5 RECOMMENDATIONS

The digital aerial photography provided an adequate low cost tool for fine scale mapping of the coastal vegetation. The vegetation monitoring tool was developed from existing methods and provided suitable data to support remote mapping and document community and geomorphic change. It is recommended that:

1. the TWWHA coastal geomorphology and vegetation be mapped every ten years using high resolution aerial photography;

2. vegetation change and geomorphic process monitoring be implemented for representative sites on the TWWHA coast;

3. monitoring programs be developed for at species risk in the TWWHA coastal zone;

4. a submetre DEM be obtained for the TWWHA coastline to facilitate improved vegetation and geomorphic mapping;

5. the mapping method used in this study be investigated for monitoring and management of other ecosystems at risk from climate change that are not able to be monitored using the existing TASVEG mapping program eg snow patch communities within alpine vegetation.

Specific recommendations relating to aspects of the method are provided below.

5.1 Monitoring vegetation community distribution

- An accurate vegetation spatial analysis allowing resolution of change less than 20m would rely on obtaining a submetre DEM or an extensive array of ground control points. Further refinement of the digital elevation model (DEM) for the TWWHA along with establishment of further GPS control points on the ground will reduce spatial errors. An improved DEM would greatly enhance geo-rectification of images as well as provide more comprehensive vegetation community information such as accurate canopy heights and densities. LiDAR mapping has the capability of producing a DEM with a resolution of approximately 0.5m which would greatly improve spatial accuracy and enable detailed geomorphic monitoring of erosion fronts. It is envisaged that this technology will become more accessible in the future.

- More field data will allow better understanding of the coastal vegetation community types within the TWWHA particularly in relation to digital airphoto interpretation.

- Low density beach grasslands and herbfields were not successfully mapped however higher density beach grasslands and herbfields can be mapped. A number of vegetation types are mappable now while others require additional field survey to establish the relationship between appearance of communities on photographs and the type of community in the field.

- Aerial photographs should be taken at an interval of 10 years. Due to large spatial errors accumulated via geo-rectification, only significant shifts in vegetation can be detected and these are unlikely to occur in less than ten years.

- Aerial photos should preferably be taken in midsummer when sun is overhead and on clear days as shadow and cloud limit interpretation of photographs. Photos should be taken between 2000ft and 2300ft and not above 2600ft. This gives good resolution of ground vegetation, with textures and colours easily differentiated.

- Aerial photo runs should include some of the inland areas behind coast as to allow more accurate geo-referencing of photos. However the photo centre should lie on the beach side

of any tall vegetation if immediately adjacent ground cover is to be observed eg. marsupial lawns that occur along eroding edges of scrub communities.

- As far as possible straight photo runs should be taken to minimise oblique angle photography and allow better rectification. Use of a gimbal arrangement to support the camera is highly desirable as it will minimise spatial errors resulting from oblique photographs.

5.2 Geo-referencing and rectification of images

- Deployment of electronically linked Camera - GPS system is highly desirable for programming and recording photo locations accurately. This technology should become more readily available in the future.

- Although differential GPS with dual frequency gives better accuracy, a hand held single frequency GPS would give sufficient accuracy for this project and would allow more efficient collection of field data.

- To improve rectification and minimise spatial errors, permanent, identifiable (from air and ground), geo-reference points should be established for each location. At least four points for each location should be established, and more if possible. Control points need to include both shoreline and inland points. These points should be accurately located with differential GPS.

- Geo-rectification control points used for image rectification within this project are available and should be used as supplementary control points for future rectification.

- All aerial photos taken for this project should be rectified against the 1988 1:25000 WHA aerial photographs. These photographs were originally used for WHA vegetation base mapping, as well as for rectification of digital aerial photos used in this project.

