Queensland Wetland Definition and Delineation Guideline

Part A: A Guide to Existing Wetland Definitions and the Application of the Queensland Wetlands Program Definition

Australian Government

Queensland Wetlands Program

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Introduction

What is the Queensland wetland definition and delineation guideline?

The Queensland wetland definition and delineation guideline is comprised of two parts.

Part A of the guideline is a guide to existing wetland definitions and the application of the Queensland Wetlands Program wetland definition (Program Wetland Definition).

Part B is the delineation and mapping guideline.

The intent of Part A is:

1. to provide guidance on the range of wetlands definitions used in Queensland
2. to introduce the Program Wetland Definition, provide guidance on how to interpret and apply the Program Wetland Definition, and explain the relationship with other Queensland Wetlands Program (Program) tools.

This guideline is intended to assist government agencies, landowners, conservationists, natural resource managers and others wanting to identify whether a feature[1] is a wetland for decision making and planning purposes.

In addition to identifying wetlands it is anticipated that this guideline will be useful for a number of other activities relating to wetlands, including their delineation, mapping, classification, assessment and management.

The Queensland wetlands definition and delineation guideline applies to all wetland ecological systems and types in Queensland but are somewhat restrictive when applied to subterranean systems.

This guideline should be read in conjunction with more detailed information contained in other relevant technical documents for which links are provided.

Why is this guideline needed?

Queensland is a large state that features diverse climate, geology, landform, rainfall, hydrological regimes and regional ecosystems. Consequently, Queensland contains a variety of different wetland ecosystems and types, the characteristics of which can vary significantly over time. Furthermore, wetlands are transition areas between land and water, a continuum from episodically wet areas to purely aquatic ecosystems. This makes it difficult to develop one definition that consistently and precisely describes and delineates all wetlands in Queensland.

Some wetlands, such as permanent lakes and rivers, are easily identifiable as wetlands; while others are more difficult to identify. This is because wetland characteristics vary in association with factors such as rainfall, hydrological (water) processes and seasonal variations. Due to the broad range of habitats, the difficulties in identifying wetlands, and the wide range of purposes for which policy and legislation has been developed, there are currently a variety of wetland definitions in use in Queensland. Detailed information is available on the WetlandInfo website.

The different wetland definitions in use, and the lack of consistency in how those definitions are interpreted and applied, compounds the difficulties associated with defining wetlands. It also creates confusion, at times leading to conflicting approaches to wetland-related decision making and actions. Although not presently the situation, a single wetlands definition and process to apply that definition would assist in addressing these problems if it was used throughout Queensland.

[1] In this guideline “feature” is different to “site”, which is reserved to indicate the area for ground survey and may include surrounding non-wetland support areas. A site should not be confused with the actual wetland feature, i.e. a site may contain a wetland feature(s) but a site may also contain non-wetland features.

Wetland definitions in Queensland

Introduction

This section provides a guide to currently used wetlands definitions, including those in Queensland legislation. This section does not provide any commentary or guidance on the value or utility of these definitions or their legislative interpretation. It is important to read statutory definitions in their full legislative context and with any available interpretative material. The Wetland*Info* website provides an introduction to applicable legislation. Queensland legislation and accompanying explanatory notes are available at the Office of the Queensland Parliamentary Counsel, and Australian Government legislation at the ComLaw website.

> Wetlands definitions may be described in a number of ways using qualitative criteria via a definition, entries on a schedule or list, references to a series of datasets or maps, description by metes and bounds or a combination of these.

International and national definitions

The internationally accepted wetland definition used in Australia is that in 'The Convention on Wetlands of International Importance especially as Waterfowl Habitat' (1971) (also known as the 'Ramsar Convention on Wetlands (1971)' or 'the Ramsar Convention'). The Ramsar Convention is an intergovernmental treaty that provides a framework for national action and international cooperation on the conservation and wise use of wetlands. Australia is a contracting party to the Ramsar Convention.

Article 1 of the Ramsar Convention defines wetlands as:

> Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water to the depth of which at low tide does not exceed six metres.

In addition, Article 2.1 provides that wetlands:

> May incorporate riparian and coastal zones adjacent to wetlands, and islands or bodies of marine water deeper than six metres at low tide within the wetlands.

The Ramsar Convention defines wetlands in a broad and inclusive manner that is applicable to all types of wetlands in all of its signatory nations. Ramsar definitions and classifications are relevant for Ramsar listed wetlands in Australia.

'A Directory of Important Wetlands in Australia' (DIWA) is a document that identifies nationally important wetlands and provides a classification system for them. The wetland definition used in DIWA is adapted from the Ramsar Convention to suit most Australian conditions. No specific reference is made in the DIWA definition to the additional areas covered in Article 2.1 of the Ramsar Convention.

Many of the other wetland definitions used in Australia and Queensland are based on the Ramsar definition and have been developed to provide greater clarity on its use under Australian conditions. For further information see the Australian Government's Ramsar website.

Queensland Wetland Strategy definition

The Strategy for Conservation and Management of Queensland's Wetlands [1] (the Queensland Wetland Strategy) 1999 provides the overarching Queensland policy position on wetlands, and defines wetlands as:

> Areas of permanent or periodic/intermittent inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres.

This definition is largely consistent with the Ramsar definition, but has been altered to make it more suitable to Queensland. References to marshes, fens and peatland have been removed, as these are not terms commonly used in Queensland. The term 'temporary', used in the Ramsar definition, is interpreted in the Queensland

context as including 'periodic or intermittent' wetlands, to reflect cyclical inundation (e.g. tidal changes), and ephemeral wetlands associated with Queensland's variable rainfall patterns.

The Queensland Wetland Strategy comments (page 6) that:

"… typically, wetlands include areas which show evidence of adaptation of soil or vegetation to periodic water logging — lakes, swamps, freshwater or brackish marshes, Melaleuca forests, lignum swamps, canegrass swamps, wooded swamps, claypans, ponded pastures and water storage dams; estuaries, rivers, streams, channels, waterholes and springs; intertidal sand flats, mud flats, salt flats, tidal marshes and mangroves; and shallow marine areas, such as seagrass beds or fringing coral reefs.

Though entire floodplains could be interpreted as 'intermittent wetlands', this is not the definition's intention. *Rather, intermittent wetlands — such as marshes, pot-holes, or shrub- or tree-dominated areas showing evidence of adaptation of soil to, or vegetation tolerant of, waterlogging — may occur as part of a mosaic of vegetation types on floodplains…"*

Wetland definitions in legislation

In addition to the broad definitions in use in Queensland referred to above, there are other wetland definitions, references to wetlands, and related terms in legislation applicable to Queensland, which reflect the many different purposes for the legislation. Several of these definitions are based on the Queensland Wetlands Strategy definition. Others include a list of wetland types, such as the *Coastal Protection and Management Act 1999* which lists …salt marshes, *Melaleuca* swamps, …mangrove areas…'.

Wetland*Info* contains a legislative and planning toolbox (a compendium of applicable legislation linked to catchment, natural resource management (NRM) or local government region) that provides more information.

The Queensland Wetlands Program Definition

The Queensland Wetlands Program (the Program) was established in 2003 to support projects that will result in long-term benefits to the sustainable use, management, conservation and protection of Queensland wetlands. The Queensland Wetlands Program Wetland Definition (Program Wetland Definition) was developed at a series of stakeholder meetings in April 2004 for use in the Program's projects, specifically those that provide the spatial basis for all other wetlands projects, the Wetland Mapping and Classification Methodology). The following section provides the details of the Program Wetland Definition.

The Program Wetland Definition[2]

Wetlands are areas of permanent or periodic/intermittent inundation[3], with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres. To be a wetland, the area must have one or more of the following attributes:

1. The land supports, at least periodically, plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle

2. The substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers[4]

3. The substratum is not soil[5] and is saturated with water, or covered by water, at some time[6].

Examples under this definition include:

- those areas shown as a river, stream, creek, swamp, lake, marsh, waterhole, wetland, billabong, pool or spring on the latest Sunmap[7] 1:25,000, 1:50,000, 1:100,000 or 1:250,000 topographic map[8]
- areas defined as wetlands on local or regional maps prepared with the aim of mapping wetlands
- wetlands regional ecosystems (REs) as defined by the Queensland Herbarium
- areas containing recognised wetland plants
- saturated parts of the riparian zone
- artificial wetlands such as farm dams
- water bodies not connected to rivers or flowing water, such as billabongs and rock pools.

[2] This is the full text of the Program Wetland Definition including a footnote and needs to be read with Appendix 1 and other sections. Other clarifying footnotes that provide clarity on the intent of the original QWP definition have been added.

[3] This footnote does not form part of the original Program definition. "Inundation" includes saturation.

[4] This footnote does not form part of the original Program definition. "Upper layers" is usually the top 0.3 m but may be deeper if overlain by permeable material.

[5] This footnote does not form part of the original Program definition. Artificial water bodies with artificial bed and banks are not included (see Appendix 1 and Section 4.7).

[6] This footnote does not form part of the original Program definition. When water is in a channel, the intent is to capture surface wetlands without soils, such as rocky river beds, waterfalls, boulders at headwaters, etc, and also subterranean wetlands. When water is outside a channel, the intent is to capture gamma holes and similar water holding depressions.

[7] This footnote does not form part of the original Program definition. Now refers to Geoscience Australia's map series.

[8] Although the above mentioned Geodata feature codes are generally typical of wetland systems, they are by no means exclusively typical of such systems or an exhaustive list of topographic features which may be wetlands.

Examples under this definition exclude:

- areas that may be covered by water but are not wetlands according to the definition
- floodplains that are intermittently covered by flowing water but do not meet both the biotic and soil criteria
- the riparian zone above the saturation level.

