CITY OF KARRATHA

COASTAL HAZARD RISK MANAGEMENT ADAPTATION PLAN

October 2014

City of Karratha

Coastal Hazard Risk Management Adaptation Plan

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1. INTRODUCTION

The coastal communities located within the City of Karratha (the City) are at risk from coastal processes such as coastal erosion and storm surge. Projected sea level rise will increase the risk from coastal hazards and therefore it is important that the City adopts a risk management and adaption strategy to manage growth and development pressure in a sustainable way that responds to these known coastal hazards.

This Coastal Hazard Risk Management Adaptation Plan (CHRMAP) has been prepared for the City and applies to the entire City District (study area).

This CHRMAP has generally been prepared in accordance with the requirements of *State Planning Policy 2.6 – State Coastal Planning Policy* (SPP2.6) and associated guidelines.

1.1 What is a Coastal Hazard Risk Management Adaptation Plan?

The parameters for the establishment of a CHRMAP is set out in SPP 2.6. The purpose of a CHRMAP is to establish a hierarchical approach to the management of coastal hazards and risk. The hierarchy for this approach is established on a sequential basis as per the following, with the first being the preferred approach and the last being an option when all other approaches are not deemed appropriate or applicable:

(1) **Avoid** new development being located within an area identified as being affected by coastal hazards.
(2) **Planned or Managed Retreat** involving the relocation or removal of assets within an area identified as likely to be subject to intolerable risk from coastal hazards over the planning timeframe.
(3) **Accommodate** or provide adaption measures to suitably address and mitigate the identified risks.
(4) **Protect** areas of the coast where there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable.

The document is a non-statutory document, however has been prepared to fulfill the requirement of SPP2.6 to provide a risk management and adaptation planning framework for areas at risk of being affected by coastal hazards over the relevant planning timeframe. The relevant planning timeframes for different coastal processes are as follows:

- Coastal erosion and accretion processes are to be measured using a 100 year planning time frame.
- Storm Surge events are to be measured using a 500 year planning timeframe.
- The allowance for sea level rise should be based on a vertical sea level rise of 0.9 metres over a 100 year planning timeframe using a 100 year timeframe and this impact is to be factored into the above events.

1.2 Purpose

The purpose of this CHRMAP is to provide strategic guidance to decision makers and applicants on the application of a risk assessment and management framework in relation to applications for planning approval relating to land identified as being prone to a 500 year ARI storm surge event.

A CHRMAP should document a risk management and adaptation planning process undertaken by the decision making authority, in this case the City of Karratha, and should bring the City to a point on deciding whether, in the context of a particular type of development, activity or function, a coastal hazard risk is deemed as being acceptable or requires further action.

This CHRMAP takes direction from existing coastal strategies prepared within the City district including the following:

- Karratha Coastal Vulnerability Study;
- Dampier Coastal Vulnerability Study;
- Point Sampson Stormwater and Coastal Management Study;
- Roebourne Stormwater and Management Plan;
- Rio Tinto – Wickham Townsite Accommodation Expansion Project Local Water Management Strategy;
- Draft Storm Surge and Storm Water Flood Risk Assessment.

The mapping of Karratha, Campier, Point Sampson and Roebourne has been undertaken as these are key development nodes along the coast. Karratha has been identified as a future City planned to accommodate in excess of 50,000 people and therefore it is important that this CHRMAP focuses on risk assessment and adaptation planning in relation to Karratha.

The City in preparing this CHRMAP has undertaken a high level risk assessment of storm surge effects on social, environmental, economic and infrastructure.

The objectives of this CHRMAP include:

1. Improve the understanding and awareness of coastal features, processes and hazards within the District;
2. Identify and map the extent of coastline vulnerable to coastal processes and storm surge where mapping is already available;
3. Build and improve mapping over time and resources become available to better understand the impacts of coastal processes and storm surge within the District;
4. Determine the likelihood and consequence of the adverse impacts of coastal hazards on the assets, and assign a level of risk through application of the City's risk assessment framework;
5. Identify a range of possible management and adaptation measures to guide decision making.

1.3 Background

In 2011, the State Government commissioned the Karratha Coastal Vulnerability Study (KCVS 2011) to evaluate flooding from storm surge and riverine or overland runoff that may occur during major storm event, and to ascertain what impact this might have on the future growth of Karratha and surrounds.

Since 2011 the Draft State Planning Policy 2.6 State Coastal Planning Policy (SPP 2.6) was released and this policy requires that development proposals relating to land that is identified as being prone to a 500 year ARI storm surge event to have regard to coastal hazard risk management and adaption planning measures as set out in the draft SPP 2.6 and associated guidelines.

1.4 Study Area

This CHRMAP is intended to apply to the coastline contained within the City of Karratha's local government district but has a particular focus on the following localities, representing the primary population nodes within the City located in proximity to the Coast:

- Karratha;
- Dampier;
- Point Sampson;
- Roebourne; and
- Wickham.

1.5 Terminology

The following definitions are provided for terminology used throughout this report.

Annual Encounter Probability (or AEP);

The average statistical probability of a particular event occurring or being exceeded within a given year. For example an event that occurs on average once every 100 years has an AEP of 1%.

Average Recurrence Interval (or ARI);

A means of describing how likely an event is to occur. For example a 100 year ARI event is an event that occurs or is exceeded on average once every 100 years.

Coastal Inundation;

*Flooding of coastal areas caused by **Storm Surge**, **Wave Setup**, Tides and other ocean induced water level fluctuations.*

Storm Surge;

A rise in water level in the open coast caused by the action of wind stress as well as atmospheric pressure on the sea surface.

Wave Setup;

Super-elevation of the water surface over the normal surge elevation attributable to onshore mass transport of the water by wave action alone.

1.6 Implementation

The implementation of this CHRMAP will be supported by the City's Town Planning Scheme No. 8 (TPS8). TPS8 is in the process of being amended to require a local planning policy to address matters relating to the 500 year event storm surge risk as part of the process of seeking planning approval.

The DP 19 Storm Surge Risk Local Planning Policy will be the primary tool for implementing coastal hazard risk adaptation planning in relation to land use and development. The objectives and key requirements of this policy are detailed further on in this report.

2.0 CONTEXT

2.1 State Planning Policy 2.6

State Planning Policy 2.6 – State Coastal Planning Policy and associated guidelines has been prepared to guide decision making and policy in relation to planning along the State's coastline. Amongst other matters, SPP2.6 seeks to ensure coastal hazard risk management and adaptation planning is established to guide the location and form of development along the coast.

The policy establishes a hierarchy for undertaking coastal hazard and risk adaptation planning as previously outlined in this report. The adaptation measures of Avoid, Planned or Managed Retreat, Accommodate and Protect are to operate on a sequential and preferential basis starting with avoid as part of the coastal hazard risk management adaptation planning process.

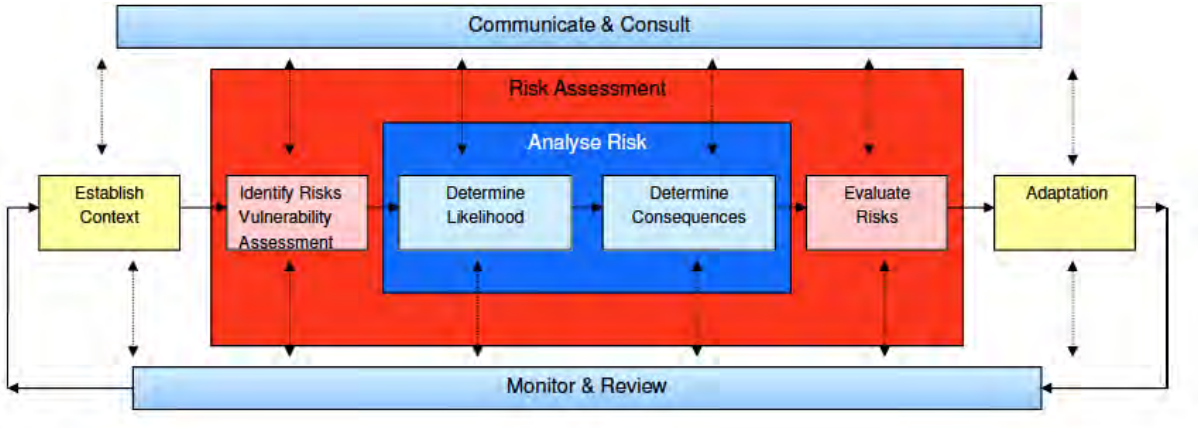
With respect to development within the Karratha locality, there is a general presumption that land already zoned for development within TPS8 will be developed in accordance with the 'Accommodate' philosophy, meaning that development of that land may occur provided that appropriate mitigating measures are established to permit that development to occur at an acceptable level of risk.

SPP2.6 further establishes a process for undertaking risk assessment, as follows:

1. Establish the context;
2. Undertake a risk vulnerability assessment;
3. Determine the likelihood of the hazard occurring;
4. Determine the consequences;
5. Evaluate the risks;
6. Set in place adaption management measures; and
7. Undertake monitoring and review.

This process is best illustrated in the following diagram.

Figure 1 – Risk Management and Adaptation Process Flowchart



Source: Department of Planning 2012

The risk assessment and management framework adopted by the City and contained within this CHRMAP generally accords with the above. It is expected that applicants lodging planning applications relating to land identified as being prone to a 500 year storm surge event, will complete the risk assessment matrix and identify an appropriate development response to the level of risk accordingly.

2.2 The City's Risk Management Framework

The approach is to integrate and align the City's planning assessment process for storm surge affected areas with the City's overall approach to risk management and will be guided by the City's corporate responsibilities.

The application of the City's risk management framework is detailed further on in this report.

3.0 COASTAL HAZARD RISK IDENTIFICATION

The characteristics of the coastline within the City of Karratha vary significantly throughout its extent. This variance in coastal form, otherwise termed coastal geomorphology, effects how the shoreline will respond to the action of coastal processes during short term episodic events and over the longer term.

Understanding the potential shoreline behavior and the probability and consequences of storm events can help to identify land and assets that may be at risk presently, or in the future. Identification and acknowledgement of these coastal hazards is therefore required to inform the risk management and adaptation planning approach for development.

The City's draft Coastal Management Strategy prepared by LandVision describes the Pilbara Coast as follows:

"The Pilbara coast comprises a diverse range of landforms including tidal flats, coastal dunes, cheniers and spits, wide sub – tidal terraces and extensive sand shoals. Coastal lowlands can extend up to 20 km inland and include river channels, riverine outwash plains and river deltas which extend more than 2 km for the majority of the Pilbara.

The Pilbara's hard rock terrain is commonly overlain or abutted by sediments of coral reefs, flood plains, which when lithified form coastal limestone outcropping along the shore along with old reef structures and beachrock.

The Pilbara coast is naturally dynamic in response to tide, weather and climatic variations. It is noted for its areas of high tides and the occurrence of extreme weather conditions, particularly cyclones and storm surges.

The complex interface between land and sea along the Pilbara coast have recently been studied in detail which allows a better understanding of coastal processes. One such study provides a "vulnerability" index or ranking for sections of the coast based on instability and unsustainability of particular types of coastline which has informed this Coastal Management Strategy."

This CHRMAP deals exclusively with coastal hazards. In its simplest form, there are two types of coastal hazards that need to be considered. These are:

- coastal erosion; and
- coastal inundation.

3.1 Coastal Erosion

Changes to a coastline can occur over varying timescales, from storm to post storm, seasonal and longer term. An assessment of the potential for coastal erosion to impact upon development needs to consider the combined effect of the coastal processes that occur over each of these different timeframes. Local coastal geology, geomorphology, sediment dynamics and exposure to metocean

conditions as well as the presence of existing coastal structures can all affect the shoreline response and potential for erosion.

An assessment of the potential for coastal erosion is required to inform development planning. Such an assessment should be consistent with the requirements of Schedule One of SPP2.6. The assessment should be based upon the coastal classification (type) and should consider each of the factors relevant to that classification. Where applicable, it is expected that the mapping of the potential coastal erosion risk will include allowances for:

- the current risk of storm erosion (termed the S1 Allowance);
- historic shoreline movement trends (termed the S2 Allowance);
- erosion caused by future sea level rise (termed the S3 Allowance); and
- an allowance for uncertainty.

Assessment of the potential risk posed by coastal erosion should generally be completed for a 100 year planning horizon. Within this assessment consideration needs to be given to the potential erosive impacts of a storm with an annual encounter probability (AEP) of 1% (which is equivalent to a 1 in 100 year average recurrence interval (ARI)). Consideration also needs to be given to the potential impacts of sea level rise over the planning horizon, as outlined in *Sea Level Change in Western Australia Application to Coastal Planning* (2010).

The assessment methodology outlined above, and in accordance with SPP2.6, should result in the identification of a Physical Coastal Processes line that delineates areas that are potentially at risk from the action of physical coastal processes over the planning horizon. Where the subject site sits in relation to this line is critical with regard to the risk management and adaptation planning and will be covered in later sections of this CHRMAP.

3.2 Coastal Inundation

Within the Pilbara, coastal inundation is predominantly caused by the passage of tropical cyclones. However, within this CHRMAP an important distinction is drawn between coastal inundation that is caused by the combined effects of storm surge, wave setup, tide and other ocean induced water level fluctuations and inundation that is caused as a result of rainfall and runoff. This CHRMAP focuses only on coastal inundation caused by storm surge and oceanic water level fluctuations. Flooding caused by rainfall and runoff is a separate consideration and is covered by other aspects of the planning process.

