732	37.4	37	2.06	7
Shoalwater	894	36.8	38	0.66	15
Port Alma-Casuarina Creek	5593	36.6	39	4.12	2
Cooktown	375	36.3	40	0.27	24
Woodgate-Gregory River	2769	36.2	41	2.02	8
Gladstone-Calliope River	1246	35.3	42	0.89	13
Port Alma-Raglan Creek	3053	35.0	43	2.15	6
Caloundra	281	34.8	44	0.20	34
Total	49680				

The process initially identified approximately 50 000 ha of potential land that possess the basic requirements for aquaculture development with minimal MSES, vegetation clearing and agricultural land constraints – all located along the east coast of Queensland from Starke River (Cape Flattery) in the north to the Logan region in the south.

Virtually no potential land with minimal constraints was identified in the Gulf of Carpentaria-Cape York region due to large conservation areas, MSES and regulated vegetation.

Further refinements of these clusters are required to identify the best areas for aquaculture. Several information layers are available or have been developed to aid in the scrutiny and refinement of the potential aquaculture land layer (Appendix 3).

Factors that may be considered to identify the most suitable areas within clusters include:

- highest scoring areas within clusters
- downstream impacts (marine parks, Ramsar wetlands of international importance, Fish Habitat Areas)
- Great Barrier Reef catchment nutrient/sediment loading caps
- water quality for intake and discharge (e.g. management intent – High Ecological Value waters, Slightly Disturbed, Moderately Disturbed, Highly Disturbed)
- groundwater impacts
- wetland protection areas (WPA) and WPA trigger areas
- Key Resource Areas (KRA) and KRA trigger areas
- separation distances to residential/urban areas/sensitive receptors/airports/recreational areas
- separation distances from existing aquaculture farms
- distance to towns/airports
- distance to power
- avoiding future planned roads/powerlines/rail lines
- intake discharge options (e.g. 1 vs 2 creek access)
- soil clay content
- groundwater vulnerability
- contaminated land
- acid sulfate soils
- number/size/tenure/land use/landowners of lots within clusters and of lots required to cross for seawater access/discharge
- coastal hazard areas
- flooding levels (Q100)
- native title
- compatibility with local and regional plans
- freshwater run-off
- land use (e.g. sewage treatment plant, agricultural run-off)
- economic feasibility (e.g. possible linkage with North Queensland aquaculture economic feasibility study).

Consultation

Following the ‘first pass’ identification of potential ADA clusters, which identified approximately 50 000 ha, targeted consultation was undertaken with industry and local government to refine potential aquaculture land and expansion areas. Following refinement, consultation was also undertaken with landholders where a potential ADA was identified.

As identification of ADAs required a coordinated approach from government agencies and input from the aquaculture industry, an Aquaculture Advisory Committee was established to oversee the identification of ADAs. The committee included government, industry and academic representation.

