A landscape hazard assessment for wetlands in the Great Barrier Reef catchment

May 2015

Queensland Government

Queensland Wetlands Program

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Summary

The Queensland Wetlands Program (Program) was established by the Australian and Queensland governments in 2003 to support projects and programs that enhance the wise use and sustainable management of Queensland's wetlands. The program covers all aspects of wetlands management and has included the development of tools for assessing wetland status and pressures.

As part of the Queensland Wetlands Program (QWP), an assessment system was required to provide a conceptual and operational framework for assessing and monitoring the state of, and hazard to, the functions and values of lacustrine (lake) and palustrine (swamp) wetlands. The adopted approach uses the DPSIR (Driver, Pressure, State, Impact, Response) model as a causal framework to deliver an environmental values-based approach for assessment and monitoring, with the aim of informing the ongoing management of wetlands and the catchment landscapes in which they are located.

This report details the approach taken to assess hazards to lacustrine and palustrine wetlands in the Great Barrier Reef (GBR) catchments in Queensland. It provides a landscape scale assessment of hazard (as opposed to fully quantified 'risk') arising from land-use, and is conducted as a desktop GIS analysis.

In particular the assessment aims to:

- characterise human induced pressures arising from land-use
- enable the attribution of mapped wetlands with a modelled level of hazard.

Outputs may be used, in conjunction with other decision criteria, in prioritising targeted wetland specific monitoring and assessment and other management needs.

Potential pressures on wetlands were identified and qualitatively associated with broadscale land-uses and infrastructure types by a process of expert elicitation and literature review. Queensland Land Use Mapping Project (QLUMP) and State held infrastructure data sets were used to provide a mapped level of hazard for 22 individual pressures which include:

- input pressures (including nutrients, sediments, pesticides etc.)
- harvesting/exploitation pressures
- water regime change pressures
- biological introduction/perpetuation pressures
- habitat disturbance or alteration pressures.

Hazard was also evaluated for combined broadscale land-use pressures, for infrastructure pressures and finally with all pressures combined to give an overall indication of land-use hazard for freshwater wetlands across the Great Barrier Reef catchment landscape. Hazard mapping is presented for all 22 individual pressures and for combined pressures across the whole GBR.

The land-use/pressure characterisation process and hazard assessment indicated that the most ubiquitous land-use generated pressures influencing wetlands are changes to natural flow patterns, inputs of nutrients, inputs of sediments, direct surface water abstraction/addition and animal and plant pests. Hazard from other pressures such as groundwater abstraction are concentrated in specific locations. The land-uses with the strongest associations with individual pressures and driving multiple pressures on wetlands were urban, irrigated cropping and horticulture, extensive grazing, intensively managed grazing and mining.

Overall land-use hazard generally increased toward the south of the GBR catchment, with Cape York exposed to the lowest hazard compared to the Burnett-Mary region with the highest relative hazard. The areas with the highest land-use hazard for wetlands were mostly around urban centres and towards the eastern coastal zone. Examples of mapped wetland areas with displayed land-use hazard levels are presented, however the key management tool for future use is the associated attributed Geographic

Information system (GIS) layer which can be interrogated for the more than 14,000 individual mapped wetlands in the GBR catchment.

The hazard assessment undertaken here forms an important step in the operationalisation of pressure and values assessments across the GBR catchments. It enhances the conceptual understanding of pressures acting on wetland ecosystems and provides an accurate picture of human induced hazards to aquatic ecosystems that can be applied in any region.

It provides a key tool and information source which will assist with meeting the Reef Water Quality Protection Plan Target that 'There is no net loss of the extent, and an improvement in the ecological processes and environmental values, of natural wetlands'. The assessment can be improved by the addition of factors for individual pressures such as applying landscape scale risk influences (for example taking into consideration soil type and rainfall for sediment input pressure and risk). The assessment can be updated as new information and data becomes available and can assist with the prioritisation of monitoring targeting specific pressures and locations.

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1 Introduction

1.1 Purpose of the report

This report documents the methods and results of a broadscale hazard assessment of palustrine and lacustrine wetland ecosystems within the Great Barrier Reef catchment area. This is the first broadscale assessment undertaken as part of the Queensland Wetlands Program (QWP). The underlying framework aims to establish causal linkages between land-use drivers, pressures, the state of wetlands, impacts upon the associated environmental values of those wetlands and ultimately to management actions in response to those impacts.

The conceptual framework assumes that land-use drives pressures. This broadscale assessment aims to align land-uses with their associated pressures and subsequently quantify the hazard arising from land-use using these associations and extent of land-use types. Once hazards are mapped across the landscape areas with the potential to cause changes in wetland values are highlighted.

The outputs of this report represent the potential 'hazards' to wetlands from land-use drivers and does not identify 'risk'. A hazard is something likely to cause harm, in this case to a wetland. Risk, on the other hand, is the product of 'likelihood' and the 'consequence' of exposure to the hazard. At the landscape scale, at which this assessment is conducted, the hazard arising from land-use is being characterised. To adequately assess 'risk' to wetlands many other factors must be considered to make a truly informed judgement about the likelihood and consequences of the pressures arising from land-use. These factors include natural drivers (climate, geology, hydrology), landscape vulnerability factors (e.g. soil erosivity), wetland type (structure, functions and factors affecting its ecological resilience), management practices and the specific location of wetlands. Some wetlands are more vulnerable to specific pressures than others, and management practices can modify the impact of pressures (DERM b unpublished). Some of these factors can be considered at the landscape scale while others are more suitably incorporated into local wetland scale risk assessments. These factors are not considered in this broadscale assessment.

In particular the report aims to:

- present a conceptual understanding of land-use related pressures acting on palustrine and lacustrine wetland ecosystems
- contribute to the prioritisation of wetlands for targeted wetland specific monitoring and assessment.

1.2 Queensland Wetland Assessment framework

The wetland assessment framework underpinning this report is designed to deliver an environmental values-based approach for assessing and monitoring lacustrine and palustrine (lakes and freshwater vegetated swamps) wetlands to inform the ongoing management of both wetlands and catchment landscapes. It applies the Driver, Pressure, State, Impact, Response (DPSIR) model (EEA 1999) to provide an effective causal framework for describing, assessing and reporting on the interactions between society and the environment. It incorporates a three tiered whole of landscape perspective to address pressures on wetlands, their values and state.

1.2.1 Three tiered monitoring and assessment

The assessment framework incorporates a three tiered level assessment and monitoring approach which allows for scale and purpose appropriate parameters, indicators and methods to be identified and selected. This multi-scale approach is consistent with many monitoring and assessment schemes such as that adopted by the modified national Framework for Assessing River and Wetland Health (FARWH) (NWC 2011) and the Queensland Integrated Waterways Monitoring Framework (DERM 2011).

The 3 Tiers of assessment and monitoring are:

- Tier 1 assessments which focus on 'Drivers' at the regional and landscape scales and determine the potential hazard to wetlands at the broadscale using Geographical Information Systems (GIS) methods. This hazard assessment is a Tier 1 scale assessment applied at the regional scale.
- Tier 2 assessments which focus on monitoring individual wetlands using assessment techniques and indices of pressures and wetland state (condition). Local pressures on wetlands that can be

spatially assessed from the desktop and combined with general field based condition assessments.

- Tier 3 assessments which focus on intensive data collection and studies required to answer project specific scientific questions more often related to processes within or influencing a wetland.

Using this three tiered approach, the differences between and within wetlands can be explored at increasing levels of detail.

The purposes, parameters, indicator types and methods for the monitoring and assessment tiers are outlined in Table 1. Figure 1 depicts the monitoring and assessment units used within the framework. These range from sites at the finest scale, at which multiple replicates might be used as components of Tier 2 or 3 assessments, to the regional scale such as the GBR catchment, at which this hazard assessment is conducted.

Table 1 Monitoring and assessment tiers within the Framework

Scale	Description	Methods	Application/purpose
Tier 1 **Landscape scale**	Broad landscape assessments	GIS and spatial methods	• Extent mapping and inventory • Monitoring land-use pressure drivers • Disturbance characterisation and hazard assessment assisting prioritisations • Targeting restoration and monitoring programs
Tier 2 **Wetland scale**	Generalised or rapid assessments	Desktop methods based on qualitative and quantitative methods; simple observational metrics; checklists; field-based methods using course resolution observations and diagnostic tools	• Assessments addressing general questions about the state of a wetland and its values • Assessments addressing general questions about pressures using course validation of Tier 1 hazard assessment. Preliminary assessments for more detailed Tier 3 studies.
Tier 3 **Wetland scale**	Specific detailed assessment and scientific investigations	Intensive quantitative studies, inventory or fixed station for monitoring involving repeated measurements of physical, chemical and biological metrics and diagnostic analyses of wetland values, processes and change	• Studies to complement monitoring data • Studies of management impacts • Intensive studies examining cause effect relationships among pressures, components and processes for wetland types • Validation of Tier 1 and Tier 2 assessments

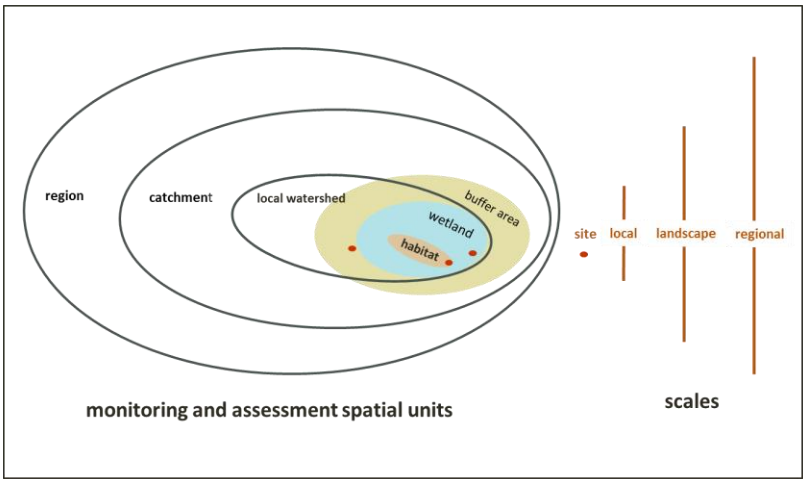


Figure 1 Monitoring and assessment scales

1.2.2 The DPSIR framework

The flexibility of the DPSIR framework (see Figure 2) allows it to be applied in different circumstances, for varying purposes and at different scales. It also gives the potential to integrate science-based thinking and outputs for management purposes and allows dissemination to a broader audience (Friberg 2010). This hazard assessment applies the DPSIR framework to define drivers and pressures. Land-uses are conceptualised as drivers directly causing pressures on wetland ecosystems which result in changes in a wetland's natural characteristics.

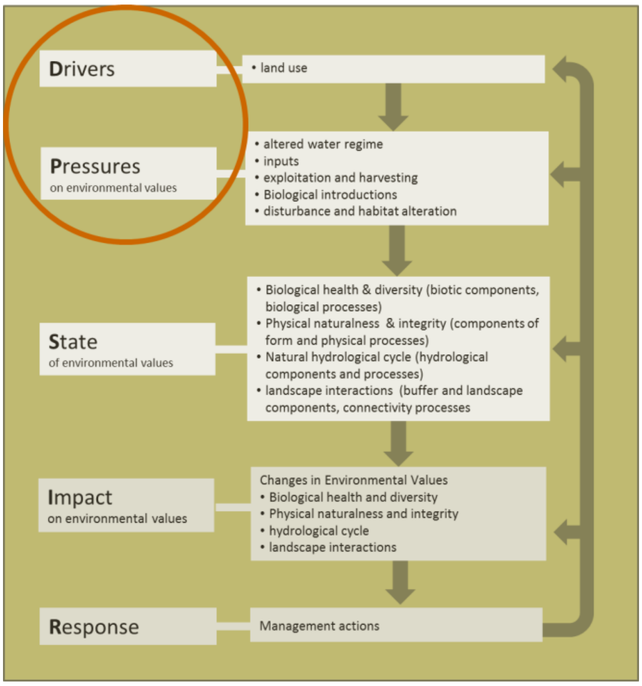


Figure 2 DPSIR Framework showing Drivers and Pressures as the focus of this hazard assessment

1.3 Scope

The assessment presented in this report details the principle methods and outcomes of a Tier 1 regional and landscape hazard assessment under the broad DPSIR framework. Whilst this method was developed for application to any region, this report outlines its application to the Great Barrier Reef (GBR) catchment, which is defined as the river basins that flow eastwards into the Coral Sea (see Figure 3).

This is a prioritised area and aligns with the Great Barrier Reef Water Quality Protection Plan management targets and strategies, specifically the wetland target that 'there will be no net loss of natural wetlands extent, and ecological processes and environmental values will be improved' (The State of Queensland 2013).

Within the GBR catchment this assessment aims to consider all relevant pressures associated with human influences arising from land-use. The assessment specifically considers hazard to lacustrine (lakes) and palustrine (vegetated swamps) wetland systems. While the landscape scale hazard outputs of this assessment may be relevant to other wetland types (e.g. riverine, marine, estuarine, subterranean), they are not applied to them as part of this assessment.

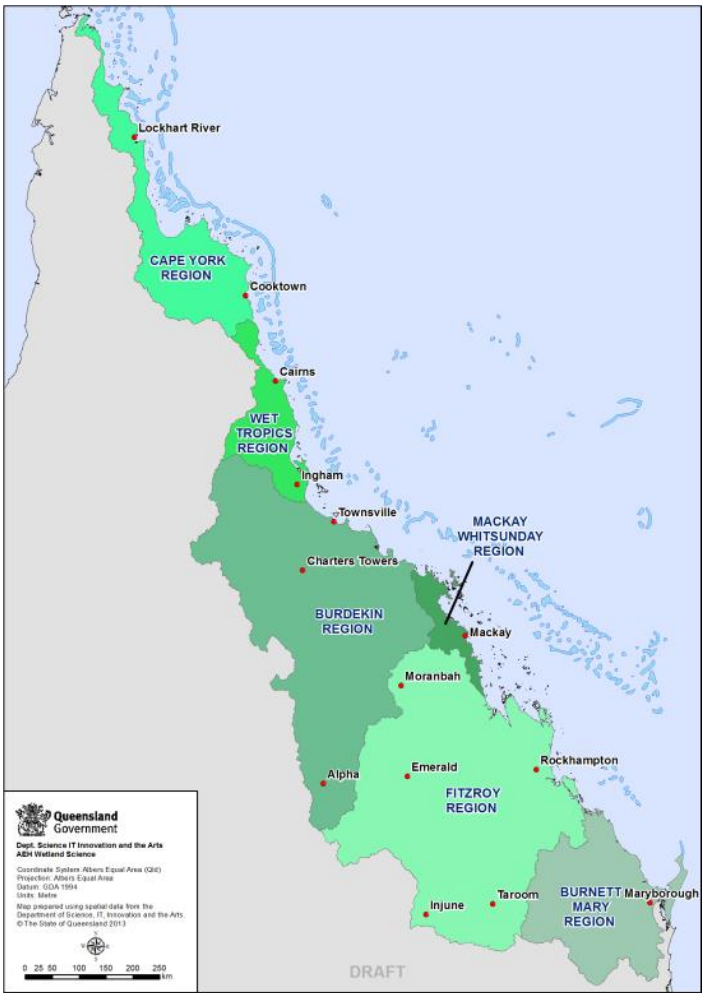


Figure 3 The Great Barrier Reef catchments—the area of interest for the wetland hazard assessment

2 Methodology

2.1 Objectives

The approach used in this assessment was to establish hazards to wetlands from anthropogenic land-use within the landscape. It provides a mechanism for conceptually linking land-uses and pressures within the DPSIR framework by:

- establishing a characterisation of pressures arising from land-use and infrastructure drivers with the potential to affect palustrine and lacustrine wetland ecosystems and align land-use/pressures associations within the framework
- providing weightings for functional land-use categories (based on the pressure characterisation) to be used in a wetland hazard mapping process
- attributing each mapped wetland (based on the latest Queensland wetland mapping information) with a modelled level of hazard from land-use pressures.
- attributing hazard from individual pressures and overall hazard (for combined land-use and infrastructure) to all areas within the GBR catchment.

2.2 Background

Disturbance in the landscape surrounding a wetland is an important factor in determining wetland condition (Papas *et al*. 2011). The broadscale assessment of risk to aquatic ecosystems (including wetlands) has been undertaken in a number of studies and programs. The National Framework for the Assessment of River and Wetland Health (FARWH) developed a Catchment Disturbance Index (CDI) incorporating the effects of land-use, change in vegetation cover and infrastructure (e.g. roads, rail lines) (NWC 2007) which was applied at the Surface Water Management Area (SWMA) scale. FARWH trials were conducted across Australia including in Queensland (Alluvium Consulting 2011, Senior *et al*. 2010) and New South Wales (Turak *et al*. 2010) which applied the CDI specifically to wetlands. The Victorian Wetland Catchment Disturbance Index (developed by Papas *et al*. (2011) (also following on from the FARWH model) utilised an expert elicitation of weights derived from the potential for land-uses to impact on wetlands through different pressure pathways. This approach was expressly considered in the development of this hazard assessment.

The Queensland Waterways Integrated Monitoring Framework (QWIMF) project (DERM 2011) used a variety of data sources in combination (including some land-uses and infrastructure/point source data) to gain a wide-ranging perspective of catchment scale risk to aquatic systems across the state. Whilst the approach was inclusive there was also some disparity (both spatially and temporally) between the different data sets used in the assessment. As part of this hazard assessment a review and reworking of the QWIMF methodology was undertaken and findings from that process were incorporated into the methodology presented here. This assessment aims to provide a repeatable landscape level hazard assessment for palustrine and lacustrine wetlands, using expert elicited weights for particular land-use categories and infrastructure in the landscape, based on the pressures they are driving. It builds on the methodology developed under the QWIMF assessment using many of the same point type data sources but applied consistently and comparably across parameters. This is combined with a comprehensive assessment of broad land-use pressures using the full range of mapped land-uses available under the Queensland Land Use Mapping Program (QLUMP) mapping protocols. The QWIMF assessment was presented as a 'risk' assessment however due to the scale at which the assessment was conducted it is felt that threats to aquatic ecosystems are better expressed in terms of magnitude of 'hazard' rather than 'risk'. This is because at the desktop evaluation stage, the pressures or threats can only be potential or inferential unless landscape scale vulnerability and mediation factors are adequately factored in.

The development of this present hazard assessment method was an iterative process. Initially a quantitative risk assessment procedure was used to attempt to align land-uses with pressures. The assessment was undertaken with input from a group of expert participants with knowledge of wetland ecosystems and/or land management practices. They were from a variety of backgrounds and expertise in the area of wetland science and policy development (a list of workshop participants is shown in Appendix C). They included representatives from state and local government departments from science and policy backgrounds, university academics, natural resource management organisations and private consultants. Participants were asked to complete a risk assessment exercise linking pressures on wetlands with land-use across the Great Barrier Reef catchment area. Subsequently, and building on the feedback and expert input from the workshop and an ongoing consultation process, a refined and simplified model for assessing pressures associated with land-use and infrastructure was developed. The synthesis of that model and a process overview is presented in the following sections.

2.3 Scale

The overall reporting scale of the hazard assessment is the Great Barrier Reef catchment. Within that area, the assessment was undertaken at two different spatial scales using both the Natural Resource Management (NRM) mapping units and Aquatic Conservation Assessment (ACA) mapping units as the basis for assigning hazard levels across the landscape. Clayton *et al.* (2006) recognised that the scale chosen for defining spatial units must be reconcilable with respect to reporting scale or resultant management action. As such, hazard is mapped at these two different scales so that it can be easily and appropriately utilised depending on its intended application.

Regional NRM bodies play a key role in protecting and managing Australia's natural resources. There are six regional NRM groups within the Great Barrier Reef catchment which broadly align with the regional areas of Cape York (Cape York NRM), Wet Tropics (Terrain NRM), Burdekin (NQ Dry Tropics NRM), Fitzroy (Fitzroy Basin Association), Mackay-Whitsunday (Reef Catchments) and Burnett–Mary (Burnett Mary NRM) used in this report (Figure 3). The NRM mapping units used in this assessment are those defined by regional NRM bodies as the basis for natural resource management and reporting in their area (e.g. Neighbourhood Catchments in the Fitzroy Basin) and are generally in alignment with hydrological sub-catchments. Reporting hazard at the NRM mapping unit spatial scale is appropriate to fit with the implementation of management plans and on-ground works by the regional bodies. There are a total of 413 NRM catchments across the area of interest.

The ACA mapping units (or subsections) are those defined under the Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM)—a comprehensive methodology developed by the Department of Environment and Heritage Protection (EHP) for assessing the conservation values of wetlands in Queensland (Clayton *et al*. 2006). The method uses available data to produce an Aquatic Conservation Assessment (ACA) for the wetlands through a Geographic Information System (GIS) platform. ACAs are designed to support processes such as natural resource management and planning, water resource management, determining priorities for protection, regulation or rehabilitation of aquatic ecosystems and guiding on-ground investment in aquatic ecosystems. As such, the ACA mapping units are also considered an appropriate scale for reporting under this assessment to link with the ACA program objectives. The ACA units are smaller in size than the NRM units and are defined on the basis of shared ecological characteristics. There are a total of 5514 ACA units across the area of interest. Figure 4 shows a comparison of scale between the NRM and ACA units for an example area in the Burdekin region.

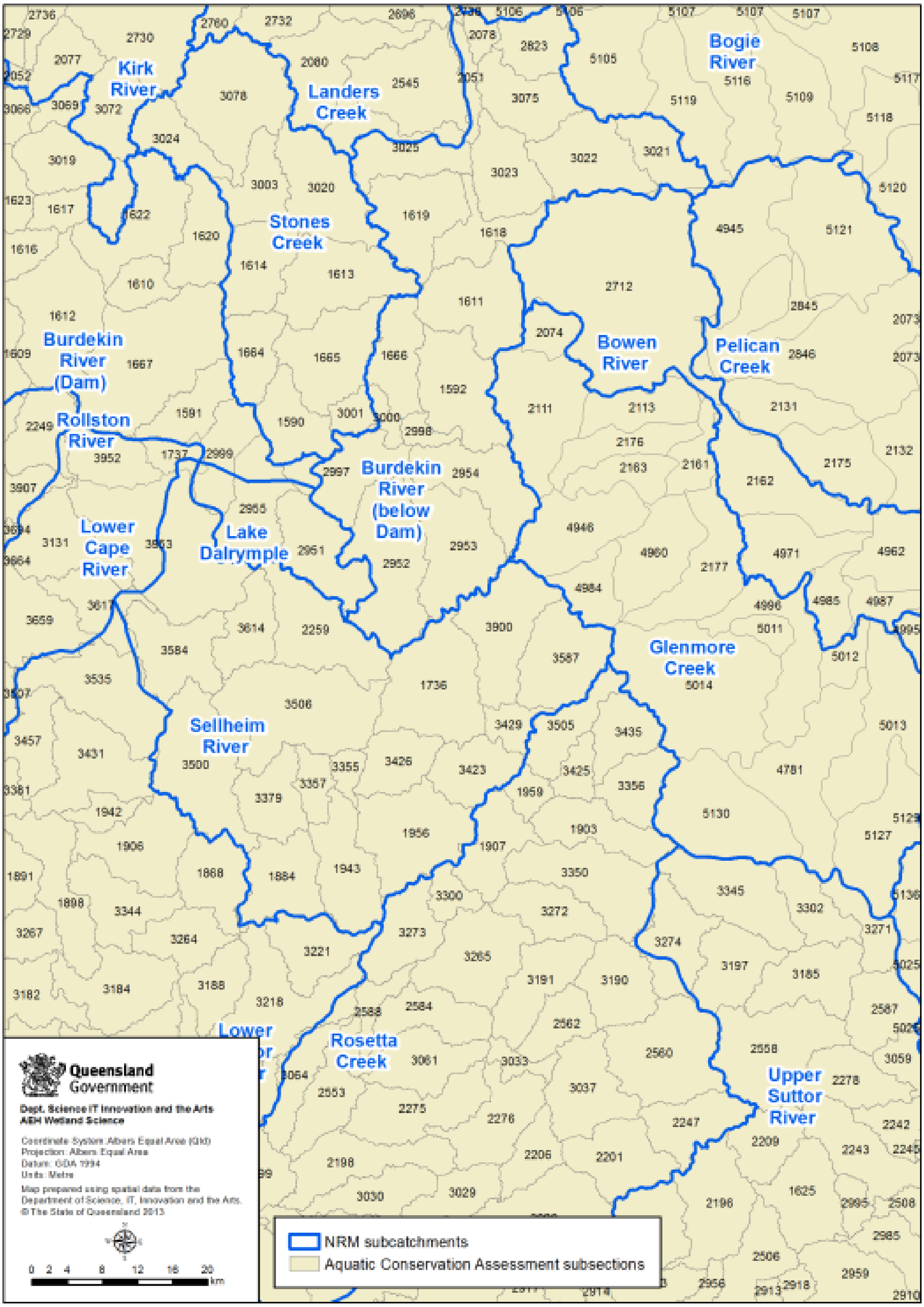


Figure 4 Comparison of scale between NRM and ACA mapping units

2.4 Approach

The hazard assessment uses a GIS based approach to apply the results of expert elucidated weightings for land-use groups, and different types of infrastructure, across the whole of the area of interest. The approach involved a number of key steps:

- identifying and defining pressures to wetland ecosystems
- grouping land-uses together based on their similarity and shared propensity to drive pressures on wetlands
- identifying infrastructure and finer scale land-uses driving pressures to wetlands (not accounted for in broadscale land-use mapping)
- developing a pressure characterisation or profile for each land-use group and allowing weights to be assigned to each group on the basis of the pressures associated with them
- generating a hazard score for each reporting unit (either NRM or ACA unit) based on its land-use composition and infrastructure content
- generating maps for each pressure, combined land-use pressure, infrastructure pressure and combined land-use/infrastructure pressures.

2.4.1 Identifying and defining pressures to wetlands

Wetlands in Queensland are subject to a wide range of pressures which can occur across a range of scales, and which may be located a long way from the wetland itself, e.g. water abstraction at the top of a catchment may significantly alter the hydrology of a downstream wetland. In many areas, such as the Great Barrier Reef catchment, the functioning of freshwater ecosystems and their capacity to provide ecosystem services is impaired by land and water management practices, hydrological change, riparian degradation and weed infestations (DPC 2008). Comprehensive information about the pressures on and the impact to wetland values is crucial for effective management, providing benchmarks for assessing future changes and informing policy decisions (DERM 2011). It is also important that wetlands are managed from a whole-of-landscape perspective to help ensure pressures are addressed at appropriate scales.

Several studies have identified and categorised pressures on aquatic ecosystems in Queensland (DERM 2011, Marshall *et al*. 2006, DERM b—unpublished) including DERM (2011) which used a risk-based framework to classify pressures under a mixed group of categories strongly focused on land-use as a key pressure. The pressure categories were mining, intensive animal production, agriculture and urban and industrial, water use, biota (i.e. invasive and pest species) and landscape management (altered fire regimes). Other studies applied a pressure-vector-response framework (Marshall *et al*. 2006), or pressure-stressor-response framework (e.g. DERM b—unpublished, Negus et al. 2009), classified pressures to include human activities and land-uses which influence stressors (vectors), such as pest species or sediment processes affecting ecosystem change. Stressors (vectors) are often confused with pressures and the terms are frequently used interchangeably.

This hazard assessment applies an alternative approach. It identifies and defines pressures and pressure relationships from the perspective of land-use being defined as the primary anthropogenic driver of pressures rather than a pressure in itself. From this foundation the pressures and stressors identified in previous Queensland studies and the conceptual models associated with them, were reviewed, redefined where appropriate and categorised to align with land-use drivers. In particular, it draws on pressure indicators derived from the DERM study ‘A framework for assessing the health of, and risk to, Queensland’s lacustrine (lake) and palustrine (swamp) wetlands’ (DERM b—unpublished) which describes causal relationships between disturbance, pressures and state through stressors.

This hazard assessment identifies twenty-two individual pressures grouped into five broad categories applicable to aquatic ecosystems:

- Inputs—direct/indirect
- Harvesting
- Changes to the water regime
- Biological introductions and perpetuation
- Habitat disturbance/alteration.

These categories are in alignment with those presented in Dudgeon *et al.* (2010) and adapted from those developed by Lynch (2010). They infer similarities of pressure types suitable for meaningful interpretation at a broadscale, although all pressures are still considered individually to allow a detailed examination of land-use driven pressures. The individual pressures within these categories were developed specifically for the present assessment to allow easier conceptual links to be made in association with a particular land-use. The pressure categories and individual pressures were developed and endorsed by the expert panel for use in the pressure characterisation process. Descriptions of these pressures are given in Table 3.

Table 3 Pressures and pressure categories used in the Tier 1 landscape hazard assessment

Pressure category	Pressure	Description
Inputs—direct/indirect	Nutrient inputs	Increases in the levels of nitrogen and phosphorus (as limiting nutrients in aquatic ecosystems) caused by human activities
	Sediment inputs	Increase in the loads of sediments, suspended sediments and deposition of sediments associated with human activities
	Pesticide inputs	Pesticides (herbicides, insecticides, veterinary medicines etc.) entering wetlands due to human activities to control plants, insects and other animals
	Chemical and metal inputs	Inputs of metals, metalloids, organometallics or other chemicals entering wetlands as a result of human activities.
	Organic matter inputs	Changes in levels of organic compounds (plant and animal matter or their waste products) in wetlands caused by human activities
	Saline inputs	Increases in water salinity that adversely affects wetlands as a result of human activities
	Acid inputs	Increases in water acidity that adversely affects wetlands as a result of human activities
	Hot/cold water inputs	Input of water of different temperature compared to that of the receiving wetland caused as a result of human activities
	Litter and rubbish inputs	Non-biodegradable litter and rubbish inputs as a direct result of human activities
Harvesting	Plant biota harvesting	Plant biota removal activities such as aquarium plant species collection from a wetland or timber harvesting from the buffer zone on a recreational or commercial scale.
	Animal biota harvesting	Animal biota removal activities from the wetland or buffer zone including fishing, bait collection or aquarium animal species collection on a recreational or commercial scale.
Changes to the water regime	Surface Water abstraction or addition	Abstraction of surface water for any purpose (e.g. for irrigation, stock watering or domestic use) or addition of water into surface ecosystems (dam releases, mine dewatering etc.).
	Groundwater abstraction or addition	Abstraction of groundwater for any purpose (e.g. for irrigation, stock watering or domestic use) or addition of water into the ground (e.g. reinjection of water).
	Changes to natural surface water flow patterns	Changes to surface water flow patterns due to impoundments, barriers, levees or alteration of natural drainage pathways caused by human activities that can affect the natural water regime within a wetland.
Biological introductions and perpetuation	Bacteria and pathogens	Changes to natural levels or introductions of bacteria, viruses, protozoa or fungi through anthropogenic causes such as sewage treatment plant discharges, feed lots and aquaculture.
	Aquatic pest animal species	Introductions and perpetuations of aquatic animal pest species caused by accidental/deliberate release.
	Aquatic pests plant species	Introductions and perpetuations of aquatic plant pest species caused by accidental/deliberate release.

Table 3 Pressures and pressure categories used in the Tier 1 landscape hazard assessment (continued)

Pressure category	Pressure	Description
Biological introductions and perpetuation (continued)	Buffer zone pest animal species	Introductions and perpetuations of buffer zone animal pest species (does not include managed livestock).
	Buffer zone pest plant species	Introductions and perpetuations of buffer zone plant pest species
Habitat alteration/disturbance	Aquatic biota disturbance	Changes to the aquatic species community structure, abundance or distribution caused by the direct disturbance of wetland habitat components or processes by humans or managed livestock.
	Buffer zone biota disturbance	Changes to riparian/buffer zone species community structure, abundance or distribution caused by the direct disturbance of habitat components or processes by humans or managed livestock.
	Landform or physical habitat disturbance	Direct disturbance to the physical habitat or landform by humans or managed livestock.

2.4.2 Defining landscape scale pressure drivers

Defining the land-uses that drive pressures on wetlands is the second step in the hazard assessment method and also fundamentally within the DPSIR framework, where it allows diagnostic linkages between ‘drivers’ (land-use) and ‘pressures’ to be established.

For the purposes of this assessment, groupings of broadscale land-use were drawn from the Australian Land Use and Management Classification (ALUMC) categories, however they were customised and defined based on their propensity to drive similar pressures used in this hazard assessment. Previous landscape scale risk assessments, such as that conducted for the QWIMF risk assessment project (DERM 2011), recognised that point source pressures and small scale land-use are under-represented in broadscale mapping. Indeed the guidelines for land-use mapping in Australia state that ‘Point features are not well supported under the mapping procedures, as they are generally smaller than the minimum mapping unit. They are therefore often incorporated into the surrounding land-use. Other datasets should be sourced for the location of such features (e.g. infrastructure datasets), rather than the land-use data sets’ (ABARES 2011). Due to these recognised limitations, a two-step process, incorporating an infrastructure pressure assessment, is required. This process identifies and recognises finer scale and point source pressures and small scale features that are potentially missed under a broadscale land-use hazard assessment. It is a complimentary assessment that is later combined with the broadscale land-use/pressure data to provide a comprehensive assessment of landscape scale land-use hazard.

2.4.2.1 Broadscale land-uses

The Australian Land Use and Management (ALUM) Classification system provides a nationally consistent method to collect and present land-use information across Australia. The latest version (Version 7) of the classification has a three-level hierarchical structure (Appendix F). Primary, secondary and tertiary classes are broadly structured by the potential degree of modification or impact in the landscape. The basis of the classification shows five primary classes, identified in order of increasing levels of intervention or potential impact. Water is included separately as a sixth primary class. The secondary level in the three-level hierarchical structure is the minimum attribution level for land-use mapping in

Queensland. Primary and secondary levels relate to land-use (i.e. the principal use of the land in terms of the objectives of the land manager). The tertiary level includes data on commodities or vegetation, (e.g. crops such as cereals and oil seeds). Where required and possible, QLUMP maps land-use classes to tertiary level (DSITIA 2012).

For the purposes of this assessment, 15 custom land-use groupings were devised that encompass the entire QLUMP layer, based on second and third tier ALUM categories (see Table 4). These groupings were chosen in consultation with expert panel members and aimed to group land-uses considered to drive similar pressures (e.g. irrigated cropping and horticulture and intensive horticulture are both likely to be associated with water abstraction, nutrient, sediment and pesticide inputs) or split off those that were perceived to have more specific pressure associations (for instance aquaculture was split from other intensive animal production classes and recognised as a separate land-use group to take account of the unique potential for introduction of aquatic pest animal species into wetland environments).