5.3 Geomorphology classification and mapping

- Further geomorphic mapping and modelling is considered critical to assessing the potential impact of coastal recession on vegetation communities and species. This includes:

    - Improvement of the assessment criteria for current geomorphic process mapping;
    - geomorphic type mapping (polygon) in areas identified as at high risk from climate change by Sharples (2006);
    - the review and identification geomorphic values, reference sites and outstanding examples for linking with vegetation values;
    - development of broadscale coastal process maps;
    - and the modelling of climate induced coastline change.

- All survey data should be consistent with, or result in the data being able to be used by, other similar projects across the state (ie Sharples coastal geomorphology polygon mapping and the TASMARK project).

- Where permanent vegetation transects are established, geomorphology should also be incorporated into the long term monitoring.

5.4 Vegetation monitoring

5.4.1 Priority species

- Monitoring of individual species requires considerable resources and should be targeted carefully. The threatened species and restricted endemics considered most at risk from climate change impacts on the coast are:
  - the herb *Veronica novae-hollandiae* that occurs rarely in the coastal grasslands, is distinctive but uncommon and inconspicuous;
  - the tree *Persoonia muelleri* subsp. *densifolia* that is widely spaced but prominent along the littoral edge of coastal scrub and forest;
  - and the shrub *Westringia brevifolia* var. *raleighii*.

- Abundance data for these species is unlikely to be captured within general community level monitoring with sufficient power to estimate a significant change in their populations. Each of these species warrant separate monitoring strategies to suit the different habitat, observability and population densities of the species.

- The *Veronica novae-hollandiae* is small and inconspicuous unless it is flowering. Its populations are poorly known and a survey of its extent and density is warranted. It is likely to be best monitored by identifying potential grassland habitat and searching transects systematically at a time when the species is in flower. The number of plants, location on the transect and density could be recorded. The start and end of each transect would be fixed by an offset survey peg. There would seem little point in marking individual plants given the environment. Monitoring could only be established along a limited number of beaches and these might be chosen on the basis of accessibility and known population concentrations.

- *Persoonia muelleri* subsp. *densifolia* is a distinctive tree and might be best sampled by walking along the beach and recording individual trees with a GPS. This could be undertaken along several beaches. The survey should also check for the presence of *P. muelleri* subsp. *angustifolia*. Estimates of height, cover, diameter and health should be recorded. Labelling trees might be appropriate where several occur close together to assist with distinguishing individuals in long term monitoring data. Population monitoring may then be matched with habitat mapping and species distribution records to gauge changes in overall populations.

- *Westringia brevifolia* var. *raleighii* can be distinguished most easily when flowering. Survey should cover several different habitat types including areas of high risk from coastal erosion as well as dune accumulation. Population monitoring may then be matched with habitat mapping and species distribution records to gauge changes in overall populations.

5.4.2 Monitoring vegetation communities

- In understanding change it is clear that longshore as well as inland transects need to be established on beaches. Transects perpendicular to the shore extending 30 m inland from the littoral edge of the vegetation are adequate in most cases. If additional communities of interest are identified on aerial photographs that are greater than 30 m from the beach, transects should be extended to incorporate them.

- 10mx1m quadrats were found to be adequate for sampling most communities at the beach edge and should used in future monitoring.

- In communities above 2 m in height, a 2.5 X 10m plot is required for vegetation between 2 and 5 m in height. This equates with 5 x 5m plots normally used in this community type but better suits the narrow linear nature of coastal communities.

- Quadrat placement should be intensive at the interface between the beach and vegetation. One quadrat should be located on the beach, one at the interface between the beach and vegetation (at the scarp), and one directly behind this. Quadrats should then be placed within each vegetation community along the transect.

- Permanent photopoints for transects should be used to record both vegetation and geomorphology.

- The following locations (Table 6) should be considered for inclusion in a monitoring program, in addition to Cox Bight and New Harbour, as they contain communities that may have conservation significance or contain communities that were not characterised by this study. Locations are listed in order or priority and the merits of each location are described.

  Towterer Beach. The digital aerial photography of this location has already been geo-rectified. This location has an extensive and unique coastal rainforest that starts very near the shoreline. There are also large patches of marsupial lawn and grassland. Two transects in this location would be ideal and should attempt to cover all three communities (Figure 8).