Assessment of the current risk of storm surge inundation (termed the S4 Allowance) should be completed in accordance with the requirements of Schedule One of SPP2.6. Consistent with the requirements for the Coastal Erosion, the planning timeframe for consideration of inundation should also generally be 100 years, however for Coastal Inundation consideration is given to the potential impacts of a storm with a 0.2% AEP (which is equivalent to a 1 in 500 ARI) within the 100 year planning timeframe. The potential implications of sea level rise over the planning horizon also need to be considered. Where the subject site sits in relation to the areas potentially vulnerable to coastal inundation during the design event is critical with regard to the risk management and adaptation planning and will be covered in later sections of this CHRMAP.

3.3 Coastal Hazard Mapping

Several regional scale coastal vulnerability assessments have been completed for the major population areas within the City. These coastal vulnerability assessments should provide the foundation for the coastal hazard risk identification within the respective areas. From time to time, and as new information becomes available, these assessments will be revised, expanded or renewed. Presently, the relevant versions of the assessments are outlined in the following table.

Town	Title	Author	Year
Karratha	Karratha Coastal Vulnerability Study	JDA et al	2012
Dampier	Dampier Coastal Vulnerability Study	JDA et al	2012
Point Samson	Point Samson Stormwater & Coastal Management Strategy	Essential Environmental	2013
Roebourne	Roebourne Townsite Stormwater and Flood Management Plan	Essential Environmental	2013
Wickham	Not yet available	-	-

For development located within the areas covered by the regional scale assessments the proponent should be informed by the existing coastal hazard mapping. If development is not covered by existing mapping, or if the existing mapping is not adequate, the onus will be on the proponent to undertake the necessary coastal hazard identification process in accordance with the requirements of this CHRMAP.

To further assist with the risk identification process, additional coastal hazard mapping has been completed for coastal inundation to help indicate the potential inundation depths that could be experienced during the 0.2% AEP event.

The coastal hazard mapping identifies that the following main areas are potentially vulnerable to coastal erosion and coastal inundation. Mitigation options may therefore need to be explored for these areas in the future. This could include requirements for both private and/or Local Government funded mitigation measures.

The coastal hazard mapping identified above is contained at Appendix A.

Coastal Erosion

- Point Samson foreshore, including areas along Mears Drive, Miller Close and Vitenbergs Drive.

Coastal Inundation

- Northern sections of Millars Well and Pegs Creek adjacent to Balmoral Road, and sections of Bulgara along Searipple Road and across to Maitland Road in Karratha.
- Hall Street, Nairn Street, North West Coastal Highway, Sholl Street, Mundamia Way and Aerodrome Road in Roebourne.
- The area surrounding the Johns Creek Boat Harbour and Samson Point road in Point Samson.

4.0 COASTAL HAZARD RISK ANALYSIS AND EVALUATION

4.1 Risk Assessment Process

The City employed LGIS to run two separate workshops to evaluate risk in relation to storm surge and storm water flooding within the District. The primary purpose of the workshops was to develop risk based templates to aid in the development application decision making process. The broad methodology undertaken through the workshop process to define the risk included the following:

Risk Description – description of the risk events from flooding and water runoff from a storm surge and storm water event in consideration of the critical success factors.

Existing Controls – noting some of the existing controls the City of Karratha has implemented in relation to managing the risks associated with flooding and water runoff from a storm surge and storm water event.

Risk Analysis – Identified risks are analysed, applying the City of Karratha Risk Assessment and Acceptance Criteria, for each storm surge and storm water event scenario in terms of consequence category, levels of consequence and likelihood to determine the level of risk. It is important to note the measure of likelihood was a combination of the likelihood of the storm surge and storm water event occurring and likelihood of the level of consequence occurring.

Risk Treatment – Where discussed and/or identified additional risk treatment options were captured.

4.2 Risk Treatment Options

As part of the second workshop, stakeholders were asked to consider specific treatment options that can be applied to the risk of storm surge and storm water flooding and the issues associated with the planning and development approval processes. The following is a summary of the identified treatment options:

Category	Risk Treatment Options
Public Safety	• Additional roads from northern to southern suburbs connecting suburbs reducing single access roads • Kerbing replacement program in old suburbs to improve drainage • Increase data capture from actual storm events • Underpass depth indicators • Review Kelly line and evacuation requirements • Public education • Seek Water Corporation input regarding sewage vulnerability and resilience
Property	• For 100 year ARI - raise floor level to TBC - provide fill to TBC - combined effect of floor level & fill must reach TBC - City must carry out flood mitigation works - no sensitive land uses allowed without extensive meeting each of the above, where sensitive means people likely to be resident cannot effect their own evacuation in case of flood or where

	contaminants/toxic substances are stored • For 500 year ARI - consider combined effect of floor level & fill so that it exceeds TBC - evacuation must be considered and evaluated - protection and storage of contaminants/toxic substances must be demonstrated • Review planning application for single dwellings • Consider cumulative effect of new dwellings • Kerbing replacement program in old suburbs to improve drainage • Infrastructure and Planning alignment for approvals and design • Drainage review programme • Increase capacity of culverts • Infrastructure input to lazy lands for drainage implications • Realign drainage at Crane Circle • City housing policy to address storm surge and storm water risk • Review mix and location of staff housing tenants to reduce impacts to key operational areas • Review verge policy and enforcement to reduce cracker dust run off onto roads and drainage • Hedging and vegetation to reduce speed of drainage flows
Critical Infrastructure	• Follow up with Horizon Power to explore vulnerability of sub stations based on flood study information • Follow up with telecommunications companies to explore vulnerability of infrastructure based on flood study information • Widen pavement alongside roads to reduce road erosion • Increase strength of roads to resist erosion • Review options to get storm water to mud flats quicker • Enforcement of illegal dumping in drainage channels • Culvert inspection program • New effluent system in conjunction with Water Corporation • Reuse old landfill site • Identify alternate temporary landfill dumping site until storm surge and flood water have subsided • Business Continuity Planning
Community	• Replacement and restoration of cemetery
Environmental	• Include environmental health in treatment response • Identify ponding sites and remove water after flooding • Engage Water Corporation regarding sewage contamination issues
Administration & Governance	• Residents awareness of flood studies • Include flood data in lifecycle costing • Include asset management within planning and development considerations • Business Continuity Planning • Include CBD data • Review climate change prediction and data modeling assumptions when new information becomes available

4.3 Development and Asset Management Risk Assessment Matrix

The Development and Asset Management Risk Assessment Matrix developed by the City in consultation with LGIS was based on the City's existing risk assessment framework which is summarised in the following tables.

Measures of Consequence

Level	Descriptor	Health	Financial	Service Interruption	Environment	Reputation	Compliance
1	Insignificant	Negligible injuries	Less than $10k	No material service interruption	Contained, reversible impact, managed by on site response	Unsubstantiated, low impact, low profile or 'no news' item	No noticeable regulatory or stator impact
2	Minor	First aid treatment	$10k-$50k	Short term temporary interruption – backlog cleared by additional resources <1 day	Contained, reversible impact managed by internal response	Substantiated, low impact, low news item	Some temporary non compliances
3	Moderate	Medical treatment	$50k-$200k	Medium term temprorary interruption – backlog cleared by additional resources <1 week	Contained, reversible impact managed by external agencies	Substantiated, public embarrassment, moderate impact, moderate news profile	Short term non compliance but with significant regulatory requirements imposed
4	Major	Death or permanent disablement	$200k-$500k	Prolonged interruption of services – additional resources, performance affected	Uncontained, reversible impact managed by a coordinated response from external agencies	Substantiated, public embarrassment, high impact, high news profile, third party actions	Non compliance results in termination of services or imposed penalties
5	Catastrophic	Multiple deaths or severe permanent disablements	More than $500k	Indeterminate prolonged interruption of services – non-	Uncontained, irreversible impact	Substantiated, public embarrassment, very high multiple impacts, high widespread	Non compliance results in litigation, criminal charges or significant

				performanc e > 1 month		multiple news profile, third party actions	damages or penalties

The City has derived a risk assessment matrix from the above framework which is to be used as an applicant self assessment tool to guide applicants when preparing applications for planning approval in relation to land that has been identified as being vulnerable to storm surge in accordance with the City's draft Storm Surge Risk Policy.

Measures of Likelihood

LEVEL	DESCRIPTOR	DESCRIPTION	FREQUENCY
5	Almost Certain	The event is expected to occur in most circumstances	More than once per year
4	Likely	The event will probably occur in most circumstances	At least once per year
3	Possible	The event should occur at some time	At least once in 3 years
2	Unlikely	The event could occur at some time	At least once in 10 years
1	Rare	The event may only occur in exceptional circumstances	Less than once in 15 years

Risk Matrix

Likelihood	Consequence	Insignificant	Minor	Moderate	Major	Catastrophic
		1	2	3	4	5
Almost Certain	5	5	10	15	20	25
Likely	4	4	8	12	16	20
Possible	3	3	6	9	12	15
Unlikely	2	2	4	6	8	10
Rare	1	1	2	3	4	5

Risk Acceptance Criteria

Level of Risk	Descriptor	Description	Criteria for Risk Acceptance	Responsibility
1-4	Low	Acceptance	Risk acceptable with adequate controls, managed by routine procedures and subject to annual monitoring	Operational Manager
5-9	Moderate	Monitor	Risk acceptable with adequate controls, managed by specific procedures and subject to semi-annual monitoring	Operational Manager
10-16	High	Urgent Attention Required	Risk acceptable with excellent controls, managed by senior management/executive and subject to monthly monitoring	CEO / Council

17-25	Extreme	Unacceptable	Risk only acceptable with excellent controls and all treatment plans to be explored and implemented where possible, managed by highest level of authority and subject to continuous monitoring	CEO / Council

The Development Hazard Risk Assessment Matrix for the City is contained at Appendix B.

5.0 COASTAL HAZARD RISK ADAPTATION PLANNING

5.1 Risk Management and Adaptation Planning Approaches

Where a risk associated with a coastal hazard has been identified, there is a requirement for that risk to be managed. SPP2.6 provides a hierarchy of adaptation responses to coastal hazards. This hierarchy is outlined as follows, in order of general preference.

- **Avoid** locating development within areas vulnerable to the coastal hazard.
- **Planned or Managed Retreat** of assets located within areas that may be vulnerable to coastal hazards over their planning timeframe.
- **Accommodate** the risks associated with the potential coastal hazards through measures such as design and/or management strategies that reduce the risk posed by coastal hazards to acceptable levels.
- **Protect** where the risk from coastal hazards cannot be accommodated, coastal protection works may be completed.

The City's general approach to adaptation planning is as follows.

Asset / Infrastructure Type	Coastal Hazard Type	City's Preferred "As of Right" Approach	Comments
New Greenfield Subdivision	Coastal Inundation	Avoid	Where coastal inundation is an issue for the site Accommodation, consistent with the requirements outlined below, may be acceptable.
	Coastal Erosion	Avoid	
Infill Development / Redevelopment	Coastal Inundation	Accommodate	
	Coastal Erosion	Planned or Managed Retreat	Protection may be acceptable when considering the reasonable and likely future protection requirements of adjacent development

Existing Development	Coastal Inundation	Accommodate	Risk may be accommodated through evacuation to prevent loss of life and acceptance of risk associated with damage to infrastructure.
	Coastal Erosion	Protect	Monitoring will be completed of areas that are potentially at risk. Where that monitoring shows that the risk has increased to an unacceptable level, protection may be required
Public Foreshore Infrastructure	Coastal Inundation	Accommodate	Should be completed in accordance with Coastal Management Strategy.
	Coastal Erosion	Planned or Managed Retreat	Should be completed in accordance with Coastal Management Strategy.

Details of the requirements / recommendations for development based on each of the different adaptation approaches are outlined below.

5.1.1 Avoid

Avoidance of risks associated with coastal hazards, in accordance with the risk profile outlined in SPP2.6, requires development to be located outside of the areas identified as being vulnerable to coastal erosion over a 100 year planning timeframe and coastal inundation associated with the 500 year ARI storm surge event. For new development this is the preferred approach, except in instances where a thorough assessment is completed and is able to satisfactorily demonstrate that some form of Accommodation is acceptable.

5.1.2 Planned or Managed Retreat

Where Planned or Managed Retreat is deemed an acceptable outcome, the timeframes for retreat should be considered in the context of the expected design life of the infrastructure. For instance, foreshore infrastructure with an expected design life of 20 years should consider the potential vulnerability of that item to coastal erosion and coastal inundation over that period. The infrastructure should then be placed in a location where the level of risk is deemed acceptable over the design life of the structure.

Once the structure is in place, some form of monitoring should be undertaken to track any changes to the potential vulnerability of the infrastructure during its design life. If the monitoring shows that the level of risk to that infrastructure reaches an unacceptable level the item could then be removed and replaced following the same procedure of risk quantification and acceptance as used initially. Conversely, if the potential vulnerability of the item to coastal hazards are not realized over the design life, the requirement for retreat may be negated.

5.1.3 Accommodate

Several options are available to Accommodate the risks associated with Coastal Inundation. Potential options for risk accommodation are outlined below.

Site Planning (Coastal Inundation)

Where possible Accommodation of coastal inundation risk would require the proponent to locate development on the least vulnerable portion of the site. Under this scenario consideration should be given to the potential exposure of the site to hazards associated with coastal inundation, such as impacts of waves and wave run-up. Development or redevelopment should therefore review the vulnerability of the site to these conditions and seek to locate development accordingly to reduce the risk.

In addition to developing on the least vulnerable portion of the site, consideration needs to be given to any other structures that could be swept away, possibly causing damage to surrounding infrastructure. Notwithstanding the requirements for any structure to adhere to the requirements of the Building Code of Australia and the relevant Australian Standards for wind loading, all structures should be designed to withstand the potential additional forces associated with storm surge forces.