Table 4 Land-use groupings and descriptions used in the land-use/pressure characterisation

Grouping of ALUM (Version 7) categories				
	Land-use group	**Land-use description**	**ALUMC name**	**ALUMC number**
1	Conservation & natural environments	Land designated for nature conservation and other minimal uses (e.g. national parks, habitat/species protection areas, managed indigenous uses, defence land-natural areas)	Nature conservation	1.1.0
			Managed resource protection	1.2.0
			Other minimal use	1.3.0
2	Extensive grazing	Grazing by livestock on native vegetation where there has been little/no deliberate pasture modification	Grazing native vegetation	2.1.0
3	Intensively managed grazing	Grazing on significantly and actively modified pastures with or without irrigation (e.g. dairy farms, fodder crops)	Grazing modified pastures	3.2.0
			Grazing Irrigated modified pastures	4.2.0
4	Production from natural forests	Wood (sawlogs and pulpwood) and other forest production (e.g. firewood, fence posts and wildflowers) from natural forests	Production forestry	2.2.0
5	Plantation forestry	Plantations of trees or shrubs, for production or resource protection, established on cleared and managed land	Plantation forestry	3.1.0
			Irrigated plantation forestry	4.1.0
6	Dry land cropping and horticulture	Cropping (e.g. sugar cane, cereals, cotton etc.), perennial (e.g. tree fruits/nuts, citrus, grapes, perennial flowers/vegetables etc.) and seasonal horticulture (e.g. seasonal vegetable fruits/flowers etc.) on *non-irrigated* land. Involves a relatively high degree of nutrient, weed and moisture control	Cropping (Dry land)	3.3.0
			Perennial horticulture	3.4.0
			Seasonal horticulture	3.5.0
			Land in transition	3.6.0

Table 4 Land-use groupings and descriptions used in the land-use/pressure characterisation (continued)

7	Irrigated cropping and horticulture	Cropping (e.g. sugar cane, cereals, cotton, pulses, rice etc.), perennial (e.g. tree fruits/nuts, citrus, grapes, perennial flowers/vegetables etc.), seasonal (e.g. seasonal vegetable fruits/flowers etc.) and intensive horticulture (glasshouses, shade houses etc.) on *irrigated* land. Involves a relatively high degree of nutrient, weed and moisture control and where water is applied to promote additional growth	Cropping (irrigated)	4.3.0
			Irrigated perennial horticulture	4.4.0
			Irrigated seasonal horticulture	4.5.0
			Irrigated land in transition	4.6.0
			Intensive horticulture	5.1.0
8	Aquaculture	Aquaculture installations for cultivating fish and crustaceans (lobsters, yabbies, etc.), molluscs (oysters, mussels) or crocodiles	Aquaculture	5.2.6
9	Intensive animal production	Intensive animal production or holding yards (including dairy sheds, cattle/sheep feedlots, piggeries, poultry farms, horse studs etc.)	Intensive animal production (excluding aquaculture)	5.2.1 5.2.2, 5.2.3 5.2.4, 5.2.5, 5.2.7, 5.2.8, 5.2.9
10	Manufacturing and industrial	Manufacturing and industrial (including general/food production factories, industrial complexes, bulk grain storage, oil refineries, sawmills, abattoirs etc.)	Manufacturing and industrial	5.3.0
11	Waste treatment and disposal	Waste treatment and disposal (includes sewage treatment infrastructure, landfill, waste transfer and incinerators)	Waste treatment and disposal	5.9.0
12	Urban	Urban/rural residential (houses, flats, domestic gardens, hobby farms), farm infrastructure (farm buildings, sheds etc.) commercial and public services (shops, schools, parks, sportsgrounds etc.) and utilities (e.g. power/water/gas infrastructure)	Residential and farm infrastructure	5.4.0
			Services	5.5.0
			Utilities	5.6.0
13	Transport	Transport (roads, railways, airports, ports) and communications infrastructure (radar stations, beacons etc.)	Transport and communication	5.7.0
14	Mining	Mines (open cut and deep shaft mines), quarries (for extraction of stone, gravel, clay, sand, soil etc.) and tailings (dumps and dams for storage and treatment of mining/quarrying waste) and disused mines	Mining	5.8.0
15	Water (Artificial)	Reservoir/dams (reservoirs, farm dams, evaporation basins) and artificial channels/aqueducts (for the supply, distribution or removal of water for irrigation, land reclamation or drainage).	Reservoir/dam	6.2.0
			Channel/aqueduct	6.4.0
		NB Water (natural) (categories 6.1.0, 6.3.0, 6.5.0, 6.6.0) excluded from the pressure assessment and masked in GIS mapping procedure		

2.4.2.2 Infrastructure land-uses

The infrastructure land-use pressure assessment is conducted using compiled data sets of different kinds and obtained from a variety of sources. These are largely the same as many of those used for the 'Risk assessment for prioritising integrated waterway monitoring in Queensland' (DERM 2011); however they are applied using a 'per hectare' calculation as opposed to the catchment risk scores applied in that assessment. The expression of all hazard metrics on a 'per unit' area basis, rather than a mapping unit basis, means they are genuinely comparable across all mapping units regardless of mapping unit size. A description of these data sets is given in Table 5. They include point data sets for aquaculture installations, manufacturing and industrial sites, waste treatment and disposal sites, buildings, mining sites (including oil and gas wells) and licensed groundwater bores. Polygon type data sets are used for intensive animal production (based on numbers of cattle, pigs or poultry associated with licences for lot plan parcels) and artificial water bodies. Line type data sets are included for roads, railways and power lines.

The assessment excludes features used in the broadscale land-use pressure characterisation process. For example, mine sites that were large enough to be mapped as a discrete land-use within the QLUMP mapping are not considered as part of the infrastructure assessment. This is to ensure that land-use features are not double counted. This is undertaken using a search radius around a particular data point and eliminating the point if the search radius intersected with an existing site for that land-use within the broadscale mapping. All data sets are converted to a metric relating to a per hectare value which are then applied to the ACA (or NRM) mapping units.

Table 5 Data sets used in the infrastructure pressure characterisation process

Land-use grouping	Data set type	Description	No. features within AOI
Aquaculture	point	Location of aquaculture sites (hatcheries and grow-out ponds)	541
Intensive animal production	polygon	Location of licenced cattle feedlots	713
Intensive animal production	polygon	Location of licenced piggeries	542
Intensive animal production	polygon	Location of poultry farms with >10,000 birds	23
Manufacturing & industrial	point	Location of significant Industrial/processing plants	197
Waste treatment and disposal	point	Location of sewage treatment plants	105
Waste treatment and disposal	point	Location of treated sewage outfalls	101
Urban	point	Location of permanent non-urban buildings	87,118
Urban	line	Location of high voltage transmission power-lines	361
Transport	line	Location of roads within the State Digital Road Network	128,637
Transport	line	Location of railways	376
Mining	point	Location of coal seam gas wells	1611

Mining	point	Location of all worked mines	6690
Mining	point	Location of petroleum exploration and production wells	304
Water artificial	polygon	Location of artificial surface water impoundments	5674
Water use	point	Location of licensed groundwater boreholes	67,288

2.4.3 Pressure characterisation

It has been recognised that there is a lack of a comprehensive categorisation of threats and disturbances to wetlands (and to natural ecosystems more widely) and that this is a critical information gap (Lynch 2011). As the key methodological step of this hazard assessment, a comprehensive characterisation of the pressures associated with different land-uses was undertaken. This enabled a pressure profile for each land-use group to be developed. These pressure profiles underpin the conceptual understanding of the extent that land-use can drive pressures on wetlands, and also form the basis for the quantitative derivation of hazard in this assessment.

Land-use pressure profiles were generated by an expert panel (the small group workshop participants given in Appendix C) who considered the potential for each land-use group (see Table 4) to drive each of the pressures known to influence wetlands (see Table 3). Each broadscale land-use group/pressure combination was considered in turn and assigned a numerical score, on the basis of the guidelines shown in Table 6, after a consensus was reached as to the degree of association. These decisions are presented in the tables in Appendix A. The reasoning for that score, as agreed by the expert panel, is recorded (see Appendix B) and a level of confidence in the degree of association is also noted (low, medium or high) to highlight any uncertainty in the decisions.

There are a number of assumptions implicit in the decisions made by the expert panel. These are presented and discussed below:

- *The assessment is based on the premise that land-use is a key driver of specific pressures.* It is recognised that there are other drivers—natural processes such as geology, climate, hydrology or fire regimes. Pressures arising from land-use are 'human induced' and above the levels caused by natural processes.
- *The land-use/pressure associations are not geographically bounded*. This is a conceptual characterisation of the strength of association between a land-use and a particular pressure regardless of the location of those land-uses in the landscape.
- *The assessment considers only pressures arising from existing land-uses and does not consider land-use change* (e.g. establishment of new areas of a particular land-use, change from one land-use type to another or land-use intensification). Anticipated trends in land-use development or future infrastructure associated with population growth are not considered as part of this assessment. It is recognised that land-use change is a highly important in driving changes in pressures on wetlands but that this cannot be expressly and meaningfully evaluated using a mapping product such as QLUMP except on a long temporal cycle when the mapping is updated. However while land-use change is not included in the assessment projected land-use change could be used to model future wetland hazard and pressures based on those land-use changes.
- *The assessment does not consider variation in specific land management practices within land-use groups* (i.e. it is known that sugar cropping land is managed differently across the state and also differently to other crops). While this can change the influence of specific pressures, in the context of this broadscale land-use assessment, key pressures in common within the wider land-use group of irrigated cropping and horticulture are considered together.

- *The assessment considered the chronic (ongoing) and acute (incident) pressure pathways potentially associated with a land-use combined into a single categorisation*. Incident based pressures are unpredictable and could arise from accidents or unexpected events. Ongoing hazards are those known to occur either continually or regularly. During the initial expert workshop process undertaken during the development of this assessment, a separate quantitative assessment of risk was conducted for incident and ongoing pressures, the same approach as conducted during the QWIMF risk assessment (DERM 2011). Difficulties in appropriately assigning and differentiating between acute and chronic risk for many of the pressures were encountered by the participants. The method ultimately developed for the hazard assessment, combining the two pressure pathways, was adopted following recommendations and feedback from experts involved in the initial workshop.
- *The assessment applied a realistic but precautionary principle based approach*. Land-use/pressure association scores aimed to be realistic but take into account known high pressure scenarios associated with that land-use.

Table 6 Guidelines for pressure assessment scoring

Potential for land-use to drive pressure	Score	Definition
Very High	5	Very high potential for this land-use to drive this pressure.
High	4	High potential for this land-use to drive this pressure.
Moderate	3	Moderate potential for this land-use to drive this pressure.
Minor	2	Minor potential for this land-use to drive this pressure.
Very Minor	1	Very minor potential for this land-use to drive this pressure.
None	0	No potential for this land-use to drive this pressure.

2.4.4 Assigning land-use weights

Weightings for each individual pressure are simply the numerical values assigned to each land-use/pressure combination determined by the expert panel. These scores are given in Table 7 and reflect the qualitative decisions documented in Appendix A.

To determine a weight for all pressures combined, individual land-use/pressure association scores are summed for each land-use and the resultant score is rescaled between 0 and 1 based on the theoretical minimum of 0 (if all 22 pressures scored a 0) and maximum score of 110 (if all 22 pressures scored a 5). The combined land-use pressure weights are also shown in Table 7.

Infrastructure data sets were given a weight on the basis of that assigned to the corresponding land-use. In most cases the infrastructure data set is a direct component of that land-use category (e.g. roads and railways are a component of the 'Transport' land-use grouping and are therefore justifiably weighted based on the pressures associated with that grouping). Groundwater bores were allocated a weighting based on the land-use that they were associated with (i.e. they received a weighting relevant to extensive grazing if they are located in a mapped parcel of this land-use). Mines other than oil or gas wells (which are assigned the generic weight for mining from the land-use scoring) are given a custom weighting adjusted based on their type and size. This is due to the highly variable potential impacts from different mine types and the extreme range of production capacities present in the data set (e.g. a small scale opal mine versus landscape scale open cast coal or iron ore extraction). Production capacity is derived from an attribute within the spatial data and the custom weights for commodities were based on expert opinion (DSITIA personal communication). The weights used for infrastructure pressures are shown in Table 8.

Table 7 Weightings used for broadscale land-use hazard mapping

	Inputs direct/indirect									Harvesting		Changes to the water regime			Biological introductions and perpetuation					Habitat alteration and disturbance				
	Nutrients	Sediments	Pesticides	Chemical and metals	Organic matter	Saline	Acid	Hot/cold water	Litter and rubbish	Plant biota	Animal biota	Surface water abstraction	Ground water abstraction	Changes to natural surface water flow patterns	Bacteria and pathogens	Aquatic pest animal species	Aquatic pest plant species	Buffer zone pest animal species	Buffer zone pest plant species	Aquatic distrubance	Buffer zone disturbance	Landform disturbance	**Sum of all pressures combined**	**All pressures combined (weight used)**
Conservation and Natural Environments	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	2	3	2	0	0	0	**11**	**0.10**
Extensive Grazing	3	4	1	0	3	1	0	1	1	0	0	3	3	3	1	1	4	3	4	4	5	3	**48**	**0.44**
Intensively managed grazing	5	4	3	0	4	3	0	0	0	0	0	4	4	4	1	1	4	1	4	1	1	1	**45**	**0.41**
Production from natural forests	2	3	0	0	2	0	0	0	0	1	1	1	0	1	1	1	3	3	4	3	4	3	**33**	**0.30**
Plantation forestry	2	2	3	0	1	0	0	0	0	1	1	0	2	3	0	1	1	2	3	0	1	0	**23**	**0.21**
Dryland cropping and horticulture	4	5	4	0	4	2	0	0	0	0	0	0	0	3	0	1	2	1	2	0	3	2	**33**	**0.30**
Irrigated cropping and horticulture	5	5	5	0	3	4	3	0	0	0	0	5	5	5	0	1	2	1	2	0	3	2	**51**	**0.46**
Aquaculture	5	0	4	0	3	3	0	0	0	0	0	4	2	4	4	3	1	0	0	0	0	3	**36**	**0.33**
Intensive animal production	5	3	4	0	5	0	0	0	0	0	0	4	4	2	3	0	0	1	2	0	0	1	**34**	**0.31**
Manufacturing and industrial	3	2	1	3	2	3	2	2	3	0	0	1	1	1	1	0	1	1	0	0	0	0	**27**	**0.25**
Waste treatment and disposal	3	2	1	2	3	3	2	0	3	0	0	3	0	2	1	1	0	1	1	0	0	0	**28**	**0.25**
Urban	4	4	3	3	3	2	3	2	5	4	5	4	3	5	3	5	5	4	5	4	5	3	**84**	**0.76**
Transport	1	3	1	3	1	3	0	0	4	4	5	0	0	5	0	0	0	2	3	2	2	3	**42**	**0.38**
Mining	2	4	0	5	1	4	4	0	0	0	0	5	3	5	0	0	0	2	2	2	3	3	**45**	**0.41**
Water (artificial)	3	3	1	0	3	2	1	1	1	0	0	5	2	5	1	3	3	2	2	1	1	0	**40**	**0.36**

Table 8 Infrastructure land-use weights

Metric	Weight applied
Aquaculture sites per hectare	0.33
Licenced cattle feedlots per hectare	0.31
Licenced piggeries per hectare	0.31
Poultry farms >10,000 birds per hectare	0.31
Significant industrial/manufacturing plants hectare	0.25
Sewage treatment plants per hectare.	0.25
Sewage treatment outfalls per hectare.	0.25
Permanent non-urban buildings per hectare.	0.76
Kilometres of high voltage transmission line per hectare.	0.76
Kilometres of state digital road network road per hectare.	0.38
Kilometres of railway per hectare.	0.38
Gas wells per hectare	0.41
Mines per hectare	Custom weight using normalised (size x commodity type) based on the following: 1 where SIZE_ORDER = 1 10 where SIZE_ORDER = 2 100 where SIZE_ORDER = 3 1000 where SIZE_ORDER = 4 • Heavy metals 0.7 • Coal 0.4 • Iron 0.4 • Industrial Feedstuffs 0.2 • Quarries 0.1 • Gemstones 0.1
Oil wells per hectare	0.41
Artificial surface water impoundments per hectare	0.36
Boreholes per hectare	Weighted according to all pressure land-use scores as given in Table 7 e.g. extensive grazing 0.44

2.4.5 Generating landscape hazard scores

Landscape hazard scores for each pressure within each mapping unit are derived using the following process:

- Percentage area of each land-use group present within an ACA or NRM mapping unit is assessed using GIS techniques. Water (natural) was masked from the land-use mapping and did not contribute to the assessment.
- Percentage area of each land-use group present is multiplied by a weight (given in Table 7) derived from the land-use pressure association scoring.
- The results of all the land-use x weight calculations for that mapping unit are summed to produce a single land-use hazard score for each NRM and ACA mapping unit.
- Mapping units are attributed with separate hazard scores for each individual pressure.

This is illustrated in Figure 5 where an example NRM mapping unit is shown. This illustrates how the unit is divided up in terms of its land-use and the basis on which a land-use hazard score is calculated. The combined broadscale land-use hazard was determined using the procedure outlined above using all the pressures combined land-use weights given in Table 7.

Infrastructure hazard scores are calculated using the following process:

- infrastructure features present within an ACA or NRM mapping unit are assessed using GIS techniques to assign a per hectare value for each type
- scores for each infrastructure type are normalised (0 to1 score) based on the minimum and maximum ranges for the entire data set
- each infrastructure type present is weighted according to its alignment with the broadscale land-use groups (given in Table 8)
- weighted normalised scores are summed to produce a single infrastructure hazard score for each NRM and ACA mapping unit.

This is illustrated in Figure 6.

Scores for overall hazard (i.e. combined broadscale land-use pressures plus infrastructure pressures) are calculated by normalising the infrastructure data set to the same data range as the combined land-use scores before adding them together for each mapping unit.

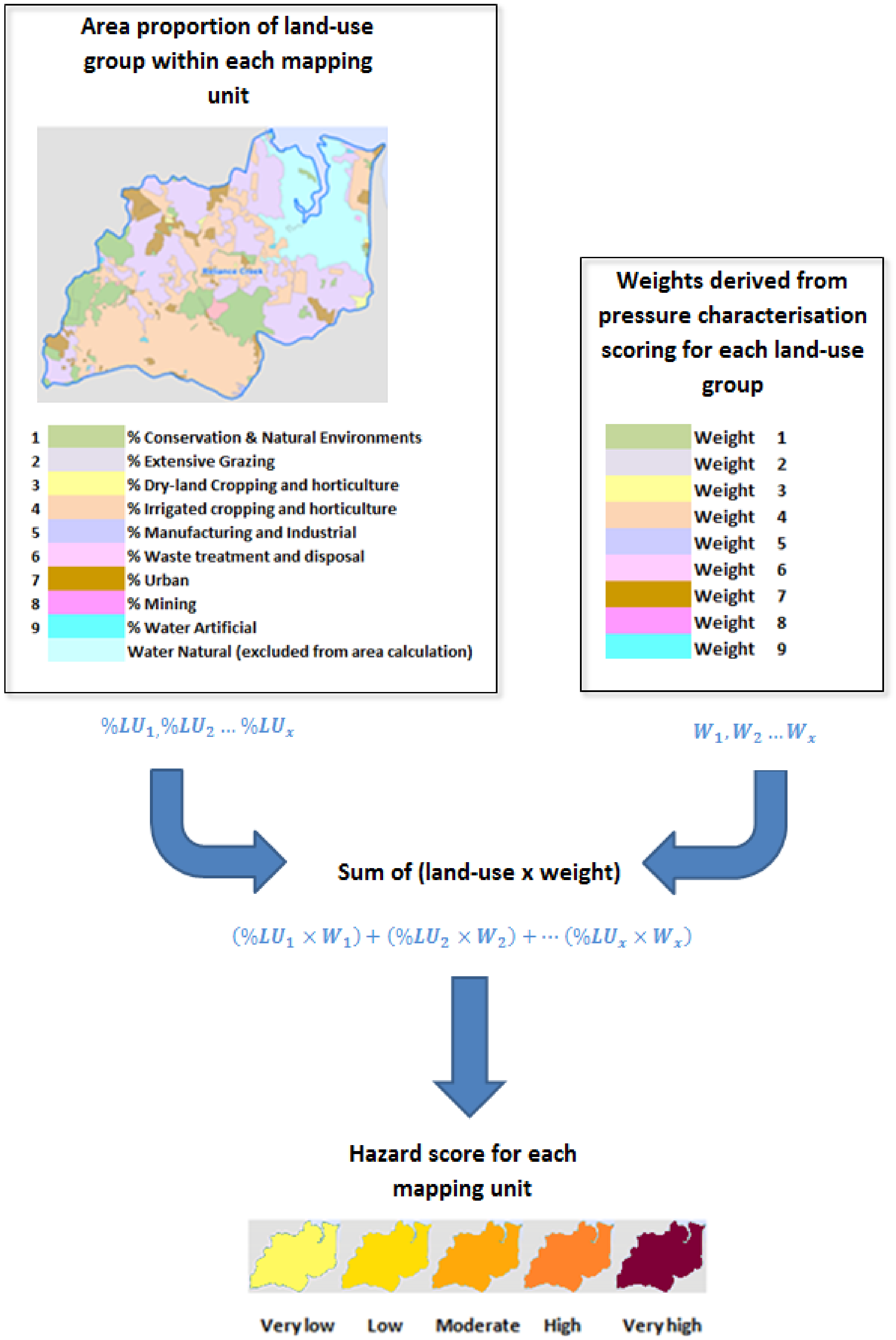
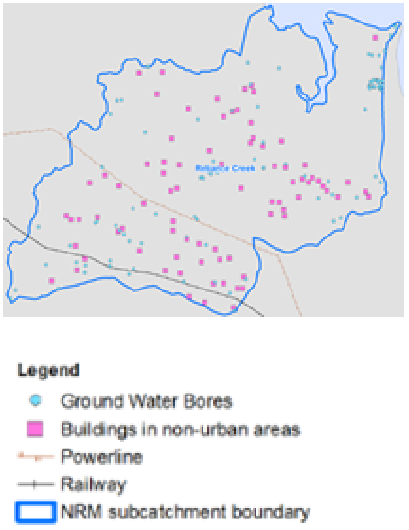


Figure 5 Example of steps taken to calculate a land-use based hazard rating for each pressure within each mapping unit

Per hectare value for each infrastructure type present within each mapping unit



Weight derived from pressure characterisation scoring for each infrastructure type

GW bore	LU based weight dependant on location
Buildings	Urban LU weight
Powerline	Urban LU weight
Railway	Transport LU weight

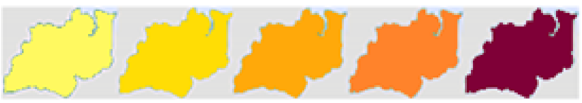
$I_1, I_2 \ldots I_x$

$W_1, W_2 \ldots . W_x$

Sum of normalised (Infrastructure type x weight)

$$normalised\ (I_1 \times W_1) + normalised(I_2 \times W_2) + \cdots normalised(I_x \times W_x)$$

Infrastructure hazard rating for each mapping unit



Very low Low Moderate High Very high

Figure 6 Example of steps taken to calculate an infrastructure hazard rating for each mapping unit

2.4.6 Generating hazard maps

Hazard maps were produced for each of the pressures, for combined land-use pressure, infrastructure and overall hazard (combined land-use + infrastructure) across the GBR catchment. Individual hazard maps relating to each pressure were produced based on ACA mapping units only. Maps for combined land-use pressures, infrastructure and overall hazard were produced based on both the NRM and ACA mapping units for comparison. In all cases, maps were produced using a GIS processing platform and hazard scores were attributed and then presented cartographically as maps. For the individual pressures this was displayed using an equally distributed five point scale, with five equal shading intervals, based on the following categories:

- Very low hazard
- Low hazard
- Moderate hazard
- High hazard
- Very high hazard

The scoring breaks within these hazard categories differ between each pressure. Each map shows the range of land-use hazard for a specific pressure from lowest to highest. Although a common set of five class intervals is used (i.e. very low, low, moderate, high, very high) the score ranges within and between each pressure are different. Because each map is based on its own unique score range the hazard rankings should not be compared between pressures only within a single pressure.

For the combined, infrastructure and overall hazard maps an equally distributed ten point scale (with corresponding shading intervals) was used to allow for the meaningful summation of combined land-use and infrastructure hazards into the overall hazard map. Here too the score ranges are unique. Therefore the depicted hazard classes are representative only of overall hazard and should not be directly compared to the individual pressure maps.

2.5 Limitations and sources of uncertainty

There are a number of recognised limitations with the land-use/pressure characterisation method as conducted in this assessment. The method currently does not include the following factors:

- The alteration of natural fire regimes. Natural fire regimes have been altered through grazing management and fire management practices (DERM 2011). This pressure was not considered as part of this assessment.
- The hydrological connectivity of mapping units and the potential implications for increasing or amplification of the hazard in ‘downstream’ mapping units.
- The location and proximity of wetlands to sources of pressure is not directly considered. An increasing level of accuracy in this regard is achieved through the use of smaller mapping units (e.g. the ACA units compared to NRM units). The potential to develop a hazard proximity analysis is considered in section 4.2—Further work

A number of data limitations and procedural issues have been identified that could cause uncertainty in the results of this hazard assessment. These are associated with:

- quality and contemporariness of the spatial data
- assessment unit scale
- conceptual uncertainty.

2.5.1 Spatial data limitations

The mapping resolution of the QLUMP data set is a potential source of error in this assessment. In particular, land-uses that are linear are not mappable at a scale of 1:50,000 (which has a specified minimum mapping width of 50 metres) (DSITIA 2012). As a result, the area estimates of linear land-use features such as roads, railways, power-lines or rivers that are under this minimum width are generally underrepresented. Other land-uses that fall under the QLUMP minimum mapping area of 1 hectare (e.g. many farm dams or coal seam gas well heads) are also not explicitly mapped. In this instance these features are aggregated into the surrounding land-use class. This will have the inverse effect of over-estimating the area of other land-use classes within which these small features lie; for example grazing native vegetation, where tracks and farm infrastructure, road reserves and drainage lines are included in the surrounding land-use. This was the reason that the infrastructure assessment was undertaken in addition to the land-use hazard assessment in an attempt to ensure that finer scale infrastructure features were included.

There are recognised difficulties in the discernment between certain QLUMP secondary classes (DSITIA 2012), due to interpretation of satellite imagery, aerial photography and field observation on which the land-use mapping is based. For instance, livestock grazing occurs on a range of pasture types including native and exotic as well as mixtures of both (which could therefore be grouped into grazing native vegetation or grazing modified pasture). Identifying and separating these is difficult, can be highly variable and classification therefore may not be consistent.

It was noted by the expert panel that livestock grazing is present across a number of land-use types as opposed to just extensive grazing. In particular, there is a known and licenced presence of livestock in state and private forest reserves (e.g. land classified as production from natural forests in this assessment). This was explicitly discussed by the small workshop expert panel and the presence of livestock (albeit at a lower potential density due to the generally lower quality of the grazing land) was taken into account when assigning land-use pressure association scores.

It is recognised that there may be omissions as a result of the limitations of a particular data set (i.e. that there are missing or misrepresented sites within the spatial data sets used). When compiling the data to be used (in particular for the infrastructure assessment) most data sets were government compiled state-wide data sets as were used in the QWIMF risk assessment. These data sets were chosen as they provide data at a consistent and known quality, scale and that is contemporary. Ease of access to data (another benefit of government held data sets) was also a key consideration in enabling a defensible and repeatable hazard assessment method.

2.5.2 Mapping scale

The size of the mapping units (NRM vs. ACA) has a direct effect on the hazard score, for example, the highest overall hazard for any polygon was in Mackay (very small unit and dominated by almost entirely urban land-use). Potentially the ACA polygons give a more accurate representation of the hazard to wetlands as they are smaller and therefore the hazard generated by land–use is potentially geographically closer to the wetlands in most cases. While useful for defining management actions and reporting, mapping of hazard at a regional/landscape scale using the larger NRM units (which are still small compared to the catchment scale used in the QWIMF risk assessment project (DERM 2011) potentially provides a less accurate hazard assessment output for an individual wetland.

The use of mapping units overall has the potential to provide a source of error as no account is taken regarding the position of wetlands within the mapping units. For instance, a wetland could be located within a low hazard mapping unit but be on the boundary of a mapping unit with a much higher hazard rating. Even within an individual mapping unit, a specific wetland can be geographically very close to an area of high hazard but will be attributed with a lower hazard rating due to the 'dilution' effect of the other lower pressure land-uses in the mapping unit. A wetland with in the mapping unit may also lie upstream or downstream from hazardous land-uses or point sources.

To address this potential uncertainty a proximity analysis approach is being investigated as further work, following on from this assessment, as a potential method for more accurately attributing hazard to specific wetlands across the area of interest.

2.5.3 Confidence in attribution

In some instances there is uncertainty regarding the conceptual links and strengths of association between land-use/infrastructure and pressures as these were elucidated on the basis of expert opinion and available literature. This source of uncertainty was minimised by consulting experts with extensive experience and expertise across the range of pressures and land-uses under consideration. When assigning pressure associations to land-use groups, a measure of confidence was recorded in the conceptual understanding of the issue under discussion. In the majority of cases it was felt that due to the depth of knowledge of the expert panel that the confidence in the pressure associations (and therefore the land-use weighting applied to derive the hazard scoring) was high. However, low or medium confidence scores were assigned to some land-use/pressure associations.

The presence of pests may be a consequence of a number of drivers. It can be argued that their presence and perpetuation can be partly independent of land-use (due to the propensity of pest species to perpetuate in the landscape as a result drivers other than land-use). However, the expert group recognised the potential for land-use to drive the introduction and perpetuation of pests and that it varied between the different land-use groups used in this assessment.

3 Results

3.1 Landscape hazard from individual pressures

Landscape hazards arising from individual pressures associated with broadscale land-uses have been assessed across the whole of the GBR catchment. Hazard maps are presented for each individual pressure (see Figures 7–28) and results are summarised and discussed further below under each of the pressure categories.

Inputs: direct and indirect

Input pressures (see Figures 7–15) were found to be highly associated with cropping and horticulture (dry-land and irrigated), intensively managed grazing, intensive animal production, mining, urban and transport land-uses. Of all the input pressures, increased sediments, nutrients, organic matter and pesticides were the most prominently associated with land-use drivers and this is reflected in the amount of high and very high hazard areas depicted on the relevant hazard maps. The hazard mapping for sediment pressures in particular (see Figure 8) show considerable areas of 'high' hazard across a large proportion of the GBR, with areas of 'very high' hazard particularly in the Fitzroy region. Nutrient input pressures (see Figure 7) show a similar distribution across the landscape but at a reduced intensity, with large areas of 'moderate' hazard and considerable areas of 'high' hazard in the Fitzroy and also across the Burdekin region.

Hazard arising from acid inputs, saline inputs, hot and cold water, litter and rubbish and chemicals and metals were either 'very low' or 'low' across the vast majority of the GBR catchment.

Harvesting

Overall harvesting was determined to be a low potential source of pressure upon wetlands with the majority of land-uses having no association with this pressure category. The hazard mapping (see Figures 16 and 17) shows that there is 'very low' or 'low' potential hazard, across the majority of the area of interest for both of the pressures in this category. The most highly associated land-uses were urban and transport categories reflecting the fact that pressures within this category are directly related to the potential magnitude of human access to wetland areas. As a consequence the areas of highest hazard (classified as 'moderate') are a small number of mapped units around the major urban centres of Cairns, Townsville and Mackay. Relatively minor associations were recorded for conservation and natural environments, production from natural forests and plantation forestry (due to the licensed harvesting and recreational fishing activities that are permitted in these areas). Some areas of the Wet Tropics and Cape York are rated as having a 'moderate' potential hazard from harvesting of animal biota as conservation and natural environments land-use is higher proportionally than other regions. Overall it is recognised that harvesting pressures are highly localised and will be better addressed using wetland specific (see Tier 2 and 3) assessments.

Changes to the water regime

Changes to the hydrology of wetlands (see Figures 18–20) arising from broadscale land-use was found to be considerable based on its 'high' or 'very high' association with many land-use groups for individual pressures within this category (see Appendix A). This was noted particularly from irrigated agriculture, mining, urban, artificial water and intensively managed grazing. Aquaculture and intensive animal production were also highly associated with these pressures.

Surface water abstraction hazard or addition (see Figure 18) was highest in areas around Mackay, Ayr, Atherton, Proserpine and Bundaberg. This is likely to be due to the high occurrence of irrigated cropping and horticulture in these areas and the very high association recorded for that land-use group with pressures in that category. Groundwater abstraction or addition hazard (see Figure 19) showed a similar distribution with the highest hazard recorded from the same areas. Hazard from changes to surface water flow patterns (see Figure 20) were more prevalent across larger areas of the GBR than the other water regime change pressures with considerable areas of 'high' hazard across many regions. This is likely to be due to the very high association recorded against a greater range of land-uses for this pressure (see Appendix A).

Biological introductions and perpetuation

Although it is recognised this can result from a range of drivers the potential for land-use to drive the introduction and perpetuation of pests is also recognised and varies between the different land-use groups used in this assessment

Bacteria and pathogens hazard (see Figure 21) is 'very low' across nearly all of the GBR with only small patches of low hazard in all regions. 'High' hazard is recorded for the introduction and perpetuation of both aquatic and terrestrial pest plant species (see Figures 23 and 25 respectively) across much of the GBR catchment. In particular, these pressures were recorded as being associated with extensive grazing lands (due to the unrestricted access of livestock across the landscape). This has resulted in 'high' hazard ratings being recorded across those areas where extensive grazing is predominant. Hazard from buffer zone animal pests (see Figure 24) was 'moderate' over the majority of the area of interest with small patches of 'high' hazard in some areas.

Alteration and disturbance of habitat

The alteration of buffer zone biota in particular, is determined to be a highly important pressure type that is classified as a 'very high' hazard across the majority of the GBR catchment (see Figure 27). The majority of the Burdekin, Fitzroy and Burnett–Mary regions are in this 'very high' hazard category due to the high percentage of extensive grazing land in these areas and the degree of association of this pressure with this land-use group. The Wet Tropics and Cape York regions have a greater percentage of 'low' or 'very low' hazard areas although there are some areas of 'very high' hazard particularly in southern Cape York and the western highland areas of the Wet Tropics. Aquatic biota disturbance hazard shows a similar distribution but with a lower intensity where hazard was recorded as 'high' across the majority of the GBR catchment (see Figure 26). Hazard from landform and physical habitat disturbance (see Figure 28) is less severe with a 'moderate' rating across the majority of the regions. Cape York and the Wet Tropics had a higher proportion of areas with 'very low' hazard.