  Wreck Bay. This location has a variety of different vegetation communities, including areas of *Leptospermum* shrubland, a community that is not present at either New Harbour or Cox Bight. Mixed broadleaf shrubland, herbfield and grassland are also present. There appears to be distinct zonation of the coastal scrub and shrubland communities from the beach inland, which would provide a good opportunity to better define different coastal shrubland types thereby improving digital photo interpretation. Two transects in this location, targeting the different communities, would be advisable (Figure 13).

  Hannant Inlet. This area has some exceptional herbfields right on the shoreline. Hannant Inlet is also different from the other locations in that it is not an oceanic bay but lies within Bathurst Harbour, and would allow an understanding of the affect of sea level rise on vegetation in a low energy, non-sandy shoreline (Figure 14).

  Prion Bay. This area contains interesting hydrological features. The vegetation communities of the area appear similar to those of Cox Bight and transects could be set up so that vegetation communities already sampled along the south coast at either Cox Bight or New Harbour are replicated at Prion Bay (Figure 15).

  One additional transect at Cox Bight and New Harbour should be set up. At Cox Bight the transect should fall within the coastal rainforest of the eastern side of Point Eric. At New Harbour the transect should be at the eastern end of the beach where there is strandline grassland community and coastal shrubland.

Table 6. Locations and target vegetation communities for future monitoring.

Location	Target Community
Cox Bight	coastal shrubland , coastal rainforest
New Harbour	coastal broadleaf, coastal grassland, coastal shrubland
Towterer Beach	coastal rainforest, closed herbfield, coastal grassland
Wreck Bay	coastal shrubland, closed herbfield, coastal broadleaf
Hannant Inlet	closed herbfield, Eucalypt woodland
Prion Bay	coastal shrubland, Eucalypt woodland

Figure 13 Possible locations for vegetation monitoring at Wreck Bay.

