4. Basis for Monitoring Action Plan

4.1. EROSION MONITORING PROTOCOL

An approach to determine coastal monitoring recommendations for each tertiary sediment cell along the PNP coast is outlined here (Table 12). A monitoring hierarchy based on physical vulnerability and the presence of infrastructure has been developed, that supports several levels of management and their corresponding monitoring objectives (Table 3). Recommendations are based on this hierarchy, with refinement of applicable monitoring techniques based on the local morphology and existing knowledge of coastal dynamics.

Table 12: Steps Used to Identify Monitoring Recommendations

Step 1	Determine physical vulnerability
Step 2	Evaluate presence of coastal infrastructure
Step 3	Assign monitoring level based on risk, to define 'basic' techniques
Step 4	Review applicability of monitoring techniques
Step 5	Recommend monitoring

It is important to note that the guidance for monitoring discussed here is based on a conceptual assessment of cell specific vulnerability and considers infrastructure assets only. Further, it should be recognised that the guidance provided is not wholly prescriptive as each LGA is likely to have different priorities and concerns with respect to their ongoing coastal management, including financial capacity. Further refinement may require consideration of environmental and social 'values' that each LGA assigns to discrete coastal areas in addition to the consideration of infrastructure assets presented here.

Physical vulnerability was evaluated on a cell-by cell basis through review of available coastal change information, including vegetation line changes collated as part of the Managing Coastal Vulnerability Project, coastal setback studies [101] and published coastal change studies. Physical vulnerability was indicated by:

- Relative variability of vegetation lines, with a decadal range (generalised) of >40m indicating high vulnerability, and <10m indicating low vulnerability;
- Historic patterns of behaviour, with ongoing erosion or significant step-changes indicating high vulnerability and stability or accretion indicating low vulnerability;
- Acute erosion allowance >25m suggests high vulnerability and <10m low vulnerability.

High, medium or low vulnerability was used to identify the width of a coastal zone (80m, 50m or 20m) in which infrastructure may be considered subject to erosion threat. The relative density of infrastructure across this zone was used to assign a risk rating of high, medium or low, taking into account the distance from shore. This rating was subjective, with resilient coastal infrastructure not included in the rating, where its presence was known to the consultant. An understanding of the relative need to monitor for coastal trend, acute response or to co-ordinate active coastal management was based on the distance of infrastructure from the shore (Figure 18). In terms of SPP 2.6 allowances, distance greater than 2xS1 suggests monitoring for trend, and less than S1 suggests active management.

Table 13: Monitoring Levels and Intended Use

Monitoring 'Level'	Risk Level	Monitoring Purpose	Type of Monitoring	Intended Use
0	Low	Context	Qualitative	Supports a wider understanding of behaviour to suit contextual analysis of sediment cell behaviour.
1	Low	Trend	Qualitative	Supports forecast of time for which a foreshore buffer may give protection (before hazard phase). Should allow distinction between a trend and a fluctuation.
2	Medium	Hazard	Quantitative	Supports estimation of the likelihood of events requiring management action. Greater precision may be needed to limit early interventions.
3	High	Active Management	Quantitative	Supports decision-making for active management, such as stabilization works or sand bypassing.

In turn, monitoring 'levels' are aligned to a range of techniques (detailed in the associated monitoring manual) that generally increase in accuracy, cost and capacity and time requirements (Table 14). For example, Level 0 techniques are low cost, low resolution, easy to implement, and generally require less time; whereas Level 3 techniques are more expensive (external funding required), higher resolution, normally needing external consultants, with longer timeframes for collection and analysis.

Table 14: Coastal Monitoring 'Levels' and Associated Monitoring Techniques

		Monitoring Level			
		0	1	2	3
Monitoring Technique	Photo Monitoring	✓	✓	✓	✓
	Beach Width		✓ →		
	Beach Profiles			✓ →	
	Spatial Survey Coverage				✓
	Oblique Aerial Imagery	✓	✓	✓	✓
	Vertical Aerial Imagery	(✓)	✓ →		
	Hydrographic Survey			✓	✓
	LIDAR Monitoring				✓

(✓) indicates this method may be used at a lower level; Arrows indicate the method may be used at a higher level (with modification).

Descriptions of typical monitoring methods are outlined in the PNP Monitoring Manual, prepared in parallel with this document. Corresponding applications for the identified monitoring levels are described following:

Photographic monitoring:
A qualitative method of beach change assessment, useful due to its low cost and the ability for non-technical support, such as community groups, to complete monitoring. Refinement to the use of photographic monitoring may include definition of photo points [40] and use of smartphone applications to collate community photographs [102]. Photographic monitoring may be used effectively at different levels depending upon coverage and frequency of collection (Table 15). Monitoring locations may correspond to (i) stress points adjacent to coastal infrastructure; (ii) indicators points that are 'representative' of an extended length of coast; or (iii) sinks and source points, typically near the boundary of coastal compartments. For use in a detailed monitoring program (Level 3), photographic monitoring should capture locations used for management triggers at a high frequency, supporting quantitative monitoring such as profiles at a lower frequency.

Table 15: Photographic Monitoring Levels

Monitoring	Coverage	Frequency
Level 0	Key Stress Points	Annual or Twice Yearly
Level 1	Indicator Points	Monthly
Level 2	Sinks, Sources & Indicators	Monthly
Level 3	Trigger Points	Weekly in peak season

Complete coverage of a spatial unit (say of a sediment cell) is generally more cost-effective by aerial photography (obliques or vertical imagery) than by land-based photographs.

Beach Width:
A quantitative method of beach change assessment, useful due to its low cost and ease of measurement, which may be used for Level 1 or 2 monitoring (Table 14). Further refinement of this technique may include identification of beach levels, through reference to a fixed feature or installed marker. Beach width measurement should be supported by concurrent photographic monitoring, to demonstrate that the width measurement is meaningful for a significant length of coast. Beach width measurement is of reduced value where the coastal varies significantly alongshore, and therefore it is only appropriate for measurement at indicator sites which are 'representative' for an extended length of coast, such as along a long straight section of coast. Beach width variation is often systematic along a compartmentalised coast, such that a minimum of three points of measurement in a cell may be sufficient to attribute much of the character of coastal change (see Section 3.4.3).

Table 16: Beach Width Monitoring Levels

Monitoring	Coverage	Frequency
Level 1	Indicator Points (minimum of 3 per cell)	Annual or Twice Yearly
Level 2	Indicator Points (increased density)	Annual or Twice Yearly
Level 3	*Inadequate due to uncertainty associated with beach levels*	

A program of monthly beach width measurement is recommended as an initial means of identifying the appropriate months of the year for annual or twice yearly monitoring.

Beach Profiles:
A quantitative method of beach change assessment, which may be used at a range of levels depending on coverage and frequency (Table 17). Beach profile measurement should be supported by concurrent photographic monitoring, to demonstrate that the profile is meaningful for a significant length of coast. When used on parts of the coast which may vary in aspect, such as adjacent to structures or rock features, profile should be related to alongshore beach measurements, such a beach crest line and a start of vegetation line. Where a complete description of volumetric change is required (note Figure 16), high density beach profile measurements may be combined with hydrographic surveys.

Table 17: Beach Profile Monitoring Levels

Monitoring	Coverage	Frequency
Level 1	Indicator Profiles (minimum of 3 per cell)	Five Yearly
Level 2	Indicator Profiles (typically 5-7 per cell)	Annual or Twice Yearly
Level 3	Distributed Profiles (typically 50-250m spacing)	Annual or Twice Yearly

Spatial Survey Coverage:
An intensive quantitative method for beach change assessment, which is not typically used for low level monitoring due to cost (Table 18). Available scanning methods are mostly valid for the section of coast above water and therefore are often conducted in parallel with hydrographic survey when a complete description of volumetric change is required (Figure 16). Physical limitations to access may leave a gap between the two types of survey.

Table 18: Spatial Survey Coverage Monitoring Levels

Monitoring	Coverage	Frequency
Level 1	*Not considered suitable due to cost*	
Level 2	Area to be quantified	Every 5 to 10 Years
Level 3	Area to be quantified (preferably whole cell)	Annual

Oblique Aerial Imagery:
A qualitative method for identifying behavioural change from a large spatial perspective, this method is far simpler than vertical aerial imagery, and may be conducted by PNP or LGA officers with limited training, although it is not inexpensive due to the cost of hiring a pilot and aircraft. This method is not considered suitable for quantitative analysis normally desired for Level 2 or 3 monitoring, although it may be suitable as either Level 0 or 1 monitoring depending upon the monitoring frequency (Table 19). The main aspect of coastal change that can be picked up by oblique imagery but not beach width measurement is the behaviour at areas with large alongshore variation, typically local sink or source areas and often adjacent to coastal structures or natural barriers to alongshore sediment transport.

Table 19: Oblique Aerial Imagery Monitoring Levels

Monitoring	Coverage	Frequency
Level 0	Area to be described (preferably whole cell)	Every 5 to 10 Years
Level 1	Area to be described (preferably whole cell)	Annual or Twice Yearly
Level 2	*Limited quantitative analysis due to field of view*	
Level 3	*Limited quantitative analysis due to field of view*	

Vertical Aerial Imagery:
Georeferenced vertical aerial imagery provides a quantitative measure of coastal change at a large spatial perspective. This has been the main method of capturing coastal change along the Western Australian coast since the 1950s. Interpretation of vertical imagery is typically undertaken using various 'markers' including the swash line, the beach crest, wrack lines (especially high water marks) and the line of coastal vegetation. Each of these measures may behave slightly differently to the overall beach volume and therefore care should be taken to ensure that meaningful measures are used at each site. Despite these constraints, in most situations vertical aerial imagery is suitable for assessment of beach change, with the effective monitoring level determined by the frequency of photography capture (Table 20).

Table 20: Vertical Aerial Imagery Monitoring Levels

Monitoring	Coverage	Frequency
Level 1	Area to be quantified (preferably whole cell)	Every 10 Years
Level 2	Area to be quantified (preferably whole cell)	Every 5 Years
Level 3	Area to be quantified (preferably whole cell)	Annual

Hydrographic Survey:
A quantitative measure of coastal change underneath the water surface, this method requires a skipper, vessel, specialised equipment and team and therefore is a relatively high cost approach, only suited to high levels of monitoring (Table 21). The greatest need for hydrographic surveys occurs where it is necessary to develop a volumetric understanding of coastal change, including the possibility of post-storm recovery (see Section 2.5.1). Partial coverage by hydrographic survey may therefore be appropriate if cross-shore sediment movement is focused on dynamic sites, such as in the vicinity of coastal structures.

Table 21: Hydrographic Survey Monitoring Levels

Monitoring	Coverage	Frequency
Level 1	*Not considered suitable due to cost*	
Level 2	Area to be quantified (focused on dynamic sites)	Every 5 to 10 Years
Level 3	Area to be quantified (preferably whole cell)	Annual

LIDAR Monitoring:
An intensive high-precision quantitative measure of coastal change that is most cost-effective over moderate to large spatial areas, this method requires a pilot, aircraft, specialised equipment and team and therefore is a high cost approach, only suited to Level 3 monitoring (Table 22). The cost of LIDAR monitoring for a moderate area should be evaluated carefully in comparison to a combination of hydrographic and spatial area surveys.

Table 22: LIDAR Monitoring Levels

Monitoring	Coverage	Frequency
Level 1	*Not considered suitable due to cost*	
Level 2	*Not considered suitable due to cost*	
Level 3	Area to be quantified (preferably whole cell)	Every 5 Years

4.2. PROTOCOL APPLICATION

Application of the protocol (Table 12) to determine recommended coastal monitoring has been undertaken on a tertiary cell basis. For each tertiary sediment cell, the following fields have been populated:

Cell Identifier	From Vlamingh Region tertiary sediment cells [35]
Location	Names of the cell alongshore boundaries
LGA	Responsible Local government agency
Physical Vulnerability	Indication of susceptibility to coastal hazards based upon vegetation lines and hazard mapping [73]
Significant Historic Events	Events known to have caused significant erosion or flooding impact
Infrastructure Presence	Existing infrastructure and relative proximity to the coast
Existing Coastal Management	Activities that may affect the decision-making time frame or require coastal monitoring
Presence of Coastal Structures	Known existing coastal protection works
Active Coastal Processes	Coastal processes that may modify or limit the interpretation of coastal monitoring
Decision-making Time Frame	Typical time frame required for management of coastal hazards
Minimum Monitoring	Level of monitoring suitable for the cell, based on physical vulnerability, existing infrastructure, coastal management and active coastal processes.