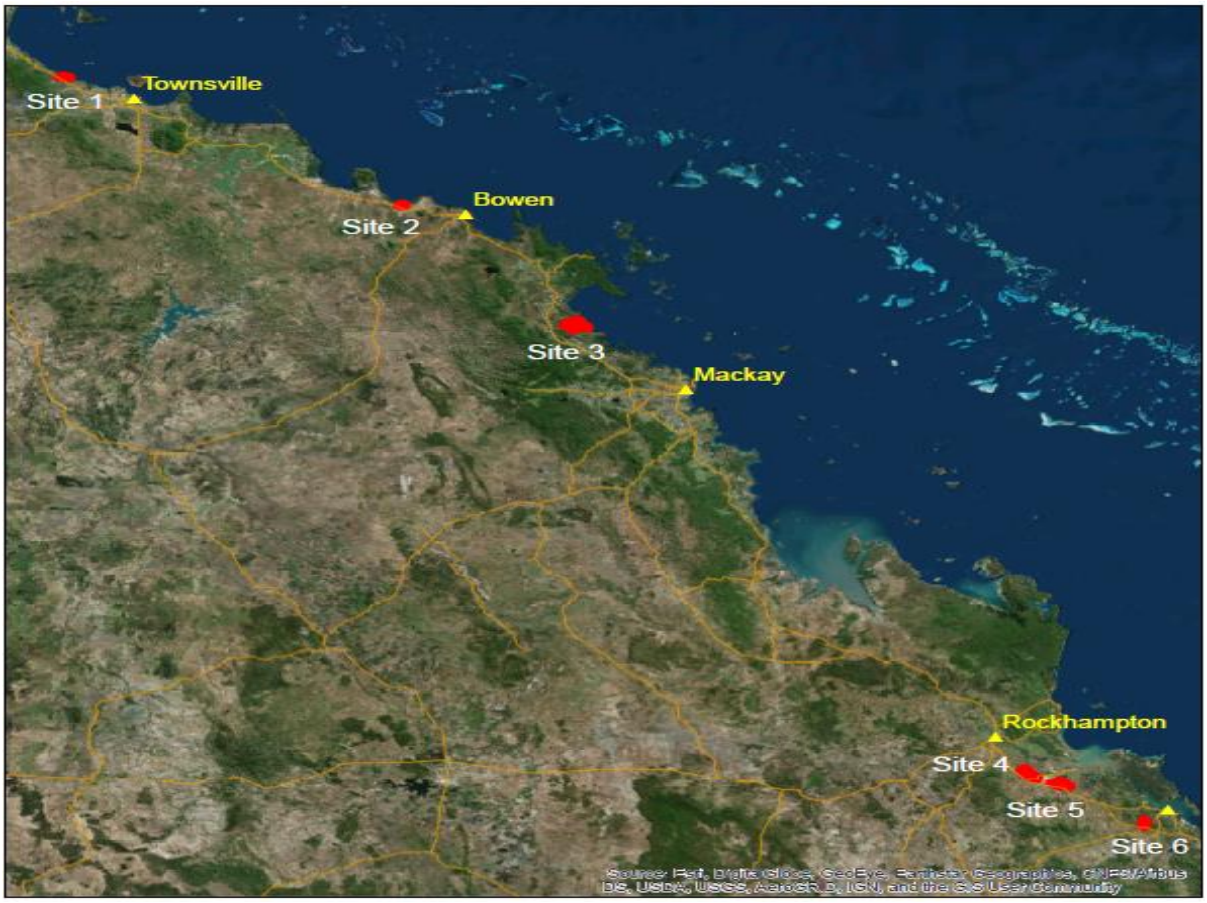
Identification of aquaculture development areas

Following the consultation process a total of seven sites were identified as having the least constraints and highest potential as ADAs (Table 3 and image 1).

Table 3. Identification of ADAs in Queensland based on a range of environmental, economic and other criteria, and constraints mapping.

ADA site	Name	Local government area	ADA size (ha)
1	Sleeper Log Creek / Leichhardt Creek	Townsville City Council	319
2	Abbot Bay / Good Fortune Bay	Whitsunday Regional Council	316
3	Bloomsbury	Mackay Regional Council	2126
4	Rockhampton / Casuarina Creek	Rockhampton Regional Council	2278
5	Rockhampton / Raglan Creek	Rockhampton / Gladstone Regional Council	1430
6	Gladstone / Calliope River	Gladstone Regional Council	579
			Total: 7048

Image 1. Location of ADAs in Queensland



While all ADA sites assessed include certain levels of operational, environmental and planning constraints, the sites ranked ‘1’ in Table 3 were the most suitable to gaining approvals for land-based marine aquaculture development.

Other ADA sites were ranked ‘2’ (moderately-suitable but with more operational constraints) or ‘3’ (unsuitable) due to various local issues raised during targeted consultation, which generally meant the sites no longer met the methodology and selection criteria for the identification and selection of terrestrial ADAs in the coastal zone. However, such sites could be investigated further.

It is important to note that while ADAs have been identified, it does not limit investors in exploring other areas for land-based marine aquaculture development in Queensland.

Appendix 1: Selection criteria

Table A1. Selection criteria used to identify potential ADAs with basic siting, local government area zoning and tenure requirements. Selection criteria are grouped into themes and themes are broken down into categories that reflect preferences/constraints for locating an aquaculture operation. Category scores applied in the analysis are indicated in parentheses.

