Regional Biodiversity Values Methodology

Identification of landscape level biodiversity interests for the South East Queensland Regional Plan (2018)

Queensland Government

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Contents

Overview

This document provides the conceptual and methodological underpinnings for the creation of the regional biodiversity overlay used in the South East Queensland Regional Plan 2017 (SEQ RP).

The State Planning Policy (SPP) defines specific matters of state interest in land use planning and development. The SPP – Biodiversity focuses on matters of environmental significance providing an instrument for local government when making or amending local planning instruments.

The SPP – Biodiversity allows for the refinement of biodiversity interests at a regional level to compliment Matters of State Environmental Significance. The biodiversity overlay in the SEQ RP identifies landscape level biodiversity interests specific to the SEQ RP area.

The objective of the Regional Biodiversity Values (RBV) methodology is to identify conservation values at the landscape scale. This approach enables the protection of ecosystem functions, and associated species and genetic diversity, in the following ways:

- Maintaining an intact and connected network of terrestrial and aquatic ecosystems across the landscape incorporating large core habitat areas and corridors.

- Maintaining the diversity of species and habitats, including areas of richness and abundance, refugia and habitats that are critical to the long term survival of species.

- Retaining representation of the spectrum of ecosystems and unique landscape features, each which provides a different set of ecosystem functions that are vital to biodiversity conservation.

- Ensuring that ecosystems, habitat and species are resilient to changing climate conditions.

The Queensland Government has several datasets and methods for prioritising landscape-scale biodiversity values. Important methodologies include the Biodiversity Assessment and Mapping Methodology (BAMM) (EHP 2014) and the Aquatic Biodiversity Assessment Mapping Methodology (AquaBAMM) (Clayton et al 2006). Many of the RBV measures are drawn from BAMM and AquaBAMM. Several additional key datasets include the Queensland regional ecosystems, Queensland wetlands, woody non-remnant and regrowth, groundwater dependent ecosystems and fish passage prioritisation data.

The following questions were also considered when identifying the appropriate landscape components, data and methodological approach for RBV:

- What is the availability and currency of data?
- What are the important risk factors in the landscape and how can the criteria be used to answer those questions to maximise biodiversity outcomes?
- What is the scale of the mapping exercise? Will the data be scrutinised at the property level or is it a broad indicative map only.
- What biodiversity considerations are not captured in the current MSES?
- What are some of the competing land use interests that may inhibit the full inclusion of particular values?

The criteria used in this method is described in the following sections, including differentiation between general landscape (terrestrial) and wetland specific criteria and a guidance on dataset use.

It is important to note that this document provides details of the baseline mapping used to inform the SEQ RP. Further refinements were applied to ensure its compatibility with the overall intent, such as the delineation of the urban footprint, and the A4 scale of the final map.

Criteria 1. Landscape connectivity

In general terms, landscape connectivity encapsulates the degree to which landscape components interact with one another. Landscape connectivity can be considered to be both positive and negative. From the perspective of regional planning it is desirable that ecosystem components are able to disperse across the landscape supporting the viability of populations, reducing fragmentation impacts and increasing ecosystem resilience. Connectivity can occur at a variety of temporal and spatial scales.

1.1 Vegetation and Corridors

1.1.1 Tracts of vegetation

It is generally accepted that tract size has a positive relationship with the viability of populations within a tract, and where the shape allows, decreases the impact of edge effects. From a regional planning perspective it is important that the integrity of larger tracts are maintained and enhanced. The larger tracts are generally a high priority particularly those that are at risk of fragmentation and development.

BAMM Criterion C (Tract Size) can be used to compare relative tract sizes across subregions. The importance of tract size needs to be considered in terms of the fragmentation level within the landscape. For intact landscapes the importance of tract size should be given lower consideration when prioritising across the landscape (EPA 2002).