Table 23 through to Table 51 summarise the information used to apply the protocol for each tertiary sediment cell. Coastal monitoring recommendations for the entire PNP coast (by cell) are summarised in Table 52.

Table 23: CMAP Protocol Application for Cape Peron to Bird Island

Cell Identifier	R06D14.c (see Figure 21)	
Location	Cape Peron to Bird Island	
LGA	Rockingham	
Physical Vulnerability	Moderate erosion associated with movement of salient	
Infrastructure Presence	One building within 11m, three shacks within 25m, Point Peron Rd within 25m	
Active Coastal Processes	Salient response implies high importance of plan form measurement	
Decision-making Time Frame	5 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly monitoring to cover beaches	
2) Beach Widths		1. North – Existing Track (TBA) 2. Pt Peron Rd
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	

Table 24: CMAP Protocol Application for Bird Island to Seal Island

Cell Identifier	R06D14.b (see Figure 21)	
Location	Bird Island to Seal Island	
LGA	Rockingham	
Physical Vulnerability	Moderate erosion associated with movement of salient (north) and general retreat (central)	
Infrastructure Presence	Arcadia Drive within 10m, shacks within 25m	
Active Coastal Processes	Salient response implies importance of plan form measurement	
Decision-making Time Frame	5 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly monitoring to cover beach area	
2) Beach Widths	Annual or twice yearly	1. Todd Ave 2. Boundary Rd 3. Gloucester Ave
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	

Table 25: CMAP Protocol Application for Seal Island to Mersey Point

Cell Identifier	R06D14.a (see Figure 21)	
Location	Seal Island to Mersey Point	
LGA	Rockingham	
Physical Vulnerability	Low, with general history of accretion	
Infrastructure Presence	Car parks within 25m, Arcadia Drive within 55m	
Decision-making Time Frame	20 years	
Minimum Monitoring	Level 0	
1) Photographic Monitoring	Annual or twice yearly	
2) Beach Widths	Annual or twice yearly	1. Track S of Coventry Rd 2. Seaforth Rd
3) Oblique Imagery	Every 5 to 10 years (higher frequency is practical for LGA)	
4) Vertical Imagery	Every 10 to 20 years (higher frequency practical for LGA)	

Table 26: CMAP Protocol Application for Mersey Point to Safety Bay

Cell Identifier	R06D13.a (see Figure 21)
Location	Mersey Point to Safety Bay
LGA	Rockingham
Physical Vulnerability	High, with long term dynamic behaviour Minor flood risk Safety Bay foreshore
Significant Historic Events	Cyclic pattern of change at Tern Island 6
Infrastructure Presence	Two boat ramps, Safety Bay Road within 12m
Existing Coastal Management	Protection through defence
Presence of Coastal Structures	Mersey Point seawall (buried)
Active Coastal Processes	Complex three-dimensional behaviour implies very high importance of plan form measurement & need to undertake hydrographic survey
Decision-making Time Frame	5 years
Minimum Monitoring	Level 2
1) Photographic Monitoring	Monthly
2) Oblique Imagery	Annual or twice yearly
3) Vertical Imagery	Every 5 to 10 years
4) Hydrographic Survey	Every 10 to 20 years
5) Condition Assessment	Every 5 to 10 years when seawall is exposed
6) Flood Mapping	Event-driven, Safety Bay foreshore

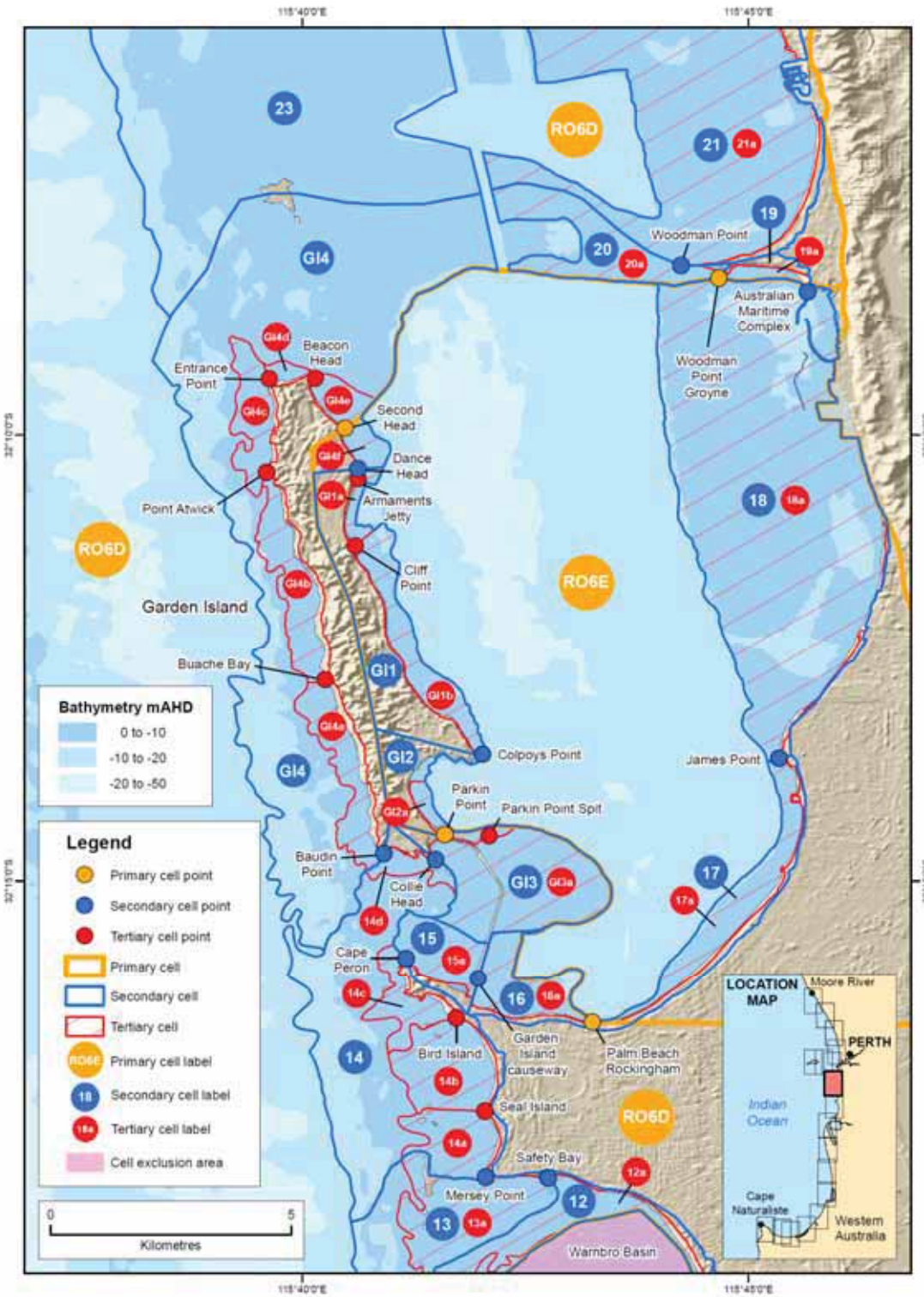

Figure 21: Woodman Point to Mersey Point, Secondary Cells 12 to 20

Table 27: CMAP Protocol Application for Safety Bay to North Becher Point

Cell Identifier	R06C12.a (see Figure 22)	
Location	Safety Bay to North Becher Point	
LGA	Rockingham	
Physical Vulnerability	Moderate, with gradual coastal erosion (N)	
Infrastructure Presence	Beach access ramp, DUP within 6m, SLSC within 15m, carpark within 18m, Warnbro Beach Road within 30m	
Existing Coastal Management	Minor renourishment works	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport	
Decision-making Time Frame	5 years	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Ernest St 2. Hilda Rd 3. St Ives Cove 4. Bayeux Ave 5. Wave Cove
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 years	

Table 28: CMAP Protocol Application for North Becher Point to Ansteys Car Park

Cell Identifier	R06C11.a (see Figure 22)	
Location	North Becher Point to Ansteys Car Park	
LGA	Rockingham / Mandurah	
Physical Vulnerability	Moderate, generally accreting but with high sensitivity to occasional reversals	
Significant Historic Events	Massive rapid erosion observed in 1964 Beach ridge dating suggests substantial transport reversals may be sustained for decades	
Infrastructure Presence	SLSC and carparks within 75m	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. Dune growth on foredune plain.	
Decision-making Time Frame	10 to 20 years (due to episodic events)	
Minimum Monitoring	Level 0	
1) Photographic Monitoring	Annual or twice yearly	
2) Beach Widths	Annual	1. North (TBA) 2. Central (TBA) 3. South (TBA)
3) Oblique Imagery	Every 5 to 10 years (higher frequency is practical for LGA)	
4) Vertical Imagery	Every 10 to 20 years (higher frequency practical for LGA)	

Table 29: CMAP Protocol Application for Ansteys Car Park to San Remo

Cell Identifier	R06C10.b (see Figure 22)	
Location	Ansteys Car Park to San Remo	
LGA	Rockingham	
Physical Vulnerability	Moderate, with history of transferred erosion	
Significant Historic Events	San Remo groyne built in 2005	
Infrastructure Presence	Car parks within 15m, Sabina Drive within 35m	
Existing Coastal Management	Occasional dune management	
Presence of Coastal Structures	San Remo groyne	
Active Coastal Processes	Active distribution of sediment by alongshore transport.	
Decision-making Time Frame	5 to 10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Palisades Blvd 2. Bight Reefs Rd 3. Madora Beach Rd
3) Beach Profiles	Twice yearly	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 to 10 years	
6) Condition Assessment	Every 5 years	

Table 30: CMAP Protocol Application for San Remo to Roberts Point

Cell Identifier	R06C10.a (see Figure 22)	
Location	San Remo to Roberts Point	
LGA	Mandurah	
Physical Vulnerability	High, with history of transferred erosion	
Significant Historic Events	Successive phases of groyne & seawall construction, with stresses in 1970s and intermittently from 1995 storms	
Infrastructure Presence	Ormsby Terrace within 15m, housing within 20 to 40m	
Existing Coastal Management	Annual sand bypassing, dune management, sea defences	
Presence of Coastal Structures	northern beaches groyne field, Seashells seawall, entrance seawall and training walls, Janis St groyne	
Active Coastal Processes	Structures limit meaning of beach widths. Dune fencing limits interpretation of vegetation lines	
Decision-making Time Frame	Annual	
Minimum Monitoring	Level 3	
1) Photographic Monitoring	Monthly or fortnightly	
2) Beach Widths* may be extracted from profiles	Annual or twice yearly	1. Acheron Rd 2. Cook St/Wade St 3. Stewart St
3) Beach Profiles	Twice yearly	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Annual	
6) Hydrographic Surveys	Annual (nearshore), 5 yearly (further offshore)	
7) Condition Assessment	Every 5 years	