Theme	Categories / *(scores)*	Description
Seawater Source (intake water and discharge points)	• Ocean beach • Estuarine creek/river ***Information Layer***	Saline water is sourced from marine oceanic sources at locations along the entire Queensland coastline, as well as estuarine rivers/creeks that extend inland from the coastline. A 'Seawater Source' data layer was derived by merging components of Queensland Coastline and State Border (2014), Queensland Waterways for Waterway Barrier Works (2016) and Queensland Wetland Data Version 4 – wetland areas (2015) (estuarine water and areas under tidal influence). Refinement of this layer involved manually deleting areas considered to be constraints on intake/discharge infrastructure access including: • protected areas • Fish Habitat Areas • High Ecological Value waters • elevation bounding on coastline >20 m AHD (Australian Height Datum) • residential/industrial/urban areas that would restrict access. This layer represents waterways by which seawater can be sourced for intake purposes as well as potential discharge areas of wastewater.
Area of Interest (access to seawater)	• Land <5 km from coastline or estuarine water (include) • Land >5 km from coastline or estuarine water (not practical) ***Information Layer***	The maximum feasible distance to pump and transfer water to land-based farms with a production area of 100 ha was considered to be 5 km. A coastal strip of land was derived by applying a 5 km buffer from the 'Seawater Source' layer (land 5 km from ocean beach or estuarine water source) and formed the base area of interest (AOI), from which further selection criteria are applied and potential ADAs selected.

Elevation	• <0 m (0) • 0–5 m (8) • 5–10 m (10) • 10–15 m (5) • 15–20 m (3) • > 20 m (0)	The costs of pumping seawater to land-based ponds is correlated with land elevation above sea level – 20 m is considered to be the maximum elevation to feasibly pump water to pond level; land under 10 m AHD is preferred but 0–5 m may be subject to acid sulfate soil considerations. The majority of existing coastal dependent aquaculture farms lie within 0 m and 5 m. Scoring reflects preferred elevation. Elevation was derived from 1 second DEM (Digital Elevation Model; 30 m x 30 m cells) raster clipped to AOI, reclassified and converted to shapefile.
Topography (slope)	• 0% (flat) (6) • 0–1% (10) • 1–2% (7) • 2–3% (5) • 3–5% (2) • >5% (0)	Preferred areas for land-based coastal marine aquaculture are generally flat with a slight slope towards the discharge area – either an estuarine creek or ocean outfall. For commercial purposes, slope is generally restricted to inclines of <5%, with 0–2% preferred. Increasing slope increases excavation costs and >5% may require extensive/expensive earthworks. Slope was derived using ArcGIS slope tool (Spatial Analyst) applied to 1 second DEM raster clipped to AOI, reclassified and converted to shapefile.
Distance to Water Source	• < 1 km (10) • 1–2 km (8) • 2–3 km (6) • 3–4 km (4) • 4–5 km (2) • >5 km (0)	The costs of pumping and channelling water from water source to ponds increases with distance (increasing elevation and distance to construct intake/discharge channels), with preferred areas being close to a water source/discharge point. Increased distance also increases potential for difficulties in obtaining access (e.g. multiple lots to cross, area of potential MSES/regulated vegetation disturbance). Therefore, scoring reflects preferred proximity to water source. The ‘Distance to Water Source’ layer was derived by creating a raster file (Euclidean Distance, 30 m x 30 m cells) based on the ‘Seawater Source’ source file, clipped to AOI, reclassified and converted to shapefile.