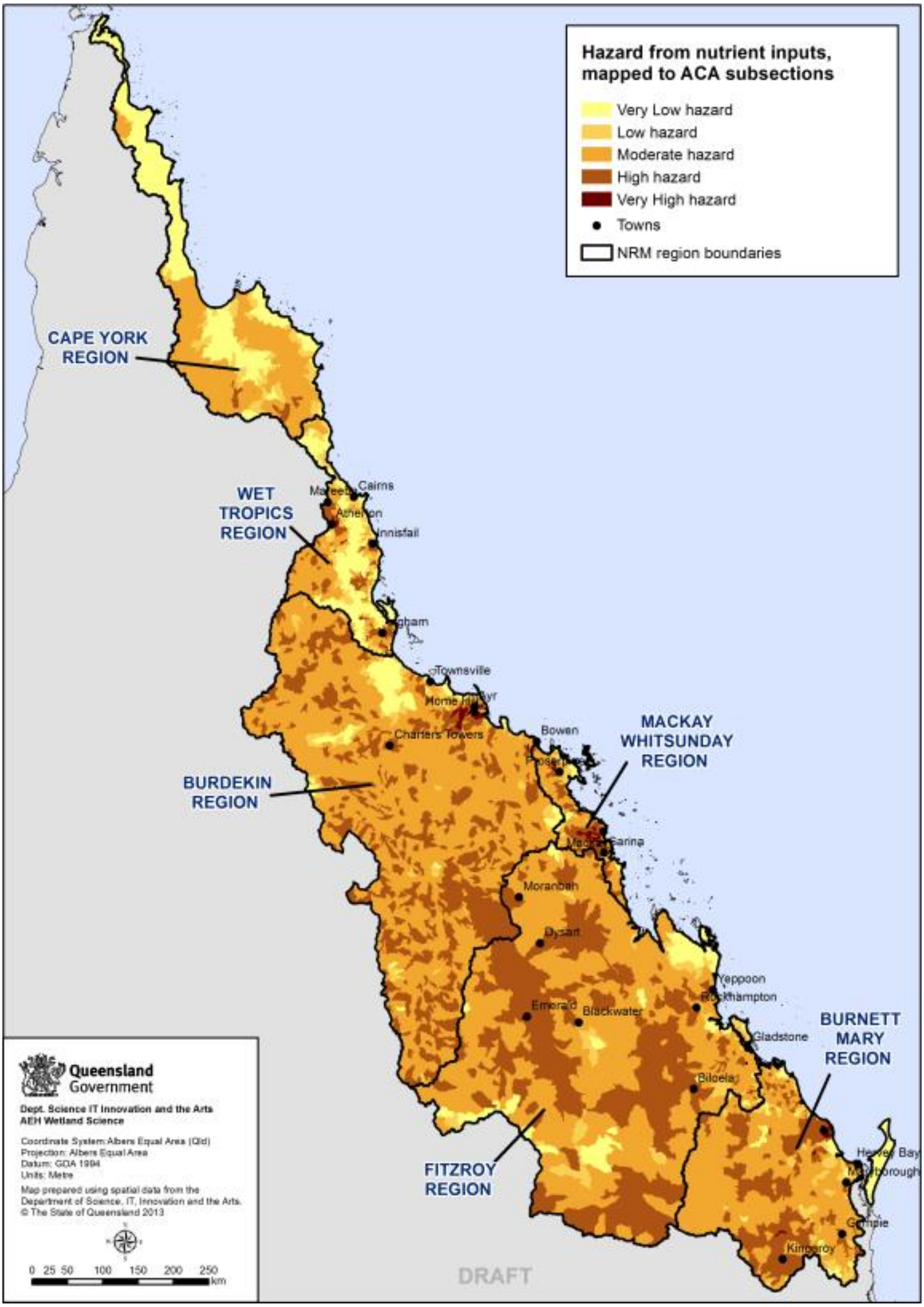


Figure 7 Hazard from nutrient inputs across the GBR catchment

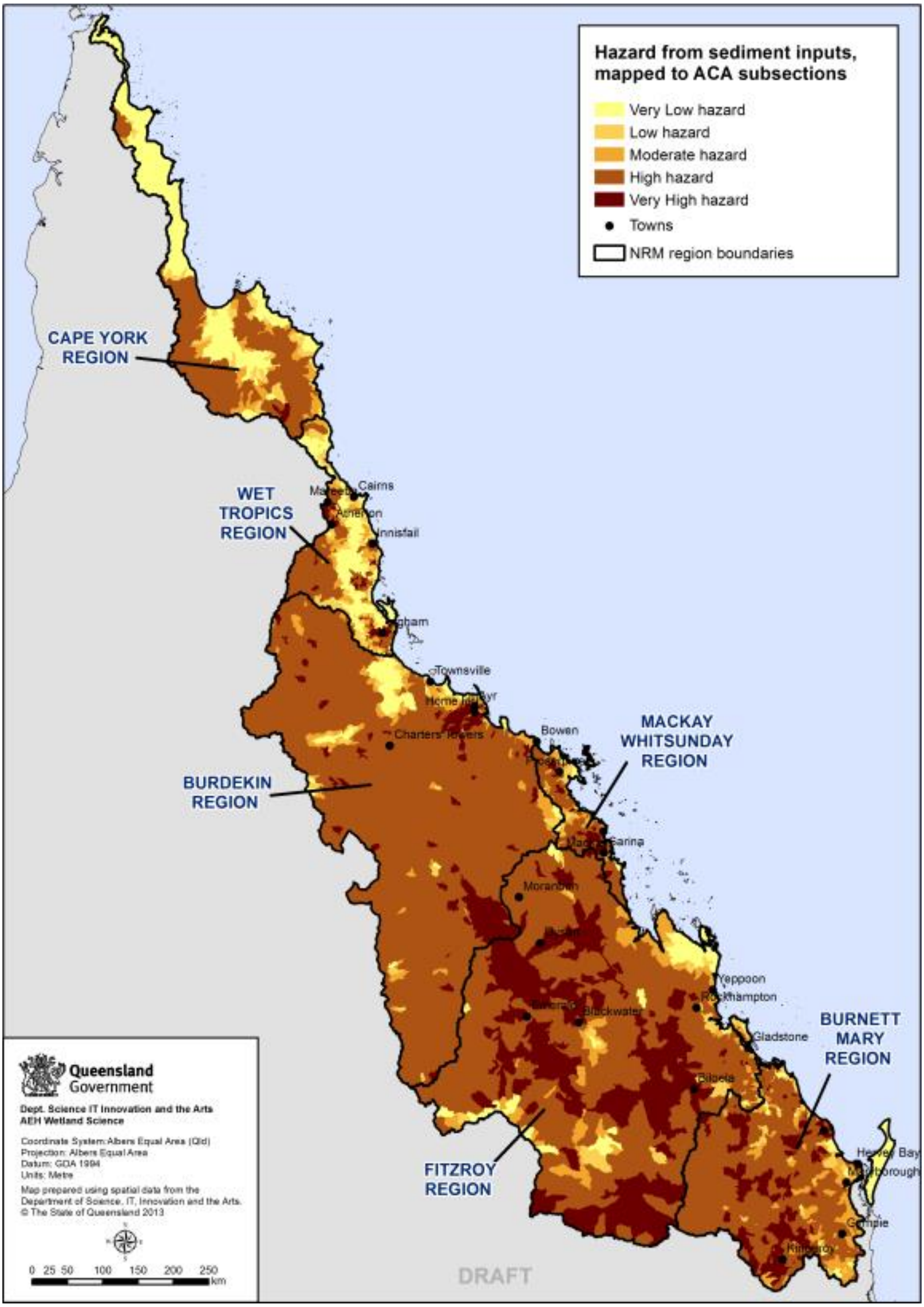


Figure 8 Hazard from sediment inputs across the GBR catchment

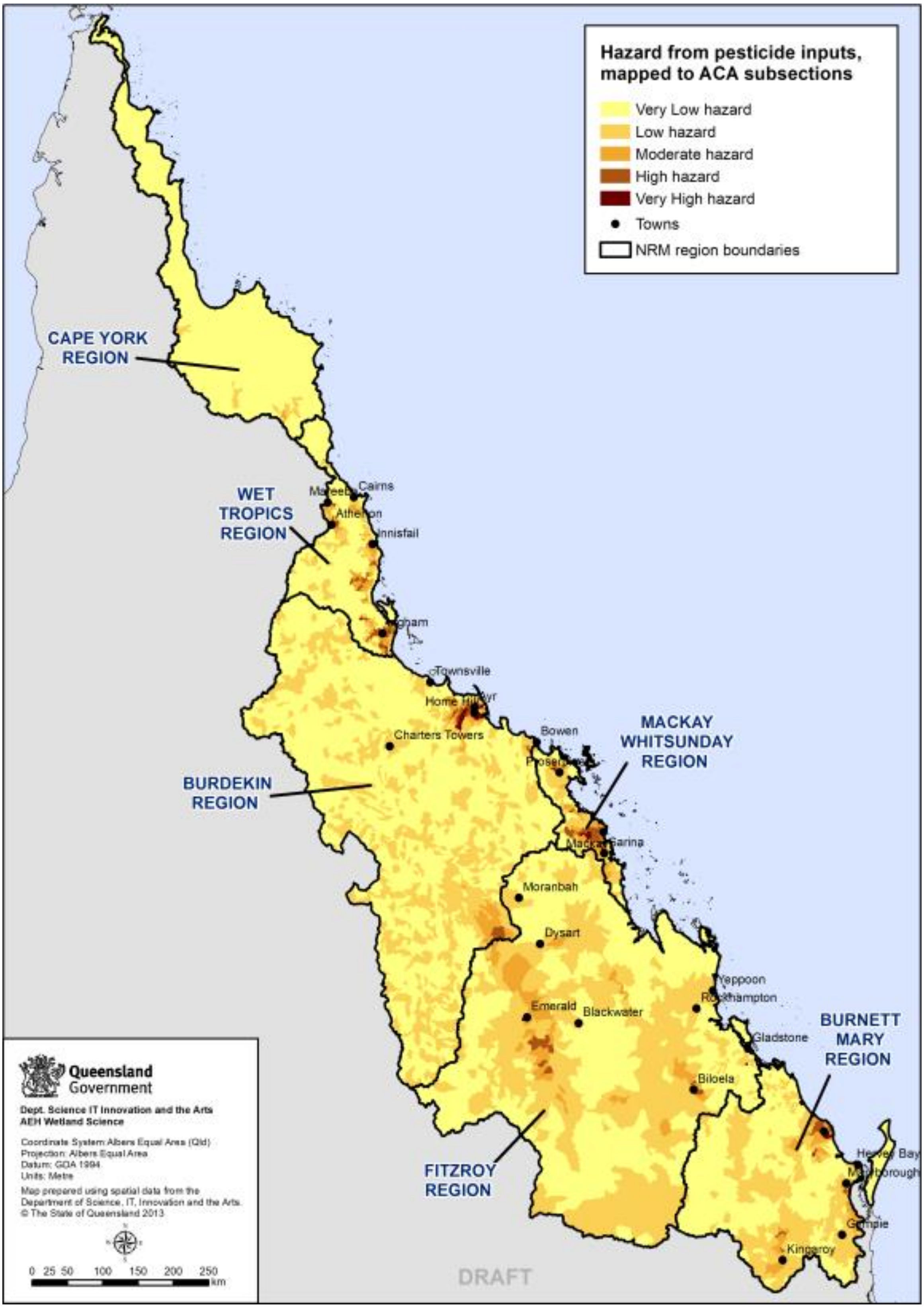


Figure 9 Hazard from pesticide inputs across the GBR catchment

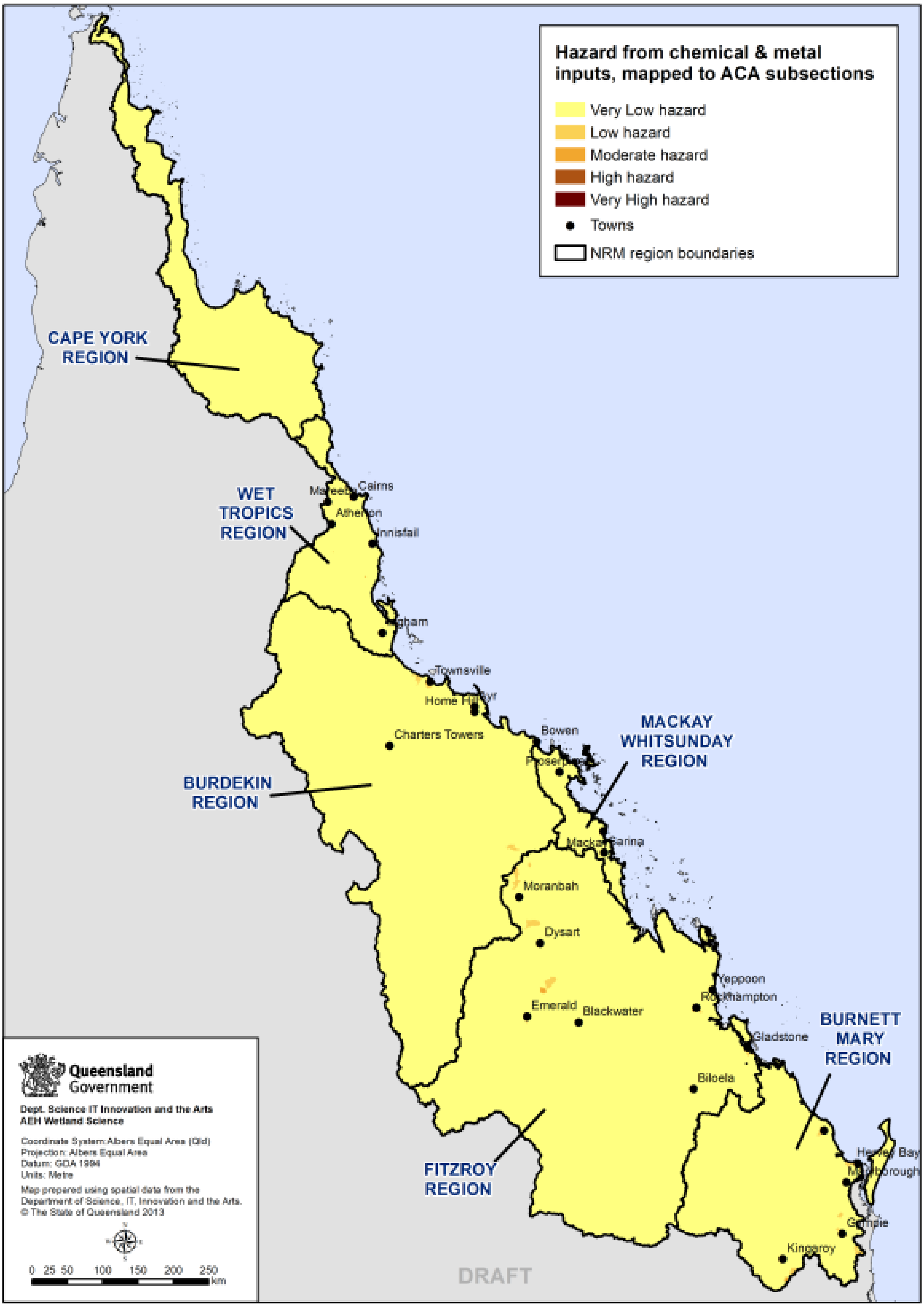


Figure 10 Hazard from chemical and metal inputs across the GBR catchment

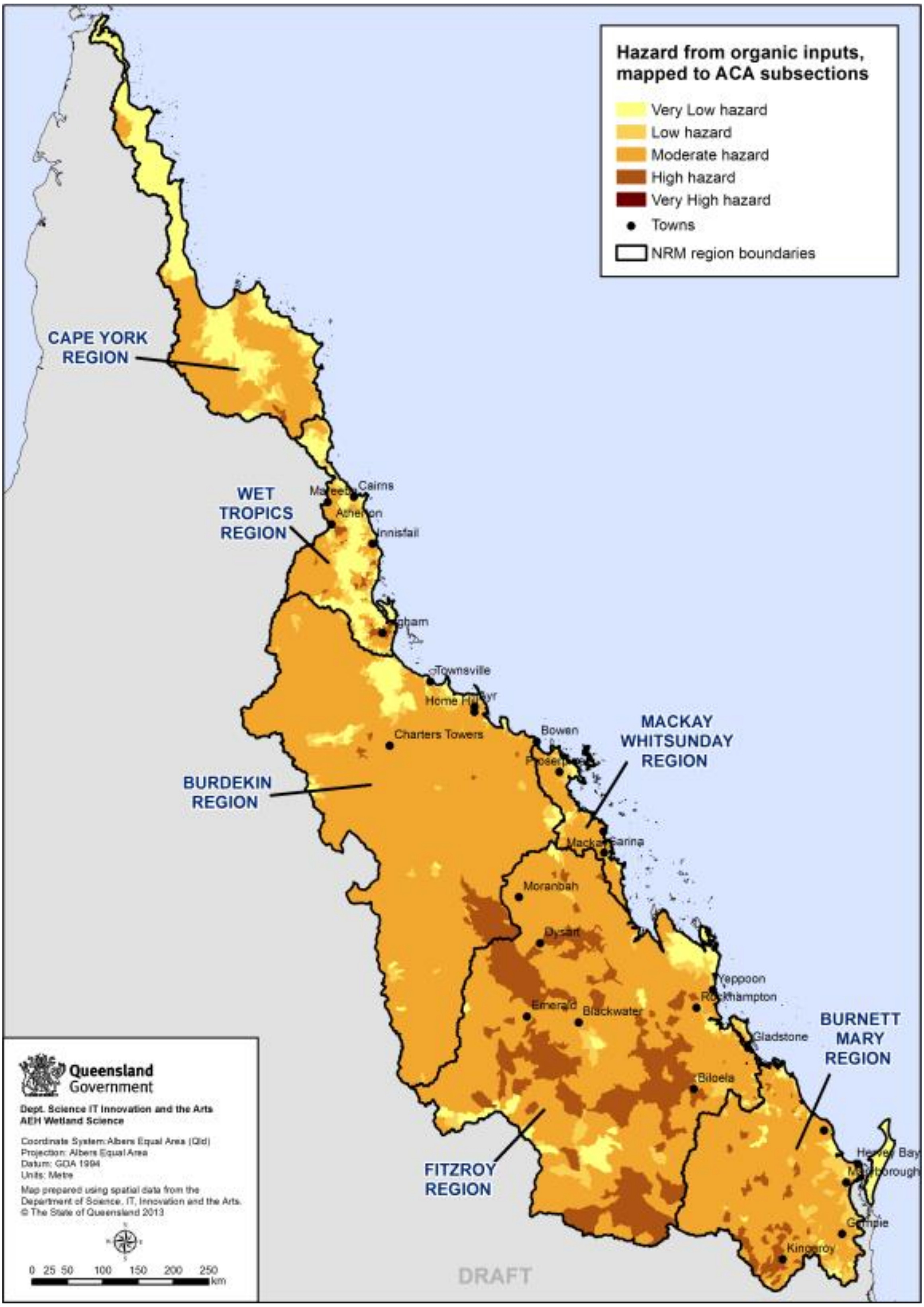


Figure 11 Hazard from organic matter inputs across the GBR catchment

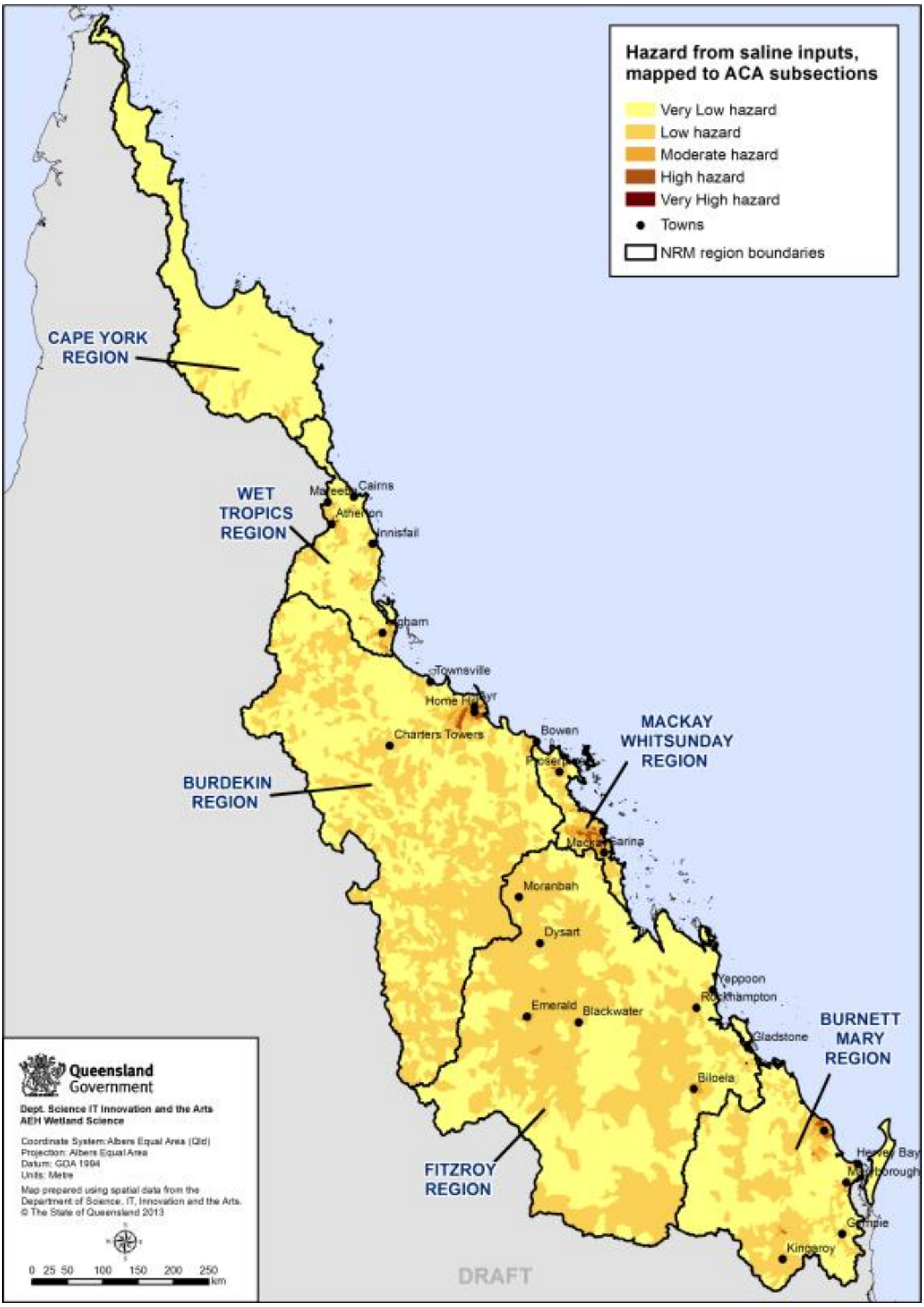


Figure 12 Hazard from saline inputs across the GBR catchment

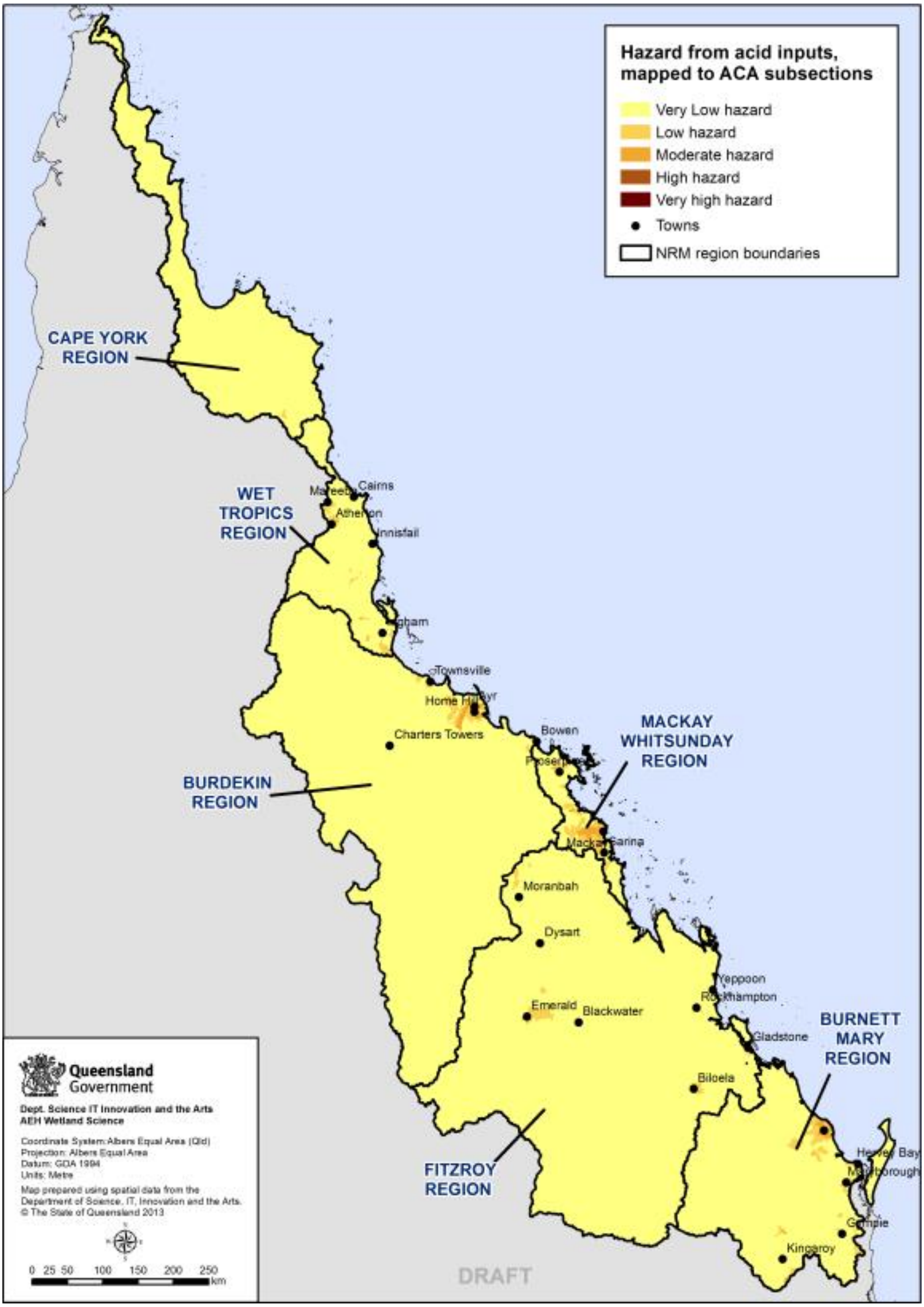


Figure 13 Hazard from acid inputs across the GBR catchment

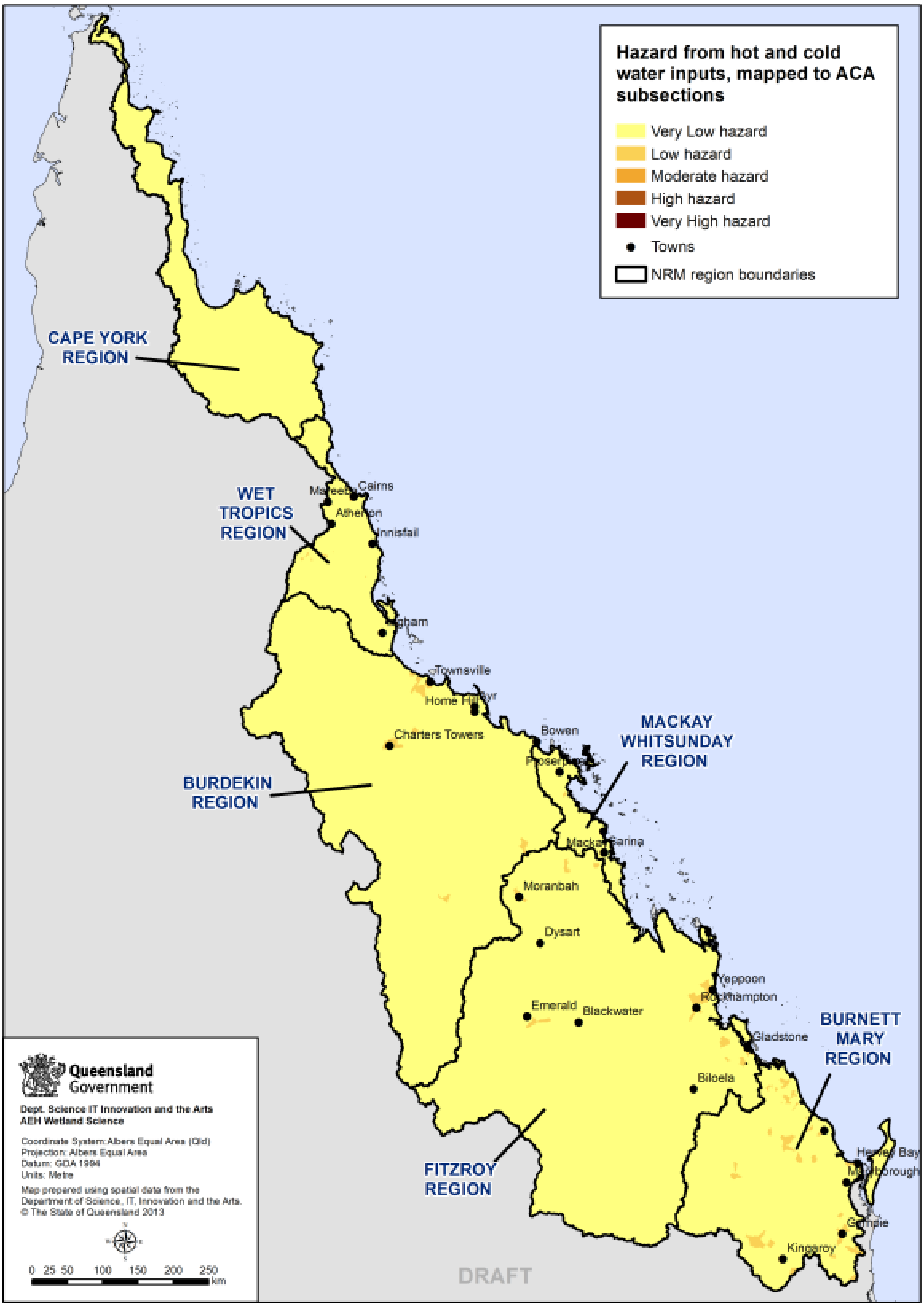


Figure 14 Hazard from hot or cold water inputs across the GBR catchment

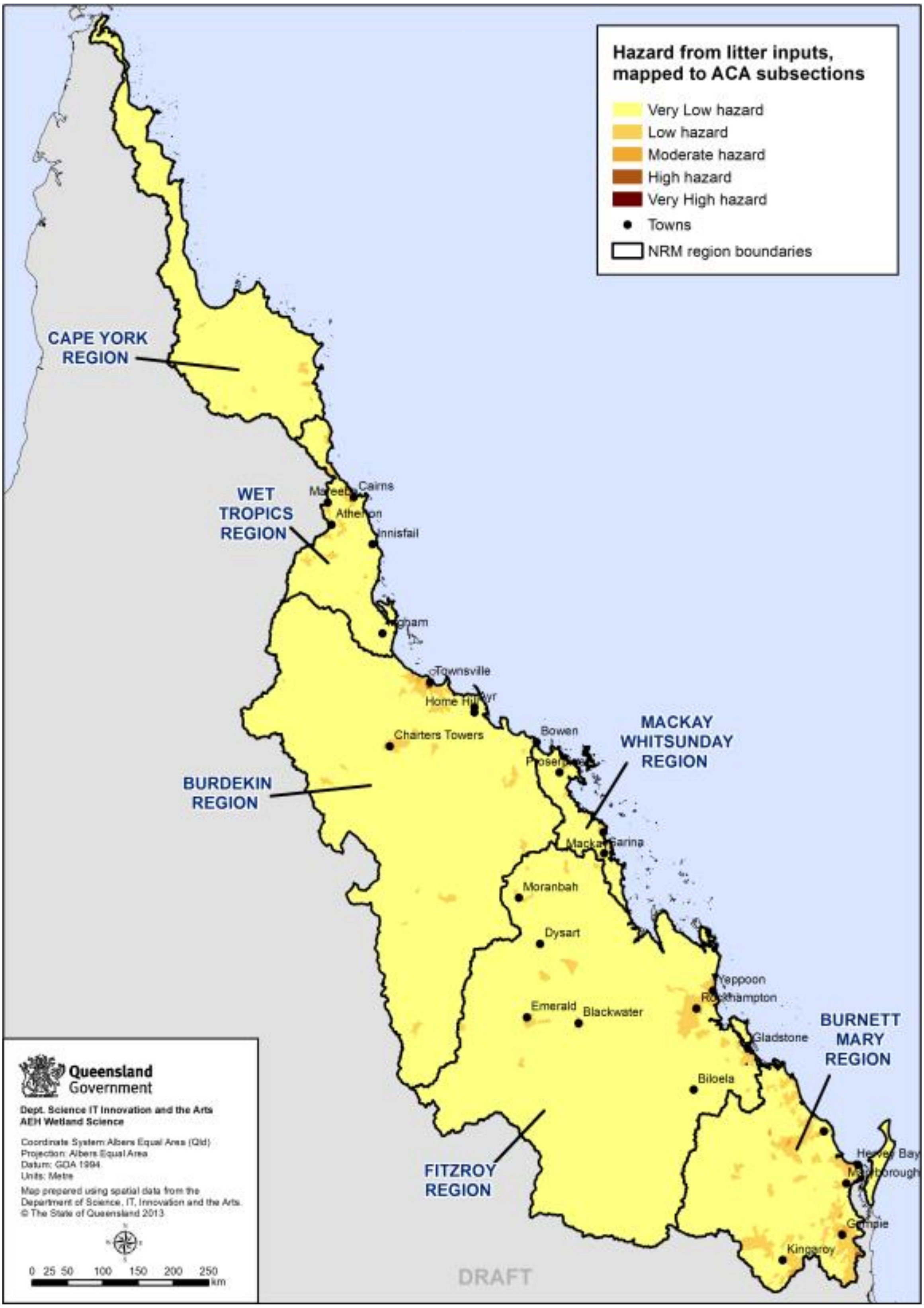


Figure 15 Hazard from litter and rubbish inputs across the GBR catchment

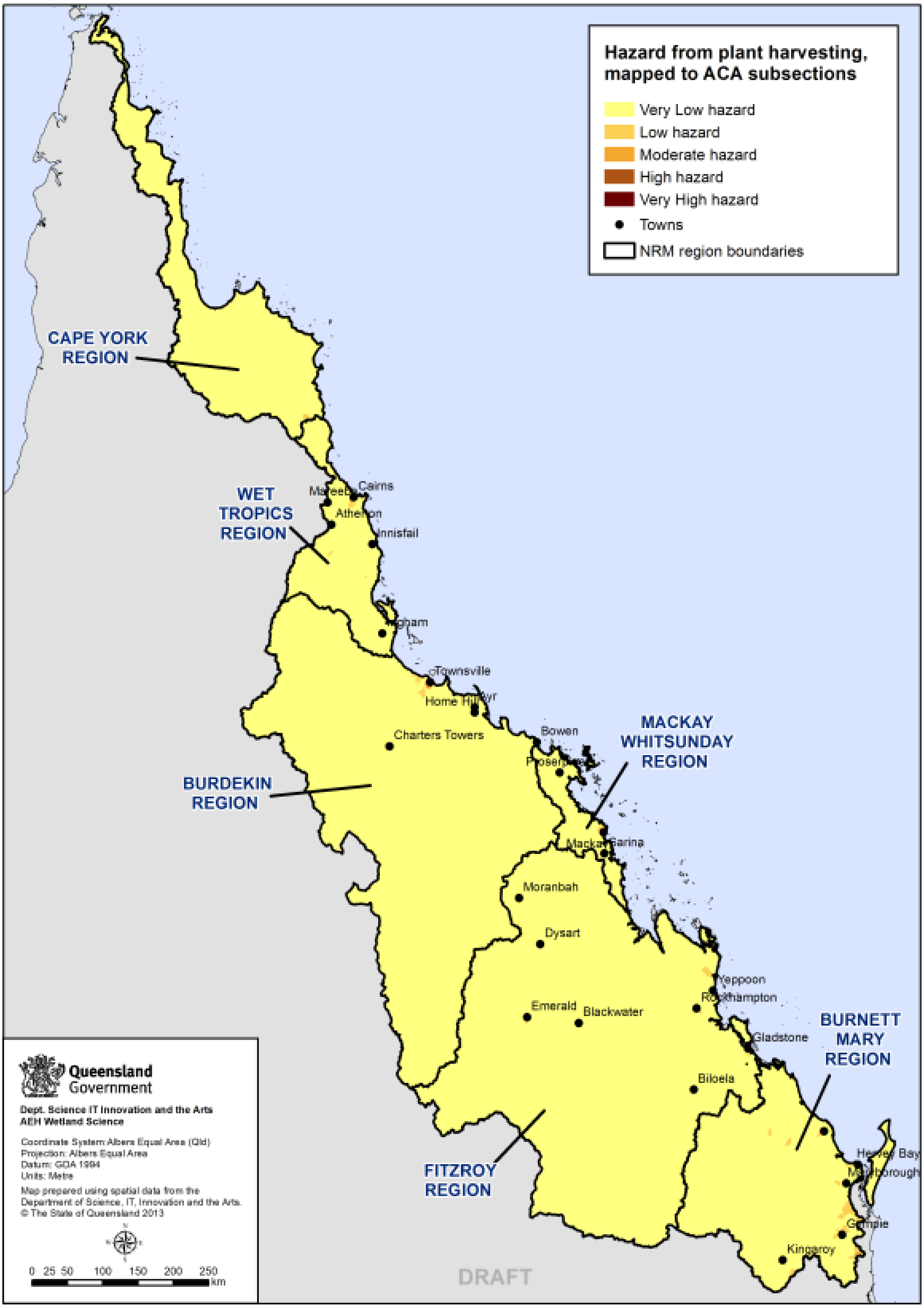


Figure 16 Hazard from plant biota harvesting across the GBR catchment

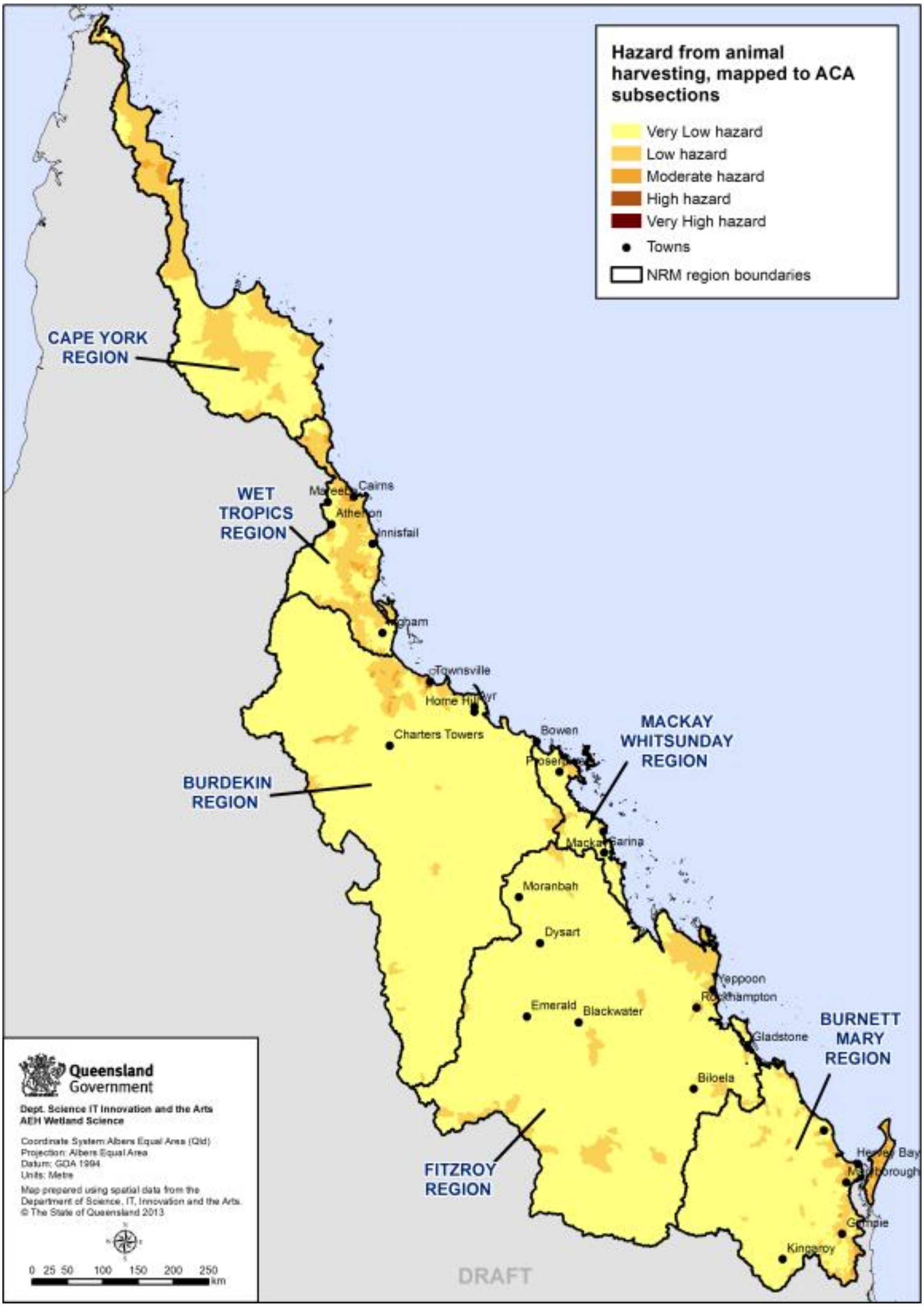


Figure 17 Hazard from animal biota harvesting across the GBR catchment

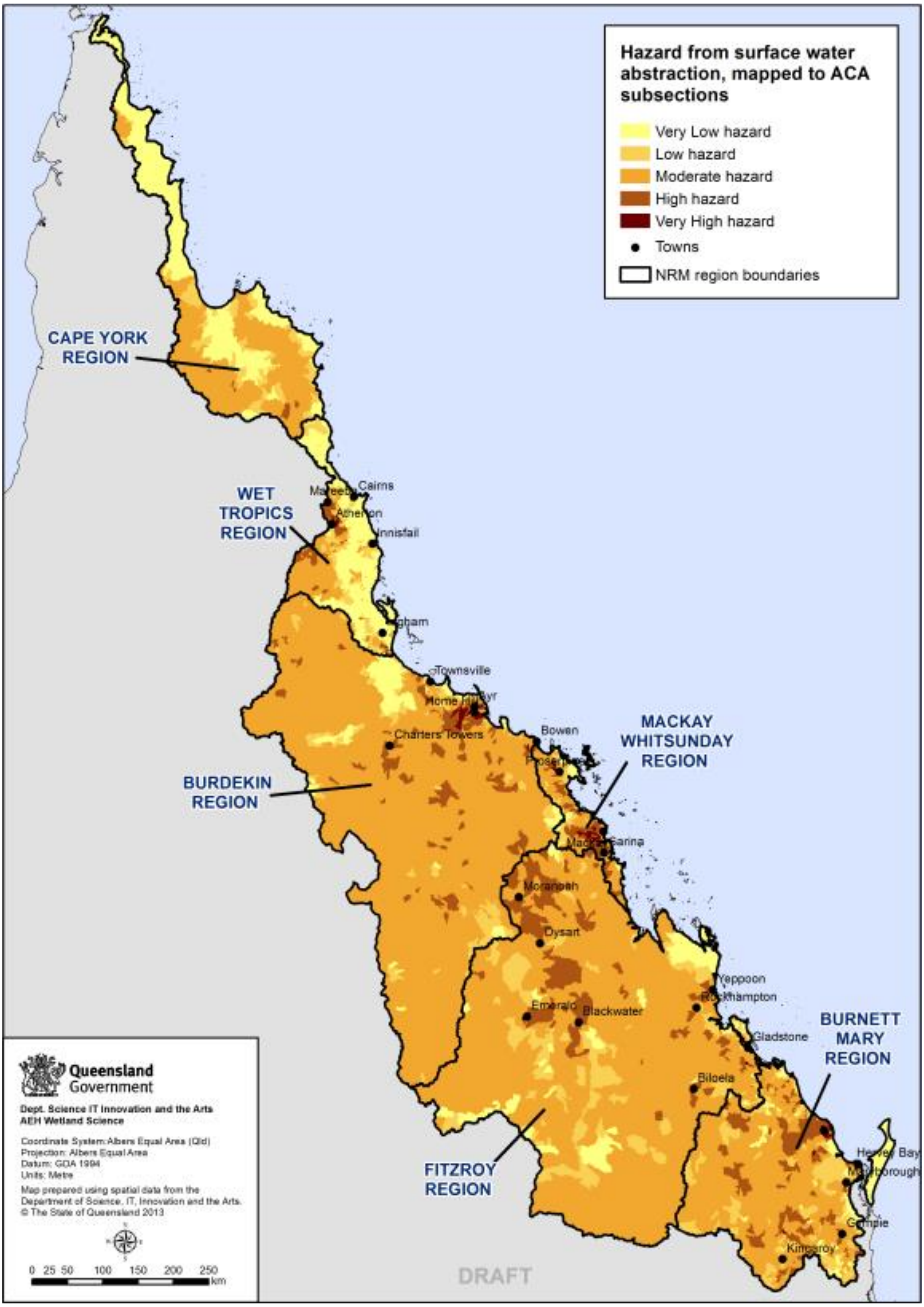


Figure 18 Hazard from surface water abstraction or addition across the GBR catchment

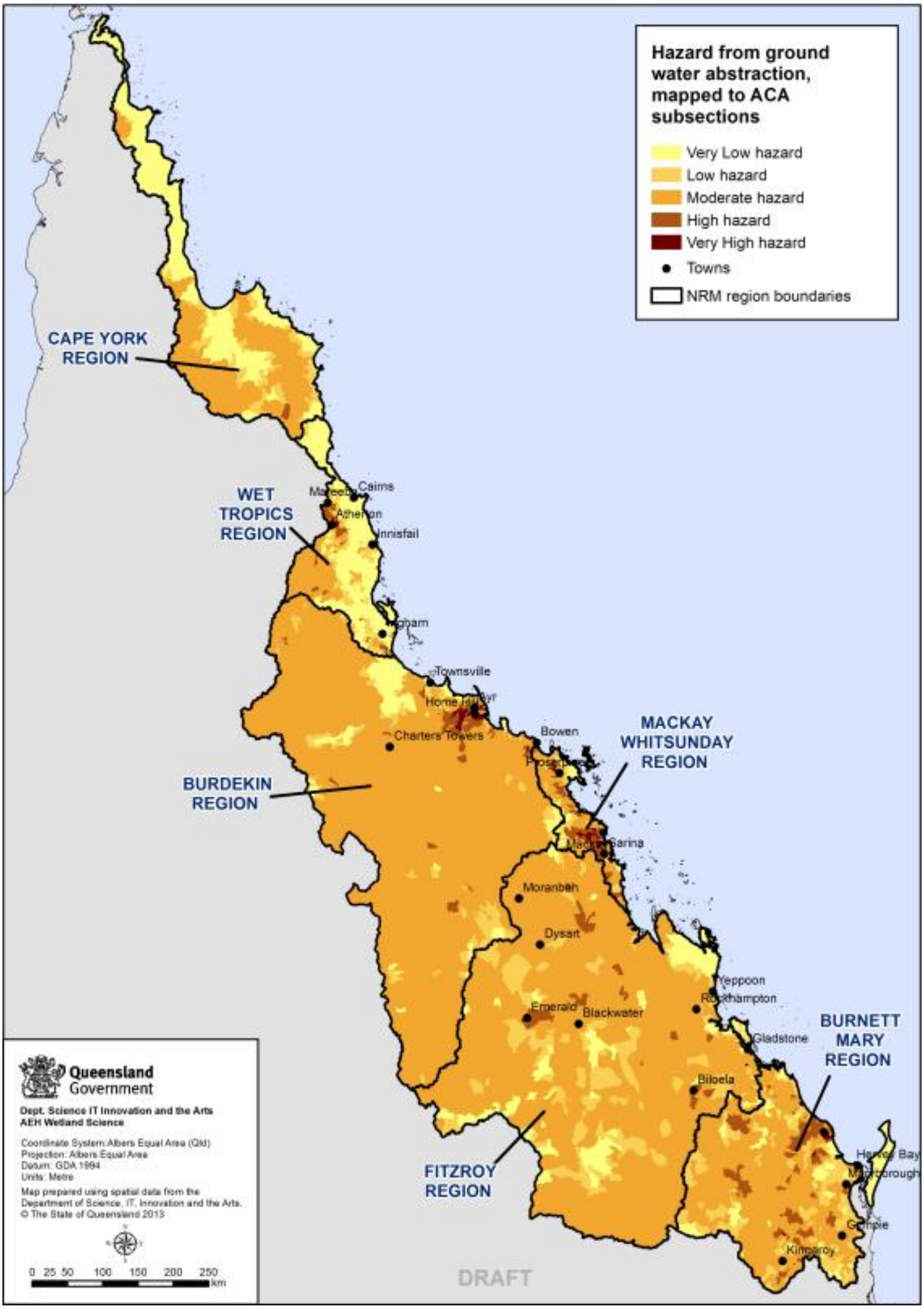


Figure 19 Hazard from groundwater abstraction or addition across the GBR catchment

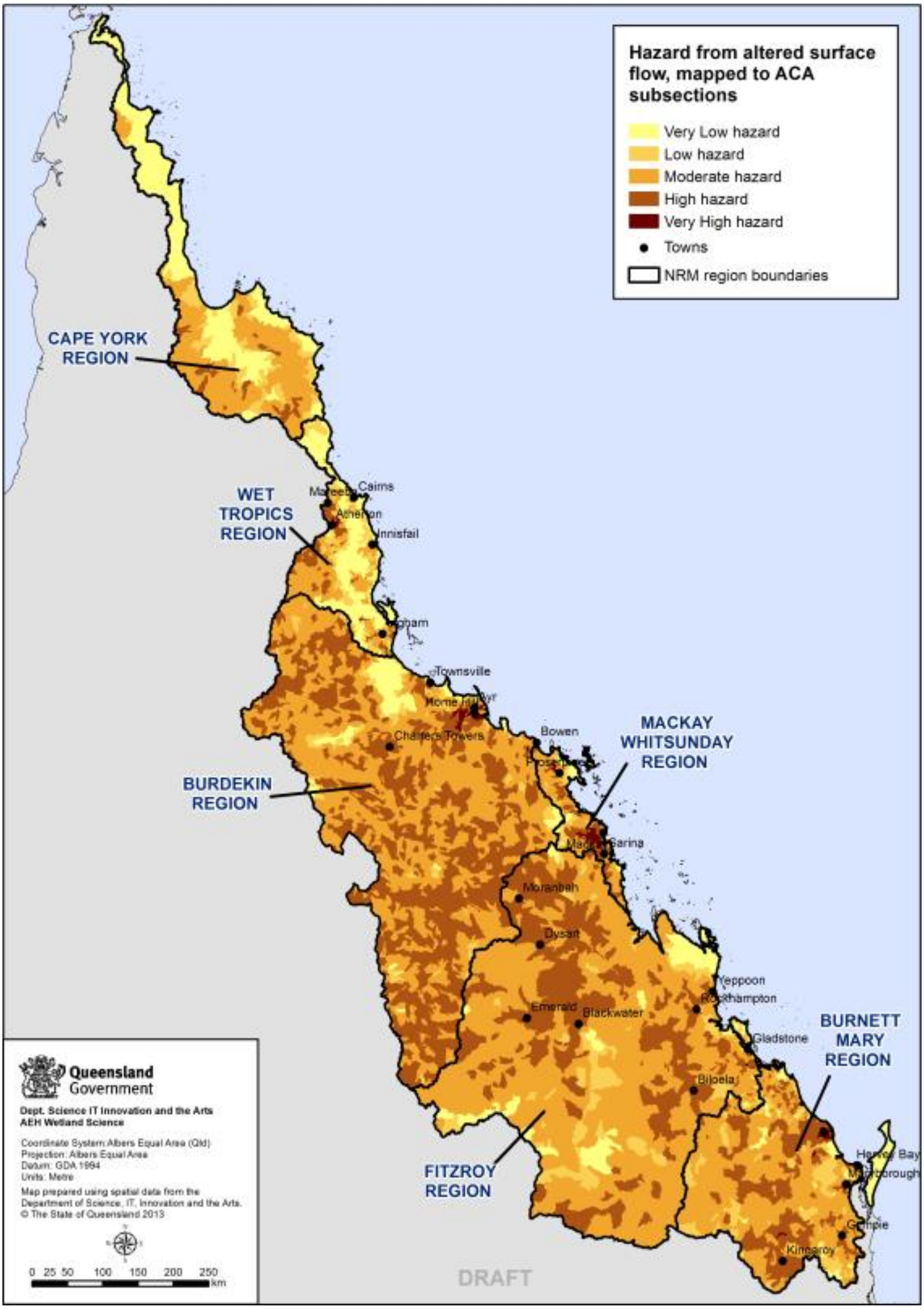


Figure 20 Hazard from changes to natural surface water flow patterns across the GBR catchment

