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Rockhampton City Council
Natural Hazards and Climate Change Study
Final Report
December 2010



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Executive Summary

GHD Pty Ltd was engaged by Rockhampton Regional Council to prepare the Rockhampton Region Natural Hazards and Climate Change Study. The purpose of study was to provide a suite of specific planning and development outcomes to manage and prevent the impacts of natural hazards in the Rockhampton Region. This report will inform the Rockhampton Regional Council's Planning Scheme, and more specifically will:

- ▶ Develop recommendations for the identification and protection of land vulnerable to natural hazards and possible future climate change; and
- ▶ Propose planning scheme outcomes for the management and adaption of the impacts of natural hazards and climate change to inform the new Planning Scheme's Strategic Framework.

The natural hazards identified by Rockhampton Regional Council for inclusion in this study are:

- ▶ Storm Tide and Flooding;
- ▶ Severe Storm and Cyclones;
- ▶ Bushfire;
- ▶ Landslide;
- ▶ Erosion Prone Land;
- ▶ Acid Sulfate Soils;
- ▶ Sea Level Rise; and
- ▶ Climate Change.

The study is a desktop analysis to provide planning recommendations for the Rockhampton Region and the future strategic framework within the future local government planning scheme. The study therefore provides for desktop like planning recommendations and assumptions.

The methodology for the study has included a review of all available information, a desktop analysis of all existing plans, data and relevant reports and taken note of the two previous connected studies:

- ▶ The issues report (including a literature review and SWOT analysis); and
- ▶ The initial outcomes report (including strategic principles and outcomes, strategic mapping, check list for areas not spatially identified and principles to guide the PIP).

The recommendations provided in this report are focused on providing planning advice to manage the effects of natural hazards in the Rockhampton region and for each of the hazards the following sections are addressed:

- ▶ Hazard definition;
- ▶ Methods and approaches;
- ▶ Strategic planning;
- ▶ Statutory planning; and
- ▶ Key points for consideration.



The key points for consideration for each of the natural hazards provide guidance for future planning and identify the elements of the hazard which needs to be considered in the process of development of the planning scheme. The following table provides a summary of the key points for each of the natural hazards.

Natural Hazard	Key Points for Consideration
Storm Tide and Flooding	<ul style="list-style-type: none"> ▶ The risk, severity and frequency of the flood/storm tide risk; ▶ Understanding there are many scales of storm tide and flood events; ▶ Zoning, land use intensities and scale can complement and consider the natural hazard event of the particular area; ▶ Sensitive, smart and appropriate building design can allow for natural hazard events to occur while reducing the consequential impacts; and ▶ Storm tide and flooding events will continue to occur but their frequency and severity may differ due to climate change, thus the need for well-informed planning decisions.
Severe Storm and Cyclones	<ul style="list-style-type: none"> ▶ The risk, severity and frequency of the severe storm/cyclone risk; ▶ The hazards associated with a severe storm and cyclone event including: <ul style="list-style-type: none"> – Extreme winds; – Extreme waves; – Storm surges; – Storm tides; and – Flooding. ▶ Coastal areas are subject to greater impacts from extreme wind events than inland areas (DERM 2010); ▶ As predicted in the Climate Change in Queensland What the Science is Telling Us, cyclone events will increase between 22-56% in Queensland; ▶ Strategic land use planning and zoning has the ability to reduce harm to development and populations by placing appropriate development in areas of high, medium and low risk of severe storm and cyclone; ▶ Statutory planning has the ability of enforcing planning and management measures sometimes not enforced by other means; and ▶ Due to extreme winds, waves, storm tide and storm surge, there is a need for increased design requirements in areas of high and medium severe storm and cyclone risk.



Natural Hazard	Key Points for Consideration
Bushfire	<ul style="list-style-type: none"> ▶ The risk, severity and frequency of the bushfire hazard risk; ▶ Understand that bushfires spread and intensify due to wind and fuel (vegetation); ▶ Bushfire hazards can be managed with controlled burning events to limit the quantities of fire fuel (vegetation); ▶ Statutory and strategic planning can influence land use designations, zoning, building design and prevention measures; ▶ Zoning, land use intensities and scale can complement and should have consideration to the natural hazard characteristics of the particular area; ▶ Sensitive, smart and appropriate building design can allow for these natural hazard events to occur whilst reducing the possible impacts; and ▶ All properties, developments and land uses can be fitted with bushfire management equipment.
Landslide	<ul style="list-style-type: none"> ▶ The risk, severity and frequency of the landslide hazard risk; ▶ Landslide hazards occur from natural occurrences; ▶ Landslide hazards occur from human occurrences: <ul style="list-style-type: none"> – Removal of vegetation; – Interference with, or changes to, natural drainage; – Leaking pipes such as water and sewer reticulation; – Modification of slopes by construction of roads, railways, buildings, etc; – Overloading slopes; – Mining and quarrying activities; – Vibrations from heavy traffic, blasting, etc; and – Excavation or displacement of rocks (Australian Government, 2010). ▶ Zoning, land use intensities and scale of development should consider the natural hazard risk of the particular area; ▶ Vegetation, natural contours and allowing for natural water flows and avoiding ponding all contribute to natural landforms and reduce the frequency and severity of landslide events; ▶ Sensitive, smart and appropriate building design enhances management for landslide natural hazard events; and ▶ Statutory and strategic planning can influence land use designations, zoning, building design and prevention measures.



Natural Hazard	Key Points for Consideration
Erosion Prone Land	<ul style="list-style-type: none"> ▶ The risk and severity of the erosion hazard risk; ▶ Adequate levels of surface cover play an important role in erosion control (DERM 2004); ▶ Zoning, land use intensities and scale of development should consider the erosion hazard risk of the particular area; ▶ Where possible new development should not exceed the current intensity of use (Queensland Government 2003b); and ▶ Where there is existing development of new development cannot be avoided, appropriate protection and management is required to decrease possible erosion effects (Queensland Government 2003b).
Acid Sulfate Soils	<ul style="list-style-type: none"> ▶ Identification of the areas having a high probability of containing ASS and incorporating mapping of these areas; ▶ Where possible avoidance of these areas should be the key principle with appropriate land uses being those that avoid or minimise disturbance; ▶ Land uses that involve significant earthworks should be avoided in areas identified as having high probability of containing ASS; and ▶ Site identification and treatment of ASS should be undertaken in accordance with State Planning Policy 2/02 Guideline – Planning and Managing Development Involving Acid Sulfate Soils.
Sea Level Rise	<ul style="list-style-type: none"> ▶ The strategic and statutory planning process must consider the effect of rising sea level in evaluating the flooding areas and coastal inundation areas in association with development; ▶ Development avoids or minimises exposure to immediate risks of sea level rise impacts (within the immediate hazard line and shore lines); ▶ The development provides for the safety of residents, workers or other occupants on-site from the risks associated with sea level rise; ▶ Development will not adversely affect the safety of the public off-site from a change in sea level risks as a result of the development; ▶ Development will take into account the natural processes of sea level rise; ▶ Development where appropriate will take into account the use of buffering and the appropriate calculations as outlined by the DERM; and ▶ Development, services and utilities on-site maintain their function and achieve their intended design performance.



Natural Hazard	Key Points for Consideration
Climate Change	<ul style="list-style-type: none"> ▶ The severity, frequency and impacts of climate change are unknown; ▶ Current scientific, planning and management policies, documents and regimes are inconsistent with management strategies and planning advice; ▶ There are two approaches for addressing the issue of climate change in the planning sphere: <ul style="list-style-type: none"> – Mitigation measures; and – Adaptation measures.

As per the Queensland Planning Provisions and the natural hazards outlined in this report, the following table provides a suite of planning scheme outcomes for the management and adaption of the impacts of natural hazards and climate change to inform Rockhampton City Councils new Planning Scheme's Strategic Framework.

Element	Specific Outcomes	Land Use Strategies
Settlement Patterns		
Climate Change Adaption and Mitigation	The potential impacts of climate change are managed and reduced via a range of planning and design mechanisms.	<p>Development includes a range of sustainable urban design characteristics and outcomes in new developments;</p> <p>Developments implement management practices to address the potential climate change impacts of flood, sea level rise, bushfire, landslide, severe storm, cyclone and storm tide natural hazards; and</p> <p>Developments are designed, sited, located and constructed in a manner which increases resilience and adaption to climate change and its associated impacts.</p>
Natural Hazard Management	The adverse impacts and potential impacts of natural hazards are managed and mitigated to avoid the loss of development and population.	<p>Developments implement high level best management practices to manage natural hazard impacts of flood, sea level rise, bushfire, landslide, severe storm, cyclone and storm tide natural hazards; and</p> <p>Strategic land use zoning and allocation takes into account the future intensity, frequency and severity of natural hazard impacts, especially those affected by climate change.</p>



Element	Specific Outcomes	Land Use Strategies
Natural Environment		
Soil Management and Erosion	The economic and natural resource of the regions soils are managed to ensure their longevity and sustainability.	Development utilises land management and soil erosion limiting practices.
Climate Change Impacts and Natural Environment Vulnerability	Environmental vulnerability of the region to climate change will be increased.	<p>Areas identified as prone to climate change are managed and developed in a manner which considers the sustainability and longevity of the natural environmental; and</p> <p>Areas identified as prone to climate change and the associated impacts will be managed in a way which encourages their natural integrity and ecological processes.</p>
Acid Sulfate Soil Management	Soil and water bodies will be free from the impacts of Acid Sulfate Soils.	<p>Development will be consistent with the intentions of the SPP 2/02 Planning and Managing Development Involving Acid Sulfate Soils.0;</p> <p>Development will be consistent with the intentions of the SPP 2/02 Guideline Planning and Managing Development involving Acid Sulfate Soils;</p> <p>Development including excavation, cutting and filling avoids land which is identified as having Actual Acid Sulfate Soil (AASS); and</p> <p>Development does not disrupt and remove or potentially impact any Acid Sulfate Soils or impact any water features in the immediate site or locality if identified as Actual Acid Sulfate Soil.</p>
Storm Tide and Flooding Natural Hazard Management	Adverse impacts to development and the regions population are to alleviate the impacts caused during a storm surge or flooding event.	<p>Development avoids areas prone to storm tide and flood natural hazard areas;</p> <p>Development complies with the intentions of the SPP 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0;</p> <p>Development complies with the intentions of the SPP 1/03 Guideline Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0; and</p> <p>Development is designed, sited, located and constructed to manage the impacts of storm tide and flooding.</p>
Severe Storm and Cyclones Natural Hazard Management	In the event of a severe storm or tropical cyclone, the region will remain resilient.	Development uses design and construction methods (e.g. BCA, AS1170.2) that cater for high rain falls, strong winds and hail events, especially on beachfront locations.



Element	Specific Outcomes	Land Use Strategies
Natural Environment		
Bushfire Natural Hazard Management	Potential impacts are managed regarding bushfire hazards.	<p>Land identified in a medium/high risk bushfire area is appropriately managed by using, buffers and fire breaks in all development scenarios;</p> <p>Development takes into account the potential adverse effects of bushfire natural hazards and responds accordingly through siting and design;</p> <p>Development complies with the intentions of the SPP 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0; and</p> <p>Development complies with the intentions of the SPP 1/03 Guideline Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0.</p>
Landslide Natural Hazard Management	The impacts of landslide natural hazards are minimised and managed within the region through planning and design mechanisms.	<p>Development which occurs on land identified as landslide prone will be designed, sited and constructed to take into account the potential adverse affects of landslide natural hazards;</p> <p>Development is constructed in such a way that it protects, strengthens and acknowledges the native vegetation and embankments in areas that are prone to landslide; and</p> <p>Development complies with the intentions of the SPP 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0.</p>
Sea Level Rise Natural Hazard Management	The region's coastal community is protected from the potential event of sea level rise natural hazard.	<p>Development located near a shore line, creek line, river line or waterway is to be undertaken in a manner which ensures development is setback at a distance which takes into account possible future sea level rise and the associated impacts;</p> <p>Land located in an area prone to sea level rise will avoid intensifying land uses in coastal risk areas through appropriate strategic land use planning;</p> <p>Minor engineering and structural works will be utilised but not encouraged to manage past and current development in areas prone to sea level rise in the region; and</p> <p>The acquisition of land will occur so that inappropriate development does not occur in areas which are identified as having extreme risk to sea level rise.</p>



1. Introduction

1.1 Background

Natural hazards, extreme weather events and the unknown impacts of climate change have, and will continue, to impact and affect the integrity of urban environments and the citizens which live in these areas. Responding to these events from a planning and development perspective is important in ensuring adverse impacts to the built environment and human lives are reduced. Furthermore with the increasing awareness of climate change and its potential effects on an array of natural hazards, the role of planning and management of these natural hazards an increasingly focus.

The Rockhampton region is one of the areas in Central Queensland which has identified the need to manage these natural hazard impacts through planning mechanisms to assist in avoiding their potential destructive impacts on urban development and population.

In response to this, GHD Pty Ltd was engaged by Rockhampton Regional Council (RCC) to prepare Rockhampton Region Natural Hazards and Climate Change Study. This study provides planning advice to reduce the impacts from the following natural hazards:

- ▶ Storm Tide and Flooding;
- ▶ Severe Storm and Cyclone;
- ▶ Bushfire;
- ▶ Landslide;
- ▶ Erosion Prone Land;
- ▶ Acid Sulfate Soil;
- ▶ Sea Level Rise; and
- ▶ Climate Change.

1.2 Purpose

The purpose of this study is to provide a suite of specific planning and development outcomes to manage and prevent the impacts of natural hazards in the Rockhampton Region. This study will inform the Rockhampton Regional Council's Planning Scheme (RRCPS), and more specifically will:

- ▶ Develop recommendations for the identification and protection of land vulnerable to natural hazards and possible future climate change; and
- ▶ Propose planning scheme outcomes for the management and adaption of the impacts of natural hazards and climate change to inform the new Planning Scheme's Strategic Framework.



1.3 Connection to Other Studies

This study has been prepared alongside other studies being undertaken for Rockhampton Regional Council. These studies include:

- ▶ Economic Development and Employment Study;
- ▶ Industrial Land Use Study;
- ▶ Heritage Study, Urban Design and Riverfront Options Plan;
- ▶ Natural Environment Study;
- ▶ Commercial Centres Study; and
- ▶ Population and Residential Development Study.

The Natural Hazards and Climate Change Study are closely linked with some of these studies through the provision of applicable planning advice to guide their planning and development outcomes.



2. Study Methodology

2.1 Introduction

The methodology for the study has included a review of all available information, a desktop analysis of all existing plans, data and relevant reports and taken note of the two previous connected studies:

- ▶ The issues report (including a literature review and SWOT analysis); and
- ▶ The initial outcomes report (including strategic principles and outcomes, strategic mapping, check list for areas not spatially identified and principles to guide the PIP).

The methodology will help guide the overall planning outcomes of the study report and ensure deliverables are from a variety of planning and management sources.

2.2 Storm Tide and Flooding

The assessment for storm tide and flooding incorporated a review of existing information and desktop analysis of existing plans, relevant reports and existing storm tide and flooding hazard, vegetation, land use, slope/terrain and aerial imagery data to determine the validity and gaps in storm tide and flooding hazard data and the need for further studies or analysis.

In the absence of storm tide and flooding hazard mapping for the Rockhampton region, this assessment was supported by the development of a raster based storm tide and flooding hazard map prepared at a desktop level using GIS based on the collation of available data. No storm tide or flooding studies or analysis was undertaken as a part of this study.

This study incorporated a review of Council flooding and storm surge spatial data undertaken in conjunction with flood modelling in the former Livingstone Shire and new flood modelling undertaken as part of the Fitzroy River Floodplain and Road Planning Study.

2.3 Severe Storm and Cyclone

The assessment for severe storms and tropical cyclones incorporated a review of existing information and a desktop analysis of existing plans, relevant reports and existing severe storm and cyclone data to determine the validity and gaps in hazard data and the need for further studies or analysis.

The key data inputs into this assessment were meteorological data from the Bureau of Meteorology on the frequency, severity and impact areas of cyclones in the Rockhampton region.

2.4 Bushfire

Bushfire assessment incorporated a review of existing information and a desktop analysis of existing plans, relevant reports and existing bushfire hazard, vegetation, slope/terrain, and aerial imagery data (including bushfire fire hazard data from the Queensland Fire and Rescue Service) to determine the validity and gaps in bushfire hazard data and the need for further studies or analysis. Queensland Fire and Rescue Service Bushfire Risk mapping was used as the baseline for the assessment.

The identified gaps and the need for further studies or analysis was documented in the issues paper, with this including the identification of any inconsistencies between the Bushfire Hazard data from the Queensland Fire and Rescue Service and reviewed data.



2.5 Landslide

Review of existing information and a desktop analysis of existing plans, relevant reports and existing slope/terrain, vegetation, geology, hydrology and aerial imagery data to determine at a strategic level landslide risks and impacts on people, environment, economy, public administration, social and infrastructure formed the landslide assessment.

In the absence of landslide hazard mapping for the Rockhampton region, the risk assessment was supported by the development of a raster based landslide hazard map prepared at a desktop level using GIS and available slope/terrain, vegetation, geology, hydrology, land use, historical records of landslide and aerial imagery data showing the range of landslide risks (i.e. low, medium, high). The landslide hazard map was also informed by State Planning Policy 1/03 and other relevant studies.

2.6 Erosion Prone Land

The assessment for erosion prone land was undertaken through a review of existing information and a desktop analysis of existing plans, relevant reports and existing slope/terrain, vegetation, geology, hydrology and aerial imagery data to determine at a strategic level erosion risk and impacts on people and the environment.

2.7 Acid Sulfate Soil

The assessment for acid sulphate soils was based on a review of the existing acid sulphate soils overlay and the latest available acid sulphate soils data. Council's acid sulphate soils constraint mapping data was reviewed as part of this study.

2.8 Sea Level Rise

The determination of sea level rise hazard was compiled from existing storm tide and flood data for Rockhampton in particular the 5, 10, 20, 50 and 100yr ARI flood events and slope/terrain, aerial imagery and contour data.

2.9 Climate Change

The assessment of climate change and its effects in the region was atypical of the suite of other natural hazards identified in the study. Due to the unknown severity and frequency of climate change, the climate change related hazard (other than sea level rise estimates) has been noted as an identified gap in the study. Therefore the information provided is that of broad planning assumptions based on current planning and management theory and practice.



3. Development Recommendations

3.1 Introduction

The recommendations provided in this report are focused on providing planning advice to manage the effects of natural hazards in the Rockhampton region. The following section incorporates specific planning advice, management techniques and approaches best suited to manage the possible impacts caused by each of the natural hazards. For each natural hazard the following sections are provided:

- ▶ Hazard definition;
- ▶ Effects;
- ▶ Methods and approaches;
- ▶ Strategic planning;
- ▶ Statutory planning; and
- ▶ Key points for consideration.

These sections hope to cover all the needed planning aspects and provide broad planning outcomes to best manage the natural hazards.

3.2 Storm Tide and Flooding

3.2.1 Definition

For this assessment flooding is taken as the temporary inundation of land by expanses of water that overtop the natural or artificial banks of a watercourse.

Storm tide events are defined as the effect of coastal water from a storm surge combined with a naturally occurring astronomical tide (including wave setup).

3.2.2 Effects

The effects of storm tide or flooding will be the temporary inundation of lands where the effects may be caused by either:

- ▶ A rainfall induced flood emanating from the upstream catchment breaking the watercourse banks and inundating the land upstream;
- ▶ A storm event generating a wave setup that inundates lands from the coastal direction; or
- ▶ A combination of both of the above effects.

The effects of this form of inundation may include:

- ▶ Temporary inundation of land by either slowly or rapidly moving water with potential inundation or damage of developments on the land;
- ▶ Potential erosion and migration of watercourse and beach/ocean foreshores;
- ▶ Potential transportation of beach sand landward to form migrating sand dunes; and/or
- ▶ Modified flow paths of inundation as the sea level progressively rises.



3.2.3 Methods and Approaches

The methods and approaches used for the management of Storm Tide and Flooding take into account the need to manage risk, control development and provide specific performance criteria. An overview of the planning methods and approaches to address Storm Tide and Flooding within the Rockhampton Regional Council planning framework is outlined in Table 1.

Table 1 Methods and Approaches – Storm Tide and Flooding

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk associated with the hazard ▶ Assess the level of the associated risk ▶ Control the bulk, scale, lot size, height and floor space ratio of future development ▶ Provide specific performance criteria relevant to the natural hazard which ensures management options prevail in the event of a natural hazard
Overlays and Overlay Code	<ul style="list-style-type: none"> ▶ Identify hazard area ▶ Control construction methods and works ▶ Control built form and building materials ▶ Provide specific design attributes not covered in the LAPs
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions should ensure that development is responsive, sensitive and minimises the exposure to the potential risks of flood natural hazards, and does not increase and contribute to the effects of storm tide of flooding.

3.2.4 Strategic Planning

Storm Tide

To address the effects of past historical storm tide events and the future unknown storm tide events, the creation of a standard hazard benchmark for development is advised. These would apply along the immediate coastline, canal estates, inland creeks and river systems.

The standard hazard benchmark includes a hierarchy of hazard risk areas including:

- ▶ The immediate shore line and potentially along banks of some of the larger marine watercourses - development not to occur;
- ▶ The immediate hazard line and potentially along banks of some of the larger marine watercourses - development not to occur;
- ▶ The future designated 2050 hazard line (created from past historical events and future predictions) in keeping with Rockhampton Towards 2050 - development to occur to the digression of the applicable local area plan, development control plan and the local government planning scheme); and



- ▶ The 2100 hazard line (created from future predictions of climate change processes) as advised by the local area plan, development control plan and the local government planning scheme.

Note: The 'hazard bench marks' are not reflective of other natural hazards and are to only reflect the natural hazard of storm tide and flood.

Flooding

To manage the effects of past historical flooding events and future unknown flooding risks, the creation of standard hazard bench marks for development should be advised in areas prone to flooding impacts. This would include a hierarchy of 'risk areas' including:

- ▶ 20 year ARI risk areas;
- ▶ 50 year ARI risk areas; and
- ▶ 100 year ARI risk areas.

The use of 20, 50 and 100 year ARI risk areas provide an understanding of the need to plan for future flooding uncertainties in the region. The increase of flooding events and the severity of the events is unknown due to climate change processes, thus the need for rational and comprehensive planning mechanisms to cater for this uncertainty.

3.2.5 Strategic Land Use Zoning

Storm Tide

To address the effects of past historical storm tide events and the future unknown storm tide events, the use of strategic land use zoning would be advised to reduce future impacts of storm tide natural hazard impacts.

- ▶ Land uses within the immediate hazard line should include parks, public recreational areas, open space and other land uses which do not require the construction, development or inclusion of large scale structures or buildings. Subdivisions for residential, commercial and industrial uses should be prohibited.
 - Zoning categories under the Queensland Planning Provisions appropriate in the hazard line area would be recreation and open space, open space, environmental management and conservation and limited development.
- ▶ Land uses in the 2050 hazard line should be low in density, be easily decommissioned, and not encourage an increase of population living or working in the vicinity. Subdivisions for residential, commercial and industrial uses should be discouraged.
 - Zoning categories under the Queensland Planning Provisions in the hazard line area would be recreation and open space, open space, limited development, tourist accommodation, sport and recreation, general residential, low impact industry and community purposes.
- ▶ Land uses which are within the 2100 hazard line should be low/medium density, with high rise and long lasting buildings and structures discouraged, and the subdivision of small lots avoided.
 - Zoning categories under the Queensland Planning Provisions appropriate in the hazard line area would be tourist accommodation, community purposes, general residential, residential living, residential choice, apartment residential, district centre, local centre, neighbourhood centre, industry, low/medium impact industry, emerging communities, mixed use and township.