Features of the Program Wetland Definition

As outlined above, the Program Wetland Definition has been adapted from international, national and state definitions and was based on the definition developed for the Strategy for Conservation and Management of Queensland's Wetlands (EPA, 1999) (the Strategy definition). The Program Wetland Definition adopts the text of the Strategy definition as its starting point and builds on it by including three additional attributes, or criteria, that an area must meet to be a wetland. The additional criteria define more precisely the intent of the strategy definition that wetlands are areas that 'show evidence of adaptation of soil to, or vegetation tolerant of, water-logging'. The effect of these criteria is that wetlands are defined where wet conditions are a dominant environmental factor shaping the values of an area. In addition, these criteria provide a fairly good description of a wetland environment, i.e. the observable attributes of plants and/or animals or soils associated with a wetland.

The inclusion of the additional criteria refines the Strategy definition and also helps to overcome some of the difficulties associated with identifying wetlands in the field due to seasonal variations or disturbances. For example, a wetland may be identifiable due to the presence of wetland plant species, despite the fact that it is dry at the time. Alternatively a wetland might be identifiable due to evidence of wetland soil conditions, despite lacking wetland plant species due to clearing.

General approach

Factors, criteria and indicators

The Program Wetland Definition and associated guidelines are conceptually similar to other wetland definitions in Australia [2–5] and the world [6, 7]. The definition consists of criteria for four factors: hydrology, biota, soils, and non-soils/non-biota, which are used to test if a feature is a wetland or not (Table 1)[9]. Each criterion is assessed by indicators that can be described by the collection of information or evidence from field survey or other sources (Table 2).

Table 1 Factors and criteria from Program Wetland Definition

Factor	Criterion
Hydrology	Areas of permanent or periodic/intermittent inundation, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres
Biotic	Supports plants and animals, at least periodically, that are adapted to or dependent on living in wet conditions for at least part of their life cycle
Soils	The substratum is predominately undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layer (hydric soils)
Non-soils, non-biotic	The substratum is not soil and is saturated with water, or covered by water, at some time.

[9] The description of the definition as factors, criteria, and indicators follows the approach outlined by the Committee on Characterisation of Wetlands in North America.

Table 2 Examples of conclusive and less conclusive indicators and sources of information for factors in the Program Wetland Definition

Factor	Conclusive indicators and thresholds – criterion is met	Less conclusive indicators and thresholds – additional information required to conclude criterion is met	Sources of evidence
Hydrology	Direct observation; water saturation/inundation Indirect observations; micro relief, Debil Debil, algal mats, aerial roots, floodmarks, iron staining Presence of wetland soils (part 1 of wetland key in soils field guide), vegetation dominated by wetland indicator plants, observation of inundation on imagery, hydrological monitoring	Wetland landform such as closed depressions, wetland drainage patterns, mud cracks, surface staining, algal flakes and salt crusts, stream flow meter data Indicators of hydrological modification may mean that conclusive soil and biotic indicators are inconclusive on their own	Historic records, time series imagery, field observations. Tidal level and stream flow records
Biota			
-Flora	Predominance of wetland indicator plants	Presence of any flora species, or parts of these, e.g. underground perenneating plant parts and seeds although seeds can by found anywhere floodwaters go, previously compiled wetland or vegetation mapping	Field survey by relevant expert Queensland Wetland flora/fauna indicator list, site databases such as Wildnet, CORVEG (caveats of precision and currency)
-Fauna	Species recorded at lifecycle stage known to be dependent on wet conditions Species known to be dependent on wetlands for all stages of their lifecycle	Presence of any species that are not confined to a wetland for all of life, or evidence of fauna, e.g. eggs, skeleton remains or shells	
Soils	Indicators in parts 1 and 2 of wetlands soil key	Indicators in part 3 of wetlands soil key	Field survey, soils maps
Non-soil, non-biotic	Partially or non-weathered rock. Beds and banks of creeks, rivers and other drainage lines, beaches below Highest Astronomical Tide (HAT) but exposed at low tide		

Multiple lines of evidence

The Program Wetland Definition is satisfied if sufficient information is provided to demonstrate inundation as well as one (or more) of three further criteria. For each criterion there may be a variety of indicators, which range from those that are broadly applicable across Queensland (e.g. wetland indicator plants) to more specific indicators that may only be applicable in certain regions (e.g. some soil indicators). More conclusive indicators can be used by themselves to determine that a criterion has been met, while other, inconclusive, indicators only suggest a feature has some wetland characteristics and require additional supporting evidence to confirm if a criterion has been met. Under these circumstances the more and varied information that is used to apply the definition to a particular site, the stronger the evidence, and the more likely it is that the definition will be applied correctly. If the feature is then found to be a wetland, the more accurate its field delineation is also likely to be.

The wetland definition is, therefore, applied using a multiple-lines-of-evidence approach in which more conclusive indicators can be used on their own to reliably determine a criterion has been met, whilst less conclusive indicators are used with other information to determine if a criterion has been met.

For example, soils that indicate the possible presence of anaerobic conditions, sightings of a few obligate wetland fauna species, or the presence of a few wetland plants indicate that the feature could be a wetland, but considered individually are not conclusive. However, the combination of these multiple evidence lines together gives greater support to the interpretation that the feature may be a wetland. The best approach when undertaking and investigating to apply the Program definition is to collect as much information from as many different reliable sources about as many of the attributes set out in the definition as possible.

The strength of evidence used depends on the type and quantity of evidence presented. Examples are presented below as dot-points.

Type – how accurate or reliable the evidence is as a wetland indicator:

- some soils indicators (such as the accumulation of organic materials) conclusively identify a wetland soil, whereas others (such as redox features, e.g. mottles) may be relict landscape features and require careful consideration against the current hydrologic regime in order to assist in wetland identification. More conclusive soil indicators may be utilised on their own for wetland identification, while less conclusive indicators may need to be supported with landscape information
- some fauna, while dependent on living in wet conditions, are not necessarily confined to a wetland, so a sighting could either be interpreted as indicating that a feature is a wetland, or it could just be incidental
- some lines of evidence are subject to greater variability in their interpretation than others, such as the utility of soil organic carbon content as a wetland indicator.

Quantity of a particular piece of evidence:

- replicated observations and/or multiple positive soil test indicators at the intensity appropriate to the scale of survey provide more compelling evidence than just a single observation and/or positive indicator
- a waterfowl breeding colony with many nests will be more conclusive than the sighting of a few waterfowl
- dominance by wetland indicator plants in an area indicates that hydrology is the dominant environmental factor operating compared to areas where non-wetland plants predominate or wetland plants are sub-dominant.

Quantity of different sources of evidence of one particular criterion:

- combination of results from a number of different soils observations conducted on site in addition to soils mapping that indicated hydric soils in the area
- combination of sighting of waterfowl and nests in the field with literature that suggests this is a nesting area.

Wetland criteria and indicators

The following section provides background to the indicators, thresholds and evidence outlined in Table 2 that are used to assess the definition criteria.

Hydrology

Hydrology is the most important environmental driver of wetlands. Ideally wetlands would be defined in terms of a hydrological regime, such as duration and frequency of inundation or saturation. However, the hydrological regime that supports wetlands varies with wetland type, region and associated environmental factors such as climate. For example, flooding for 14 consecutive days each growing season is considered a minimum wetland hydrological regime in North America [7] while wetland soil characteristics can develop in inland Australia in areas saturated for less than five weeks every three years [8]. Wetlands in Australia also include areas flooded episodically – even once every 100 years – because of their importance to wetland fauna such as water birds [4].

There is generally little information from which to define minimum hydrological thresholds for any wetlands in Queensland. Thus the Program definition is structured so that it requires indicators of the presence of inundation while the degree of inundation is assessed by the biotic and soils criterion. In other words water-logging must be present but of sufficient duration and/or frequency to create conditions that support wetland indicator plants, animals or soils.

Saturation in the root zone is fundamental for defining wetland hydrology [9]. Thus water-logging generally must be within the upper 0.3 m of surface because this is the part of the substrate that influences most of the plants and animals. Inundation with water can be from a variety of sources including flooding from tidal inundation, water overflowing from water courses, or ponding by water collection in a depression or saturation from groundwater. This is consistent with the Queensland Wetland Strategy, which lists wetlands that receive water from a variety of sources (e.g. springs, floodplains) as well as definitions used elsewhere in Australia [2, 4, 10] and overseas [6, 7, 11, 12].

While direct evidence of saturation may be used as an indicator, this is often difficult to obtain due to the temporal and spatial variability in wetland hydrology and because a site often needs to be evaluated at one point in time. Therefore, in the absence of hydrological information the dominance of wetland plant or soil indicators, in conjunction with other hydrological indicators, provide enough evidence that the hydrological criteria have been met. Other indicators include micro-relief, air-photo or satellite image record (which can be used to quantify hydrological regime if obtained as a time series) or hydrological models. Wetlands typically occur in topographic settings where surface water collects or groundwater discharges [9]. Thus, landform situations such as closed depressions, oxbows and clay-pans provide a useful indication of potential inundation or saturation. Analysis of topographical and groundwater contours may provide an indication of inundation or water-logging.

Biota

Plants

Plants are widely used as indicators of wetlands overseas [7, 9, 13] and in Australia [2, 3, 5, 14, 15]. This is because there is often a strong relationship between soil saturation and the development of communities dominated by plants adapted to and requiring such conditions. Therefore, plants are often particularly useful indicators for the identification and delineation of wetlands. As many lacustrine and riverine wetland types are often fringed with palustrine wetland vegetation along their upland edge (Figure 3), plants can often be used to delineate wetland boundaries even for water dominated wetlands.

A list of wetland indicator plants that are adapted to and dependent on living in wet conditions for at least part of their life has been prepared for Wetland*Info* [16] to help identify wetlands. While the criterion in the definition includes land that supports wetland plants, to be conclusive it is considered that the vegetation has to be dominated by such plants, as this indicates that inundation with water is the dominant factor determining the types of plant (and animal) communities associated with the site [6]. Plant dominance is determined as the dominant species within the ecological dominant layer (EDL). Vegetation is assessed as being dominated by wetland plants when the ecological dominant layer is dominated by wetland plants. The EDL is defined in Queensland [17] and Australia [18] as the layer of vegetation that makes the greatest contribution to the overall biomass at a site. As there is generally a relationship between biomass and the commonly used abundance measures of crown cover or basal area, dominance can be assessed by estimates of these abundance measures

using standard methodologies [17]. Under this definition dominant species are generally tree species, where present, rather than ground layer species, which are more likely to be influenced by short term environmental fluctuations such as drought, grazing or fire.