1.1.2 Corridor networks

Conceptually, corridor networks are areas that provide linkages across the landscape at a variety of scales. In terms of regional planning, the biodiversity interests are in the connectivity pathways that link core areas of vegetation and habitat. For example, wildlife corridors are one of the best ways to mitigate the effects of climate change on biodiversity. Effective wildlife corridors allow organisms to move across the landscape connecting habitat for endemic, rare or threatened animal and plant species. In doing so, corridors promote ecosystem resilience and adaptation to threatening process such as climate change. Restoring connectivity can increase ecosystem resilience.

What constitutes a connectivity pathway can vary between ecosystem components and the purpose of the connection. For this reason it is important to clearly define the objective of the connection. These connections can also be used to prioritise investment areas for rehabilitation and offsets.

BAMM Criterion J (Corridors) identifies expert derived State and Regionally significant corridor networks including major vegetation linkages and stepping stone corridors. The non-buffer components of BAMM Criteria G (Context and Connection) can also be considered at a local scale (EPA 2002).

1.2 Aquatic system connections and wetlands

This indicator identifies the key connectivity components of aquatic systems and their importance in the maintenance of connectivity.

1.2.1 Instream connectivity

Instream barriers act as an impediment to passage for aquatic species. For this reason it is important to prioritise areas free of barriers to ensure that development does not impact the instream processes such as migration. This is particularly important for fish species where the life cycle depends upon movement between freshwater and marine habitats.

O'Brien et al 2016, prioritised the stream network for the assessment of risk to fish passage as a result of barrier works. These linear features although limited to fish are useful for prioritising broad passage requirements for instream connectivity.

1.2.2 Groundwater recharge zones

Recharge zones refer to those areas where water infiltrates through the permeable rock and sediment but the saturated zone is at a depth where surface ecosystems (e.g. palustrine, lacustrine and riverine wetlands, riverine water bodies and terrestrial vegetation) are unable to access the groundwater (WetlandInfo 2013). From a connectivity point of view recharge zones provide groundwater sources to a variety of ecosystems including subterranean groundwater dependant ecosystems (GDE), marine and estuarine GDEs as well as wetland systems associated with discharge areas such as palustrine and lacustrine wetlands.

Risks to recharge areas include contamination of groundwater and altered hydrology, such as the creation of impervious surfaces. These impacts can be caused by a number of different land use changes including agriculture, mining and urban development (Böhlke 2002, Hancock 2002, Jacobson 2011).

The GDE mapping contains information on the permeability of recharge areas in the landscape which can guide future management and planning decisions (DSITI 2012). Areas of high permeability should be protected from incompatible land use and management practices.

1.2.3 Riparian ecosystems

Riparian ecosystems are important components of the landscape for biodiversity. These ecosystems frequently exhibit higher species richness and abundance than surrounding habitats. They act as movement pathways along riparian systems for a number of species, especially birds (Bennet et al 2014). They also often provide critical resources for many species in terms of food, shelter and nesting sites (Lovett & Price 2007). Riparian areas also provide many ecosystem services that can include the provision of shade, nutrient and debris inputs, bank stabilisation, and water bourn pollution reduction.

Due to historical and preferential clearing, remaining systems are often heavily fragmented and have undergone a substantial reduction in their extent. In many areas, condition is often poor and subject to considerable weed problems.

For conservation prioritisation of highly connected riparian systems it is important to consider both size of patches and their configuration against a fully connected stream bank baseline (Clark et al 2015).

1.2.4 Native floodplain vegetation

Floodplain vegetation is found on the alluvia of catchments, usually adjacent to fringing riverine systems, wetlands and water bodies. This vegetation is usually dependant on subsurface groundwater in unconsolidated sedimentary aquifers (EHP 2017).

Floodplain vegetation provides a range of ecosystem services including flood mitigation, soil retention, and supports biodiversity in receiving environments such as rivers, estuaries and marine areas. Floodplain vegetation has been heavily cleared in many parts of Queensland particularly in east coastal bioregions and the Brigalow Belt bioregion (EHP, 2016a).