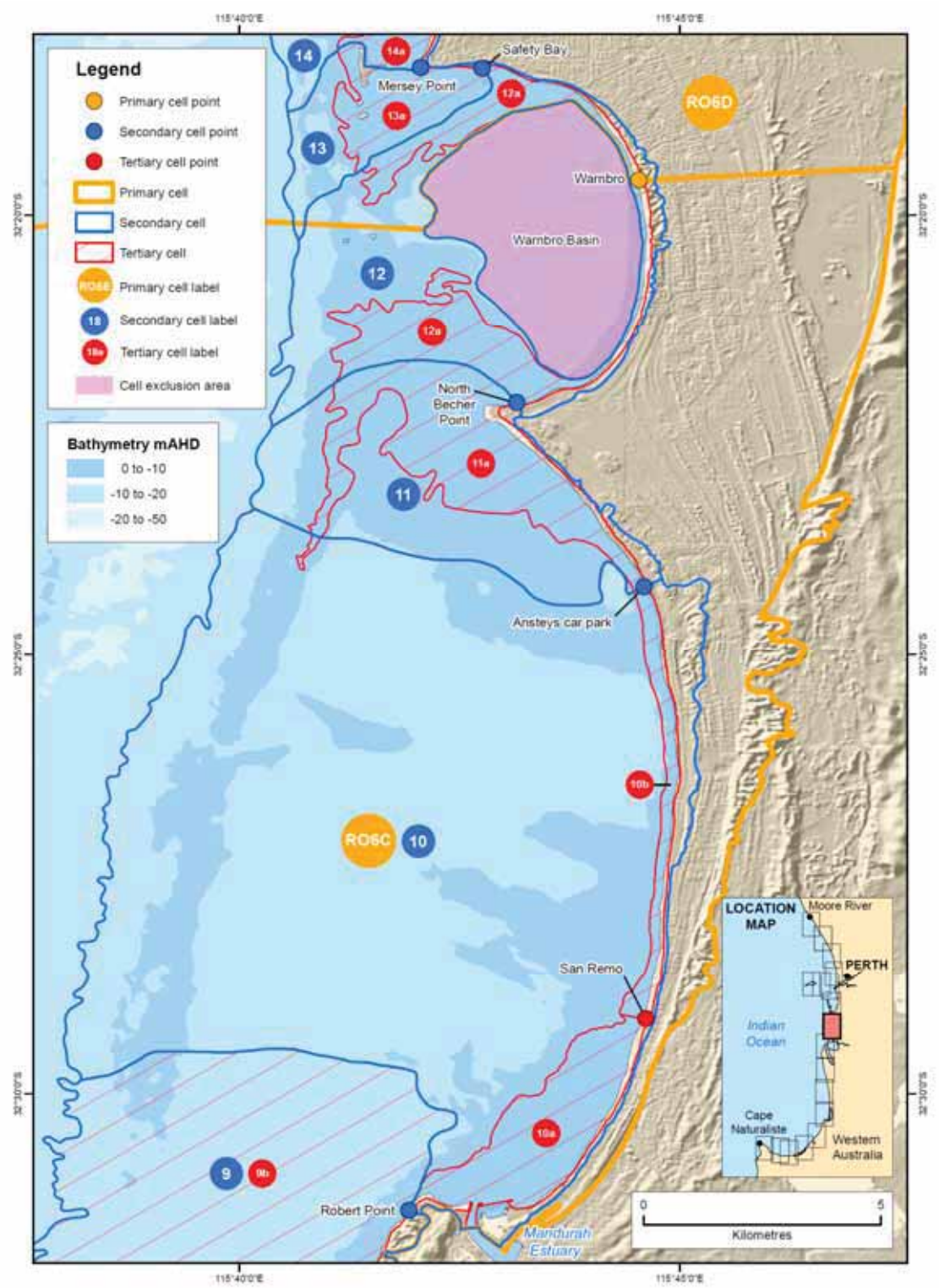

Figure 22: Mersey Point to Robert Point, Secondary Cells 10 to 13

Table 31: CMAP Protocol Application for Robert Point to Dawesville

Cell Identifier	R06C9.b (see Figure 23)	
Location	Robert Point to Dawesville	
LGA	Mandurah	
Physical Vulnerability	Limited due to rock features Locally high sensitivity to bypassing at Falcon & Avalon	
Significant Historic Events	Increased sensitivity following construction of Dawesville Channel, completed in 1994	
Infrastructure Presence	Hall Head Parade, Rakoa Street, Gretel Drive and Spinaway Parade within 25m	
Existing Coastal Management	Influenced by Dawesville annual sand bypassing	
Active Coastal Processes	Structural controls encourage vertical rather than horizontal beach change, limiting use of beach widths.	
Decision-making Time Frame	Annual	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths* may be extracted from profiles	Annual or twice yearly	1. Oversby St 2. Daydream Plaza 3. Philante St 4. Mercedes Ave 5. Cesia Lane
3) Beach Profiles	Limited to Falcon & Avalon every 5 years	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	
6) Hydrographic Surveys	Every 5 years	

Table 32: CMAP Protocol Application for Dawesville to Cape Bouvard

Cell Identifier	R06C9.a (see Figure 23)	
Location	Dawesville to Cape Bouvard	
LGA	Mandurah	
Physical Vulnerability	Moderate sensitivity to alongshore sand supply, partly limited by rock features	
Significant Historic Events	Increased sensitivity following construction of Dawesville Channel, completed in 1994 & subsequent sand bypassing	
Infrastructure Presence	Melros Beach Road within 15m, housing within 50m	
Existing Coastal Management	Dawesville annual sand bypassing	
Presence of Coastal Structures	Dawesville Channel Training Walls	
Active Coastal Processes	Capacity for cross-shore transfer of sand into reefs	
Decision-making Time Frame	5 to 10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Annual or twice yearly	
2) Beach Widths	Annual or twice yearly	1. Hunter St 2. Melros Beach Rd 3. Tims Thicket Rd
3) Beach profiles	Annual, adjacent to Dawesville Channel, for bypassing	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Annual, relevant to bypassing	
6) Hydrographic Surveys	Annual adjacent to Dawesville Channel, for bypassing Every 5 to 10 years	
7) Condition Assessment	Every 5 years	

Table 33: CMAP Protocol Application for Cape Bouvard to Lake Clifton North

Cell Identifier	R06B8.b (see Figure 24)	
Location	Cape Bouvard to Lake Clifton North	
LGA	Mandurah	
Physical Vulnerability	Low	
Infrastructure Presence	Negligible infrastructure, with setbacks exceeding 100m	
Active Coastal Processes	Capacity for cross-shore transfer of sand into reefs	
Decision-making Time Frame	20 years	
Minimum Monitoring	Level 0	
1) Photographic Monitoring	Annual	
2) Beach Widths	Annual or twice yearly	1. Track S of White Hills Rd 2. Central (TBA) 3. South (TBA)
3) Oblique Imagery	Every 5 to 10 years (higher frequency is practical for LGA)	
4) Vertical Imagery	Every 10 to 20 years (higher frequency practical for LGA)	

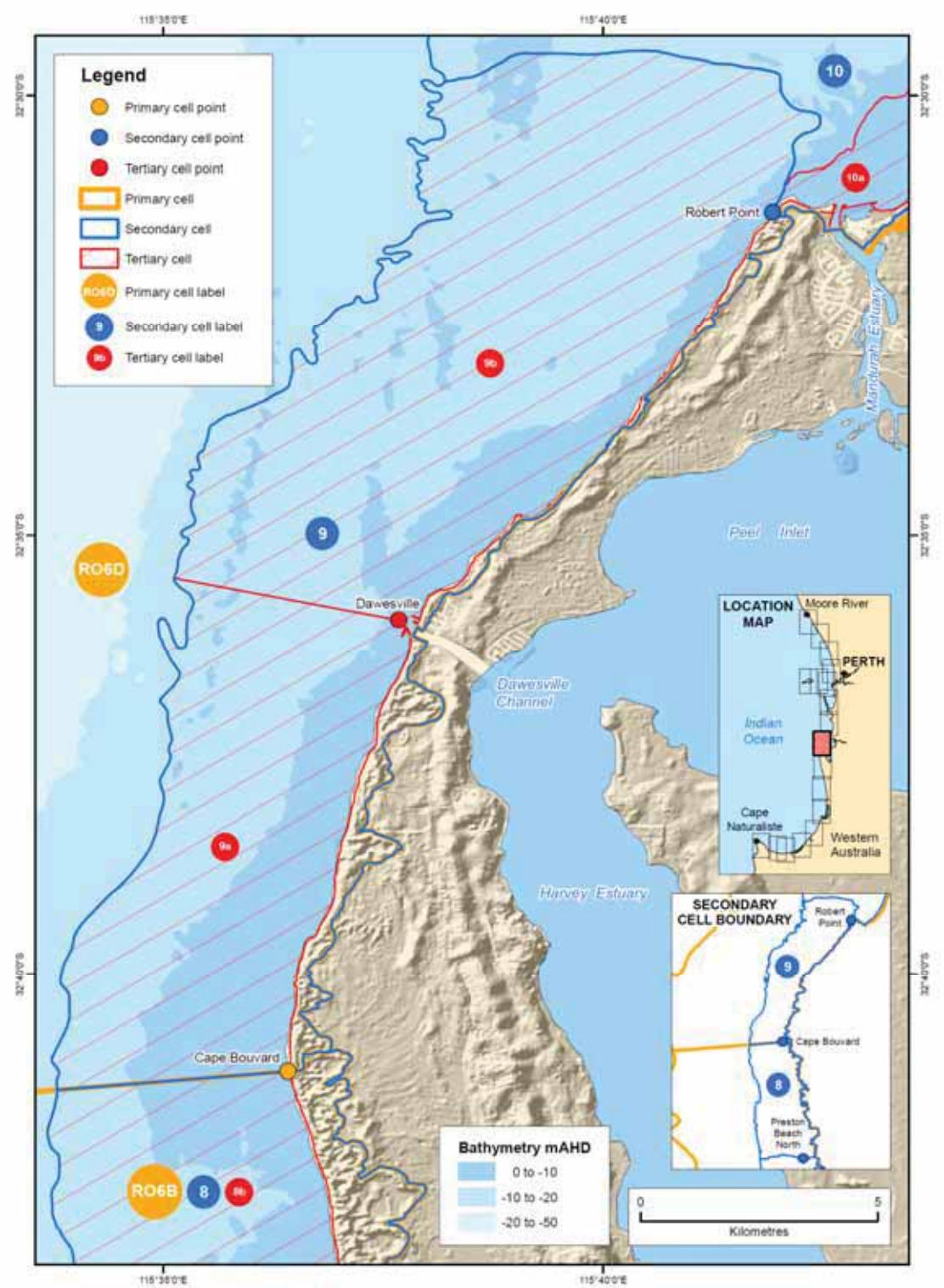

Figure 23: Robert Point to Cape Bouvard, Secondary Cell 9

Table 34: CMAP Protocol Application for Lake Clifton North to Preston Beach North

Cell Identifier	R06B8.a (see Figure 24)	
Location	Lake Clifton North to Preston Beach North	
LGA	Mandurah / Waroona	
Physical Vulnerability	Low	
Infrastructure Presence	Negligible infrastructure, with setbacks exceeding 100m	
Active Coastal Processes	Capacity for cross-shore transfer of sand into reefs	
Decision-making Time Frame	20 years	
Minimum Monitoring	Level 0	
1) Photographic Monitoring	Annual	
2) Beach Widths	Annual or twice yearly	1. W of Boundary Lake 2. W of Lake Clifton Airstrip 3. W of Lake Pollard
3) Oblique Imagery	Every 5 to 10 years (higher frequency is practical for LGA)	
4) Vertical Imagery	Every 10 to 20 years (higher frequency practical for LGA)	

Table 35: CMAP Protocol Application for Preston Beach North to Lake Preston South

Cell Identifier	R06B7.a (see Figure 24)	
Location	Preston Beach North to Lake Preston South	
LGA	Waroona	
Physical Vulnerability	Low, with high sensitivity to dune mobility	
Infrastructure Presence	Limited. Preston Beach car park within 80m, building setbacks exceed 200m	
Active Coastal Processes	Capacity for cross-shore transfer of sand into reefs Sand sheet movement within nearshore lagoon Mobile coastal dunes	
Decision-making Time Frame	20 years	
Minimum Monitoring	Level 0	
1) Photographic Monitoring	Annual	
2) Beach Widths	Annual or twice yearly	1. North (TBA) 2. Mitchell Rd 3. South (TBA)
3) Oblique Imagery	Every 5 to 10 years (higher frequency is practical for LGA)	
4) Vertical Imagery	Every 10 to 20 years (higher frequency practical for LGA)	
5) Dune monitoring	Annual	