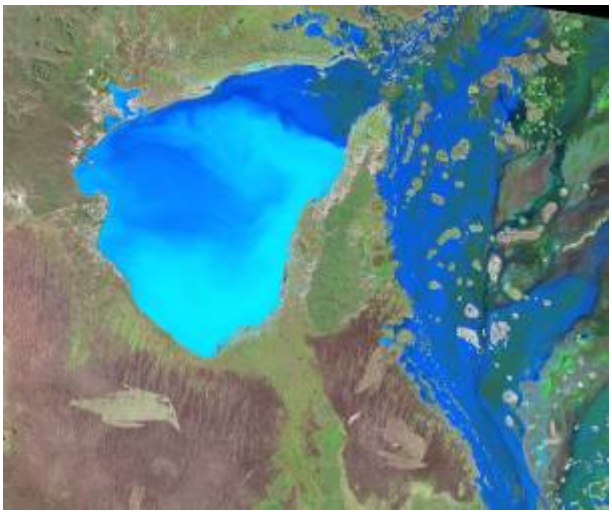

Figure 1 Landsat TM satellite image (April 1999) showing flooding on the Cooper Creek

Figure 2 River red gum seeds show the maximum extent of inundation, Goondiwindi (B. Wilson)

Fauna

Criterion (i) of the Program Wetland Definition recognises that there are species that are adapted to and dependent on living in wetland conditions for all, or at least part of, their life. Wetland fauna species' ancestors are considered to originally have been entirely aquatic and some have evolved into amphibian and terrestrial fauna, with some (dolphins and dugong) readapting to an entirely aquatic lifestyle. The Queensland Wetland Indicator Fauna Species List (WIFSL) contains an extensive suite of wetland species that have been selected by a justification process and, therefore, can be used as one line of evidence when testing a feature for wetland status. For ease of use only significant larger fauna are included in the WIFSL.

Wetland environments where no plants exist (shoals, extensive intertidal mudflats, super saline features) can be inhabited entirely by fauna. Highly mobile fauna wetland species have an advantage of moving from wetland to wetland to maximise resource use. Less mobile species are usually able to either burrow and aestivate until water returns, or breed and leave non-desiccating eggs.

Wetland ecosystems are the product of co-evolution of flora and fauna in aquatic features to produce interacting ecosystems for mutual benefit.

Figure 3 Brown Lake, North Stradbroke Island (Photo K. Stephens)

Most water-dominated wetlands are fringed by palustrine vegetation that can be used to delineate the boundary.

Figure 4 A bare, dry claypan, Currawinya NP (photo J. Silcock)

Many ephemeral wetlands in inland Queensland are often dry and bare of vegetation.

Figure 5 Magpie geese (photo R. Jaensch)

Mobile wetland fauna can be found in non-wetland areas so their presence alone may not be a conclusive wetland indicator.

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Figure 6 Ibis nests in a lignum swamp on the Cooper Creek floodplain (R. Jaensch)

Nesting of these water birds is a conclusive wetland indicator because they are known to require at least 90 days flooding to successfully breed in lignum swamps [19].

Substrate – soils

Comprehensive reports on the wetland soils indicators and methodologies and a field guide to wetland soil indicators [21] have been prepared to support the interpretation of the Program wetland definition with respect to hydric soils. These reports define the upper layer of soil as generally within 0.3 m of the surface, but may be deeper if overlain by permeable material. Soil indicators that conclusively identify a wetland soil are the accumulation of organic (decomposed plant) materials, the presence of sulfidic materials and gleyed soil matrix colours. Other indicators such as mottles, segregations, ferruginous root channel and decreasing matrix chroma may be relict landscape features and require careful consideration against the current hydrologic regime in order to assist in wetland identification. Some soil indicators vary with climatic region (tropical/equatorial, subtropical, semiarid and arid), wetland system (palustrine, lacustrine and estuarine) and by inundation frequency (periodically or commonly wet).

The field guide to soil indicators includes a key to help identify and delineate Queensland wetland soils and provides a user friendly system for applying soil indicators to assist wetland identification across Queensland.

Soils – biota absent

This criterion is required because some obvious wetland features in Queensland have no vegetation or soil present and cannot be consistently identified from fauna indicators. These features include water in a channel, such as rocky river beds, waterfalls, boulders, headwaters, etc, and also subterranean wetlands. When water is outside a channel, the intent is to capture features such as gamma holes, beaches and similar water holding depressions. Features not included in this criterion include areas with banks and bed made from artificial materials.

Terms used in the Program Wetland Definition

Appendix 1 provides an explanation of terms used in the Program Wetland Definition and their intended interpretation. This explanation should be used in order to gain an understanding of the definition, and also in the event of any uncertainty or dispute as to the meaning or interpretation of any of the terms in the context of the definition. The Glossary (Appendix 3) provides definitions not covered in Appendix 1, excluding common words with standard dictionary definitions.

Applying the Program Wetland Definition

The four-step process

In order to check if a feature is or is not a wetland, the Program Wetland Definition is applied using a four-step process, in which evidence is systematically collected and evaluated to determine whether the definition is satisfied. The process involves:

- knowing and understanding the definition
- planning of the investigation of a potential wetland feature
- conducting the investigation and recording information
- applying the wetland decision tree.

Once it has been determined that a wetland exists, the data recorded during the investigation can also be used to better understand the wetland's ecosystems, classification and values, and to delineate its extent.

The following provides general guidance only. Readers should refer to the delineation and mapping guideline and other sources for detailed sampling methodologies.

Step 1: Knowing and understanding the definition

Knowing and understanding the Program Wetland Definition, its features and terminology is essential to being able to apply it correctly. Refer to:

- Sections 3.1. 3.2 and 3.3 to extend any understanding of the definition
- Appendix 2: Wetland Definition Terms to ensure an understanding the meaning of terms used within the definition and can interpret them appropriately.

The Queensland Wetlands Program defines wetlands on ecological principles in a more systematic way than earlier definitions. However, just as a literal, broad application of this definition would expand the scope of "wetland" areas beyond what is reasonable, a narrow interpretation would improperly exclude many obvious "wetland" areas from consideration. In some cases, the application of the wetland definition is still likely to require assistance by experts taking note of the intent and values upon which the definition is based.

Step 2: Planning the investigation of a potential feature

The investigation of a potential wetland feature will generally involve the consideration of existing information about the site and recording of new information during field work. Issues to consider include:

- checking existing mapping
- determining why the investigation is required, what is the purpose of the investigation, what data are required and what data are recordable as well as whether the investigation will involve a single survey or require several
- determining what scale of investigation and accuracy is appropriate, according to its purpose and how the resulting information will be used for applying the definition and other related activities (see Section 4.1). For example, an urban local government may need to consider wetlands at a more detailed scale for assessing development proposals at the property level than a regional planner who is developing a plan for a large river basin
- considering the scale and position of the wetland site; where and how the wetland sits within the surrounding landscape including over all landform, hydrology, position within the catchment (local and broad scale geophysical situation), buffer zone and also review available data (climatic, bioregion, bio-province), wetland mapping and aerial photography
- considering the wetland condition with regard to season (e.g. what migratory species will be present or absent), weather conditions, previous rainfall, flooding, drought, cyclonic wind damage, bush fire frequency and currency, tide, human interference (e.g. vegetation clearing, cutting-filling and hydrological alterations)
- deciding if a survey is the most appropriate action, and if so:
    - the type of survey – survey a given area to define wetland type and existence, series of transects or other survey methods that best fit data recording objectives, optimal times and durations to survey based on expected flora and fauna and potential breeding activity and whether nocturnal surveys are necessary

  - whether the survey is a single disciplinary project or a multidisciplinary project (flora, fauna, soil, water, other data)

- selecting the mix of personnel required and equipment needed (including safety precautions, arrangements and equipment).

Step 3: Conducting the investigation and recording information

On arrival at the site check that the wetland condition is as expected and that any alterations are not so severe that the survey purpose is compromised. If proceeding with the survey, the site description should be modified as necessary to reflect actual conditions. Preparation for the field work is important to achieve the required outcomes. Field work requires careful planning and the data collection increases in rigour when recorded over more than one site visit. In fact it is beneficial to separate some activities from others that may disrupt or influence the outcomes.

As an example, combining some soil sampling techniques (such as mechanical coring) with bird or ground reptile surveys may be inconsistent with proper fauna observation due to the mechanical noise and vibrations:

- preventing identification by call e.g. bird calls
- disturbing some birds causing them to leave the area
- causing some fauna to hide or leave, thus biasing the survey.

Some fauna surveys might require particular times when the fauna are present and observable, such as after rain, at night or around dawn, and this may not fit with other survey techniques.

Climatic and seasonal events must be taken into account when planning and surveying because many wetlands and wetland processes are ephemeral and the past and current climatic and seasonal rainfall is very important to consider. Flooding and drought events can alter wetlands to display vastly differing physical and ecological characteristics. Wetlands can progress from being difficult to identify and characterise because they are dry, to difficult to identify because of flooding, within a few hours (WetlandInfo's conceptual models are a useful tool to support this step).

To accurately investigate and record information:

- fit the field surveys for optimum data rigour and organise the field data recording accordingly
- record habitat structure including dominant, overstorey, understorey and groundcover, both within the proposed wetland and in adjacent area
- record that which relates to the wetland criteria set out in the Program Wetland Definition: inundation as well as wetland plants or animals, wetland soils or saturation of the substratum
- appropriate care should be taken with the use of existing information (e.g. accuracy, age, scale). Scale issues may also affect identification as previously discussed. Therefore, Queensland wetlands mapping should not be relied upon as the sole evidence of a wetland location. Identification and survey of wetland indicators using the process outlined in this section will be needed to map a more accurate wetland boundary
- include sources of information such as literature, imagery, government documents, species lists as well as field data recorded from the site itself.