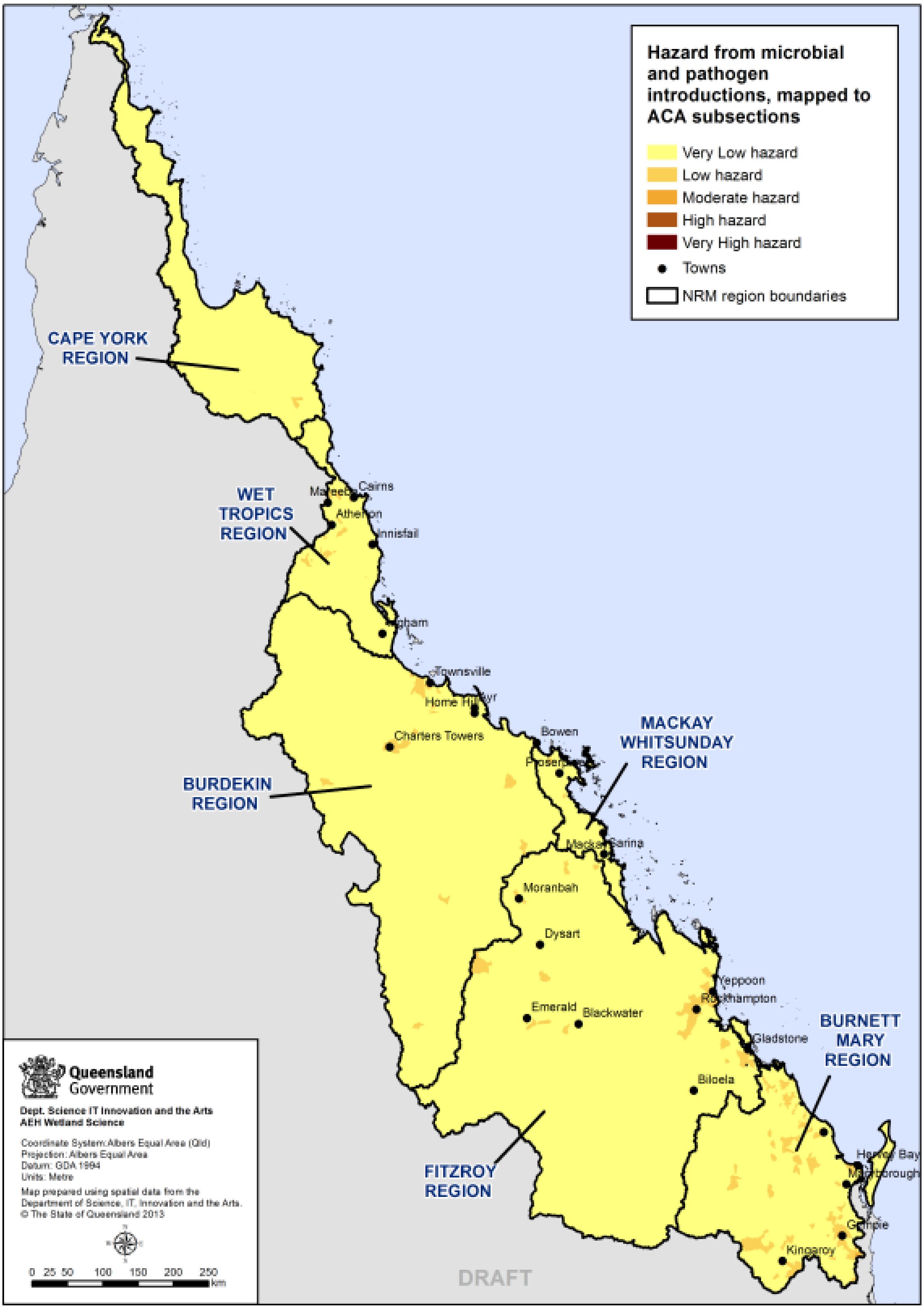


Figure 21 Hazard from bacteria and pathogens across the GBR catchment

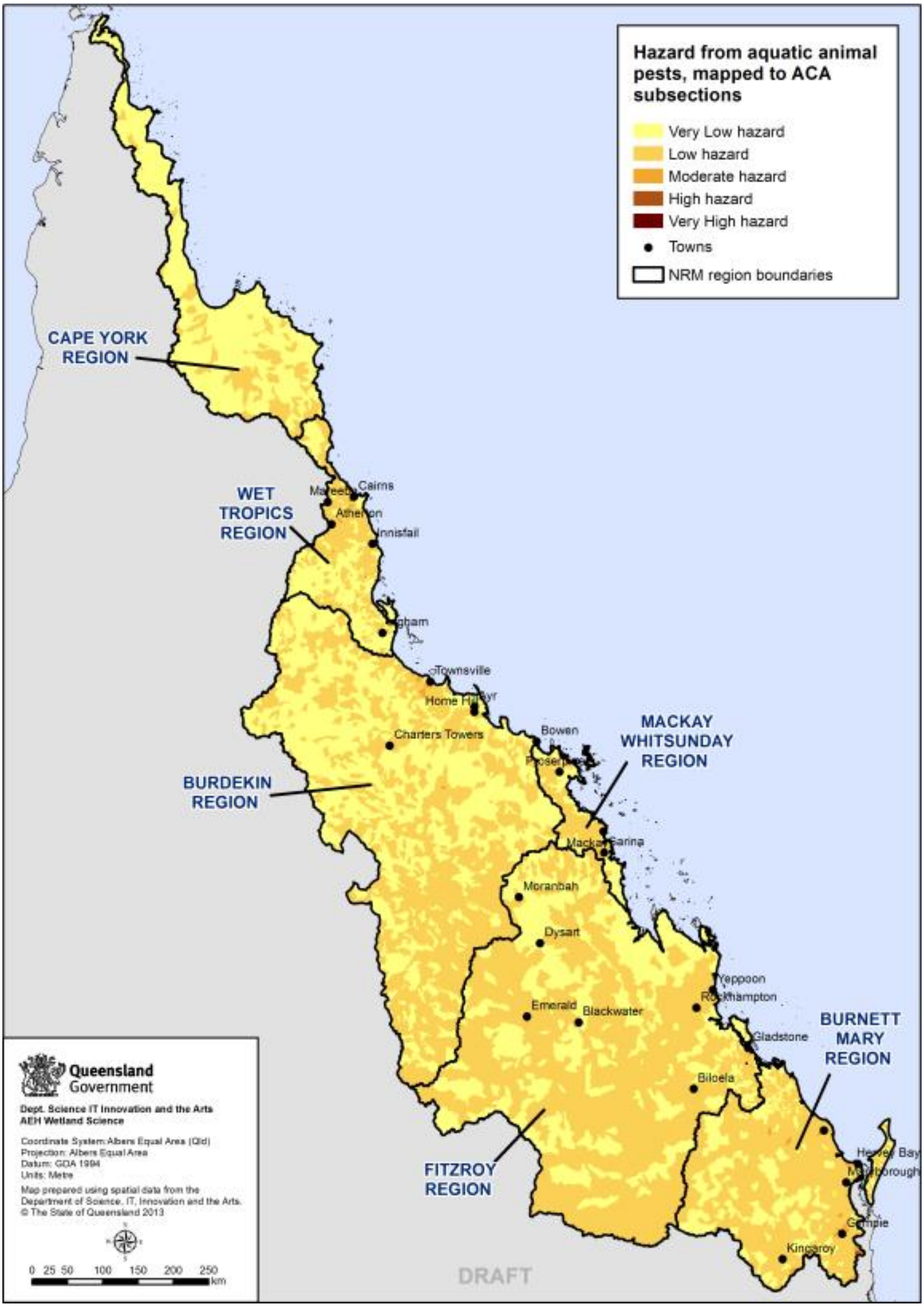


Figure 22 Hazard from aquatic pest animal species across the GBR catchment

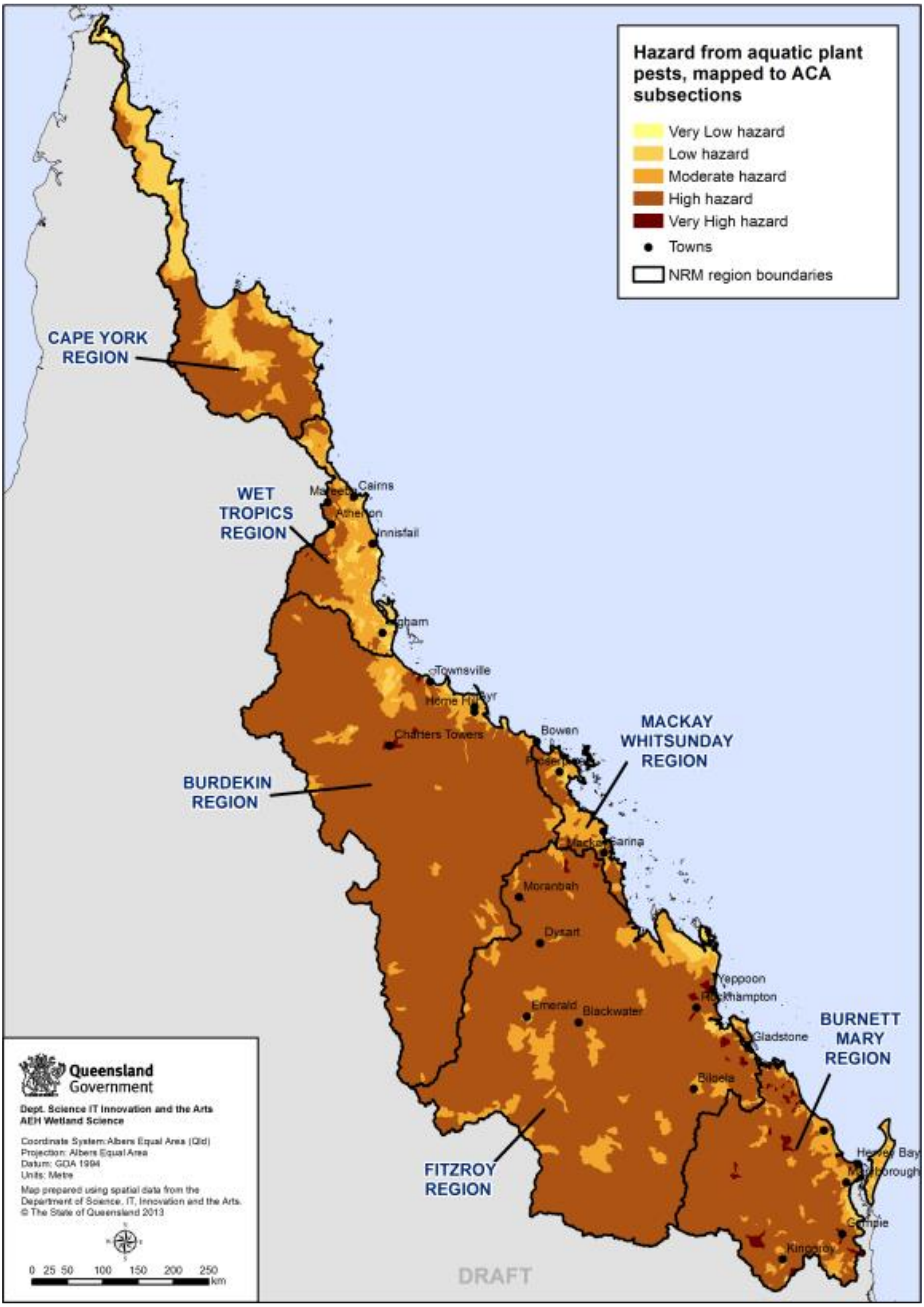


Figure 23 Hazard from aquatic pest plant species across the GBR catchment

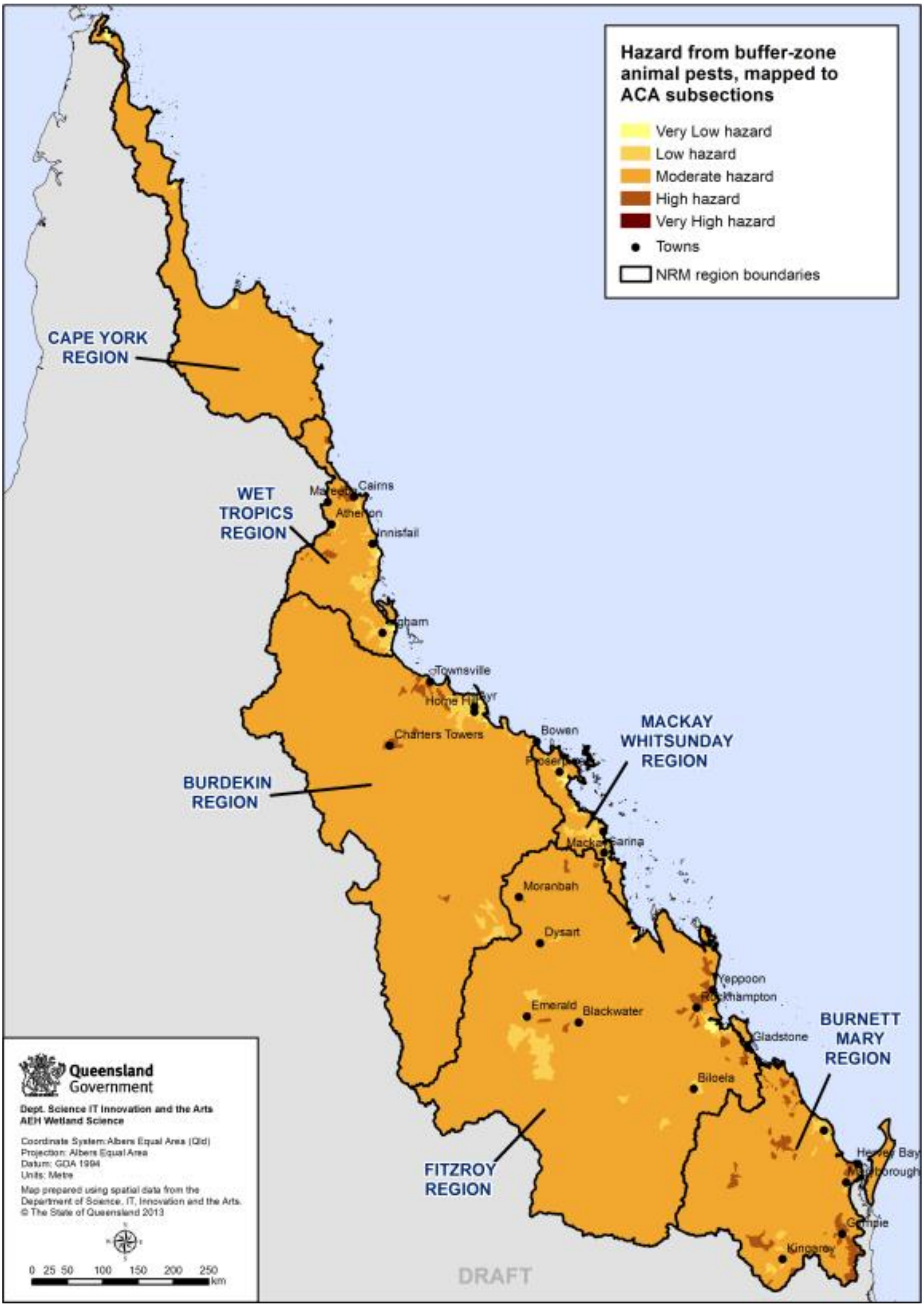


Figure 24 Hazard from buffer zone pest animal species across the GBR catchment

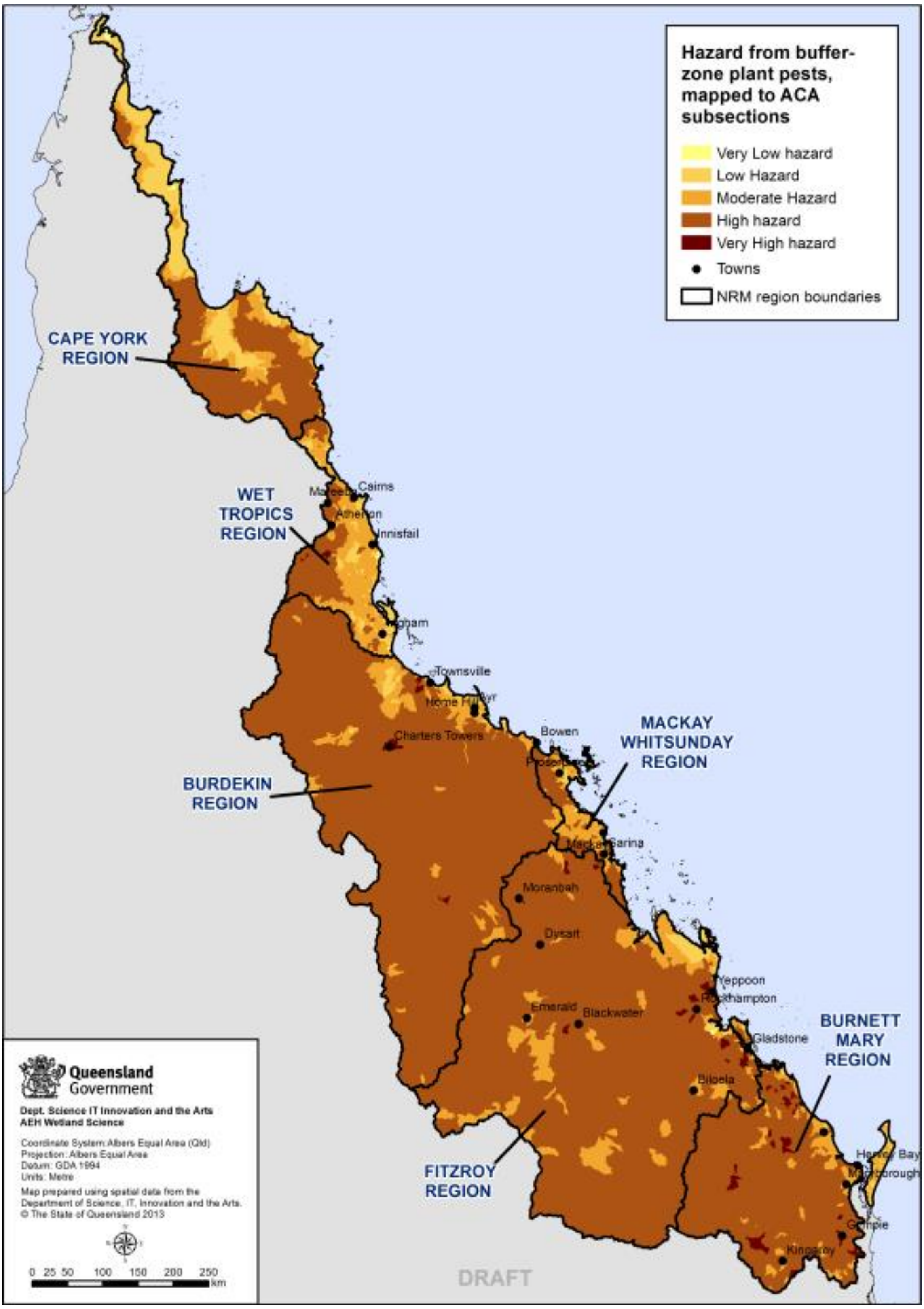


Figure 25 Hazard from buffer zone pest plant species across the GBR catchment

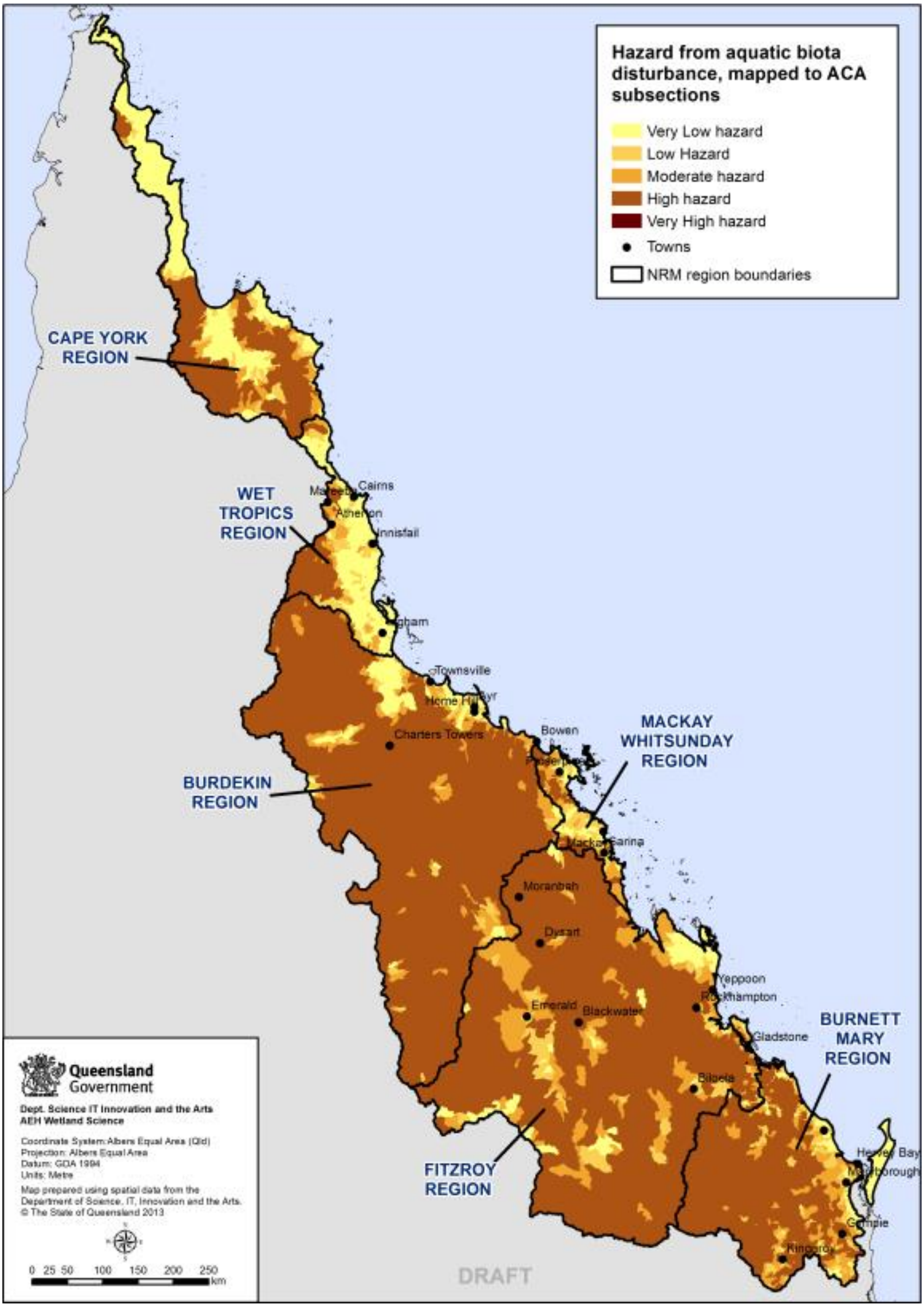


Figure 26 Hazard from aquatic biota disturbance across the GBR catchment

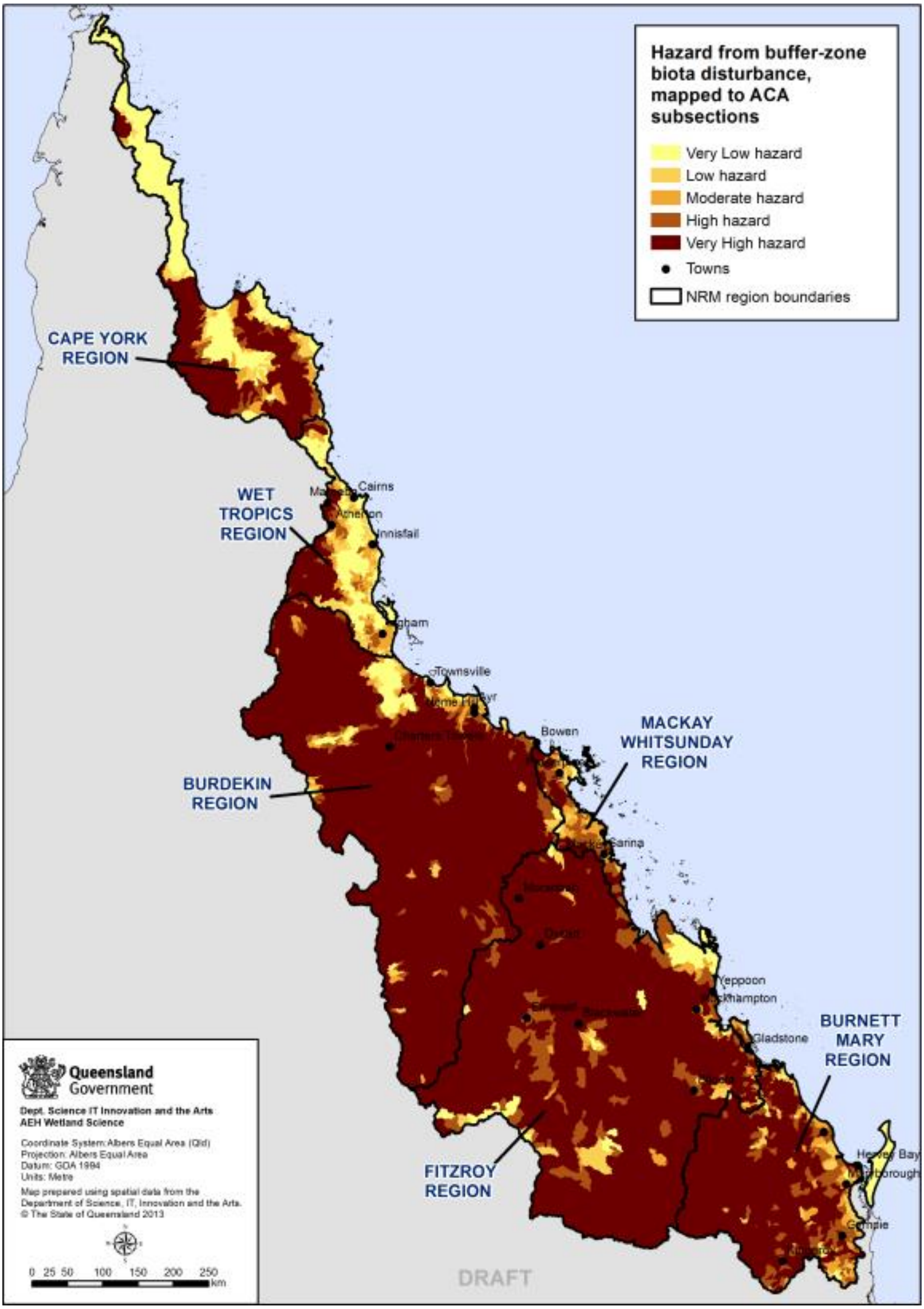


Figure 27 Hazard from buffer zone biota disturbance across the GBR catchment

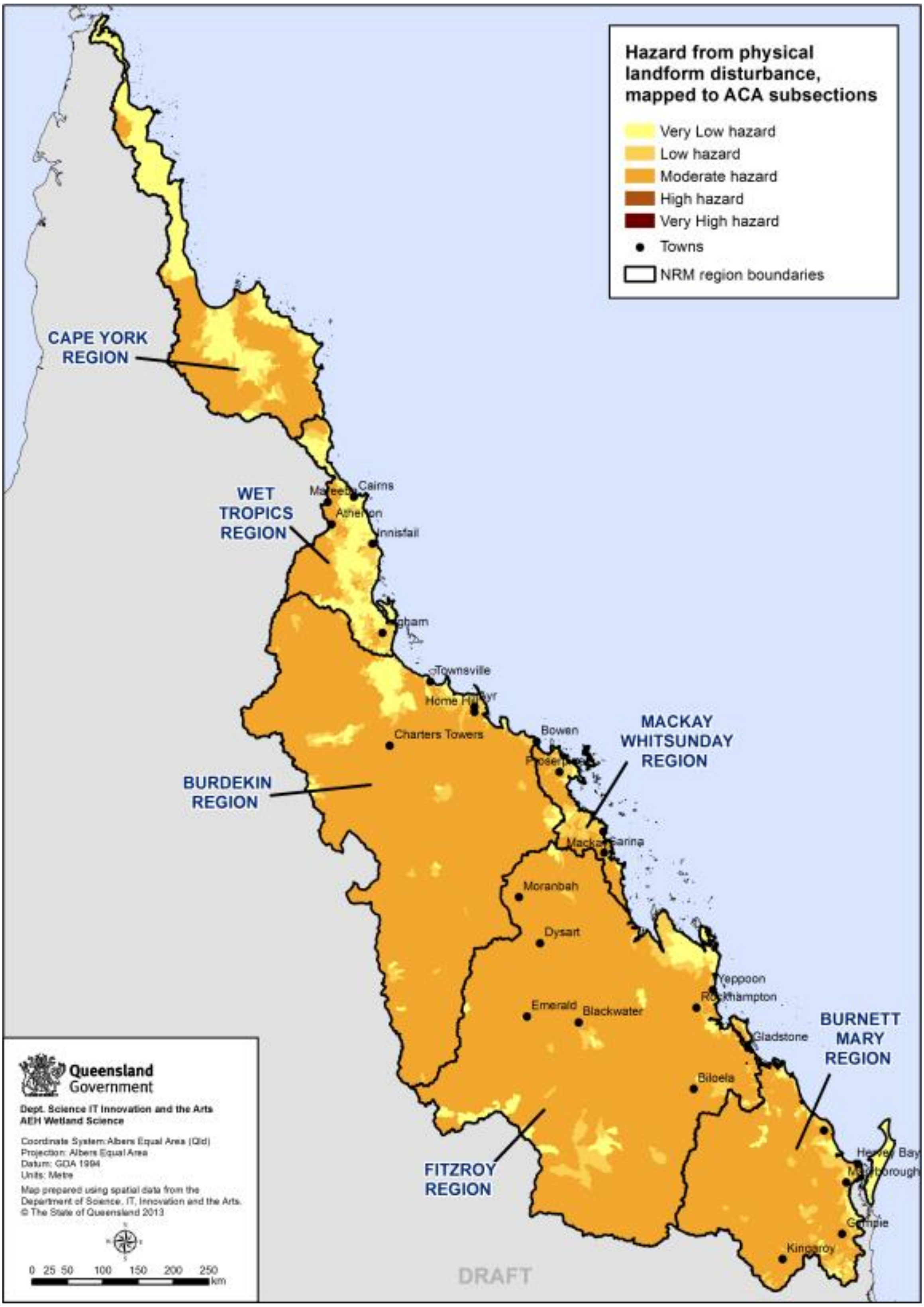


Figure 28 Hazard from landform or physical habitat disturbance across the GBR catchment

3.2 Landscape hazard from combined pressures

Landscape scale hazard was mapped across the entire GBR region, using both the ACA and NRM mapping units, for combined land-use pressures (see Figures 29 and 30), infrastructure pressures (see Figures 31 and 32) and combined land-use plus infrastructure pressures (Figures 33 and 34). Summary results presented in Figures 35, 36 and 37 represent the percentage area of ACA mapping units in each hazard category for combined land-use, infrastructure and overall hazard respectively.

3.2.1 Broadscale land-use

Hazard from the combination of all broadscale land-use pressures is shown in Figures 29 and 30. A regional summary of the percentage of area within each hazard category is shown in Figure 35. Generally, combined broadscale land-use hazard fell into bands 1–5 (the lower to moderate end of the scale) across the majority of the GBR catchment (Burdekin, Fitzroy, Burnett–Mary). These areas contain a high percentage of extensive grazing land-use which is strongly associated with pressures in the categories relating to water regime changes, pest species and habitat disturbance/alteration. There were very small areas (less than 1%) of higher hazard (band 6) in the Burnett–Mary, Mackay–Whitsunday and Wet Tropics regions where there is a greater intensity of higher pressure land-uses. Despite pockets of higher hazard areas, Cape York and the Wet Tropics showed a lower hazard profile than the other regions. This is due to the high proportion of these regions under conservation and natural environments land-use.

3.2.2 Infrastructure

Hazard specifically from infrastructure pressures is shown in Figures 31 and 32. Infrastructure hazard was very low across the majority of the GBR catchment. As would be expected, small pockets of higher hazard areas are centred on urban centres such as Rockhampton, Mackay, Moranbah and Charters Towers. Generally the level of hazard from infrastructure increases towards the south of the GBR catchment (with the highest proportion of mapping units in higher categories in the Burnett-Mary region) which reflects the level of population density and its associated infrastructure.