- ▶ Land outside these hazard lines would provide for an increase of densities, transport depots and communal facilities which cater for high levels of interaction. Subdivision of land for residential, commercial and industrial uses would be recommended due to the reduced associated risk in these areas.
 - Zoning categories under the Queensland Planning Provisions would all apply, depending upon the urban fabric at the specific location.

Flooding

To address the effects of past historical flooding events and the future unknown tidal events, the use of strategic land use zoning would be advised to reduce future impacts of flooding natural hazard impacts.

- ▶ Land uses in the 20 year ARI risk area would include single storey residential dwellings, parks, public recreational areas, open spaces and other land uses which do not require small scale construction. Subdivisions for residential, commercial and industrial uses should be undertaken with consideration to flooding impacts.
 - Zoning categories under the Queensland Planning Provisions be best suited include tourist accommodation, community purposes, general residential, neighbourhood centre, low impact industry, emerging communities and mixed uses.
- ▶ Land uses which are in the 50 year ARI risk area should be of low/medium density, with high rise development discouraged.
 - Zoning categories under the Queensland Planning Provisions appropriate in the hazard line area would be tourist accommodation, community purposes, general residential, residential living, residential choice, apartment residential, district centre, local centre, neighbourhood centre, industry, low/medium impact industry, emerging communities, mixed use and township.
- ▶ Land uses which are in the 100 year ARI risk area would accommodate increased densities, transport depots and communal facilities which cater for high levels of interaction. Subdivision of land for residential, commercial and industrial uses would be recommended due to the reduced risk associated with land outside the hazard lines.
 - Zoning categories under the Queensland Planning Provisions would all apply, depending upon the urban fabric at the specific location.

3.2.6 Statutory Planning

Storm Tide

The following performance criteria should be proposed under LAPs in dealing with development within storm tide hazard lines:

- ▶ Development is responsive, sensitive and minimises the exposure to potential storm tide natural hazards;
- ▶ Development provides safe, multiple entry and exit points, and is easily accessible for the residents, visitors and employees of the premises – preferably the access to the entry points is graded upward so that areas of “trapped” or isolated dwellings will not occur;
- ▶ Development does not in any physical manner increase, contribute to, or alter the natural processes of storm tide natural hazards;



- ▶ Development will not increase and contribute to the effects of storm tide on neighbouring sites;
- ▶ Existing shorefront, foreshore and waterfront access is maintained and not impacted upon by the development; and
- ▶ Development will accommodate the natural coastal processes of storm tide natural hazards.

Further development criteria through other planning mechanisms may include:

- ▶ Constructing, maintaining and ensuring protection works on shorelines;
- ▶ Constructing buildings and structures which are easily disassembled, relocatable or decommissioned when located within a hazard line;
- ▶ Evacuation routes are easily accessible, safe and provide for a range of destination choices;
- ▶ Building habitable floor levels are above storm tide planning levels, especially in the 2050 hazard line;
- ▶ Buildings constructed to standards to ensure they will be structurally sound in a storm tide event, especially in the 2050 hazard line;
- ▶ If applicable for large scale, high density and high intensity developments an accompanying flood report, EIA or EIS report would be required. Also a report detailing the developments compliance with the local LAP and DCP would be required;
- ▶ For development occurring within an area identified as being subject to storm tides and there is likely to be a change to any of the underlying hydraulic conditions, hydrological analysis/modelling should be undertaken to ensure development will not be impacted upon by such events; and
- ▶ A quantitative risk assessment undertaken by an appropriate professional would be required if within the 2050 or 2100 hazard lines.

For development located in a storm tide hazard line, a pre-DA consultation with local, regional and state agencies will be required to ensure impacts are mitigated and reduced from project inception through to construction.

Flooding

The following performance criteria are suggested under relevant LAPs and Overlay Codes to address development within the flooding hazard lines.

- ▶ Development is responsive, sensitive and minimises the exposure to the potential risks of flood natural hazards;
- ▶ Development provides safe, multiple entry and exit points, and is easily accessible for the residents, visitors and employees of the premises;
- ▶ Development does not in any physical manner increase, contribute to, or alter the natural processes of flood natural hazards;
- ▶ Development will not increase and contribute to the effects of flooding impacts on neighbouring sites; and
- ▶ Development will not alter, change or increase the natural velocity of flood waters in the event of a flood event.

Further development criteria through other planning mechanisms may include:



- ▶ Evacuation routes are easily accessible, safe and provide a range of destination choices;
- ▶ Buildings have habitable floors above flood planning levels, especially in the 20 and 50 year ARI risk areas;
- ▶ Buildings will be structurally sound in a flood event, especially in the 20 and 50 year ARI risk areas;
- ▶ Information of height, scale, bulk, foundation type and existing or proposed floor levels in AHD;
- ▶ An appropriate risk assessment undertaken by an appropriate professional would be required if within the 20 year ARI risk area; and
- ▶ For development occurring within an area identified as being subject to flooding and there is likely to be a change to any of the underlying hydraulic conditions, hydrological analysis/modelling should be undertaken to ensure development will not be impacted upon by such events; and
- ▶ If applicable for large scale, high density and high intensity developments an accompanying flood report, EIA or EIS report would be required. Also a report detailing the developments compliance with the local LAP and DCP would be required; and
- ▶ Public Infrastructure must be provided with due regard to flood risks associated with safety, function, economic loss and periods of lost access.

For development located in a 20 year ARI risk area, a pre-DA consultation with local, regional and state agencies will be required to ensure impacts are managed and reduced from project inception through to construction.

3.2.7 Key Points for Consideration

The key points to consider when planning for storm tide and flooding natural hazard events are:

1. The risk, severity and frequency of the flood/storm tide risk;
2. Understanding there are many scales of storm tide and flood events;
3. Zoning, land use intensities and scale can complement and consider the natural hazard event of the particular area;
4. Sensitive, smart and appropriate building design can allow for natural hazard events to occur while reducing the consequential impacts; and
5. Storm tide and flooding events will continue to occur but their frequency and severity may differ due to climate change, thus the need for well-informed planning decisions.

3.3 Severe Storm and Cyclone

3.3.1 Definition

Cyclones are defined as 'giant whirlwinds of air and dense cloud spiralling at over 120 km/hr around a central 'eye' of extreme low pressure' (Queensland Government 2005).

Severe storms as 'the process where dense, cold air overlies less dense, warm, moist air, which is triggered by solar heat, a front or a trough'. The definition explains 'strong rising currents of air develop and heat energy stored in the air and water vapour is converted into electrical energy, when the atmosphere is particularly unstable and the wind flow provides an efficient input of energy to a growing



cloud, a severe thunderstorm develops with accompanying updraughts and down draughts'.
(Queensland Government 2005)

3.3.2 Effects

Severe cyclones are projected to be reduced in frequency but increased in intensity in the coming decades, with it being estimated that severe cyclones could increase by between 22% and 56% by 2050 which may result in:

- ▶ A rainfall induced flood emanating from the upstream catchment breaking the watercourse banks and inundating the land upstream
- ▶ A storm event generating a wave setup that inundates lands from the coastal direction, or
- ▶ A combination of the above effects.

The effects of this form of inundation may include:

- ▶ Temporary inundation of land by either slowly or rapidly moving water with potential inundation or damage of developments on the land
- ▶ Potential erosion and migration of watercourse and beach/ocean foreshores
- ▶ Potential transportation of beach sand landward to form migrating sand dunes
- ▶ Modified flow paths of inundation as the sea level progressively rises.

3.3.3 Methods and Approaches

The methods and approaches used for the management of Severe Storm and Cyclone hazard require consideration of risk, controlling development and provide specific performance criteria. As outlined in the Queensland Climate Change and Community Vulnerability to Tropical Cyclones report in 2008, the following are characteristics needing to be managed in the event of a tropical cyclone:

- ▶ Extreme winds;
- ▶ Extreme waves;
- ▶ Storm surges;
- ▶ Storm tides; and
- ▶ Flooding.

Table 2 Methods and Approaches – Severe Storm and Cyclone

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk associated with the hazard ▶ Assess the level of the associated risk ▶ Control the bulk, scale, lot size, height and floor space ratio of future development ▶ Provide specific performance criteria relevant to the natural hazard which ensures management options prevail in the event of a natural hazard



Planning Mechanism	Role in addressing Natural Hazard
Overlays and Overlay Code	<ul style="list-style-type: none"> ▶ Identify hazard area ▶ Control construction methods and works ▶ Control built form and building materials ▶ Provide specific design attributes not covered in the LAPs
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions should ensure that development is responsive, sensitive and minimises the exposure to the potential risks of severe storm and cyclone hazards.

3.3.4 Strategic Planning

To manage the effects of past severe storm and cyclone events, future unknown risks and the associated natural hazard risks, the adoption of standard hazard bench marks for development should be adopted in areas of high and medium risk to severe storm and cyclone. These areas are those located in extreme close proximity to the shoreline. This would include a hierarchy of 'risk areas' including:

- ▶ The immediate shore line and potentially along banks of some of the larger marine watercourses - development not to occur;
- ▶ The immediate hazard line and potentially along banks of some of the larger marine watercourses - development not to occur;
- ▶ The future designated 2050 hazard line in keeping with Rockhampton Towards 2050. (development to occur to the digression of the applicable local area plan, overlays, and the local government planning scheme); and
- ▶ The 2100 hazard line (created from future predictions of climate change processes) as advised by the local area plan, development control plan and the local government planning scheme.

3.3.5 Strategic Land Use Zoning

In adhering to the use of hazard bench marks, the utilization of strategic land use zoning will assist in minimising the impacts to population and development. The land use zoning will see low level uses and zones in areas located in the immediate shorelines and hazard lines and a staggered increase of land use intensification moving outwards to the future designated 2050 and 2100 hazard lines. This overall strategy is supported by *Climate Change in Queensland What the Science is telling us*, which identifies that coastal areas are subject to greater impacts from extreme wind events than inland areas (DERM 2010).

- ▶ Land uses which are in the immediate hazard line should included those which are resilient to extreme winds, extreme waves, storm surges, storm tides and flooding impacts. These may include parks, public recreational areas, open space and other land uses which do not require the construction, development or inclusion of large scale structures or buildings. Subdivisions for



residential, commercial and industrial uses should be prohibited. The reduction of vegetation with weak root systems and the use of loose playground equipment, recreation items and other miscellaneous items are to be reduced in the area. Land uses should be resilient of storm tides, storm surges, extreme winds and flooding impacts.

- Zoning categories under the Queensland Planning Provisions appropriate in the hazard line area would be recreation and open space, open space, environmental management and conservation and limited development. Zoning choices should be chosen with storm tides, storm surges, extreme winds and flooding impacts kept in mind.
- ▶ Land uses in the 2050 hazard line should be resilient to extreme winds and flooding impacts, be low density in nature, be easily decommissioned, and not encourage increased population or workforce in the vicinity. Subdivisions for residential, commercial and industrial uses should be discouraged.
 - Zoning categories under the Queensland Planning Provisions in the hazard line area would be recreation and open space, open space, limited development, tourist accommodation, sport and recreation, general residential, low impact industry and community purposes. Zoning choices should reflect possible extreme winds and flooding impacts.
- ▶ Land uses which are in the 2100 hazard line should be low/medium density in nature with high rise development, and subdivision of small lots discouraged. Land uses should be resilient to high winds and flooding impacts.
 - Zoning categories under the Queensland Planning Provisions appropriate in the hazard line area would be tourist accommodation, community purposes, general residential, residential living, residential choice, apartment residential, district centre, local centre, neighbourhood centre, industry, low/medium impact industry, emerging communities, mixed use and township. Zoning choices should reflect possible extreme winds and flooding impacts.
- ▶ Land outside these hazard lines would provide for increased densities, transport depots and communal facilities which cater for high levels of interaction. Subdivision of land for residential, commercial and industrial uses would be recommended due to the reduced risk associated with land outside the hazard lines.
 - Zoning categories under the Queensland Planning Provisions would all apply, depending upon the urban fabric at the specific location.

3.3.6 Statutory Planning

The following performance criteria should be proposed under relevant local area plans in dealing with development in the hazard lines as mentioned above:

- ▶ Development is responsive, sensitive and minimises the exposure to the potential risks of severe storm and cyclone;
- ▶ Development provides safe, multiple entry and exit points, and is easily accessible for the residents, visitors and employees of the premises;
- ▶ Development in an immediate shore line, immediate hazard line and areas, and in the high hazard zone maintains the safety of people and avoids increases in loss or damage to property from a defined storm tide event;
- ▶ Buildings identified in a hazard bench mark line are to be constructed using severe storm and cyclone impact-resistant materials, especially external claddings and glazing;



- ▶ Buildings identified in a hazard bench mark line are to be constructed with enhanced external finishes and claddings that prevent water access, greater window designs of increased thickness, glazing or reduced panel sizes to reduce wind forces;
- ▶ Development will not increase and or contribute to the effects of severe storm and cyclone impacts on neighbouring sites; and
- ▶ Development will not alter, change or increase the possible effects of wind tunnelling in the event of a severe storm or cyclone.

Further development criteria through other planning mechanisms may include:

- ▶ Evacuation routes are easily accessible, safe and provide a range of destination choices;
- ▶ Public Infrastructure must be provided with due regard to severe storm and cyclone risks associated with safety, function, economic loss and periods of lost access;
- ▶ If applicable for large scale, high density and high intensity developments in a 2050 hazard line, an accompanying EIA or EIS report would be required. Also a report detailing the developments compliance with the local LAP and DCP would be required; and
- ▶ For development located in future designated 2050 hazard line, a pre-DA consultation with local, regional and state agencies will be required to ensure impacts are managed and reduced from project inception through to construction.

3.3.7 Key Points for Consideration

The key points to consider when planning for severe storm and cyclone natural hazard events are:

1. The risk, severity and frequency of the severe storm/cyclone risk;
2. The hazards associated with a severe storm and cyclone event including:
 - Extreme winds;
 - Extreme waves;
 - Storm surges;
 - Storm tides; and
 - Flooding.
3. Coastal areas are subject to greater impacts from extreme wind events than inland areas (DERM 2010);
4. As predicted in the *Climate Change in Queensland What the Science is Telling Us*, cyclone events will increase between 22-56% in Queensland;
5. Strategic land use planning and zoning has the ability to reduce harm to development and populations by placing appropriate development in areas of high, medium and low risk of severe storm and cyclone;
6. Statutory planning has the ability of enforcing planning and management measures sometimes not enforced by other means; and
7. Due to extreme winds, waves, storm tide and storm surge, there is a need for increased design requirements in areas of high and medium severe storm and cyclone risk.



3.4 Bushfire

3.4.1 Definition

Bushfires are defined as an uncontrolled fire burning in forest, scrub or grassland vegetation, and are also referred to as wildfire (Queensland Government 2003a). Bushfires occur when weather conditions are conducive (generally in the dry season), fuels are available (quantity, type and location in the landscape), and an ignition source is present (human induced (arson, accidental, escape) or lightning).

3.4.2 Methods and Approaches

The methods and approaches used for the management of Bushfire events within a planning framework take into account the need to manage risk, control development and provide specific performance criteria. The opportunities for management of Bushfire events through planning are detailed in Table 3.

Table 3 Methods and Approaches – Bushfire

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk associated with the hazard ▶ Assess the level of the associated risk ▶ Control the bulk, scale, land lot size associated with future development ▶ Provide specific performance criteria relevant to the natural hazard which ensures management options prevail in the event of a natural hazard
Overlays and Overlay Code	<ul style="list-style-type: none"> ▶ Identify hazard area ▶ Control construction methods and works ▶ Control built form and building materials ▶ Provide specific design attributes not covered in the LAPs
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions should ensure that development is responsive, sensitive and minimises the exposure to the potential risks from bushfire. ▶ Use of tools such as Bushfire Management Plans to mitigate risks associated with proposed development.

3.4.3 Strategic Planning

The strategic planning options appropriate to the management of bushfire hazards include the following measures:

- ▶ Specific zoning of land in 'high risk' bushfire hazard mapped areas should reflect the level of risk. Zoning categories under the Queensland Planning Provisions appropriate in bushfire hazard areas



include recreation and open space, open space, environmental management and conservation, limited development, neighbourhood centre and low impact industry; and

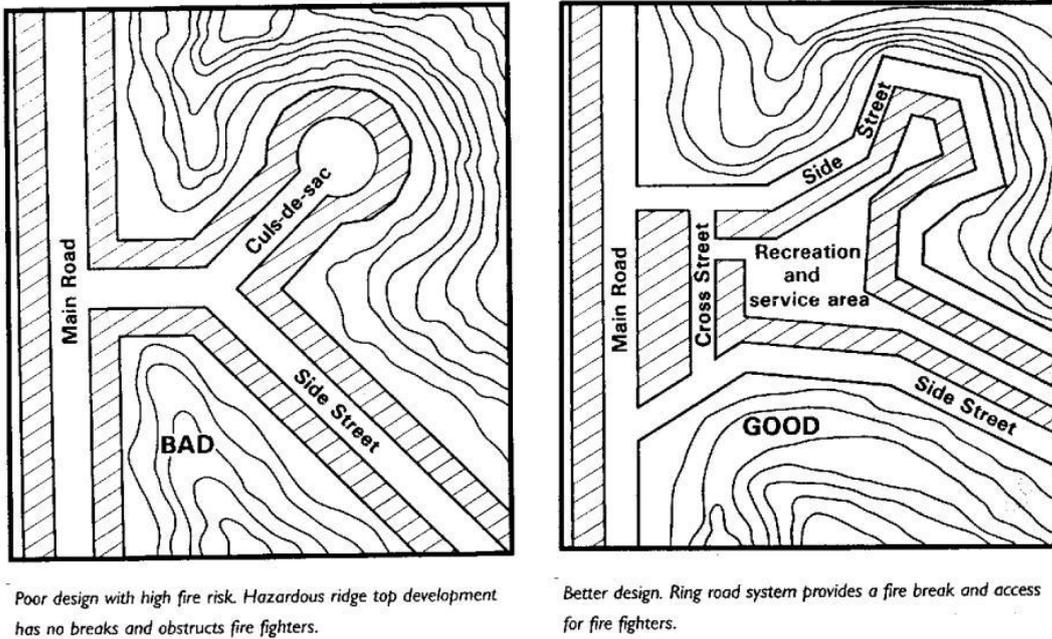
- ▶ Land uses in 'high risk' bushfire hazard mapped areas should include development which is of low density, low intensity, does not encourage large numbers of residents, employees or visitors. In addition, land uses within this hazard area should not involve the storage of high volumes of explosives, flammable materials or other type materials which could encourage the spread of a bushfire event.

3.4.4 Statutory Planning

The following performance criteria are recommended in identified bushfire risk areas:

- ▶ Development is responsive, sensitive and minimises the exposure to the potential risks of bushfire natural hazards;
- ▶ Buffering techniques and fire breaks should be a minimum of 100m as reflective of the SPP 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0, on-site water tanks and the applicable fire prevention measures should also be implemented for development in this 'high risk' bushfire management area;
- ▶ Development provides safe, multiple entry and exit points, and is easily accessible for the residents, visitors and employees of the premises;
- ▶ Development does not in any physical manner encourage, contribute or alter the natural processes of bushfire natural hazards;
- ▶ Development will not increase and or contribute to the effects of bushfire impacts on neighbouring sites;
- ▶ Development will not alter, change or increase the natural speed of bushfire embers/flames in a fire event;
- ▶ Land uses established in high risk areas are include on site a reliable water supply to enable effective fire fighting if and when required;
- ▶ New roadways should allow for multiple entry and exit points and allow drivers an array of route and destination choices shown in Figure 1.

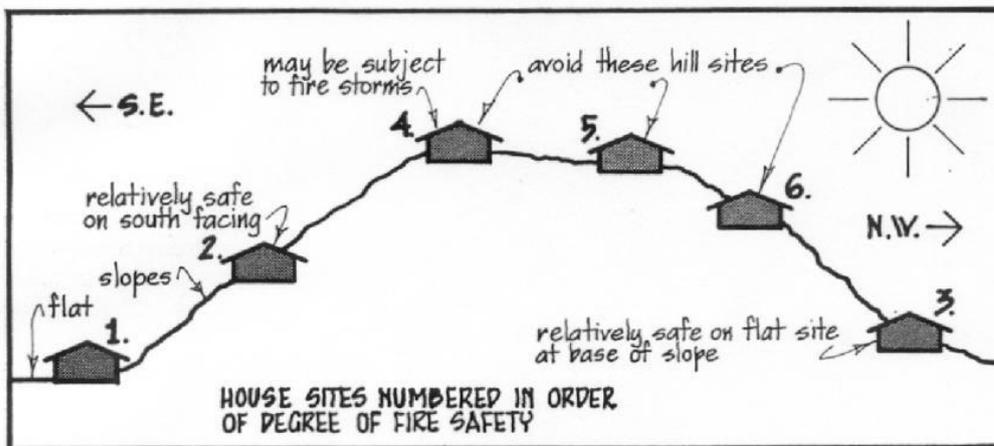
Figure 1 Road Design Examples



(Bushfire Hazard Planning in Queensland 1998)

- ▶ Buildings are sited or able to be sited:
 - in cleared areas or where the environmental impacts of vegetation clearing are acceptable; and
 - On land which is least prone to Potential Bushfire Risk having regard to aspect, elevation, slope and vegetation (Figure 2).

Figure 2 Siting and Design of Residential Buildings



(Queensland Fire Service and Department of Housing, Local Government and Planning 1998)



Performance criteria and prescriptive outcomes should be enforced in the planning scheme overlay codes, the local area plan and the development control plan. Performance criteria should ensure the regulation of all development, construction, operating and end land use components, and ensure the risk of bushfire hazards are integral to all development phases.

The preparation of Bushfire Management Plans also provide a tool that can be incorporated into planning scheme provision to assist in providing the necessary information regarding the mitigation of bushfire risks to a proposed development. These plans assist in the IDAS process with the plan forming part of an application lodged for a development. The purpose of a Bushfire Management Plan is to mitigate the effects of a bushfire hazard regarding development and human life and would apply to proposed development of significant intensity, scale, height, bulk if located in a medium/high risk bushfire hazard area. Bushfire management plans:

- ▶ Involve research, information and analysis of past and future risks, prevention methods, prepare development for a bushfire hazard risk, be able to respond in the event of a bushfire and have sufficient ability to recover from the event;
- ▶ Identify bushfire hazard areas – bushfire hazard areas are spatially identified on a GIS data set/map and categorised as low, medium and high risk;
- ▶ Incorporate requirements/codes – performance criteria and prescriptive outcomes would be included to regulate development outcomes;
- ▶ Involve consultation with the relevant authorities – the local fire brigade, local council, Queensland Fire and Rescue Service and the Department of Environment and Resource Management would all be consulted in the plan process; and
- ▶ Are prepared by the appropriate professional/s.