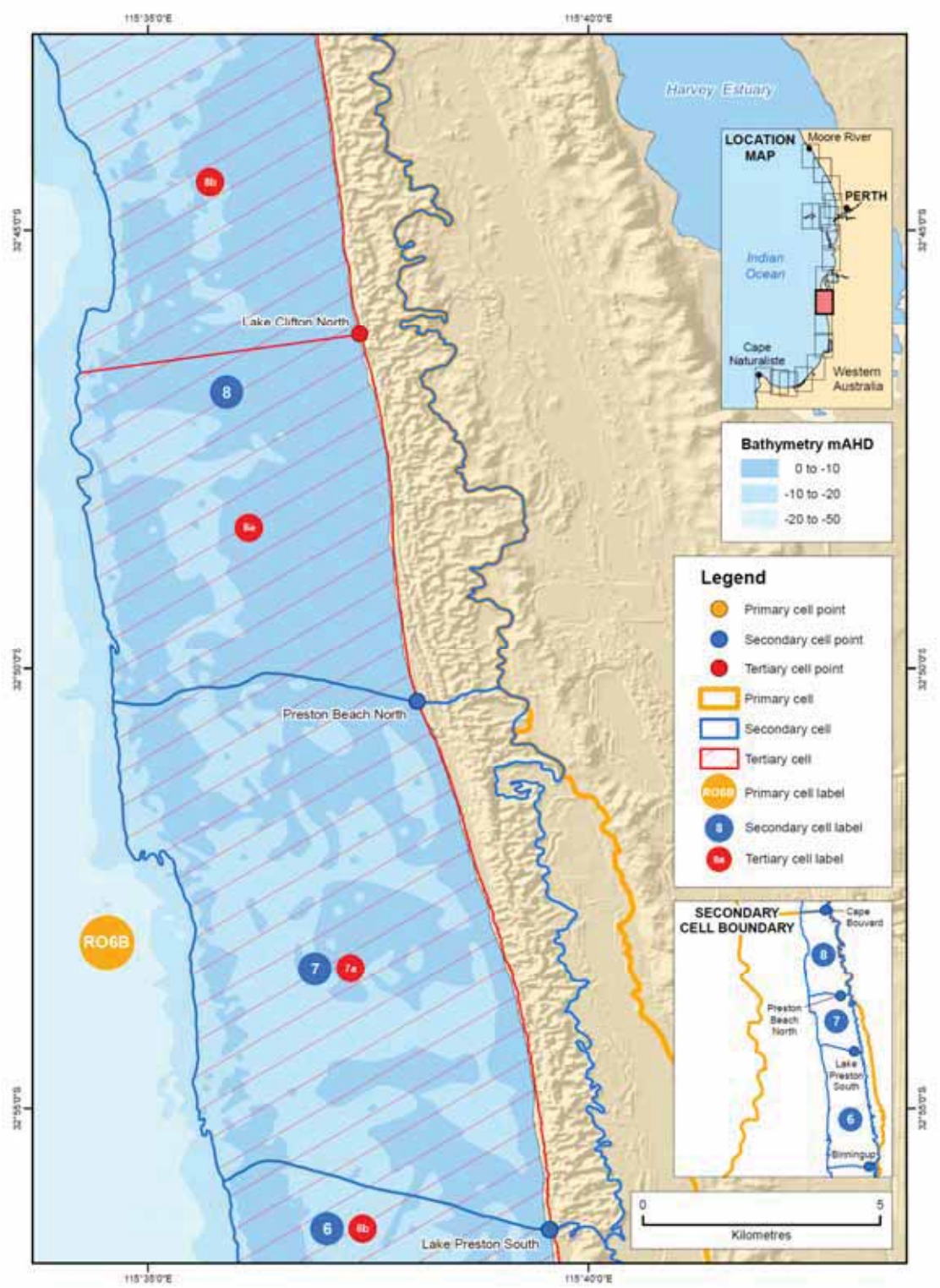

Figure 24: Cape Bouvard to Lake Preston South, Secondary Cells 7 and 8

Table 36: CMAP Protocol Application for Lake Preston South to Myalup North

Cell Identifier	R06B6.b (see Figure 25)	
Location	Lake Preston South to Myalup North	
LGA	Waroona / Harvey	
Physical Vulnerability	Moderate to high, with long-term and modern history both erosional. High sensitivity to dune mobility.	
Significant Historic Events	Transferred erosion in 1980s and 1990s following severe erosion to the south	
Infrastructure Presence	Negligible infrastructure, with setbacks exceeding 100m	
Active Coastal Processes	Mobile coastal dunes	
Decision-making Time Frame	5 to 10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly, for indicator sites	
2) Beach Widths	Annual or twice yearly	1. North (TBA) 2. Central (TBA) 3. South (TBA)
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	
5) Dune monitoring	Annual	

Table 37: CMAP Protocol Application for Preston Beach North to Lake Preston South

Cell Identifier	R06B6.a (see Figure 25)	
Location	Myalup North to Binningup	
LGA	Harvey	
Physical Vulnerability	High, with long-term erosional structure and modern history of acute erosion. High sensitivity to dune mobility.	
Significant Historic Events	Rapid erosion between 1955 and 1972 Dune destabilisation following industrial waste disposal	
Infrastructure Presence	Binningup beach ramp, Harvey Diversion, Indian Ocean Drive within 55m, Southern Seawater Alliance desalination plant pipeline leads to inshore risers	
Presence of Coastal Structures	Binningup beach ramp	
Active Coastal Processes	Mobile coastal dunes	
Decision-making Time Frame	5 to 10 years, with Annual at Binningup beach ramp	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly, for indicator sites	
2) Beach Widths	Annual or twice yearly	1. W of 'causeway' 2. Myalup 3. West Coast Drive
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	
5) Dune monitoring	Annual	
Local Monitoring	Binningup beach ramp	
6) Beach profiles / crest line	Annual (Sep-Oct)	

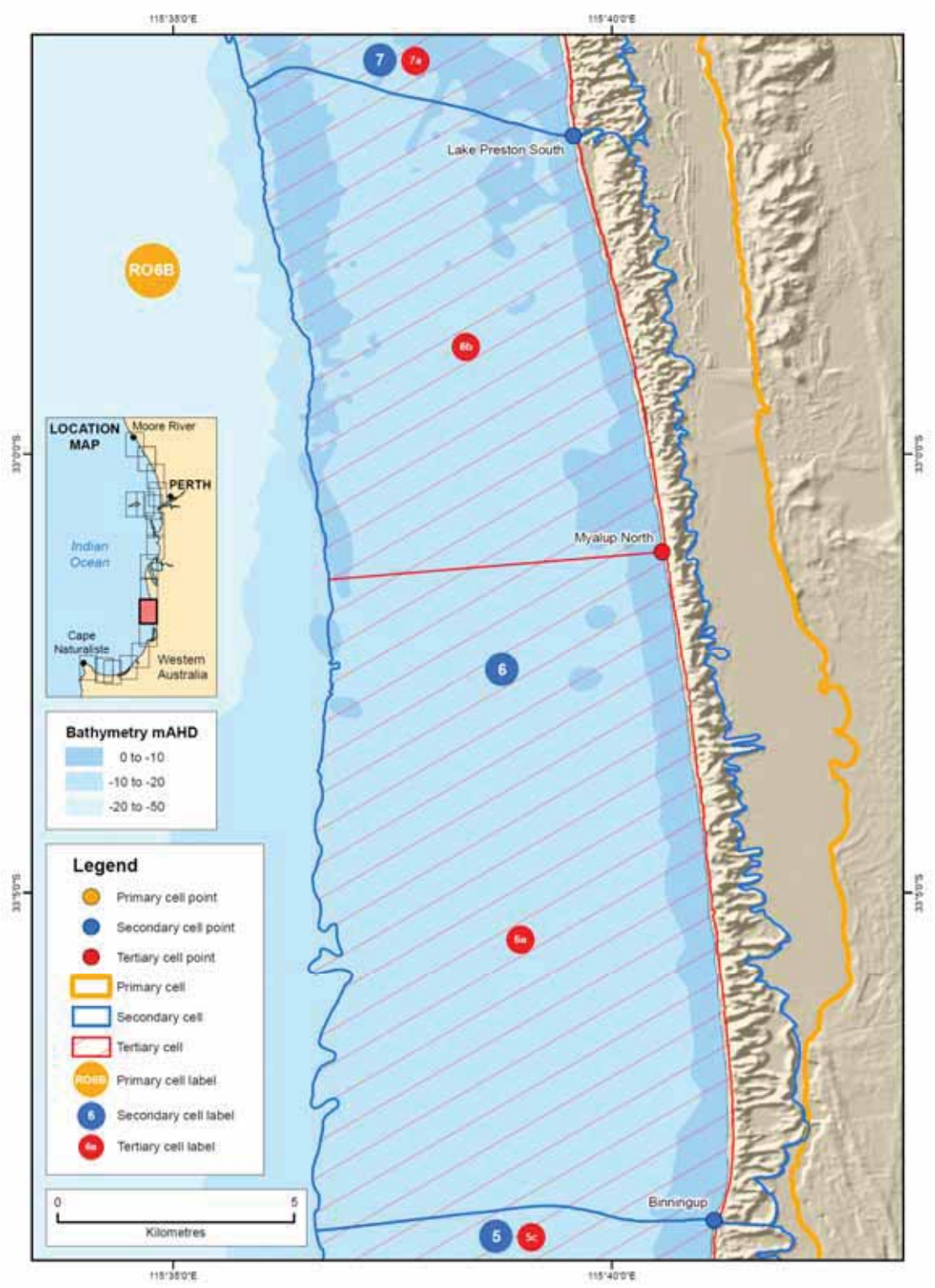

Figure 25: Lake Preston South to Binningup, Secondary Cell 6

Table 38: CMAP Protocol Application for Binningup to Buffalo Road

Cell Identifier	R06B5.c (see Figure 26)	
Location	Binningup to Buffalo Road	
LGA	Harvey	
Physical Vulnerability	Moderate, long-term erosion locally offset by rock platform. High sensitivity to dune mobility.	
	Dune destabilisation following industrial waste disposal	
Infrastructure Presence	Negligible infrastructure, with setbacks exceeding 100m	
Active Coastal Processes	Mobile coastal dunes	
Decision-making Time Frame	5 to 10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly, for indicator sites	
2) Beach Widths	Annual or twice yearly	1. Valentine Rd 2. Central, N of blowouts 3. Buffalo Rd, S of blowouts
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	
5) Dune monitoring	Annual	

Table 39: CMAP Protocol Application for Buffalo Road to Leschenault South

Cell Identifier	R06B5.b (see Figure 26)	
Location	Buffalo Road to Leschenault South	
LGA	Harvey	
Physical Vulnerability	Moderate, long-term erosion. High sensitivity to dune mobility.	
Significant Historic Events	Dune destabilisation following industrial waste disposal	
Infrastructure Presence	Negligible infrastructure, car park within 50m	
Active Coastal Processes	Mobile coastal dunes	
Decision-making Time Frame	5 to 10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly, for indicator sites	
2) Beach Widths	Annual or twice yearly	1. S of Buffalo Rd access 2. Access track 3. South (TBA)
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	
5) Dune monitoring	Annual	

Table 40: CMAP Protocol Application for Leschenault South to Bunbury Harbour

Cell Identifier	R06B5.b (see Figure 26)	
Location	Leschenault South to Bunbury Harbour	
LGA	Harvey / Bunbury	
Physical Vulnerability	(N) Moderate, long-term erosion. High sensitivity to dune mobility. (S) Moderate, foreshore slowly adjusting to various works	
Significant Historic Events	Harbour works from 1920s, Flooding of Preston River 1970s, Relocation of Preston River, including excavation of The Cut, Bunbury flood mitigation works, Dune destabilisation following industrial waste disposal	
Infrastructure Presence	Port infrastructure, Dolphin Discovery Centre, Koombana Beach facilities, Koombana Sailing Club & Marlston waterfront all have minimum setback	
Existing Coastal Management	Coastal stabilisation, with occasional renourishment on Koombana Beach	
Presence of Coastal Structures	The Cut training walls, Power Station groyne, Bunbury Inner Harbour, Point Busaco seawall, Koombana groyne, Leschenault Inlet entrance, Marlston waterfront, Bunbury Outer Harbour, including main port breakwater	
Active Coastal Processes	Local dynamics due to Leschenault Estuary entrance. Mobile coastal dunes (N)	
Decision-making Time Frame	2 to 5 years	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. The Cut N 2. The Cut S 3. Power House E 4. Power House W 5. Koombana E 6. Koombana W
3) Beach Profiles	Every 5 years (Koombana Beach)	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	
6) Dune monitoring	Annual (N of the Cut)	
7) Hydrographic Surveys	Every 5 to 10 years (Koombana Beach)	
8) Condition Assessments	Every 5 years	