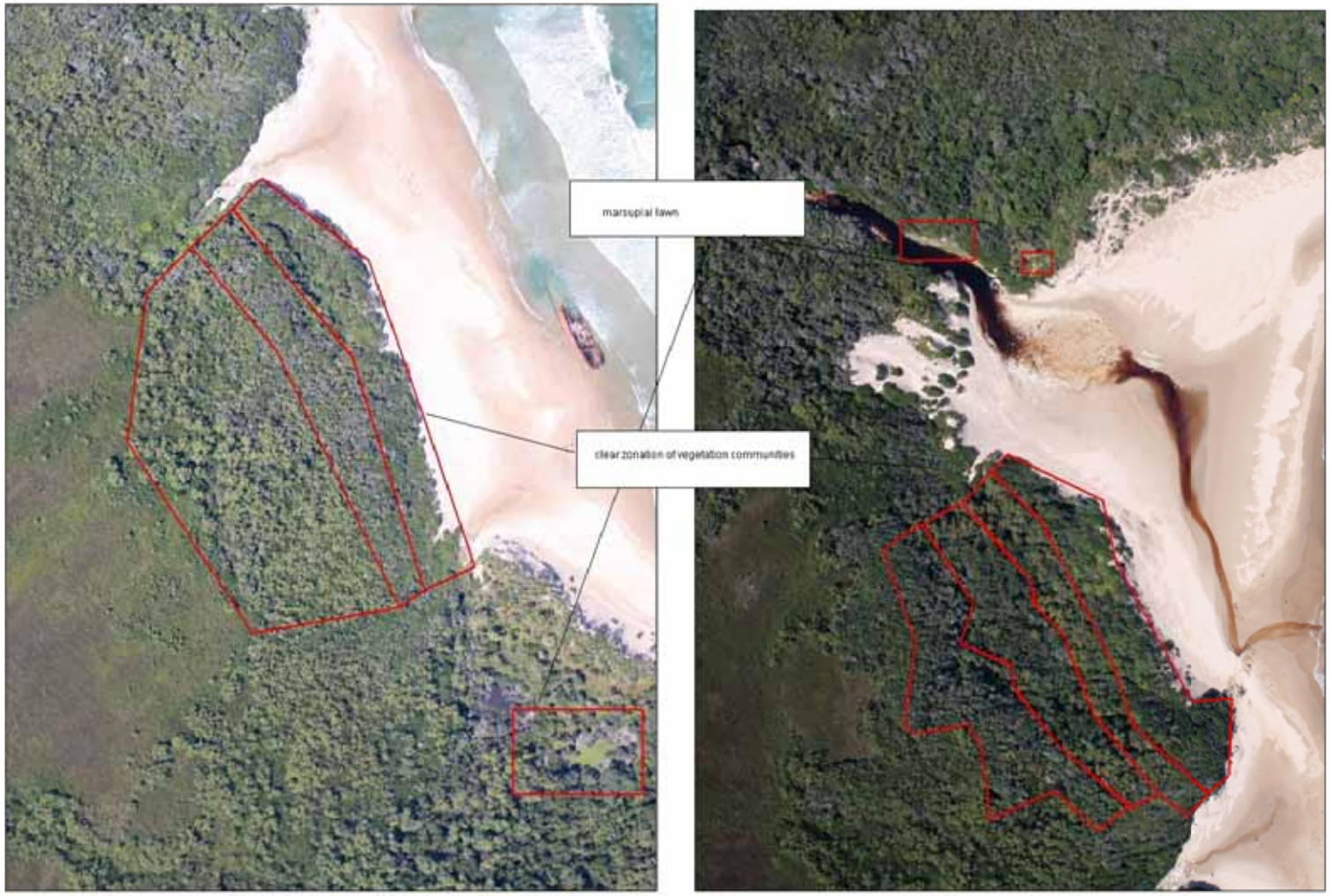