3.4.5 Key Points for Consideration

Key points for consideration in planning for bushfire natural hazard events are:

1. The risk, severity and frequency of the bushfire hazard risk;
2. Understand that bushfires spread and intensify due to wind and fuel (vegetation);
3. Bushfire hazards can be managed with controlled burning events to limit the quantities of fire fuel (vegetation);
4. Statutory and strategic planning can influence land use designations, zoning, building design and prevention measures;
5. Zoning, land use intensities and scale can complement and should have consideration to the natural hazard characteristics of the particular area;
6. Sensitive, smart and appropriate building design can allow for these natural hazard events to occur whilst reducing the possible impacts; and
7. All properties, developments and land uses can be fitted with bushfire management equipment.



3.5 Landslide

3.5.1 Definition

Landslide events are described as a movement of material down slope in a mass as a result of shear failure at the boundaries of the mass (Queensland Government 2003).

3.5.2 Effects

Landslides have the ability to cause extreme environmental, built environment and human harm and can occur due to heavy rainfalls, disturbance of soils, rock and geological issues, construction, erosion and the clearing of land.

3.5.3 Methods and Approaches

The methods and approaches used for the management of landslide events take into account the need to manage risk, control development and provide specific performance criteria. Table 4 outlines some planning methods for the management of landslide hazard.

Table 4 Methods and Approaches – Landslide

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk associated with the hazard ▶ Assess the level of the associated risk - natural hazard assessment ▶ Control the bulk and scale of future development, including intensity of development through lot size ▶ Provide specific performance criteria relevant to the natural hazard which ensures management options prevail in the event of a natural hazard
Overlays and Overlay Code	<ul style="list-style-type: none"> ▶ Identify hazard area ▶ Control construction methods and works ▶ Control built form and building materials ▶ Provide specific design attributes not covered in the LAPs
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions should ensure that development is responsive, sensitive and minimises the exposure to the potential risks from landslide. ▶ Use of tools such as Landslide Management Plans to mitigate risks associated with proposed development.



3.5.4 Strategic Planning

The most appropriate method of planning for landslides at a strategic planning level, involves a natural hazard assessment or risk assessment. The assessment identifies the hazard rating and the implication and description of this as detailed in Table 5. This assessment then provides the basis for the implementation of specific provisions that reflect the associated level of risk for a particular location.

Table 5 Landslide Hazard Assessment Table

Hazard Rating	Description	Hazard Implication
Very High (VH)	The event of a landslide natural hazard is very likely to occur under adverse conditions	High level planning and management mechanisms are needed. Extensive investigation, and geotechnical works are needed to ensure population and development life is not destroyed.
High (H)	The event of a landslide natural hazard is likely to occur under adverse conditions	High level planning and management mechanisms and geotechnical works are needed
Moderate (M)	The event of a landslide natural hazard may occur under some adverse conditions.	Planning and management mechanisms are needed, including design, siting and regulation of construction standards.
Low (L)	The event of a landslide natural hazard is unlikely to occur under very adverse conditions.	Planning and management mechanisms are required with these incorporated through planning scheme mechanisms.
Very Low (VL)	The event of a landslide natural hazard is very unlikely to occur under exceptional conditions.	

3.5.5 Statutory Planning

The following performance criteria are recommended through LAPs dealing with development in identified landslide hazard management areas:

- ▶ 50% of the native vegetation on the site, especially that of mature trees, shrubs and other vegetative flora which experience a deep and complex root system, is to be retained;
- ▶ If natural vegetation is removed, revegetation of native flora must be undertaken, especially the planting of species which experience a deep and complex root system;
- ▶ Retention of the natural landform of the development site;
- ▶ Where site development works are required, 'cut and fill' depths should be minimised; and
- ▶ The development of swimming pools is prohibited if on slopes with a gradient greater than 15°.

Table 6 details suggested specific development requirements for each of the landslide hazard management areas



Table 6 Development in Landslide Hazard Management Areas

Landslide Hazard Management Area	Development Requirements
Very High	<ul style="list-style-type: none"> ▶ Carry out a Landslide Management Plan prepared by a suitable qualified geotechnical professional. The report should include the following facets: <ul style="list-style-type: none"> - an extensive site investigation; - frequency of site investigation locations of no less than 1 location per 30m x 30m grid with an assessment of material strength by appropriate in-situ or laboratory testing. These should include modelling over the entire development site; - a review of potential hazards; - installation of groundwater monitoring points with measurements over at least one typical wet season and comparison of groundwater levels to rainfall events should be made; and - analysis of slope stability using a suitable model appropriate for the conditions. ▶ Where the analysis of slope stability reveals poor indicators for development and population safety, a detailed risk assessment will be required; ▶ Siting of the development is to have regard to potential hazards, including restricting design of major structures and inappropriate earthworks will be needed where appropriate; ▶ Design advice from a qualified engineering professional, including adoption of good hillside construction practices will be necessary and ensure compliance with the recommendations of the geotechnical report; and ▶ Planning and implementation of a program of regular maintenance of slopes, clearing of drainage course and monitoring of slope for signs of distress.
High	<ul style="list-style-type: none"> ▶ Carry out a Landslide Management Plan prepared by a suitable qualified geotechnical professional. The report should include: <ul style="list-style-type: none"> - an extensive site investigation; - frequency of site investigation locations of no less than 1 location per 30m x 30m grid with an assessment of material strength by appropriate in-situ or laboratory testing. These should include modelling over the entire development site; - a review of potential hazards; - installation of groundwater monitoring points with measurements over at least one typical wet season and comparison of groundwater levels to rainfall events should be made; and - analysis of slope stability using a suitable model appropriate for the conditions. ▶ Where the analysis of slope stability reveals poor indicators for development and population safety, a detailed risk assessment will be



Landslide Hazard Management Area	Development Requirements
	<p>required;</p> <ul style="list-style-type: none"> ▶ Siting of the development is to have regard to potential hazards, including restricting design of major structures and inappropriate earthworks will be needed where appropriate; ▶ Design advice from a qualified engineering professional, including adoption of good hillside construction practices will be necessary and ensure compliance with the recommendations of the geotechnical report; and ▶ Planning and implementation of a program of regular maintenance of slopes, clearing of drainage course and monitoring of slope for signs of distress.
Moderate	<ul style="list-style-type: none"> ▶ Carry out a Landslide Management Plan prepared by a suitable qualified geotechnical professional. The report should include the following facets: <ul style="list-style-type: none"> - an extensive site investigation; - frequency of site investigation locations of no less than 1 location per 30m x 30m grid with an assessment of material strength by appropriate in-situ or laboratory testing. These should include modelling over the entire development site; - a review of potential hazards; - installation of groundwater monitoring points with measurements over at least one typical wet season and comparison of groundwater levels to rainfall events should be made; and - analysis of slope stability using a suitable model appropriate for the conditions. ▶ The development must consider the risks to the community with regards to injury or loss of life and damage to potential development; and ▶ Design advice from a qualified engineering professional, including adoption of good hillside construction practices will be necessary and ensure compliance with the recommendations of the geotechnical report.
Low/Very Low	<ul style="list-style-type: none"> ▶ The development must consider the risks to the community with regards to injury or loss of life and damage to potential development; and ▶ The development must comply with the codes and performance outcomes as detailed in the planning scheme.

The preparation of Landslide Management Plans provide the necessary information regarding the management of landslide risks to a propose development and assist in the development assessment process. In addition to the specific information detailed in Table 6, Landslide Management Plans are intended to mitigate the effects of a landslide hazard with regards to development and human life and incorporate a complete geotechnical report including the potential risk of the hazard occurring and the risk to property and population safety.

Landslide Management Plans:

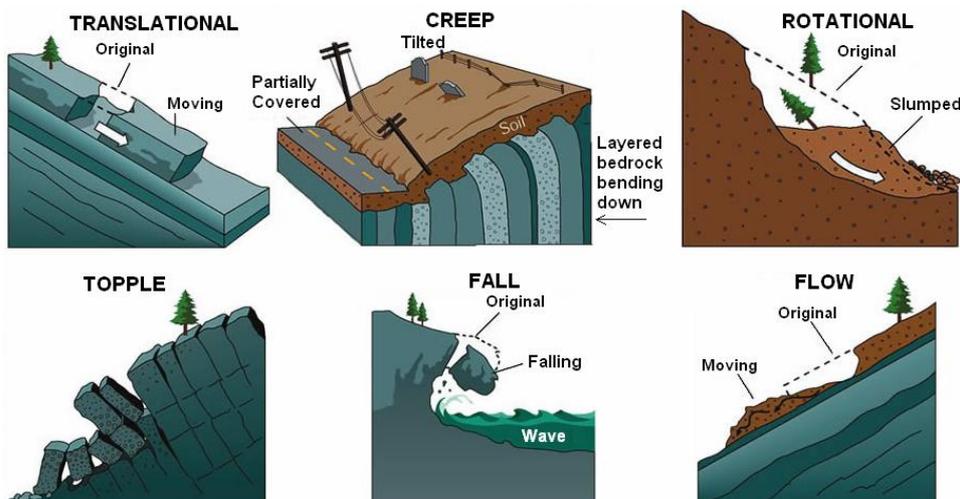
- ▶ Involve research, information and analysis of past and future risks, prevention methods, prepare development for a landslide hazard risk, be able to respond in the event of a landslide and have sufficient ability to recover from the event;
- ▶ Identify landslide hazard areas – landslide hazard areas are spatially identified on a GIS data set/map and categorised as low, medium and high risk;
- ▶ Develop requirements/codes – performance criteria and prescriptive outcomes would be included to regulate development outcomes;
- ▶ Are prepared by appropriate professional/s.

3.5.6 Key Points for Consideration

Key points for consideration in planning for landslide natural hazard events are:

1. The risk, severity and frequency of the landslide hazard risk;
2. Landslide hazards occur from natural occurrences (Figure 3);

Figure 3 Common Types of Landslide



(Australian Government 2010)

3. Landslide hazards occur from human occurrences:
 - Removal of vegetation;
 - Interference with, or changes to, natural drainage;
 - Leaking pipes such as water and sewer reticulation;
 - Modification of slopes by construction of roads, railways, buildings, etc;
 - Overloading slopes;
 - Mining and quarrying activities;
 - Vibrations from heavy traffic, blasting, etc; and
 - Excavation or displacement of rocks (Australian Government, 2010).



4. Zoning, land use intensities and scale of development should consider the natural hazard risk of the particular area;
5. Vegetation, natural contours and allowing for natural water flows and avoiding ponding all contribute to natural landforms and reduce the frequency and severity of landslide events;
6. Sensitive, smart and appropriate building design enhances management for landslide natural hazard events; and
7. Statutory and strategic planning can influence land use designations, zoning, building design and prevention measures.

3.6 Erosion Prone Land

3.6.1 Definition

Soil erosion is defined as the process whereby water and wind sees exposed ground surface soils experiencing loss of top soils which degrades soil quality and increases geological soil impacts' (Queensland Government 2009)

3.6.2 Methods and Approaches

The methods and approaches used for the management of landslide events take into account the need to manage risk, control development and provide specific performance criteria. Table 7 outlines some planning methods for the management of risk associated with erosion hazard.

Table 7 Methods and Approaches – Erosion Prone Land

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk associated with the hazard ▶ Assess the level of the associated risk - natural hazard assessment ▶ Control the bulk and scale of future development, including intensity of development through lot size ▶ Provide specific performance criteria relevant to the natural hazard which ensures management options prevail in the event of a natural hazard
Overlays and Overlay Code	<ul style="list-style-type: none"> ▶ Identify hazard area ▶ Control construction methods and works ▶ Control built form and building materials ▶ Provide specific design attributes not covered in the LAPs
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions should ensure that development is responsive, sensitive and minimises the exposure to the potential risks from



Planning Mechanism	Role in addressing Natural Hazard
	erosion. <ul style="list-style-type: none"> Use of tools such as Erosion Management Plans to mitigate risks associated with proposed development.

3.6.3 Strategic Planning

Providing buffers and the like is a contemporary strategic planning mechanism which caters for the ability to integrate urban development into sites and areas which may be restricted by a single constraint or multiple constraints. The use of buffering has been noted by the DERM as effective as a manage option, resilient to environmental future change and gives the option to be used as a passive recreation area for the community. However the dimensions which apply to these buffer zones vary in opinions, regulations and management documents. DERM (Queensland Government 2005) however state the following is the most appropriate calculation for determining buffer zones in a specific site, area or region:

Erosion Prone Buffering/Width Calculation:

$$E = [(NxR) + C + G] \times (1 + F) + D \text{ (Equation 1)}$$

Where:

- E = Erosion-prone area width (metres)
- N = Planning period (years)
- R = Rate of long-term erosion (metres/year)
- C = Short-term erosion from the "design" storm/cyclone (metres)
- G = Erosion due to greenhouse effect (metres)
- F = Factor of safety on short-term and long-term erosion estimates
- D = Dune scarp component to allow for slumping of the erosion scarp (metres)

In the above equation, the values of R, C, G and D can be determined for individual beaches based on collected data. The choice of values for N and F, as well as the specifications of the storm used to determine C, are more subjective decisions that require reliance on accepted practices.

Note: For further information on this calculation the following document will provide further specific information: Queensland Government (2005) *Information Sheet: Coastal erosion and assessment of erosion prone area widths*, Queensland Department of Environment and Resource Management

The preparation of regional Erosion Management Plans are a tool that can provide guidance to the development of specific planning provisions including those contained with LAPs. Erosion Management Plans:

- Highlight coastal and inland erosions problems specific to the region;
- Provide for a specific understanding and rationale of the coastal processes/inland processes which contribute to the problems that cause the erosion;



- ▶ Evaluate and undertake viable options for the protection and management of sites impacted by erosion in the region;
- ▶ Facilitate and allow for community input on erosion issues specific to the site and the region;
- ▶ Prepare for the implementation and delivery of specific protection and management options; and
- ▶ Provide for consistency with local, regional and state policies, schemes and management plans.

Further strategic planning options to manage erosion prone areas could include:

- ▶ Incorporate erosion risk studies into the development assessment process and strategic planning process in all developments; and
- ▶ Construction of minor engineering works, structural works, sea walls, revetments, gabion walls, artificial reefs and groynes which would serve to minimise coastal erosion.

3.6.4 Statutory Planning

Development situated on land with a gradient greater than 15°, located within an area identified as being within an area of erosion hazard or possibly considered erosion prone land, must be undertaken with regard to the following planning advice:

- ▶ Development must not remove, destroy or reduce the native vegetation along river banks, creeks, major waterways, embankments, ridgelines and hills;
- ▶ Development must not increase stormwater velocity, mass and natural flows in the area;
- ▶ If the development causes the removal of native vegetation from hills, creeks, embankments or slopes greater than 15° then the following erosion controls must be implemented:
 - Soil stabilisation & mulching mat be introduced to the site;
 - Recycled fibre weed & erosion matting be introduced to the site; and
 - Matting installation sheet is introduced to the site.
- ▶ If natural vegetation is removed then the revegetation of native flora must be undertaken, especially the planting of species which experience a deep and complex root system;
- ▶ The development must ensure that top soil is not exposed or vulnerable to the effects of wind and water erosion effects; and
- ▶ The footings of all development must be parallel to the natural flow of stormwater.

3.6.5 Key Points for Consideration

The key points for consideration in planning for erosion prone hazard areas are:

1. The risk and severity of the erosion hazard risk;
2. Adequate levels of surface cover play an important role in erosion control (DERM 2004);
3. Zoning, land use intensities and scale of development should consider the erosion hazard risk of the particular area;
4. Where possible new development should not exceed the current intensity of use (Queensland Government 2003b); and



5. Where there is existing development of new development cannot be avoided, appropriate protection and management is required to decrease possible erosion effects (Queensland Government 2003b).

3.7 Acid Sulfate Soil

3.7.1 Definition

Acid sulfate soil is the name given to soils and sediments containing iron sulfides, the most common being pyrite. When exposed to air due to drainage or disturbance, these soils produce sulfuric acid, often releasing toxic quantities of iron, aluminum and heavy metals. Acid Sulfate soils have the ability to impact environmental, ecological, health, economic, engineering and building sectors and thus have been flagged by all three tiers of government within Australia (DERM 2010)

3.7.2 Methods and Approaches

The methods and approaches used for the management of areas identified as potential acid sulfate soils take into account the need to manage risk and provide specific performance criteria. Table 8 outlines some planning methods for the management of risk associated with acid sulfate soils.

Table 8 Methods and Approaches – Acid Sulfate Soils

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk associated with the hazard ▶ Assess the level of the associated risk - natural hazard assessment ▶ Control the bulk and scale of future development, including intensity of development through lot size ▶ Provide specific performance criteria relevant to the natural hazard which ensures management options prevail in the event of a natural hazard
Codes	<ul style="list-style-type: none"> ▶ State Planning Policy 2/02 – Planning and Managing Development Involving Acid Sulfate Soils requires the preparation of a code against which developments with the potential to disturb ASS area assessed
Overlays and Overlay Code	<ul style="list-style-type: none"> ▶ Identify hazard area ▶ Control construction methods and works ▶ Control built form and building materials ▶ Provide specific design attributes not covered in the LAPs
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions should ensure that development is responsive, sensitive and minimises the exposure to the potential risks from erosion.



Planning Mechanism	Role in addressing Natural Hazard
	<ul style="list-style-type: none"> ▶ Use of tools such as Acid Sulfate Soil Management Plans to mitigate risks associated with proposed development.

3.7.3 Strategic Planning

The most appropriate method of planning for ASS is through the identification of areas that have a high probability of containing ASS and recognition of these at a regional scale through overlays and code requirements. Consideration given to the appropriateness of land uses within these areas that require significant amounts of excavation landslides on a strategic planning level, involves a natural hazard assessment or risk assessment.

The use of strategic land use zoning would be advised to reduce impacts associated with areas that have a high probability of containing ASS.

3.7.4 Statutory Planning

The following prescriptive performance criteria are proposed to help manage the impacts of acid sulfate soils and reduce their potential impacts:

- ▶ All development and works are undertaken so in a way so as to minimise disturbance to acid sulfate soils or works, and development is managed to avoid or minimise the release of acid sulfate contaminants;
- ▶ The disturbance of ASS is avoided by:
 - Not excavating or otherwise removing soil or sediment identified as containing ASS;
 - Not permanently or temporarily extracting groundwater that results in the aeration of previously saturated ASS;
 - not undertaking filling that results in:
 - (i) actual ASS being moved below the watertable; and
 - (ii) previously saturated ASS being aerated.
- ▶ The release of acid and metal contaminants from ASS does not have significant impacts on the natural, built environment and human health;
- ▶ Where excavation or filling is to be undertaken in areas of ASS, a comprehensive approach to management is required to:
 - Maintain the water quality and ecological health of the receiving environment;
 - Avoid adverse effects on environmentally sensitive areas; and
 - Avoid accelerated corrosion of assets such as buildings, structures, roads and other infrastructure.

Where development is being undertaken on site that are identified as having or the potential to have ASS the preparation of an ASS Management Plan should be required incorporating:

- ▶ Objectives, principles and performance criteria;
- ▶ Detailed action plans and strategies for prevention and management of ASS;



- ▶ Detailed monitoring and assessment program to assess the effectiveness of the performance criteria;
- ▶ Detailed implementation guide for the plan including timing of the environmental initiatives;
- ▶ Detailed guide for reporting requirements and auditing responsibilities; and
- ▶ Guide of actions to rectify any deviations from performance standards.

Treatment of ASS is to be undertaken in accordance with State Planning Policy 2/02 Guideline – Planning and Managing Development Involving Acid Sulfate Soils.

3.7.5 Key Points for Consideration

Key points for consideration in planning for ASS are:

1. Identification of the areas having a high probability of containing ASS and incorporating mapping of these areas;
2. Where possible avoidance of these areas should be the key principle with appropriate land uses being those that avoid or minimise disturbance;
3. Land uses that involve significant earthworks should be avoided in areas identified as having high probability of containing ASS; and
4. Site identification and treatment of ASS should be undertaken in accordance with State Planning Policy 2/02 Guideline – Planning and Managing Development Involving Acid Sulfate Soils.

3.8 Sea Level Rise

3.8.1 Definition

Sea level rise has been adopted for this study as the progressive raising of the permanent average sea level. Further to that, the tide range will still be superimposed upon the rise in average sea level leading to a progressing raise in both the high tide and lower tide levels.

3.8.2 Effects

The effects of a rising sea level include:

- ▶ The progressive permanent inundation of additional areas of land adjacent to the coastline and banks of estuarine streams;
- ▶ The increase in frequent inundation of additional land areas due to the increased tidal levels (even though the range may remain the same);
- ▶ A potential change in the coastal wind wave propagation due to the increased sea level;
- ▶ A potential change in beach due locations with the beach moving more landward;
- ▶ Potential changes to beach recession rates as the sea level rises;
- ▶ The progressive relocation of marine and brackish water ecosystems as the water chemistry changes; and/or
- ▶ Changes in water chemistry potentially affecting the tourism and tourist features.



3.8.3 Methods and Approaches

The methods and approaches used for the management of sea level rise take into account the need to manage risk, control development and provide specific performance criteria (Table 9).

As detailed in *Climate Change in Queensland What the Science is Telling Us*, Queensland is currently using 0.8 meters as the projected sea level rise by 2100 for planning purposes (DERM 2009). Engineers Australia (2003) also provides methodologies for assessing the impacts of sea level rise in the coastal environment.

Table 9 Methods and Approaches – Sea Level Rise

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk associated with the hazard ▶ Assess the level of the associated risk - natural hazard assessment ▶ Control the bulk and scale of future development, including intensity of development through lot size ▶ Provide specific performance criteria relevant to the natural hazard which ensures management options prevail in the event of a natural hazard
Overlays and Overlay Code	<ul style="list-style-type: none"> ▶ Identify hazard area ▶ Control construction methods and works ▶ Control built form and building materials ▶ Provide specific design attributes not covered in the LAPs
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions should ensure that development is responsive, sensitive and minimises the exposure to the potential risks from erosion. ▶ Use of tools such as Acid Sulfate Soil Management Plans to mitigate risks associated with proposed development.

3.8.4 Strategic Planning

Council will need to develop a response strategy to all the water related hazards as an integrated unit as they are very much interrelated as sea level rise will directly affect flooding levels and frequency and also the potential effects of cyclones and the effect of climate change will also modify these same hazards. That response strategy could include pockets of retreat, manage the impacts to reduce the severity, protect and defend etc. The assessment would be needed to select the best combination of integrated strategies.

The identification of land upon which may become affected by sea level rise should be supported by predictive modelling to:



- ▶ Establish predictions of sea level rise and the progressive areas of potential affectation, levels of affectation (hazards) and forms of affectation;
- ▶ Identify the impacts the hazards may have on existing urban development, land uses, infrastructure (physical and social), environmental biodiversity, and human safety;
- ▶ Identify the impacts the hazards may have on an expanded urban footprint to assess appropriate land uses, infrastructure locations (physical and social), environmental biodiversity, and human safety to establish the appropriate response to the hazard for incorporation into the planning framework; and
- ▶ Ensure that the flooding and coastal inundation assessment makes allowance for the rising sea level.