Water Source (water quality/quantity)	• < 1 km (5) • 1–2 km (4.5) • 2–3 km (4) • 3–4 km (3.5) • 4–5 km (3) • 5–6 km (2.5) • 6–7 km (2) • 7–8 km (1.5) • 8–9 km (1) • 9–10 km (0.5) • >10 km (0.5) ***Information only***	This 'Information' layer is based on the assumption that oceanic water provides the best water quality and quantity for supplying a marine aquaculture development. This supply would be available through beach access and/or at river mouths. Reduced flushing rate, water volume and salinity would be expected with increasing distance upstream from river mouths. Therefore, this layer provides a rough surrogate for water quality and quantity in the absence of site-specific data. As upstream water quality/quantity parameters would be highly variable among river/creek systems and the distances from coast are 'as the crow flies' rather than longitudinal upstream distances, this layer is scored lower than other categories. The 'Water source – quality/quantity' layer was derived by creating a raster file (Euclidean Distance, 30 m x 30 m cells) based on the 'Queensland Coastline' source file, clipped with 'Water Source', reclassified and converted to a new shapefile, 'Water Source – distance from coast'. The layer is scored so that all oceanic water along the coastline scores highest (5) and estuarine water upstream from river/creek mouths are scored lower with increasing distance from the coast. This layer is then used to create a new raster ('Water Source – distance to coast') whereby land is scored according to the nearest water source (see next criterion).
Water Source (distance from coast)	• < 1 km (5) • 1–2 km (4.5) • 2–3 km (4) • 3–4 km (3.5) • 4–5 km (3) • 5–6 km (2.5) • 6–7 km (2) • 7–8 km (1.5) • 8–9 km (1) • 9–10 km (0.5) • >10 km (0.5)	This layer scores land according to the score of the nearest water source (score derived from distance from coastline). The score is based on the assumption that oceanic water provides the best water quality and quantity for supplying a marine aquaculture development. This supply would be available through beach access and/or at river mouths. Reduced flushing rate, water volume and salinity would be expected with increasing distance upstream from river mouths. Therefore, this layer provides an approximation of the water quality/quantity that a parcel of land might have access to. The lower scores assigned to this layer is a reflection of the variability and uncertainty of the water quality/quantity parameters of intake waters and that the nearest water source is not necessarily the only source of intake and is therefore scored lower than other criteria. This layer would assist in assessing sites with a common estuarine water source. The 'Water source – distance to coast' layer was derived by creating a raster file (Euclidean Allocation, 30 m x 30 m cells) based on the 'Water source – quality/quantity' as source file, clipped with AOI, reclassified and converted to a new shapefile, 'Water Source – distance from coast'. This layer produces land polygons that take on the score of its nearest water source. Therefore, land areas that have ocean beach access score highest (5) and land accessing estuarine water upstream from river mouths are scored progressively lower (e.g. land that accesses water that is >9 km from the coastline scores 0.5).

Tidal Influence	Land: • above HAT line (5) • between HAT & TI (1) • within tidal influence (0)	State government policies constrain development in order to protect environmental values such as fish habitats. For example, State Planning Policy (SPP) Guideline – Agriculture 2014 (Part 4. Model land use codes for aquaculture) suggests that a buffer is provided of suitable width to support and protect tidal fish habitats which is: (a) 100 m from highest astronomical tide outside an urban area, or (b) 50 m from highest astronomical tide within an urban area. The tidal Influence layer was derived by including all land categorised as 'Tidal Influence (TI) in Queensland Wetland Data (Version 4) – wetland areas (2015). EHP has produced a predicted highest astronomical tide line (HAT) that represents an approximation of the land-tidal water interface at the highest water level that can be predicted to occur under any combination of astronomical conditions. This HAT line can be at higher levels than the TI line. Therefore, land was scored as being incompatible for development within the TI region + 100 m buffer (score = 0), compatible above the HAT line +100 m buffer (score = 5), and possibly compatible in those regions between the HAT line and region of tidal influence (score = 1).
LGA Zoning	• Rural zone • Aboriginal shires • All other local government area (LGA) zones (incompatible) ***Information only***	Land deemed compatible for coastal-dependent aquaculture aligns with SPP state interest guidance material Agriculture – Part E Model land use codes for aquaculture (2017) aquaculture (discharging): *AO1.1 If the development involves excavated ponds, it is a compatible use for the rural zone only*. Land parcels that were classified as 'Rural' in QLD Composite Planning Scheme (2011) or as 'Aboriginal Shire' in QLD Local Government Body Clip Digital Cadastre DataBase (DCDB) CUR (2013) were selected as being compatible for ADA consideration. Entire Aboriginal shires were selected as these LGAs were not included in the Composite Planning Scheme spatial data and local plans are still under development. The statewide composite dataset was developed between July 2009 and January 2011. It should be considered as a point in time dataset as of 27 January 2011 and therefore does not reflect changes in zoning since that date. This dataset was used to derive a combined Tenure/Zoning layer (below).