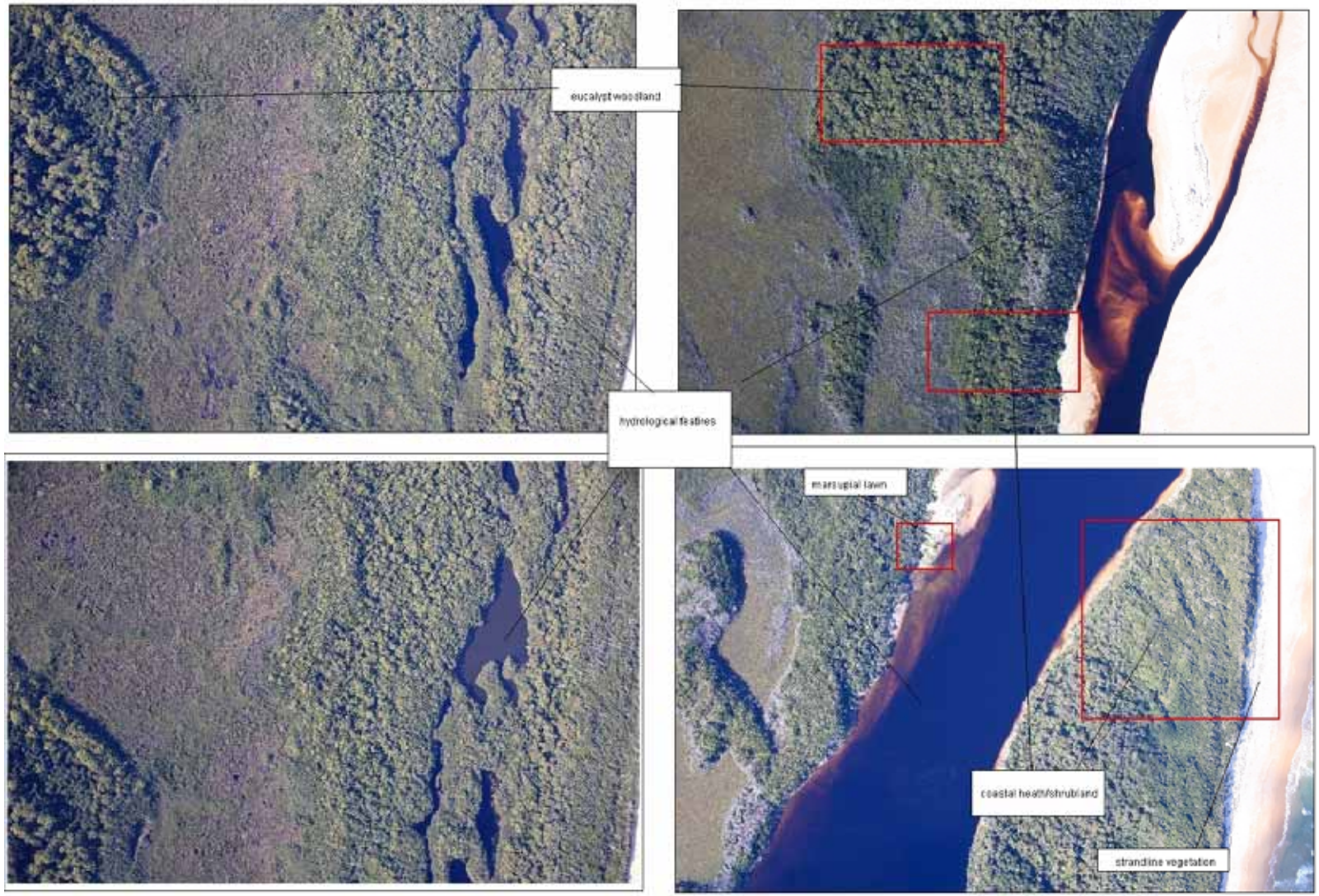