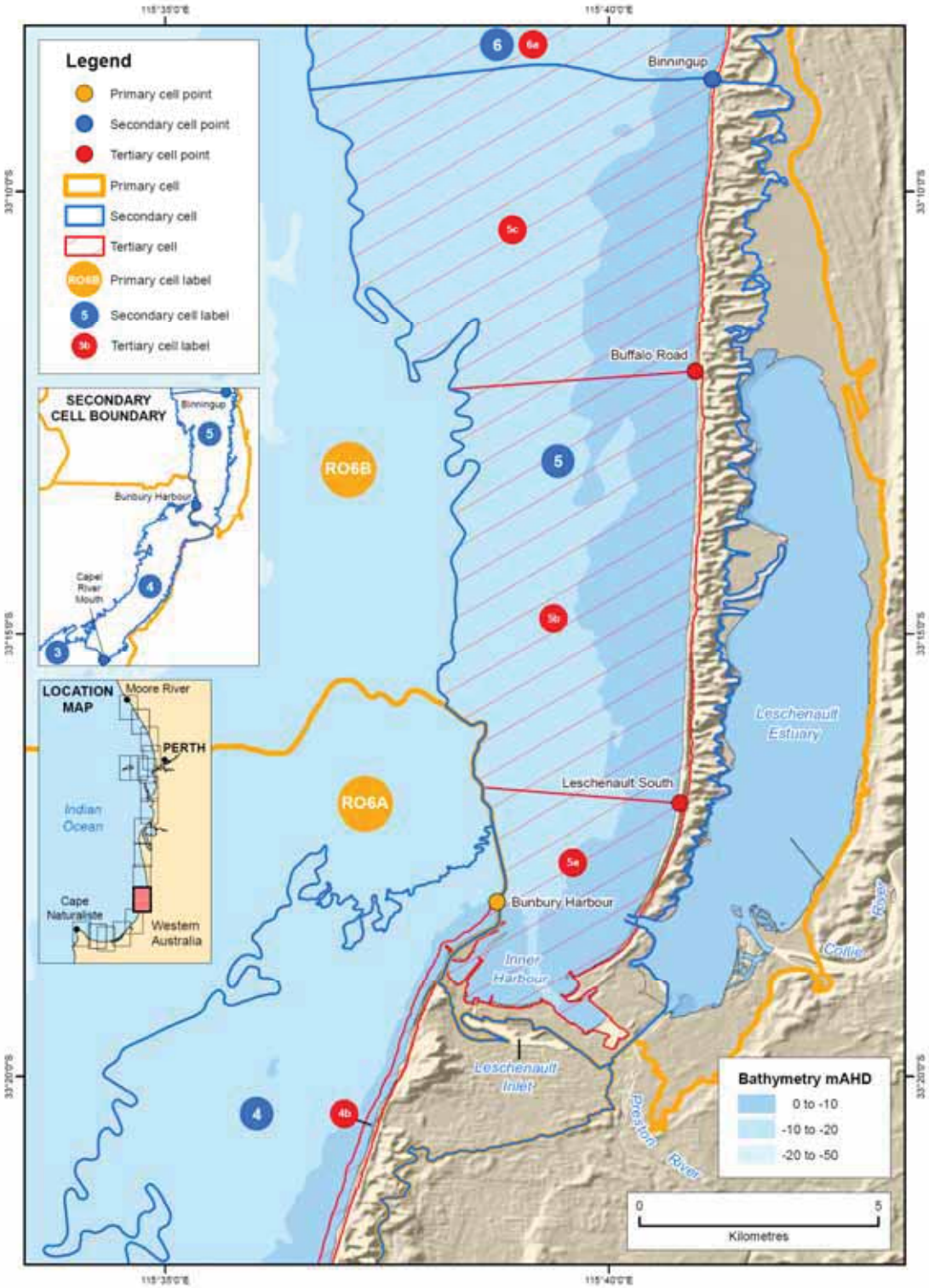

Figure 26: Binningup to Bunbury, Secondary Cells 4 and 5

Table 41: CMAP Protocol Application for Bunbury Harbour to Stirling Beach

Cell Identifier	R06A4.b (see Figure 27)	
Location	Bunbury Harbour to Stirling Beach	
LGA	Bunbury / Capel	
Physical Vulnerability	Moderate, with sensitivity to storm events but extensive presence of rock features. High sensitivity to dune mobility S of Bunbury.	
Significant Historic Events	Repeated phases of acute erosion	
Infrastructure Presence	Ocean Drive within 10m, larger setback for Dalyellup, flood diversion drain outlet	
Presence of Coastal Structures	Surf Club flexmat seawall	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. Dune mobility.	
Decision-making Time Frame	Annual * (highly episodic)	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Beach Rd 2. Norton Promenade 3. Hutt Dr
3) Beach Profiles	Following severe erosion events (Back Beach)	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	
6) Dune monitoring	Annual (S of Bunbury)	
7) Condition Assessments	Every 5 years, if seawall is exposed	

Table 42: CMAP Protocol Application for Stirling Beach to Capel River Mouth

Cell Identifier	R06A4.a (see Figure 27)	
Location	Stirling Beach to Capel River Mouth	
LGA	Capel	
Physical Vulnerability	Low, with historic slow accretion. Moderate sensitivity to dune mobility, with risk of breaching to lowlands	
Infrastructure Presence	Limited infrastructure, carpark, buildings within 60m	
Existing Coastal Management	Dune stabilisation	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. Dune processes active adjacent to lowlands.	
Decision-making Time Frame	5 to 10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly (indicator points)	
2) Beach Widths	Annual or twice yearly	1. North (TBA) 2. South (TBA)
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 years	
5) Dune monitoring	Annual	
6) Flood Mapping	Following extreme flood events	

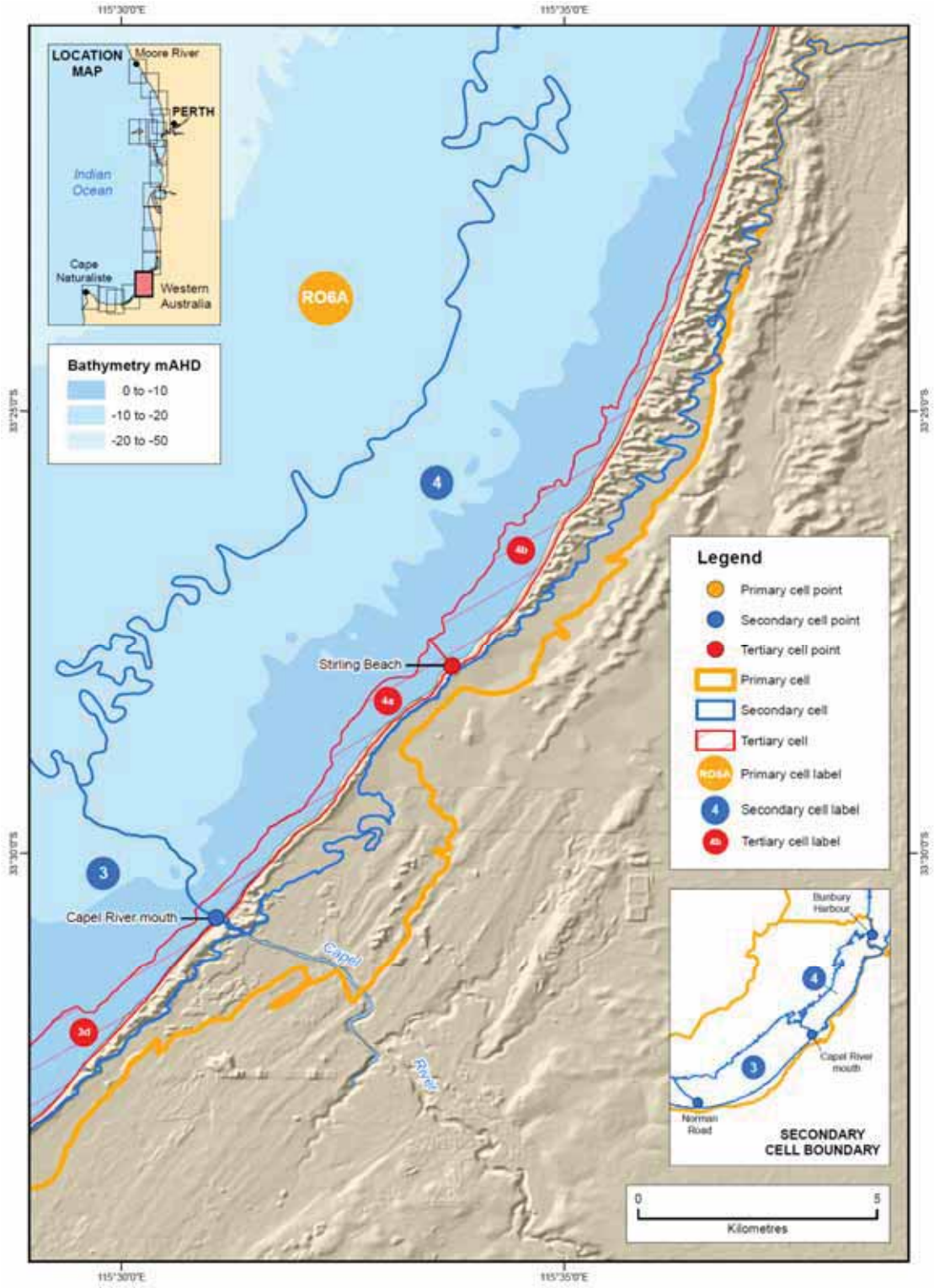

Figure 27: Bunbury to Capel River, Secondary Cell 4

Table 43: CMAP Protocol Application for Capel River Mouth to Forrest Beach

Cell Identifier	R06A3.d (see Figure 28)	
Location	Capel River Mouth to Forrest Beach	
LGA	Capel	
Physical Vulnerability	Low, with historic stability. Minor risk of dune breaching to lowlands. Presence of rock 'pavement' offshore.	
Infrastructure Presence	McCourt Place within 20m, buildings within 40m, Coast Road within 20m	
Decision-making Time Frame	10 to 20 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly (indicator points)	
2) Beach Widths	Annual or twice yearly	1. View Ct 2. Hardey Tce 3. Forrest Beach Rd
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 10 years	

Table 44: CMAP Protocol Application for Forrest Beach to Wonnerup

Cell Identifier	R06A3.c (see Figure 28)	
Location	Forrest Beach to Wonnerup	
LGA	Busselton	
Physical Vulnerability	Moderate - historic general accretion affected by management of Busselton coast and Port Geographe Flood risk into Wonnerup lowlands	
Significant Historic Events	Busselton stabilisation works, including Guerin St groyne, Port Geographe construction, Vasse-Wonnerup flooding	
Infrastructure Presence	Layman Road within 25m, 'Marine Terrace' within 45m	
Existing Coastal Management	Sand bypassing at Port Geographe	
Presence of Coastal Structures	Port Geographe & Wonnerup groyne field	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. Some sensitivity to sand bar movement.	
Decision-making Time Frame	5 years	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Lot 115 Coast Rd 2. Layman Rd (N) 3. 623 Layman Rd
3) Beach profiles	Every 5 years (Wonnerup groyne field influence)	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	
6) Hydrographic Survey	Every 5 years (Wonnerup groyne field influence and sand bar movement)	
7) Condition Assessment	Every 5 years	
8) Flood Mapping	Following extreme flood events	