Elevated Finished Floor Level (Coastal Inundation)

In order to help Accommodate the risk associated with potential inundation, and to reduce the requirements for repairs after an inundation event, it is recommended that new development seek to locate the finished floor level above the peak steady water level associated with a 500 year ARI storm surge event. This may require the finished floor levels to be elevated above the natural ground level. The acceptable design responses associated with this approach are outlined in the following table.

Height of Storm Surge above Natural Ground Level of Subject Property	**'As of Right' Design Response**

0 – 500mm	• Raise height of the finished floor level for all habitable rooms (dwellings) or finished floor level of the net lettable area for a commercial/community building above the identified storm surge level through either:
	  • Filling of the land; or
	  • Structural / building design response (i.e. Elevated 'Queenslander' style housing); or
	  • A combination of fill/retaining and stilt construction.

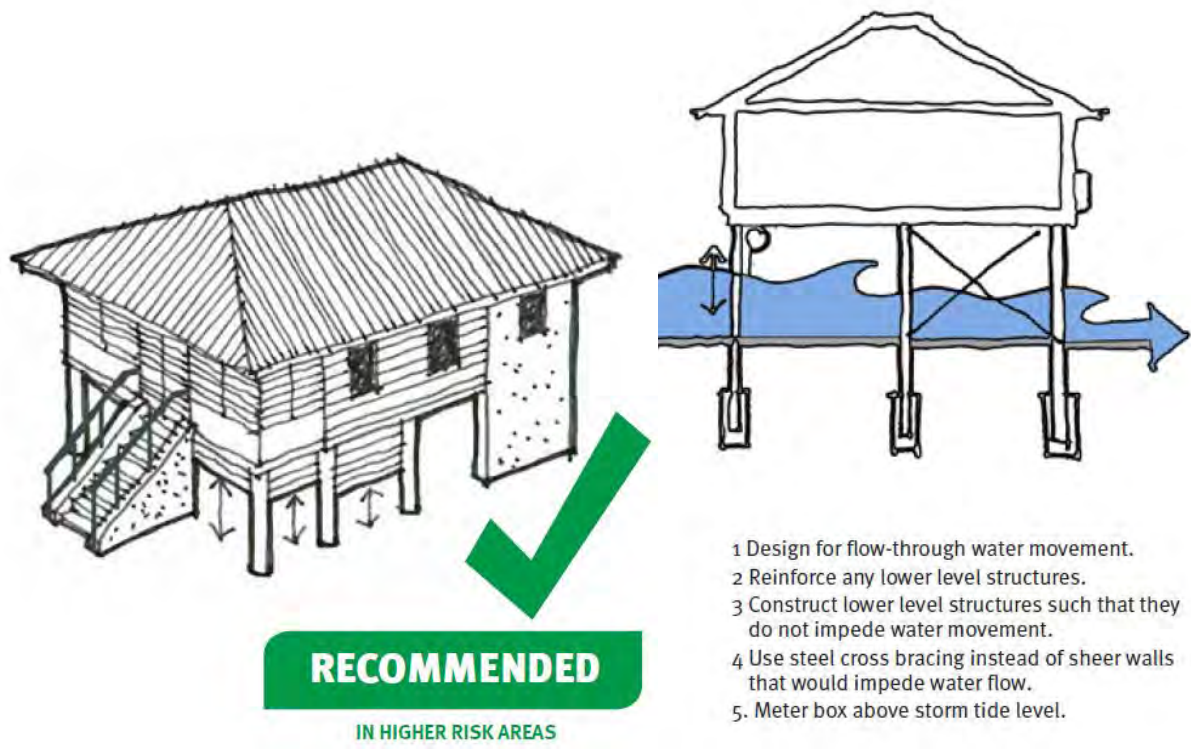
500mm – 1 metre	• Raise height of the finished floor level for all habitable rooms (dwellings) or finished floor level of the net lettable area for a commercial/community building to the height of the identified storm surge level through either:
	  • Filling of the land*; or
	  • Structural / building design response (i.e. Elevated 'Queenslander' style housing); or
	  • A combination of fill/retaining (to a maximum of 0.5m) and stilt construction.
	* Filling of the site between 500mm and 1 metre above natural ground level may be considered on a case by case basis however the onus will

	be on the applicant to demonstrate that this approach will not have a detrimental impact on the amenity of adjoining properties and that the application complies with other relevant policy considerations (i.e. height of retaining wall at boundary, building height and privacy setbacks that comply within the Residential Design Codes and relevant local planning policies).
1m – 2m +	• Raise height of the finished floor level for all habitable rooms (dwellings) or finished floor level of the net lettable area for a commercial/community building above the identified storm surge level through a structural / building design response (i.e. Elevated 'Queenslander' style housing); or • A combination of fill/retaining (to a maximum of 0.5m) and stilt construction.

Where a structural / building design response (i.e. 'Queenslander' style housing) is adopted, the design should draw upon the requirements outlined within the *Queensland Reconstruction Authority* guidelines, including those regarding *Rebuilding in Storm Tide Prone Areas: Tully Heads and Hull Heads*. The general recommendations for development are to:

- Not enclose the understory in order to minimise the potential loads on the structure associated with water flow or wave impact. If enclosure is required consideration should be given to providing retractable enclosures that can be closed in day to day use, but can be easily opened during a storm surge alert.
- Use minimal profile bracing systems rather than shear walls for lower floor bracing. Lower floor columns and bracings should also be designed to resist potential wave action and the impact of debris, which could include vehicles, boats, caravans and the like. This should be considered in the design in addition to the required wind loads outlined within the relevant standards.
- Ensure foundations and footings are adequate to withstand potential erosive action during coastal inundation.
- Ensure that all important services, including electricity, permanent fixtures and plumbing are elevated and / or protected from the impact of waves.

Figure 2 – Design recommendations for dwellings



Source: Queensland Reconstruction Authority

It is important to note that construction of elevated housing does not necessarily preclude the requirement for evacuation prior to a coastal inundation event. This includes evacuation of large valuables such as vehicles, boats, caravans and trailers when emergency warnings are announced. The requirement to evacuate these items is to not only reduce the risk of them being damaged, but also to prevent them from causing damage to adjacent development if mobilised by the storm surge and associated effects.

Evacuation of residents will be managed by the Department of Fire and Emergency Services (DFES) in consultation with the Bureau of Meteorology. The extent of evacuations will be advised by DFES based on the expected storm surge. Where possible, residents in areas shown to be vulnerable to inundation during the 500 year ARI storm surge event should develop a plan for evacuation to a pre-determined location.

<u>Recommendations Regarding Building Construction (Coastal Inundation)</u>

Where, for some reason, it is not possible for construction to occur above the 500 year ARI storm surge level, the increased risk associated with the development must be acknowledged. This could include a Section 70A notification on Title advising that the land and dwelling is vulnerable to storm surge inundation.

In addition to the above, for areas in the wave zone, or where inundation is expected to be greater than 1 metre above the floor level, the development should incorporate large windows or doors with an open design to allow storm surge water to flow through the building as easily as possible.

For areas outside of the wave zone, or where inundation is expected to be less than 1 metre above the floor level, the building should be designed to force water around the building. Whilst preventing

inundation within the building would be almost impossible, this approach would limit the potential effects of waves, currents and/or debris within the building.

Additionally, development should seek to:

- Keep all electrical wiring and installations as high as possible.
- Have options available to quickly raise furniture and valuables to reduce the potential for damage during inundation.
- Ensure footings are appropriately designed to prevent undermining by scour.
- Ensure the building is designed to handle structural loads associated with storm surge flow, waves and debris impact.
- Ensure appropriate materials and construction techniques are used to minimize the impacts of the inundation on the building elements. Guidance on material suitability is outlined in the following table.

Figure 3 – Recommended Construction Materials

COMPONENT	SUITABLE*	MILD EFFECTS*	MARKED EFFECTS*	SEVERE EFFECTS*
Floor, Sub-Floor Structure	- slab-on-ground - suspended concrete	- timber T&G (with ends only epoxy sealed and provision of side clearance for board swelling) or plywood	- standard grade plywood	- particleboard flooring close to the ground
Walls Support Structure	- reinforced or mass concrete - large windows low to the ground	- full brick/block masonry	- brick/block veneer with venting (stud frame) cavity brick	- inaccessible openings
Wall and Ceiling Linings	- fibre cement sheet - face brick or blockwork - cement render - ceramic wall tiles - galvanised steel sheet - glass and glass blocks - stone, solid or veneer - plastic sheeting or tiles with waterproof adhesive	- common bricks - solid wood, fully sealed - exterior grade plywood fully sealed - non ferrous metals	- exterior grade particleboard hardboard - solid wood with allowance for swelling - exterior grade plywood	- particleboard fibreboard or strawboard - wallpaper - cloth wall coverings - standard plywood - gypsum plaster plasterboard
Doors	- solid panel with waterproof adhesive - flush marine ply with closed cell foam - aluminium or galvanised steel frame	- flush or single panel marine ply with waterproof adhesive - painted metal construction timber frame, full epoxy sealed before assembly	- standard timber frame	- standard flush hollow core with PVA adhesives and honeycomb paper core Note: lowest cost and generally inexpensive to replace
Window frames	- aluminium frame with stainless steel or brass rollers	- timber frame, full epoxy sealed before assembly with stainless steel or brass fittings		- timber with PVA glues - mild steel fittings
Insulation	- plastic/polystyrene boards - closed cell solid insulation	- reflective foil perforated with holes to drain water if used under timber floors		- materials which store water and delay drying open celled insulation (batts etc)
bolts, hinges, nails, fittings and connections	- brass, nylon/stainless steel, removable pin hinges	- galvanised steel, aluminium		- mild steel
floor covering	- clay/concrete tiles - epoxy or cementilious floor toppings on concrete - rubber sheets (chemically set adhesives) - vinyl sheet (chemically set adhesive)	- terrazzo - rubber tiles (chemically set adhesives) - polished floor and loose rugs - ceramic tiles	- loose fit nylon or acrylic carpet (closed cell rubber underlay)	- wall to wall carpet - wall to wall seagrass matting - cork - linoleum

Adapted from CSIRO

These materials or products are relatively unaffected by submersion and flood exposure and are the best available for the particular application.

These materials or products suffer only mild effects from flooding and are the next best choice if the most suitable materials or products are too expensive or unavailable.

These materials or products are more liable to damage under flood than the above category.

These materials or products are seriously affected by floodwaters and have to be replaced if inundated.

Source: Queensland Reconstruction Authority

5.1.4 Protect

In some instances it may be necessary to protect infrastructure that is already in place. Alternatively, there may be instances where new infrastructure is proposed that provides benefit to the local community and in which case the option of protection may be accepted.

Protection methods should generally conform to best practice design standards and should be commensurate with the design life, vulnerability and importance of the infrastructure that is being protected. In all cases the appropriate protection options should be considered on a site and case specific basis.

5.2 City's Risk Management Adaptation Plan

Based on the areas deemed to be vulnerable to coastal hazards as outlined in Section 3.0 and contained identified in the storm surge mapping contained in Appendix A, the proposed adaptation approaches for the areas that are considered vulnerable to coastal hazards are outlined in Appendix B.

5.3 Town Planning Scheme No. 8

At the time of writing this document, TPS8 contained a Clause 7.5 which establishes how development within the Storm Surge Special Control Area (which incorporates all land between the North West Coastal Highway and the coastline) should be considered and assessed. Specifically, Clause 7.5 establishes requirements within the Storm Surge Risk Special Control Area, and with reference to certain sensitive categories in the zoning table of the planning scheme (i.e. residential, commerce or health, welfare and community) specifies Council's ability to consider development proposals within an area of land known to be affected by a 100 year ARI storm surge event.

Clause 7.5 is required to be amended to firstly, change the reference from a 100 year event to a 500 year event consistent with SPP 2.6, and secondly, to grant Council the discretion to consider development within land prone to a 500 year storm surge event, by applying a risk management and mitigation approach as promoted within SPP2.6.

The proposed amendment will ensure that TPS8 is brought into alignment with the following documents and will support the implementation of this CHRMAP consistent with State policy:

- State Planning Policy 2.6 – State Coastal Planning Policy;
- State Planning Policy 3.4 – Natural Hazards and Disasters;
- Application of current mapping and modeling of the 500 year storm surge event (as opposed to a fixed Special Control Area), which will be calculated consistent with the methodology contained within SPP 2.6 to identify areas vulnerable to a 500 year storm surge event. The mapping prepared to date is contained in Appendix A.

5.4 DP 19 Policy – Storm Surge Risk

The principal tool for implementing the requirement for applications to address storm surge risk in areas vulnerable to storm surge is via a new local planning policy on storm surge. The objectives of this draft policy are:

a. To establish procedures for the identification of areas where land may be vulnerable to 500 year ARI Storm Surge events;
b. To provide guidance for applicants in relation to the information required to support development applications for sites identified in the mapping maintained and administered by the City as being vulnerable to 500 year ARI Storm Surge events;
c. To clarify the circumstances in which 500 year ARI Storm Surge information is required;
d. To provide decision guidelines, assessment procedures and development standards for assessment of development proposals on land identified as being vulnerable to a 500 year ARI Storm Surge event;

e. To ensure adequate provision is made for the management of risk for all land identified as being vulnerable to the 500 year ARI Storm Surge event.