Information sources

Useful information to consider and possible sources of existing information include:

- the location of the site
- a written description of the site including:
  - climate
  - recent weather
  - geology
  - position within catchment and proximity to other known or potential wetland features
  - current and past uses
  - cultural characteristics
  - artificial constructions

- mapping including:
    - Queensland Wetlands Program wetland mapping
    - other local wetland mapping
    - Queensland regional ecosystem mapping
    - topographical mapping (showing contours and hence drainage patterns)
    - flood mapping
    - soil and land resource mapping
    - hydrological mapping (revealing any evidence of ponding or depressions, inflows and outflows, contours and disruptions to the hydrological processes)
    - digital elevation and flow accumulation models
- aerial photos and satellite images of the site
- wetland flora and fauna indicator lists including:
    - DERM wetland indicator species lists
    - Wildnet
    - other local information
- soils indicators:
    - recommended soil indicators in the Soil Indicators of Queensland Wetlands, the statewide assessment and methodology and the associated field guide
    - contextual information to support soil indicator interpretation (e.g. presence of current versus relict water regimes) including salt profiles, mottles and segregation boundaries, microrelief, floodmarks and algal mats
- national soil and land survey methodologies are provided by the Australian Soil and Land Survey Handbooks Series, which can be purchased from CSIRO Publishing. Key products include:
    - *The Australian Soil and Land Survey Field Handbook* (Volume 1 of the series) provides one reference set of definitions for the characterisation of landform, vegetation, land surface, soil and substrate
    - *The Guidelines for Surveying Soil and Land Resources* (Volume 2 of the series) promotes the development and implementation of consistent methods and standards for conducting soil and land resource surveys in Australia
    - *The Australian Soil Classification*, Revised edition (Volume 4 of the series), which is also available as an online version
- information from those who are recognised as having sound local knowledge of the site
- vegetation survey and mapping methods[17].

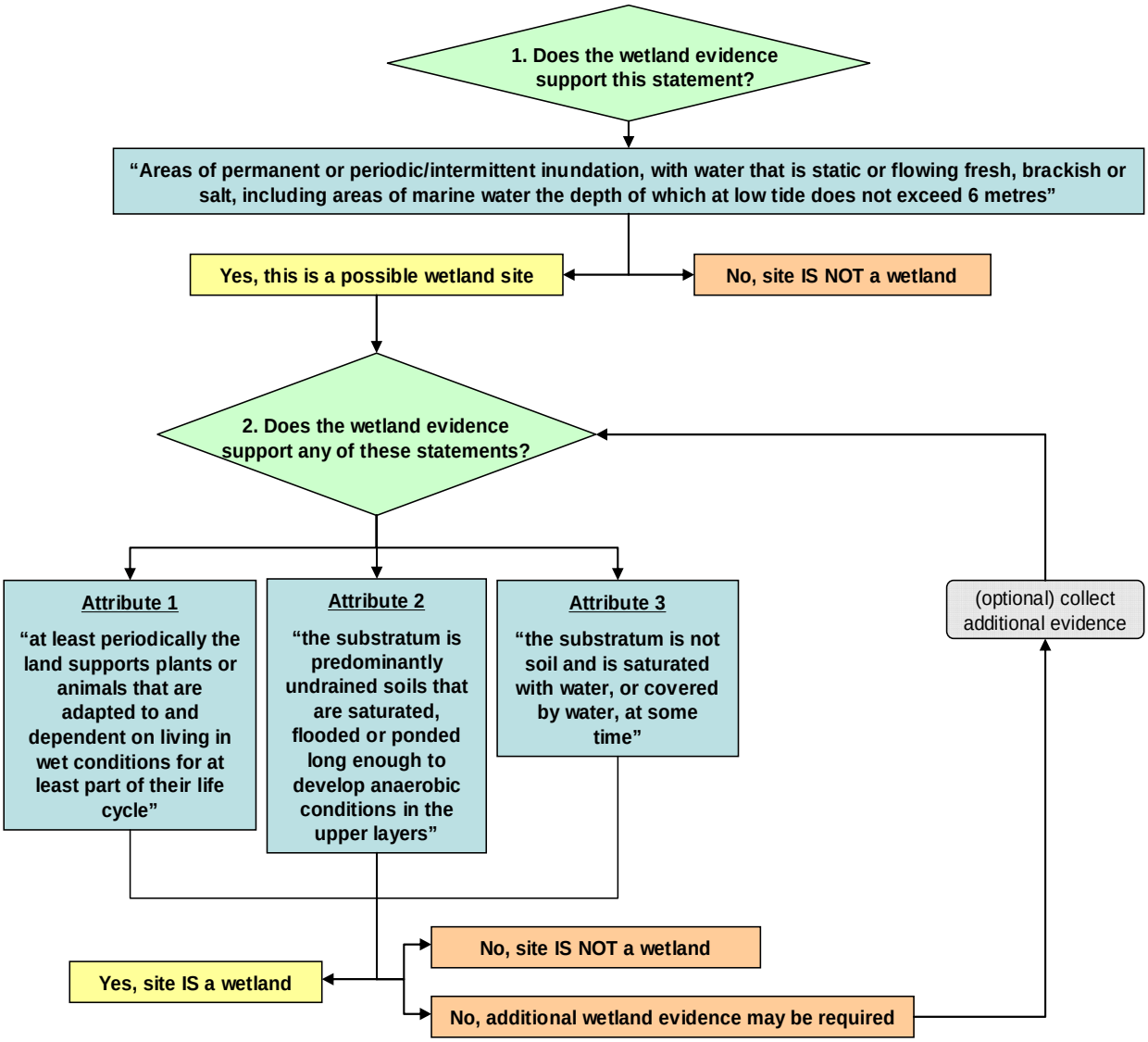
The Department of Environment and Resource Management has a database to store data contributed to the wetland inventory database by external parties. An online information capture system called Wetland Information Capture system (WIC) has been developed. Any individual or organisation that contributes data to the wetland inventory database remains the custodian or owner of their data.

Field investigators are strongly encouraged to contribute data to the wetland mapping and inventory database using WIC. For more information on WIC and online data capture tools, see WetlandInfo website's Contribute inventory data.

Step 4: Applying the wetland decision tree

The wetland decision tree is applied to the collected information to determine whether the feature is a wetland in accordance with the Program Wetland Definition.

Figure 7 The wetland decision tree



To apply the wetland decision tree:

Step 1: Test whether the wetland evidence supports the first paragraph of the Queensland wetland definition:

> Areas of permanent or periodic/intermittent inundation with water that is static or flowing; fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

If the wetland evidence provides some support for this statement, then it might be a wetland, so proceed to Step 2.

If the wetland evidence does not support the statement, then the feature is not a wetland.

Step 2: Test whether the wetland evidence indicates one or more of the three wetland criteria of the Queensland wetland definition.

- at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle; or
- the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layer; or
- the substratum is not soil and is saturated with water, or covered by water, at some time.

If the wetland evidence does support at least one of the criteria the site is a wetland. Each of the criteria should be tested to gain a full appreciation of the feature's standing as a wetland.

If the wetland evidence does not support any of the criteria then either:

- the feature is not a wetland; or
- additional wetland evidence may be required, and the wetland decision tree process repeated if an initial assessment of a site has identified inconclusive wetland indicator.

Scale

Scale is an essential consideration when applying the Program Wetland Definition for mapping and on-ground (field) assessment. Selecting an assessment/mapping scale determines the minimum size of an area that can be identified under the definition. Only at certain scales do relatively smaller wetlands become distinguishable from the surrounding land while the scale of assessment also affects the minimum size of non-wetland features delineated at a site. Scale will also impact on the positional accuracy of a mapped boundary line.

The appropriate scale for definition and delineation will vary with the purpose of investigation but also the characteristics of the site. For particular purposes finer resolution may be appropriate, such as a study of frog habitat or for wetland rehabilitation mapping or road surveying. Small isolated high value wetlands, such as springs, may require a larger scale to enable there delineation. However, for larger wetland areas it may be inappropriate to survey at a larger scale that would break the area up into a mosaic of wetland and non-wetlands (see below for discussion of mosaics).

Minimum size of features delineated

The scale of identification/delineation will determine the minimum size of features that can be identified (Table 3). Wetland mapping and classification has been conducted for Queensland through the Program at a scale of 1:100,000 to 1:50,000. At a scale of 1:50,000 wetlands larger than 1 ha or 35 m wide are distinguishable. At a scale of 1:100,000 wetlands larger than 5 ha or 75 m wide are distinguishable. More detailed imagery and/or field assessment can be used to distinguish smaller or more complex wetland systems. However, there is always a lower limit to the appropriate scale to use, beyond which the definition will separate out components within a community rather than different communities. For example,

Figure 7 shows an area where small (<0.25 ha) areas, which do not have wetland indicators, can be shown at a large scale but are considered part of the larger wetland areas depicted on the map.

Generally, for statewide assessment purposes/consistency an assessment/mapping scale of 1:25,000 that identifies areas to a minimum size of 0.25 ha is appropriate.

Table 3 Effect of map compilation scale and method on feature resolution and line (boundary) precision

Feature	Min. size delineated[1]	Traverse with hand held GPS	Map/assessment scale					
			1:5,000	1:10,000	1:25,000	1:50,000	1:100,000	1:250,000
Area of smallest feature depicted	2 × 2 mm		0.05 ha	0.1 ha	0.25 ha	1.0 ha	4 ha	25 ha
Minimum width of linear features depicted	1 mm	10 m	5 m	10 m	25 m	50 m	100 m	250 m
Accuracy/ precision of line/boundary[2]	±0.5 mm	10 m	5 m	10 m	25 m	50 m	100 m	250 m

Source: Neldner et. al. 2005, Table 5.

[1]The minimum size delineated will determine the area of the smallest feature depicted.

[2] The accuracy of the base imagery must be added to this to give overall accuracy of the final boundary.

Figure 7 Minimum size of wetland features delineated

Areas in yellow are also considered wetland features because they can be identified as not having wetland indicators at 1: 5000 scale, they are less than 0.25 ha and therefore appropriately assessed as part of the larger wetland area (blue areas).