Figure 14 Possible locations for vegetation monitoring at Hannet Inlet.

Figure 15 Possible monitoring locations at Prion Beach.



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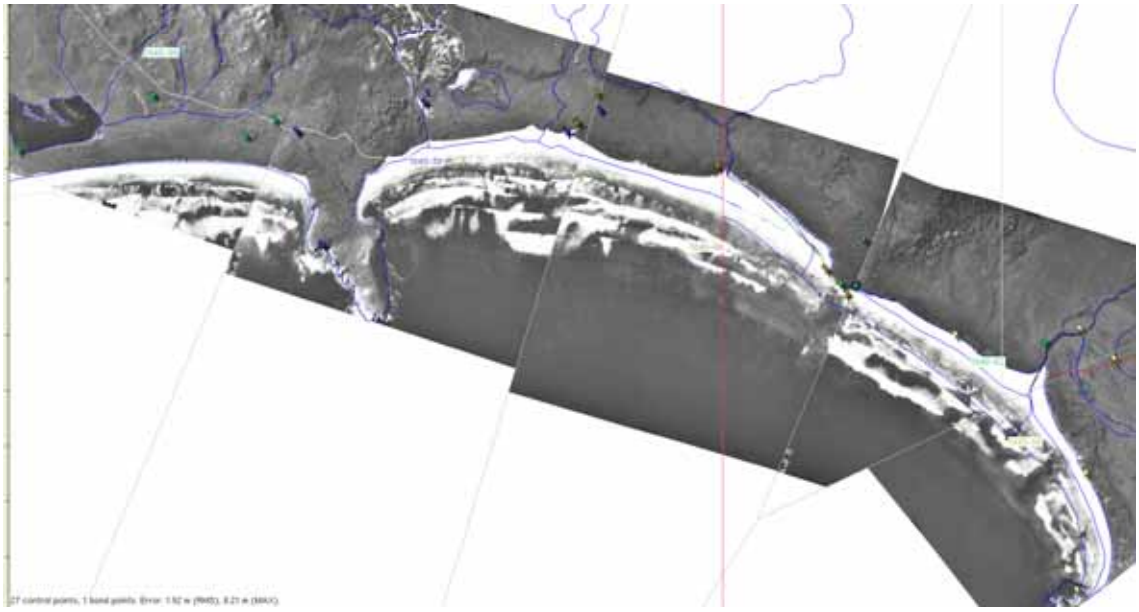
APPENDIX 1

Geo-referencing control points

The location of control points used to georeference aerial images.