To address the effects of future sea level rise events, the creation of a standard hazard benchmark for development are advised. These would apply along the immediate coastline, canal estates, inland creeks and river systems.

The standard hazard benchmarks include a hierarchy of hazard risk areas including:

- ▶ Where development is near a shore line, creek line, river line or waterway that is potentially subject to direct coastal impact (beach erosion, sand transportation landward, permanent inundation or increased inundation) then no new development should occur. However, consistent with the hazard assessments, expansions to existing infrastructure may be appropriate depending upon the infrastructure life and likely period to inundation;
- ▶ Where development is near a shoreline, creek line or waterway that is not subject to direct effects (beach erosion, sand transportation landward, permanent inundation or increased inundation) then construction should be undertaken in a manner which ensures development is setback at a distance which takes into account possible future sea level rise;
- ▶ Development in areas not spatially recognised for possibly being affected by the impacts of sea level rise should be included in a 'low risk' category for this natural hazard;
- ▶ Development within the future designated 2050 hazard line (created from past historical events and future predictions - in keeping with Rockhampton Towards 2050) is to reflect the relevant planning provisions; and
- ▶ Development within the 2100 hazard line (created from future predictions of climate change processes) is to reflect the relevant planning provisions.

Further strategic planning methods could see the following approaches applied:

- ▶ Accommodate appropriate new growth in coastal areas which are not prone to the impacts of sea level rise;
- ▶ Discouraging the intensification of development in coastal risk areas, especially that of 'greenfield' development sites where potential impacts of sea level rise cannot be effectively mitigated; and
- ▶ Planning for adaptable land uses through time i.e. utilise areas not currently impacted by sea level rise but predicted to be in the future for some development and then adapt to a more environmental land use as sea level rise impacts increase.



3.8.5 Strategic Land Use Zoning

To address the future unknown sea level rise events, the use of strategic land use zoning would be advised to reduce future impacts;

- ▶ Land uses within the immediate hazard line should include parks, public recreational areas, open space and other land uses which do not require the construction, development or inclusion of large scale structures or buildings. Subdivisions for residential, commercial and industrial uses should be prohibited.
 - Zoning categories under the Queensland Planning Provisions appropriate in the hazard line area would be recreation and open space, open space, environmental management and conservation and limited development.
- ▶ Land uses in the 2050 hazard line should be low in density, be easily decommissioned, and not encourage an increase of population living or working in the vicinity. Subdivisions for residential, commercial and industrial uses should be discouraged.
 - Zoning categories under the Queensland Planning Provisions in the hazard line area would be recreation and open space, open space, limited development, tourist accommodation, sport and recreation, general residential, low impact industry and community purposes.
- ▶ Land uses which are within the 2100 hazard line should be low/medium density, with high rise and long lasting buildings and structures discouraged, and the subdivision of small lots avoided.
 - Zoning categories under the Queensland Planning Provisions appropriate in the hazard line area would be tourist accommodation, community purposes, general residential, residential living, residential choice, apartment residential, district centre, local centre, neighbourhood centre, industry, low/medium impact industry, emerging communities, mixed use and township.
- ▶ Land outside these hazard lines would provide for an increase of densities, transport depots and communal facilities which cater for high levels of interaction. Subdivision of land for residential, commercial and industrial uses would be recommended due to the reduced associated risk in these areas.
 - Zoning categories under the Queensland Planning Provisions would all apply, depending upon the urban fabric at the specific location.

3.8.6 Statutory Planning

The development application process should take into account:

- ▶ Information outlining the type of proposed development including:
 - nature, bulk, scale and location of proposed development; and
 - proposed use and occupation of buildings, and those adjoining land.
- ▶ Plans illustrating the position and configuration of the proposed development in relation to coastal risks including:
 - positions of all surrounding buildings and the proposed building;
 - ground levels in AHD;
 - proposed levels in AHD; and
 - foundation types.



- ▶ The requirement for the submission, with a development application, of a report addressing the following issues relating to sea level rise as they relate to the development site;
 - increase in sea level and increased tidal range;
 - soft coast erosion;
 - coastal and land flooding;
 - entrance behaviour of the coast; and
 - cliff and slope stabilities.
- ▶ Information that demonstrates whether the development proposal:
 - is consistent with the relevant coastline or flood risk management plan;
 - consistent with the LAP and DCP; and
 - incorporates appropriate management responses and adaptation strategies.

This information is based on the consideration of hazards and the design (or likely) life of development. This approach is consistent with normal risk based decision processes and that discussed in *Increasing Queensland's resilience to inland flooding in a changing climate: Final report on the inland flooding study*.

3.8.7 Key Points for Consideration

1. The strategic and statutory planning process must consider the effect of rising sea level in evaluating the flooding areas and coastal inundation areas in association with development;
2. Development avoids or minimises exposure to immediate risks of sea level rise impacts (within the immediate hazard line and shore lines);
3. The development provides for the safety of residents, workers or other occupants on-site from the risks associated with sea level rise;
4. Development will not adversely affect the safety of the public off-site from a change in sea level risks as a result of the development;
5. Development will take into account the natural processes of sea level rise;
6. Development where appropriate will take into account the use of buffering and the appropriate calculations as outlined by the DERM; and
7. Development, services and utilities on-site maintain their function and achieve their intended design performance.

3.9 Climate Change

3.9.1 Definition

The Queensland government has adopted the definition of climate change as a statistical description of the mean and variability in the weather patterns over a period of time.



3.9.2 Effects

The effects of climate change, as related to the hazards being considered in this study, are predicted in *Climate Change in Queensland what the Science is Telling Us* and *ClimateQ* to include:

- ▶ An increase in the average sea level –with the current Queensland projection in sea level rise being 0.8 m by 2100;
- ▶ A change in the sea temperature and chemistry;
- ▶ An increase in the annual average temperature by approximately 1°C in 2030 (medium scenario) to +1.2 (low scenario) to +2°C (high scenario) by 2050 and by +1.7 (low scenario) to +3.2°C (high scenario) by 2070;
- ▶ There will be minimal change in the seasonal projections for temperature increase with all seasons projected to increase by the annual projections;
- ▶ The likely change in the annual number of days over 35°C is likely to be a an additional 10 by 2030 (medium scenario) to 13 (low scenario) to 24 (high scenario) by 2050;
- ▶ Minimum temperatures are likely to increase by more than the mean temperatures;
- ▶ A change in the annual average rainfall by approximately -3% in 2030 (medium scenario) to -4% (low scenario) to -7% (high scenario) by 2050 and by -6% (low scenario) to -10% (high scenario) by 2070;
- ▶ The largest reduction in rainfall is predicted for spring while the least reduction in rainfall is projected for summer;
- ▶ Projections for cyclones is more variable however there is a trend for there to be an overall reduction in the cyclone frequency but an increase in the severe cyclones by between 22% and 56% by 2050 ;
- ▶ An increase in storm surge magnitude;
- ▶ A potential increase in wind gust speeds during cyclones;
- ▶ A change in the annual average potential evaporation by approximately +3% in 2030 (medium scenario) to +4% (low scenario) to +7% (high scenario) by 2050 and by +5% (low scenario) to +10% (high scenario) by 2070; and
- ▶ The change in seasonal potential evaporation was similar – there was a marginal trend toward the change being greatest in spring (Queensland Government 2010).

The effects of these changes are likely to be reflected in:

- ▶ A change in the sea level hazard;
- ▶ A change in the sea temperature together with possible relocation of some fish species and an affect on some tourist features (eg Great Barrier Reef);
- ▶ A change to the bushfire hazard;
- ▶ A change to the flooding and coastal hazards;
- ▶ A change in cyclonic wind gusts; and
- ▶ A change in temperature.



3.9.3 Methods and Approaches

There are two approaches for addressing the issue of climate change in the planning sphere:

- ▶ Mitigation measures; and
- ▶ Adaptation measures.

The focus of the planning scheme response to climate change is on managing and reducing the vulnerability of the community to the impacts associated with climate change. The planning scheme provides a mechanism for the inclusion of a development framework that manages development in areas that may be subject to the effects of climate change. Methods and approaches to addressing climate change in the planning context are outlined in Table 10.

Table 10 Methods and Approaches – Climate Change

Planning Mechanism	Role in addressing Natural Hazard
Local Area Plan	<ul style="list-style-type: none"> ▶ Manage the risk resulting from climate change ▶ Management scale of future development ▶ Assess the level of the associated risks ▶ Manage development form and location
Codes	<ul style="list-style-type: none"> ▶ Manage the risks associated with the hazards; ▶ Provisions for implementation climate change adaption measures for future development
Zoning	<ul style="list-style-type: none"> ▶ Use of appropriate zonings, land uses and development provisions that are based on a detailed risk analysis that considers all environmental, financial and social issues.
Development Provisions	<ul style="list-style-type: none"> ▶ Planning provisions to address climate change mitigation and adaptation

3.9.4 Strategic Planning

In the *Improving Community Resilience to Extreme Weather Events*, the Insurance Council of Australia (ICA 2008) there is a focus on two strategies that are relevant to climate change:

- ▶ Risk management of the built environment; and
- ▶ Policies and human behaviours that underpin community resilience to extreme weather events (ICA, 2008).

Council response to this should include, in part, risk-appropriate land use planning legislation to prevent inappropriate development (ICA, 2008). Such strategic planning responses may include the opportunities detailed in Table 11.



Table 11 Climate Change Strategic Planning Responses

Element	Response Opportunity
Climate Change Mitigation	Energy efficiency provisions for the design of new developments including passive solar design
	Renewable energy for new development (e.g. green star ratings)
	Application of sub tropical design principles
	Manage travel demand
	Encourage use of re-used resources and recycled materials in new developments
Climate Change Adaptation	Hazard management of risks associated with climate change impacts
	Adaptable land use
	Settlement pattern arrangements
	Management of vegetation clearing and provision of off-sets

3.9.5 Statutory Planning

Planning scheme codes provide a mechanism through which sustainability and climate change adaptation principles can be adopted and implemented. Opportunities include provisions relating to:

- ▶ Development site location – restriction of development in areas identified as a current or future hazard area associated with climate change eg storm surge, coastal erosion;
- ▶ Settlement Patterns - arranged to generate low transport emissions;
- ▶ Buildings;
 - energy efficiency and sustainability provisions for the design of new developments
 - passive design through the application of tropical design features
 - resilience against potential increased wind gusts; and
 - encourage use of reused resources and recycled materials in new developments.
- ▶ Water efficiency – incorporated into new houses, commercial, industry and multi-unit residential
- ▶ Drainage – appropriate water sensitive urban design in new developments including permeable surfaces, rainwater harvesting

In relation to risk associated with the impacts of climate change, development carried out on land which may become affected by climate change must be undertaken with regard to the following planning advice:

- ▶ Environmental modelling may be undertaken to outline future predictions, severity and the potential impacts the hazard may cause with respect to urban development, environmental biodiversity and safety;



- ▶ As a result of the unknown factors associated with climate change, the creation of a 100 year plan with low, medium and high projections would allow for flexible and resilient planning decisions. The plan would cover frequency, severity, location and type of hazard. Climate change has been identified as a natural hazard with many associated effects thus making it the most difficult hazard to plan for.

Additional actions that may be undertaken by council:

- ▶ Review building requirements to maximise natural cooling and ventilation;
- ▶ Review, in conjunction with Queensland government and appropriate agencies, appropriate design wind speeds; and
- ▶ Council work with the Queensland government to deliver appropriate health controls and measures.

3.9.6 Key Points for Consideration

Key points for consideration in planning for Climate Change are:

1. The severity, frequency and impacts of climate change are unknown;
2. Current scientific, planning and management policies, documents and regimes are inconsistent with management strategies and planning advice;
3. There are two approaches for addressing the issue of climate change in the planning sphere:
 - Mitigation measures; and
 - Adaptation measures.



4. Proposed Planning Scheme Outcomes

4.1 Introduction

The proposed planning scheme outcomes in this report are focused at informing the relevant themes, elements, specific outcomes and land use strategies, when drafting the Rockhampton Regional Council's future Planning Scheme's Strategic Framework. Under the statutory guidelines of the Sustainable Planning Act 2009 and intentions of the Queensland Governments Queensland Planning Provisions (QPPs), local government planning schemes must include Section 3 Strategic Framework.

The strategic framework as outlined by the QPPs Version 2.0 does the following:

- ▶ Sets the policy position for the whole of the planning scheme area;
- ▶ Identifies the future development intent for the planning scheme area;
- ▶ Where there is a regional plan, identifies that it is consistent with the regional plan;
- ▶ Is used in the assessment of impact assessable development; and
- ▶ Is used where the development does not comply with the applicable code/s.

In the strategic framework the following headings are used and are mandatory:

- ▶ Theme;
- ▶ Strategic outcomes;
- ▶ Elements;
- ▶ Specific outcomes; and
- ▶ Land use strategies.

4.2 QPP – Applicable Themes and Elements

As per the natural hazards outlined in the study report and the 'themes' within the QPP the themes and elements are applicable to the study report are detailed in Table 12.

Table 12 Applicable Themes and Elements included in the QPP

Theme	Element
Settlement Pattern	Climate Change Adaption and Mitigation
	Natural Hazard Management
Natural Environment	Soil Management and Erosion
	Climate Change Impacts and Natural Environment Vulnerability
	Acid Sulfate Soil Management
	Storm Tide and Flooding Natural Hazard Management



Theme	Element
	Severe Storm and Cyclones Natural Hazard Management
	Bushfire Natural Hazard Management
	Landslide Natural Hazard Management
	Sea Level Rise Natural Hazard Management

4.2.1 Settlement Pattern

As per the QPPs and the natural hazards outlined in the study report, the following table provides a suite of planning scheme outcomes for the management and adaption of the impacts of natural hazards and climate change to inform the new Planning Scheme's Strategic Framework, specifically that of settlement patterns.

Table 13 Settlement Pattern Strategic Outcomes

Element	Specific Outcomes	Land Use Strategies
Climate Change Adaption and Mitigation	The potential impacts of climate change are managed and reduced via a range of planning and design mechanisms.	Development includes a range of sustainable urban design characteristics and outcomes in new developments; Developments implement management practices to address the potential climate change impacts of flood, sea level rise, bushfire, landslide, severe storm, cyclone and storm tide natural hazards; and Developments are designed, sited, located and constructed in a manner which increases resilience and adaption to climate change and its associated impacts.
Natural Hazard Management	The adverse impacts and potential impacts of natural hazards are managed and mitigated to avoid the loss of development and population.	Developments implement high level best management practices to manage natural hazard impacts of flood, sea level rise, bushfire, landslide, severe storm, cyclone and storm tide natural hazards; and Strategic land use zoning and allocation takes into account the future intensity, frequency and severity of natural hazard impacts, especially those affected by climate change.



4.2.2 Natural Environment

As per the QPPs and the desired natural hazards outlined in the study report, the following table provides a suite of planning scheme outcomes for the management and adaption of the impacts of natural hazards and climate change to inform the new Planning Scheme’s Strategic Framework, specifically that of natural environments.

Table 14 Natural Environment Strategic Outcomes

Element	Specific Outcomes	Land Use Strategies
Soil Management and Erosion	The economic and natural resource of the regions soils are managed to ensure their longevity and sustainability.	Development utilises land management and soil erosion limiting practices.
Climate Change Impacts and Natural Environment Vulnerability	Environmental vulnerability of the region to climate change will be increased.	Areas identified as prone to climate change are managed and developed in a manner which considers the sustainability and longevity of the natural environmental; and Areas identified as prone to climate change and the associated impacts will be managed in a way which encourages their natural integrity and ecological processes.
Acid Sulfate Soil Management	Soil and water bodies will be free from the impacts of Acid Sulfate Soils.	Development will be consistent with the intentions of the SPP 2/02 Planning and Managing Development Involving Acid Sulfate Soils.0; Development will be consistent with the intentions of the SPP 2/02 Guideline Planning and Managing Development involving Acid Sulfate Soils; Development including excavation, cutting and filling avoids land which is identified as having Actual Acid Sulfate Soil (AASS); and Development does not disrupt and remove or potentially impact any Acid Sulfate Soils or impact any water features in the immediate site or locality if identified as Actual Acid Sulfate Soil.



Element	Specific Outcomes	Land Use Strategies
Storm Tide and Flooding Natural Hazard Management	Adverse impacts to development and the regions population are to alleviate the impacts caused during a storm surge or flooding event.	<p>Development avoids areas prone to storm tide and flood natural hazard areas;</p> <p>Development complies with the intentions of the SPP 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0;</p> <p>Development complies with the intentions of the SPP 1/03 Guideline Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0; and</p> <p>Development is designed, sited, located and constructed to manage the impacts of storm tide and flooding.</p>
Severe Storm and Cyclones Natural Hazard Management	In the event of a severe storm or tropical cyclone, the region will remain resilient.	Development uses design and construction methods (e.g. BCA, AS1170.2) that cater for high rain falls, strong winds and hail events, especially on beachfront locations.
Bushfire Natural Hazard Management	Potential impacts are managed regarding bushfire hazards.	<p>Land identified in a medium/high risk bushfire area is appropriately managed by using, buffers and fire breaks in all development scenarios;</p> <p>Development takes into account the potential adverse effects of bushfire natural hazards and responds accordingly through siting and design;</p> <p>Development complies with the intentions of the SPP 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0; and</p> <p>Development complies with the intentions of the SPP 1/03 Guideline Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0.</p>
Landslide Natural Hazard Management	The impacts of landslide natural hazards are minimised and managed within the region through planning and design mechanisms.	<p>Development which occurs on land identified as landslide prone will be designed, sited and constructed to take into account the potential adverse affects of landslide natural hazards;</p> <p>Development is constructed in such a way that it protects, strengthens and acknowledges the native vegetation and embankments in areas that are prone to landslide; and</p> <p>Development complies with the intentions of the SPP 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide 1.0.</p>



Element	Specific Outcomes	Land Use Strategies
Sea Level Rise Natural Hazard Management	The region's coastal community is protected from the potential event of sea level rise natural hazard.	<p>Development located near a shore line, creek line, river line or waterway is to be undertaken in a manner which ensures development is setback at a distance which takes into account possible future sea level rise and the associated impacts;</p> <p>Land located in an area prone to sea level rise will avoid intensifying land uses in coastal risk areas through appropriate strategic land use planning;</p> <p>Minor engineering and structural works will be utilised but not encouraged to manage past and current development in areas prone to sea level rise in the region; and</p> <p>The acquisition of land will occur so that inappropriate development does not occur in areas which are identified as having extreme risk to sea level rise.</p>



5. Data Limitations and Future Studies

5.1 Data Limitations

This Natural Hazards and Climate Change Study is based on a desktop analysis of available data provided by council and other relevant sources. As no associated field work or additional investigations were undertaken the outcomes are limited by the extent and accuracy of the available data.

Engineering comments are based upon readily available information and generalised information and therefore further site specific consideration of matters would be prudent.

5.2 Future Study Recommendations

5.2.1 Integrated Assessment of Coastal Hazards

It is recommended that Rockhampton Regional Council undertake an integrated assessment of coastal hazards, flooding impacts and sea level rise to define the complete risk profile (spatial extent of problem as well as temporal variation). This assessment could be completed in two stages comprising:

- ▶ A desk top assessment that compiles results of local flood studies, historical local information, regional studies and assessments and then identifies gaps require additional work; and
- ▶ Undertaking a regional study, or studies, focussed on the quantification of the areas of affectation and potential hazard (flow velocity and flow depth) from a rise in static sea level, flooding along with effects of severe storms. Combinations of the effects should be evaluated to quantify the aerial extent of affects and the risks from different events and the likely timeframe for the affectation.

Using results of the regional assessment, it is recommended that Rockhampton Regional Council complete a risk analysis assessment to determine the appropriate design standards to mitigate the risks for existing and future development. It is highlighted that the same mitigation standard need not be applied to all risks or all areas. The risk assessment should include a triple bottom line assessment (to appropriately include social impacts of the planning decisions) and then be used to establish the criteria for inclusion in the strategic and statutory planning documents.

The final component would be the documentation of the regional assessment and identification of development forms/standards that would conform to the planning principles, without the need for a comprehensive engineering assessment of water related issues. This will ensure that all parties have a common understanding of the development process and requirements.

5.2.2 Storm Tide

A comprehensive tropical cyclone storm tide study should be undertaken for the region to quantitatively assess the variability in storm tide levels, inundation extents, coastal impacts, riverine propagation and the like. Such a study would address present climate as well as future potential tropical cyclone climates for 2050 and 2100 in association with sea level rise projections. Outcomes could also include tailwater design criteria for assisting in fluvial flood studies or considerations of joint probability of riverine floods and extreme storm tides. Such a study would also directly inform emergency planning.



5.2.3 Severe Storms

There is currently no specific study for the region that addresses the potential impacts of severe thunderstorm events. While AS1170.2 (SA 2003) and the Building Code of Australia (ASCB, 2010) provide guidance and provisions for design to resist extreme winds, which encompass severe storms and tropical cyclones, no such advice is available for hail damage. Likewise, the occurrence of associated tornadoes is presently unquantified.

5.2.4 Climate Change

Detailing the management procedures and mechanisms for climate change, a planning study should be undertaken to establish specific climate change parameters, based on existing internationally accepted science, for input into each of Council's land use, infrastructure and community planning functions.

A planning study to determine climate change considerations which will inform the planning and the identification of environments most at risk from the impacts of climate change is also suggested to further strengthen the assumptions made in this report and also Council.

Taking regard of emerging science findings, assumptions and conclusion will allow for the strengthened analysis of the potential risks to the Rockhampton City posed by the range of future natural hazards and climate change scenarios which also include sea level rise parameters occurring at a more rapid rate than anticipated.



6. Conclusion

GHD Pty Ltd was engaged by Rockhampton Regional Council to prepare the Rockhampton Region Natural Hazards and Climate Change Study. The purpose of the study was to:

- ▶ Develop recommendations for the identification and protection of land vulnerable to natural hazards and climate change;
- ▶ Propose planning scheme outcomes for the management and adaption of the impacts of natural hazards and climate change, to inform the new Planning Scheme's Strategic Framework; and
- ▶ Outline any relevant data limitations and possible future studies recommended to strengthen assumptions, conclusions and planning responses in this study report.

The report has completed the above purpose through the provision of a desktop analysis of all contemporary and relevant planning and environmental management literature; the interpretation of these documents, policies and strategies to region specific planning outcomes; the analysis of the Queensland Planning Provisions to provide the inclusion of natural hazards into the future planning schemes strategic framework and has identified a list of recommendations for future studies and inquiries.