The use of both remnant and woody non-remnant overlayed with regional ecosystem information linked to the Regional Ecosystem Description Database (REDD), provides an indication of floodplain type vegetation and extent.

1.2.5 Wetland extent

Wetlands play numerous roles across the land and seascape providing connectivity and habitat for many species. Wetlands also filter catchment runoff, provide protection from wave action and storms, and reduce the impacts of floods (EHP 2016b).

At a global scale there have been significant reductions in natural wetland extent, with an average of 17% loss in Oceania, of which Australia is a part, occurring between 1970 and 2008 (Dixon et al 2016). Extent was identified as being key factor in measuring risk factors to wetland systems in the Framework for the Assessment of river and wetland health - FARWA (Alluvium Consulting 2011).

For this reason it is important for planning schemes to protect wetlands that still contain considerable habitat cover and appropriate levels connectivity compared to that of pre-European extent. Refer to Appendix 2 for the method used for determining the proportion of wetland extent compared to preclear.

Criteria 2. Diversity

Diversity is a measure of the richness and relative density of unique species or ecosystems within the landscape. From a regional planning perspective it is important to prioritise areas of high diversity for protection and to identify opportunities for investment in areas that have the potential for high diversity given their ability to recover. DES is interested in three general measures of richness and diversity including:

- habitats that support species and critical habitats,
- areas containing high species richness, and
- areas containing high ecosystem diversity.

2.1 Critical habitats for species

The Nature Conservation Act 1992 defines critical habitat as "habitat that is essential for the conservation of a viable population of protected wildlife or community of native wildlife, whether or not special management". In mapping critical habitat it is important that known locations of species habitat are represented spatially. This criterion capture these areas and draws on expert knowledge and quantitative data where available.

2.1.1 Critical terrestrial habitats

BAMM Criterion I (Special Biodiversity Values) include areas identified by experts as important habitat within a bioregion. BAMM groups and rates these areas across a number of categories including: Centres of endemism (IA), Wildlife refugia (IB), Centres with concentrations of disjunct populations of taxa (IC), Areas with concentrations of taxa at the limits of their geographical ranges (ID), Centres of high species richness (IE), Areas considered to be important for maintaining populations of ancient and primitive taxa (IF), Areas considered to be important because of the high relative density of hollow-bearing trees (II), and Breeding and roosting sites (IJ).

2.1.2 Critical wetland habitats

A number of AquaBAMM measures are used to categorise expert elicited information about important wetland systems for species habitat within the landscape including Habitat for significant numbers of waterbirds (5.1.4), Presence of distinct, unique or special habitat (including habitat that functions as refugia or other critical purpose) (6.3.1), Significant wetlands identified by an accepted method such as Ramsar, Australian Directory of Important Wetlands, Regional Coastal Management Planning, World Heritage Areas (6.3.2), and Ecologically significant wetlands identified through expert opinion and/or documented study (6.3.3).

2.2 Areas of high species richness

Currently species sightings and habitat modelling is not comprehensive across all species or guilds. Given these limitations it is possible to use broad distribution data as a way of quantifying richness to identify biodiversity hotspots within the landscape. This indicator is intended to be used where quantifiable data is available to measure species richness or where other studies have identified biodiversity hotspots in the landscape.

2.2.1 Areas of high terrestrial species richness

Where the data is available it is important to identify areas of high species richness. This can be based on a confluence of modelled distributions such as those produced by DSITI (2012), or other broad areas that have been identified either through government or internationally as areas of high species richness such as Key Biodiversity Areas (KBA).

2.2.2 Areas of high wetland species richness.

It is important to consider the importance of wetlands for a variety of species.

Indicator 3.1 (Species) from the AquaBAMM identifies the richness of amphibians, native fish, aquatic dependent reptiles, native waterbirds and aquatic plants across a catchment and creates an index based on validated species sightings.