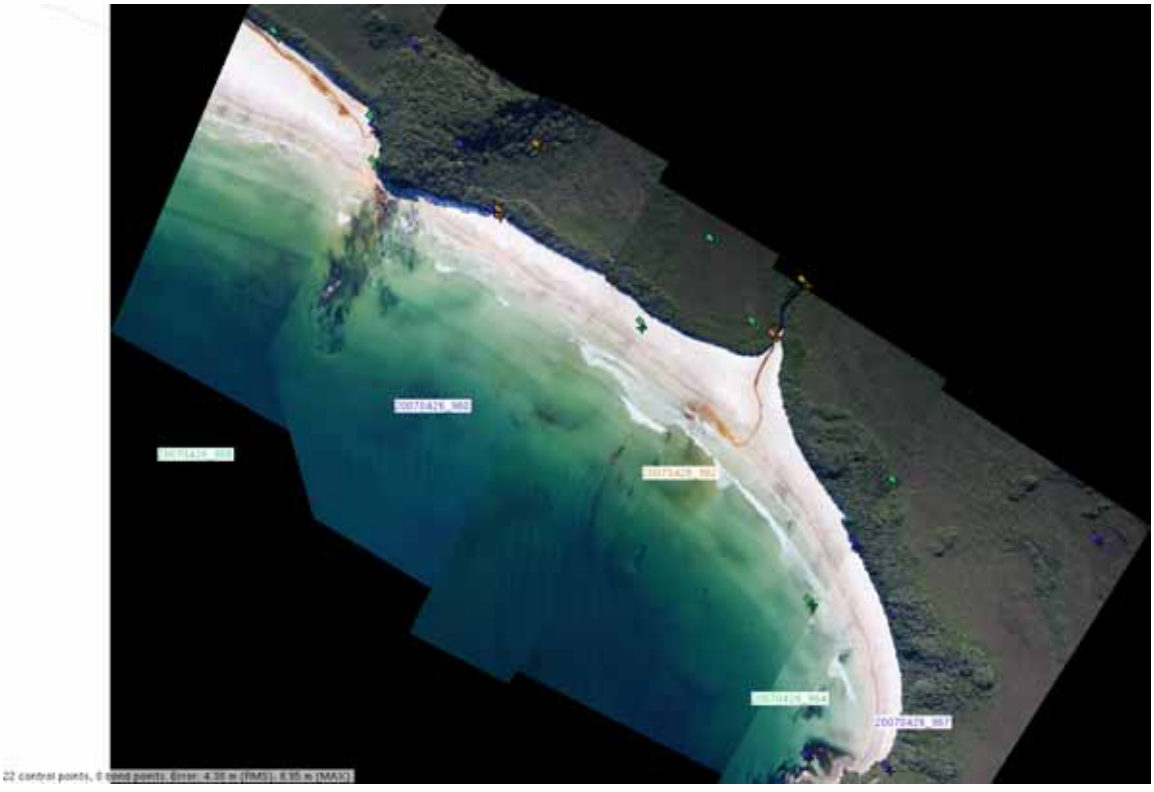
COX BIGHT 1:5000 1985 photograph



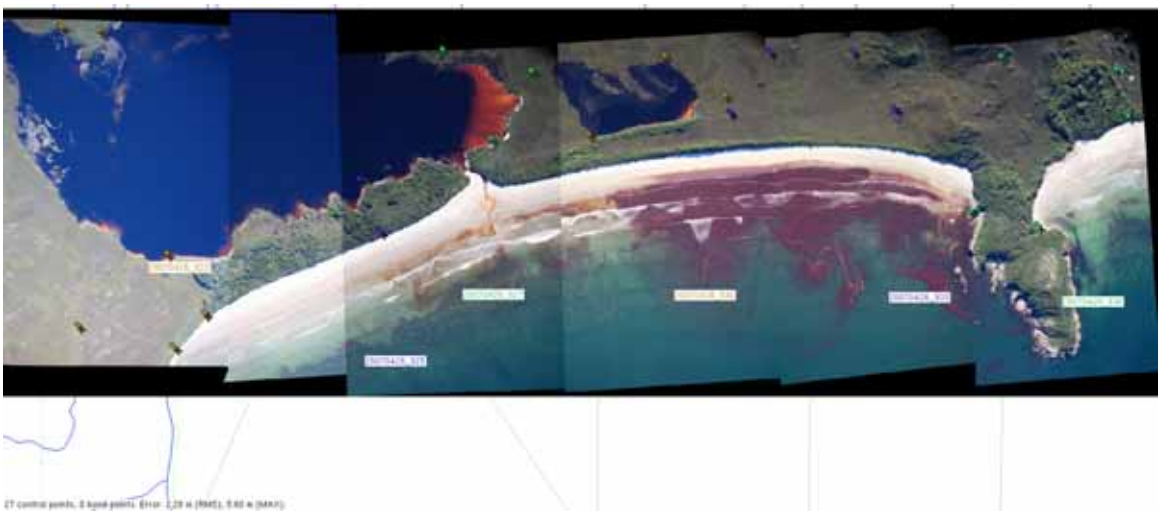
COX BIGHT 1:25000 1988 photograph