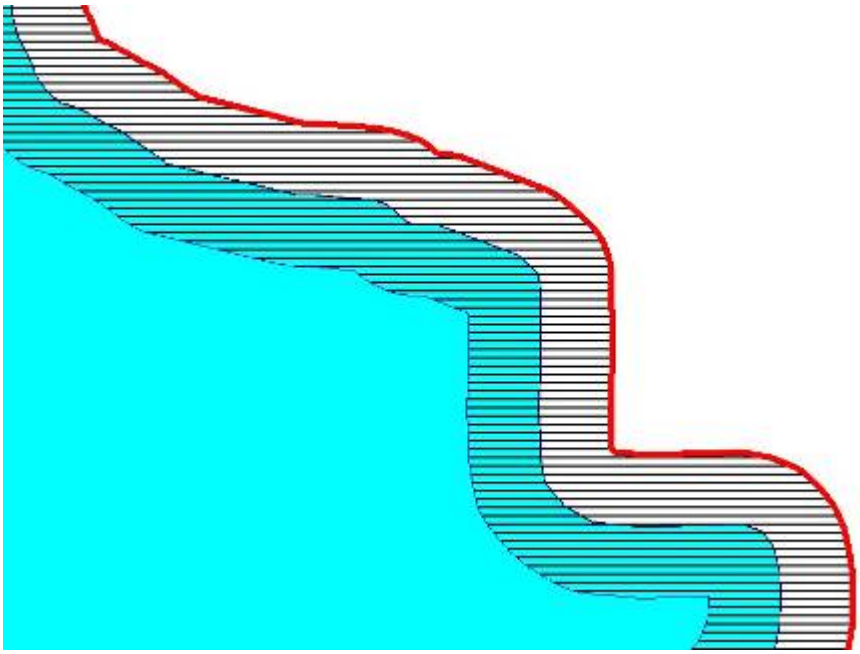


Figure 8 Wetland delineation line showing buffer that must be left to allow for specified error estimate

Extent of the wetland boundary delineation is shown in blue shading with the accuracy confidence interval indicated by horizontal hatching. The red line indicates the boundary that must be used to ensure wetland is captured.

Mosaic wetlands

Mosaic wetland sites are areas that are classified as wetlands at the specified scale of assessment but at larger scale consist of a mixture of wetland and non-wetland features. An example of a mosaic wetland is the complex patterning in the channel country shown in Figure 9, where the green areas that are lower, more frequently inundated, and support wetland plants and develop hydric soil characteristics are mixed with greyer areas that are higher less inundated and support terrestrial plants and soils that do not exhibit hydric characteristics. At an appropriate scale of assessment of 1:25,000 the whole area is dominated by wetlands and therefore classed as a wetland (mosaic).

The concept of mosaic wetlands is therefore dependent on the specified scale of assessment and, for example, a mosaic wetland defined at a scale of 1:25,000 could be divided into wetland and non-wetland features at a scale of 1:10,000.

Figure 9 Mosaic wetland/non-wetland on the Cooper Creek (B. Wilson)

At the scale of wetland definition the whole area would be classified as palustrine while at a larger scale the component green, frequently inundated palustrine vegetation is clearly discernable from the grey less frequently inundated vegetation.

A mosaic area of wetland and non-wetland features is considered a wetland if the features having wetland attributes occupy greater than 50 per cent of the area with a minimum scale of delineation 0.25 ha.

This means that at the general scale of 1:25,000 specified the whole of any 0.25 ha area is classified as a (mosaic) wetland if greater than 50 per cent of the area is wetlands.

Difficulties associated with applying the Program Wetland Definition

In some cases using the criteria and indicators outlined above to identify and determine wetland boundaries can be difficult or inconsistent determinations. Examples of situations where this can occur include wetlands that have been modified, are predominantly ephemeral or where there is a broad ecotone (transition zone) between the wetland and adjacent landscape, or where the scale of assessment makes it difficult to determine if an area is identified as a wetland or not. The following sections provide details on assessment in some of these situations.

Floodplains

Floodplains are alluvial plains characterised by frequently active erosion and aggradation by channelled over bank stream flow. The area inundated by floodwater may include various landform elements associated with floodplains, such as stream channel (stream bed and bank), plain, bar, scroll, levee, back plain, swamp, oxbow and lakes.

Flooding presents challenges to identifying features of the landscape that are wetlands, adjacent to wetlands or that are not wetlands. When floodwaters recede, the highest parts of the floodplain are drained and exposed to drying first, while the lower features within the floodplain hold floodwater for a longer period. Although periodically inundated, many parts of a floodplain do not remain wet for long enough to generate anaerobic wetland soils or to host obligate wetland species. Hence, according to the Program Wetland Definition, many parts of floodplains are not wetlands though a floodplain may contain large areas of wetlands (sometimes referred to as floodplain wetlands).

Ephemeral wetlands

The arid regions of Queensland commonly contain wetlands that naturally dry up entirely. These wetlands may often be dry for years and may only be wet for a short period (i.e. ephemerally). This makes their identification difficult. Some of these sites will require careful analysis and expertise to identify and include when dry.

In most of these cases, wetland soils may indicate that a wetland exists. Other indicators may be identifiable remains of wetland plants and animals. There may be traces of plants or seeds within the soil. The shells, bones or scales of wetland animals (such as mussels, snails, crabs, crayfish, turtles and fish) may remain. Eggs may be found in the soil, and some species may be underground waiting for the water's return. Traces of obligate animal burrows may also be evident.

Artificial wetlands

In this guideline an artificial wetland is taken to mean one built where there was no wetland prior to the construction, rather than a modified wetland (a pre-existing wetland modified through construction, extraction, etc). Artificial wetlands meet the wetland definition and incidentally provide some wetland values (for example, aquatic flora and waterbirds using a water treatment facility); however, this is not their primary purpose.

Some examples of artificial wetlands that can provide wetland values include:

- large water storage areas (ring tanks)
- ponds, farm dams, stock ponds
- aquaculture ponds
- irrigated land and channels (including tail-water recycling systems)
- seasonally flooded farm land (including ponded pastures).

These areas can mimic natural wetland processes, such as trapping sediment, nutrient processing and attenuation (slowing) of overland flows, or provide habitat for plants, birds and fish. There can be many variations in the values provided by artificial (or natural) wetlands and in some cases artificial wetlands can provide higher quality habitat than some natural wetlands.

However, artificial constructions with an artificial base and sides (i.e. bed and banks) are not included in the Program Wetland Definition because they are not 'wet lands' and as such generally function in an artificial way with very different values to wetlands. Examples of constructed water bodies with artificial bases and sides include swimming pools, some water channels, some reservoirs and constructed irrigation viaducts and piped watercourses.

An artificial water body is not included in the wetland definition if its base and sides (bed and banks) are fully constructed of artificial materials such as concrete, metals, fibreglass, synthetic geotechnical materials and composites.

Modified or disturbed sites

Natural wetlands may be modified or disturbed through human activities to such an extent that, although still wetlands, they may be difficult to identify as such. In some cases modification may have resulted in a change of wetland type or condition (change of wetland values). Conversely, areas that have been drained may exhibit wetland indicators, such as hydric soils, which are relictual and no longer reflect the current hydrological regime.

Modification can occur when wetlands are cleared of their native vegetation, drained for long periods, filled; modified by urban, commercial or industrial development; or have been laser levelled, ploughed and cropped. Applying the Program Wetland Definition to highly modified wetlands requires careful investigation and recognition that some wetland attributes or processes have changed in nature but still may be present and active in the area of interest.

Related assessments

Once the wetland has been identified, information collected as part of this process can be used for other purposes as described below.

Delineation

In many cases it is important not just to identify the presence of a wetland but to delineate the wetlands: that is, to establish and describe the boundary between wetlands and non-wetland areas.

In many situations there may be agreement about the existence of a wetland, but disagreement about how far the wetland extends towards the terrestrial boundary. Part B of the Queensland wetland definition and delineation guideline, the guideline for survey and delineation of wetlands, provides more detailed methodology.

Classification

The Program Wetland Definition provides a basis for determining if an area is a wetland or not, but does not provide a classification system for describing different types of wetlands. For many purposes it is useful to classify the diversity of wetlands into broad ‘groups’ or ‘types’.

There are many ways to classify wetlands depending on the purpose. In Queensland the broadest level of classification used recognises five wetland ecological systems (wetland systems):

- lacustrine (lake)
- palustrine (swamp)
- riverine (watercourse)
- estuarine (tidal)
- marine (sea)
- subterranean.

The WetlandInfo website provides further information to discriminate wetland systems, in the Queensland wetlands classification and mapping methodology and to subdivide the wetlands systems into wetland habitat types based on attributes, such as water regime, salinity, climatic zone, vegetation and geomorphology.

Values

Establishing whether a feature is or is not a wetland and assessing its values (environmental, economic, recreational etc) are separate assessments. However, although wetland values do not form or directly influence the use of the Program definition, it is often the values of a wetland that make its identification and delineation important. Some scientists have proposed defining wetlands by their values or functions as an alternative to the hydrological/biotic and soil criteria approach in the Program definition. However, as there are no clear thresholds in relation to values [9] this proposal does not provide any practical alternative approach at this time.

Wetland values include any aspect of wetland ecology, health and economics, and can also encompass public amenity and safety. In natural wetland systems, wetland functions (or processes) can be considered wetland values that should be managed or protected in any wetland, as they are necessary for the other values of the wetland to be maintained. For example, a wetlands hydrological value can be compromised by draining or water diversion, this in turn will impact on other wetland values such as the capacity for the wetland to carry out nutrient cycling and/or the provision of habitat. Wetland functions that should be managed or protected include:

- hydrology
- food webs
- habitats
- nutrient cycling
- sediment trapping and stabilisation.

A full suite of wetland values can be found on the WetlandInfo website. These values can be used as the starting point for identifying the environmental values of a specific wetland.

Condition

Information collected as part of wetlands identification may also be used for other assessment purposes. These include the monitoring of wetland extent and condition.