Key components and requirements of the draft policy are summarised below:

1. Schedule 1 of the policy will contain the most current storm surge mapping within the District, which may be updated by the City from time to time as more current and accurate information is prepared. All land that is identified as being vulnerable to the 500 year ARI storm surge event will be subject to the requirements of the policy.
2. The policy incorporates 'as of right' design mitigation measures which proposals may incorporate to sufficiently address the level of risk associated with storm surge inundation and therefore meet the minimum requirements of the policy. The 'as of right' design response includes raising the finished floor level of habitable rooms above the modelled 500 year ARI storm surge event level or locating the development on a portion of the site that is not vulnerable to storm surge inundation.
3. Alternatively, the policy provides a framework for applicants to take a performance approach to risk mitigation, where the proponent chooses to take an alternative approach to the 'as of right' design response and takes responsibility for consequences in the knowledge that finished floor levels are below the 500 year ARI storm surge level. In this regard, the policy contains a matrix and checklist for completion by applicants to assist in identifying and categorising the level of storm surge risk associated with the proposal. This risk assessment framework is a consolidated matrix based on the City's broader risk assessment framework.
4. The policy outlines a clear process for assessment of applications for land vulnerable to storm surge.

The mapping contained within Schedule 1 of the draft policy includes the most up-to-date mapping of the 500 year storm surge event for the five (5) major development nodes along the coast within the City. These include:

- Dampier;
- Karratha;
- Point Sampson;
- Roebourne; and
- Wickham.

The mapping is currently at varying levels of detail for different localities, with Karratha being mapped at the highest level of detail due to the recent completion of the Karratha Coastal Vulnerability Study.

The mapping of the 500 year event for the five coastal nodes represents a better and more refined approach when compared to the current Storm Surge Risk Special Control Area which captures everything west of the North West Coastal Highway.

The policy allows the City to apply a discretionary approach to the assessment of applications and ensures risk is appropriately addressed. In this regard, the draft policy has been prepared in the context of the City's draft Coastal Hazard Risk Management Adaptation Plan, which contains an overarching risk assessment of storm surge hazard within the City.

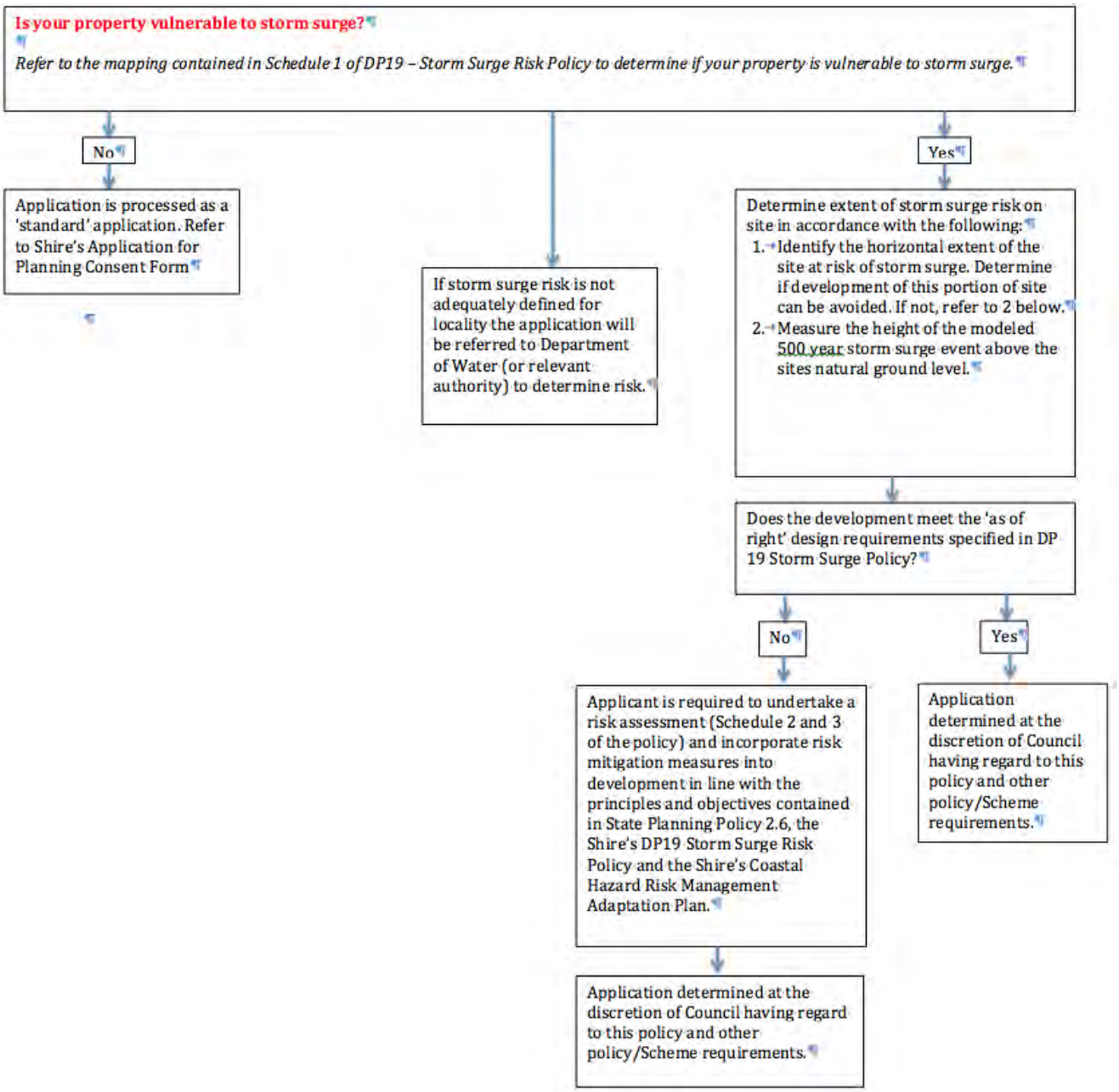
This assessment generally finds that risk associated with the modeled 500 year ARI storm surge hazard can generally be managed and mitigated through on-site development measures.

5.5 Development Approval Process

Draft DP19 Storm Surge Risk policy outlines the development assessment process with respect to storm surge, as follows:

1. Prior to lodging an application for planning approval, applicants are to refer to storm surge mapping made available by the CityRoeoburne to determine if their land would be vulnerable to a 500 year ARI storm surge event.
2. If the site is not identified as being vulnerable to a 500 year ARI storm surge event, this policy does not apply and the application can be prepared and lodged as a standard planning application subject to typical information requirements and assessment process (refer to Town Planning Scheme No. 8 Application for Development Approval).
3. If the site (or portion of the site) is identified as being vulnerable to a 500 year ARI storm surge event, then the application must either address the 'as of right' criteria contained in Section 5.2 below, or address the performance based criteria contained in Section 5.3 below.
4. If mapping is not available for a particular locality, the applicant will be referred to the Department of Water (or Responsible Authority) to determine whether a 500 year ARI AHD height can be provided.
5. If advice on the 500 year ARI AHD height is not available for a particular locality, the applicant may be required to provide a storm surge report and mapping to identify the 500 year ARI AHD height for the particular property. The report would need to recommend an appropriate risk management and adaptation response to the modelled storm surge impacts.
6. Refer to decision tree flow chart (Figure 1) for further guidance.

Figure 4 – Storm Surge Development Application Assessment Process



6.0 MONITORING AND REVIEW

It is acknowledged that the process of monitoring and reviewing this CHRMAP should be undertaken on a regular basis and is of particular importance to ensure that the management and adaptation planning established within the CHRMAP remains relevant.

Therefore, this CHRMAP will be monitored and reviewed on a regular basis as City resources permit. The CHRMAP has been prepared using the best available information to identify potential coastal hazards within the City of Karratha. This coastal hazard identification was based on data available at the time of preparation of the relevant studies and investigations, together with predictions of future change. However, over time as more data becomes available, and predictions of future change are

refined, the CHRMAP will need to be revised to make reference to newly available information. This will be particularly relevant where new areas of vulnerability, or changes to the risk exposure of those areas already considered to be vulnerable, are identified. Additionally, the CHRMAP will need to be updated periodically as management and adaptation strategies are enacted within the City.

The current mapping for the five coastal nodes of Karratha, Dampier, Roebourne, Wickham and Point Sampson will be reviewed and updated as resources and funding become available to do so. It will be important to maintain and improve the accuracy and detail contained within the mapping and also ensure that the mapping uses current best practice assumptions and methodology.

In order to measure the success of this CHRMAP, the following success criteria have been established which will form the basis of future reviews as deemed appropriate:

1. Maintenance of public safety;
2. Protection and enhancement (where applicable) of the local economy;
3. Protection of critical infrastructure (e.g. roads, sewerage infrastructure);
4. Where applicable, planned retreat and removal of indefensible infrastructure;
5. Protection of existing community structures and the lifestyle enjoyed by the community;
6. Sustaining and enhancing natural environmental values/conservation values/threatened species;
7. Ensuring sound public administration and governance.

The identified ongoing actions relevant to the monitoring and review of this CHRMAP include:

1. Raise community/resident awareness of flood studies and mappings to ensure a sufficient level of understanding of the risks associated with their property and public infrastructure;
2. Plan for and include flood data in lifecycle costing;
3. Undertake risk assessment as part of local government asset management;
4. Undertake business continuity planning;
5. Review climate change prediction and data modeling assumptions when new information becomes available.

The City should also consider this CHRMAP in reviewing and preparing new local planning strategies and town planning schemes for the District.

6.1 Other Actions

Other actions identified through the LGIS risk workshop process include:

1. Review the risk information in light of the discussions and findings and assign risk owners.
2. Controls assurance should be conducted on all controls identified. It is important that the City of Karratha ensure that these identified controls are in place, appropriate and effective in managing the identified risks.
3. Review the risks to ascertain whether any further actions need to be taken to reduce these risks and sign off on the risk acceptance / non-acceptance decision for all risks identified.
4. Review and assess the identified risk treatment options for recommendation and implementation, in terms of cost, benefit and impact to the controls assurance and level of risk.
5. Follow up with key stakeholders to establish if there are any further risks that need to be captured and/or reviewed.

7.0 CONSULTATION AND EDUCATION

7.1 Resources

The City is committed to providing the most relevant and accurate information and mapping relating to storm surge and will endeavor to source resources and funding to continue to improve the quality and availability of mapping along the coastline.

7.2 Consultation

In preparing this CHRMAP, the City engaged the services of LGIS Risk Management to facilitate risk workshops pertaining to storm surge and storm water flooding risks within the Karratha Townsite. This workshop engaged with the following stakeholder participants:

Workshop 1 (Thursday 10th November 2013)

Name	Organisation
David Pentz	City of Karratha
Sharon Boyle	City of Karratha
Kobus Niewoundt	City of Karratha
Karen Henry	City of Karratha
Martin Waddington	City of Karratha
Peter York	City of Karratha
Mark Thorbjornsen	City of Karratha
Lee Gan	City of Karratha
Craig Davey	City of Karratha
Pascal Heckeng	City of Karratha
Thomas Della Vedova	Department of Planning
Matt Yan	JDA Consultant Hydrologists
Damien Slack	JDA Consultant Hydrologists
Shelley Shepherd	Essential Environmental
Kelly Norris	Essential Environmental

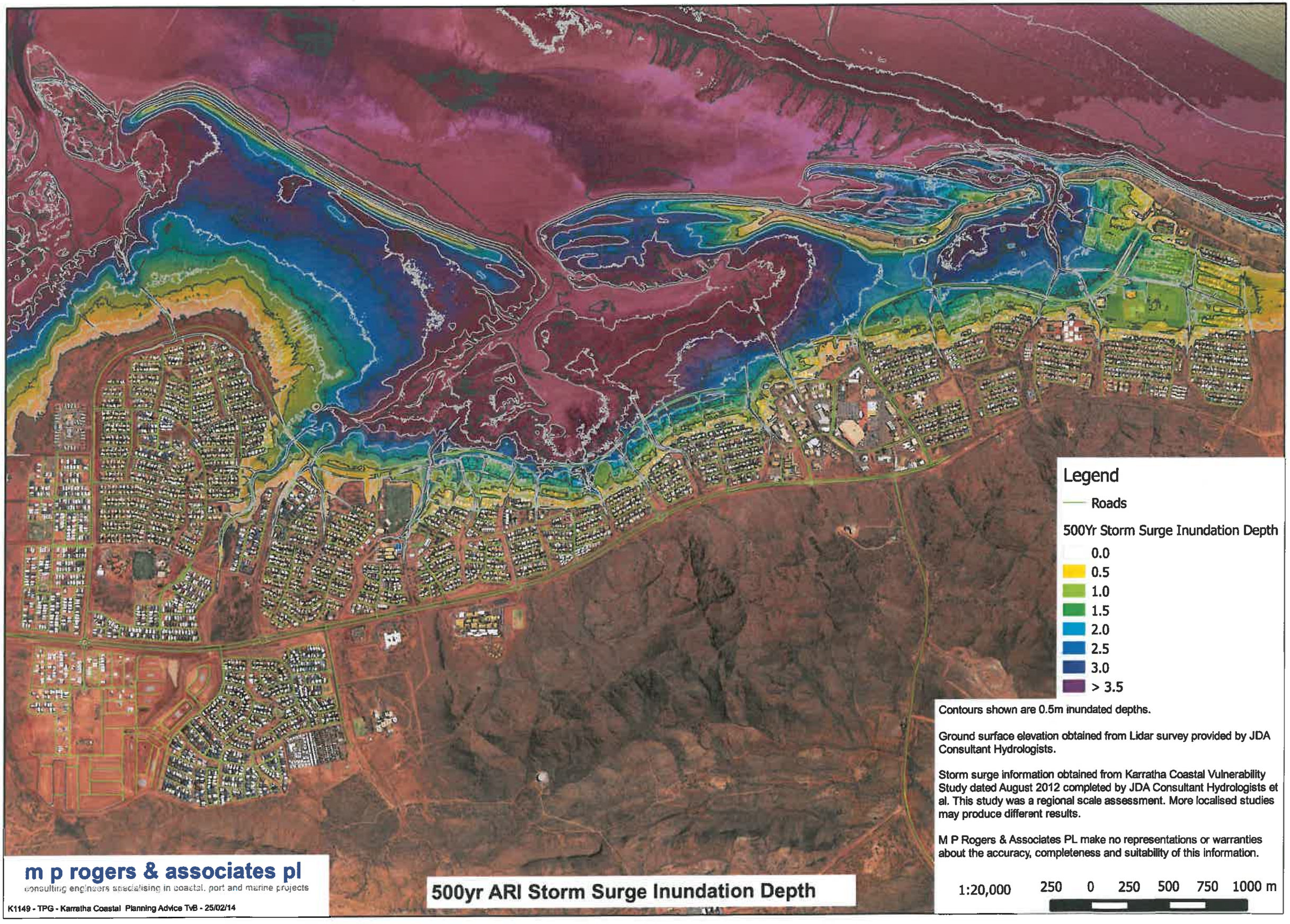
Workshop 2 (Friday 11 November 2013)