2.3 Ecosystem diversity

Ecosystem diversity refers to the variety of ecosystems within a given place. Landscapes are composed of a mosaic of interconnected ecosystems. For example, the number and size of wetlands ecosystems within an area is an indication of habitat complexity. Habitat complexity has been linked to a variety of ecosystem traits including taxonomic richness and ecosystem resilience.

2.3.1 Ecosystem diversity

The number and size of ecosystems is an indication of habitat complexity. Ecosystem diversity is commonly classified using concepts of richness and evenness. This measure quantifies ecosystem diversity using readily available information including remnant regional ecosystem mapping and statistical measures of ecosystem diversity.

BAMM Criterion F (Ecosystem Diversity) uses Simpson's diversity index and remnant ecosystem mapping to quantify habitat complexity around focus remnant units.

Criteria 3. Representation

The CAR (Comprehensive, Adequacy and Representativeness) reserve design approach aims to protect representative samples of species, forest types, communities and ecosystems from throughout their geographical range. This concept is designed to ensure that reserve systems represent the entire diversity of species, interactions and dependencies inherent to each ecological community.

The landscape also contains areas of distinct, unique or special significance from a hydrologic, geomorphic, or ecologic process perspective. Given these distinctions, prioritising areas so that their integrity can be maintained is an important consideration for land use planning.

3.1 Ecosystem Representation

Setting targets for ecosystem protection is an important as it sets benchmarks to monitor the effectiveness of the conservation network. Terrestrial protected areas currently cover just under 8% of Queensland. The Queensland Government is working towards the United Nation Convention on Biological Diversity target of 17% of the state as protected area (NPSR, 2016). Regional planning contributes to increased protected areas coverage by incorporating CAR principles and prioritising ecosystem protection.

3.1.1 Threatened ecosystems

In terms of representation the protection of threatened ecosystems within the landscape is important to safeguard their existence into the future. Often these ecosystems occur within areas that are in conflict with anthropogenic land use either through clearing or other threatening process. The Queensland Herbarium have listed the biodiversity status of regional ecosystems based on an assessment of remnant condition in addition to the pre-clearing and remnant extent. Measure 3.1.1 uses these threatened ecosystem categories to identify 'endangered' and 'of concern' ecosystems to identify threatened ecosystems to be protected for regional planning purposes.

3.1.2 Ecosystem extent in protected area

Generating ecosystem targets can be achieved at a variety of scales both in terms of geographic area and the hierarchy of vegetation classification used. For regional planning it is important to consider the context, such as overlapping bioregions, so that the protection targets can be calculated taking into account regional variation. For a local government area it would be appropriate to limit the scope to the applicable jurisdiction in most cases.

Vegetation hierarchies that can be used include regional ecosystems, regional ecosystem stems, broad vegetation groups (1, 2 and 5 million scale) and land zones.

The Queensland Herbarium regional ecosystem descriptions classify underrepresented ecosystems as medium to low where the preclear extent within protected areas is below 10% and 4% respectfully. The BAMM also considers regional ecosystems that have <10% of their preclear extent within protected area.

3.1.3 Wetland extent in protected area

Similar to ecosystem representation, it is important to ensure that different wetland types are adequately protected from development to avoid the risk of becoming threatened by inappropriate land use.

AquaBAMM Indicator 8.1 (Wetland Protection) creates an index based on the level of protection in protected areas including Nature Refuges (AquaBAMM Measure 8.1.1) and Fish Habitat areas (AquaBAMM Measure 8.1.2). This index is based on a combination of Qld Wetlands Mapping attributes: wetland class, water regime, salinity modifier, and wetland RE. Prioritisation can also be considered at the habitat group level (EPA 2005).

3.2 Unique landscape features

Landscape areas containing distinct, unique or special features of hydrologic, geomorphic, or ecologic significance should be protected given their contribution to landscape variability and important habitat niches for a number of species.