7. References

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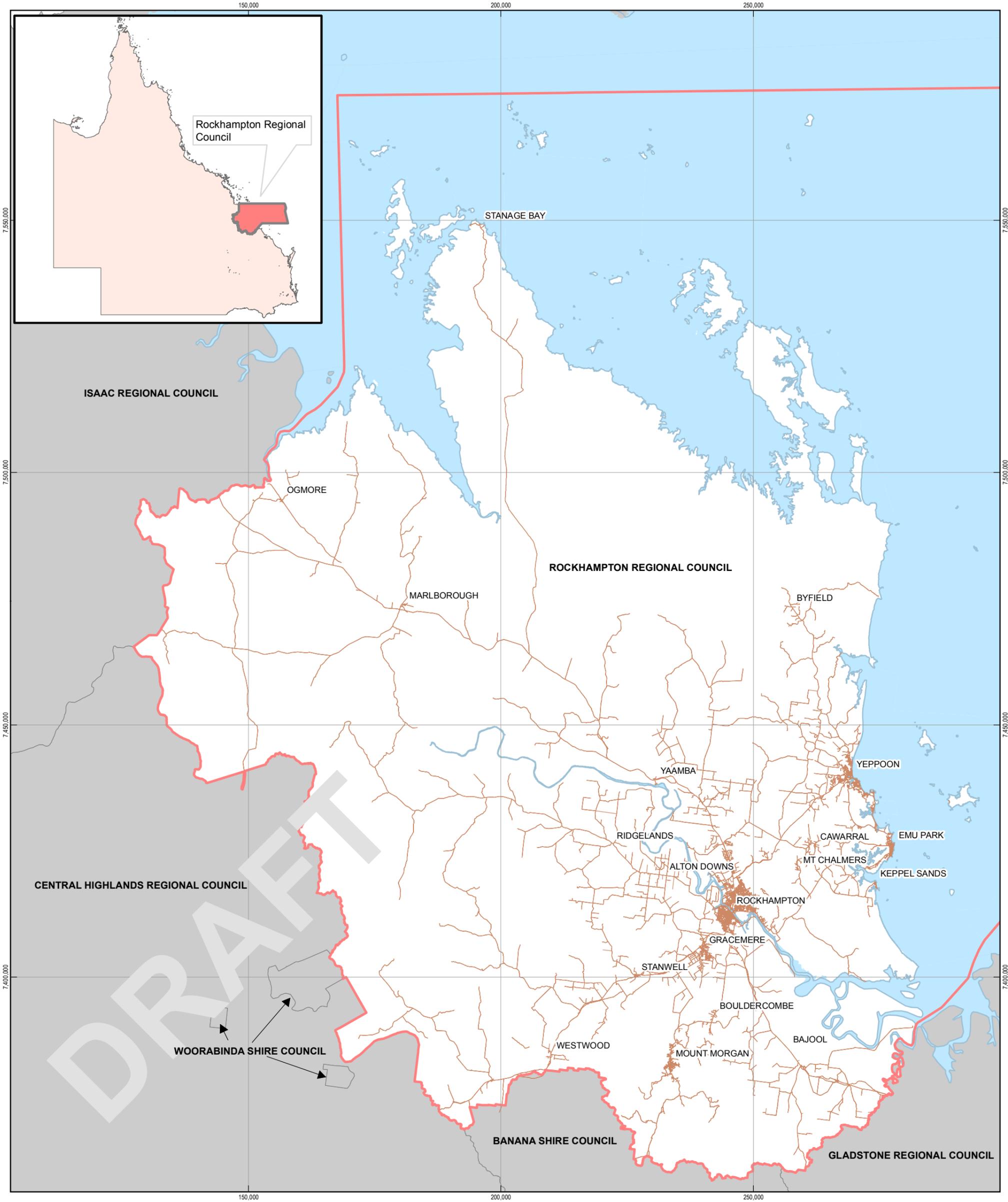
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Appendix A

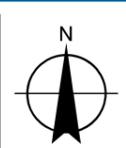
Maps



LEGEND

- Rockhampton Regional Council
- Major Road

1:700,000 (at A3)
 0 2.5 5 10 15 20 25
 Kilometers
 Map Projection: Universal Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56

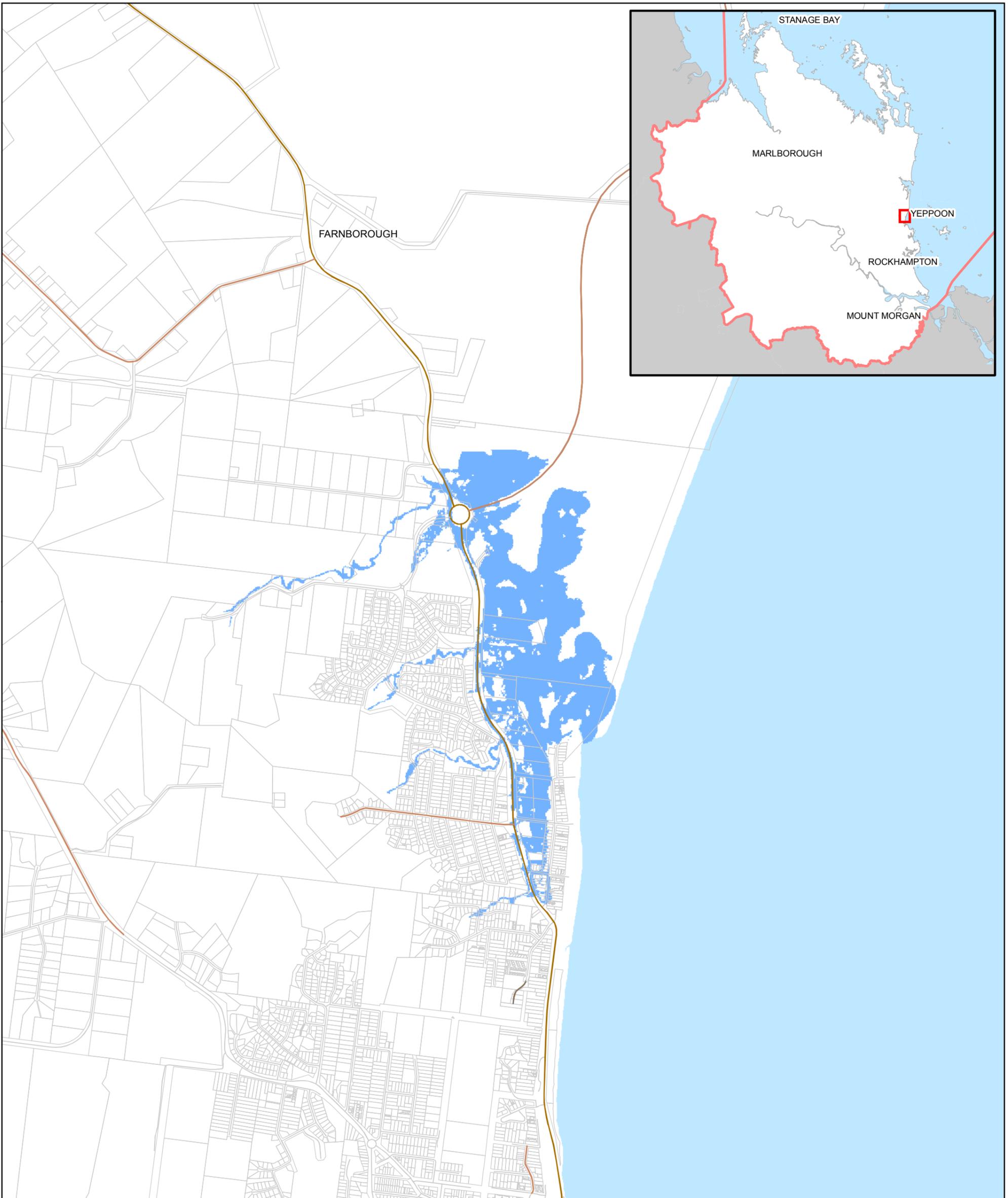


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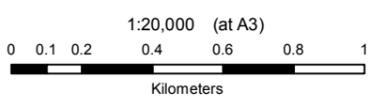
Rockhampton Regional Council Locality Map

Figure 1

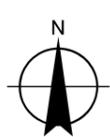


- LEGEND**
- Highway
 - Major Road
 - Road
 - Cadastre
 - GHD 100 Year ARI Flood Extent

Refer to: Report for Yeppoon Integrated Management Plan Barwells Creek Flood Risk Plan



Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

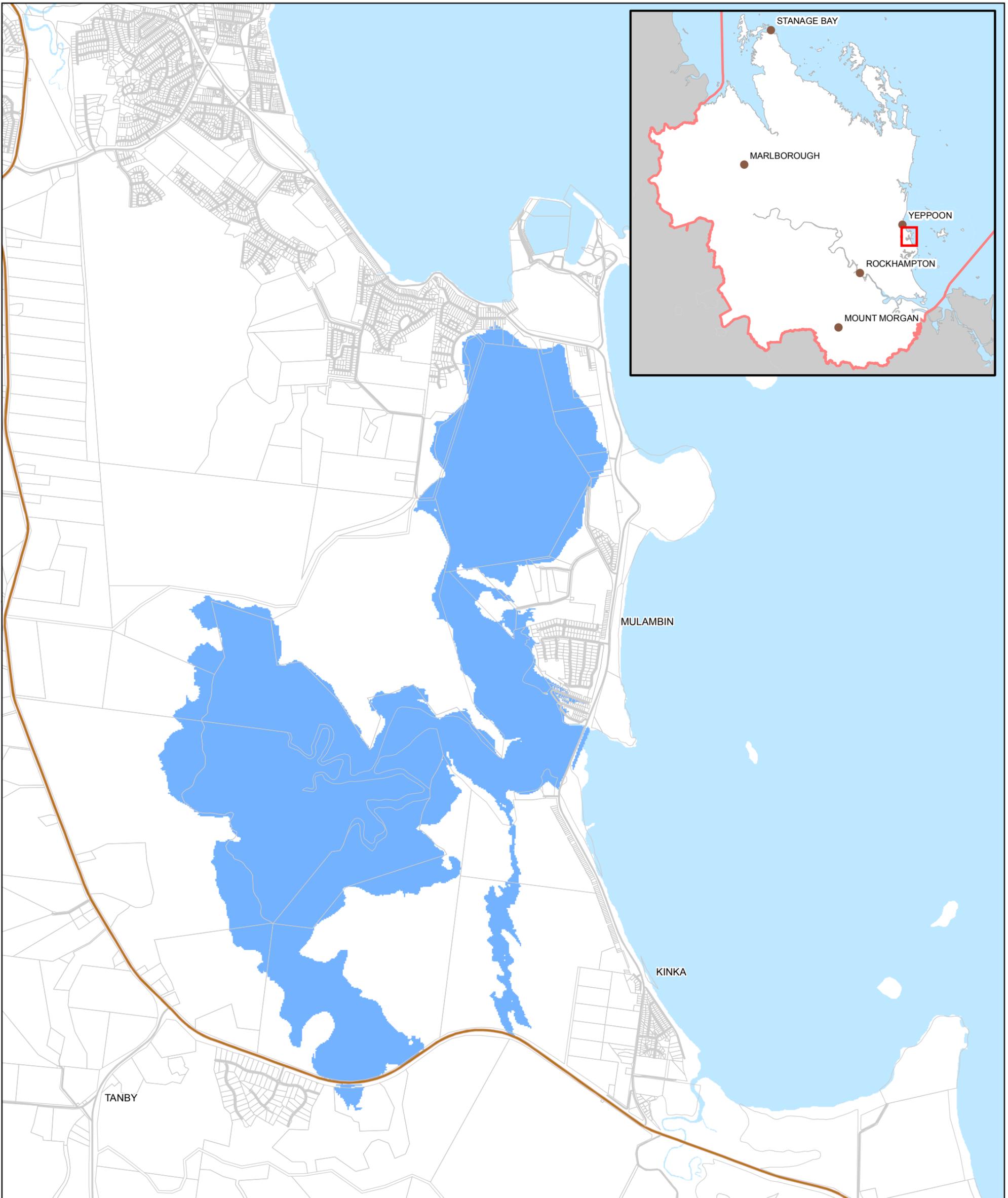


Rockhampton Regional Council
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Job Number | 41-23334
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Date | 9 NOV 2010

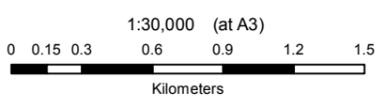
100 Year ARI Flood Hazard Extent Barwells Creek

Figure 3

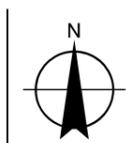


- LEGEND**
- Major Road
 - Highway
 - Road
 - Cadastre
 - GHD 100 Year ARI Flood Extent

Refer to: Report for Yeppoon Integrated Catchment Management Plan The Causeway Lake Flood Risk Study



Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

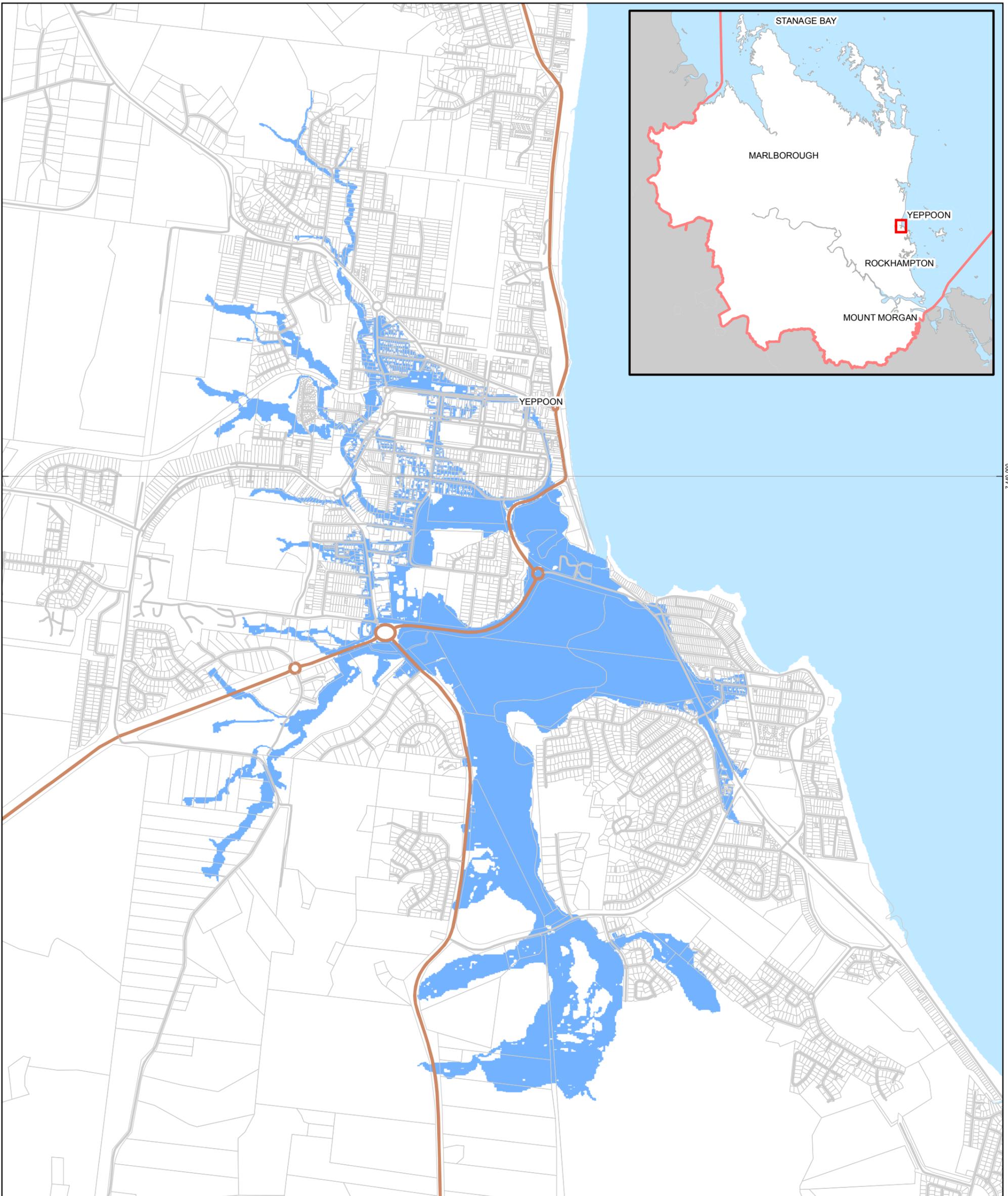


Rockhampton Regional Council
Natural Hazards and Climate Change Study

100 Year ARI Flood Hazard Extent Causeway Lake

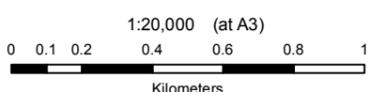
Job Number	41-23334
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Figure 4

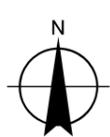


- LEGEND**
- Major Road
 - Highway
 - Road
 - Cadastre
 - GHD 100 Year ARI Flood Extent

Refer to: Report for Livingstone Integrated Management Plan Fig Tree, Ross and Yeppoon Creeks Flood Risk



Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 56

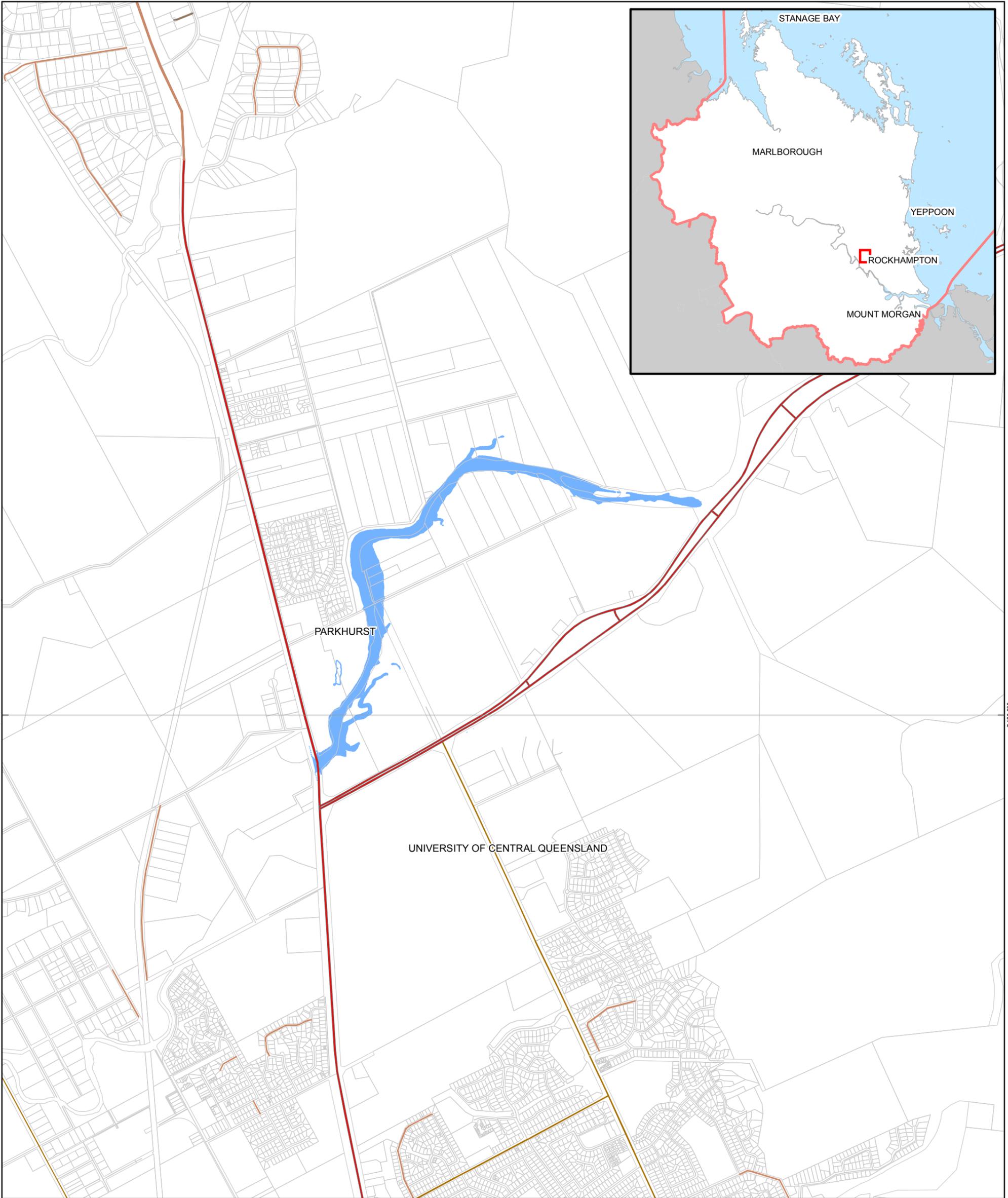


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100 Year ARI Flood Hazard Extent Figtree, Yeppoon, Ross Creeks

Figure 5

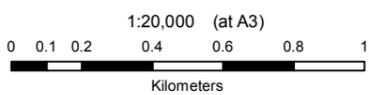


7420,000

7420,000

- LEGEND**
-  Highway
 -  Major Road
 -  Road
 -  Cadastre
 -  GHD 100 Year ARI Flood Extent

Refer to: Limestone Creek Flood Study Final Report



Map Projection: Universal Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56

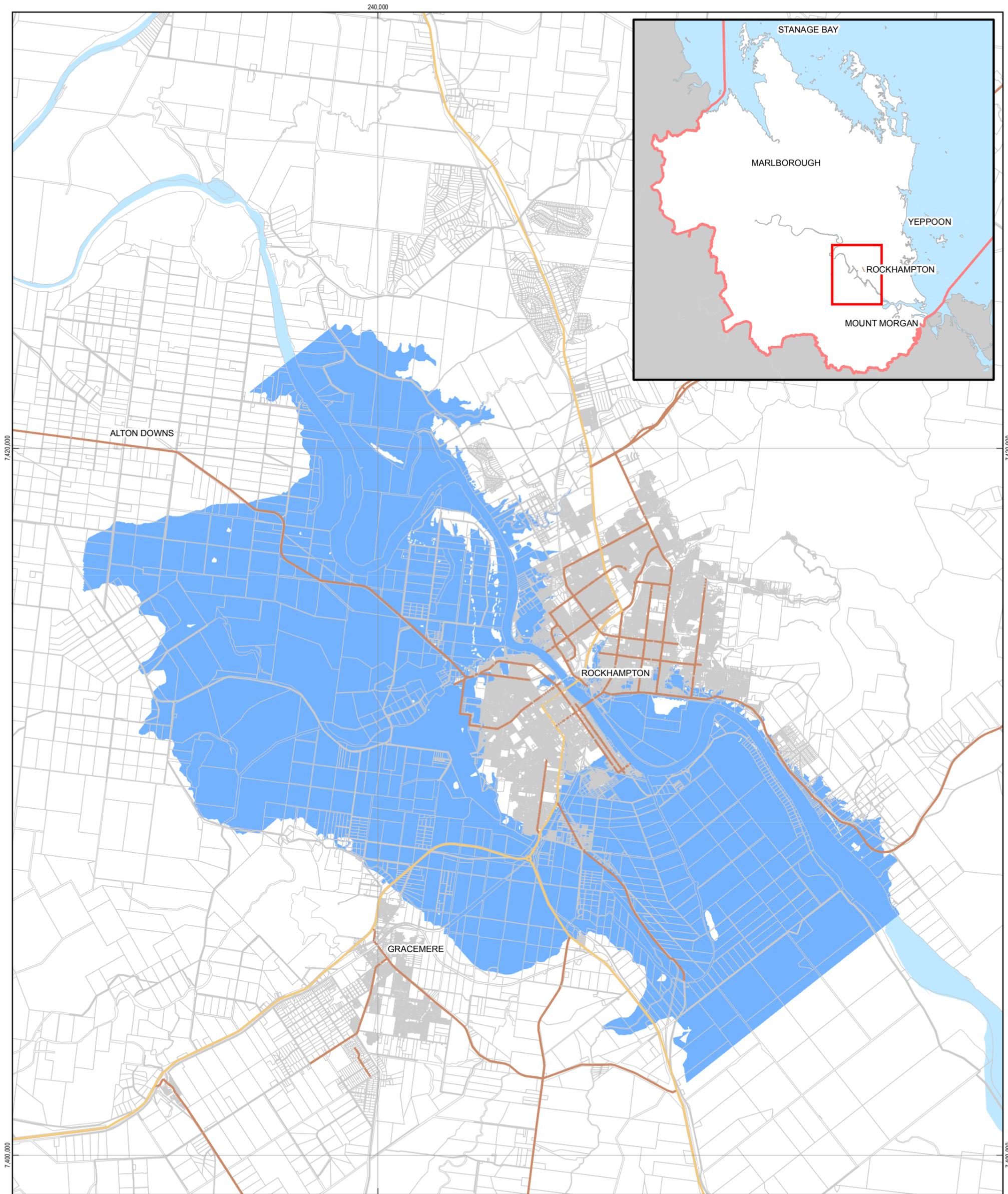


Rockhampton Regional Council
 Natural Hazards and Climate Change Study

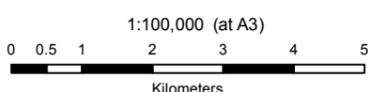
Job Number | 41-23334
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**100 Year ARI Flood Hazard Extent
 Limestone Creek**