Name	Organisation
David Pentz	City of Karratha
Sharon Boyle	City of Karratha
Kobus Niewoudt	City of Karratha
Karen Henry	City of Karratha

Peter York	City of Karratha
Max Thorbjornsen	City of Karratha
Lee Gan	City of Karratha
Craig Davey	City of Karratha
Pascal Heckeng	City of Karratha
Kellene Elder	City of Karratha
Mitchell Cameron	City of Karratha
Thomas Della Vedova	Department of Planning
Matt Yan	JDA Consultant Hydrologists
Damien Slack	JDA Consultant Hydrologists
Brad Pawlenko	LandCorp
Grant Singleton	LandCorp
Shelly Shepherd	Essential Environmental
Kelly Norris	Essential Environmental
Germaine Fabling	Wood & Grieve

APPENDIX A

STORM SURGE VULNERABILITY MAPPING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1.0
1.5
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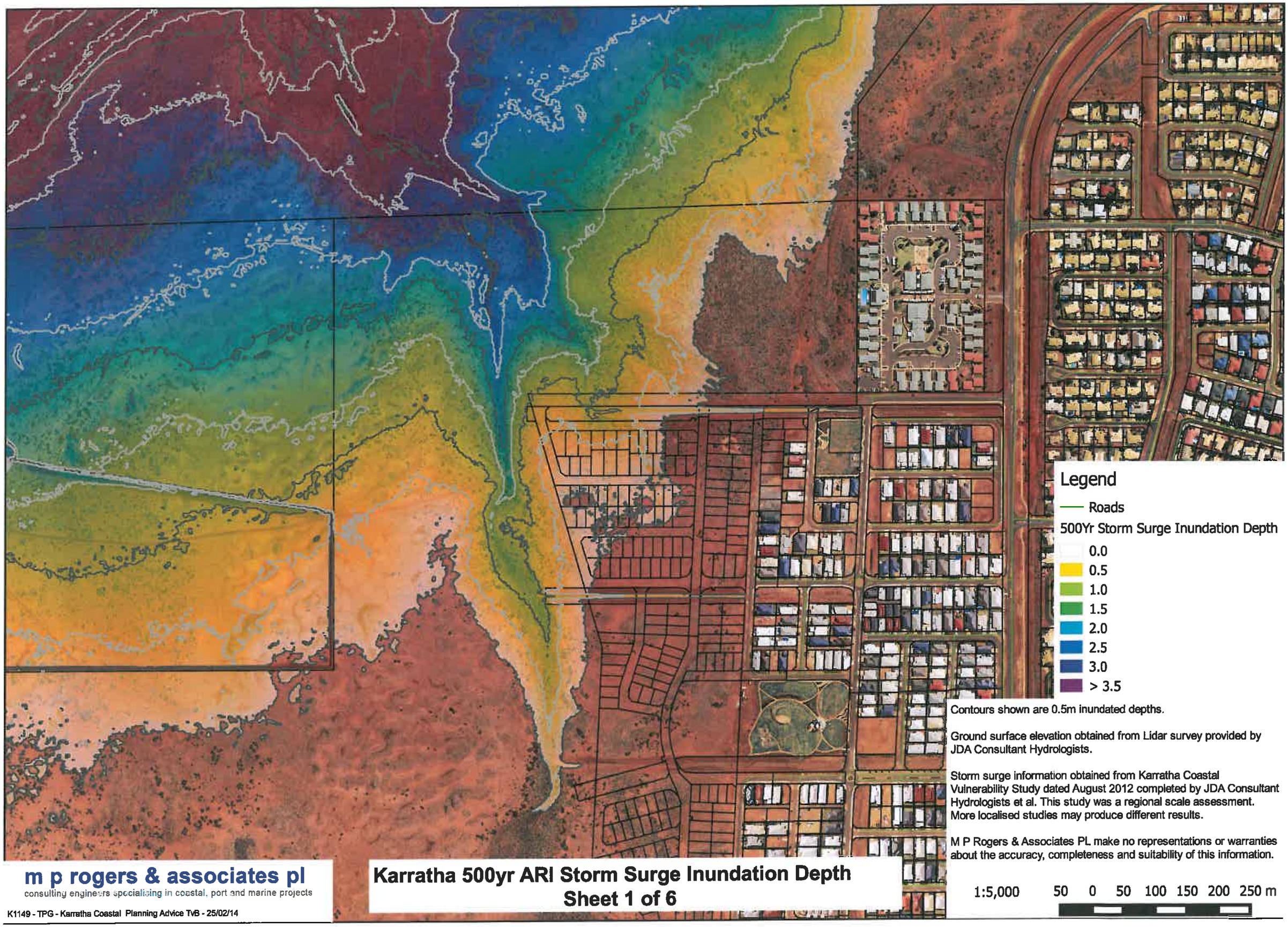
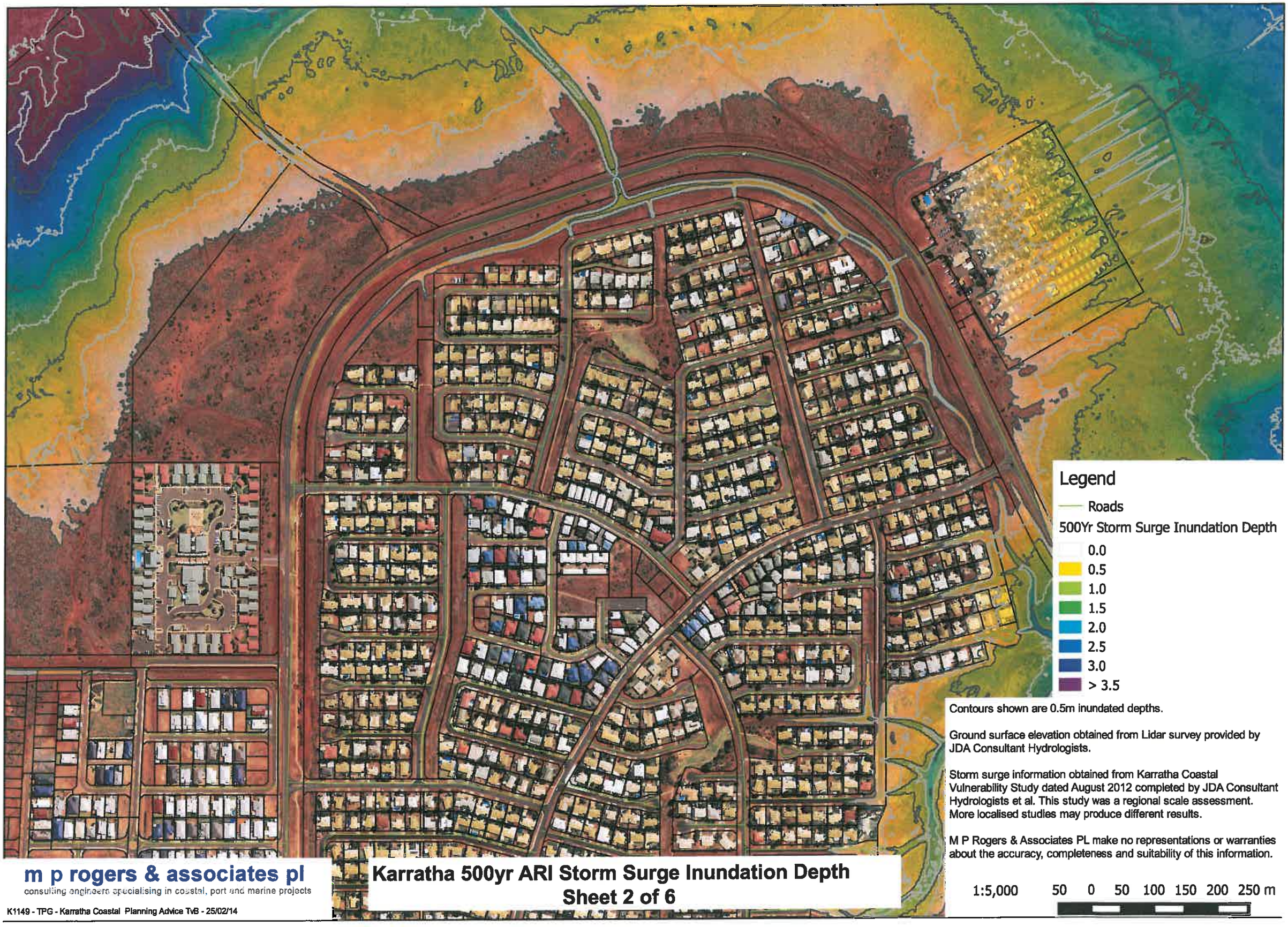
2.5
3.0
> 3.5
Contours shown are 0.5m inundated depths.
Ground surface elevation obtained from Lidar survey provided by JDA Consultant Hydrologists.
Storm surge information obtained from Karratha Coastal Vulnerability Study dated August 2012 completed by JDA Consultant Hydrologists et al. This study was a regional scale assessment. More localised studies may produce different results.
M P Rogers & Associates PL make no representations or warranties about the accuracy, completeness and suitability of this information.
1:20,000
250 0 250 500 750 1000 m
m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects
K1149 - TPG - Karratha Coastal Planning Advice TvB - 25/02/14
500yr ARI Storm Surge Inundation Depth



Karratha 500yr ARI Storm Surge Inundation Depth
Sheet 1 of 6

m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects



Karratha 500yr ARI Storm Surge Inundation Depth
Sheet 2 of 6

m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects

Contours shown are 0.5m inundated depths.

Ground surface elevation obtained from Lidar survey provided by JDA Consultant Hydrologists.

Storm surge information obtained from Karratha Coastal Vulnerability Study dated August 2012 completed by JDA Consultant Hydrologists et al. This study was a regional scale assessment. More localised studies may produce different results.

M P Rogers & Associates PL make no representations or warranties about the accuracy, completeness and suitability of this information.

1:5,000 50 0 50 100 150 200 250 m

m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects

K1149 - TPG - Karratha Coastal Planning Advice TvB - 25/02/14

Karratha 500yr ARI Storm Surge Inundation Depth
Sheet 3 of 6

Legend

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500Yr Storm Surge Inundation Depth

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- 3.0
- > 3.5

Contours shown are 0.5m inundated depths.

Ground surface elevation obtained from Lidar survey provided by JDA Consultant Hydrologists.

Storm surge information obtained from Karratha Coastal Vulnerability Study dated August 2012 completed by JDA Consultant Hydrologists et al. This study was a regional scale assessment. More localised studies may produce different results.