3.2.1 Distinct, unique or special terrestrial features of hydrologic, geomorphic, or ecologic significance.

BAMM Criteria IG (Areas containing regional ecosystems with distinct variation in taxa composition) identifies areas containing ecosystems with distinct variation in taxa composition associated with geomorphology and other environmental variables.

3.2.2 Distinct, unique or special wetland features of hydrologic, geomorphic, or ecologic significance.

A number of AquaBAMM measures are used to categorise expert elicited information about important wetland systems of hydrologic, geomorphic, or ecologic significance. These include AquaBAMM Measures Presence of distinct, unique or special geomorphic features (6.1.1), Presence of (or requirement for) distinct, unique or special ecological processes (6.2.1), and Presence of distinct, unique or special hydrological regimes (e.g. spring fed stream, ephemeral stream, boggomoss) (6.4.1).

Criteria 4. Climate change adaptation

The decline in natural populations is usually the result of multiple impacts associated with threatening processes. Ecosystem resilience refers to the capacity of an ecosystem to recover from or withstand disturbance resulting from threatening processes. Global warming resulting from climate change is an emerging threatening process with the potential to significantly disrupt or permanently impact ecological communities.

4.1.1 Climate change refugia

Ecological resilience refers to the capacity of an ecosystem, habitat, population or taxon to withstand, recover from or adapt to impacts and stressors while retaining the same structure, processes and functioning (Holling, 1973). Prioritising for the protection of areas resistant to climate change is important for building resilience to the long-term ecological impacts of climate change.

BAMM Criterion IK (Areas resilient to the effects of climate change) are those areas that have been identified by experts as important habitat within a bioregion as climate change refugia. Habitats identified in other studies as resilient to the effects of climate change should also be considered for prioritisation under this measure.

4.1.2 Habitats with permanent water supply

Habitats with permanent water supply often support additional ecological processes and ecosystems services. Groundwater dependent ecosystems are ecosystems which rely on groundwater on an intermittent or permanent basis. In terms of climate resilience the presence of permanent water in the landscape provides refugia for species, particularly when faced with drought conditions. The extraction of groundwater and changes in land use pose a risk to GDEs. The QLD Government ground water dependent ecosystem series (DSITIA, 2012) can be used to identify habitats with a permanent water supply.

South East Queensland Implementation

Based on the above framework, a prioritisation exercise was completed for the South East Queensland Regional Plan. Table 1 shows a list of the data and associated acronyms used to compile the values mapping. Table 2 has the measures that were implemented and how the data was used to delineate regional landscape scale priorities. These datasets were merged together to create a coverage across the region that represents the landscape factors of high importance from a biodiversity perspective.

Table 1. Datasets used in the South East Queensland regional biodiversity overlay.

Data	Acronym
South East Queensland Biodiversity Planning Assessment 4.1 (2016).	SEQ BPA
Brigalow Belt Biodiversity Planning Assessment (1.3) (2008).	BRB BPA
Aquatic Conservation Assessment of riverine and non-riverine wetlands in the South-East Queensland catchments v1.1.	SEQ ACA
Aquatic Conservation Assessment of riverine and non-riverine wetlands in the Queensland Murray Darling Basin v1.4.	QMDB ACA
Draft Woody non-remnant mapping (2013). Continuous FPC cut off representing woody non-remnant mapping overlayed with the preclear regional ecosystem mapping version 9.	Draft WNR
Regional ecosystem mapping (preclear and remnant) version 9. 2013 including the Regional Ecosystem Description database (REDD).	RE
Queensland Waterways for Waterway Barrier Works, Streams (January 2013).	QWWBW
QLD Protected Area Estate (January 2016).	PA
Nature Refuges (January 2016).	NR
Groundwater dependent ecosystems for South East Queensland version 1.4.	SEQ GDE
Queensland Wetland Mapping version 4.	QLD WM
South East Queensland Environmental Values Schedule 1 Database July 2010.	SEQ EPP
SEQ Catchments (2016) Climate Change Refuge and Adaptation Zone Mapping, SEQ Bioregion. South East Queensland Catchments Ltd., Brisbane.	CCRAZM

Table 2. Implementation of each measure in the South East Queensland regional biodiversity overlay.