3.2.3 Overall hazard

Figures 33 and 34 depict the distribution of combined hazard from all the assessed pressures arising from land-use and infrastructure across the GBR catchment. As such, they provide a summary of all the hazard information collated in this assessment. Hazard generally increased toward the South of the GBR catchment with Cape York at the lowest hazard ranking compared to the Mackay–Whitsunday and Burnett–Mary regions with the highest (based on the proportional area of ACA mapping units with a hazard rating of 'moderate' or greater; see Figure 37). Based on the finer scale ACA mapping (see Figure 34), the highest hazard areas are generally clustered around major coastal population centres such as Bundaberg, Gladstone, Rockhampton, Mackay, Townsville and Ayr. There are also small patches of high hazard areas in smaller regional centres around Biloela, Moranbah and Charters Towers.

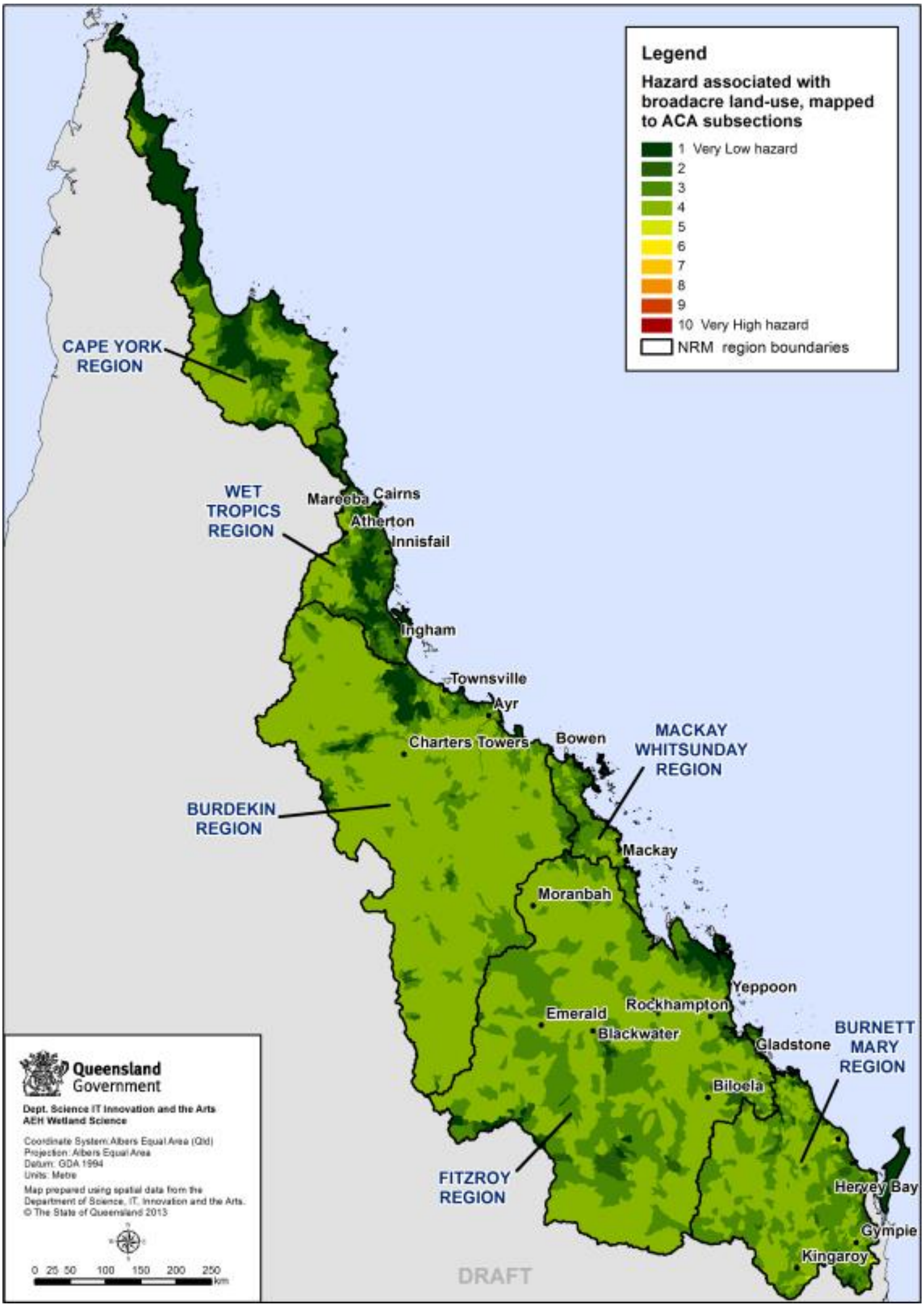


Figure 29 Hazard from combined land-use pressure across the GBR catchment (mapped to ACA units)

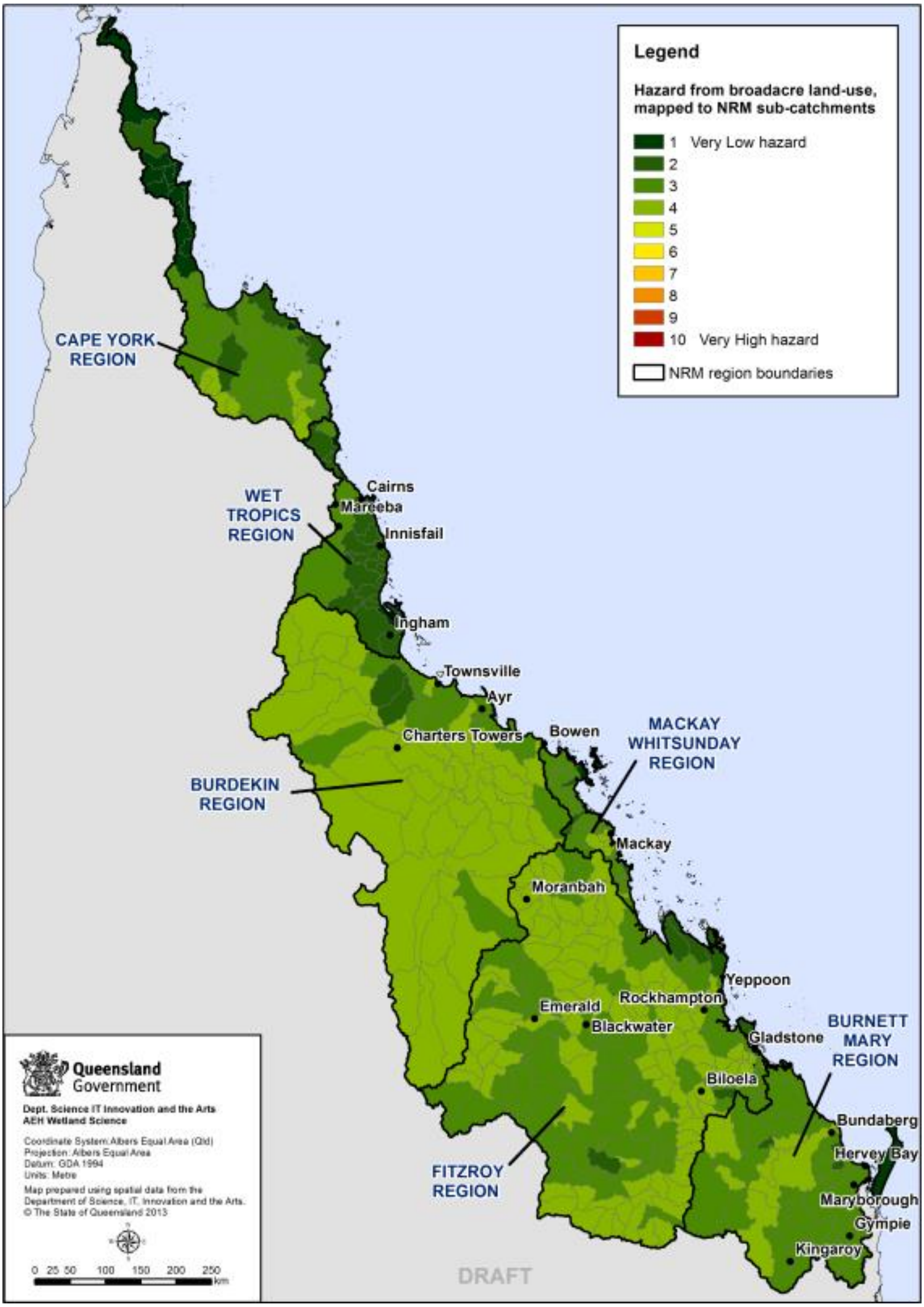


Figure 30 Hazard from combined land-use pressure across the GBR catchment (mapped to NRM units)

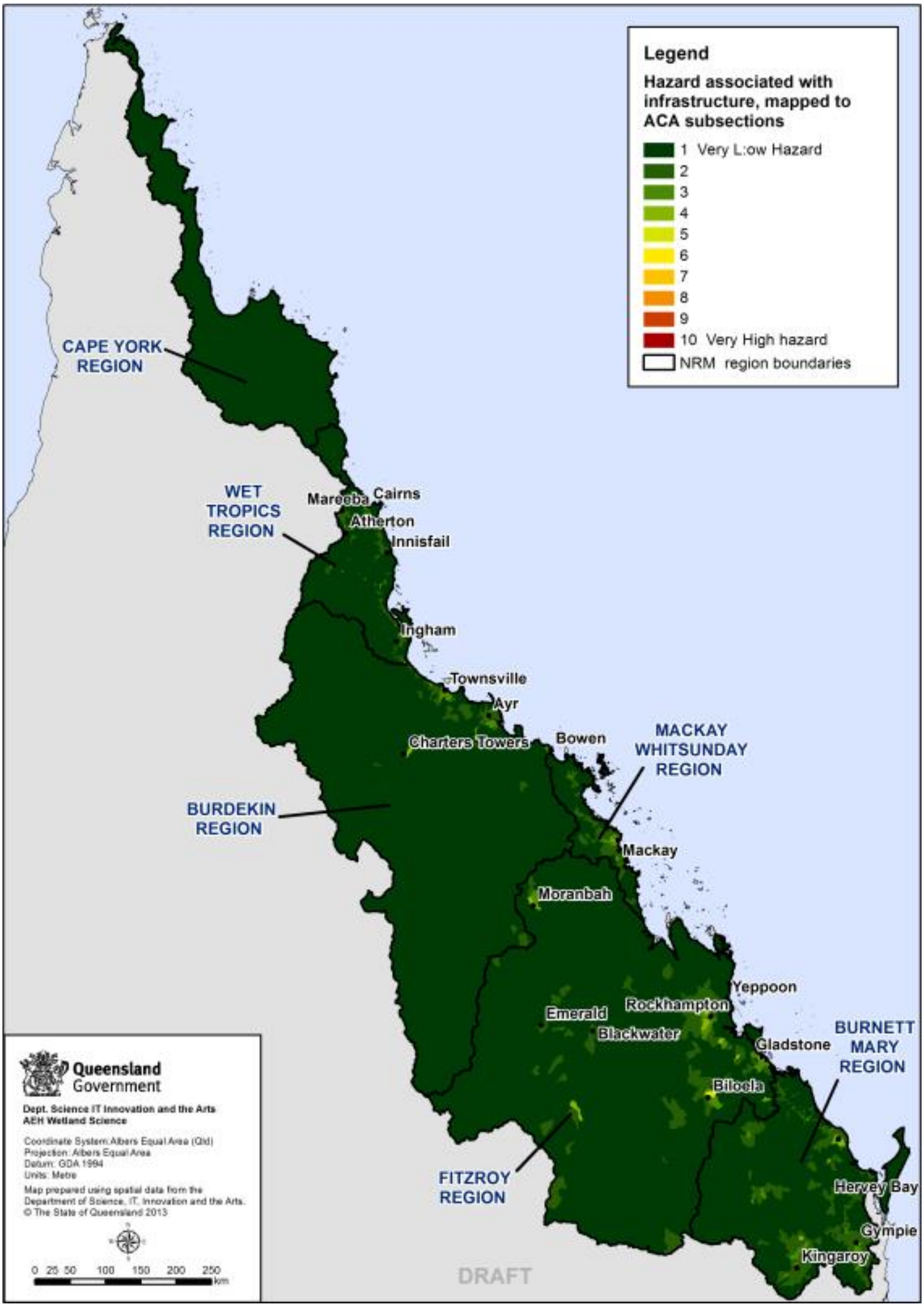


Figure 31 Hazard from infrastructure pressure across the GBR catchment (mapped to ACA units)

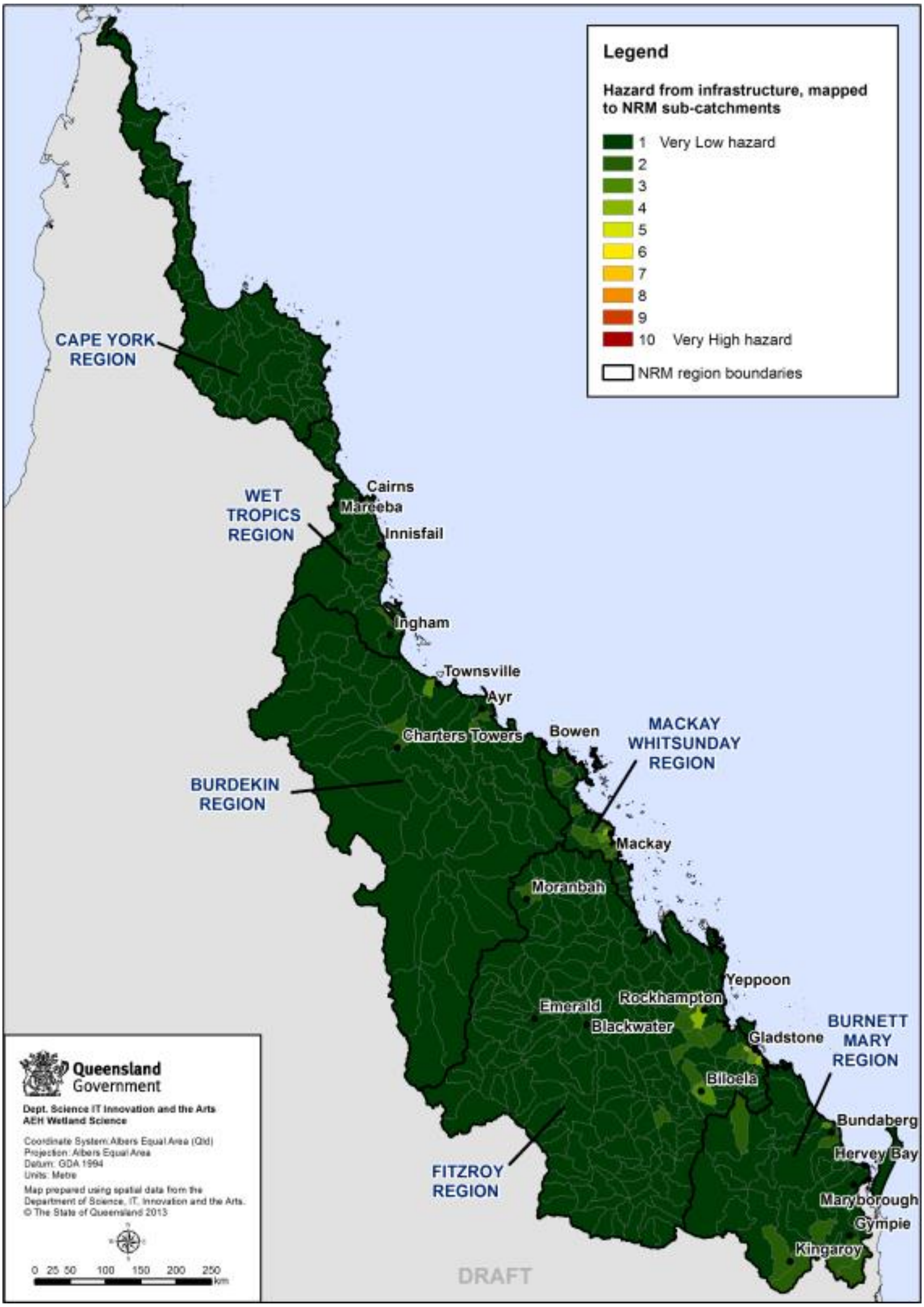


Figure 32 Hazard from infrastructure pressure across the GBR catchment (mapped to NRM units)

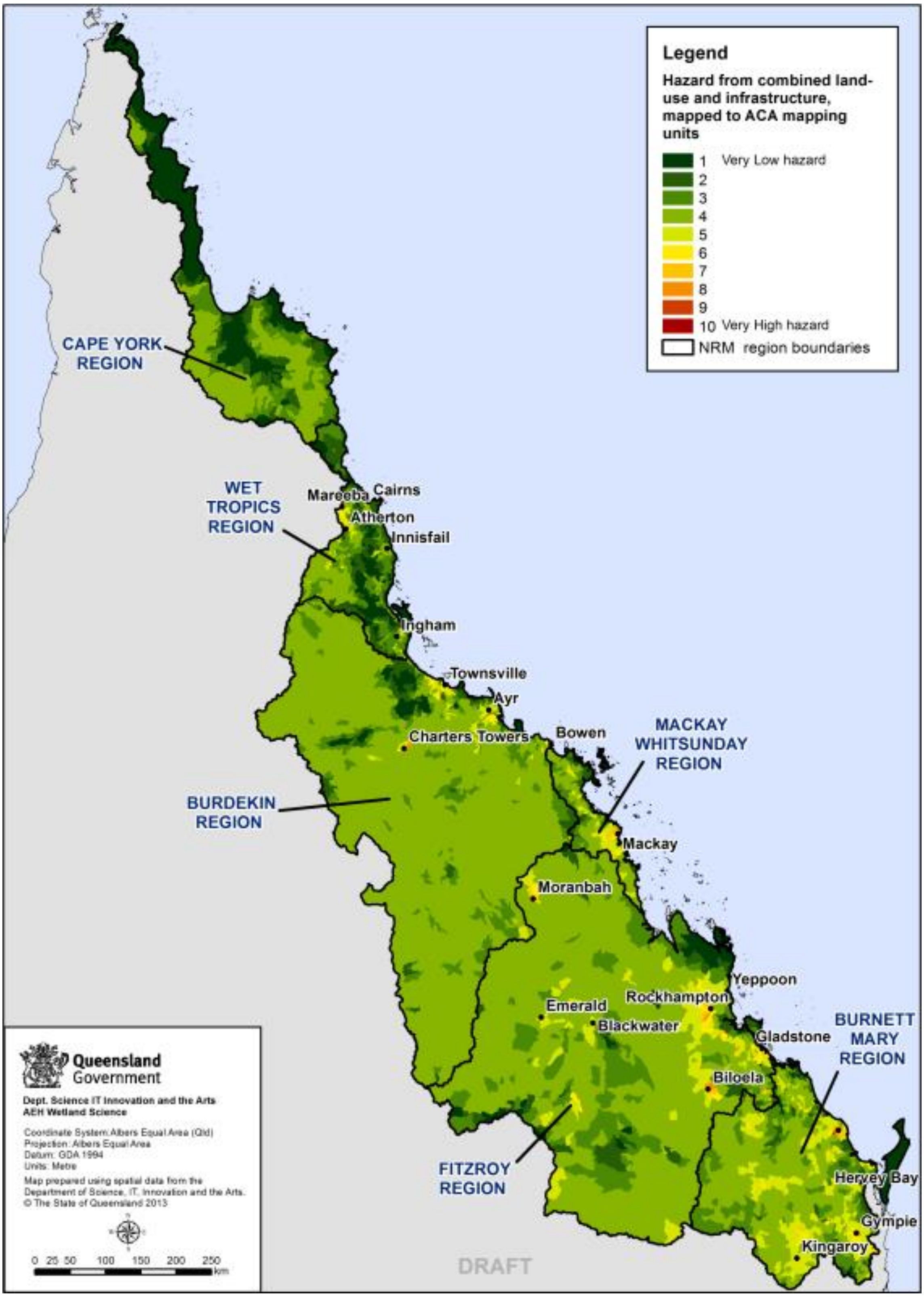


Figure 33 Hazard from combined land-use and infrastructure pressure across the GBR catchment (mapped to ACA units)

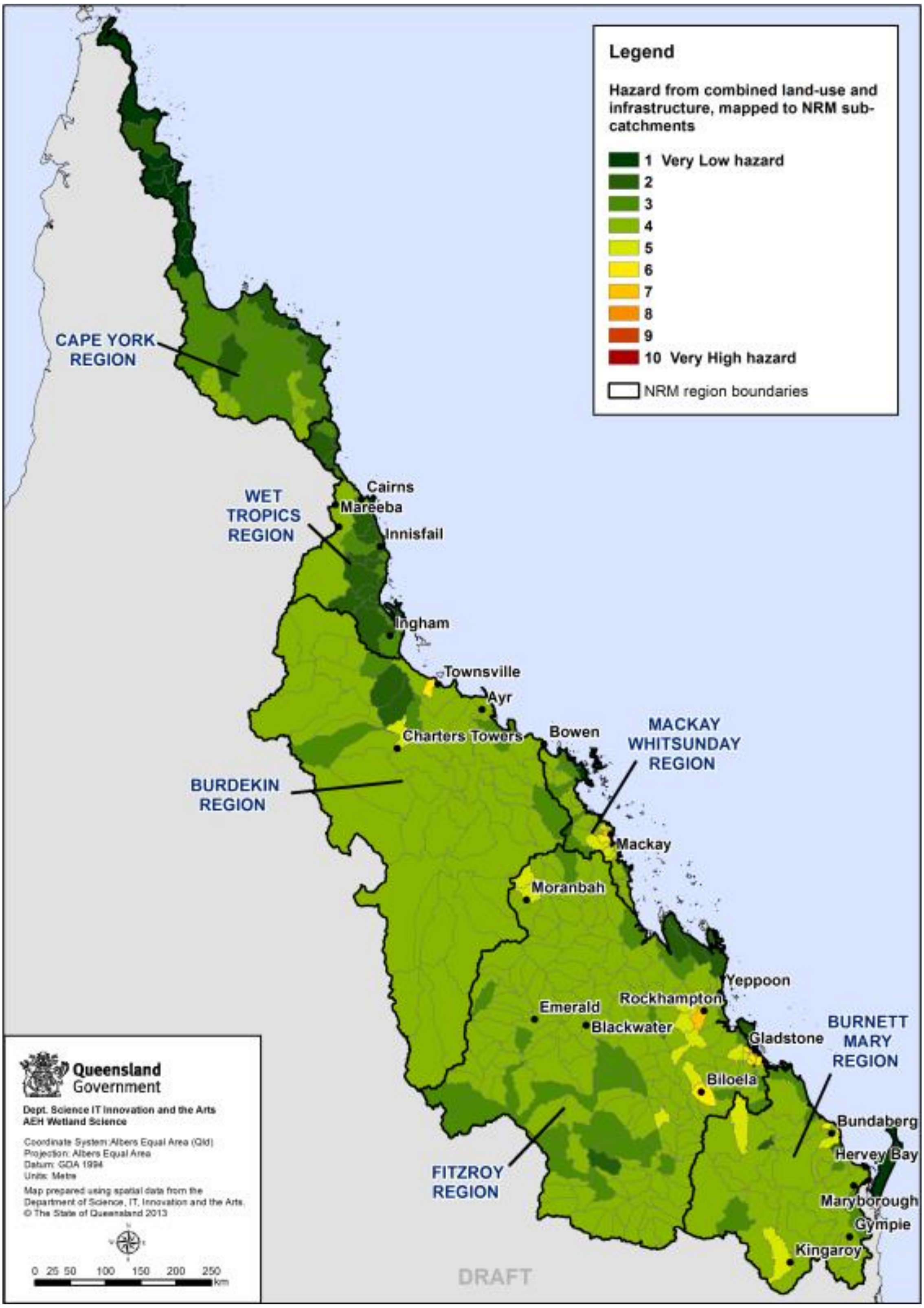


Figure 34 Hazard from combined land-use and infrastructure pressure across the GBR catchment (mapped to NRM units)

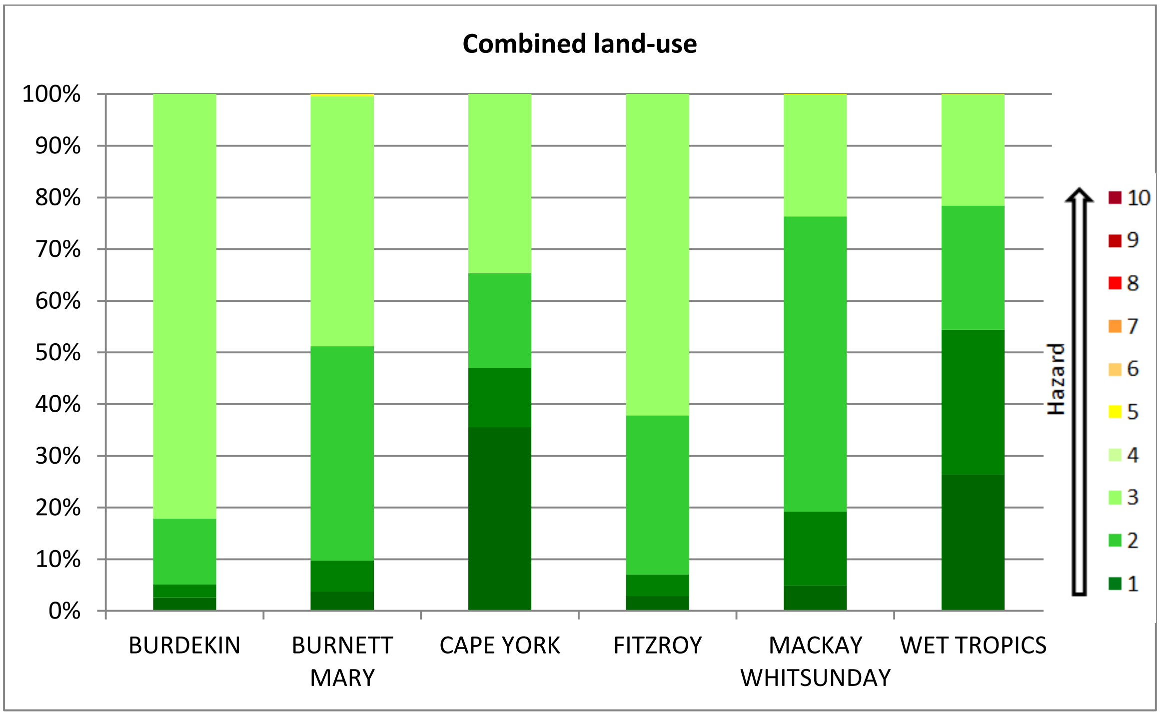


Figure 35 Regional summary of percentage area of ACA mapping units in each hazard category

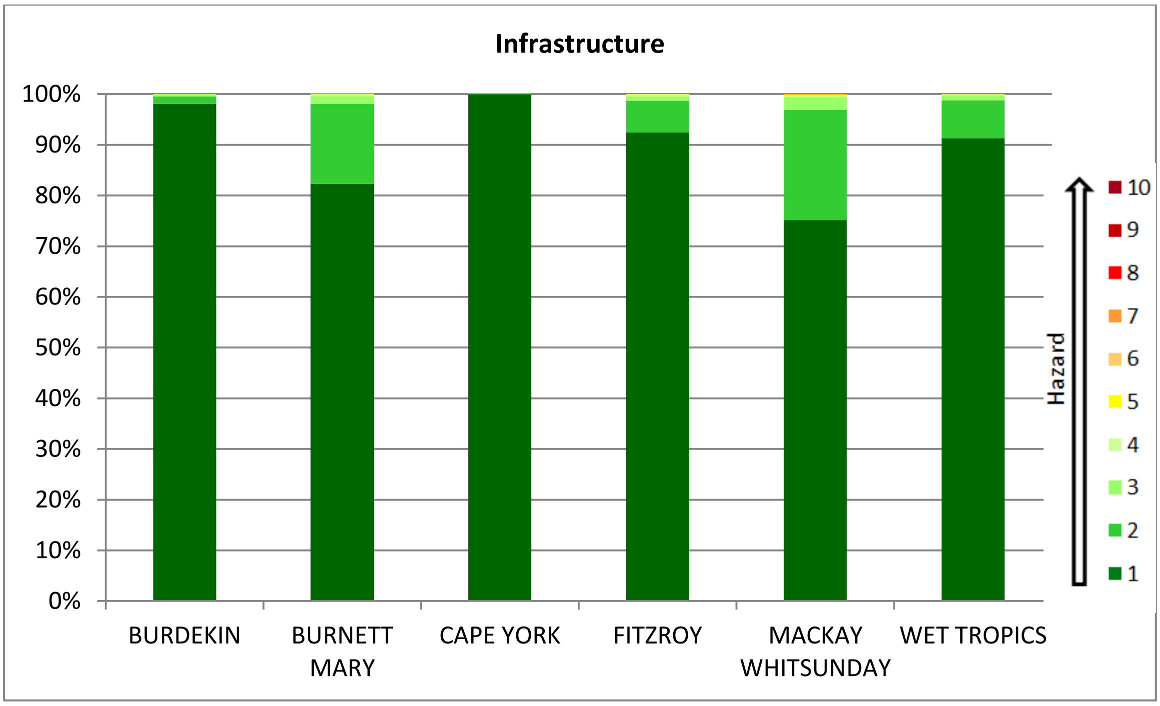


Figure 36 Regional summary of percentage area of ACA mapping units in each hazard category

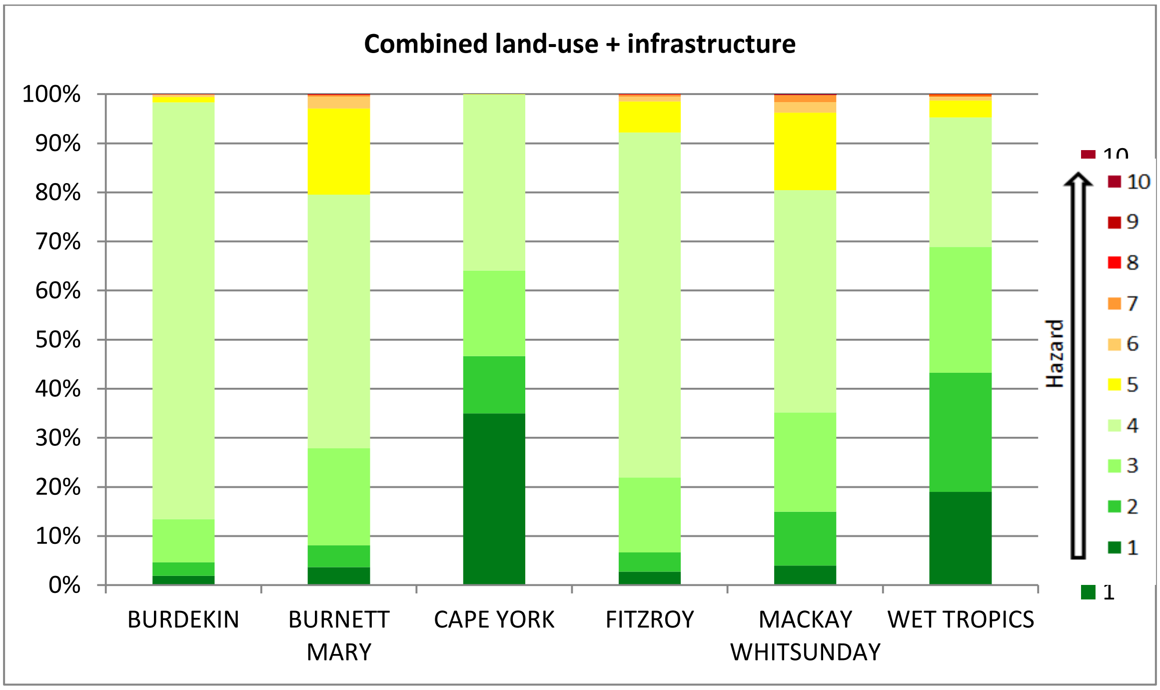


Figure 37 Regional summary of percentage area of ACA mapping units in each hazard category

3.2 Hazard to wetlands

While the landscape scale assessment has provided a picture of hazard across the GBR catchment, only a certain percentage of those mapped units actually contain wetlands. This ranged in proportion from the Mackay–Whitsunday region with the lowest percentage where 29% of ACA units actually contained near natural palustrine and lacustrine wetlands, to the Cape York region which had the highest proportion with 64% of ACA units containing wetlands.