Appendix 1: Terms used in the Program Wetland Definition

The Program Wetland Definition consists of an introductory component followed by three attributes, which more clearly define key wetland components. This appendix lists each term of the wetland definition and provides details of the intent of that term. Many words have common dictionary definitions (in quotation marks) for which the *Macquarie Dictionary*, 4th edition (2005) is the source unless otherwise specified, while others have been modified to convey specific wetland related features.

Hydrological criterion

"Areas of permanent or periodic or intermittent inundation, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."

The hydrology criterion of the wetland definition from the original Ramsar definition introduces the general parameters of a wetland.

Areas	Area refers to "any particular extent of surface, region or tract". Area is also used in the mapping sense to refer to a discrete polygon showing the boundaries of a spatial unit at a specified scale.
Permanent	'Lasting or tending to last indefinitely; remaining unchanged'[22]. In this context of the guideline it refers to the ability to have or maintain water continuously in all seasons and all years.
Periodic	Characterised by periods or rounds of recurrence, or occurring or appearing at regular intervals or intermittent [22]. Inundation events include the daily, monthly or annual tidal systems or are associated with other reasonably predictable events.
Intermittent	That which intermits, or ceases for a time: an intermittent process or (of streams, lakes, or springs) recurrent; showing water only part of the time [22]. Alternatively wet and dry but less frequently and regularly than annual cycles [4].
Inundation	The noun of inundate, meaning overspread with a flood; overflow; flood, deluge or overwhelm [22]. In relation to wetlands in Queensland inundation can occur from flooding, ponding or saturation from underground water.
Static	Static means not flowing. Static water usually occurs in closed depressions, lakes, dammed water courses, marshes or other lentic waters where the water cannot flow.
Flowing	Moving generally occurs in riverine channels or floodplains and other lotic water bodies but also in areas subject to tidal influences or underground water flow.
Fresh	Water that contains only minute amounts of dissolved salt (not discernable by taste). Water that has a salt concentration up to a maximum of 0.5 parts per 1,000 or an electrical conductivity up to a maximum of 1.5 mS/cm.
Brackish	Water that is slightly salty, being more salty than fresh water but not as salty as marine water, having a salts solution concentration of less than the lower marine standard of 34 parts per 1,000 but above the fresh water maximum salt solution concentration of 0.5 parts per 1,000. Brackish can be applied to marine and estuarine waters with mixohaline salinity and not applied to inland waters.
Salt	Mineral chemicals readily soluble in water. The concentration of dissolved salts in water is used to define water as fresh, brackish or marine.
Marine water	Marine water is water associated with oceans and seas that has a uniform salinity of approximately 34–36 parts per 1,000 or an electrical conductivity of approximately 52–54 mS/cm. Note the level and source of salinity does not determine if a feature is a wetland or not.
Low tide	"Low tide" will be considered as the lowest depth of that tide and occurs between the mean sea level and lowest astronomical tide (LAT). LAT may also be referred to as "datum of predictions" and "port datum".

Does not exceed 6 m	This section enables a separation of marine and non-marine waters, which are considered wetlands within this definition. Therefore, marine waters that are more than 6 m deeper then the lowest astronomical tide level at that site are considered not to be wetlands.

Biotic criterion

"At least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle."

Criterion 1 defines wetland plants and animals as indicators of a wetland habitat. Species lists for representative plant and animal species are listed on the WetlandInfo website.

Periodically	Characterised by periods or rounds of recurrence, or occurring or appearing at regular intervals or intermittently [22]. The occurrence of wetland biota will vary in response to seasonal conditions, which may encompass seasonal, intermittent and episodic hydrological regimes [4].
Plants	Any organism from the plant kingdom.
Animals	Any organism from the animal kingdom.
Adapted	Possessing a feature that fits the organism to the environment. The Strategy for the Conservation and Management of Queensland Wetlands (1999) comments that 'typically, wetlands include areas which show evidence of adaptation of soil or vegetation to periodic water-logging', and it is this adaptation that differentiates wetland soils, vegetation and also wetland animals from the terrestrial soils and species.
Dependent	Relies on the provision of essential resources required to support critical life cycle functions including reproduction, certain (even all) life stages, water, food, shelter, refuge and so on.
Wet conditions	Defined as areas where the root zone becomes periodically saturated or inundated during the growing season.
Life cycle	The cyclic events of life through which individuals pass, including seed, fertilisation, propagation, survival to maturity, producing of offspring and death.

Terms of wetland criterion 2

"The substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers."

Criterion 2 defines the soil associated with wetlands; this separates wetland soil from terrestrial soil and, therefore, aids wetland delineation.

Substratum	Land surface. Soils and regolith underlying a spatial area.
Predominantly	>50 per cent of area.
Undrained soils	Soils that hold water when water is available (may not have a large water holding capacity).
Saturated	"Soaked, impregnated or imbued thoroughly." When saturation occurs for sufficient periods of time it produces hydric (also know as hydromorphic) soil conditions that deprive soil of the capacity to re-oxygenate, thereby creating the low oxygen soils typical of wetlands. Soil saturation also prevents many terrestrial organisms accessing their oxygen requirements thereby excluding them from this environment. However, wetland organisms have adapted to the low oxygen environment of water saturated soils and can survive in this environment.
Flooded	Covered by overflowing water, usually stormwater but may be tidal or storm surge.

Ponded	Water that has accumulated against an obstruction, such as a depression or a barrier that prevents its flowing or overspreading further.
Anaerobic conditions	Conditions that do not have or need the presence of free oxygen to function; they may require the absence of oxygen, or at least are not destroyed by it. Organisms living in these conditions have adaptations to survive the low oxygen environment.
Upper layers	Refers to the top layers, usually the top 0.3 m but may be deeper if overlain by permeable material [20].

Terms of wetland criterion 3

"The substratum is not soil and is saturated with water, or covered by water at some time."

Criterion 3 covers wetlands that have a bed that is not soil, such as rock or ice. Subterranean wetlands, and surface wetlands with no soils, such as rocky river beds and gamma holes, are captured in this way.

Not soil	Natural substrates that are predominately not soil, such as rock or ice. Within a wetland the substratum may partially be formed of artificial materials, such as concrete, metal, composite materials (such as fibreglass and carbon fibre), plastics or synthetic geotechnical materials. If such material covers approximately 50 per cent of the bed and all banks the area contained by this construction is not a wetland.
Saturated with water	The condition of being soaked, impregnated or imbued thoroughly or completely with water.
Covered by water at some time	Has water spread over, even deeply, so as to limit contact with the free gasses of the atmosphere. For the purposes of this guideline, the area must be covered by water so that when water is in a channel, the intent is to capture surface wetlands without soils, such as rocky river beds, waterfalls, boulders at headwaters, etc, and also subterranean wetlands. When water is outside a channel, gamma holes and similar water holding depressions are captured.

Appendix 2: Case Study – Daly's Lagoon

This case study uses baseline information from 2001 with updates from recent visits (to September 2008). The example illustrates one way that data could be collated to aid the decision-making process. The Daly's Lagoon site is a slightly modified natural wetland that has experienced poor and unusual water quality conditions due to land use practices. Despite low wetland flora and fauna values and insufficient soils data it is a wetland.

Site description

Feature name:	**Daly's Lagoon (also known as one of the 'Bundamba lagoons')**
Location:	Lat. 27.7345 S Long. 152.8382 E, GDA94 datum
Bioregion:	South-eastern Queensland
Subregion:	Moreton basin
Local authority:	Ipswich City Council
Area:	~80 ha
Elevation:	~75 m
Wetland type(s):	Historically lacustrine but is now mainly palustrine
Other wetlands in the same aggregation:	One small wetland approximately 250 m upstream of Daly's Lagoon. This wetland has extensive *Typha* species present. The wetland is on Bundamba Creek.
Feature description:	The wetland is situated in a depression between hills that rise 30 m in close proximity and to over 200 m within a few kilometres. The wetland is considered to have been modified by the damming effect of a roadway, possibly established by early settlers around 100 years ago.
Physical features:	The wetland has a long history as a perennial lacustrine system. It is set in the foothills of the Mt Perry–Spring Mountain range, 15 km south of Ripley. The core water body covers 20–25 ha, which can increase by approximately 40 ha in high rainfall events.
Geology/soils/substrata:	"There is principally one soil type in the area, yellow duplex soils (yellow podzolics/orthic solonetz). The soil is sodic and dispersive, and water-logs when the subsoil is wet. The topsoil is a loamy sand that seals and disperses rapidly on wetting (National Resource Information Centre 1991, Northcote et al. 1975)." (in Knight 2002)[10]
Hydrological features:	Daly's Lagoon is filled periodically by surface runoff from a small catchment, and sedimentation processes are significant. The combined ponded and marsh areas may triple in extent during very wet seasons. The water quality of the lake is unusual. "One site survey during March 2001 found an elevated pH of pH9.2 to 9.4 and electrical conductivity levels of more than 750 uS/cm. However, the water is clear and has elevated dissolved oxygen levels exceeding 100 per cent capacity, and there are no signs of eutrophication. In comparison, a survey by Leggett (during May 1999)[11] found a water pH of pH7.8, although water temperature was 8°C less at that time. The lake's minimal thermocline might be responsible for some water quality changes." (Knight 2002)
Ecological features:	No significant ecological values are generally apparent. Loafing waterfowl (ducks and swans) noted. No wetland raptors prey species recorded and no wetland raptors recorded.
Significance:	A natural wetland, slightly modified, which has been impacted by grazing, herbicidal and

[10] Knight, A.W., 2002. Evaluation of wetlands in the south-east Queensland bioregion. Unpublished final report by the Queensland Environmental Protection Agency. Yellow podzolics/orthic solonetz would be described as Yellow Sodosols in the newer Australian Soil Classification system (Isbell 2002).