Criteria, Indicator, Measure (CIM)	Data used	Method
Criteria 1. Landscape Connectivity		
1.1.1 Tracts of vegetation	SEQ BPA BRB BPA	All areas rated as High or Very High under BAMM Criterion C.
1.1.2 Corridor networks	SEQ BPA Corridor buffer areas, derived from the SEQ BPA Draft WNR	All areas given a significance rating of 'State' or 'Regional' under criteria J. Clip woody non-remnant to the corridor buffer areas. Corridor buffers used to identify general corridor outlines. Refer to Appendix 1 for information on how the Regional Corridors were defined.
1.2.1 Instream connectivity	QWWBW	All waterways with a fish passage importance score of High (3) or Very High (4).
1.2.2 Aquifer recharge zones	SEQ GDE	Not implemented
1.2.3 Riparian area		Not implemented
1.2.4 Native floodplain vegetation		Not implemented.
1.2.5 Appropriate wetland surface connectivity	QLD WM RE SEQ EPP Draft WNR	All wetland types with a hydrological modification of H1, H2M2, H2M3, H2M5, H2M8, mosaic units, as well as remnant from the regional ecosystem mapping within a preclear wetland extent where extent remaining is 50% or more. Refer to Appendix 1 for more detail.
Criteria 2. Diversity		
2.1.1 Critical Terrestrial Habitats	SEQ BPA BRB BPA	All areas rated as High or Very High under BAMM Criterion IA, IB, IC, ID, IE, IF, II, and IJ.
2.1.2 Critical wetland habitats	SEQACA, QMMDBACA QWWBW	All areas rated as 3 or more under AquaBAMM Measures 5.1.4, 6.3.1, 6.3.2, 6.3.3 and with a hydrological modifier of H1, H2M2, H2M3, H2M4, H2M5, H2M8, '-' for non-riverine ACA results. Riverine ACA results were displayed as drainage lines based on Queensland Waterways for Waterway Barrier Works dataset.
2.2.1 Areas of high terrestrial species richness		Not implemented
2.2.2 Areas of high wetland species richness		Not implemented
2.3.1 Ecosystem diversity	SEQ BPA Criteria F rerun on the Brigalow Belt using v9 regional ecosystem mapping.	All areas rated as High or Very High under BAMM Criterion F.

Criteria, Indicator, Measure (CIM)	Data used	Method
Criteria 3. Representation		
3.1.1 Threatened ecosystems	RE	Endangered and Of Concern biodiversity status polygons present in the polygon.
3.1.2 Ecosystem extent in protected areas	RE PA NR	Including protected area tenure types NP, NS, RR, CP, FR, NY and nature refuges where root remnant regional ecosystem extent in reserve was less than 10% of its preclear extent.
3.1.3 Wetland extent in protected area	SEQ ACA, QMDB ACA	AquaBAMM indicator 8.1 (Protected areas representation for RE types) where >=3 and with hydrological modifier of H1, H2M2, H2M3, H2M5, H2M8, '-'.
3.2.1 Distinct, unique or special terrestrial features of hydrologic, geomorphic, or ecologic significance.	SEQ BPA BRB BPA	All areas rated as High or Very High under BAMM Criterion IG.
3.2.2 Distinct, unique or special wetland features of hydrologic, geomorphic, or ecologic significance.	SEQ ACA QMDB ACA QWWBW	All areas rated as 3 or 4 under AquaBAMM Measures 6.1.1, 6.2.1 and 6.4.1as 4 or 3 and with a hydrological modifier of H1, H2M2, H2M3, H2M4, H2M5, H2M8, '-'. Riverine results were displayed as drainage lines based on Queensland Waterways for Waterway Barrier Works dataset.
Criteria 4. Climate Change Adaptation		
4.1.1 Climate change refugia	SEQ BPA CCRAZM RE DRAFT WNR	For the SEQ Catchments (2016) Climate Change Refuge and Adaptation Zone Mapping, SEQ Bioregion, anywhere where there was more than 5 factors overlapping was included. This was clipped to remnant and woody non-remnant. All areas rated as High or Very High under BAMM Criterion IK.
4.1.2 Habitats with permanent water supply	SEQGDE	All permanent and near permanent surface and terrestrial GDE's (GW_CON_T_D = 'Permanent' or 'Near-permanent') with a hydro modification of H1, H2M2, H2M3, H2M4, H2M5, H2M8 were included.