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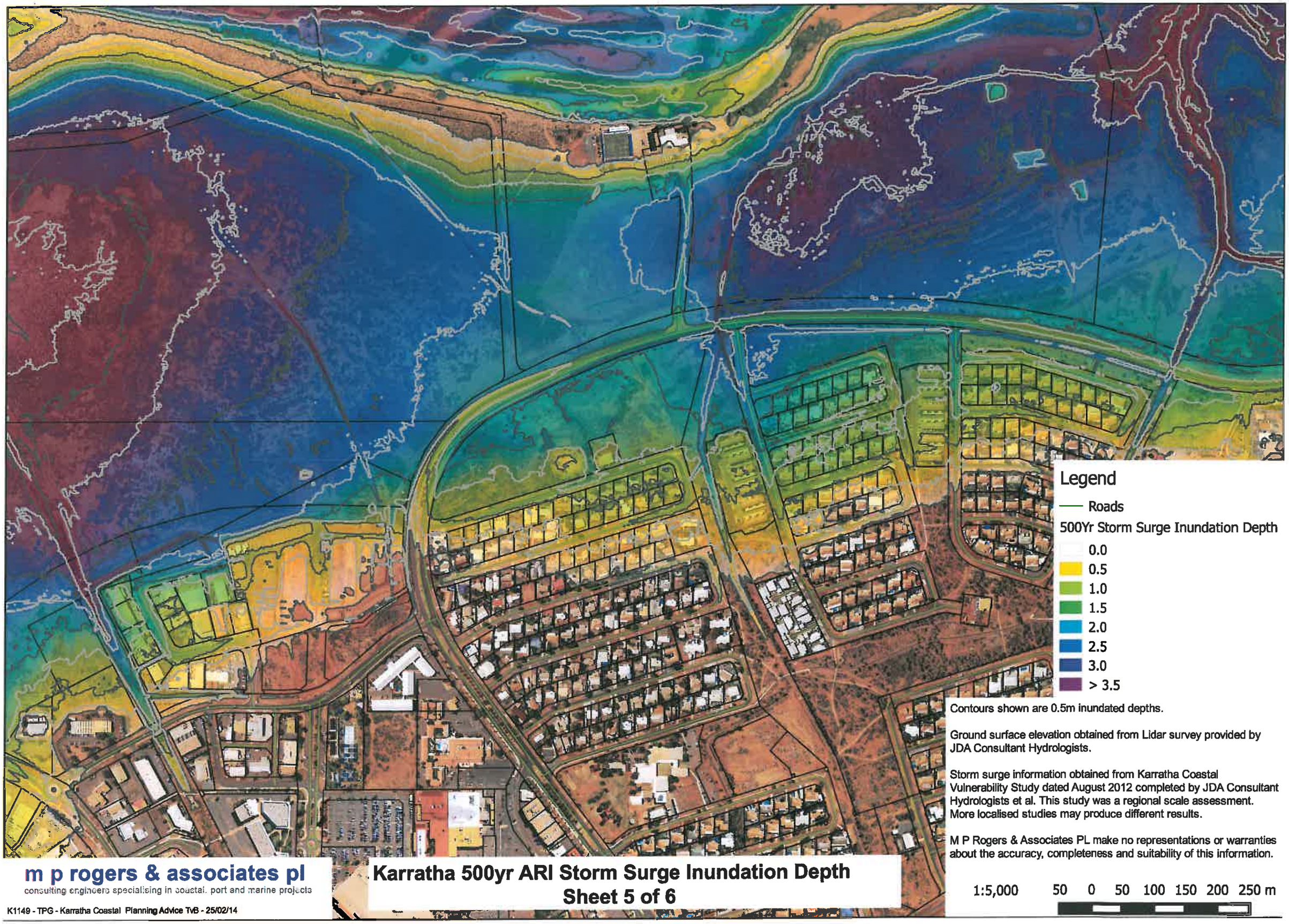
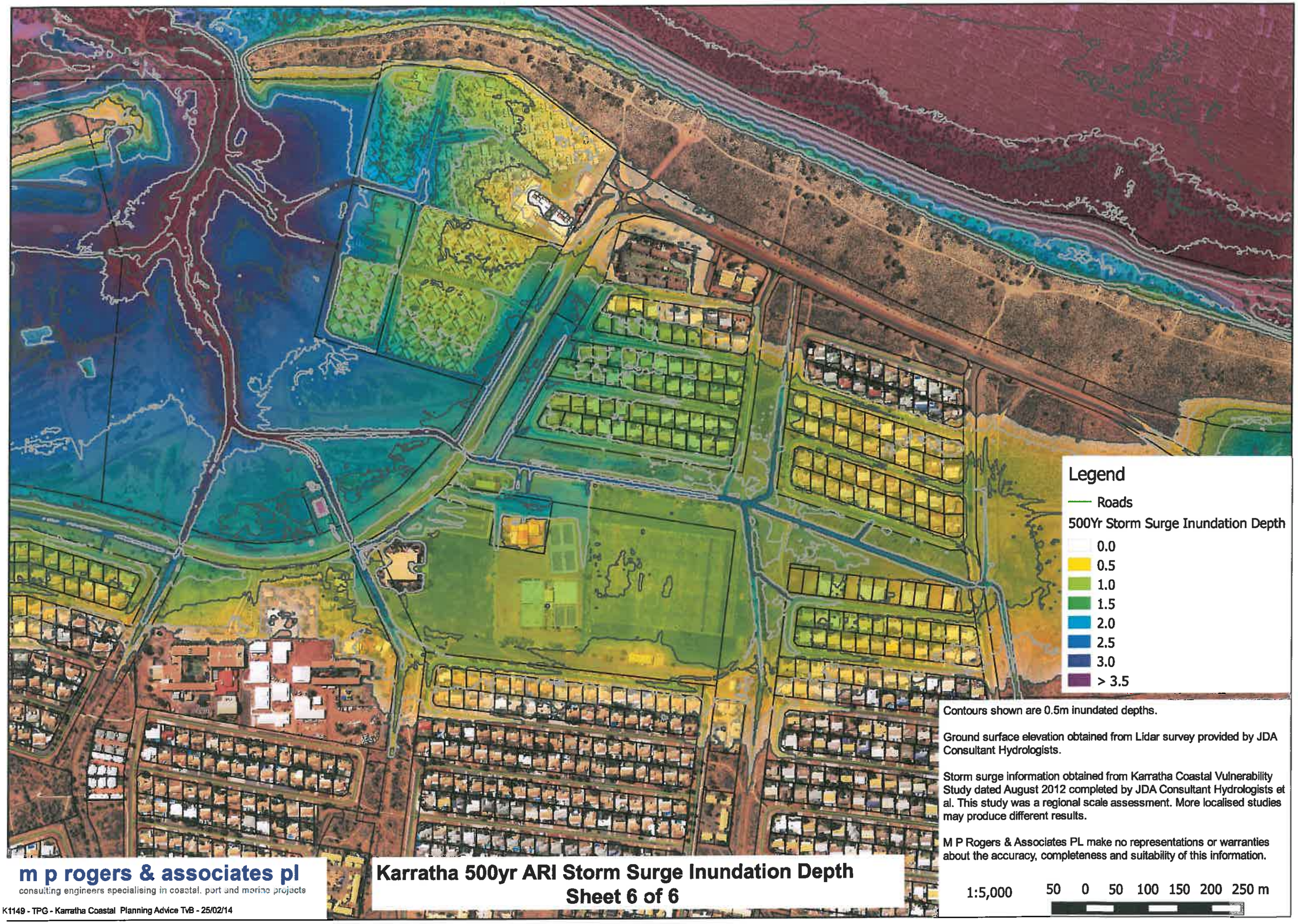
Karratha 500yr ARI Storm Surge Inundation Depth
Sheet 4 of 6

m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects



Karratha 500yr ARI Storm Surge Inundation Depth
Sheet 5 of 6

m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects



Contours shown are 0.5m inundated depths.

Ground surface elevation obtained from Lidar survey provided by JDA Consultant Hydrologists.

Storm surge information obtained from Karratha Coastal Vulnerability Study dated August 2012 completed by JDA Consultant Hydrologists et al. This study was a regional scale assessment. More localised studies may produce different results.

M P Rogers & Associates PL make no representations or warranties about the accuracy, completeness and suitability of this information.