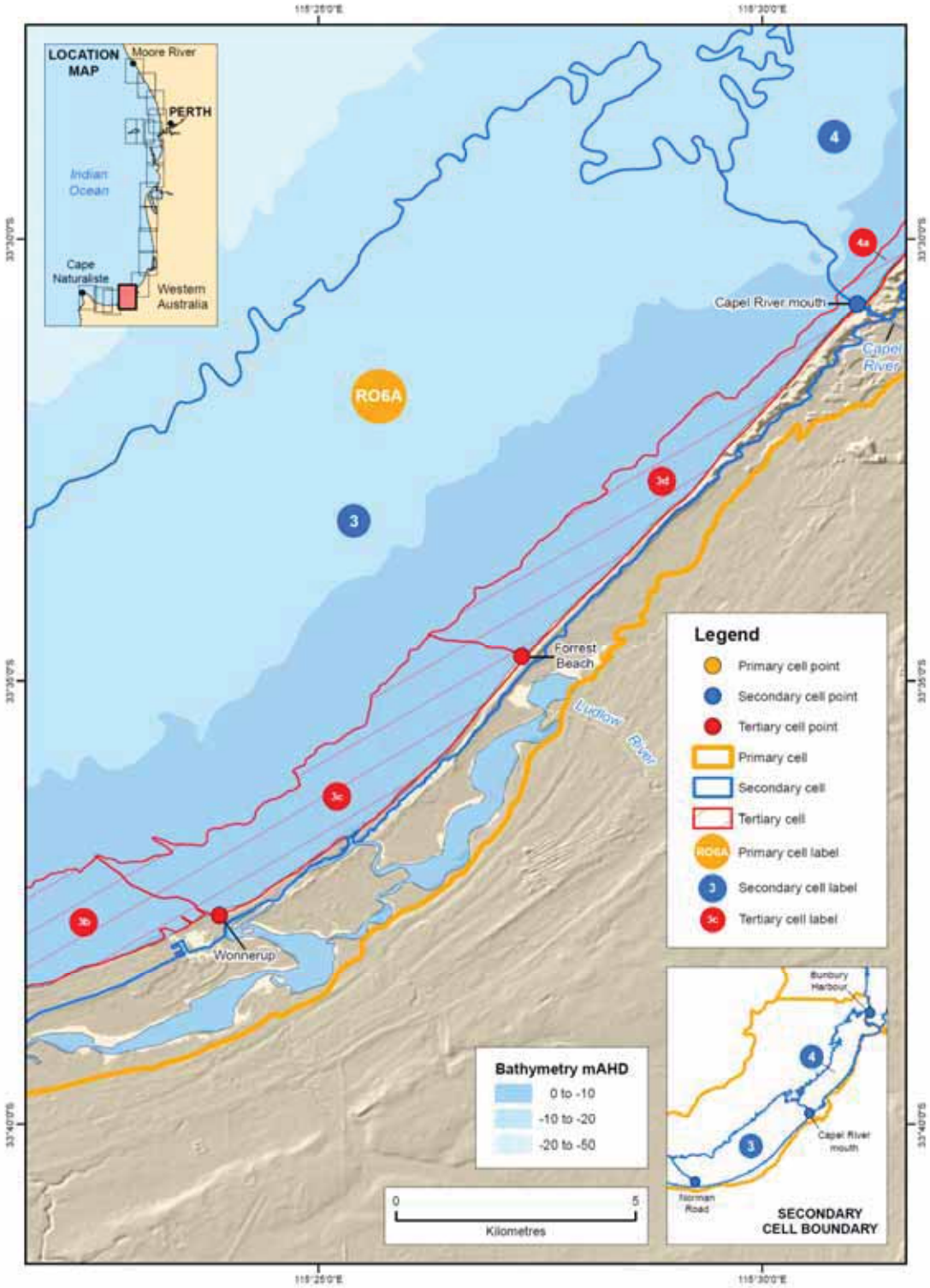

Figure 28: Capel River to Wonnerup, Secondary Cell 3 (East)

Table 45: CMAP Protocol Application for Wonnerup to Busselton

Cell Identifier	R06A3.b (see Figure 29)	
Location	Wonnerup to Busselton	
LGA	Busselton	
Physical Vulnerability	Moderate – historic general accretion, but sensitive to acute storm events. Low level areas subject to flooding.	
Significant Historic Events	TC Alby 1978.	
Infrastructure Presence	Georgette St Sea Rescue, Geographe Bay Rd within 15m, buildings within 50m	
Existing Coastal Management	Coastal works to distribute sand supply from west	
Presence of Coastal Structures	Busselton groyne field, Port Geographe	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. Local sensitivity to sand bar movement.	
Decision-making Time Frame	10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Groyne Rd 2. Herring St 3. Ford Rd
3) Beach profiles	Every 5 years (Busselton groyne field influence)	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	
6) Hydrographic Survey	Every 10 years (sand bar movement)	
7) Condition Assessment	Every 5 years	
8) Flood Mapping	Following extreme flood events	

Table 46: CMAP Protocol Application for Busselton to Norman Road

Cell Identifier	R06A3.a (see Figure 29)	
Location	Busselton to Norman Road	
LGA	Busselton	
Physical Vulnerability	Moderate – historic general accretion, but sensitive to acute storm events. Low level areas subject to flooding.	
Significant Historic Events	TC Alby 1978	
Infrastructure Presence	Car parks within 10m, Geographe Bay Rd within 10m, buildings within 25m	
Existing Coastal Management	Coastal works to distribute sand supply from west. Sea defence along Busselton foreshore	
Presence of Coastal Structures	Busselton: groyne field, jetty, seawalls; Beachlands geotube, Diversion drain training wall; Gunn St groyne, Norman Rd groyne	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. Local sensitivity to sand bar movement.	
Decision-making Time Frame	5 years	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. High St 2. Mill Rd 3. Mandalay
3) Beach profiles	Annual (indicator profiles)	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	
6) Hydrographic Survey	Every 10 years (sand bar movement)	
7) Condition Assessment	Every 5 years	
8) Flood Mapping	Following extreme flood events	

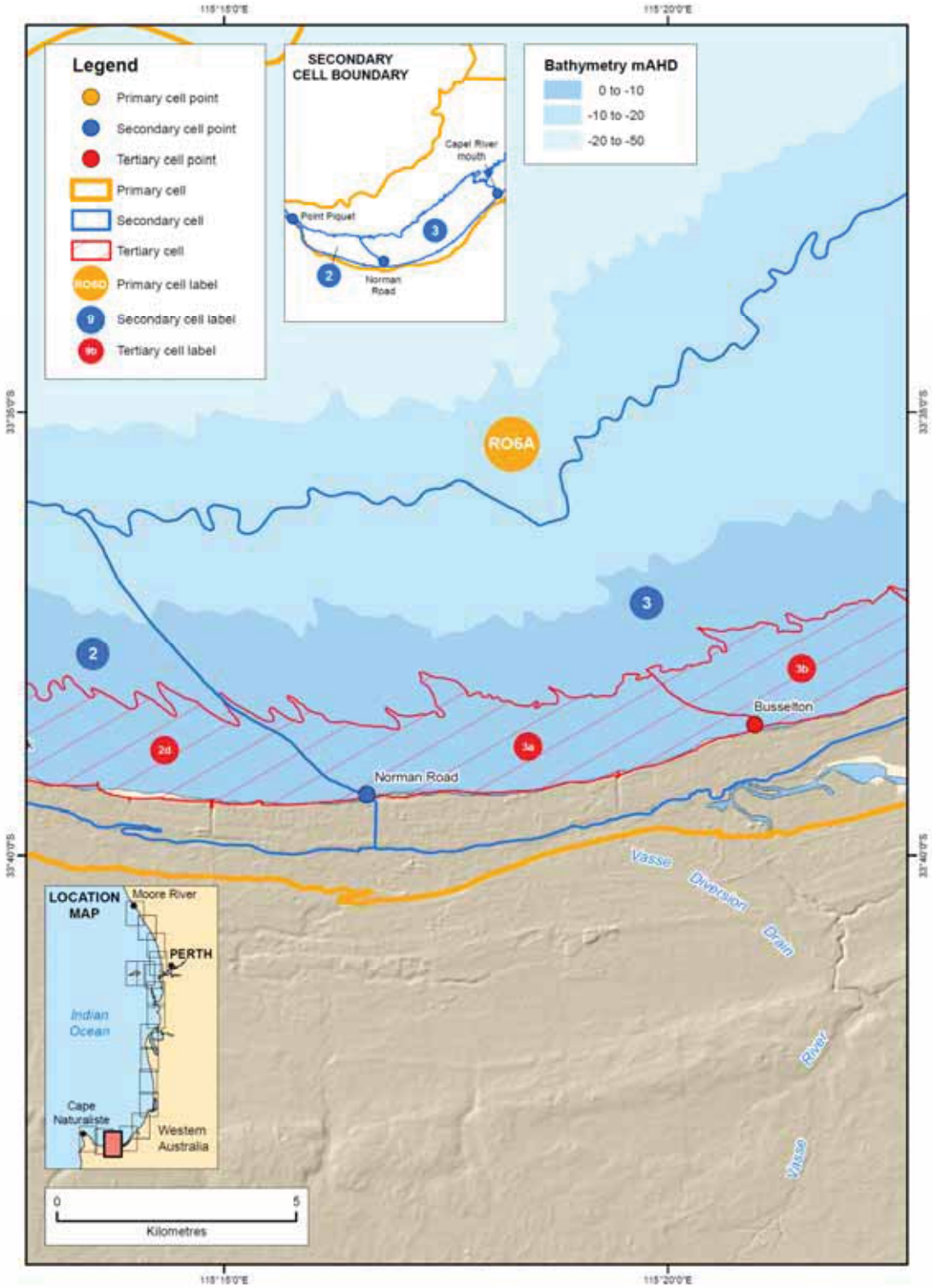

Figure 29: Wonnerup to Siesta Park, Secondary Cell 3 (West)

Table 47: CMAP Protocol Application for Norman Road to Marybrook

Cell Identifier	R06A2.d (see Figure 30)	
Location	Norman Road to Marybrook	
LGA	Busselton	
Physical Vulnerability	Moderate – historic general accretion, but sensitive to acute storm events. Low level areas subject to flooding.	
Significant Historic Events	TC Alby 1978; Coastal change following drainage works	
Infrastructure Presence	Residential buildings adjacent to beach, Geographe Bay Rd within 20m	
Existing Coastal Management	Coastal works to distribute sand supply from west & offshore.	
Presence of Coastal Structures	Multiple small groynes, Abbey Boat Ramp, Siesta Park groyne, diversion drain training walls	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. Local sensitivity to sand bar movement.	
Decision-making Time Frame	5 years (annual for isolated sites)	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. E Harvest Rd 2. W of Fourth St 3. Smith St
3) Beach profiles	Annual (indicator profiles)	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	
6) Hydrographic Survey	Every 10 years (sand bar movement)	
7) Condition Assessment	Every 5 years	
8) Flood Mapping	Following extreme flood events	

Table 48: CMAP Protocol Application for Marybrook to Point Templar

Cell Identifier	R06A2.c (see Figure 30)	
Location	Marybrook to Point Templar	
LGA	Busselton	
Physical Vulnerability	Moderate – historic general accretion, but sensitive to acute storm events. Low level areas subject to flooding. Toby Inlet breaching risk.	
Significant Historic Events	Coastal change following drainage works	
Infrastructure Presence	Boat ramp, Geographe Bay Rd within 50m	
Existing Coastal Management	Coastal works to distribute sand supply from west & offshore.	
Presence of Coastal Structures	Diversion drain training walls, minor coastal structures	
Active Coastal Processes	Active distribution of stress through alongshore sediment transport. High sensitivity to sand bar movement.	
Decision-making Time Frame	10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Vernon Track 2. Toby Inlet Bridge 3. Lagoona Pl
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	
5) Hydrographic Survey	Every 10 years (sand bar movement)	
6) Condition Assessment	Every 5 years	
7) Flood Mapping	Following extreme flood events	