[11] Leggett, R., 1999. Ipswich Environplan fauna survey 1999 (aquatic fauna, mammals, reptiles). Report for the Ipswich City Council, Ipswich.

	mechanical weed control.
Notable flora:	None (in 2001). This wetland is devoid of the edging vegetation of sedges, Typha spp., waterlilies and wetland grasses. Small areas (<8 cm by <6 cm) of blue-green algae were noted at one place on the land edge. Small samples of water couch, Paspalum dilatum and some algae noted. Native palustrine herbs and sedges have recolonised marshy areas since grazing has ceased (2005).
Notable fauna:	None. Some waterfowl loaf, in small numbers, on the water, no breeding or feeding was observed over two visits of several hours each. This lake is scarce in food resources for invertebrates and vertebrates. Not surveyed for frogs but no frogs noted by visitors, although a freshwater snake was observed in 2001.
Land tenure:	On site: freehold land. Surrounding areas: freehold and Ipswich City Council environmental reserve.
Current land use:	On site: Queensland Rifle Shooters Club Inc with shooting ranges. Cattle grazed until 2005 and is now included in a property environmental management plan. Surrounding areas: surrounding properties include acreage living with some cattle. Recreation and military training.
Disturbances or threats:	Suffers from past grazing, herbicidal and mechanical weed control practices. However, the current property owner has prepared an environmental management plan in association with the Ipswich City Council and the University of Queensland, Gatton campus. The plan includes extensive revegetation, maintaining the destocking of the property, slashing and a fire control regime. The Queensland Rifle Shooters Club Inc intends to manage this property on a long term basis.
Management authority and jurisdiction:	Queensland Rifle Shooters Club Inc.

Applying the wetland definition

Criteria for inclusion as a wetland:

Section 1 YES

The feature has an area of permanent inundation by water that is static or flowing and fresh.

Criterion (1) YES

The feature supports modest levels of wetland plants and animals.

Criterion (2) NO

There is insufficient information to determine if the substratum has anaerobic conditions.

Criterion (3) Not applicable.

Does not apply to this feature.

Therefore, the feature is a wetland as Section 1 and Attribute (1) both apply.

Appendix 3: Glossary

Term	Definition
Acid	A term applied to water with a pH less than 5.5.
Anaerobic	Without free, available oxygen.
Aquatic	Of or relating to water or living or growing in water.
Artificial	Made by human skill and labour, as opposed to natural. Within this guideline the term 'artificial wetland' refers to a wetland that is human made to substantially provide the ecosystem services of a wetland.
Bar	An elongated landform generated by waves and currents, usually running parallel to the shore, composed predominantly of unconsolidated sand, gravel, stones, cobbles or rubble, and with water on two sides.
Beach	Short, low, very wide slope, gently or moderately inclined, built up or eroded by waves, forming the shore of a lake or sea [23].
Bed	The lowest substratum of a wetland; the area that the deepest section of the banks abut.
Billabong (or oxbow)	Long, curved commonly water-filled closed depression eroded by channelled stream flow but closed as a result of aggradation by channelled or over-bank stream flow during the formation of meander plain landform pattern. The floor of an oxbow may be more or less aggraded by over-bank stream flow, wind, and biological (peat) accumulation [23].
Biodiversity	The diversity of plant and animal life on earth at the genetic, species and ecosystem levels.
Biogeographic region	An area of land that is dominated by similar broad landscape patterns that reflect major structural geologies and climate, as well as major floristic and faunal assemblages [24].
Buffer zone	A wetland buffer is the transition zone between the wetland and the surrounding land use. Its purpose is to support the values and processes of the wetland and protect it from external threats. These buffers provide a wide variety of ecological functions and benefits for the community, including flood control, improvement of water quality, stabilisation of the shoreline, erosion control, shade and drought refuge for stock, provision and protection of fish and wildlife habitats, aesthetic and recreational amenity for the community, and separation between urban and rural land uses.
Catchment	The total area draining into a river, reservoir or other body of water (ANZECC and ARMCANZ 2000a).
Channel	Linear, generally sinuous open depression in parts eroded, excavated, or built up by channelled stream flow. Comprises stream bed and banks [23].
Channel bank	Very short, very wide slope moderately inclined to precipitous, forming the marginal upper parts of a stream channel and resulting from erosion by channelled stream flow [23].
Coastal wetlands	Include tidal wetlands, estuaries, salt marshes, melaleuca swamps (and any other coastal swamps), mangrove areas, marshes, lake or minor coastal streams regardless of whether they are of a saline, freshwater or brackish nature (s14 *Coastal Protection and Management Act 1995*).
Community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another (ANZECC and ARMCANZ 2000a).
Critical habitat	Habitat that is essential for the conservation of viable population of protected wildlife, or community of native wildlife, regardless of whether special management considerations and protection are required (s13 *Nature Conservation Act 1992*).
Critical stage	In the wetland sense it applies to a species that requires the natural wetland ecosystem services to survive a section of its life cycle. This may include breeding, moulting, migration stopover, refuge from adverse events elsewhere, habitat for young, etc. The presence of a functioning wetland is essential for the life stage at this time and its absence may threaten the long term conservation of this creature.
Crown cover (%)	The crown cover (%) is the percentage of the ground surface covered by crowns of plants. Crowns for this purpose are taken to be opaque, which means that small gaps in the crown should be disregarded. Crown cover (%) of a stratum is measured as a whole, i.e. ignoring crown overlaps within a stratum.

Delineation	Of wetlands is the process of establishing and describing the boundary between wetland and non-wetland.
Dominant species	Is a species that contributes most to the overall above-ground biomass of a particular stratum. Also predominant species.
Ecologically (predominant, characteristic)	The layer or species making the greatest contribution to the overall biomass of the site and the vegetation community [25].
Ecosystem	The complex interaction of all living communities and the non-living environment through ecological processes as a functioning unit to maintain a dynamic, self supporting, evolving habitat.
Ecosystem services	The services that people receive or obtain from the natural processes of an ecosystem. The services include fresh air, food, water, flood control, nutrient recycling and spiritual well being.
EDL	Ecologically dominant layer
Ephemeral	Lasting only a short time; short lived; transitory.
Episodic	Dry most of the time with rare and very irregular wet phases [4].
Estuarine system	Includes wetlands with oceanic water that is at least occasionally diluted with freshwater run-off from the land.
Fens	Fens are shallow, swampy, peat-forming wetlands that are fed by water sources other than precipitation, usually from upslope surface water or groundwater sources. Fens tend towards alkaline pH. Some fens, known as patterned fens, are characterised by vegetated bed ridge systems separated by less productive hollows.
Flat	A level landform composed of unconsolidated sediments, usually mud or sand. Flats may be irregularly shaped or elongate and continuous with the shore, whereas bars are generally elongate, parallel to the shore and separated from the shore by water.
Floodplain	Alluvial plain characterised by frequently active erosion and aggradation by channelled or over-bank stream flow. Unless otherwise specified, 'frequently active' is to mean that flow has average recurrence interval of 50 years or less [23].
Fresh	Term applied to water with salinity less than 0.5 % dissolved salts.
GDA	'Geocentric datum of Australia is a contemporary approach to modelling the earth's surface. It provides a single international standard for data collection, analysis and storage. It supersedes previously used regional models with a more accurate and standardised approach to defining the earth's surface. A datum is a mathematical model that represents the shape of the earth. GDA is a geocentric (earth-centred) datum, which models the earth's shape as a whole. This is different to previous datums, which model a localised area (region or country) of the earth' [26].
GPS	A unit that measures coordinates by receiving and processing information from the global positioning system or other similar system of satellites.
Haline	The term used to indicate dominance of ocean salt.
Highest astronomical tide (HAT)	The highest sea level that can be predicted to occur under average meteorological conditions and any combination of astronomical conditions.
Hydric soil	Soil that is wet long enough to produce anaerobic conditions (at least periodically), thereby influencing the growth of plants. A wetland soil is a hydric soil in the upper layers.
Hydrophyte	A plant that grows in water or needs a water-logged environment [22].
Identifiable fixed features	Include road intersections, fence intersections, survey marks, built infrastructure, points with known GPS coordinates.
Indicator	Organism, ecological community or structural feature so strictly associated with a particular environmental condition that its presence indicates the existence of the condition. In the context of the guideline to the wetland definition the indicator species is used to assess criteria in the wetland definition.
Lacustrine	'The lacustrine system includes wetlands and deepwater habitats with all of the following characteristics:

system	1. situated in a topographic depression or a dammed river channel 2. lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30 per cent areal coverage 3. total area exceeds 8 ha (20 acres). Similar wetland and deepwater habitats totalling less than 8 ha are also included in the lacustrine system if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin exceeds 2 m (6.6 feet) at low water [6].'
Lentic	Pertaining to, or living in, still, freshwater in lakes and ponds. Compare with lotic.
Lotic	Pertaining to, or living in, flowing water.
Map(s)	Graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes or events in the human world [27]. The location of features is often portrayed by drawing the map to a selected scale and/or relating the map to a geographical coordinate system. Traditionally maps have been produced on paper although in more recent times they are often stored and manipulated on a computer using special geographical information system (GIS) software.
MGA94	'Map grid of Australia 1994, as defined in the GDA manual by the Intergovernmental Committee on Surveying and Mapping. MGA94: is the new map grid of Australia. The MGA94 coordinate system is a universal transverse mercator projection projected from GDA94 geographical coordinates. It replaces the AGD66 (Australian grid datum 1966) coordinate system, which is also a universal transverse mercator projection but based on the superseded AGD66 datum [26].'
Marine system	The marine system consists of open ocean overlying the continental shelf and its associated high energy coastline down to a depth of 6 m below lowest astronomical tide (LAT). Shallow coastal indentations or bays (or parts thereof) without appreciable freshwater inflows, and coasts with exposed rocky islands that provide the mainland with little or no shelter from wind or waves, are also considered part of the marine system (adapted from [6]).
Marine habitats	Exposed to the waves and currents of the open ocean, and the water regimes are determined primarily by the ebb and flow of oceanic tides. Salinities exceed 34 ppt with little or no dilution outside the mouths of estuaries.
Marine plant	The meaning of marine plant is given in section 8 of the Fisheries Act [10]: '(1) "Marine plant" includes the following— (a) a plant (a "tidal plant") that usually grows on, or adjacent [11] to, tidal land, whether it is living or dead, standing or fallen (b) the material of a tidal plant, or other plant material on tidal land (c) a plant, or material of a plant, prescribed under a regulation or management plan to be a marine plant. (2) "Marine plant" does not include a declared plant under the *Land Protection (Pest and Stock Route Management) Act 2002* [28].'
Mixohaline	Water with salinity of 0.5 to 30 per cent, due to ocean salts. The term is roughly equivalent to the term brackish.
mS/cm	Millisiemens per centimetre. A measure of electrical conductivity of salts dissolved in water.
Mud	Wet soft earth composed predominantly of clay and silt-fine mineral sediments less than 0.074 mm in diameter (Black 1968; Liu 1970).
Organic materials	See definition in *The Australian Soil Classification* (2002), Revised edition.
Palustrine	Wetlands that are dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 per cent. It also includes wetlands lacking such vegetation which have the following three characteristics: (1) where active waves are formed or bedrock features are lacking; (2) where the water depth in the deepest part of basin less than 2 m at low water; and (3) the salinity due to ocean-derived salts is still less than 0.5 per cent (adapted from [6]).
Persistent emergent	Plants that stand above water surface and normally remain standing at least until the beginning of the next growing season, e.g. spikerush (*Eleocharis* spp.) or bulrushes (*Typha* spp.).
Polygon	In mapping terminology, a polygon is an area enclosed by lines on a map.
PPT	Parts per thousand. A measure of the concentration of dissolved salts and solids in a solution.