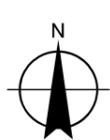
Figure 6



- LEGEND**
- Rockhampton Regional Council
 - Cadastre
 - Major Road
 - Highway
 - Road
 - Aurecon 100 Year ARI Flood Extent



Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56

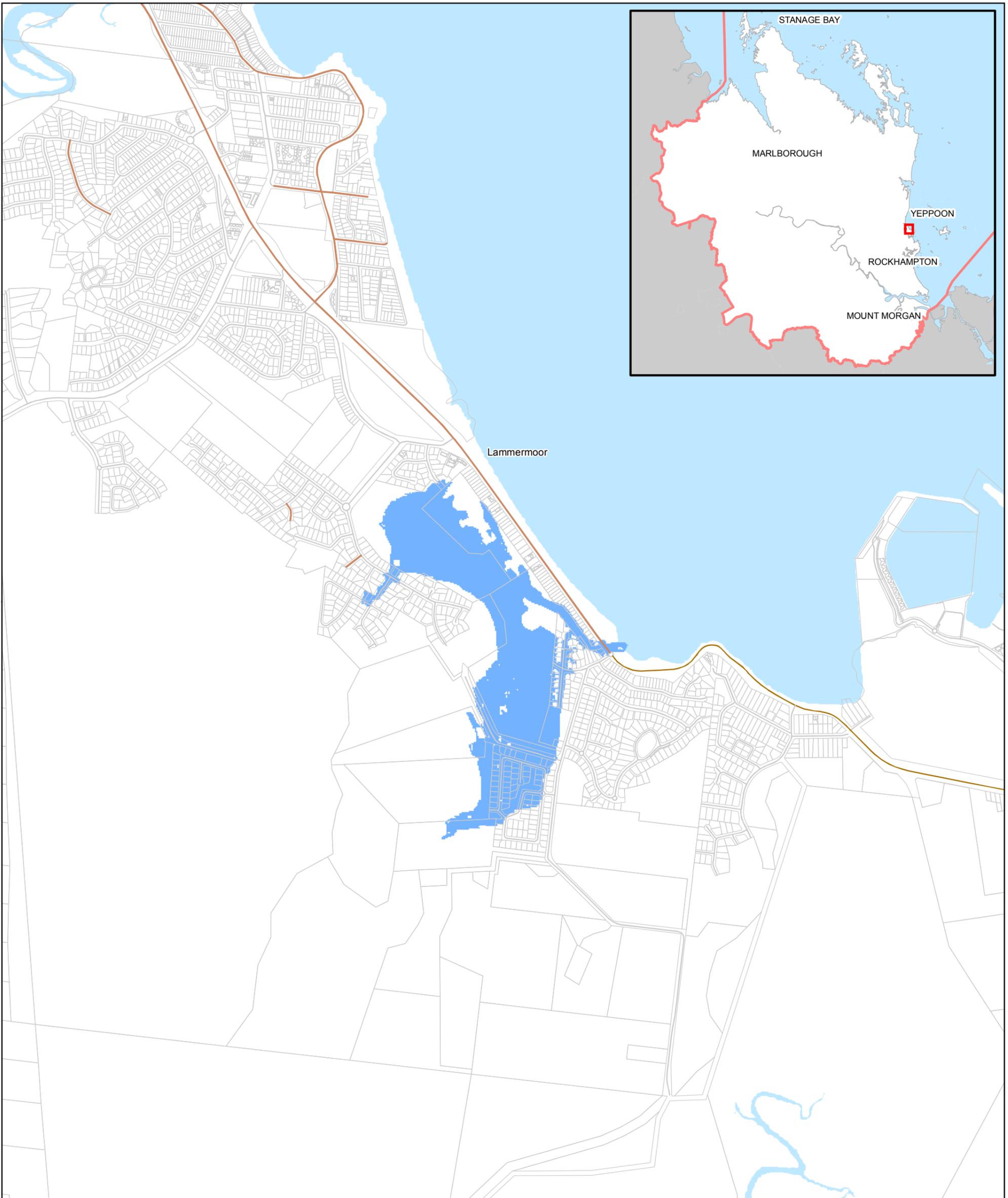


Rockhampton Regional Council
 Natural Hazards and Climate Change Study

Job Number | 41-23334
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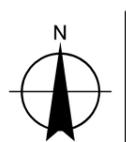
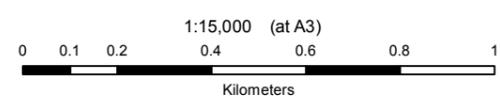
Aurecon 100 Year ARI Flood Hazard Extent Rockhampton

Figure 7



- LEGEND**
- Highway
 - Major Road
 - Road
 - Cadastre
 - GHD 100 Year ARI Flood Extent

Refer to: Report for Yeppoon Integrated Catchment Management Plan Williamson Creek Flood Risk Study

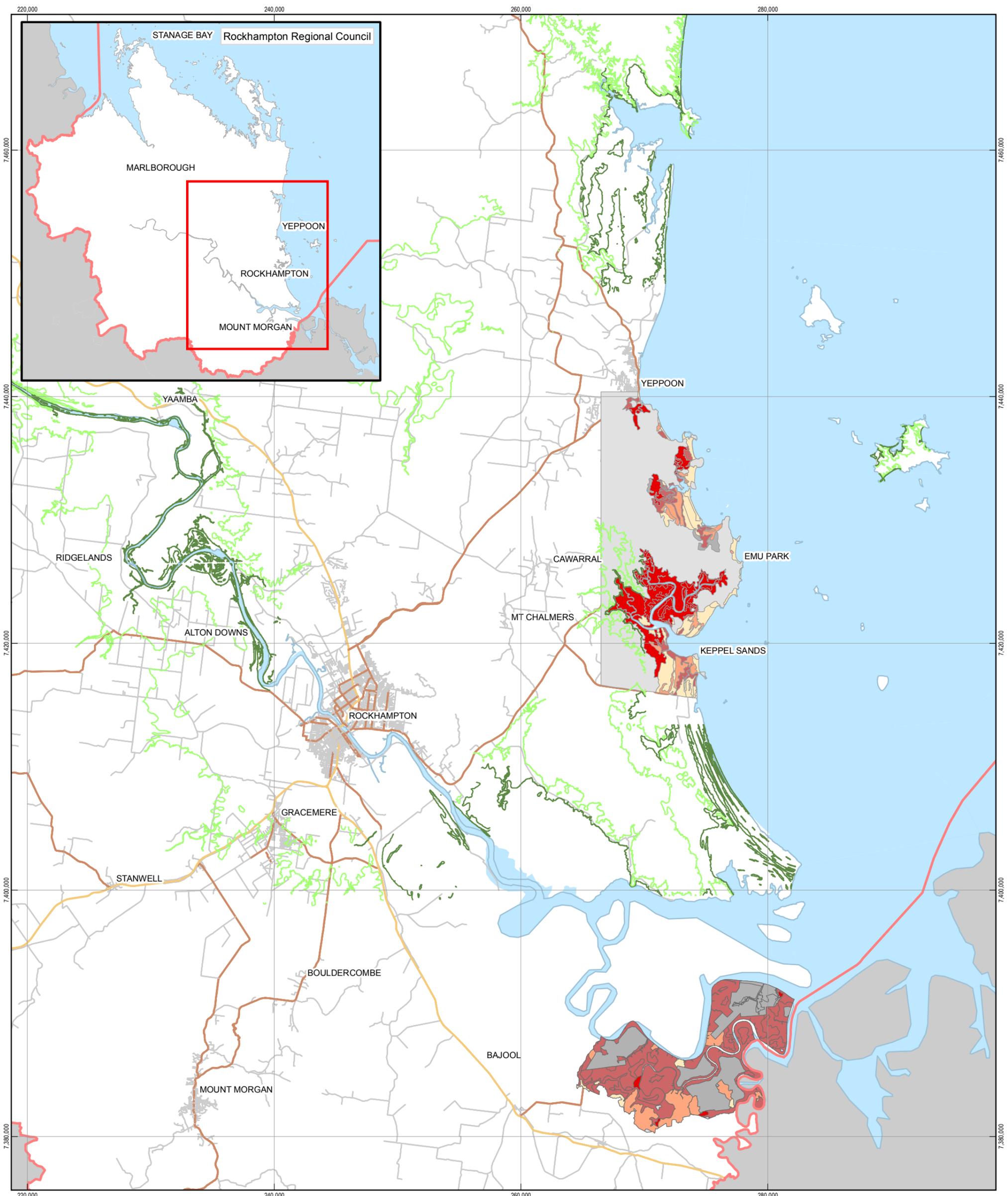


Rockhampton Regional Council
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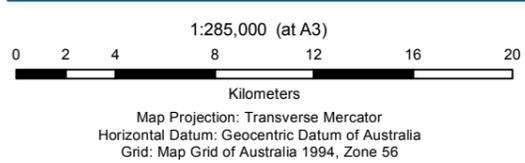
100 Year ARI Flood Hazard Extent Williamson Creek

Figure 8



LEGEND

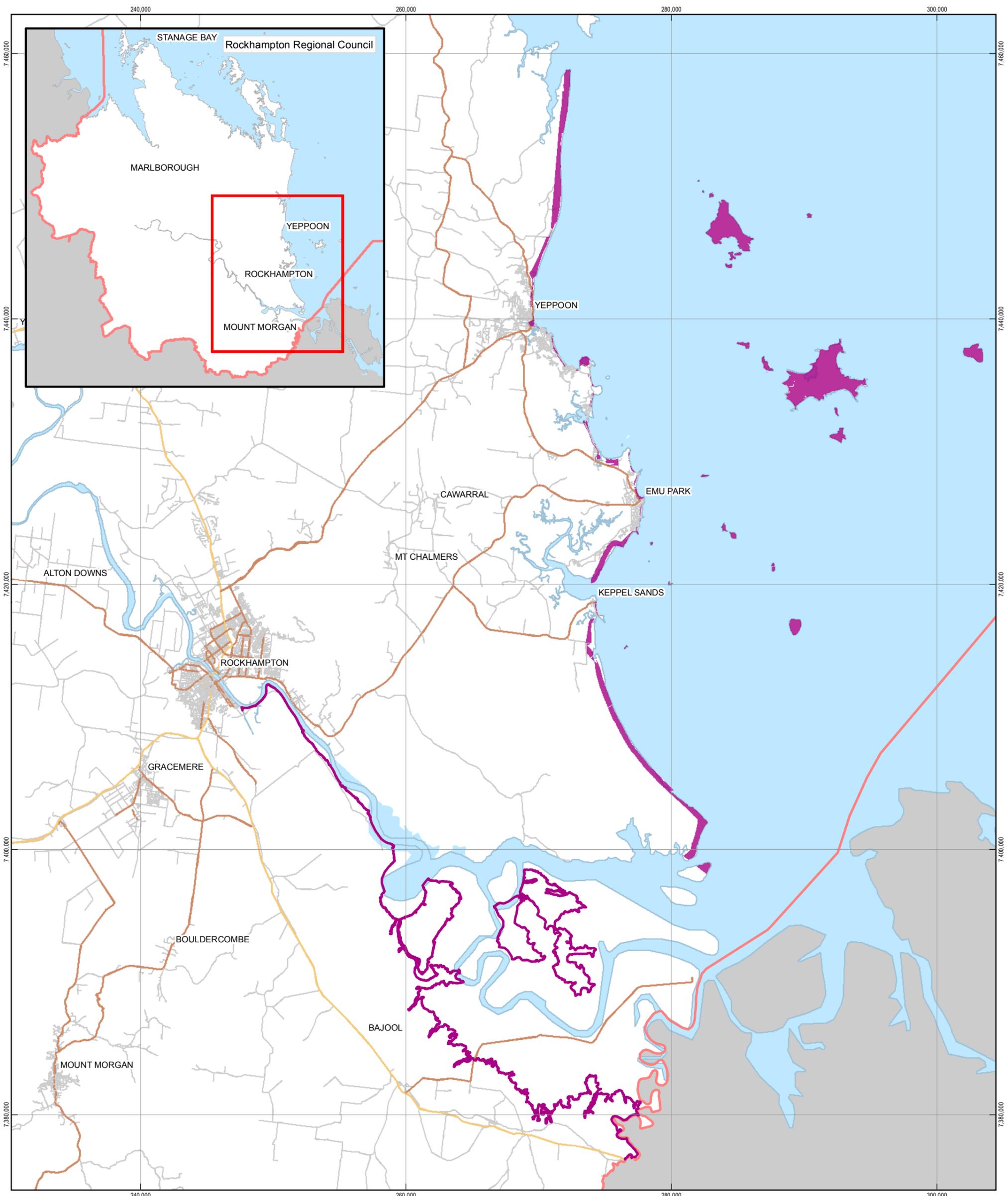
Contours	Acid Sulfate Soil Class	Very Low	Major Road
— 20m Australian Height Datum	High	Not Classified	Highway
— 5m Australian Height Datum	Moderate	Not Assessed	Road
□ Rockhampton Regional Council	Low		



Rockhampton Regional Council
 Natural Hazards and Climate Change Study
**Acid Sulfate Soil Hazard
 Rockhampton**

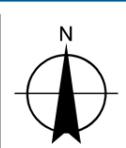
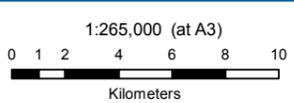
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Figure 9



LEGEND

- Rockhampton Regional Council
- Erosion Prone Land
- Major Road
- Highway
- Road

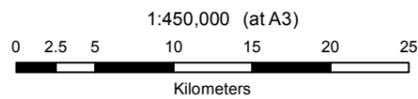
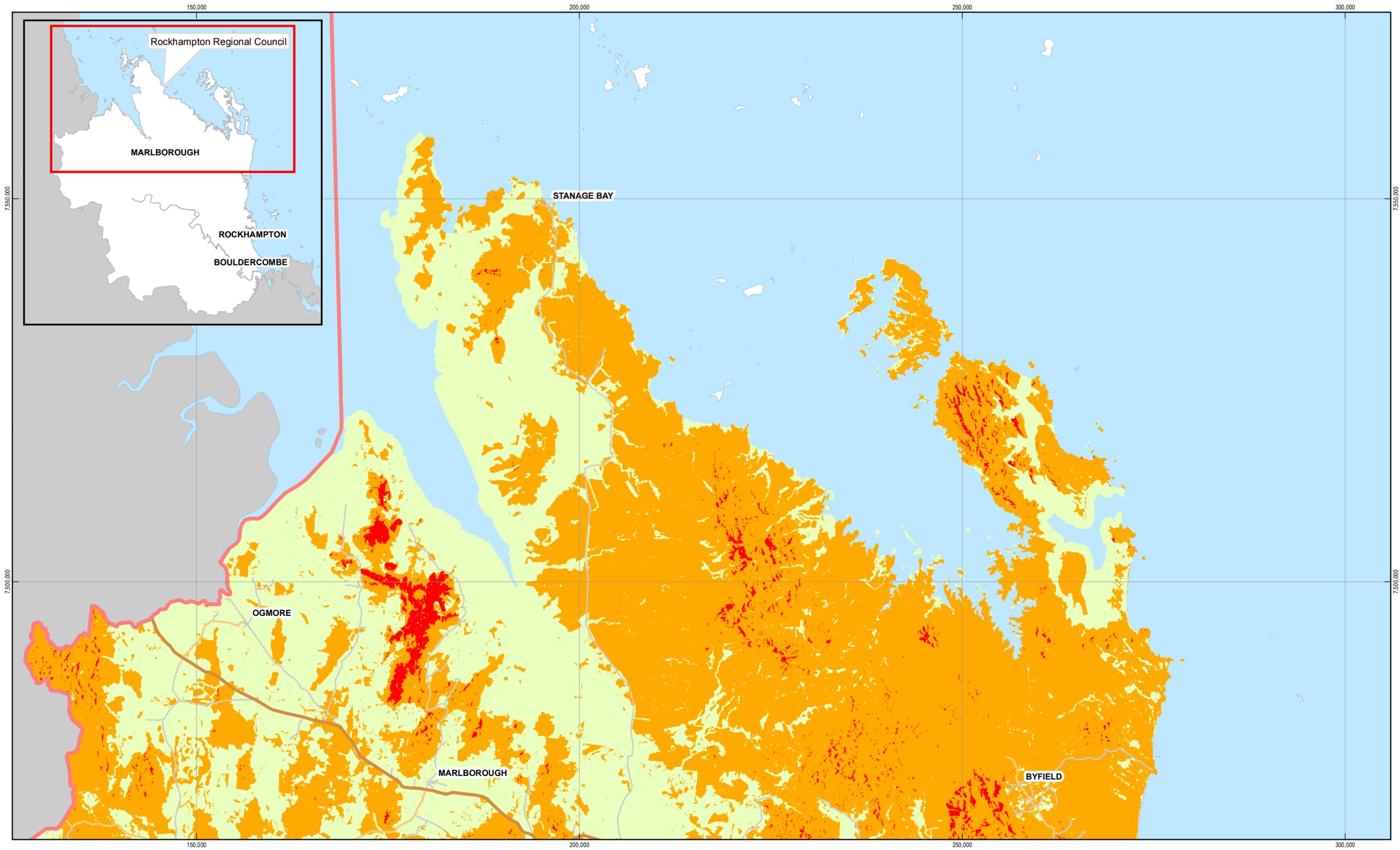


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Erosion Prone Land Hazard Rockhampton

Figure 10



Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56



LEGEND

- | | | |
|------------------------------|--|--------------------------------------|
| Rockhampton Regional Council | Highway | Bushfire Risk Hazard Analysis - High |
| Major Road | Bushfire Risk Hazard Analysis - Medium | |
| Road | Bushfire Risk Hazard Analysis - Low | |

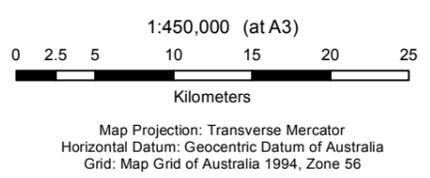
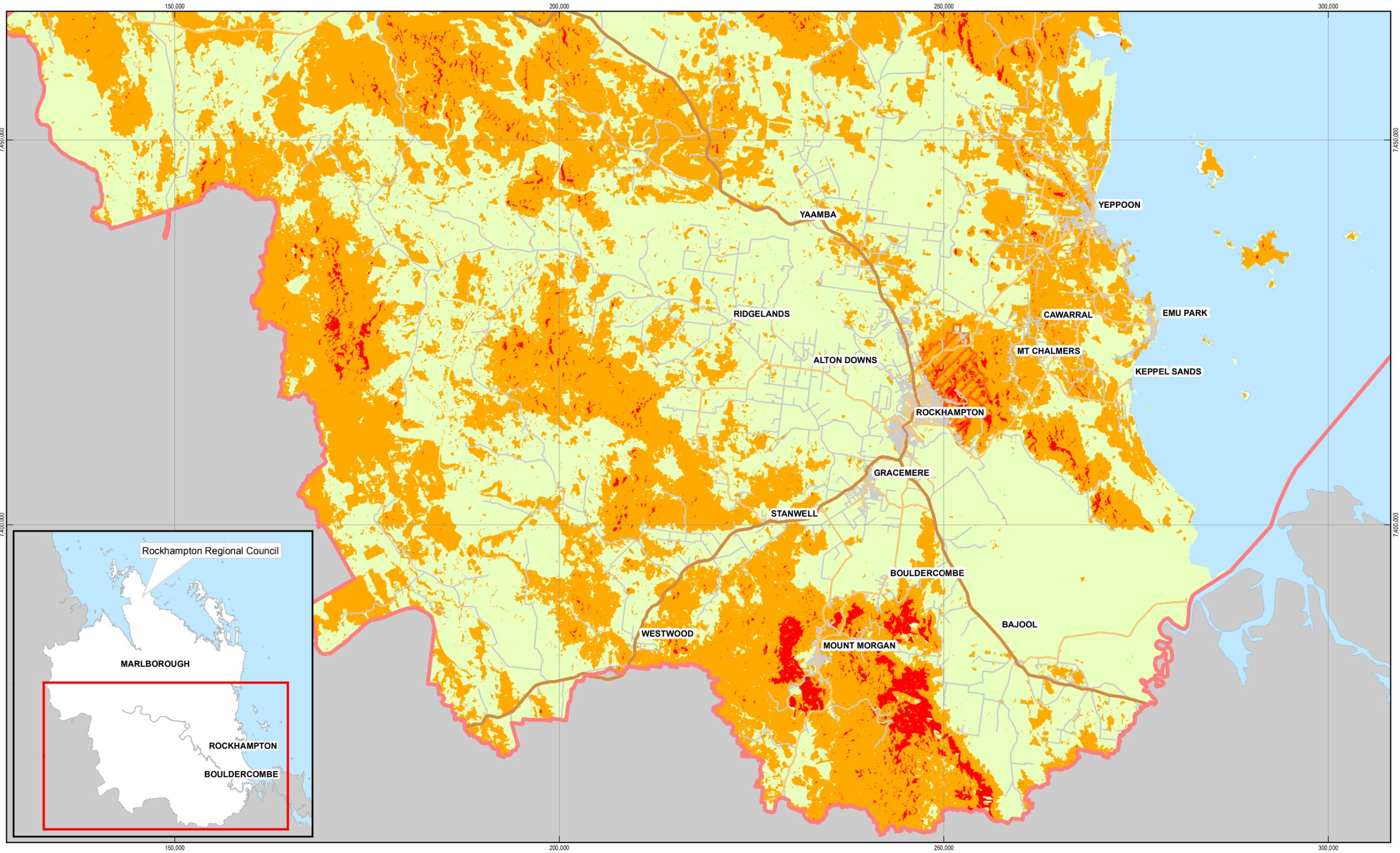