References

Alluvium Consulting 2011, Framework for the assessment of river and wetland health: findings from the trials and options for uptake, Waterlines report, National Water Commission, Canberra.

Bennet, A.F., Nimmo, D.G., Radford, J.Q 2014. Riparian vegetation has disproportionate benefits for landscape-scale conservation of woodland birds in highly modified environments. Journal of Applied Ecology 51, 513-523.

Böhlke, J.K 2002. Groundwater recharge and agricultural contamination. Hydrogeology Journal 10: 153-179.

Clayton, PD, Fielder, DF, Howell, S, Hill, CJ 2006, 'Aquatic biodiversity assessment and mapping method (AquaBAMM): a conservation values assessment tool for wetlands with trial application in the Burnett River catchment', Environmental Protection Agency, Brisbane, ISBN 1-90928-07-3.

Clark, A., Healy, A., and Tindall, D. 2015. Riparian vegetation levels in the Queensland Murray-Darling Basin and Bulloo catchments for 2013. Department of Science, Information Technology and Innovation. Brisbane.

Dixon, M.J.R, Loh. J, Davidson, N.C, Bletrame, C, Freeman, R, Walpole, M. 2016. Tracking global change in ecosystem area: The Wetland Extent Trends index. Biological Conservation 193 (2016) 27-35.

DSITIA 2012, Groundwater Dependent Ecosystem Mapping and Classification Method: a method for providing baseline mapping and classification of groundwater dependent ecosystems in Queensland. Brisbane: Department of Science, Information Technology, Innovation and the Arts, Queensland Government.

EPA 2002, Biodiversity Assessment and Mapping Methodology. Version 2.1, July 2002, Environmental Protection Agency, Brisbane.

EPA 2005, Wetland Mapping and Classification Methodology – Overall Framework – A Method to Provide Baseline Mapping and Classification for Wetlands in Queensland, Version 1.2, Queensland Government, Brisbane. ISBN 0 9757 344 6 6

EHP 2016a, State of Environment Report - Extent and Rate of Change of remnant native vegetation. https://www.ehp.qld.gov.au/state-of-the-environment/finding/?id=1.1.0.1

EHP 2016b, Wetlands in the Great Barrier Reef, Management Strategy 2016-21. https://wetlandinfo.ehp.qld.gov.au/resources/static/pdf/management/policy/wetlands-gbr-strategy2016-21v13.pdf

EHP 2017, Groundwater dependent ecosystem pictorial conceptual model 'alluvia'. https://wetlandinfo.ehp.qld.gov.au/resources/static/pdf/ecology/gde/170303-gde-pcm-alluvia.pdf

EHP 2014, Biodiversity Assessment and Mapping Methodology. Version 2.2, Department of Environment and Heritage Protection, Brisbane.

Hancock, P.J. 2002. Human Impacts on the Stream-Groundwater Exchange Zone. Environmental Management 29, 6 763-781.

Holling, C.S. 1973 Resilience and stability of ecological systems. Annual Review of Ecological Systems, 4, 1–23.NPSR 2017, Draft Protected Area Strategy. Department of National Parks, Sport and Racing, Brisbane.

Jacobson, C.R 2011. Identification and quantification of the hydrological impacts of imperviousness in urban catchments: A review. Journal of Environmental Management 92.6 1438-1442.