Tenure/Zoning	Land parcels Rural Zone and: • Freehold (10) • Leasehold (6) • State Land (3) • All other tenures (0) Non-Rural zoning (0) Aboriginal shires (10)	Suitable land tenure is required to encourage private industry to invest with security of title. Freehold land is most desirable as it provides secure title and no time limitations for occupation and development. Non-freehold land (e.g. leasehold land, unallocated state land) is under the control of the State of Queensland and aquaculture development may not be considered an appropriate use of the land, subject to time limitations for occupation, may require extensive negotiation with leaseholders/State Government (e.g. changing purpose, lease transfer, subleasing), and subject to competitive allocation processes and native title considerations. Therefore, scoring reflects the desirability/constraint on developing a land parcel relative to freehold tenure. Tenure/Zoning was derived by overlaying the LGA Zoning data with the DCDB (December, 2016), which identifies the land tenure. The merged parcels from these datasets were classified as Rural Freehold, Rural Leasehold, Rural State Land, Non-Rural, Aboriginal Shire.

Table A2. Scoring protocol for six base data layers to identify areas with minimum requirements for further consideration of land-based aquaculture development potential.

ELEVATION (m AHD)	SCORE
< 0m	0
0 - 5m	8
5 - 10m	10
10 - 15m	5
15 - 20m	3
> 20m	0

Distance to Water (km):	SCORE
1	10
2	8
3	6
4	4
5	2
>5	0

SLOPE(%)	SCORE
> 5%	0
3 - 5%	2
2 - 3%	5
1 - 2%	7
0 - 1%	10
0 (flat)	6

Water Source (km from coast)	SCORE
1	5
2	4.5
3	4
4	3.5
5	3
6	2.5
7	2
8	1.5
9	1
>10	0.5

TENURE:	SCORE
XX	0
AB	10
FH	10
LL	6
SL	3

Tidal Influence:	SCORE
> HAT line	5
>TI but < HAT	1
<Tidal Influence	0

Appendix 2. Constraint layers

Table A3. Constraint layers used to eliminate areas with environmental/conservation considerations from base layer of potential aquaculture land (PAL)

Theme	Categories / *(scores)*	Description
Matters of National Environmental Significance (MNES)	• World Heritage Properties • National Heritage Places • Commonwealth Heritage Places (exclude)	Eliminated areas within protected areas under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and heritage properties from the following databases: • *Australia, World Heritage Areas (2015)* • *Commonwealth Heritage List Spatial Database (CHL) – public (2016)* • *National Heritage List Spatial Database (NHL) – public (2015)* • *Collaborative Australian Protected Areas Database (CAPAD) 2014* Australian Government Department of the Environment (but not Indigenous Protected Areas that are Freehold, Leasehold, State Land).
Matters of State Environmental Significance (MSES)	Highly constrained Avoid where possible	Eliminated areas within MSES (Version 4.1, 2014). This aligns with Aquaculture Policy Statement (2016) – Adoption of the hierarchy of 'avoid –mitigate – offset' to address environmental impacts associated with aquaculture development in designated ADAs.
Regulated Native Vegetation (clearing and management)	Category X – no approvals required Other veg classifications require site-specific analysis	State Development Assessment Provisions (SDAP) State code 16: Native vegetation clearing (version 2.0) provides development assessment requirements for applications that may include the clearing of native vegetation. Development assessment requirements include: • groundwater discharge areas • wetland buffers • watercourse buffers (bioregion dependent) • maintaining connectivity • soil erosion control • avoiding waterlogging/salinity/acid sulfate soil impacts • avoiding high-risk areas in Protected Plant Flora Trigger Map (flora survey required). Vegetation clearing approvals require assessment on a site-by-site basis. Approvals are not required for clearing Category X vegetation. The GIS model has adopted the position of identifying areas where constraints are minimised. Therefore, in the first instance, only land identified as Category X (*Vegetation management regulated vegetation management map, 2016)* were included for further analysis of aquaculture development potential. All other land identified as Category A, B, C or R was eliminated from the potential aquaculture land layer. Note: clearing Cat C and R (e.g. clearing for firebreaks, roads, etc.) is accepted/self-assessable development.