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 Natural Hazards and Climate Change Study

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**Bushfire Hazard
 Rockhampton North**

Figure 11

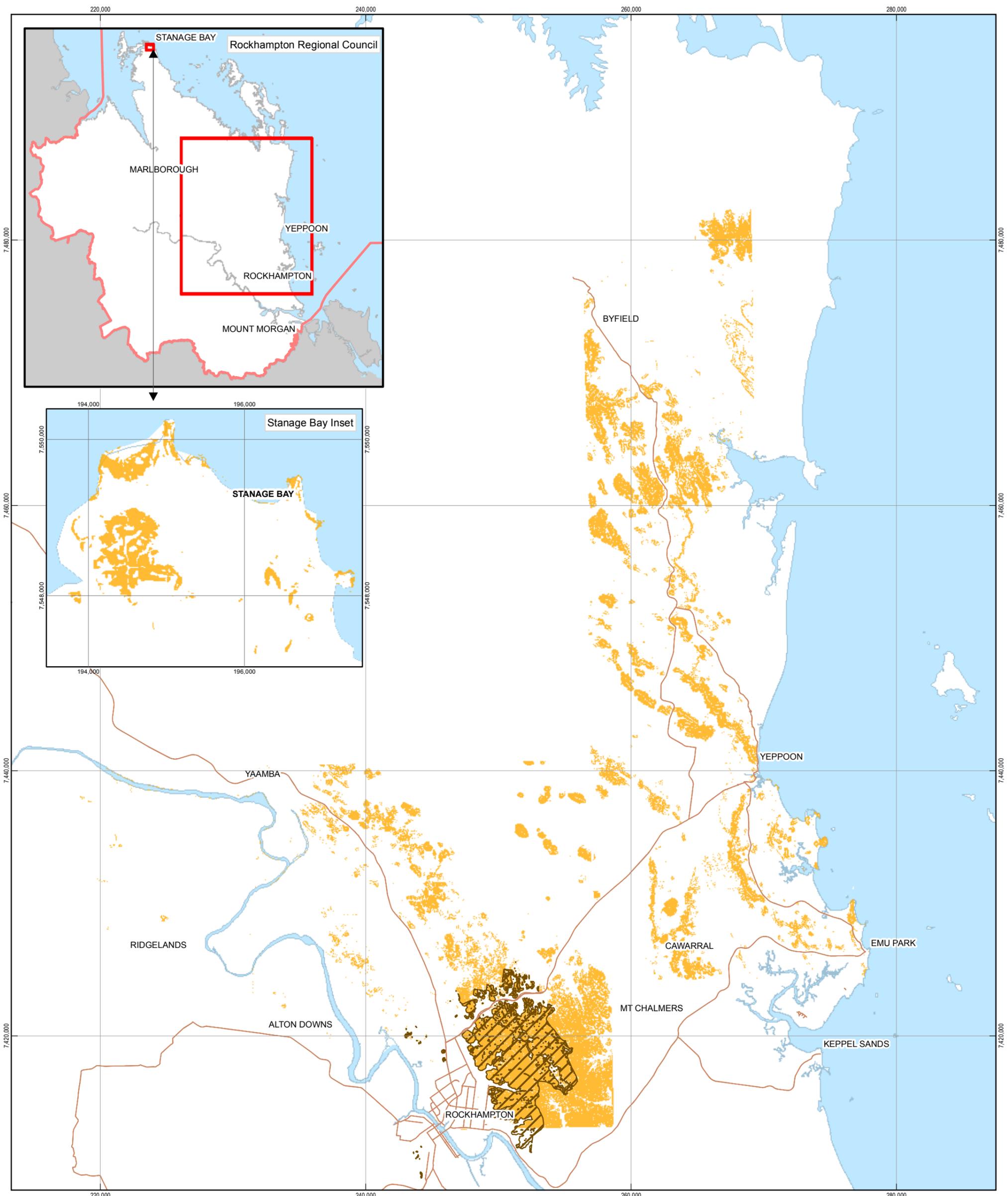


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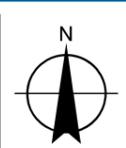
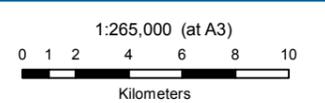
**Bushfire Hazard
Rockhampton South**

Figure 12



LEGEND

- Rockhampton Regional Council
- Major Road
- Steep Land
- Steep Land

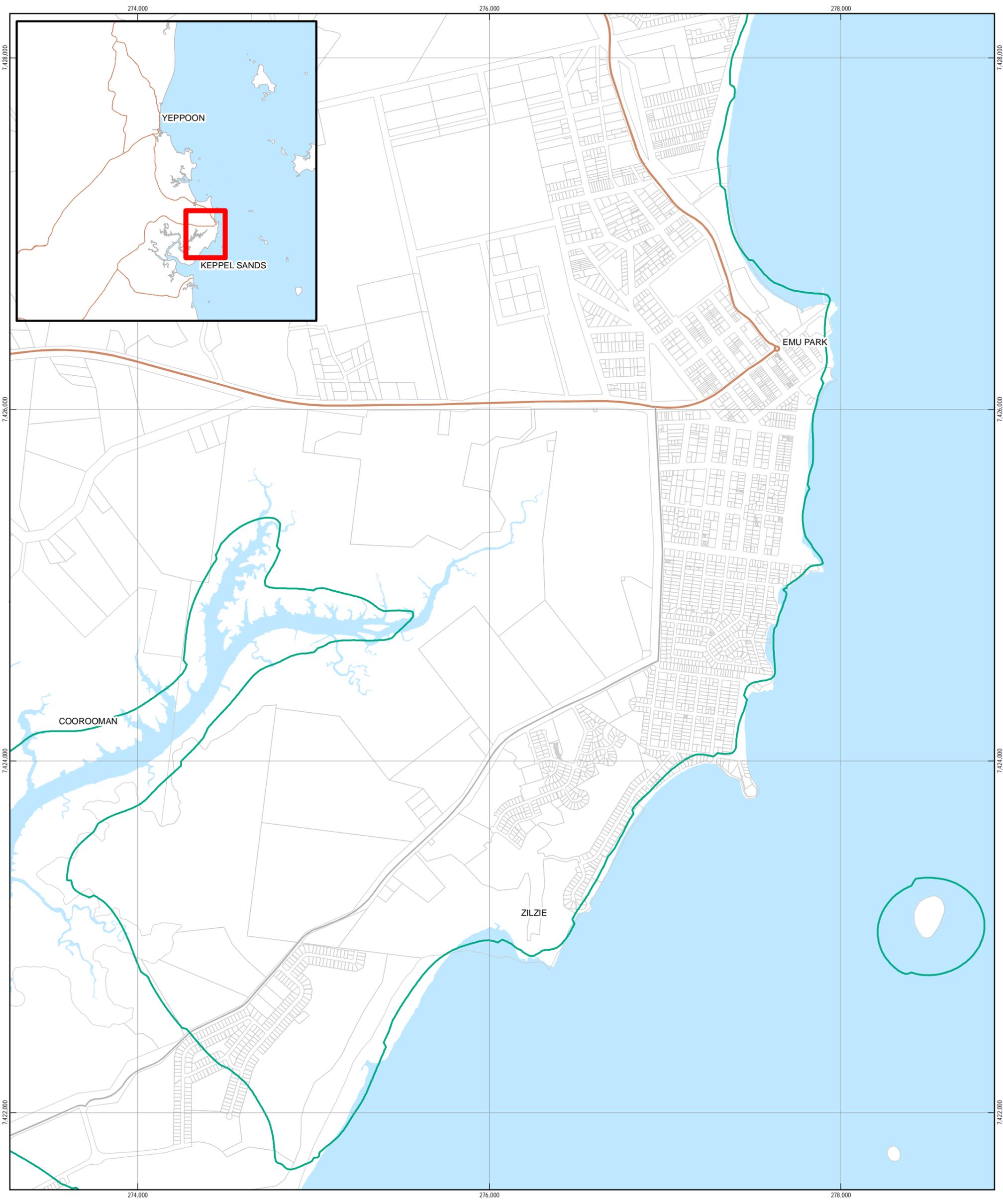


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Natural Hazards and Climate Change Study

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Date | 8 NOV 2010

**Landslide Prone Land Hazard
Rockhampton**

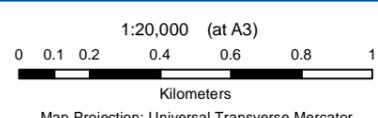
Figure 13



LEGEND

- Cadastre
- Highest Astronomical Tide (Approximate)*
- Major Road
- Highway
- Road

*The following have been mapped, but are not discernable at this scale:
 HAT + 0.3m: Predicted rise over 50 years.
 HAT + 0.8m: Predicted rise over 100 years.
 HAT + 1.5m (DSTE for developed areas), and
 HAT + 2.0m (DSTE for non developed areas)
 HAT generated using Rosslyn Bay location (Semidiurnal tidal planes 2010, Maritime Safety Queensland, July 2009).



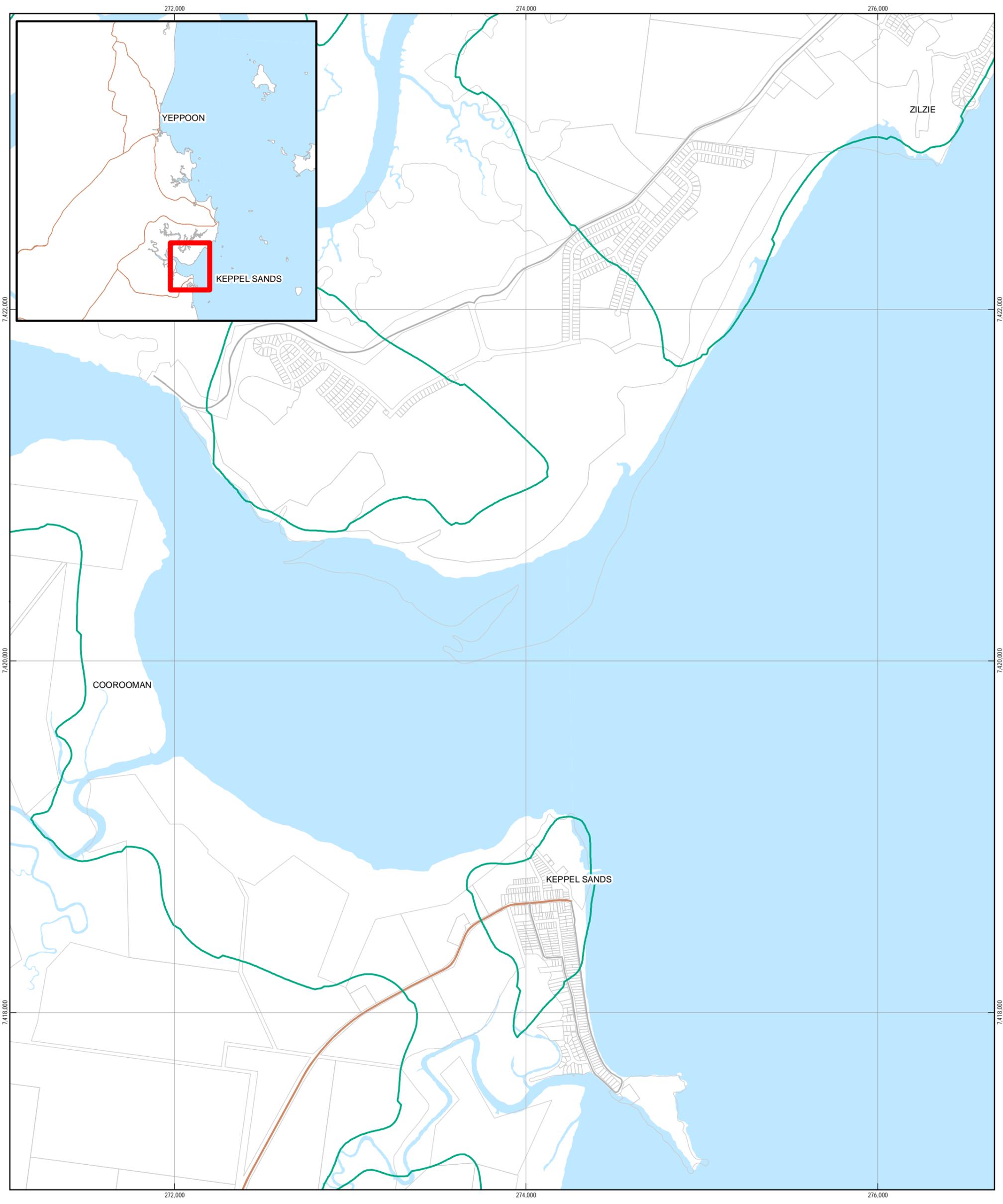
Map Projection: Universal Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56



Rockhampton Regional Council
 Natural Hazards and Climate Change Study
**Sea Level Rise Hazard
 Emu Park**

Job Number | 41-23334
 Revision | B
 Date | 14 DEC 2010

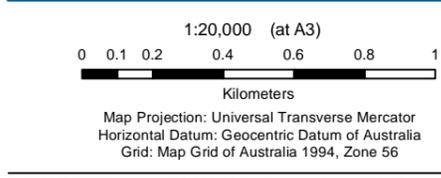
Figure 14



LEGEND

- Cadastre
- Highest Astronomical Tide (Approximate)*
- Major Road
- Highway
- Road

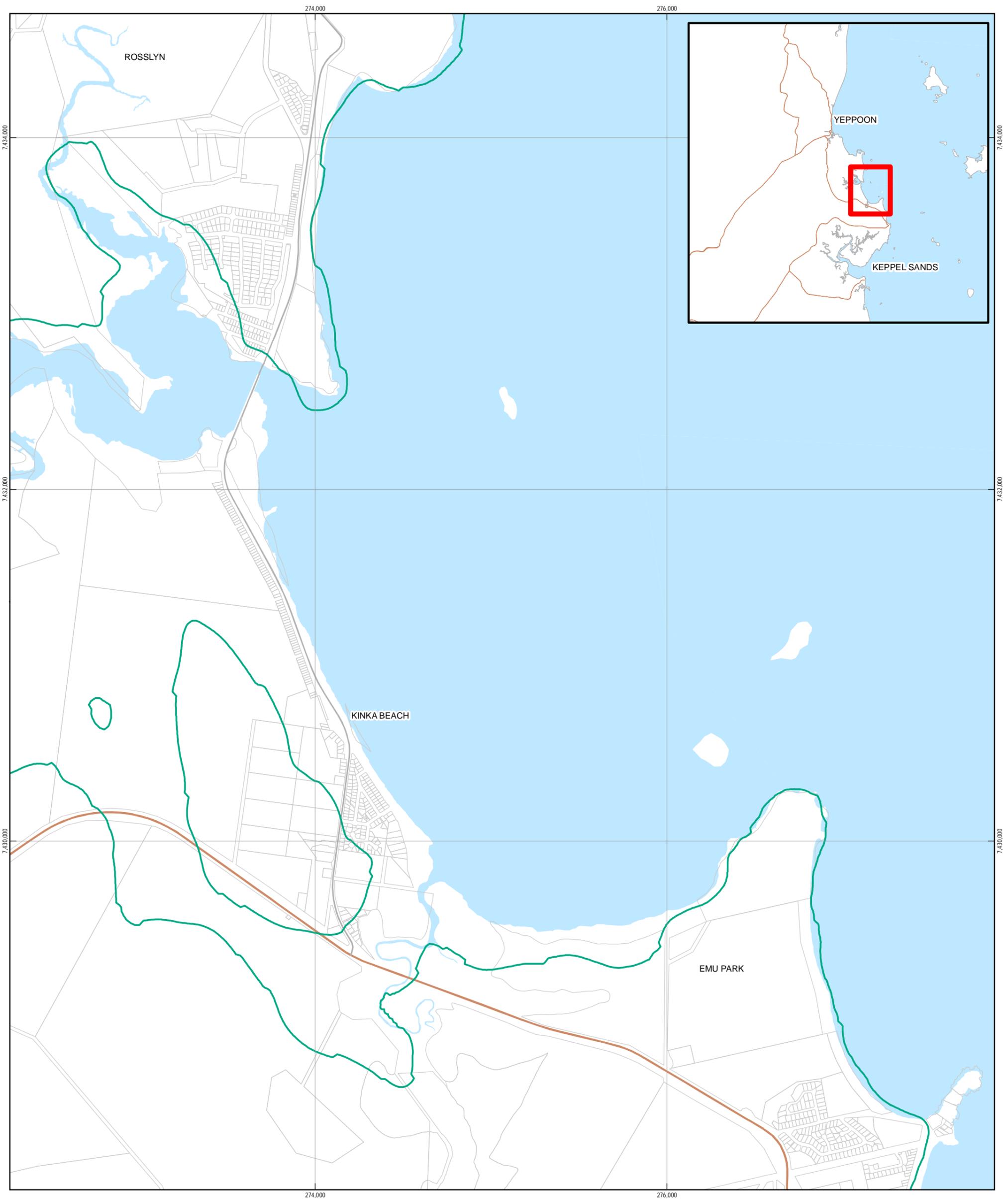
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 HAT + 0.3m: Predicted rise over 50 years,
 HAT + 0.8m: Predicted rise over 100 years,
 HAT + 1.5m (DSTE for developed areas), and
 HAT + 2.0m (DSTE for non developed areas)
 HAT generated using Rosslyn Bay location (Semidiurnal tidal planes 2010, Maritime Safety Queensland, July 2009).



Rockhampton Regional Council
 Natural Hazards and Climate Change Study
**Sea Level Rise Hazard
 Keppel Sands**

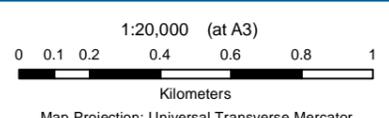
Job Number | 41-23334
 Revision | B
 Date | 14 DEC 2010

Figure 15



- LEGEND**
- Cadastre
 - Highest Astronomical Tide (Approximate)*
 - Major Road
 - Highway
 - Road

*The following have been mapped, but are not discernable at this scale:
 HAT + 0.3m: Predicted rise over 50 years,
 HAT + 0.8m: Predicted rise over 100 years,
 HAT + 1.5m (DSTE for developed areas), and
 HAT + 2.0m (DSTE for non developed areas)
 HAT generated using Rosslyn Bay location (Semidiurnal tidal planes 2010, Maritime Safety Queensland, July 2009).



Map Projection: Universal Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56



Rockhampton Regional Council
 Natural Hazards and Climate Change Study
**Sea Level Rise Hazard
 Kinka Beach**

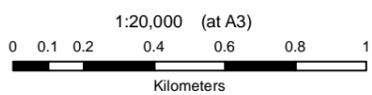
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Figure 16



- LEGEND**
- Cadastre
 - Major Road
 - Highest Astronomical Tide (Approximate)*
 - Highway
 - Road

*The following have been mapped, but are not discernable at this scale:
 HAT + 0.3m: Predicted rise over 50 years,
 HAT + 0.8m: Predicted rise over 100 years,
 HAT + 1.5m (DSTE for developed areas), and
 HAT + 2.0m (DSTE for non developed areas)
 HAT generated using Rosslyn Bay location (Semidiurnal tidal planes 2010, Maritime Safety Queensland, July 2009).



Map Projection: Universal Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56

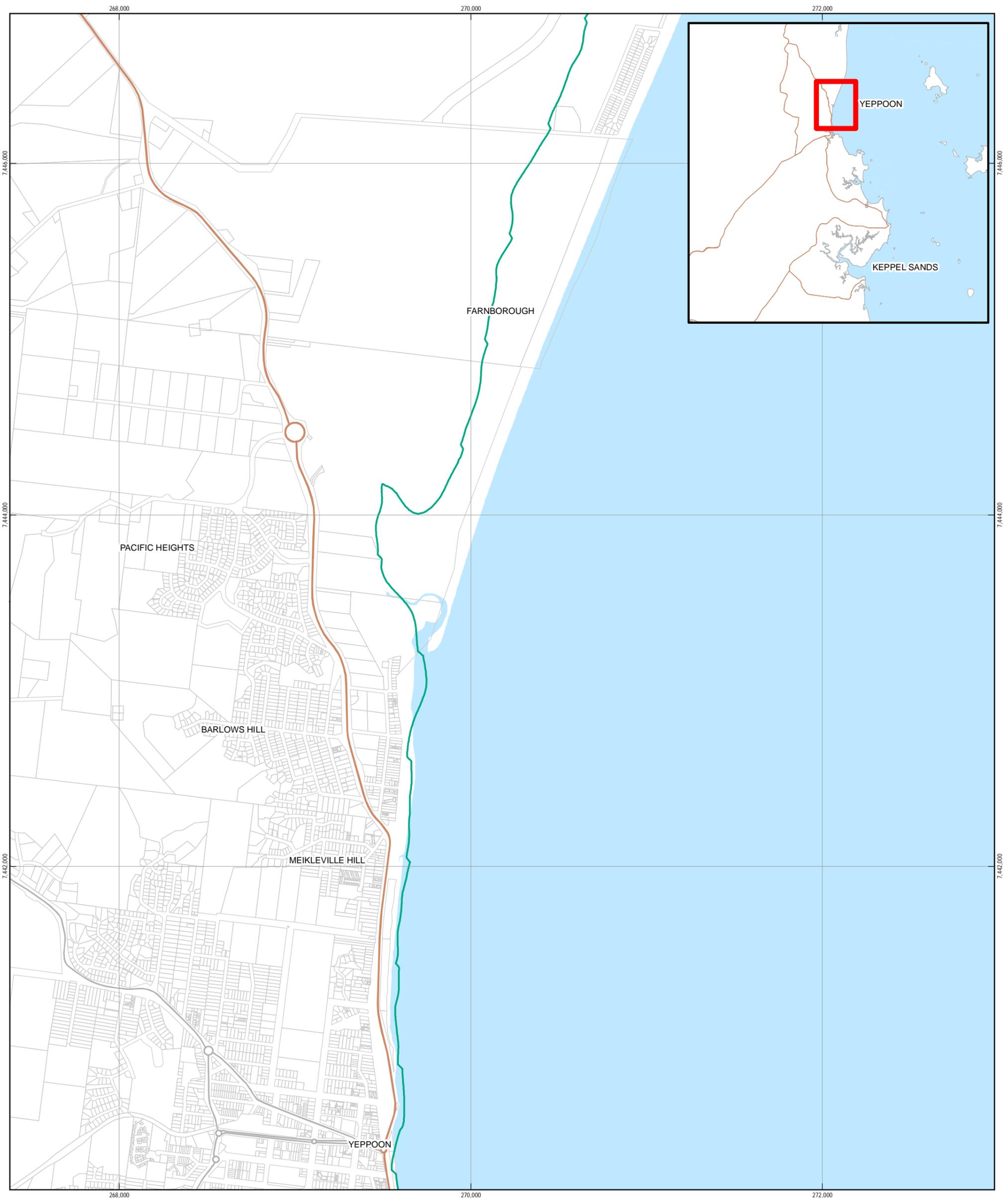


Rockhampton Regional Council
 Natural Hazards and Climate Change Study

**Sea Level Rise Hazard
 Yeppoon**

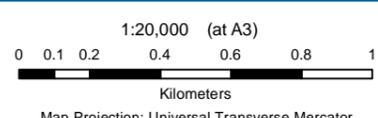
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Figure 17



- LEGEND**
- Cadastre
 - Highest Astronomical Tide (Approximate)*
 - Major Road
 - Highway
 - Road

*The following have been mapped, but are not discernable at this scale:
 HAT + 0.3m: Predicted rise over 50 years.
 HAT + 0.8m: Predicted rise over 100 years.
 HAT + 1.5m (DSTE for developed areas), and
 HAT + 2.0m (DSTE for non developed areas)
 HAT generated using Rosslyn Bay location (Semidiurnal tidal planes 2010, Maritime Safety Queensland, July 2009).