1:5,000 50 0 50 100 150 200 250 m

Karratha 500yr ARI Storm Surge Inundation Depth
Sheet 6 of 6

m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects

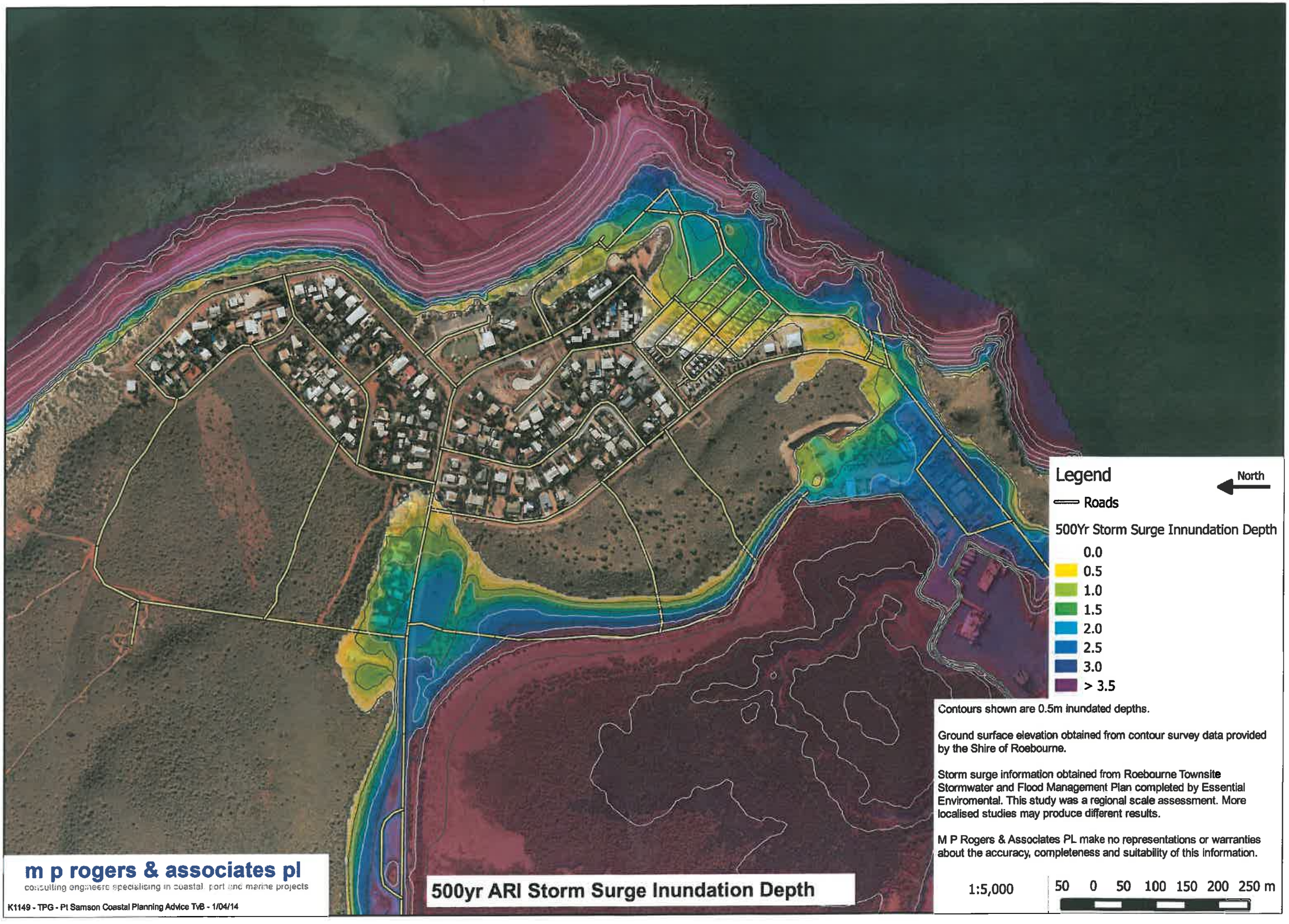
Data Source: GEMSURGE Modelling 2011

Job No. J4812
Scale 1:40,000

0 0.5 1 1.5 2 Kilometers

LandCorp
Dampier Coastal Vulnerability Study Report III: Storm Surge

Figure 22: 500yr ARI Coastal Inundation - 2110 Climate Scenario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Contours shown are 0.5m inundated depths.
Ground surface elevation obtained from contour survey data provided by the Shire of Roebourne.
Storm surge information obtained from Roebourne Townsite Stormwater and Flood Management Plan completed by Essential Enviromental. This study was a regional scale assessment. More localised studies may produce different results.
M P Rogers & Associates PL make no representations or warranties about the accuracy, completeness and suitability of this information.
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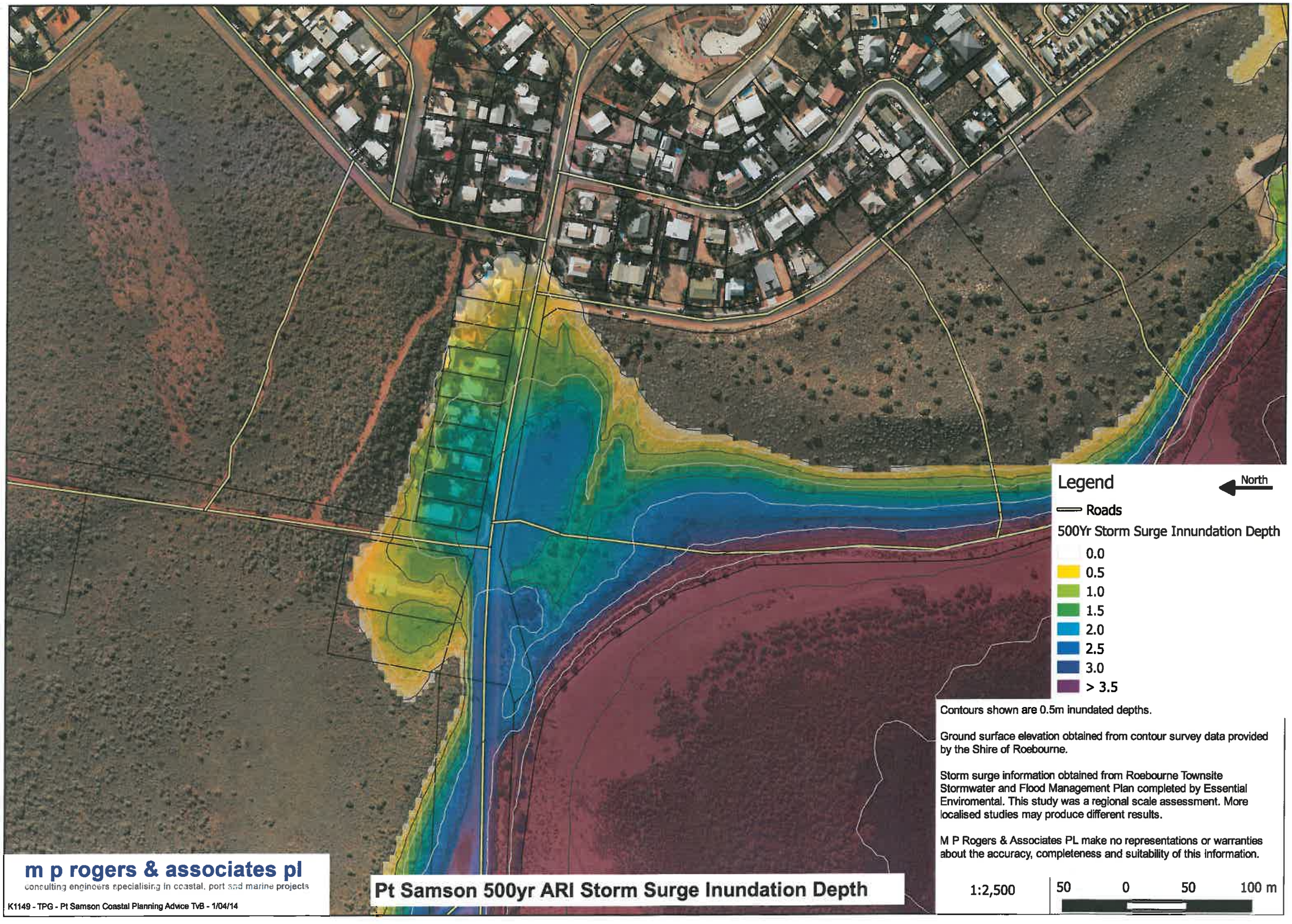
m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects
K1149 - TPG - Pt Samson Coastal Planning Advice TvB - 1/04/14
500yr ARI Storm Surge Inundation Depth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Contours shown are 0.5m inundated depths.
Ground surface elevation obtained from contour survey data provided by the Shire of Roebourne.
Storm surge information obtained from Roebourne Townsite Stormwater and Flood Management Plan completed by Essential Enviromental. This study was a regional scale assessment. More localised studies may produce different results.
M P Rogers & Associates PL make no representations or warranties about the accuracy, completeness and suitability of this information.
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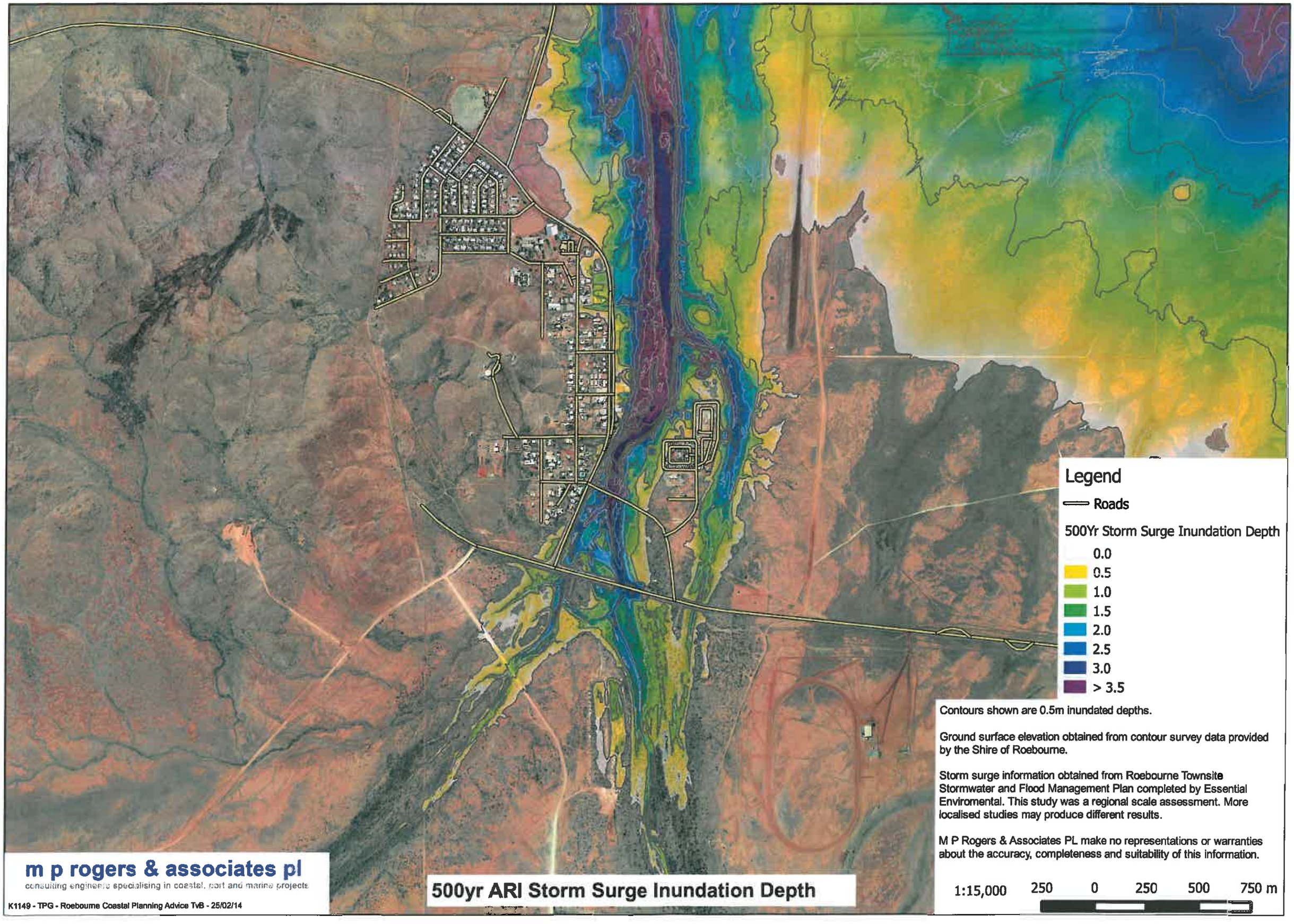
m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects
K1149 - TPG - Pt Samson Coastal Planning Advice TvB - 1/04/14
Pt Samson 500yr ARI Storm Surge Inundation Depth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Roads
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Contours shown are 0.5m inundated depths.
Ground surface elevation obtained from contour survey data provided by the Shire of Roebourne.
Storm surge information obtained from Roebourne Townsite Stormwater and Flood Management Plan completed by Essential Enviromental. This study was a regional scale assessment. More localised studies may produce different results.
M P Rogers & Associates PL make no representations or warranties about the accuracy, completeness and suitability of this information.
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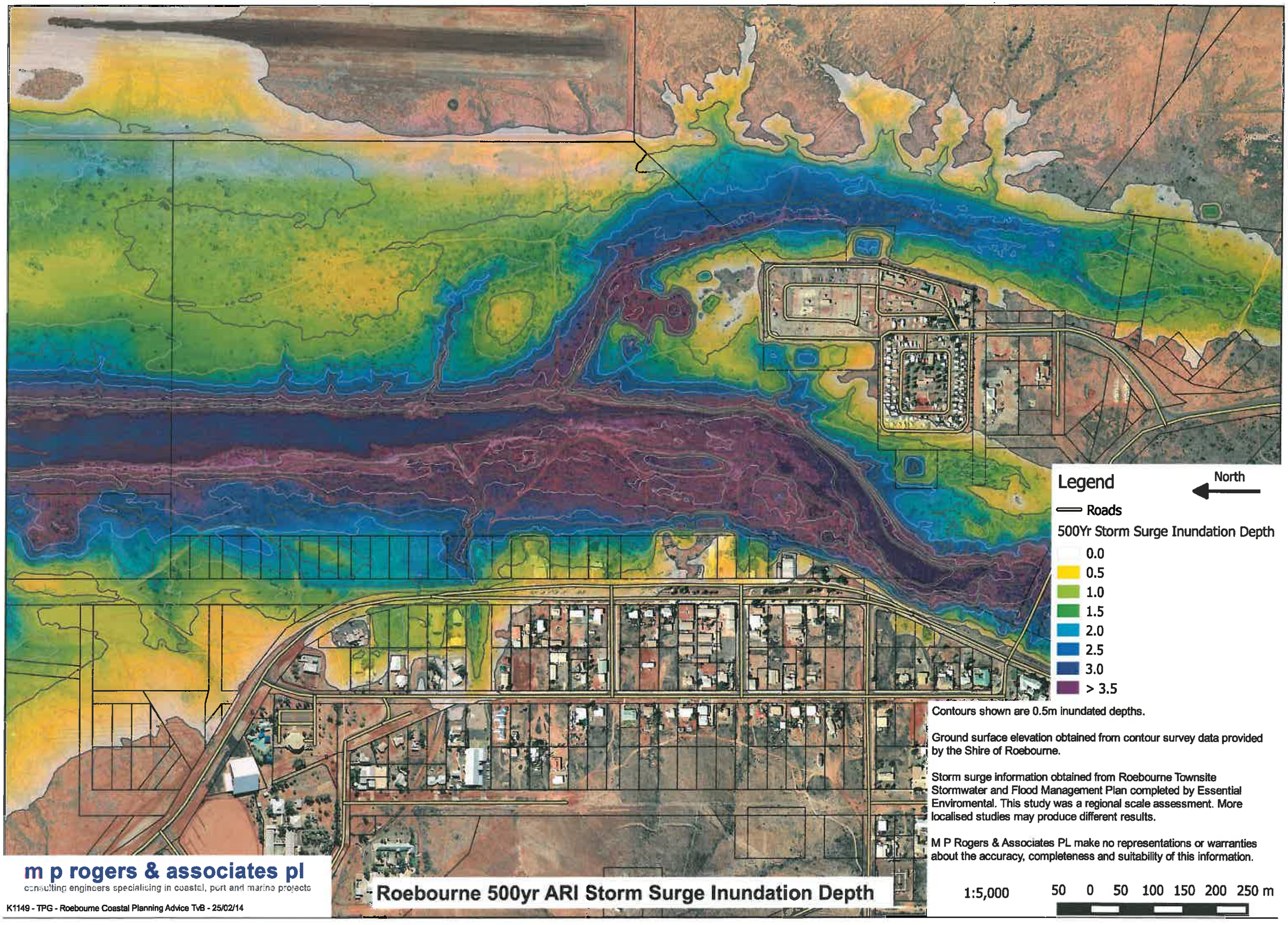
m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects
K1149 - TPG - Roebourne Coastal Planning Advice TvB - 25/02/14
500yr ARI Storm Surge Inundation Depth



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Ground surface elevation obtained from contour survey data provided by the Shire of Roebourne.

Storm surge information obtained from Roebourne Townsite Stormwater and Flood Management Plan completed by Essential Enviromental. This study was a regional scale assessment. More localised studies may produce different results.

M P Rogers & Associates PL make no representations or warranties about the accuracy, completeness and suitability of this information.

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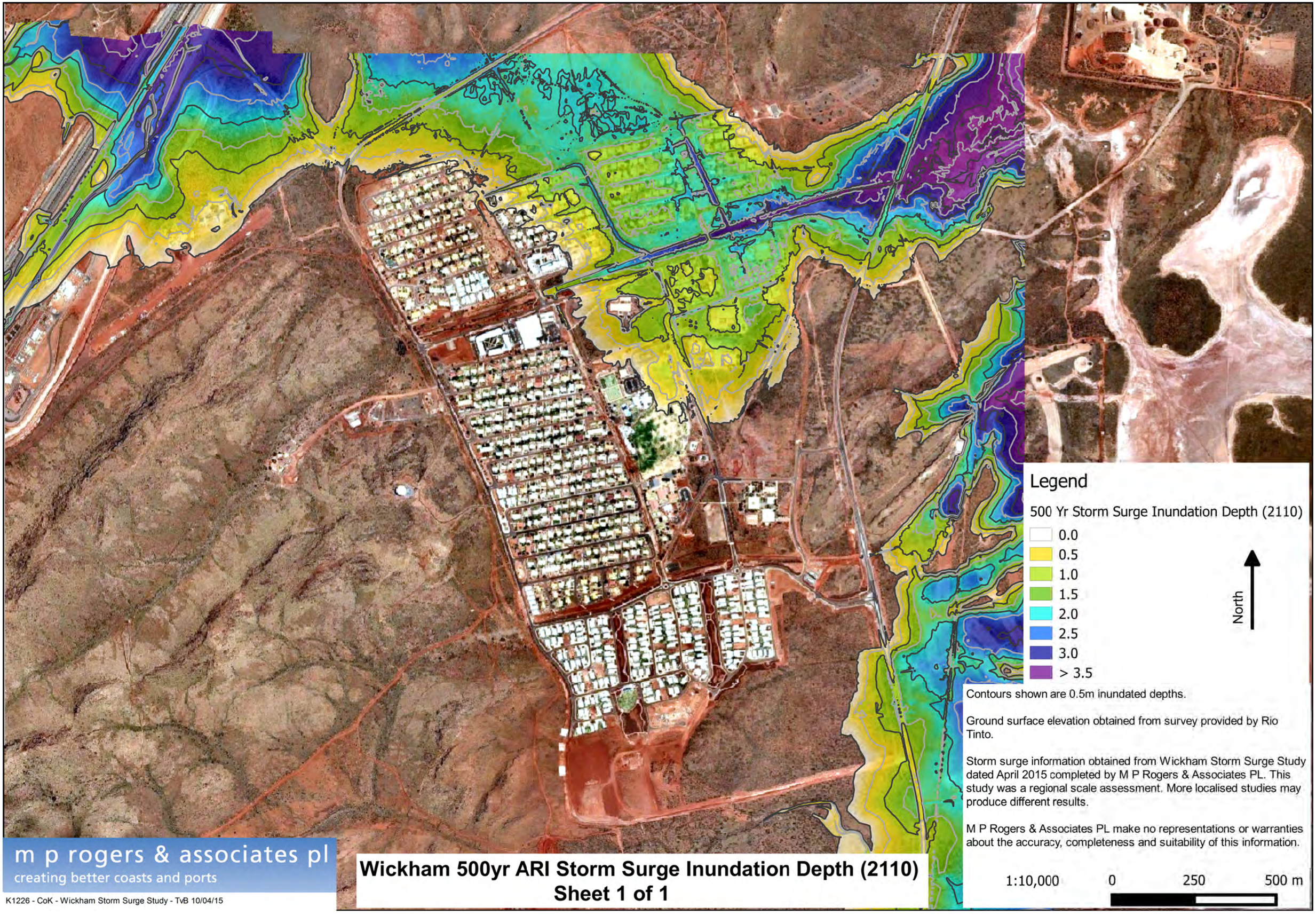
Roebourne 500yr ARI Storm Surge Inundation Depth

m p rogers & associates pl
consulting engineers specialising in coastal, port and marine projects