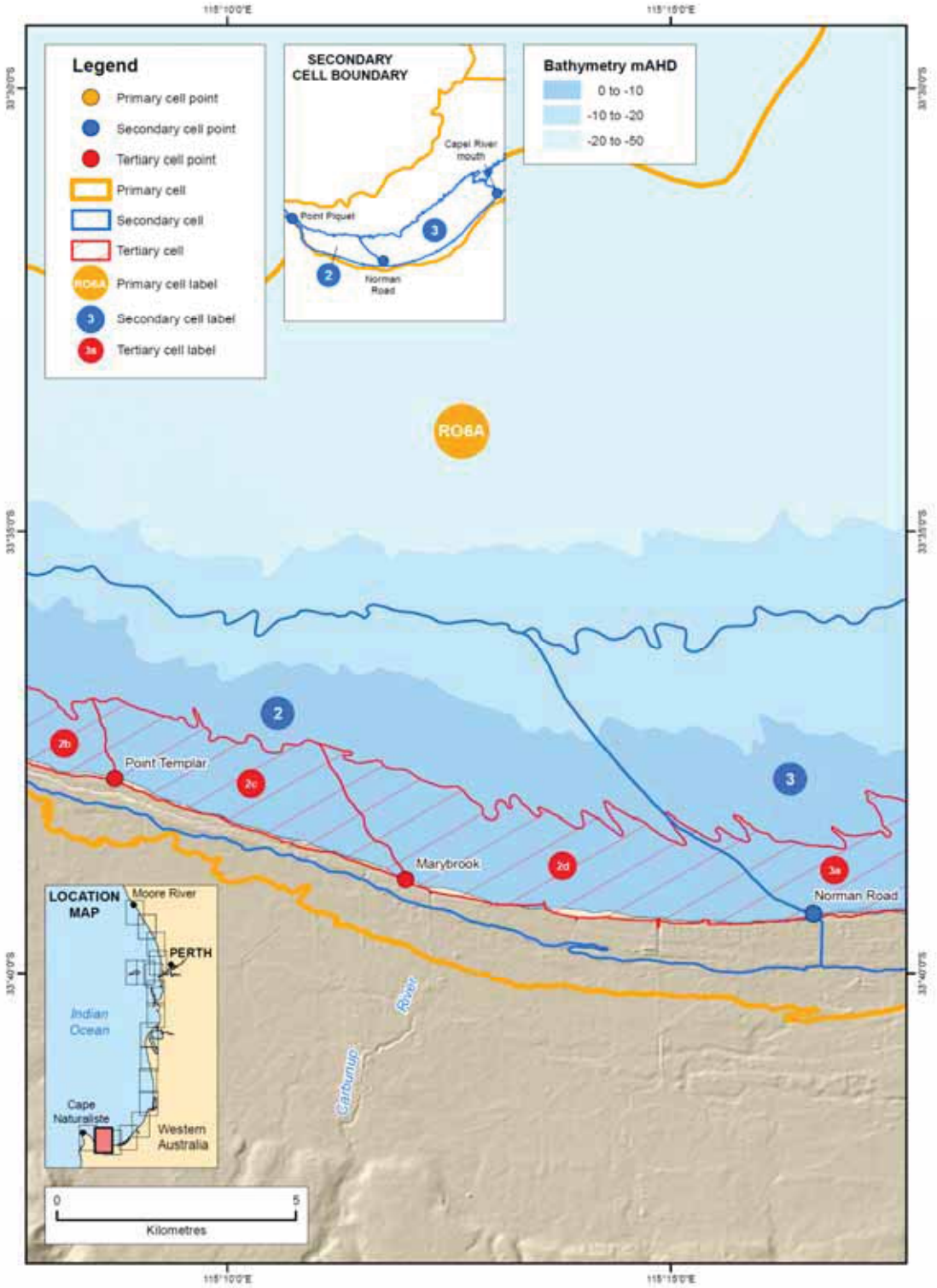

Figure 30: Norman Road to Point Templar, Secondary Cell 2 (East)

Table 49: CMAP Protocol Application for Point Templar to Point Daking

Cell Identifier	R06A2.b (see Figure 31)	
Location	Point Templar to Point Daking	
LGA	Busselton	
Physical Vulnerability	Low, with history of accretion, although local erosion following bar movement and previous acute erosion. Lagoon breaching risk.	
Significant Historic Events	Embayment infilling	
Infrastructure Presence	Bay View Cres within 10m, Vincent Rd within 20m, Geographe Bay Rd within 35m, buildings within 35m	
Presence of Coastal Structures	Quindalup seawall (buried), minor coastal structures	
Active Coastal Processes	Local sensitivity to sand bar movement.	
Decision-making Time Frame	10 years	
Minimum Monitoring	Level 1	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Wilson Ave 2. Tulloh St 3. Chester Way
3) Oblique Imagery	Annual or twice yearly	
4) Vertical Imagery	Every 5 to 10 years	
5) Hydrographic Survey	Every 10 years (Dunn Bay Bar movement)	
6) Condition Assessment	Every 5 years	
7) Flood Mapping	Following extreme flood events	

Table 50: CMAP Protocol Application for Point Daking to Point Piquet

Cell Identifier	R06A2.a (see Figure 31)
Location	Point Daking to Point Piquet
LGA	Busselton
Physical Vulnerability	Low, as mostly rocky shore
Infrastructure Presence	Boat ramp, Bay View Cres & Hurford St adjacent to beach, Buildings within 10m
Active Coastal Processes	Rocky shore limits coastal mobility
Decision-making Time Frame	5 years
Minimum Monitoring	Level 2
1) Photographic Monitoring	Monthly
2) Oblique Imagery	Annual or twice yearly
3) Vertical Imagery	Every 5 years

Table 51: CMAP Protocol Application for Point Piquet to Cape Naturaliste

Cell Identifier	R06A1.a (see Figure 31)	
Location	Point Piquet to Cape Naturaliste	
LGA	Busselton	
Physical Vulnerability	Low – headland controlled pocket beaches	
Infrastructure Presence	Meelup Rd within 15m, Meelup car park within 20m, buildings within 20m (Bunker Bay), buildings within 30m (Eagle Bay)	
Active Coastal Processes	Rocky shore limits coastal mobility. Cross-shore dune erosion and subsequent recovery observed.	
Decision-making Time Frame	5 years	
Minimum Monitoring	Level 2	
1) Photographic Monitoring	Monthly	
2) Beach Widths	Annual or twice yearly	1. Eagle Bay E 2. Eagle Bay W 3. Bunker Bay E 4. Bunker Bay W
3) Beach profiles	Annual (indicator profiles)	
4) Oblique Imagery	Annual or twice yearly	
5) Vertical Imagery	Every 5 years	

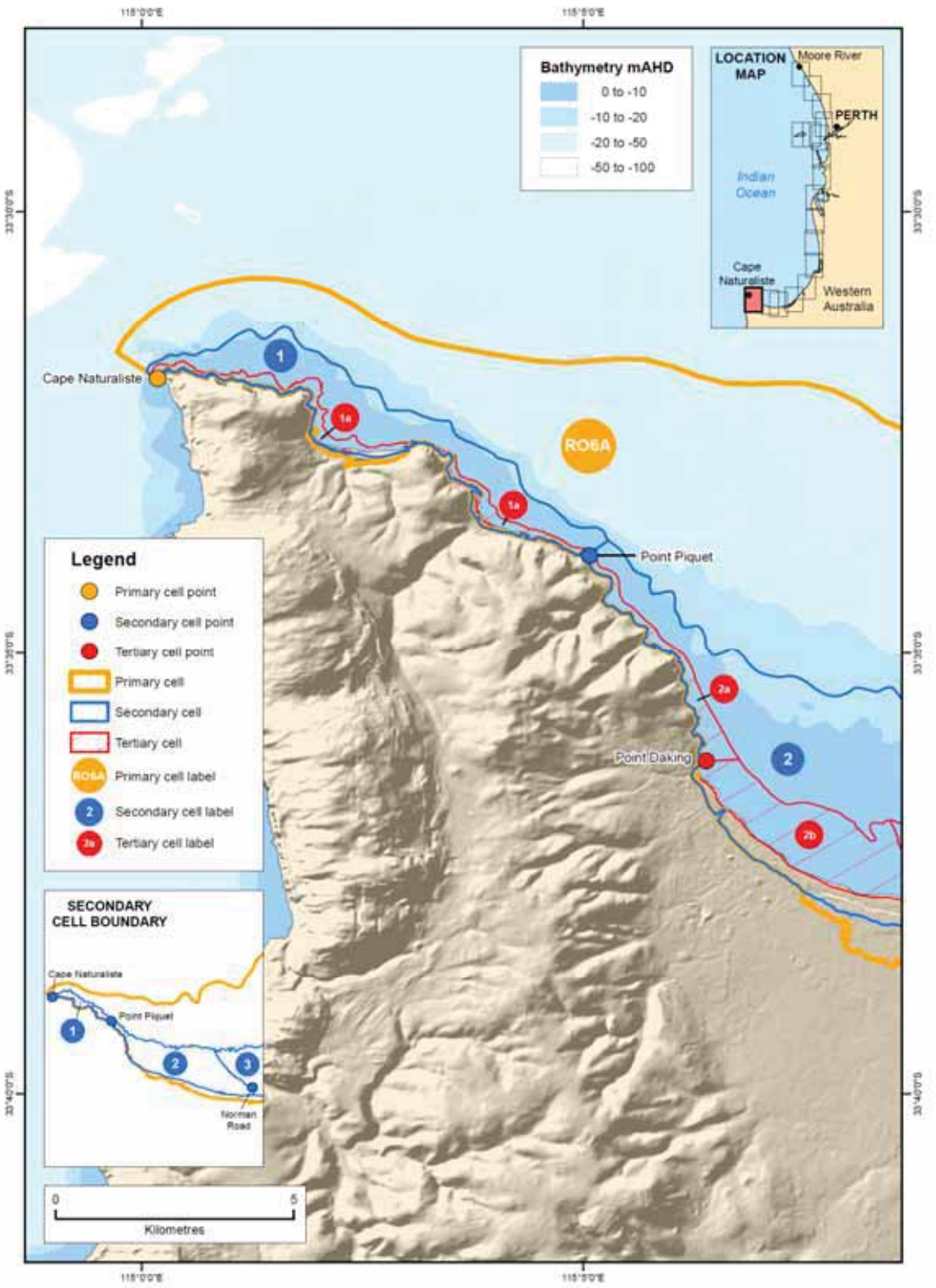

Figure 31: Point Templar to Cape Naturaliste, Secondary Cells 1 and 2

Table 52: Summary of Recommended Coastal Monitoring

LGA	Tertiary Sediment Cell	Time Frame	Monitoring Level	Photo Monitoring	Beach Width	Beach Profiles	Spatial Coverage	Oblique Aerials	Vertical Aerials	Remote Sensing	Hydro survey	Dune Mobility	Structure Condition	Flood Mapping
Rockingham	R06D14.c	5	1	M	✓			A	5					
	R06D14.b	5	1	M	✓			A	5					
	R06D14.a	20	0	A	✓			5	10					
	R06D13.a	5	2	M				A	5		10		✓	✓
	R06C12.a	5	2	M	✓			A	5					
	R06C11.a	10	0	A	✓			5	10					
	R06C10.b	5	1	M	✓	2A		A	5					
Mandurah	R06C10.a	1	3	M	✓	2A		A	5		A		✓	
	R06C9.b	1	2	M	✓	(5)		A	5		5		✓	
	R06C9.a	5	1	M	✓	A		5	10		5			
	R06B8.b	20	0	A	✓			5	10					
Waroona	R06B8.a	20	0	A	✓			5	10					
	R06B7.a	20	0	A	✓			A	5			✓		
Harvey	R06B6.b	5	1	M	✓			A	5			✓		
	R06B6.a	5	1	M	✓	(A)		A	5			✓		
	R06B5.c	5	1	M	✓			A	5			✓		
	R06B5.b	5	1	M	✓			A	5			✓		
Bunbury	R06B5.a	2	2	M	✓	(5)		A	5		10	✓	✓	
	R06A4.b	1	2	M	✓	✓		A	5			✓	✓	
Capel	R06A4.a	5	1	M	✓			A	5			✓		✓
Busselton	R06A3.d	10	1	M	✓			A	5					
	R06A3.c	5	2	M	✓	(5)		A	5		5		✓	✓
	R06A3.b	10	1	M	✓	(5)		A	5		(10)		✓	✓
	R06A3.a	5	2	M	✓	A		A	5		(10)		✓	✓
	R06A2.d	5	2	M	✓	A		A	5		(10)		✓	✓
	R06A2.c	10	1	M	✓			A	5		(10)		✓	✓
	R06A2.b	10	1	M	✓			A	5		10			✓
	R06A2.a	5	2	M				A	5					
	R06A1.a	5	2	M	✓	A		A	5					

M	Monthly monitoring	N	Approximate number of years between surveys (5, 10 or 20)
A	Annual monitoring	(N)	Brackets indicate monitoring covers a limited part of the cell
2A	Twice yearly monitoring	✓	Monitoring undertaken on either annually or event basis

Application of the coastal monitoring protocol to the PNP coast suggests several spatial patterns, which relate either to local morphology or the intensity of existing coastal development. The risk-based protocol generally supports the comparative levels of existing coastal monitoring undertaken by the various LGAs (i.e. higher for Mandurah and Busselton). Typical monitoring activities at each level have been drawn from the existing monitoring programs [58,59] and therefore are very similar to activities presently undertaken at Mandurah and Busselton.

4.3. ESTUARINE MONITORING

Estuaries are the basins in which interactions and transitions between marine and fluvial processes occur, and therefore commonly exhibit foreshore behaviour related to both. However, estuary foreshores may also display behaviour that is more like that of a lake or wetland, particularly for estuaries with a largely enclosed basin, such as those along the Peron-Naturaliste coast [103].

Erosion and inundation are the main hazards requiring foreshore management in the context of the CHRMAP framework. However, their expression differs from that occurring on the ocean coast, including:

- Low wave energy in estuaries provides greater opportunity for other processes to be dominant, including currents, boat wakes, runoff flooding and interactions with riparian or benthic vegetation;
- Local differences of currents, wave conditions and set-up may result in significant variation between parts of the estuary, even in close proximity, which may cause small-scale compartmentalisation [104];
- There are significant interactions between the estuary bed, banks and riparian zones, with extended cross-shore features (e.g. spits, sub-tidal terraces) and wide fringing wetlands that may act to locally modulate currents or wave-energy;
- Extensive interaction of bed vegetation and sediments increases the role of water quality, with potentially large changes in seabed mobility depending on the change of bed coverage [105].