Predominant canopy	In vegetation is the ecologically dominant layer (EDL); that is, that stratum of the vegetation that contains the most above ground biomass. The predominant canopy can be described in terms of growth form, height, crown cover and species. In the majority of cases, the predominant canopy is upper stratum (i.e. tree layer in a woodland or shrub layer in a shrubland, etc).
Predominant species	A species that contributes most to the overall above-ground biomass of a particular stratum (also dominant species).
Predominant stratum (or layer)	The stratum that contains the greatest amount of above-ground vegetation biomass. It is frequently the tallest stratum, but not always. Exceptions include rainforest canopies with emergent species, grasslands with scattered shrubs, etc. The dominant stratum 'because of its physiognomy and relative continuity dominates the rest of the community in the sense that it conditions the habitats of the other strata' [29].
Riparian	Of or relating to or located on the banks of a river or stream.
Riparian ecosystem	An ecosystem that has a high water table because of its proximity to an aquatic ecosystem or to subsurface water. Usually occurs as an ecotone between aquatic and terrestrial ecosystems, but with distinctive vegetation and soils. Continuous interactions occur between riparian, aquatic and terrestrial ecosystems through exchanges of energy, nutrients and species.
Riverine system	The riverine system includes all wetlands and deepwater habitats contained within a channel, with two exceptions: 1. wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and 2. habitats with water containing ocean-derived salts in excess of 0.5 ppt. A channel is 'an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water' (adapted from [6]).
Saline	General term for waters containing various dissolved salts. We restrict the term to inland waters where the ratios of the salts often vary; the term haline is applied to coastal waters where the salts are roughly in the same proportion as found in undiluted sea water.
Salinity	The presence of soluble salts in or on soils or in waters [30].
Seasonal	Alternatively wet and dry every year according to season [4].
Shrub	Woody plant multi-stemmed at the base (or within 200 mm from ground level), or if single-stemmed less than 2 m tall [18].
Static	Relating to or characterised by a fixed or stationary condition.
Stratify	To divide a site into more or less homogenous, with respect to the attributes being surveyed, sub-units or strata. Used in biological or soil survey to ensure full variation of an area is described or documented although may also apply to dividing the vegetation into different strata.
Stratum	A layer (of vegetation) produced by the occurrence at approximately the same level (height) of an aggregation of plants of the same habit [17].
Subdominant species	A species that contributes less biomass than the dominant species, but occurs as more than an isolated individual. As a general rule, the species must individually contribute more than an associated species, i.e. more than 10 per cent of the total biomass of the stratum in which it occurs [17].
Substratum	A stratum or layer lying under another [17].
Tidal land	Any land at or below the HAT mark, including mudflats, sandbanks, 'reefs, shoals and other land permanently or periodically submerged by waters subject to tidal influence' [28].
Watercourse	A stream of water, as a river or brook; the bed of such a stream (with or without water) a natural channel conveying water; a channel or canal made for the conveyance of water.
Waterway	Includes a river, creek, stream, watercourse or inlet of the sea (*Fisheries Act 1994*).
Water table	The upper surface of a zone of saturation. No water table exists where that surface is formed by an impermeable body [31].
Waypoint	A term commonly used in GPS units, referring to a point at which geographic coordinates are recorded.

Appendix 4: References

A full list of up-to-date references and web resources can be found on WetlandInfo's Bibliography page.

1. Queensland Government, *Strategy for the Conservation and Management of Queensland Wetlan*ds. 1999, Environmental Protection Agency: Brisbane.
2. Department of Land and Water Conservation, *New South Wales Wetland Management Policy*. 1996, Clarendon Press: Brookvale.
3. Duguid, A., et al., *Wetlands in the arid Northern Territory. A report to Environment Australia on the inventory and significance of wetlands in the arid N*T. 2002, Parks and Wildlife Commission of the Northern Territory: Alice Springs.
4. Paijmans, K., et al., *Aspects of Australian wetlands*. 1985, CSIRO Division of Water and Land Resources Canberra.
5. Department of Environment and Conservation, *Protocol for proposing modifications to the Geomorphic Wetlands Swan Coastal Plain dataset*. 2007, Department of Environment and Conservation: Perth.
6. Cowardin, L.M., et al., *Classification of Wetlands and Deepwater Habitats of the United States*. 1979, US Department of the Interior, Fish and Wildlife Service: Washington DC.
7. Committee on Characterisation of Wetlands, *Wetlands: Characteristics and Boundaries*. 1992: National Research Council, National Academies Press.
8. Coventry, R.J. and J.E. Williams, *Quantitative relationships between morphology and current soil hydrology in some Alfisols in semiarid Australia*. Geoderma, 1984. 33: p. 191–218.
9. Tiner, R.W, *Wetland Indicators: A Guide to Wetland Identification, Delineation, Classification, and Mapping*. 1999, Boca Raton, FL: CRC Press.
10. Hill, A.L., et al., *Wetlands of the Swan Coastal Plain Volume 2A: Wetland Mapping, Classification and Evaluation, Main Repor*t. 1996, Water and Rivers Commission and Department of Environmental Protection: Perth.
11. US Army Corps of Engineers, *Wetland Delineation Manual*. 1987, Environmental Laboratory: Vicksburg, MS.
12. Ramsar Convention Secretariat, *The Ramsar Convention Manual. A Guide to the Convention on Wetlands*. (Ramsar, Iran, 1971), 4th edition. 2006.
13. Reed, P.B. Jr, 'National list of plant species that occur in wetlands: national summary', in *Biological Report*. 1988, U.S. Fish and Wildlife Service: Washington DC.
14. Barson, M.M. and J.E. Williams, *Wetland Inventory – towards a unified approach*, unpublished report. 1991, Bureau of Rural Sciences: Canberra.
15. Boulton, A.J. and M.A. Brock, Australian *Freshwater Ecology: Processes and Management*. 1999, Glen Osmond: Gleneagles Publishing.
16. WetlandInfo, *List of Hydrophytes*. 2010, Department of Environment and Resource Management.
17. Neldner, V.J., et al., *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 3.1*. 2005, Queensland Herbarium, Environmental Protection Agency: Brisbane. p. 128.
18. Walker, J. and M.S. Hopkins, *Vegetation, in Australian Soil and Land Survey Field Handbook*, R.C. McDonald, et al., Editors. 1990, Inkata Press: Melbourne. p. 58–86.
19. Thoms, M., et al, *The Narran Ecosystem Project: the response of a terminal wetland system to variable wetting and drying. Final Report to the Murray-Darling Basin Commission*. 2007, Murray–Darling Basin Commission: Canberra.
20. Bryant, K.L., et al., *Soil Indicators of Queensland Wetlands: State-wide Assessment and Methodology*. 2009, Queensland Department of Environment and Resource Management: Brisbane.
21. Bryant, K.L., et al., *Soil Indicators of Queensland Wetlands: Field Guide*. 2008, Department of Environment and Resource Management: Brisbane.
22. Anon, *The Macquarie Dictionary Fourth Edition*. 2005, Sydney: Pan Macmillan.
23. Speight, J.G, Landform, in *Australian Soil and Land Survey Field Handbook*, 2nd edition., R.C. McDonald, et al., Editors. 1990, Inkata Press: Melbourne.
24. Sattler, P.S. and R.D. Williams, The Conservation Status of Queensland Bioregional Ecosystems. 1999, Brisbane: Environmental Protection Agency.
25. National Land and Water Resources Audit (NLWRA), *Australian Native Vegetation Assessment* 2001. 2001, National Land and Water Resources Audit: Canberra.

26. Papas, P.J. Holmes, and S. Lyon, *Index of Wetland Condition – Methods Manual. Version* 6. 2009, Department of Sustainability and Environment: Melbourne.

27. Harley, J.B. and D. Woodward, *The History of Cartography* 1987, Chicago: University of Chicago Press.

28. Couchman, D. and J. Beumer, *Management and protection of marine plants and other tidal fish habitats.* 2007, Queensland Department of Primary Industries and Fisheries: Brisbane. p. 60.

29. Beadle, N.C.W. and A.B. Costin, *Ecological classification and nomenclature*. Proceedings of the Linnean Society of New South Wales, 1952. 77: p. 61–82.

30. Department of Natural Resources and Water, *Queensland Salinity Management Handbook*. 1997, Brisbane: Department of Natural Resources and Water.

31. Langbein, W.B. and K.T. Iseri, *General Introduction And Hydrologic Definitions, in Hydrologic Definitions Manual of Hydrology; Part I. General Surface-Water Techniques*, W.B. Langbein and K.T. Iseri, Editors. 1960, Delaware University Delaware.