State Important Agricultural Areas (Agricultural Land Class A and B)	Restrictions on non-agricultural development on Agricultural Land Class A and B	State Planning Policy (SPP)—state interest guidance material Agriculture Part E, Example code for aquaculture – discharging (2017) provides guidance to regional councils regarding the assessment of aquaculture ponds on agricultural land (Table 5). Aquaculture development is permitted in Agricultural Land Class (ALC) A and B but with restrictions. Many councils have adopted variations of the SPP guideline in their planning and development codes. The SPP guidance materials states: PO2 Development – other than tank-based aquaculture – is located and designed to avoid or minimise impacts to ALC Class A or B land. AO2.1 Development is not located on ALC Class A or B land. OR AO2.2 Where there is an overriding need for the development to be located on ALC Class A or B land: • the development does not have an irreversible impact on the productive capacity of ALC Class A or B land • where soil is excavated from ALC Class A or B land for the purpose of constructing aquaculture infrastructure, the soil is to be retained, protected and treated on site to allow for future land restoration • upon cessation of aquaculture production, the soil profile of the aquaculture development area is rehabilitated, as close as practical, to pre-aquaculture development conditions. The GIS model has adopted the position of identifying areas where constraints are minimised. Therefore, in the first instance, land areas identified as ALC A or B (*Agricultural land audit – land class A and B (2014)* were eliminated from the potential aquaculture land layer.

Appendix 3. Information layers

Table A4. Information layers to apply to Potential Aquaculture Land – clusters (PALC). The following data layers will be used to refine the PALC layer to identify those areas that are most suitable for aquaculture development.

Theme	Categories / *(scores)*	Description
Matters of National Environmental Significance (MNES) other	MNES includes: • listed threatened species and communities • listed migratory species • Ramsar wetlands of international importance • Commonwealth marine environment • world heritage properties • national heritage places • the Great Barrier Reef Marine Park	MNES impacts assessed under *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) need to assess the implications of impacts on various MNES criteria and constraints on aquaculture development where MNES are located. Consider both on-site impacts as well as downstream impacts (e.g. downstream impacts on Ramsar, downstream impacts on Great Barrier Reef water quality). Threatened and migratory species impacts might be better addressed at site investigation level/technical studies phase. *Australia - Species of National Environmental Significance Database 10km Grids (2016)* Interactive mapping of MNES is available online through the Commonwealth Protected Matters Search Tool. www.environment.gov.au/topics/about-us/legislation/environment-protection-and-biodiversity-conservationact-1999/protected. This search tool can be used to generate a map and report that will assist in determining whether MNES or other matters protected by the EPBC Act are likely to occur in a particular local government area, region or on a particular site. Most areas that have potential for aquaculture have threatened/migratory species listed as possibly being present. Therefore, on-site investigations are required to assess MNES values.

Downstream Impacts	• Great Barrier Reef Marine Park (GBRMP) Zones • State Marine Parks Zones • Ramsar wetlands • Fish Habitat Areas	Areas within catchments leading to marine parks, Fish Habitat Areas and/or conservation zones may attract a higher level of scrutiny regarding discharge requirements and therefore score lower than catchments without downstream conservation considerations. Catchment layers for GBRMP, State Marine Parks, Ramsar, Fish Habitat Areas may help to refine the potential aquaculture area layer using the following hierarchy: • catchment with no downstream marine park/conservation area (preferred) • catchment upstream but discharge not directly into marine park/conservation area • catchment upstream but discharge directly into marine park/conservation area (least preferred). ***Note**: nutrient caps will soon be introduced for GBRMP catchments*
Coastal Zone Management	Coastal Hazard Areas (erosion prone area and storm tide inundation area) and Coastal Management Districts	SDAP v2.0 (2017) State code 8: Coastal development and tidal works Development restrictions are in place for coastal hazard areas including projected permanent and temporary inundation areas due to sea level rise (e.g. erosion prone areas and storm tide inundation (high and medium hazard areas). However, aquaculture involving marine species is a coastal-dependent development and is a code assessable approved activity within coastal hazard areas provided risks are mitigated to an acceptable/tolerable level (e.g. pond wall heights). Development that involves tidal works within a Coastal Management District (i.e. state coastal land) will also have development assessment requirements and will be assessed against the SDAP coastal development and tidal works state code. Information layer includes: *Erosion prone area all components 2015* *Storm tide high hazard 2015* *Storm tide medium hazard 2015* *Coastal management districts (Development Assessment Mapping System 'DAMS' layer).*