The appropriate monitoring focus within an estuary varies according to geomorphic sub-units and their associated key processes (Table 53).

Table 53: Monitoring Focus According to Estuarine Sub-unit Morphology

Geomorphic Sub-units		Key Processes	Monitoring Focus			
			Depth	Surface	Inundation	Vegetation
Entrance	Delta	tidal currents, ocean waves	✓	–	–	–
	Channel	tidal currents	✓	–	–	–
Basin	Bed	tidal currents, wind waves	✓	–	–	✓
	Banks	wind waves	–	✓	✓	–
	Flats	wind waves, water levels	–	✓	(✓)	–
	Spits	tidal currents, wind waves	–	✓	–	–
	Riparian Zone	water levels, wind waves	–	(✓)	✓	✓
River	Delta	runoff currents, wind waves	–	✓	–	–
	Channel	runoff currents	✓	✓	–	–
Walled	Banks	wind waves, water levels	✓	–	✓	–
	Canals	water levels	✓	–	✓	–

(✓) Indicates that monitoring of this type may be subject to high uncertainty

Monitoring methods which may be applicable are outlined according to the section of the estuary to which they would apply. A number of these methods are described within the *Coastal Monitoring Guidelines*, either as methods to be undertaken by LGA staff, or to be conducted by external agencies on behalf of the LGAs.

Entrance Monitoring

- Structure assessment: site photographs, condition evaluations;
- Depth measurements: sounding line (thalweg), cross-sections, sounding areas (hydrographic survey);
- Bank measurement: feature survey, aerial photographs, LIDAR;
- Low-tide features: site photographs, oblique aerials;
- Metocean monitoring: current profiling, water levels.

Estuary Monitoring

- Depth measurements: nearshore grades, cross-sections, sounding areas (hydrographic survey);
- Bank measurement: feature survey, aerial photographs, LIDAR, multi-spectral;
- Low-tide features: site photographs, oblique aerials;
- Metocean monitoring: water levels, winds, limit of flooding.

River Monitoring

- Depth measurements: sounding line (thalweg), cross-sections, sounding areas (hydrographic survey);
- Bank measurement: feature survey, aerial photographs, LIDAR;
- Flow monitoring;
- Inundation measurement: flood frequency logs.

Monitoring of Walled Sections

- Structure assessment: site photographs, condition evaluations;
- Depth measurements: sounding line (thalweg), toe depth, cross-sections, sounding areas (hydrographic survey);
- Inundation measurement: flood frequency logs, depth gauge.

Reasons for monitoring within each of the Peron-Naturaliste region estuaries has been considered, including the presence of infrastructure (mainly walling), the need for navigability and the opportunity for gross change due to estuarine processes (Table 54). Note that dynamics more typically associated with foreshore erosion and inundation are considered sub-scale, although they will typically provide the focus for management activities.

Typical monitoring methods (listed above) have been considered with respect to their practicality within each estuary and the apparent influence of dynamics upon estuarine assets (amenity, infrastructure or habitat values) to develop a recommended monitoring program for the Peron-Naturaliste estuaries (Table 55). The recommended frequency has been assigned for each monitoring component.

Table 54: Summary of Monitoring Reasons for PNP Estuaries

	Infrastructure		Estuarine Processes			
Estuary Entrance	Structures	Navigation	Sediment Flux	Dynamic Channel	Flood Response	Delta Storage
Mandurah Channel	✓	✓	✓	✓	–	✓
Dawesville Channel	✓	✓	✓	✓	–	✓✓
Harvey Diversion	✓	–	–	✓	✓	–
Leschenault Estuary	✓	✓	✓	✓	✓	✓
Leschenault Inlet	✓	✓	–	–	–	–
Capel River	✓	–	–	✓	✓	?
Vasse River	✓	–	(✓)	(–)	–	–
Broadwater	✓	–	–	–	–	–
Toby's Inlet	–	–	✓	✓	–	✓
Other drains	✓	–	–	–	✓	✓

(✓) and (–) indicate a marginal basis for monitoring

Table 55: Recommended Monitoring Activities for PNP Estuaries

	Entrance								Estuary		River			Walled			
Estuary Entrance	Structure Photos	Structure Assess	Sounding	Hydrographic Survey	Aerial Photographs	Low-tide Photos	Aerial Obliques	Current Profiling	Hydrographic Survey	Aerial Photograph	Sounding Line	Aerial Photographs	Flood Frequency	Structure Photos	Structure Assess	Sounding	Hydrographic Survey
Mandurah Channel	A	5	A	5	5	2	A	✓	20	5	A	5	✓	A	5	A	5
Dawesville Channel	A	5	A	5	5	–	A	✓	20	5	A	5	✓	A	5	A	5
Harvey Diversion	5	–	–	–	10	–	5	–	–	10	–	–	–	–	–	–	–
Leschenault Estuary	5	10	A	20	5	2	A	✓	20	5	A	5	✓	5	10	5	20
Leschenault Inlet	A	5	A	20	10	–	5	–	20	10	–	–	–	A	5	5	20
Capel River	5	10	–	–	–	–	5	–	–	10	–	5	✓	–	–	–	–
Vasse River	5	10	–	–	10	5	5	–	–	10	–	5	✓	–	–	–	–
Broadwater	5	10	–	–	–	–	5	–	–	10	–	5	✓	–	–	–	–
Toby's Inlet	–	–	–	–	10	5	5	–	–	10	–	–	–	–	–	–	–
Other drains	5	–	–	–	–	–	5	–	–	10	–	–	✓	–	–	–	–

A Annual monitoring

N Approximate number of years between surveys (2, 5, 10 or 20)

✓ Monitoring to be undertaken on either a one-off or event basis

5. Coastal Monitoring Action Plan Summary

This coastal monitoring and action plan has been prepared on behalf of the PNP to support decision-making for both active coastal management and adaptation for risk mitigation. Objectives include developing a plan that is sustainable, long-term and standardised, which is intended to reduce duplication of effort, encourage economies of scale and support comprehension of large scale coastal dynamics. A challenge faced when developing this plan is that the coastal management issues faced by each LGA vary significantly.

Existing monitoring programs were used as a foundation for this plan, with monitoring activities linked to different levels of coastal management decision-making. A risk-based protocol was developed, based on physical vulnerability, existing infrastructure, coastal management and active coastal processes, to identify an appropriate suite of monitoring suitable within tertiary sediment cells. Application of the coastal monitoring protocol to the PNP coast suggests several spatial patterns, which relate either to local morphology or the intensity of existing coastal development.

The risk-based protocol generally supports the comparative levels of existing coastal monitoring undertaken by the various LGAs (i.e. higher for Mandurah and Busselton). Due to the foundation of the protocol, monitoring activities for sites with existing monitoring programs are closely related to the existing monitoring programs.

An important distinction between the recommended and existing monitoring programs is a significant difference in decision-making time frames. Existing monitoring programs, particularly those for LGAs with low density coastal development, have historically relied heavily on the use of vegetation lines to describe coastal change. As a proxy for coastal movement, they are most meaningful employed on coasts with large development setbacks, over time frames in the order of 20-30 years. In the context of the CHRMAP framework described in the State Coastal Planning Policy, coastal monitoring must support LGA decision making over shorter time frames. Different sets of monitoring activity have been recommended according to the inferred decision-making time frame.

Relatively high frequency monitoring of discrete beach widths along the entire PNP coast has been recommended as a simple means to help distinguish between short and longer-term coastal dynamics. Beach width locations have been recommended based upon the sediment cells framework developed for the Peron-Naturaliste coast. Hence the beach width monitoring, in combination with aerial imagery, is intended to provide a cost-effective approach that supports interpretation of regional behaviour or interactions between adjacent sediment cells, without requiring intense monitoring along the wider coast.

Various elements of coastal monitoring and activities have been discussed in this document. This section summarises the recommended actions and ongoing monitoring tasks in brief. Targeted information may be obtained from the following sections and specific tables:

Metocean Monitoring	Section 3.2	Table 6
Inundation Monitoring	Section 3.5	
Coastal Erosion Monitoring	Sections 3.4 & 4.2	Table 52
Estuarine Monitoring	Section 4.3	Table 55

Recommendations include identification of ongoing coastal and estuarine monitoring programs, supporting preliminary assessment, possible scientific questions and long-term investigations relevant to coastal monitoring and management within the PNP region.

Preliminary Assessment

Selection of appropriate seasonal timing for more-expensive discrete measurements (e.g. beach profiles) requires local understanding, as it may vary over relatively small spatial scales. It is recommended that for sites without an existing monitoring record, a three year program of monthly beach width monitoring be used to describe seasonal behaviour.

State and Commonwealth Government Monitoring

Existing levels of data collection by State and Commonwealth Government agencies provide information necessary to support the interpretation of coastal monitoring, including aerial photography capture, hydrographic surveys, wave, tide, stream and meteorological data. It is recommended that the PNP continue to actively support this data collection, as reduced information will affect the capacity for LGAs to make coastal management decisions.

Ongoing Monitoring by LGAs

Coastal change information is mainly locally relevant to each LGA, and therefore co-ordination of coastal erosion monitoring or estuarine monitoring is largely managed by LGAs. The set of monitoring activities appropriate for each tertiary sediment cell or each of the PNP region's main estuaries have been recommended in Sections 3.4, 4.2 and 4.3.

Monitoring activities for each LGA are summarised in Table 56. Details regarding the frequency of monitoring and coverage are discussed in the relevant sections for inundation monitoring, coastal erosion monitoring and estuarine monitoring.

The role of the PNP, as a collaborative body for nine different LGAs provides an opportunity for co-ordinated management of the coastal and estuarine data, although requiring additional resources. Co-ordinated data management and integration may further support regional interpretation of coastal monitoring.

Capacity for flood mapping, which is only likely to be required on an occasional and intermittent basis, may be appropriately developed within a central agency, that can subsequently support individual LGAs for mapping after a severe flood event. This capacity may be held by the PNP, a State Government agency, or specialist capacity developed within a single LGA.

Table 56: Summary of Monitoring Activities per LGA

	Coastal Erosion Monitoring							Estuarine Monitoring						
	Rockingham	Mandurah	Waroona	Harvey	Bunbury	Capel	Busselton	Mandurah	Murray	Harvey	Dardanup	Bunbury	Capel	Busselton
Photo Monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Beach Width	✓	✓	✓	✓	✓	✓	✓							
Beach Profiles	✓	✓		✓	✓		✓							
Spatial Coverage														
Oblique Aerial Imagery	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vertical Aerial Imagery	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Remote Sensing														
Hydro survey	✓	✓			✓		✓	✓	✓	✓	✓	✓		
Dune Mobility			✓	✓	✓	✓								
Condition Assessment	✓	✓			✓		✓	✓	✓	✓	✓	✓	✓	✓
Flood Mapping	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
Current Profiling								✓	✓	✓	✓	✓		

Scientific Questions

Improved understanding of nearshore wave processes is required, particularly to characterise reef influences and bed friction. Short-term deployment of multiple inshore instruments is necessary to evaluate these processes. The scientific nature of the required investigations may imply a need for academic or State Government co-ordination.

Coast-estuary sediment transfers are not presently well understood in the PNP region and have implications for long-term change. Characterisation of entrance channel flow patterns and the corresponding capacity for sediment transfer is required for effective management of major PNP estuaries, including Peel- Harvey system and Leschenault Estuary.

Long-term Investigations

The potential benefits and limitations of repeating the regional scale LIDAR undertaken in 2008/09 should be understood by PNP. It is recommended that the PNP develop a dialogue with State government agencies to support regional scale LIDAR with a target date in the range of 2030 to 2040.

Over decades, coastal change will expose different sections of underlying rock formations along the PNP coast. It is recommended PNP member agencies collectively develop capacity to co-ordinate geophysical assessments within the PNP region. Definition of a scope, collation of existing information and a test case are recommended within 2016-2025.

Characterisation of coastal sediments is required for effective coastal change projections. A sediment sampling plan should be developed (by the State) to support co-ordinated collation of sediment information, supplemented by academic data collection.

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