Figure 38 depicts wetland hazard across the GBR on a single map, however the mapping of wetlands with an attributed hazard level is cartographically difficult for the whole of the GBR catchment due to the size of the region and the large number (over 14,000) and range of sizes of individual wetlands. Example maps have been included which depict how the attribution of hazard to specific wetlands is possible (see Figures 39, 40 and 41). A key output of this hazard assessment is the production of an attributed GIS layer and associated tabular outputs, from which these maps were produced, which can be used to zoom in on specific areas. This will be a key information resource to assist in the prioritisation of sites for wetland specific monitoring and assessment activities.

Hazard mapping is presented for all 22 individual pressures and for combined pressures across the whole GBR. Overall land-use hazard generally increased toward the south of the GBR catchment, with Cape York at the lowest hazard compared to the Burnett–Mary region with the highest relative hazard. The areas with the highest land-use hazard to wetlands were mostly around urban centres and towards the eastern coastal zone. Examples of mapped wetland areas with displayed land-use hazard levels are presented, however the key tool for future use is an attributed GIS layer which can be interrogated for the more than 14,000 individual mapped wetlands in the GBR catchment.

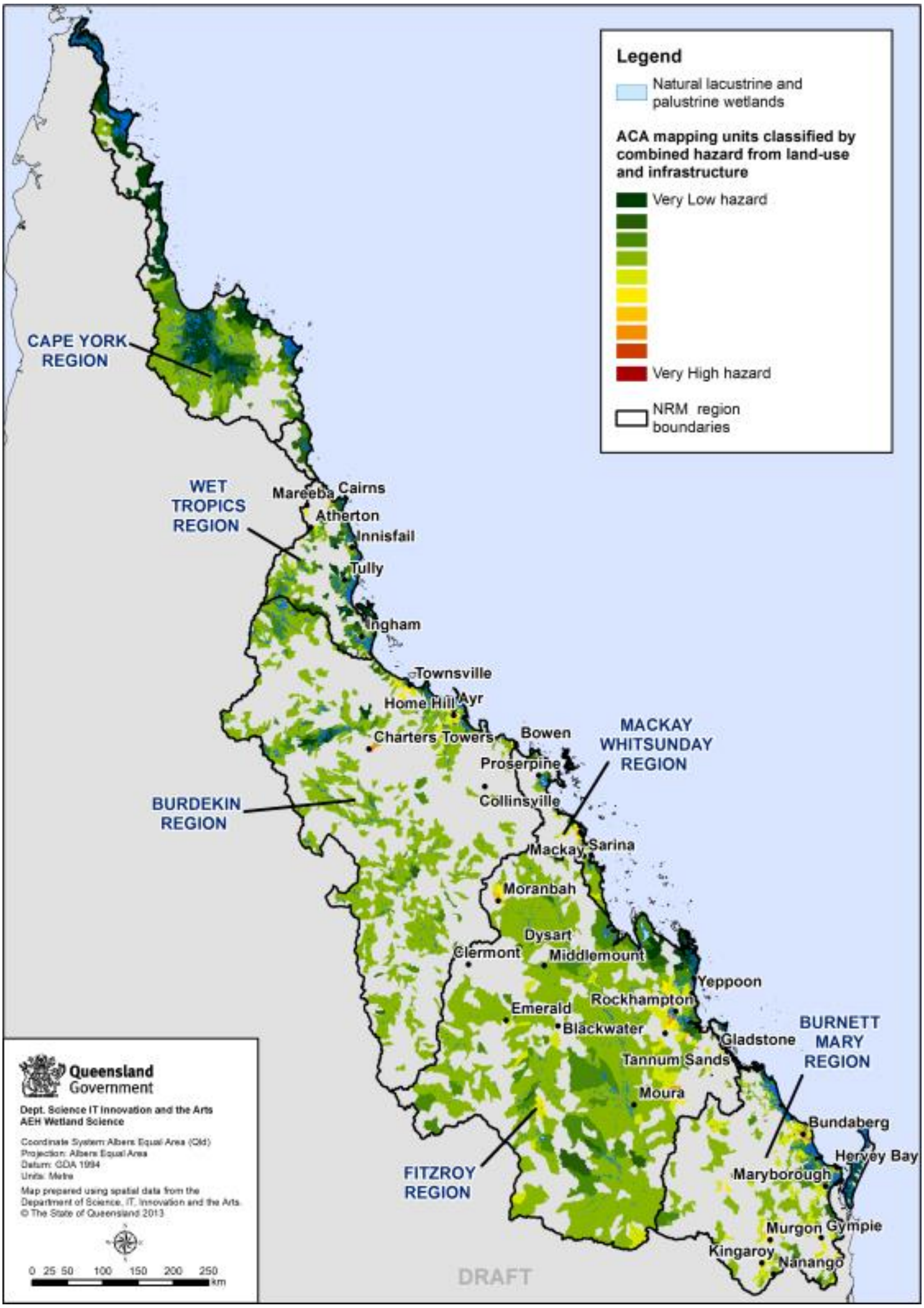


Figure 38 ACA mapping units containing natural and near natural lacustrine and palustrine wetlands with attributed overall hazard shown across the whole of the GBR catchment

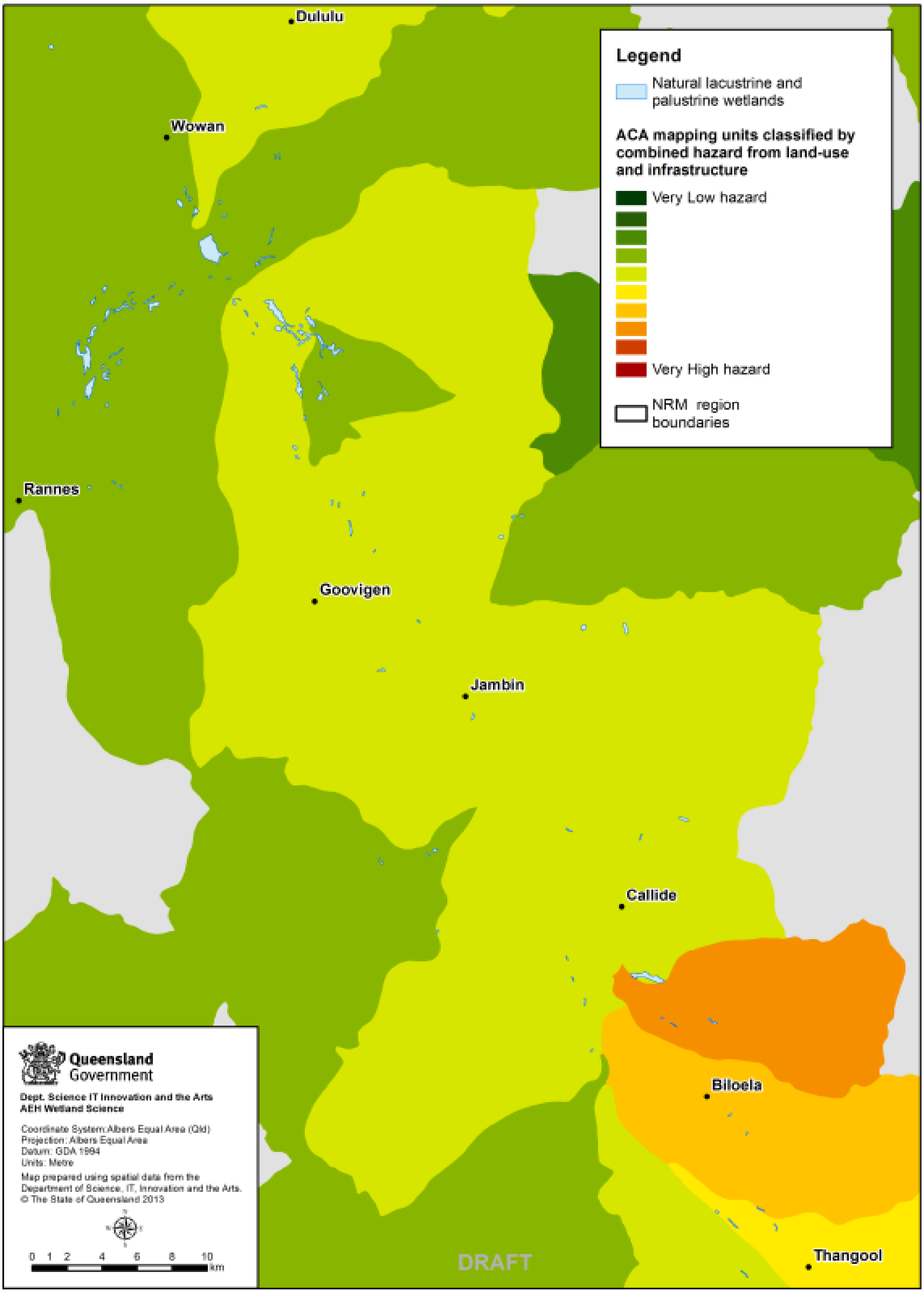


Figure 39 Example of mapped natural and near natural lacustrine and palustrine wetlands with attributed hazard (based on ACA mapping)

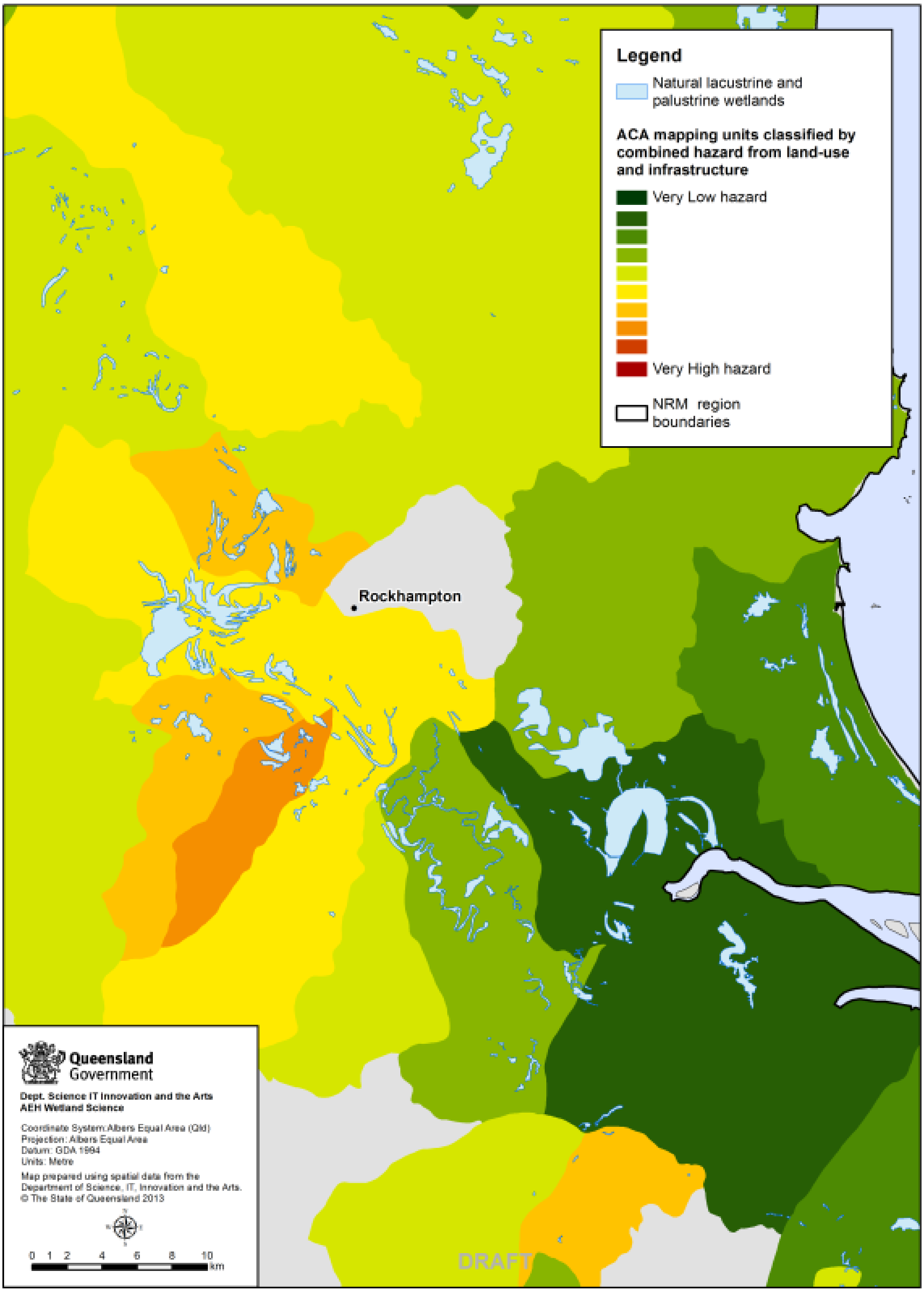


Figure 40 Example of mapped natural and near natural lacustrine and palustrine wetlands attributed hazard (based on ACA mapping)

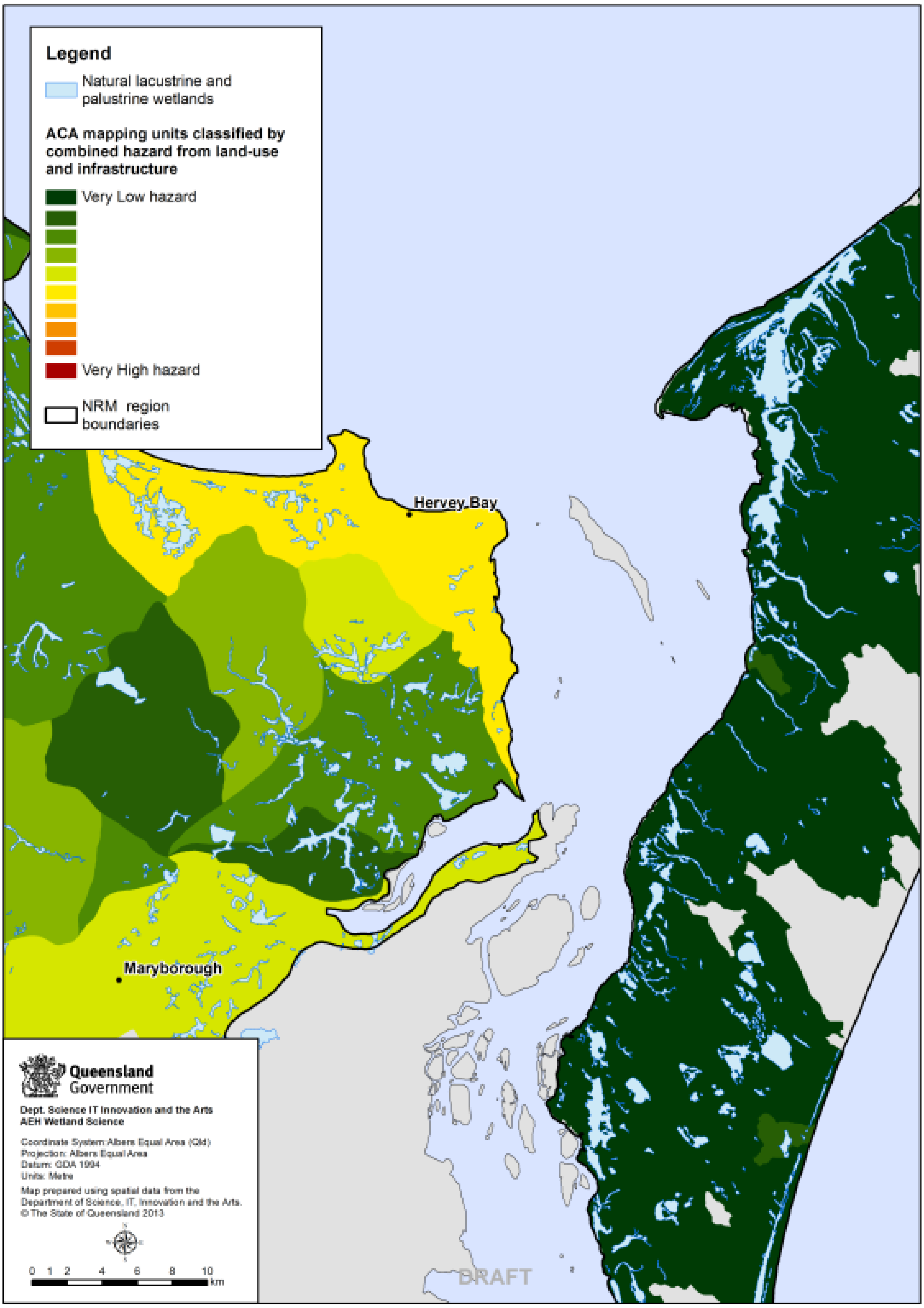


Figure 41 Example area of mapped natural and near natural wetlands with attributed hazard (based on ACA mapping)

4 Recommendations

4.1 Use of the outputs

The primary outputs of this Tier 1 assessment process are the landscape hazard assessment maps (see Figures 7–28 for individual pressures and Figures 29–34 for combined pressures) and an attributed database with landscape level hazard levels for wetlands within the GBR catchment (or mapped as depicted in Figures 38–41). They provide a clear picture of environmental hazard arising from human activities across the GBR catchment. They do not provide a condition assessment and the outputs do not show areas where wetlands are in poor condition. While wetlands in areas of high hazard are more likely to be subject to landscape scale pressures, this is not always the case, and the extent of pressures on specific wetlands will be influenced by other factors such as natural drivers, on-ground land-use management practices and the ecological resilience of different wetlands. Any inference about the state (condition) of any individual wetland will only be made on the basis of a wetland specific assessment.

As stated, the initial purpose of this assessment is to assist in identifying areas of interest for targeted wetland specific monitoring and assessment. Decisions on wetlands to target for finer scale assessment should be informed by this modelled level of hazard arising from broadscale land-use and infrastructure. While those areas exposed to the greatest level of hazard are obvious targets for assessment, it is anticipated that wetland areas under a range of modelled hazard level will be prioritised under any Tier 2 assessments. This is in part to provide on-ground field validation of modelled pressures.

While the hazard assessment data has been reported at the ACA (or in some cases NRM) mapping scale, results could also be presented at different spatial scales (by collating and cartographically displaying the data) depending upon the purpose. This hazard assessment data will make a powerful tool for interrogation of wetland information at the broader scale. This will assist in the management of pressures and implementation of on-ground measures.

While land-use change is not included in this hazard assessment the pressure land-use characterisations and hazard assessment methods could be used to model future wetland hazard based on planned or potential land-use changes. The land-use pressure characterisation also has scope for predicting change in pressures under different land-use change scenarios. Comparing hazard levels from current land-use conditions to those under proposed land-use changes would provide a powerful tool to evaluate potential pressures that could arise. This would assist in strategic planning aimed at minimising pressures on aquatic systems.

The hazard assessment outputs can also be used or adapted to help inform monitoring and assessment effort in Queensland for a variety of purposes. For example, this could include state-wide and local aquatic ecosystem monitoring programs, environmental assessments for water resource planning or conservation assessments for state planning purposes.

4.2 Further work

The location and proximity of individual pressures to wetlands and their likelihood of causing an impact on wetland values was recognised as a limitation of the risk assessment work conducted for prioritising integrated waterway monitoring in Queensland (DERM 2011). While the mapping of hazard at the two scales presented within this report are deemed appropriate for the application of the broadscale assessment, a potentially more spatially accurate hazard analysis, based on the proximity of land-use pressures to individual wetlands, is seen as a key further development. This work will inform part of the desktop wetland specific (Tier 2) assessments presently underway in the Great Barrier Reef catchments. To ensure the ongoing validity of the hazard assessment outputs the following issues should be considered in review and further iterations of this work:

- improving the conceptual understanding of land-use and pressure associations through more comprehensive reviews of literature and consultation with experts, on-ground research and validation
- incorporation of other infrastructure pressures as new or improved data sets become available
- updating and refinement of the QLUMP land-use mapping

- conducting a sensitivity analysis to explore how the individual expert elicited weightings may have influenced the assessment outcomes
- mapping uncertainty inherent in the hazard analysis results based on the recorded confidence in the expert elicited scoring and/or known accuracy of the data sets used in the analysis.

As noted at the beginning of this report, the current landscape scale (Tier 1) hazard assessment method does not incorporate natural drivers such as climate or geology and other vulnerability factors, such as measures of soil erosivity, the presence of acid sulphate soils or hydrological connectivity between mapped areas. While these factors will be incorporated into wetland specific assessments, a focus for further work could potentially include the incorporation of these other data sets, as modifiers, into a landscape scale assessment.

4.3 Conclusions

Assessment of pressures and disturbances with the potential to affect ecosystem components and processes is important for understanding the state of ecosystems but also for developing appropriate strategies for their environmental management, monitoring and evaluation (Lynch 2010). As such, the characterisation of pressures driven by different land-uses in Queensland and the resulting hazard assessment undertaken in the present assessment provides a good landscape scale management tool. This kind of broadscale land-use/pressure characterisation for lacustrine and palustrine wetlands has not been undertaken in such detail before in Queensland. It is seen as a valuable step in enhancing the conceptual understanding of pressures acting on wetland ecosystems and quantifying hazard from land-use to support strategic management activities aimed at reducing human induced land-use pressures.

While the conceptual characterisation of pressures driven by land-use presented here was designed to look specifically at hazard to lacustrine and palustrine wetlands, they are broadly applicable to other freshwater ecosystems. The conceptual underpinning and techniques involved in the land-use/pressure association scoring could be easily adapted for conducting hazard assessments across the state.

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Appendix A Land-use/pressure association justification

Conservation and natural environments

Inputs direct/indirect

The category of ***none*** was applied to the majority of the input pressures for this land-use (only litter and rubbish inputs from recreational activities were given a ***very minor*** association). Even though it was recognised that there were potentially some associations with above natural nutrient, sediment or organic matter inputs (e.g. from camping activities/toilets and access roads) these were deemed too insignificant to provide an association given the scale of them in relation to the land-use overall.

Harvesting and exploitation

'Harvesting of plant biota' was deemed as ***none*** due to it being explicitly banned as an activity in most of these areas. 'Animal biota harvesting' due to recreational fishing pressure (as a licensed activity in many locations) was recognised and given a score of ***minor***.

Changes to water regime

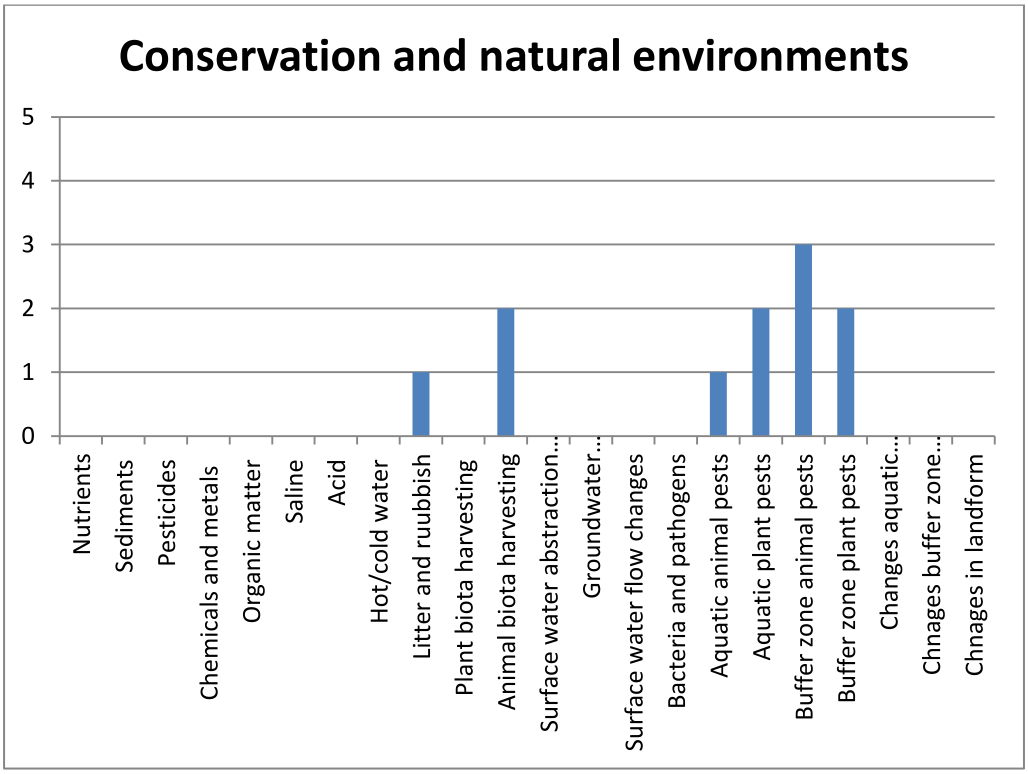
No associations with pressures from changes to the water regime were recognised above natural process.

Biological introductions and perpetuation

Pest species were recognised to exist and perpetuate within national parks and conservation areas (all pressure categories were recognised as having some level of association with the exception of bacteria and pathogen introductions) partly due to public access into these areas (to introduce pest species) and subsequently the ability for pests to perpetuate due to lack of intervention (in remote areas without control measures). Of these pressure categories 'Buffer zone animal species' was deemed as the most highly associated with conservation and natural environment areas and was given a score of ***moderate*** due to the known distribution of animal pests such as feral pigs and goats in certain areas of the state.

Alteration/disturbance of habitat

No associations with the direct alteration/disturbance of habitat by humans or livestock were recognised above natural process.



Extensive grazing

Inputs direct/indirect

The relationship with cattle and other livestock grazing as a known contributor to increased nutrients(***moderate***), sediments (***high***) and organic matter (***moderate***) were recognised as the most important of input pressures due to pugging and faeces inputs from livestock with unrestricted access across the landscape. ***Very minor*** associations were recorded between extensive grazing and pesticide inputs (due to the known small scale use of herbicide treatments in some land classed as grazing native vegetation), saline inputs (due to saline inputs from old artesian bores), hot/cold water inputs (once again due to the presence of bore water drain inputs in some areas) and litter and rubbish (due to the dumping of rubbish in erosion gullies within extensive grazing land).

Harvesting or exploitation

No explicit association between the harvesting of plant or animal biota was made with extensive grazing land.

Changes to water regime

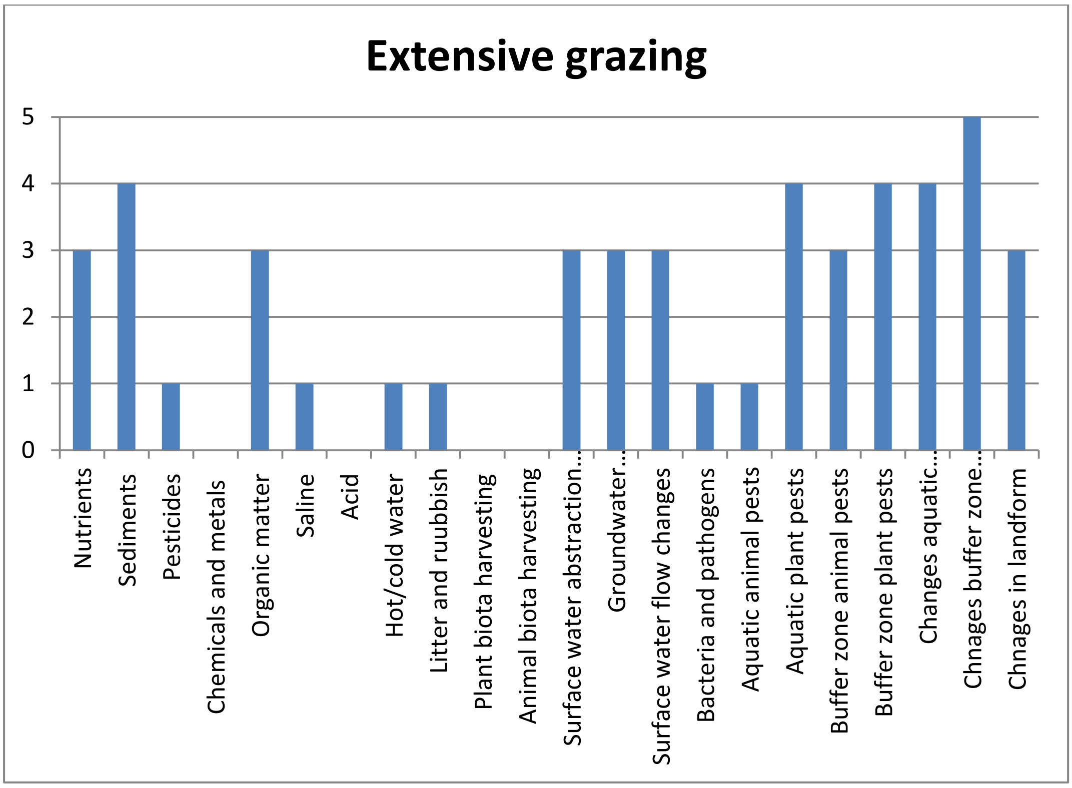
All pressures relating to changes to the water regime were classified as ***moderate*** in relation to extensive grazing. It was recognised that water for livestock is extensively provided through either the direct abstraction of surface water (pumped or through direct livestock access to a wetland) or groundwater (pumping from bores) as well as through surface water flow changes (creation of farm dams).

Biological introductions and perpetuation

The association of pest species with extensive grazing was recognised in all categories and the classification ranged from ***very minor*** (e.g. bacteria and pathogens driven through faecal inputs from livestock, and aquatic animal pests) through to ***high*** for plant pest species (both terrestrial and aquatic plants) which are easily distributed (by movement of seed and plant fragments). This is due to the generally unrestricted movement of cattle or other livestock between areas, and particularly between wetland areas, as potential water sources. Terrestrial animal pest pressures (from feral pigs etc.) were recorded as ***moderate*** due their presence across the landscape (almost independent of land-use type) where there is unrestricted access (e.g. as for conservation and natural environments or production from natural forests).

Alteration/disturbance of habitat

Extensive grazing was recognised as having ***very high*** association with the disturbance of buffer zone species (terrestrial habitats surrounding wetlands) due to the direct tramping/grazing of buffer zone species by the livestock. Pressures on aquatic species was deemed to be ***high*** (as livestock are known to enter wetland areas for grazing particularly in dry periods) but are recognised to not be as considerable as those in the buffer zone. Physical changes in the landform/topography of a wetland caused by livestock were recognised as occurring in some cases and were recorded as ***moderate***.



Intensively managed grazing

Inputs direct/indirect

Intensively managed grazing was associated with a range of direct and indirect input pathways with increased nutrients (***very high***), sediments (***high***) and organic matter (***very high***) recognised as the most important of the potential pressures. Elevated levels of nutrients are likely to due to increased stocking densities and fertilizer inputs. Sediments were recognised as being high but also potentially variable across the landscape (there are increased stocking densities but generally a more consistent vegetation coverage in comparison to extensive grazing land which can reduce the erosion potential). Organic matter was deemed to be associated with intensively managed pastures as a result of increased faecal matter but also vegetative matter from fodder crops and supplementary feeding. Pesticide inputs were recognised as having a ***moderate*** association with intensively managed grazing (e.g. veterinary treatments in intensively managed dairy herds, herbicide application for selected weeds etc.). The potential for saline inputs from use of artesian bore water in some areas were also classified as ***moderate*** (due to the higher potential level of water use in comparison to extensive grazing). Generally input pressures from intensively managed grazing were assessed as being higher compared to extensive grazing land.

Harvesting or exploitation

No explicit association between the harvesting of plant or animal biota was made with intensively managed grazing land.