Map Projection: Universal Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56

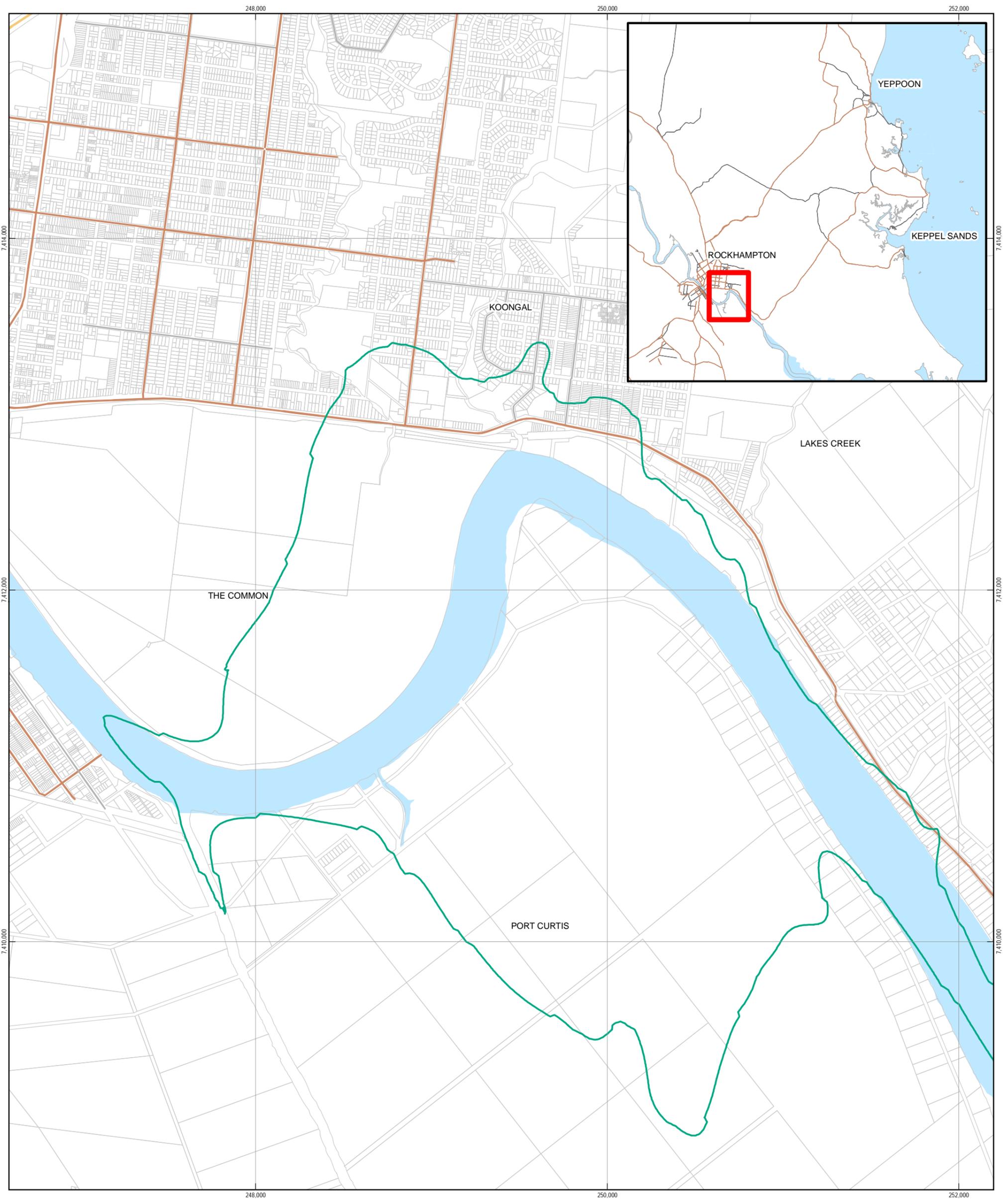


Rockhampton Regional Council
 Natural Hazards and Climate Change Study

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**Sea Level Rise Hazard
 Yeppoon (northern extent)**

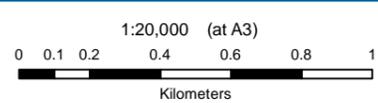
Figure 17a



LEGEND

- Cadastre
- Highest Astronomical Tide (Approximate)*
- Major Road
- Highway
- Road

*The following have been mapped, but are not discernable at this scale:
 HAT + 0.3m: Predicted rise over 50 years.
 HAT + 0.8m: Predicted rise over 100 years.
 HAT + 1.5m (DSTE for developed areas), and
 HAT + 2.0m (DSTE for non developed areas)
 HAT generated using Rockhampton location (Semidiurnal tidal planes 2010, Maritime Safety Queensland, July 2009).



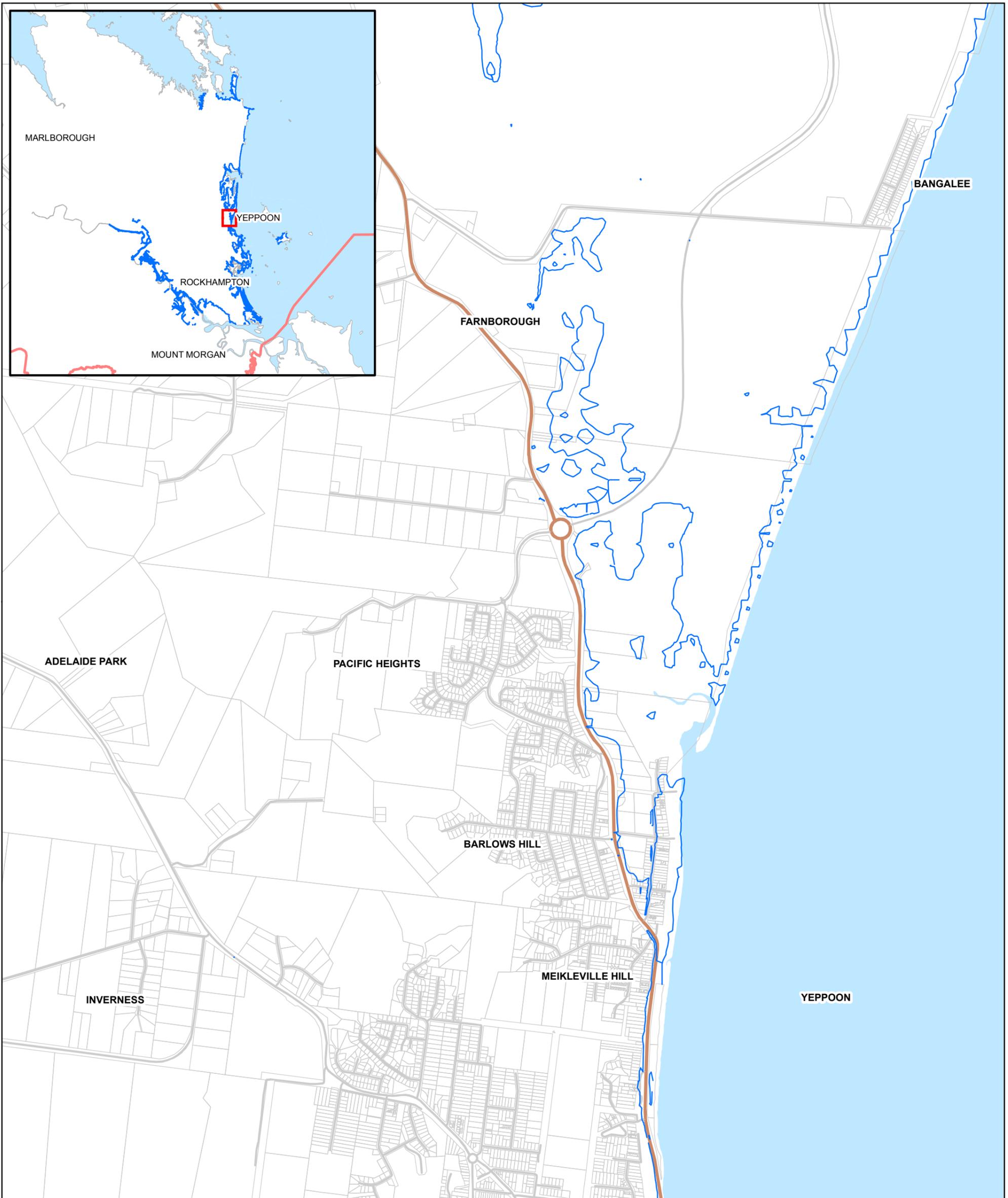
Map Projection: Universal Transverse Mercator
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 Grid: Map Grid of Australia 1994, Zone 56



Rockhampton Regional Council
 Natural Hazards and Climate Change Study
**Sea Level Rise Hazard
 Rockhampton**

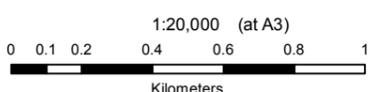
Job Number | 41-23334
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Figure 17b

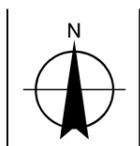


- LEGEND**
- Storm Tide Hazard*
 - Rockhampton Regional Council
 - Cadastre
 - Major Road
 - Highway
 - Road

* Capricorn Coast Storm Tide Hazard Investigation, Connell Wagner (MAY 2003).



Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56

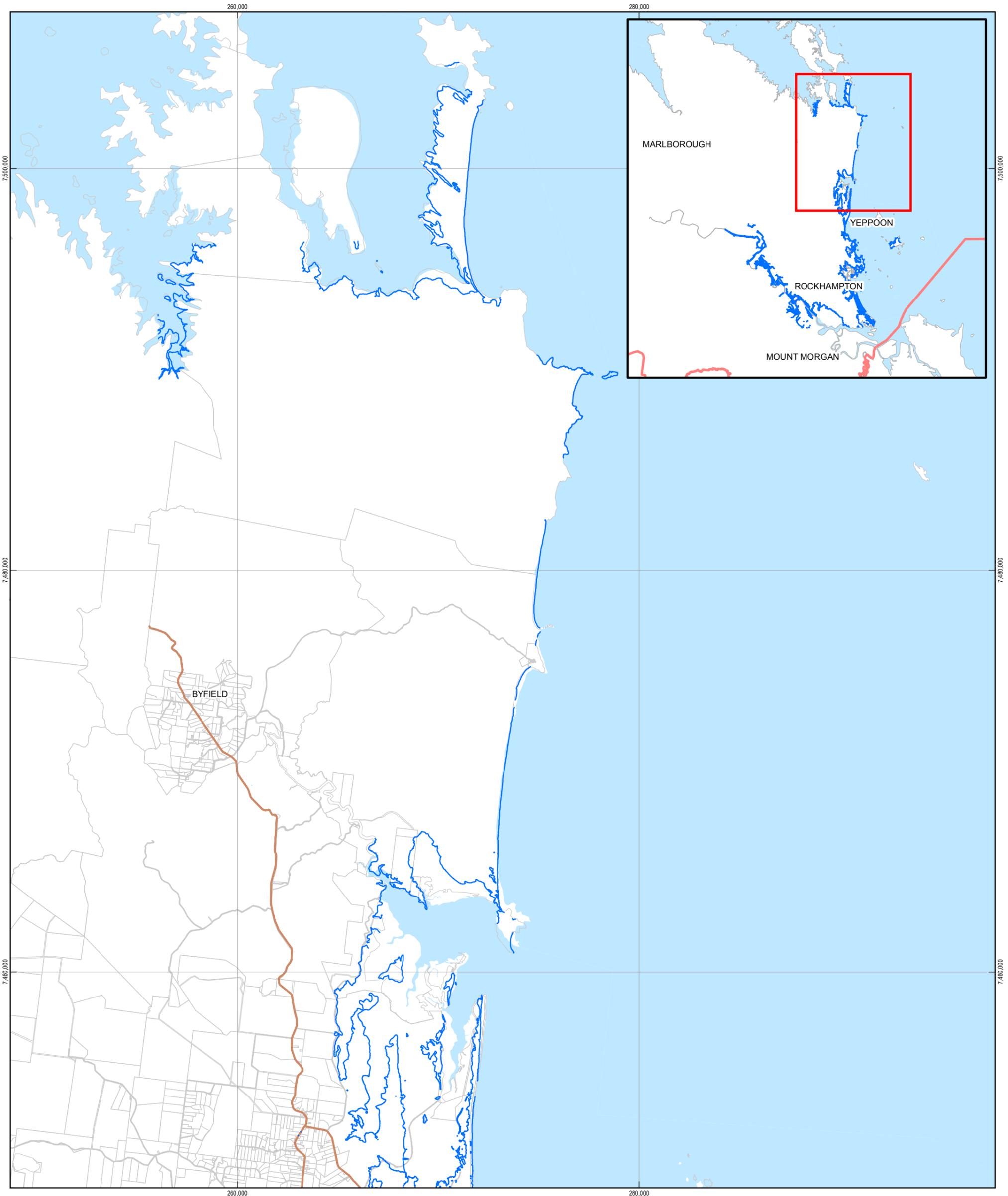


Rockhampton Regional Council
 Natural Hazards and Climate Change Study

Storm Tide Hazard Bangalee

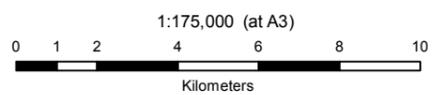
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Figure 18



- LEGEND**
- Storm Tide Hazard*
 - Rockhampton Regional Council
 - Cadastre
 - Major Road
 - Highway
 - Road

* Capricorn Coast Storm Tide Hazard Investigation, Connell Wagner (MAY 2003).



Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56

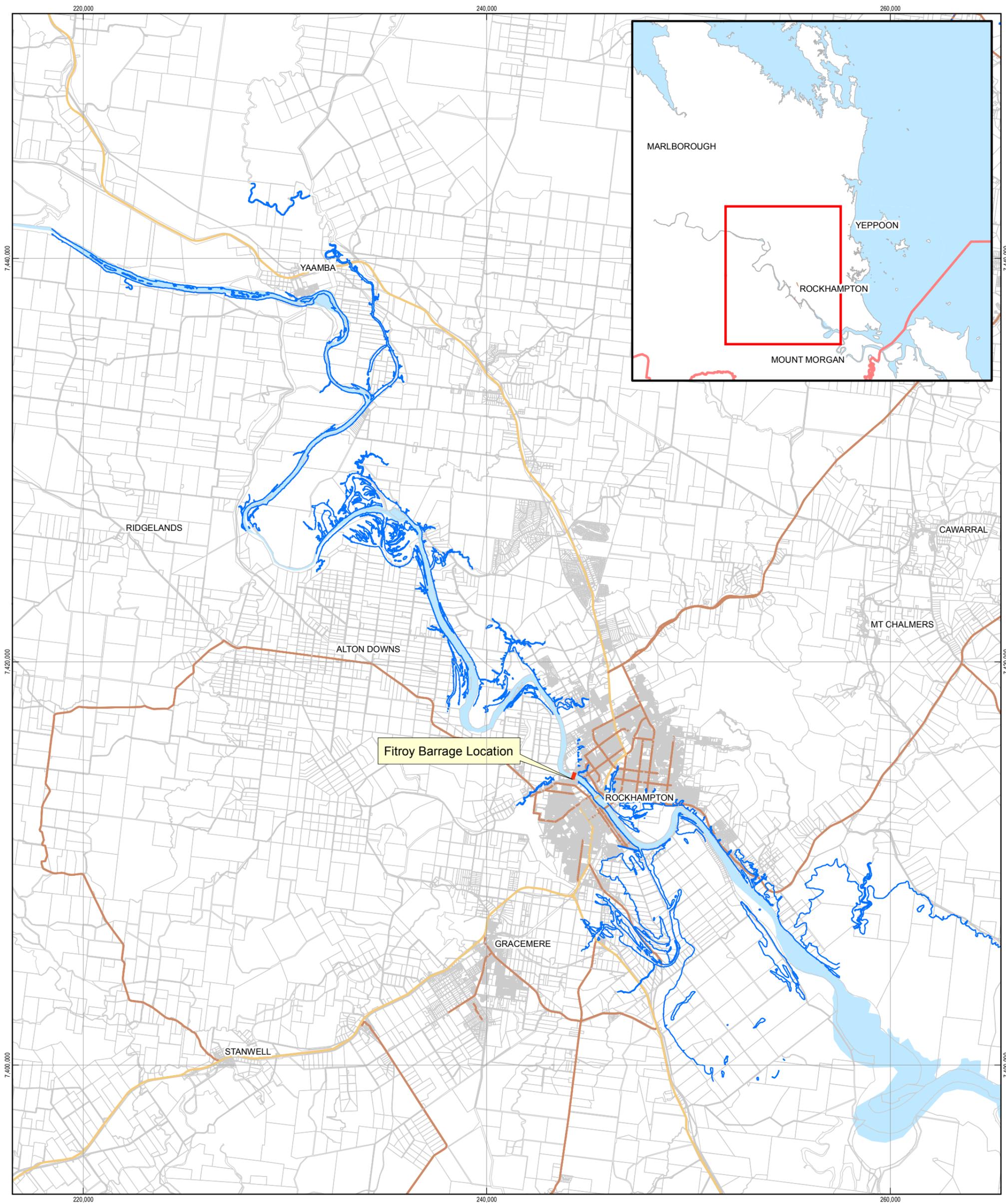


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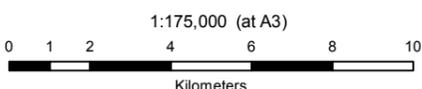
Storm Tide Hazard Byfield

Figure 19



- LEGEND**
- Storm Tide Hazard*
 - Rockhampton Regional Council
 - Cadastre
 - Major Road
 - Highway
 - Road

* Capricorn Coast Storm Tide Hazard Investigation, Connell Wagner (MAY 2003).

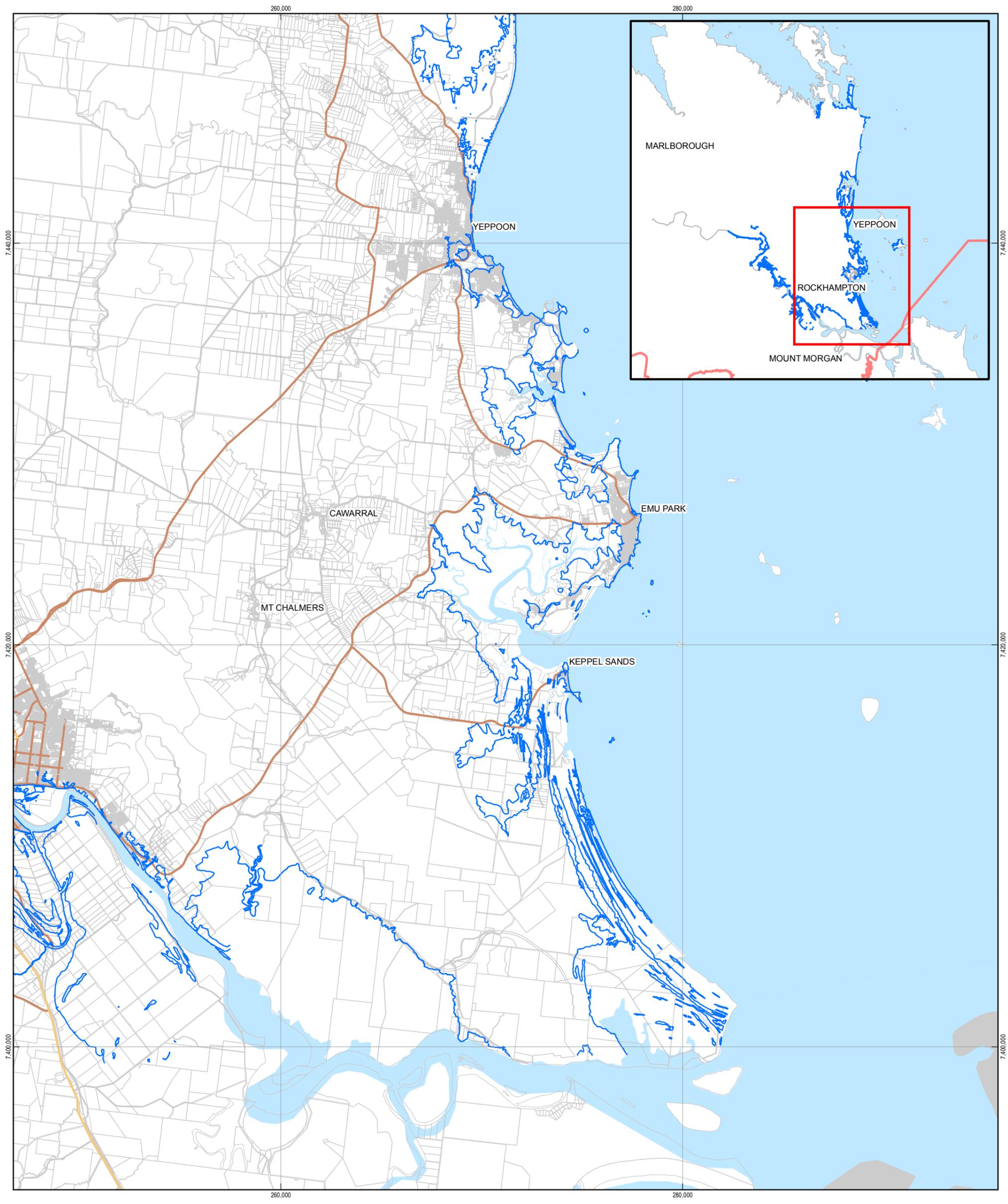


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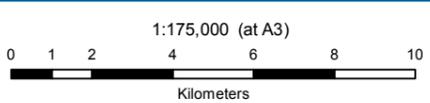
Storm Tide Hazard Rockhampton

Figure 20



- LEGEND**
- Storm Tide Hazard*
 - Rockhampton Regional Council
 - Cadastre
 - Major Road
 - Highway
 - Road

* Capricorn Coast Storm Tide Hazard Investigation, Connell Wagner (MAY 2003).



Map Projection: Transverse Mercator
 Horizontal Datum: Geocentric Datum of Australia
 Grid: Map Grid of Australia 1994, Zone 56



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Storm Tide Hazard Yeppoon

Figure 21



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		Name	Signature	Name	Signature	Date
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