Lovett, S, Price, P 2007, Principles for riparian lands management, Land & Water Australia, Canberra.

NPSR (2016), Draft Queensland Protected Area Strategy, A discussion paper on building a diverse and effective protected area system, viewed 08 February 2018 https://cabinet.qld.gov.au/documents/2016/May/ProtArea/Attachments/DraftStrategy.PDF

O'Brien, A., Marsden, T., Peterken, C. & Draper. I. 2016. Risk Management of Waterways: Impact Determination of Barrier Works for Fish Passage in Queensland, presented at 11th International Symposium on Ecohydraulics, Melbourne, 2016.

SEQ Catchments 2016, Climate Change Refuge and Adaptation Zone Mapping, SEQ Bioregion, South East Queensland Catchments Ltd, Brisbane.

WetlandInfo 2013, Recharge zones, Queensland Government, Queensland, viewed 15 August 2017, https://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/recharge-zones/.

Appendices

Appendix 1: Defining regional biodiversity corridors

The regional biodiversity corridors are a combination of the SEQ BPA terrestrial corridor buffers and the vegetation identified under CIM 1.1.2. There were a number of steps used to create the cartographic representation to indicate broad connectivity linkages:

1. A focal mean was applied across the vegetation identified in CIM 1.1.2 with a search area of 250 hectares.

2. Queensland Land Use Mapping (QLUMP) intensive land use category was used to remove areas from the corridor buffer network. A focal mean with a search area of 250 hectares was also applied to the result.

3. Both these datasets were then extracted where focal mean was greater than 0.5 (1 being the maximum score).

4. These datasets were then combined, ensuring that gaps were filled.

5. Some manual editing was applied to ensure a seamless cartographic representation and to ensure that outlier areas were removed.

Appendix 2: Measuring wetland extent

The intent of measuring wetland connectivity is to assess current wetland system aggregates in terms of their preclearing extent. Where systems have had minimal hydrological modification and there remains the presence of significant areas of unmodified wetland system and vegetation, it is deemed that there is appropriate surface connectivity within these systems that should be prioritised for protection. For those areas of lower appropriate connectivity it is also important that connectivity outcomes are improved through restoration and in some instances removal of barriers. Investment decisions can be framed in terms of the needs of these systems from a habitat connection point of view.

1. Select and dissolve the preclearing regional ecosystem extent where there is a lacustrine (L), palustrine (P), estuarine (E), contains palustrine wetlands (C), or riverine (R) wetlands present. Also, select from the QLD wetland mapping where HYDROMOD equals H1 or an 80%-50% mosaic unit, excluding estuarine and marine water bodies. Union together and dissolve. This defines the overall extent of pre-clear and remnant surface wetland systems.
2. Intersect the above with an appropriate catchment boundary layer and single-part the result. The catchment boundaries used should be accurate enough to minimise stranding wetland sections into adjoining catchments and be of an appropriate scale to allow for adequate representation of drainage flow into the receiving environment. In SEQ the catchment boundary used was the SEQ EPP sub-catchments. Further dissolving (single part) will be required as an artefact of the intersect operation. Create a unique ID for each new unit.
3. Overlay the remnant coverage, woody non-remnant and the QLD wetland mapping against the resulting layer and calculate the area of each resulting polygon in hectares.
4. Calculate the proportion of the total area that is either a HYDROMOD of (H1, H2M2, H2M3, H2M5, or H2M8) or an 80% or less mosaic unit, or is remnant or woody non-remnant.
5. Apply this proportion as a score.
6. Assign the proportion scores to the wetland features and vegetation types identified in step 4.

Note: the validity of the results is dependent on both the spatial accuracy of the input mapping and its attribution. For example using catchment boundaries to define actual connection is important as relying on a dissolved preclearing layer on its own can lead to expansive assessment areas that jump drainage areas. An assessment of the hydro-modifiers existing in the preclear extent when assigning connectivity score may need further consideration.