Changes to water regime

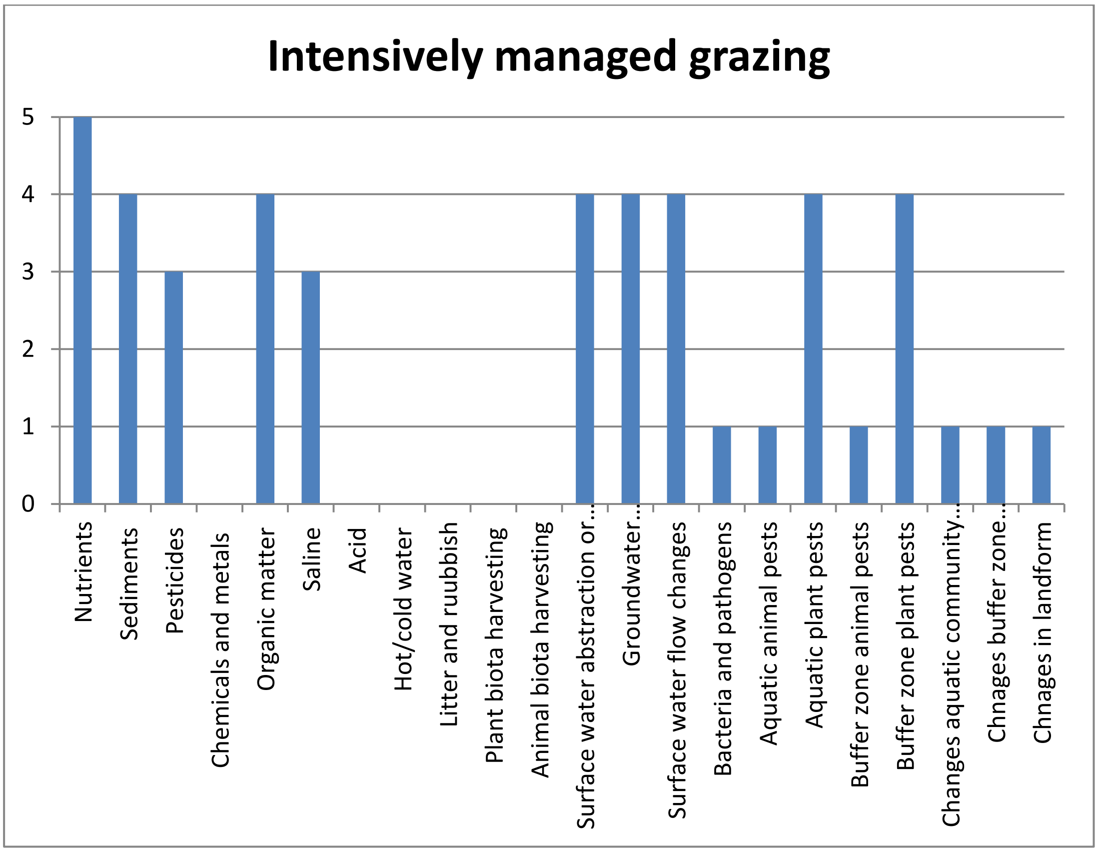
All pressures relating to changes to the water regime were classified as ***high*** in relation to intensively managed grazing. It was recognised that there is extensive potential for high water use for livestock drinking or irrigated pastures and/or fodder production associated with this land-use. This could occur either through the direct abstraction of surface water and groundwater, as well as through surface water flow changes from the creation of farm dams or changes to drainage and topography associated with intensively managed pastures.

Biological introductions and perpetuation

The association of pest species with intensively managed grazing was recognised as ***very minor*** for bacteria and pathogens, aquatic animal pest species and buffer zone pest animal species. Differences in comparison to the association given with extensive grazing was due to the generally restricted movement of cattle or other livestock (due to fencing) and pest management practices likely to be in place in intensively managed pastures. The exception in this category was both aquatic and buffer zone pest plant species which were both given a ***high*** association. This was due to the deliberate seeding of managed pastures with non-native plant species and their potential for invasion into adjoining areas and through the increased use of machinery /livestock transport involved in their management which could distribute plant pest seeds across the landscape.

Alteration/disturbance of habitat

Intensively managed grazing was recognised as having a ***very minor*** association with the alteration/disturbance of aquatic species, buffer zone species and physical habitat changes. This was primarily due to the likelihood of restriction of livestock access to wetland areas from intensively managed grazing due to the presence of fencing.



Production from natural forests

When scoring was assessed for production in natural forests pressure from cattle grazing (at a level below that found in extensive grazing land) was taken into account as livestock are legitimately present in many state and private forest areas in Queensland.

Inputs direct/indirect

Nutrient (***minor***), sediment (***moderate***) and organic matter (***minor***) inputs were recognised as pressures arising from both wood production activities (from ground disturbance/use of machinery, vegetation stripping from log production) and low level grazing (due to pugging and faeces inputs from livestock with unrestricted access across the landscape) occurring within these areas. No other input pressures were associated with production from natural forests.

Harvesting or exploitation

Very minor associations for the harvesting of both animal and plant species within natural forests were recorded. This was due to the licensed (and also potentially unlicensed) plant/animal collection activities that can and do occur within state and private forests.

Changes to water regime

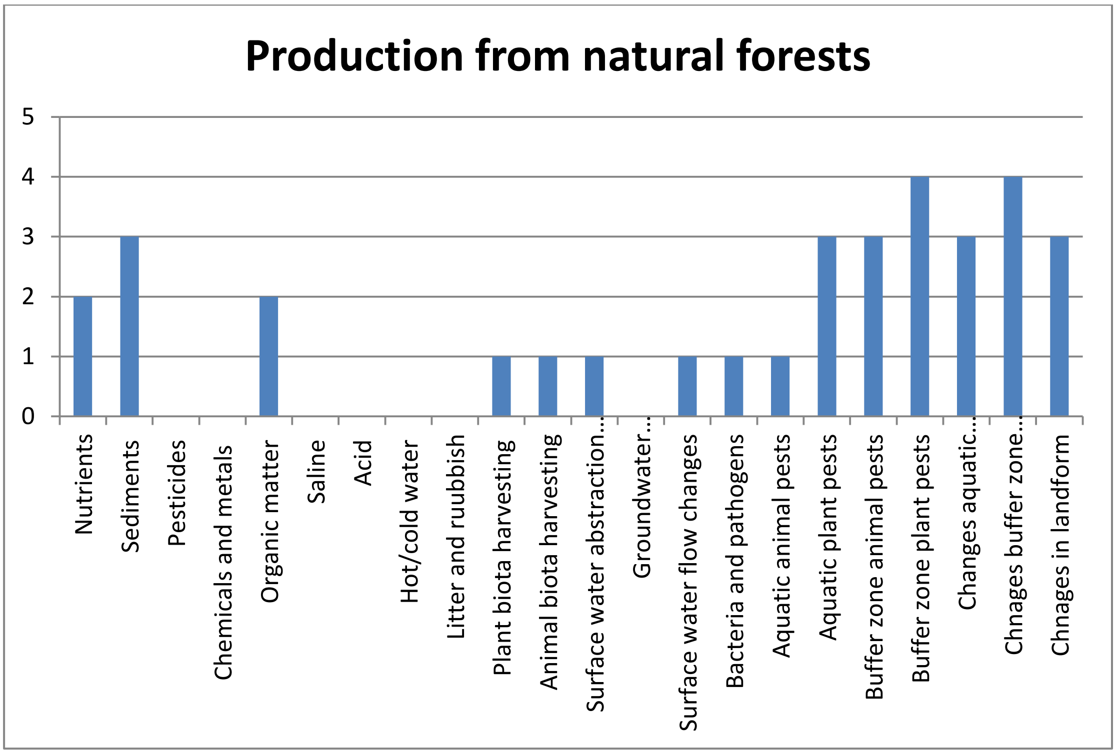
The presence of cattle in state forests means that surface water usage directly from wetlands was recorded at a ***very minor*** level (cattle can drink 70L per day each). Changes to flow regimes from the creation of small dams (for stock watering) and surface flow alterations (due to logging access track and earthworks associated with timber production) were also recorded as ***very minor***.

Biological introductions and perpetuation

The potential for the introductions of bacteria and pathogens was classified as ***very minor*** due to the presence of cattle in most areas (in line with the strength of association recorded for both extensive and intensive grazing land-use). Terrestrial (buffer zone) animal pests (e.g. feral pigs) were recognised to exist and perpetuate within natural forest areas (as they were recognised within conservation and natural environment areas) and were classified as ***moderate***. The association of aquatic pest plant species (***moderate***) and buffer zone pest plant species (***high***) were recognised due to the potential for livestock to spread pest plants throughout these areas (due to unrestricted livestock access) and the potential for perpetuation (due to remoteness and lack of specific management intervention).

Alteration/disturbance of habitat

A generally strong association with habitat alteration/disturbance pressures was noted with production from natural forests. Disturbance to aquatic species and also the physical form of wetlands were both perceived to be ***moderate*** and disturbance to buffer zone species was recorded as ***high*** due to the direct disturbance of habitats by livestock and also by human activities associated with the production of wood (saw logs and pulpwood) and other forest products such as firewood, fence posts and collection of wildflowers.



Plantation forestry

Inputs direct/indirect

Overall input pressures were perceived to be relatively low in comparison to other land-use groups. An association was recorded for nutrients (***minor***), sediments (***minor***), organic matter (***very minor***) and on the basis that input pressures from plantation forestry are more likely to be limited to establishment and harvesting phases of the plantation which is relatively short in relation to the temporal scale of the crop. Pesticides were rated as ***moderate*** due to the potential for application of herbicides and pesticides at various stages of the plantation cycle. This could include herbicide application (including the use of pre-emergent herbicides which can persist in the soil) during initial establishment to stop weeds from competing with young saplings, and more rarely pesticide treatments as required throughout the trees growth to control insect pests such as woodborers.

Harvesting or exploitation

Very minor associations for the harvesting of both animal and plant species were recorded. This was recorded above ***none*** due to the relatively easy public access that exists for most plantation forestry areas and that plant/animal collection activities were deemed to be similar to those likely to be occurring in natural forests.

Changes to water regime

It was acknowledged that there was insignificant potential for direct water abstraction from surface or groundwater sources for watering of the trees (there are however rare examples of irrigated plantation forestry using treated sewage effluent), abstraction of groundwater was recorded as ***minor*** to take into account the potential for lowering of the water table by the plantation trees (transpiration withdrawal) which has been noted in some areas.

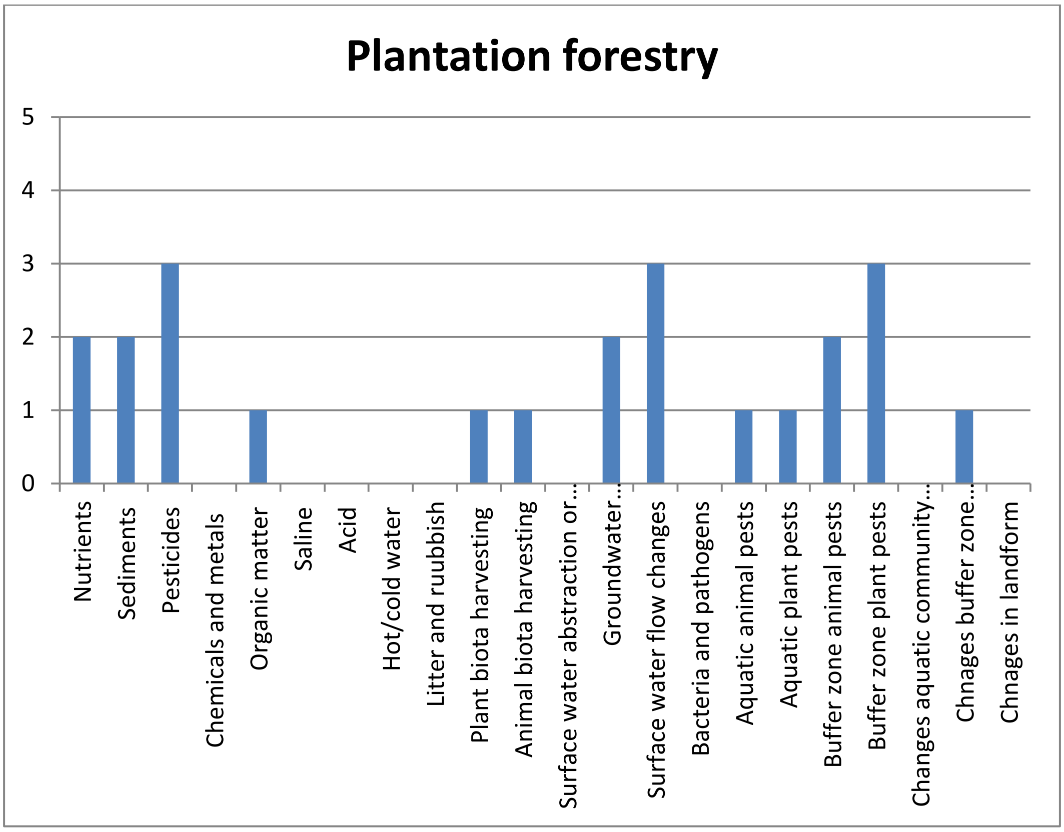
Changes to natural surface water flow patterns were ranked as ***moderate*** due to a number of potential effects including topographic changes from the use of heavy machinery and the installation of drainage ditches and access tracks that can occur during the establishment of new plantation. This can change the drainage pathways of rainfall run-off and the potential for increased rainfall capture by the trees.

Biological introductions and perpetuation

The potential for plantation forestry areas to drive the introduction and perpetuation of animal and plant pests was assessed as being relatively low. Buffer zone animal pests (e.g. feral pigs etc.) were considered to be less prevalent (and given a ranking of ***minor***) in plantations in comparison to natural forest areas in most cases. Buffer zone pest plant species were assessed as ***moderate*** due to the potential for encroachment of wetland buffer zones with planted non-native tree species.

Alteration/disturbance of habitat

A single association with the alteration/disturbance of buffer zone habitat (***very minor***) was recognised above natural process and was attributable to the potential for machinery working on the edge of plantations to directly disturb those habitats.



Dry land cropping and horticulture

Inputs direct/indirect

A considerable degree of association with nutrients (***high***), sediments (***very high***), pesticides (***high***) and organic matter (***high***) was recorded for this land-use. It was recognised that cropping and horticulture involves a relatively high degree of the direct application of nutrients, herbicides and insect pesticides, ploughing and soil disturbance (generating sediment) and a high potential for the deposition of organic trash from cane and cereals harvesting.

Minor saline inputs were associated with this land-use due to the potential for increased groundwater recharge rates in cropping areas leading to a potential rise in saline groundwater. This is due to the presence of bare ground (during planting/harvesting) or lowered water use of crops in comparison to deeper rooted native vegetation.

Harvesting or exploitation

No explicit association between the harvesting of plant or animal biota was made with dry-land cropping and horticulture.

Changes to water regime

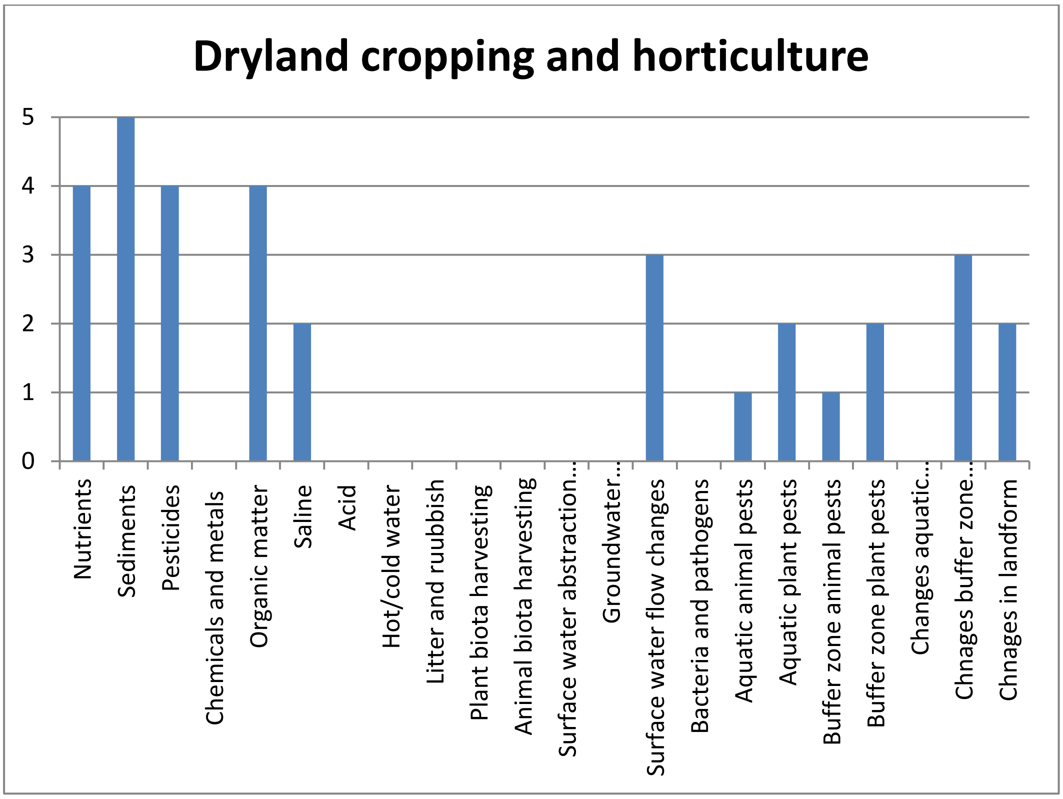
Due to the nature of this land-use the pressure of direct abstraction of water from surface or groundwater sources was ranked as ***none***. A score of ***moderate*** was recorded for changes to natural surface water flow patterns due to land management practices and effects likely to associated with cropped/horticultural land (e.g. ploughing, mulching, topographic changes, increased rainfall capture).

Biological introductions and perpetuation

Pest introductions and perpetuation were considered to have a generally low level of association with dry-land cropping and horticulture. Plant pest species (aquatic and buffer zone) were ranked as ***minor*** due to the potential for crops to escape or encroach into the surrounding environment and invade both aquatic and terrestrial wetland environments. Bacteria and pathogens were considered to have no association with this land-use and animal pest species (aquatic and buffer zone) introductions or perpetuation are considered to be ***very minor*** (taking into account increased likelihood of rodents)

Alteration/disturbance of habitat

Direct disturbance/alteration of the buffer zone habitat was considered to have a ***moderate*** association and physical habitat disturbance a ***minor*** association with dry-land cropping and horticulture. This was largely considered to be due to edge effects of field ploughing/machinery access impacting on adjacent wetland areas and their surrounds.



Irrigated cropping and horticulture

Inputs direct/indirect

There was a ***very high*** degree of potential association recorded with this land-use for nutrients, sediments and pesticide input pressures. This was due to the a high degree of nutrient, soil and weed and pest management measures considered likely to take place in irrigated and intensive horticultural. Generally pressures were perceived to be higher than dry-land cropping/horticulture due to the application of water and the greater potential for mobilisation of nutrients, sediments and pesticides via this pathway.

Saline and acid inputs were considered to have ***high*** and ***moderate*** associations respectively with irrigated cropping/horticulture. Salinity can occur through the addition of irrigation promoting rises in the water table and mobilisation of salts to the soil surface. It must be noted that acid inputs were perceived to *only* occur in areas where acid sulphate soils exist (which are relatively limited and are mainly in coastal eastern Australia) through soil disturbance and changes in the watertable resulting from irrigation practices. This particular pressure is only to be considered in these geographical areas.

Harvesting or exploitation

No explicit association between the harvesting of plant or animal biota was made with irrigated cropping and horticulture.

Changes to water regime

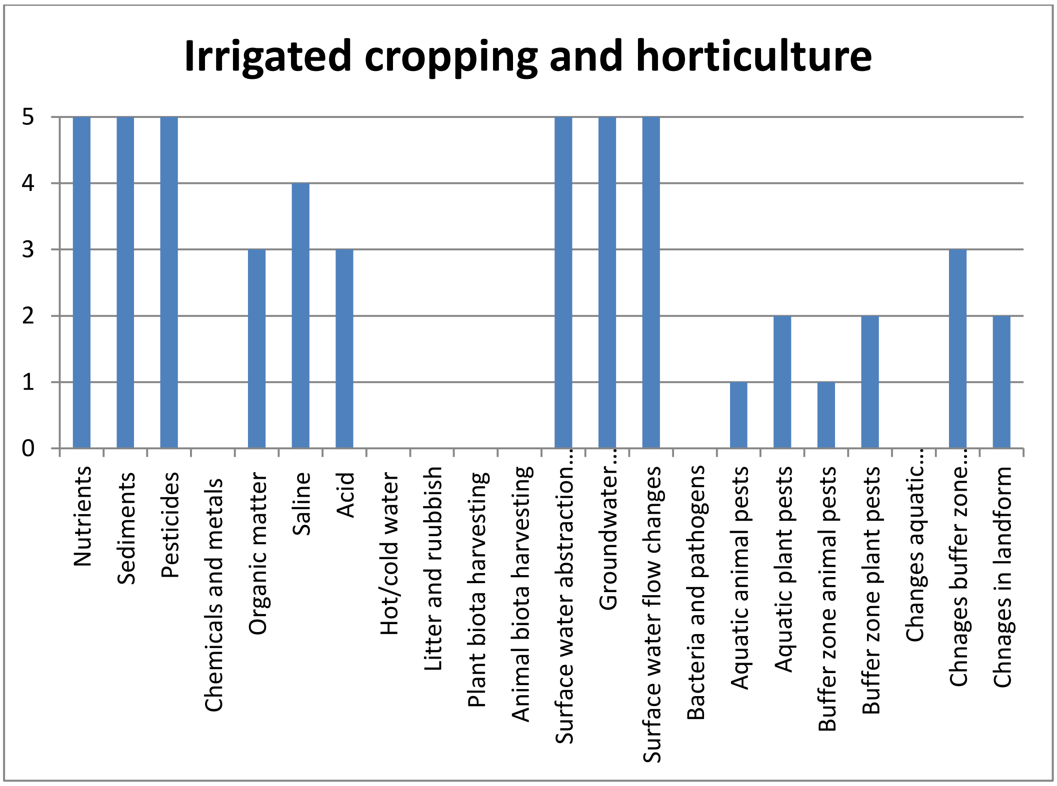
Changes to the water regime driven by irrigated agriculture were considered to be ***very high*** for surface water abstraction, groundwater abstraction and changes to natural flow patterns (creation of dams/irrigation basins etc.). This was due to the known high level of water use arising from irrigation practices from all these sources.

Biological introductions and perpetuation

Pest introductions and perpetuation were considered to have a generally low level of association with irrigated cropping and horticulture and were considered the same as those arising from dry-land horticulture (see above).

Alteration/disturbance of habitat

Direct disturbance/alteration of the buffer zone habitat was considered to have a ***moderate*** association and physical habitat disturbance a ***minor*** association with irrigated cropping and horticulture. As for dry-land cropping and horticulture this was largely considered to be due to edge effects of field ploughing/machinery access impacting on adjacent wetland areas and their surrounds.



Aquaculture

Inputs direct/indirect

Aquaculture facilities were assessed as being strongly associated with potential inputs of nutrients (***very high***) and area are likely due to supplementary feeding and increased faecal matter from high stocking densities of aquatic animals (a ***moderate*** association with organic matter was also recorded for the same reason). Use of pesticides (e.g. algaecides) and pharmaceutical chemicals for treatment of stock were expected and these were deemed ***high*** as risk in most cases they were expected to be specific to aquatic species and therefore directly of influence in a wetland environment. A ***moderate*** association with saline inputs was recorded for aquaculture due to the propagation of saline/brackish water species (e.g. barramundi, prawns) in saline ponds which is known to be relatively common practice.

Harvesting or exploitation

No explicit association between the harvesting of *natural* plant or animal biota from wetlands was made with aquaculture land-use. The harvesting of the culture organisms is not considered.

Changes to water regime

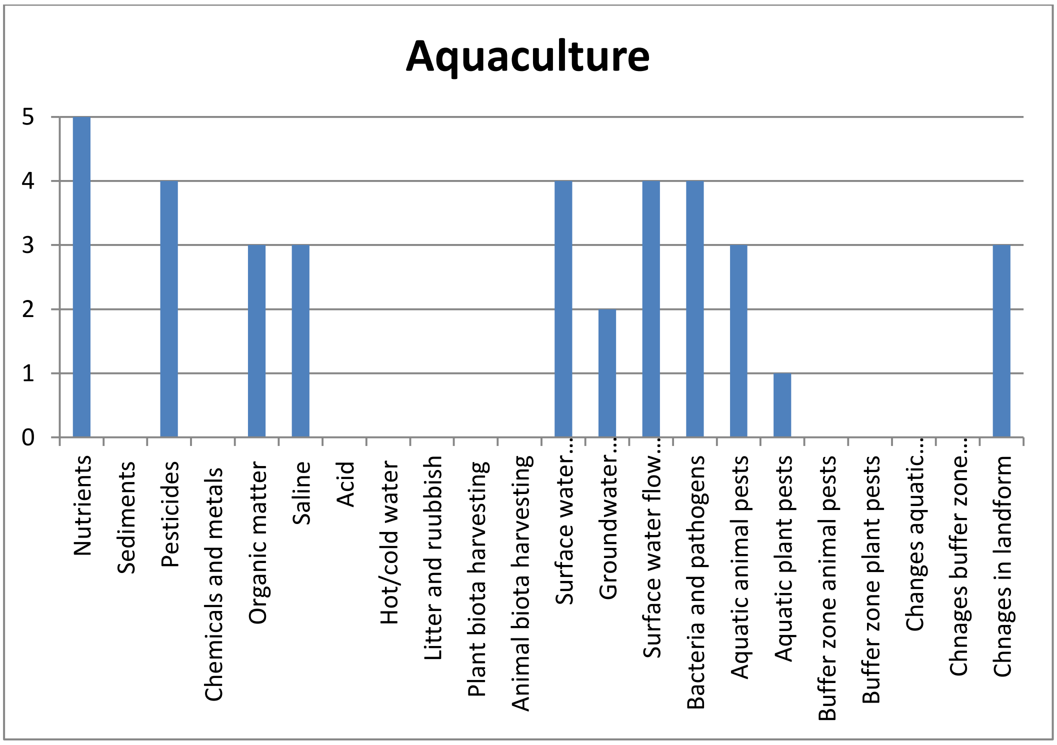
A ***high*** association with abstraction of surface water and natural surface water flow changes were recorded. Water use for aquaculture is fundamental and in most cases the primary water source was deemed to be surface water abstraction (groundwater abstraction was classified as ***minor***). Surface water flow regime changes were primarily associated with the construction of bunds, levees and drainage works which were considered to be common in aquaculture facilities.

Biological introductions and perpetuation

The potential for aquaculture to drive the introduction of bacteria and pathogens was assessed as ***high***. This takes into account the specificity of bacteria and pathogens within the livestock that are potentially directly transferable to aquatic wetland species. The potential for the introduction of aquatic animal species (e.g. from the escape of captive stock) was considered to be ***moderate*** (in most cases safeguards were considered to be in place to prevent escape). There was perceived to be a ***very minor*** potential for the introduction and perpetuation of pest plant species due to the higher nutrient levels expected but in most cases it was expected that macrophyte and algal growth would be strictly managed.

Alteration/disturbance of habitat

Direct disturbance/alteration of wetland aquatic species/habitats and buffer zone species/habitats were considered to have no association with aquaculture. The potential for physical habitat changes due to earthworks and landform modification for the creation of holding ponds etc. were considered to be ***moderate***.



Intensive animal production

Inputs direct/indirect

The intensive production of animals (e.g. poultry farms, feedlots, piggeries) are considered to be potential sources of increased inputs of nutrients (***very high***), organic matter (***very high***), sediments (***moderate***) and pesticides (***high***). This is due to the reliance on supplementary feed, high faecal outputs and use of pesticide and veterinary treatments associated very high stocking densities of animals.

Harvesting or exploitation

No association between the harvesting of plant or animal biota from wetlands was made with intensive animal production.

Changes to water regime

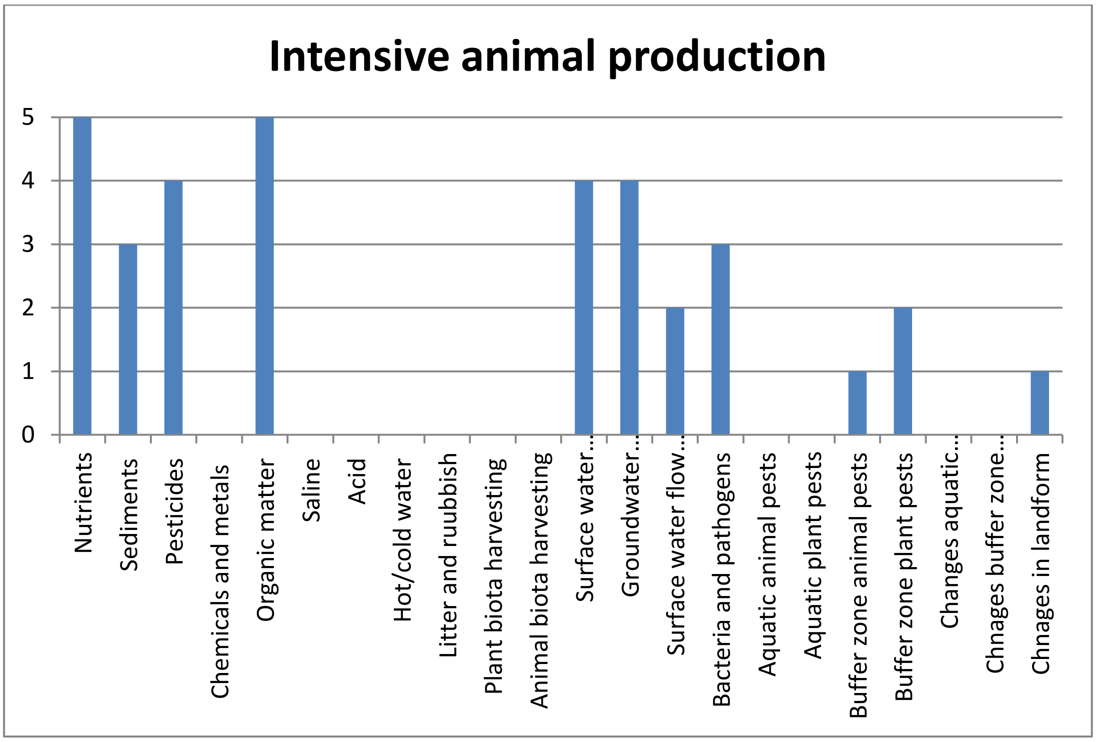
The use of water for livestock watering, wash down etc. is likely to be considerable and as such was assessed as ***high*** for both the potentially abstraction of surface and groundwater. A ***minor*** association was recorded for changes to natural surface water flow patterns due to the presence of hard surfaces, drainage etc. likely to be present in this land-use.

Biological introductions and perpetuation

The potential for raised levels of bacteria and pathogens (arising, for instance, from faecal matter or direct transmission from poultry to wetland wildfowl) was classified as ***moderate***. Regarding the introduction and perpetuation of animal pest species, the potential for increased rodent activity due to the presence of animal feeds, was classified as ***very minor***. The introduction of buffer zone pest plant species was recorded as ***minor*** due to the potential for plant dispersal through animal or machinery movements (in particular this land-use category includes facilities such as stock sale yards with large scale movement of vehicles and animals).

Alteration/disturbance of habitat

The potential for physical habitat changes within a wetland as a result of this land-use were considered to be ***very minor*** (potentially only through vehicle movements etc.). No other associations with habitat disturbance were recorded due to the fact that livestock are confined within an intensive management setting.



Manufacturing and Industrial

Inputs direct/indirect

Due to the high potential for diversity in manufacturing and industrial practices within this land-use group (which could include food processing, industrial manufacturing complexes, abattoirs, bulk grain storage facilities, oil refineries etc.) some level of association was recorded for all the input pressures within this category. This reflects the large number of potential input pressure pathways and mechanisms that exist from this diversity of tertiary land-uses. Nutrients, chemicals and metals and litter and rubbish inputs were categorised as ***moderate*** in their association. ***Minor*** associations were allocated to sediment, saline, acid and hot and cold water inputs and ***very minor*** for pesticides. These may be underestimated as some manufacturing/industrial waste streams can generate significant pressures when unchecked.

Harvesting or exploitation

No association between the harvesting of plant or animal biota from wetlands was made with manufacturing and industrial land-use.

Changes to water regime

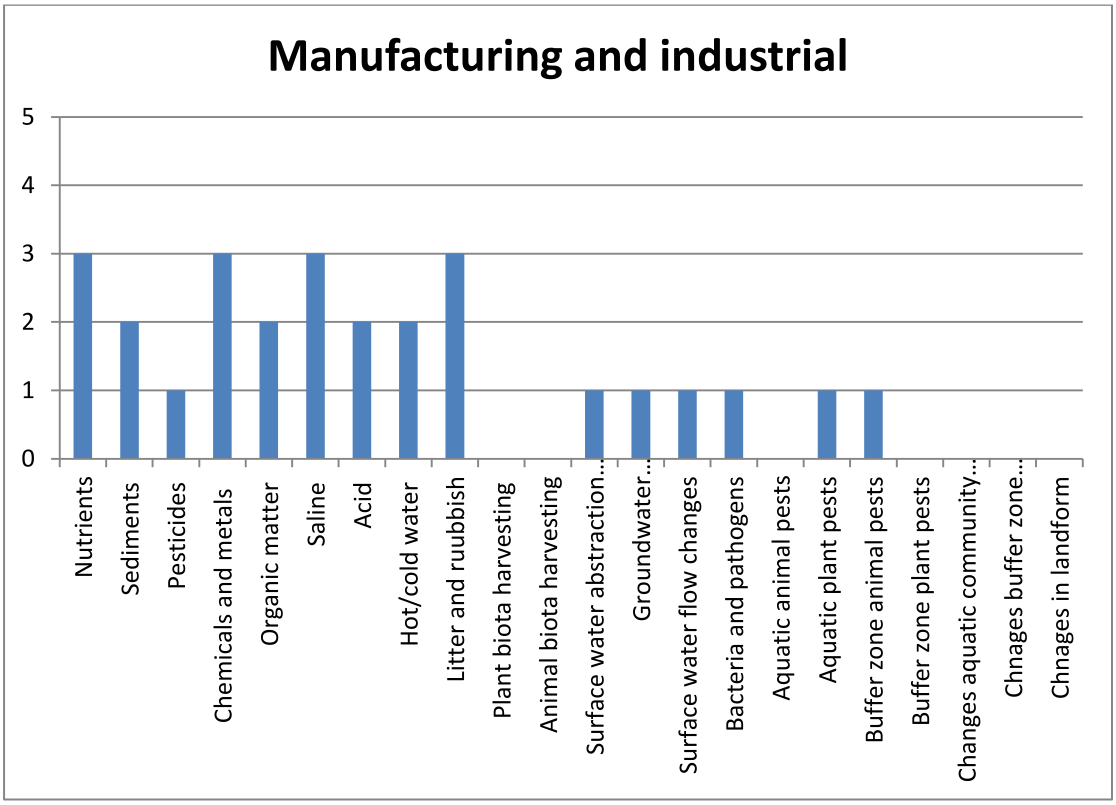
All water regime pressures were recorded as ***very minor***. While water use was recognised as key to many processes it was considered that a treated water supply would be primarily required for most industrial/manufacturing processes. Water flow regime change was also deemed to be ***very minor*** as in most cases this land-use is confined to a specific footprint (e.g. building, compound) that restricts the influence of the land-use outside its boundaries.

Biological introductions and perpetuation

Generally the association of pest species with manufacturing and industrial land-use is considered low. ***Very minor*** association was recorded for bacteria and pathogens (due to the potential for this to arise from abattoirs or food processing), aquatic pest plant species (due to perpetuation of algal blooms) and buffer zone animal species (increased likelihood of rodents).

Alteration/disturbance of habitat

No association between the alteration/disturbance of habitat was made with manufacturing and industrial land-use.



Waste treatment and disposal

Inputs direct/indirect

Direct and indirect inputs of all pressure categories were in some way associated with waste treatment and disposal (with the exception of hot/cold water inputs) due to the potential for disposal or release of all pollutants. The most important of these were classified as ***moderate*** and were nutrients, organic matter and salinity with the primary source identified as sewage treatment plant discharges containing all three of these inputs. Salinity was recognised as being particularly difficult to treat and remove from effluent. Litter and rubbish (primarily due to the inclusion of landfill sites and solid waste transfer stations in this category) was also recorded as ***moderate***. Other inputs were recorded as ***minor*** or ***very minor***.