Soil Characteristics (clay content for pond wall construction)	Clay content of subsurface soils: • >20% preferred • <20% acceptable but requires poly lining or imported clay	SPP state interest guidance material Agriculture – Part E Model land use codes for aquaculture (2017) PO7 Ponds are designed to avoid leakage. AO7 Ponds are designed and constructed in accordance with DAF's policy: Guidelines for constructing and maintaining aquaculture containment structures (2007). Aquaculture ponds are normally constructed by compacting excavated earth to a height of approximately 1.5–2 m. It is essential that a minimum clay content is present for adequate compaction to reduce the permeability of the pond walls and floor. However, there is mixed opinion on the minimum clay content required, ranging from 10–15% clay to >50% clay. Low clay content of soil may be managed through importation of clay lining or poly liners (although establishment costs are considerably increased). Soil data is broad scale in nature, whereby soil components are only indicative values and on-site soil analysis is required to determine soil suitability for pond wall construction. Percentage clay data was extracted from the Soils and Landscape Grid of Australia (SALGA). The SALGA soils data is provided in raster format with estimated clay percentages in 6 layers (0–5 cm, 5–15 cm, 15–30 cm, 30–60 cm, 60–100 cm and 100–200 cm). With regards to the excavation, only approximately 30 cm depth would be required to construct 2 m high trapezoidal banks (top of 2 m width 4 m base) for a 1 ha pond. Therefore, the soils data for the first 3 layers of the SALGA data were merged to provide a weighted percentage of clay for the first 3 layers (0–30 cm) and converted from raster to shapefile. This data is provided as information along with the percentage of clay for the 60–100 cm and 100–200 cm layers as well.
Soil Characteristics (groundwater vulnerability)	Groundwater vulnerability: • Low (preferred) • Low–Moderate • Moderate • Moderate–High • High	SPP state interest guidance material Agriculture – Part E Model land use codes for aquaculture (2017) PO7 Ponds are designed to avoid leakage. AO7 Ponds are designed and constructed in accordance with DAF's policy: Guidelines for constructing and maintaining aquaculture containment structures. Assume that preferred aquaculture sites would lie in Low or Low-Moderate rated areas of Groundwater Vulnerability. However, the risk of groundwater contamination can be managed through appropriate pond construction techniques. Groundwater vulnerability data provides useful broad scale planning information; however, site-specific geotechnical investigations for most medium to large–scale aquaculture sites would be required to determine the risk of groundwater contamination. Note: most current coastal aquaculture operations are located within moderate to high groundwater vulnerability classifications. *Queensland Groundwater Vulnerability Mapping (2002)* dataset.

Acid Sulphate Soils	Preferred areas are outside Acid Sulphate Soils (ASS) hotspots *Data available for select coastal areas only.*	Planning Act 2016. *Environmental Protection Act 1994* SDAP version 2 (2017)State code 17: Aquaculture PO6 Aquaculture development likely to cause drainage or disturbance of acid sulphate soil prevent the release of contaminants and impacts on fisheries resources and fish habitats. Determining whether or not ASS is present at a site and managing disturbed ASS appropriately can involve major costs. These costs may compromise a project's design or financial viability. Actual existence of ASS requires on-site evaluation and not all coastal areas have been assessed and mapped for ASS. Existing ASS mapping data is mainly predictive and may not be suitable for local-scale or property-scale planning. 22 data layers describing ASS from QSpatial and along the coast and an AOI clip from the Atlas of Australian Acid Sulfate Soils database are provided for information only.
Current Land Use		Land use mapping can be useful to assess potential conflicts among land users or if aquaculture development would be appropriate on rural land that is already productive. *Land use mapping - Current – Queensland (2017).*
Infrastructure and Transport		Information layer to provide guidance on proximity to major services, labour, and transport networks including: *Rail network – Queensland (2014)* *Baseline roads and tracks Queensland (2016)* *Major towns* *Airports* *Ergon electricity distribution network* *Energex electricity distribution network.*