Wickham 500yr ARI Storm Surge Inundation Depth (2110)
Sheet 1 of 1

m p rogers & associates pl
creating better coasts and ports

K1226 - CoK - Wickham Storm Surge Study - TvB 10/04/15

APPENDIX B

DEVELOPMENT HAZARD RISK ASSESSMENT MATRIX

Shire of Roebourne
Storm Surge and Flooding Risk Register as at 11Oct2013

Ref No.	Critical Success Factor	Risk Description	Causal Factors	Existing Controls	100yr ARI Surge / Water				500yr ARI Surge / 100yr ARI Water			
					Consequence Category	Consequence	Likelihood	Level of Risk	Consequence Category	Consequence	Likelihood	Level of Risk
ST PS 01	Public Safety	Flooding and water run off from a storm surge and storm water event resulting in harm to public due to public actions	Fast running water Depth of flood water Rapid onset of weather conditions Reduced emergency access Not familiar with local conditions Turnover of residents Complacency towards weather conditions Allocated housing	Cyclone warning system Evacuation plans Local Emergency Management Arrangements Storm surge history Kelly line	HEA	5	3	**15**	HEA	5	2	**10**
ST PS 02	Public Safety	Flooding and water run off from a storm surge and storm water event resulting in harm to public due to hindered emergency capacity, response and recovery	Unknown lead agency and coordination of response Unresilient community Turnover of residents Loss of key access roads (Balmoral and Searipple Rds) Hospital access/egress in flood zone 1500pax Evacuation centre reaches capacity (evacuation of Searipple camp 2000pax, Balmoral Caravan Park 400pax)	Cyclone warning system Evacuation plans Local Emergency Management Arrangements Storm surge history Kelly line	HEA	5	3	**15**	HEA	5	2	**10**
ST PS 03	Public Safety	Flooding and water run off from a storm surge and storm water event resulting in harm to public due to lack of access / egress from residential lots	Some cul-de-sacs and crescents in flood zone may isolate public Flooding of footpaths resulting in paths leading to flooded / isolated areas (drainage reserves) Flooding of underpasses at Baynton Dr, Rosemary Rd and Balmoral Road Pedestrian bridges washed away, unable to cross drains (Millers Well, Pegs Creek, Bulgarra, Nickel West, Searipple)	Cyclone warning system Evacuation plans Local Emergency Management Arrangements Storm surge history Kelly line Underpass warning signage	HEA	5	3	**15**	HEA	5	2	**10**
ST PS 04	Public Safety	Flooding and water run off from a storm surge and storm water event resulting in harm to public due to contact with biological or chemical contaminants	Sewage entering storm water Sewage back flow into houses Contaminants from industrial sites	Sewage pumps over 1:100 yr level	HEA	3	4	**12**	HEA	3	3	**9**
ST PR 01	Property	Flooding and water run off from a storm surge and storm water event impacts residential property	Buildings erected below 100yr ARI and 500yr ARI flood lines Vulnerability of Bulgarra R30 Single dwellings not captured in planning scheme Raised lots impact surrounding lots Old subdivision different floor levels New and established dwellings at different heights Individual lot flood mitigation (eg retaining walls) Planning applications considered in isolation Lot design sloped to road	State Planning Policy 2.6 Coastal Management Bulgarra assessment referred to DoWater Raise finish floor levels Emergency notification on title Planning application for multiple dwellings	FIN	4	4	**16**	FIN	5	2	**10**
ST PR 02	Property	Flooding and water run off from a storm surge and storm water event impacts commercial property including accommodation, retail, petrol station and industrial locations resulting in property damage and uncontrolled release of waste	Buildings erected below 100yr ARI and 500yr ARI flood lines Vulnerability of Bulgarra R30 Single dwellings not captured in planning scheme Raised lots impact surrounding lots Old subdivision different floor levels New and established dwellings at different heights Individual lot flood mitigation (eg retaining walls) Planning applications considered in isolation Waste water stored on TWAs and Caravan Parks	State Planning Policy 2.6 Coastal Management Evacuation plans Rezoning of Crane Circle	FIN	5	4	**20**	FIN	5	2	**10**
ST PR 03	Property	Flooding and water run off from a storm surge and storm water event impacts Shire housing resulting in evacuated staff members and cost of recovery	Vulnerability of Shire housing on Richardson Way and Warambie Service Accommodation		SER FIN	3 4	4 3	**12**	SER FIN	4 5	2 2	**10**

Shire of Roebourne
Storm Surge and Flooding Risk Register as at 11Oct2013

Ref No.	Critical Success Factor	Risk Description	Causal Factors	Existing Controls	100yr ARI Surge / Water				500yr ARI Surge / 100yr ARI Water			
					Consequence Category	Consequence	Likelihood	Level of Risk	Consequence Category	Consequence	Likelihood	Level of Risk
ST PR 04	Property	Flooding and water run off from a storm surge and storm water event impacts Shire maintained landscaping and streetscaping resulting in increased costs of recovery	Grasses in drainage swales to reduce erosion		FIN	4	4	**16**	FIN	5	2	**10**
ST CI 01	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts school bus access in residential areas	Utilised for evacuation		REP	2	2	**4**	REP	2	1	**2**
ST CI 02	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts power supply due to substation on Rosemary Rd flooding and/or loss of access from storm water			SER	3	3	**9**	SER	3	2	**6**
ST CI 03	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts food supply chain due to loss of power and air / road transport routes		Reliance on generators	SER	4	2	**8**	SER	5	1	**5**
ST CI 04	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts broadcast ability of emergency broadcasting radio stations			SER	4	2	**8**	SER	5	1	**5**
ST CI 05	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts land and/or mobile telecommunications	Telstra pits underwater Mobile towers isolated		SER	4	2	**8**	SER	5	1	**5**
ST CI 06	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event isolates main arterial routes to/from Karratha		Main Roads responsibility	SER	4	2	**8**	SER	5	1	**5**
ST CI 07	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts road and transport infrastructure	Roads washed away Roads constructed to rely on dry weather Rapid deterioration of roads during storms Changes to drainage increase water flows	Works plant, equipment, materials and crew	FIN SER REP	5 5 4	4 2 4	**20**	FIN SER REP	5 5 5	2 2 2	**10**
ST CI 08	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts drainage infrastructure, capability and capacity	Loss of culverts Erosion Sedimentation Ponding of water Sewage contamination Floodway changes Blockage	Works plant, equipment, materials and crew Main Roads inspection of culverts Drainage inspection and maintenance program	FIN SER REP	5 5 4	4 2 4	**20**	FIN SER REP	5 5 5	2 2 2	**10**
ST CI 09	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts recycled effluent irrigation ponds and tanks			HEA FIN SER	3 5 5	4 4 4	**20**	HEA FIN SER	3 5 5	2 2 2	**10**
ST CI 10	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts community emergency management infrastructure - St John, DFES, Police, Courts, Jails, Shire office (Note: outside flood study area)			HEA REP	4 4	4 4	**16**	HEA REP	4 4	2 2	**8**
ST CI 11	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts waste facilities and service (Note impacted but outside of flood study area)	Inability to access domestic collections Depot cut off during flood Seven mile tip cut off		REP ENV	2 2	4 4	**8**	REP ENV	2 2	2 2	**4**
ST CI 12	Critical Infrastructure	Flooding and water run off from a storm surge and storm water event impacts airport runway and access roads flooded. This includes loss of commercial business, long term closure of airport		Advanced warnings	REP FIN SER	5 5 5	4 4 4	**20**	REP FIN SER	5 5 5	2 2 2	**10**
ST EN 01	Environmental	Flooding and water run off from a storm surge and storm water event impacts existing land forms and structures	Erosion of soil, sand dunes in Bulgara and foreshore Land slide and/or gradual subsidence in hills		ENV	3	3	**9**	ENV	4	2	**8**
ST EN 02	Environmental	Flooding and water run off from a storm surge and storm water event impacts local vegetation in wetlands, coastal mangroves, dune vegetation			ENV	2	4	**8**	ENV	2	2	**4**

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					Consequence Category	Consequence	Likelihood	Level of Risk	Consequence Category	Consequence	Likelihood	Level of Risk
ST EN 03	Environmental	Flooding and water run off from a storm surge and storm water event impacts local protected species			ENV	2	4	**8**	ENV	2	2	**4**
ST EN 04	Environmental	Flooding and water run off from a storm surge and storm water event increases presence of disease spreading vectors - mosquitos			HEA	3	3	**9**	ENV	3	2	**6**
ST EN 05	Environmental	Flooding and water run off from a storm surge and storm water event impacts sewage plant and light industrial area resulting in contamination of water and land	Sewage contamination Contamination from waste site, petrol stations and Crane Circle		HEA	3	4	**12**	HEA	3	3	**9**
ST EN 06	Environmental	Flooding and water run off from a storm surge and storm water event exposes buried asbestos and acid sulphate soils			HEA HEA	3 4	3 1	**9**	HEA HEA	3 4	2 1	**6**
ST EN 07	Environmental	Flooding and water run off from a storm surge and storm water event impacts passive and active reserves grass due to salt contamination			SER	2	1	**2**	SER	2	1	**2**
ST CO 01	Community	Flooding and water run off from a storm surge and storm water event impacts community events			SER	3	2	**6**	SER	4	1	**4**
ST CO 02	Community	Flooding and water run off from a storm surge and storm water event impacts local sports competition and training - golf club, bowls, indoor cricket, ovals, Millers Well oval, Pegs Creek oval, Cattral Park, Bulgarra sporting precincts			REP FIN	2 5	3 4	**16**	REP FIN	2 5	2 2	**10**
ST CO 03	Community	Flooding and water run off from a storm surge and storm water event impacts local cultural sites - RSL, Cemetery (outside study area)			REP FIN	3 3	4 4	**12**	REP FIN	3 3	2 2	**6**
ST CO 04	Community	Flooding and water run off from a storm surge and storm water event impacts local registered heritage sites and other important sites of heritage	Located in drainage reserves	Development does not encroach drainage reserves	REP	2	4	**8**	REP	2	2	**4**
ST CO 05	Community	Flooding and water run off from a storm surge and storm water event impacts community recreation facilities (incl halls, playgrounds, skateparks, boat ramp etc)			FIN SER	5 3	4	**20**	REP	5	2	**10**
ST CO 06	Community	Flooding and water run off from a storm surge and storm water event impacts community facilities including Salvation Army, Lotteries House and Community Health Centre, Day Care Centres, Retirement Village - Warambie estate			SER	5	4	**20**	SER	5	2	**10**
ST AG 01	Admin & Governance	Flooding and water run off from a storm surge and storm water event forces review, increased scrutiny and investigation into Shire planning, development, building and environmental health approval decisions and processes resulting in claims for losses and liability exposures	Council or Officer negligent actions Violation of statutory or regulatory requirements Personal liability		COM REP FIN	5 5 5	4 4 4	**20**	COM REP FIN	5 5 5	1 1 1	**5**
ST AG 02	Admin & Governance	Flooding and water run off from a storm surge and storm water event forces review, increased scrutiny and investigation into Shire planning, development, building and environmental health compliance processes and activities	Resource constraints to undertake compliance activities Unknown compliance (eg Crane Circle non-compliance) Inefficient compliance processes		COM REP FIN	5 5 5	4 4 4	**20**	COM REP FIN	5 5 5	1 1 1	**5**
ST AG 03	Admin & Governance	Flooding and water run off from a storm surge and storm water event impacts Shire capacity and capability to control animals			HEA	3	3	**9**	HEA	3	2	**6**

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Storm Surge and Flooding Risk Register as at 11Oct2013

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ST AG 04	Admin & Governance	Flooding and water run off from a storm surge and storm water event impacts Shire capacity and capability to fulfil emergency management obligations	Resourcing capacity and capability Senior staff impacted due to location of flooding Staff volunteering Loss of access to plant and equipment Inability to access Shire President or CEO for emergency arrangements Loss of access to IT and records	Utilise contractor equipment and resources	SER REP	4 4	3 3	**12**	SER REP	5 4	2 2	**10**
ST AG 05	Admin & Governance	Flooding and water run off from a storm surge and storm water event impacts Shire capacity and capability to fulfil non-emergency operational obligations	Resourcing capacity and capability Senior staff impacted due to location of flooding Staff volunteering Loss of access to plant and equipment Inability to access Shire President or CEO for emergency arrangements Loss of access to IT and records		SER REP	4 3	3 3	**12**	SER REP	5 3	2 2	**10**
ST AG 06	Admin & Governance	Flooding and water run off from a storm surge and storm water event impacts Shire long term asset management and financial planning and sustainability due to immediate and costly response and recovery requirements	Litigation Buy back of flooded land Repairs Compensation	3 year asset inspection	FIN	5	3	**15**	FIN	5	2	**10**
ST AG 07	Admin & Governance	Flooding and water run off from a storm surge and storm water event differ from predicted modelling impacts	Changes or reviews of base data Climate change implications Changes to local infrastructure such as road and kerb heights reducing the capacity of drainage channels		ENV REP	4 4	2 2	**8**	ENV REP	4 4	1 1	**4**