Harvesting or exploitation

No association between the harvesting of plant or animal biota from wetlands was made with waste treatment and disposal.

Changes to water regime

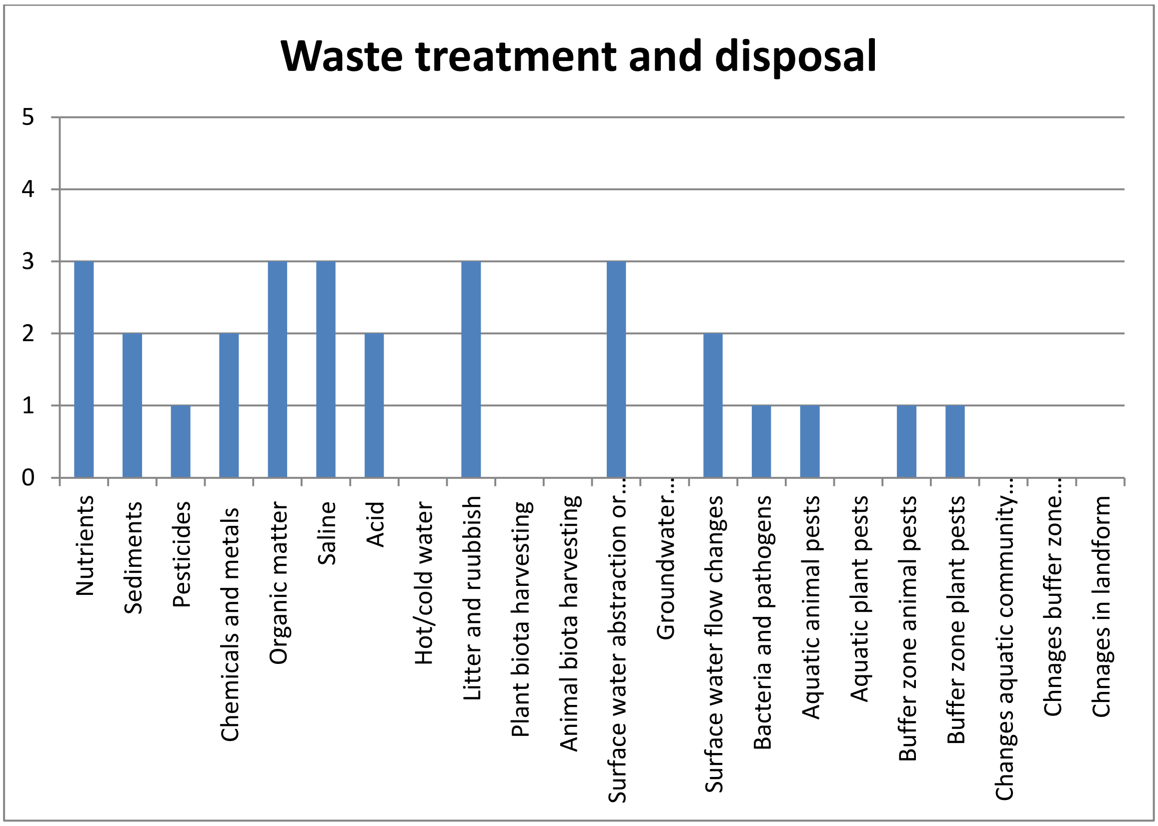
A ***moderate*** association between surface water additions was recorded due to the potential for large scale discharges of effluent from sewage treatment plants into receiving waters. While this was recognised as being likely to be into the riverine environment the potential for changes to the water regime in wetlands (from downstream effects) was still recognised. Changes to the surface water flow patterns were classified as ***minor*** due to earthworks and topographic changes associated with landfill sites and sewage treatment infrastructure.

Biological introductions and perpetuation

Bacteria and pathogens as a component of sewage effluent were recognised as being a potential pressure but due the non-specificity to wetland species were classified as ***very minor***. Waste treatment and disposal was classified as having a ***very minor*** association with aquatic pest animal species (e.g. from changes to macro-invertebrate biota either from direct introductions from sewage treatment ponds or as a result of changes in water quality associated with the discharges), buffer zone pest animal species (e.g. the increased likelihood of rodents or birds associated with sewage or solid waste facilities) and buffer zone plant species (from disposal of garden waste material and soil at landfill sites and transfer stations). Aquatic pest plant species were not recorded as being associated with this land-use.

Alteration/disturbance of habitat

No association between the alteration/disturbance of habitat was made with waste treatment and disposal.



Urban

Inputs direct/indirect

Due to the inherent pressures arising from the presence of humans in urban areas there is a strong association of input pressures with this land-use category. Litter and rubbish inputs were classified as ***very high*** due to this pressure being directly related to the population size in a particular area. Sediment and nutrient inputs were recorded as **high** (e.g. increased run-off from impervious surfaces, fertilizer application in gardens, parks and sportsgrounds etc.), while pesticides, chemicals and metals, organic matter and acid inputs were all categorised as **moderate** in their association with urban land-use. ***Minor*** was recorded for saline and hot/cold water inputs.

Harvesting or exploitation

The harvesting of plants and animal biota was classified as ***high*** and ***very high*** respectively in its association with urban areas. The proximity of urban environments, and therefore the relative ease of access for people to wetland areas, enables the exploitation of floral and faunal resources.

Changes to water regime

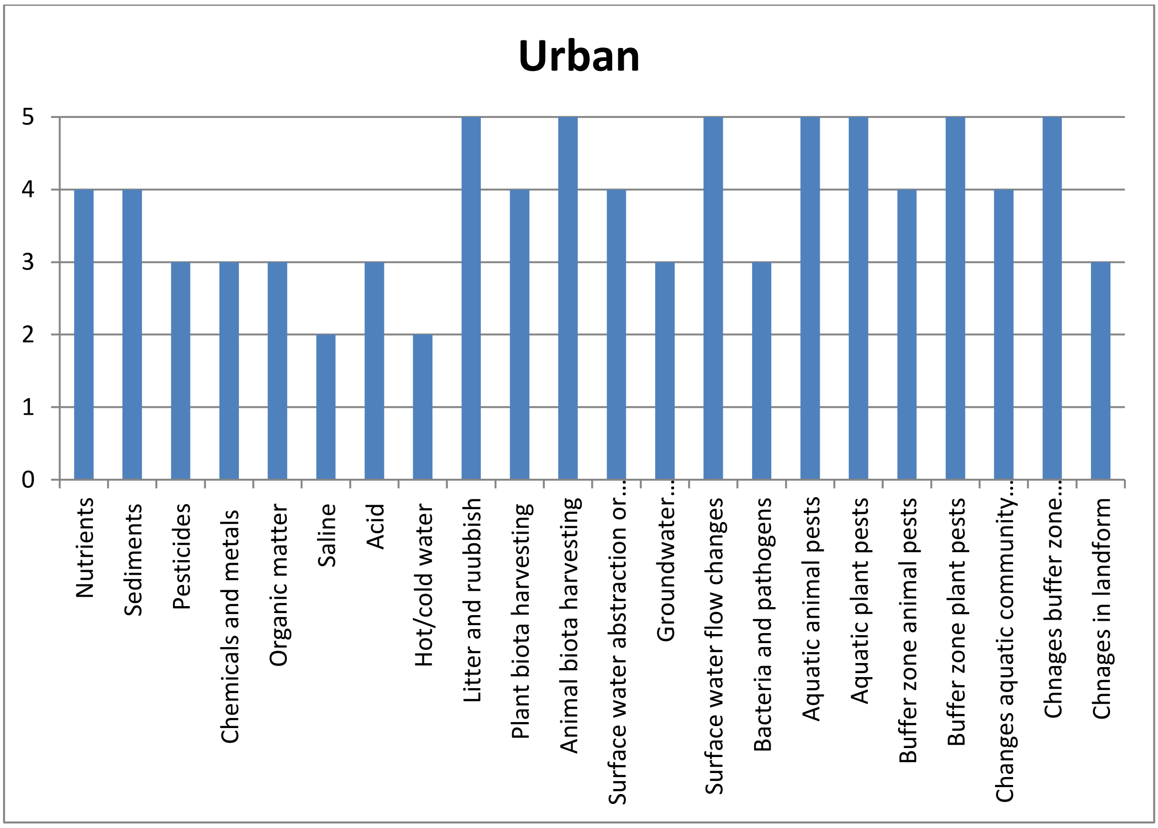
Overall there was a very strong association of changes to the water regime with urban land-use. Surface water abstraction/addition (e.g. Surface water abstraction for irrigation, water discharges from rural residential sewage and septic systems—which are not accounted for under waste treatment and disposal) was categorised as ***high*** and changes to the natural surface water flow patterns were regarded as ***very high*** in urban environments (e.g. increased run-off rates from impervious surfaces, culverts, channelling of watercourses, rainwater harvesting and storage). Groundwater abstraction and addition was recorded as ***moderate***, acknowledging that groundwater use does occur in urban environments (especially in drier and more remote rural areas) however, it was deemed less important than other pressures to the water regime.

Biological introductions and perpetuation

The introduction and perpetuation of pests was very strongly associated with urban areas. All pressures were recorded against this land-use and aquatic pest animals and plants, and buffer zone pest plants were all ranked as being ***very high*** in their association. The deliberate release of aquatic animals and plants (from aquaria and garden pond escapes etc.) are a well documented source of aquatic pests into the environment. Terrestrial plant pests (from garden escapes, and the spread of weed seeds and plant material by the movement of humans and vehicles etc.) were recorded as ***high***. The introduction of bacteria and pathogens were seen as ***moderate*** (due to the high potential pathways for these organisms to enter wetlands from rural residential sewage treatment disposal but also accounting for their lack of specificity to wetland organisms).

Alteration/disturbance of habitat

Alteration and disturbance of habitats were classified as having a ***very high*** and ***high*** association with buffer zone species and aquatic species respectively. Physical habitat changes were recorded as ***moderate***. The impacts of human movements and activities in these areas are seen as the primary factor in driving disturbance and alterations to these ecosystem components.



Transport

Inputs direct/indirect

Due to the access provided by transport corridors (particularly roads) the potential pressure pathways for the distribution of litter and rubbish inputs was recorded as ***high***. ***Moderate*** associations were recorded for sediment, chemicals and metals, and saline inputs. Increased run-off from transport corridors (particularly unsealed roads as a source of sediment, roads/rail/airstrips as sources of chemicals (oils, fuel etc. from cars, trucks, trains, planes) and there can be salinisation of the soil due to disruption of subsurface water flow. Inputs of nutrients, pesticides and organic matter were categorised as ***very minor***.

Harvesting or exploitation

In common with urban land-use category the harvesting of plants and animal biota was classified as ***high*** and ***very high*** respectively in its association with transport due to the provision of access for people to wetland areas, enabling the direct exploitation of floral and faunal resources (including recreational fishing, specimen collection etc.).

Changes to water regime

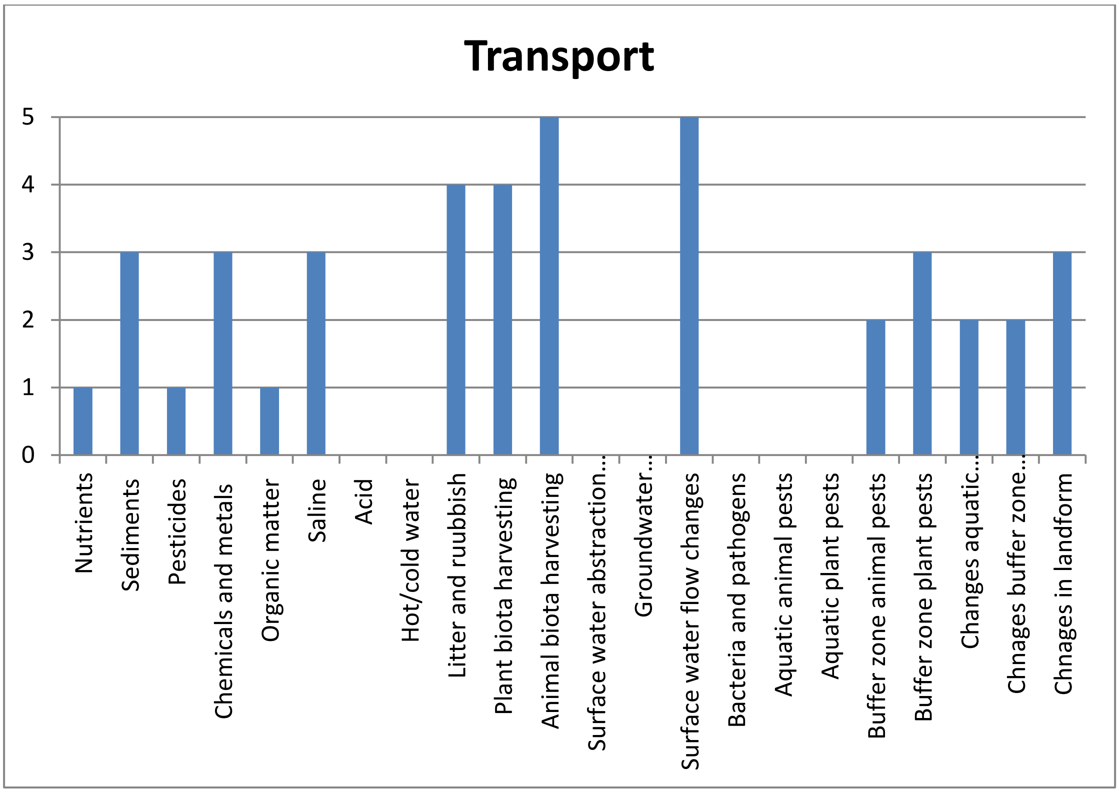
Changes to the natural surface water flow patterns from roads and railways, in particular, were seen as important barriers/modifiers to flow (from their construction, embankments, associated drainage channels etc.) and the presence of impervious surfaces (sealed roads, airports, ports etc.) were also recognised in contributing to a ***very high*** degree of association for transport land-uses with this pressure category. No association was made with surface or groundwater abstraction/addition for this land-use.

Biological introductions and perpetuation

The introduction and perpetuation of buffer zone (terrestrial) pest plant and animal species were recognised as ***minor*** and ***moderate*** respectively for transport. Linear transport corridors are known to act as a mechanism for the dispersion of plants (seed and plant fragments) from the movement of vehicles and trains, and facilitating the perpetuation of pest plants in cleared and disturbed areas alongside the road and railway. Likewise transport corridors can act as pathways for the distribution for terrestrial feral animals such as pigs. Transport was not considered to be directly driving the introduction or proliferation of aquatic plant or animal species, or bacteria and pathogens.

Alteration/disturbance of habitat

All pressures within the category of habitat alteration or disturbance were associated with this land-use to some degree. Considered the most relevant (***moderate***) were changes to landform/physical habitat and ***minor*** associations with disturbance to aquatic and buffer zone species/habitats were recorded. This was deemed to potentially arise from earthworks /use of machinery and the passage of vehicles (particularly on unsealed roads where vehicles can 'spread' on to the verges to bypass flooded or rutted sections).



Mining

Inputs direct/indirect

Mining was perceived to have the potential to drive several input pressures. Of most significance was its association with chemicals and metals inputs, particularly from extractive heavy metal mining practices and also in particular arising from leachate from abandoned mines of which there are many thousands in Queensland, and was therefore classified as ***very high***. A ***high*** degree of association was also recorded for inputs of sediments, saline and acid inputs (from abandoned mine drainage, mine de-watering or storage ponds which can potentially deliver all of these input pressures). A ***minor*** association was recorded for nutrients, and ***very minor*** for organic matter (potentially arising from vegetation clearing in open cast mining practices). No association was made for pesticides, hot/cold water or litter and rubbish inputs arising from mining practices.

Harvesting or exploitation

No association between the harvesting of plant or animal biota from wetlands was made with mining land-use.

Changes to water regime

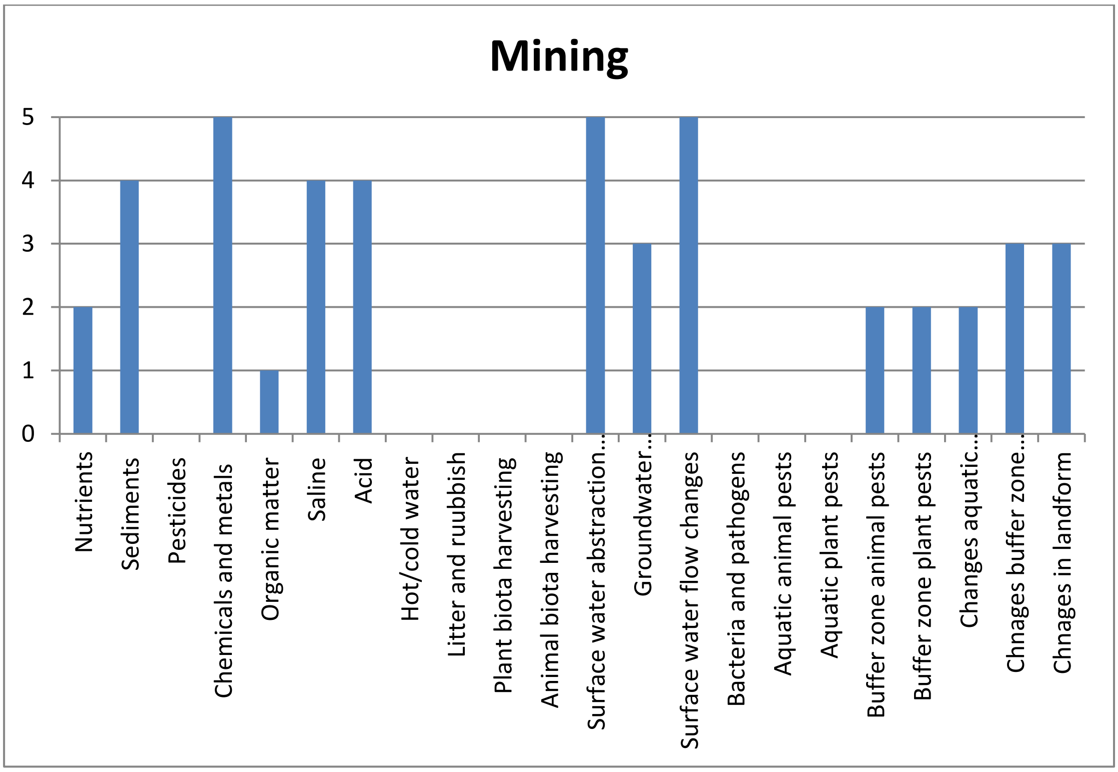
This pressure category was seen as being particularly associated with mining. Surface water abstraction or addition (e.g. from settlement ponds or the addition of abstracted groundwater from CSG mining activities being discharged into the surface water environment) and changes to the surface flow regimes (from the sometimes landscape scale topographic changes and drainage modification which can occur) were both categorised as ***very high***. The abstraction of groundwater was also recognised as an issue (again particularly with respect to the emerging coal seam gas industry in Queensland) and mining generally was classified as a ***moderate*** driver of this pressure to wetlands.

Biological introductions and perpetuation

Only ***minor*** associations between mining and buffer zone pest plant and animal species were recorded under this pressure category. This was deemed due to the potential for spreading of seed and plant fragments from vehicle movements, weed proliferation in areas of disturbed ground, etc. Terrestrial animal pests were also perceived to be slightly more prevalent in disturbed areas and along vehicle access routes. Aquatic pest plants and animals and bacteria and pathogens were not associated with mining activities.

Alteration/disturbance of habitat

Due to the nature of land disturbance undertaken in many mining activities there was thought to be a ***moderate*** association with physical habitat alteration and disturbance/alteration of buffer zone species/habitats within this pressure grouping. It was deemed less likely (***minor***) that mining activities would directly disturb or alter aquatic ecosystems.



Water (artificial)

Inputs direct/indirect

All pressures within this category (with the exception of chemicals and metals inputs) were in some way associated with artificial water bodies. The most important of these were nutrients, sediments and organic matter inputs which were categorised as ***moderate***.

Harvesting or exploitation

No association between the harvesting of plant or animal biota from wetlands was made with artificial water.

Changes to water regime

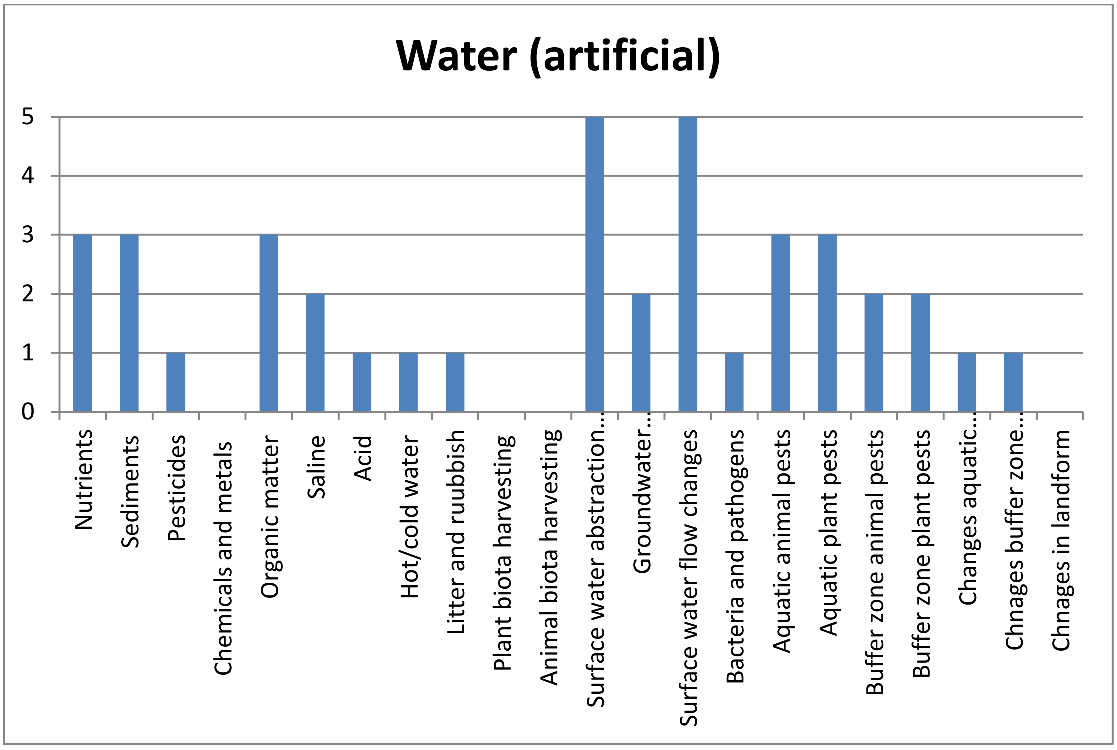
This land-use category (which by its nature is an alteration of the natural flow regime) includes reservoirs, farm dams, artificial channels for irrigation, aqueducts etc. and so the potential for alteration of natural flow regimes and surface water abstraction/addition are considered very important. As such these two pressures were classified as ***very high***. A ***minor*** association was recorded for groundwater abstraction/addition (mainly from the potential for changes to groundwater levels associated with the presence of artificial water bodies e.g. stored water recharging shallow aquifers or drainage channels affecting sub-surface water flows).

Biological introductions and perpetuation

Artificial water bodies were considered to be a ***moderate*** driver of aquatic pest plant and animal species introductions and perpetuation. This level of association was recorded as artificial water bodies have a demonstrated link with a higher occurrence of algal blooms, and the potential to spread aquatic pest plant species through flows along artificial channels or reservoir releases. Deliberately stocked and/or released aquatic animal biota (e.g. stocked fish/crayfish—even if native they may be outside their natural range and present at above natural levels) were also considered important. The likelihood of toxins from blue-green algal growth was considered in the ***very minor*** association accorded to bacteria and pathogens. Buffer zone pest plant and animal species were considered to be ***minor*** in their link to artificial water and were recognised primarily from the ability to provide a vector for weed dispersal through water flow and also to act as pathways through the landscape for terrestrial animal pests.

Alteration/disturbance of habitat

Disturbances to wetland aquatic and buffer zone habitats and species were recognised as ***very minor*** due to the increased potential for the access of humans (for recreational purposes) or livestock to those wetlands adjoining artificial water bodies such as reservoirs or farm dams. A direct link between artificial water as a land-use and physical habitat changes to a wetland was not recognised.



Appendix B Workshop participants

Workshop participants (30th April 2013)

Forename	Surname	Organisation	Position
Angela	Arthington	Griffith University, Qld	Emeritus professor, Australian Rivers Institute
Donna	Audas	GBRMPA	A/Manager Coastal Ecosystems
John	Bennett	EHP	Chief Scientific Officer—Reef Water Quality
Geoff	Borschmann	DSITIA—Wetland Science	Senior Natural Resource Officer
Jon	Brodie	James Cook University, The Centre for Tropical Water and Aquatic Ecosystem Research	Leader, Catchment to Reef Research Group
Chris	Carrol	DNRM—Rockhampton	Theme Leader—Reef Science
Darren	Fielder	Redleaf projects	Environmental Consultant
Andy	Grodecki	DSITIA—Science Strategy and Integration	Facilitator
Rob	Hassett	DNRM	Senior Natural Resource Officer
Nyssa	Henry	DSITIA	Program Manager—Reef Science
Steven	Howell	EHP—Biodiversity Assessment Team	Manager, Biodiversity Assessment
Arthur	Knight	EHP—Queensland Wetlands Program	Senior Biodiversity Planning Officer
Jaye	Lobegeiger	DSITIA—Water Planning Ecology	Scientist
Reiner	Mann	DSITIA—Aquatic Ecosystem Risk and Decision Support	Principal Scientist
Jon	Marshall	DSITIA—Water Planning Ecology	Principal Scientist
Glenn	McGregor	DSITIA—Water Planning Ecology	Principal Scientist
Shauna	Naron	EHP—Queensland Wetlands Program	Project Manager
Peter	Negus	DSITIA—Water Planning Ecology	Senior Scientist (Team Manager)
Chris	Pennay	DSITIA—Queensland Herbarium	Scientist (Queensland Herbarium)
Claire	Peterken	Reef Catchments	
Peter	Richardson	DSITIA—Wetland Science	Senior spatial analyst
Paul	Roff	EHP—Environmental Planning	Manager
Mike	Ronan	EHP—Queensland Wetlands Program	Manager—Queensland Wetlands Program
Bill	Senior	DSITIA—Wetland Science	Senior Environmental officer (Wetland Sciences)
Chris	Small	EHP	Scientist (wetlands)
Neil	Tripodi	DSITIA—Aquatic Ecosystem Risk and Decision Support	Principal Scientist (Water Assessment and Systems)
Maria	Vandergragt	DSITIA—Wetland Science	Principal Environmental officer (Wetland Sciences)

Bruce	Wilson	DSITIA—Queensland Herbarium	Chief Scientist (Regional ecosystem survey and mapping)

DSITIA Department of Science, Information Technology, Innovation and the Arts
EHP Department of Environment and Heritage Protection
DNRM Department of Natural Resources and Mines
GBRMPA Great Barrier Reef Marine Park Authority

Workshop participants (6th June 2013)

Forename	Surname	Organisation	Position
Geoff	Borschmann	DSITIA—Wetland Science	Senior Natural Resource Officer
Rob	Hassett	DNRM	Senior Natural Resource Officer
Erin	Kenna	EHP—Biodiversity Assessment Team	Principal Spatial Analyst (Team Leader)
Andrew	Moss	DSITIA—Aquatic Ecosystem Health	Principal Scientist
Peter	Negus	DSITIA—Water Planning Ecology	Senior Scientist (Team Manager)
Pete	Richardson	DSITIA—Wetland Science	Senior spatial analyst
Mike	Ronan	EHP—Queensland Wetlands Program	Manager - Queensland Wetlands Program
Bill	Senior	DSITIA—Wetland Science	Senior Environmental officer (Wetland Sciences)
Neil	Tripodi	DSITIA—Aquatic Ecosystem Risk and Decision Support	Principal Scientist (Water Assessment and Systems)
Maria	Vandergragt	DSITIA—Wetland Science	Principal Environmental officer (Wetland Sciences)
Bruce	Wilson	DSITIA—Queensland Herbarium	Chief Scientist (Regional ecosystem survey and mapping)

Appendix C—Australian Land Use and Management Classification

[Show greater detail]

AUSTRALIAN LAND USE AND MANAGEMENT CLASSIFICATION Version 7 (Revision as at 19 May 2010)

1 Conservation and Natural Environments

1.1.0 Nature conservation
- 1.1.1 Strict nature reserves
- 1.1.2 Wilderness area
- 1.1.3 National park
- 1.1.4 Natural feature protection
- 1.1.5 Habitat/species management area
- 1.1.6 Protected landscape
- 1.1.7 Other conserved area

1.2.0 Managed resource protection
- 1.2.1 Biodiversity
- 1.2.2 Surface water supply
- 1.2.3 Groundwater
- 1.2.4 Landscape
- 1.2.5 Traditional indigenous uses

1.3.0 Other minimal use
- 1.3.1 Defence land - natural areas
- 1.3.2 Stock route
- 1.3.3 Residual native cover
- 1.3.4 Rehabilitation

minimum level of attribution

2 Production from Relatively Natural Environments

2.1.0 Grazing native vegetation

2.2.0 Production forestry
- 2.2.1 Wood production
- 2.2.2 Other forest production

3 Production from Dryland Agriculture and Plantations

3.1.0 Plantation forestry
- 3.1.1 Hardwood plantation
- 3.1.2 Softwood plantation
- 3.1.3 Other forest plantation
- 3.1.4 Environmental forest plantation

3.2.0 Grazing modified pastures
- 3.2.1 Native/exotic pasture mosaic
- 3.2.2 Woody fodder plants
- 3.2.3 Pasture legumes
- 3.2.4 Pasture legume/grass mixtures
- 3.2.5 Sown grasses

3.3.0 Cropping
- 3.3.1 Cereals
- 3.3.2 Beverage and spice crops
- 3.3.3 Hay and silage
- 3.3.4 Oil seeds
- 3.3.5 Sugar
- 3.3.6 Cotton
- 3.3.7 Alkaloid poppies
- 3.3.8 Pulses

3.4.0 Perennial horticulture
- 3.4.1 Tree fruits
- 3.4.2 Oleaginous fruits
- 3.4.3 Tree nuts
- 3.4.4 Vine fruits
- 3.4.5 Shrub nuts, fruits and berries
- 3.4.6 Perennial flowers and bulbs
- 3.4.7 Perennial vegetables and herbs
- 3.4.8 Citrus
- 3.4.9 Grapes

3.5.0 Seasonal horticulture
- 3.5.1 Seasonal fruits
- 3.5.2 Seasonal nuts
- 3.5.3 Seasonal flowers and bulbs
- 3.5.4 Seasonal vegetables and herbs

3.6.0 Land in transition
- 3.6.1 Degraded land
- 3.6.2 Abandoned land
- 3.6.3 Land under rehabilitation
- 3.6.4 No defined use
- 3.6.5 Abandoned perennial horticulture

4 Production from Irrigated Agriculture and Plantations

4.1.0 Irrigated plantation forestry
- 4.1.1 Irrigated hardwood plantation
- 4.1.2 Irrigated softwood plantation
- 4.1.3 Irrigated other forest plantation
- 4.1.4 Irrigated environmental forest plantation

4.2.0 Grazing irrigated modified pastures
- 4.2.1 Irrigated woody fodder plants
- 4.2.2 Irrigated pasture legumes
- 4.2.3 Irrigated legume/grass mixtures
- 4.2.4 Irrigated sown grasses

4.3.0 Irrigated cropping
- 4.3.1 Irrigated cereals
- 4.3.2 Irrigated beverage and spice crops
- 4.3.3 Irrigated hay and silage
- 4.3.4 Irrigated oil seeds
- 4.3.5 Irrigated sugar
- 4.3.6 Irrigated cotton
- 4.3.7 Irrigated alkaloid poppies
- 4.3.8 Irrigated pulses
- 4.3.9 Irrigated rice

4.4.0 Irrigated perennial horticulture
- 4.4.1 Irrigated tree fruits
- 4.4.2 Irrigated oleaginous fruits
- 4.4.3 Irrigated tree nuts
- 4.4.4 Irrigated vine fruits
- 4.4.5 Irrigated shrub nuts, fruits and berries
- 4.4.6 Irrigated perennial flowers and bulbs
- 4.4.7 Irrigated perennial vegetables and herbs
- 4.4.8 Irrigated citrus
- 4.4.9 Irrigated grapes

4.5.0 Irrigated seasonal horticulture
- 4.5.1 Irrigated seasonal fruits
- 4.5.2 Irrigated seasonal nuts
- 4.5.3 Irrigated seasonal flowers and bulbs
- 4.5.4 Irrigated seasonal vegetables and herbs
- 4.5.5 Irrigated turf farming

4.6.0 Irrigated land in transition
- 4.6.1 Degraded irrigated land
- 4.6.2 Abandoned irrigated land
- 4.6.3 Irrigated land under rehabilitation
- 4.6.4 No defined use (irrigation)
- 4.6.5 Abandoned irrigated perennial horticulture

5 Intensive Uses

5.1.0 Intensive horticulture
- 5.1.1 Shadehouses
- 5.1.2 Glasshouses
- 5.1.3 Glasshouses (hydroponic)
- 5.1.4 Abandoned intensive horticulture

5.2.0 Intensive animal husbandry
- 5.2.1 Dairy sheds and yards
- 5.2.2 Cattle feedlots
- 5.2.3 Sheep feedlots
- 5.2.4 Poultry farms
- 5.2.5 Piggeries
- 5.2.6 Aquaculture
- 5.2.7 Horse studs
- 5.2.8 Stockyards/saleyards
- 5.2.9 Abandoned intensive animal husbandry

5.3.0 Manufacturing and industrial
- 5.3.1 General purpose factory
- 5.3.2 Food processing factory
- 5.3.3 Major industrial complex
- 5.3.4 Bulk grain storage
- 5.3.5 Abattoirs
- 5.3.6 Oil refinery
- 5.3.7 Sawmill
- 5.3.8 Abandoned manufacturing and industrial

5.4.0 Residential and farm infrastructure
- 5.4.1 Urban residential
- 5.4.2 Rural residential with agriculture
- 5.4.3 Rural residential without agriculture
- 5.4.4 Remote communities
- 5.4.5 Farm buildings/infrastructure

5.5.0 Services
- 5.5.1 Commercial services
- 5.5.2 Public services
- 5.5.3 Recreation and culture
- 5.5.4 Defence facilities - urban
- 5.5.5 Research facilities

5.6.0 Utilities
- 5.6.1 Fuel powered electricity generation
- 5.6.2 Hydro electricity generation
- 5.6.3 Wind farm electricity generation
- 5.6.4 Electricity substations and transmission
- 5.6.5 Gas treatment, storage and transmission
- 5.6.6 Water extraction and transmission

5.7.0 Transport and communication
- 5.7.1 Airports/aerodromes
- 5.7.2 Roads
- 5.7.3 Railways
- 5.7.4 Ports and water transport
- 5.7.5 Navigation and communication

5.8.0 Mining
- 5.8.1 Mines
- 5.8.2 Quarries
- 5.8.3 Tailings
- 5.8.4 Extractive industry not in use

5.9.0 Waste treatment and disposal
- 5.9.1 Effluent pond
- 5.9.2 Landfill
- 5.9.3 Solid garbage
- 5.9.4 Incinerators
- 5.9.5 Sewage/sewerage

6 Water

6.1.0 Lake
- 6.1.1 Lake - conservation
- 6.1.2 Lake - production
- 6.1.3 Lake - intensive use
- 6.1.4 Lake - saline

6.2.0 Reservoir/dam
- 6.2.1 Reservoir
- 6.2.2 Water storage - intensive use/farm dams
- 6.2.3 Evaporation basin

6.3.0 River
- 6.3.1 River - conservation
- 6.3.2 River - production
- 6.3.3 River - intensive use

6.4.0 Channel/aqueduct
- 6.4.1 Supply channel/aqueduct
- 6.4.2 Drainage channel/aqueduct
- 6.4.3 Stormwater

6.5.0 Marsh/wetland
- 6.5.1 Marsh/wetland - conservation
- 6.5.2 Marsh/wetland - production
- 6.5.3 Marsh/wetland - intensive use
- 6.5.4 Marsh/wetland - saline

6.6.0 Estuary/coastal waters
- 6.6.1 Estuary/coastal waters - conservation
- 6.6.2 Estuary/coastal waters - production
- 6.6.3 Estuary/coastal waters - intensive use