COX BIGHT 1:42000 aerial photograph

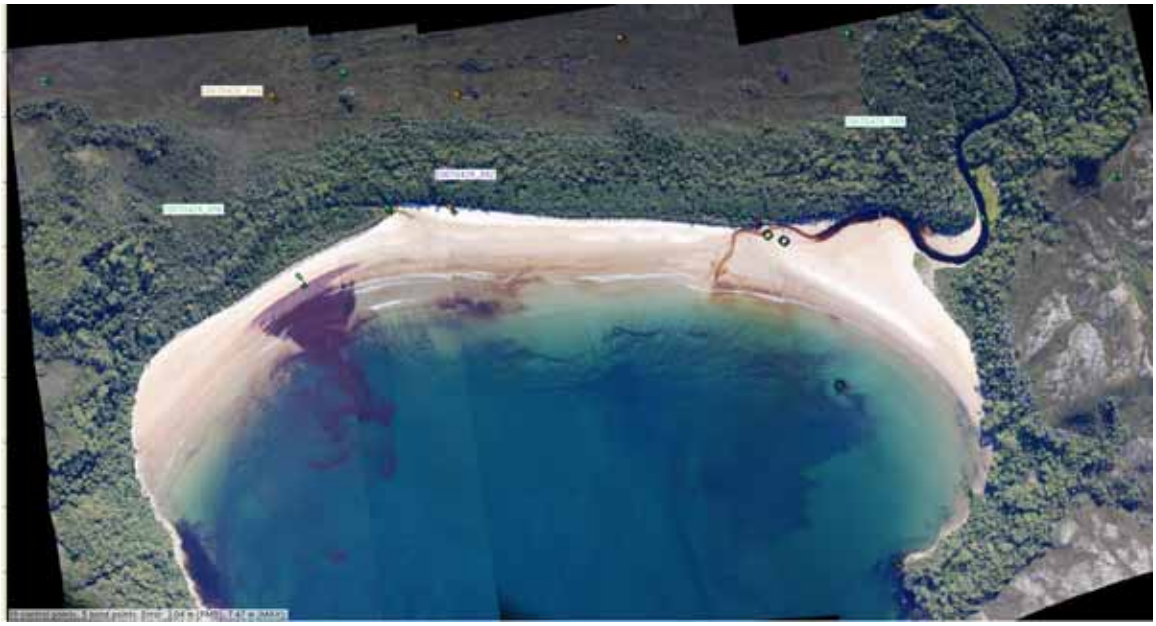
COX BIGHT 2007 digital images



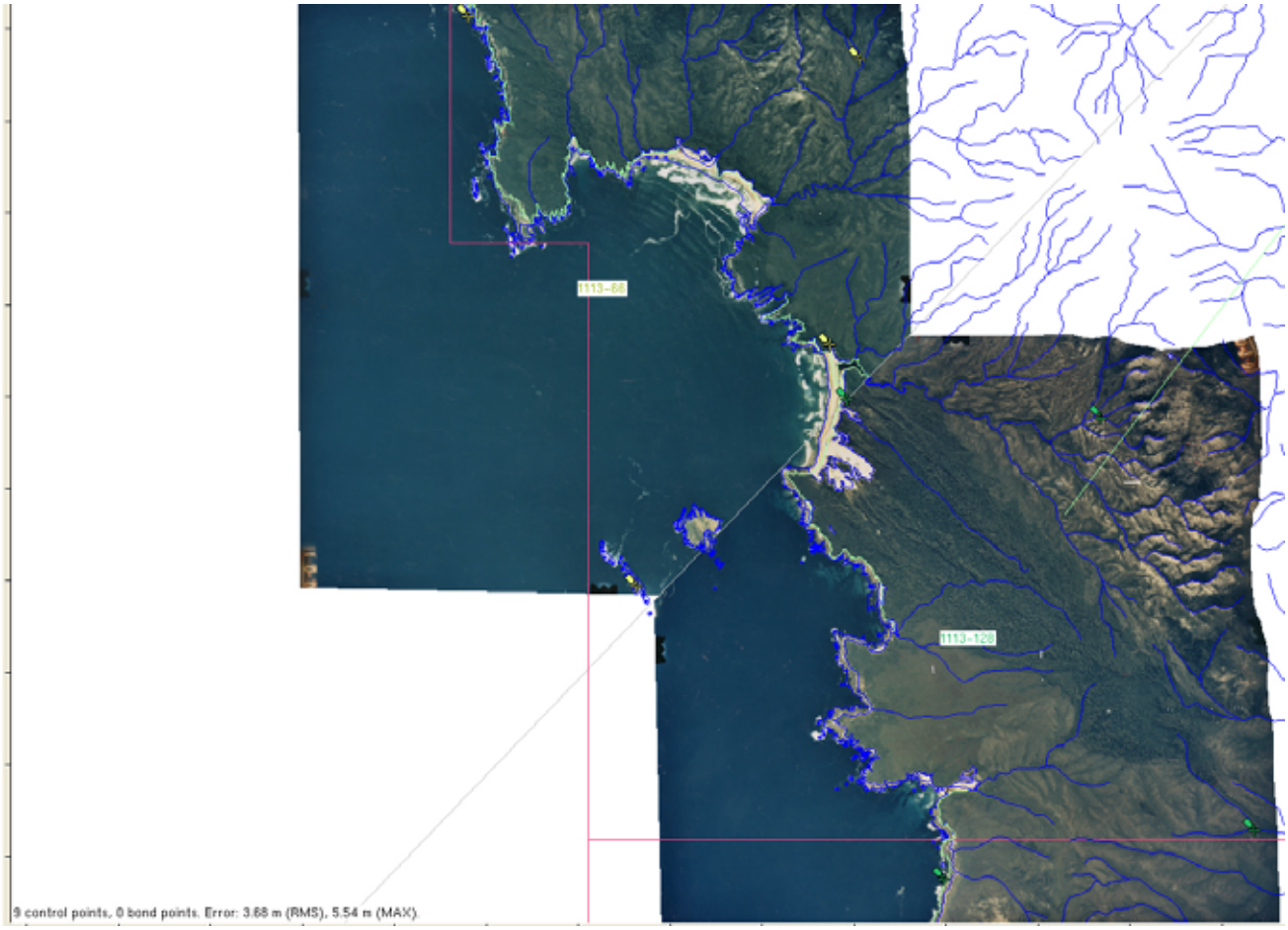
Cox Bight



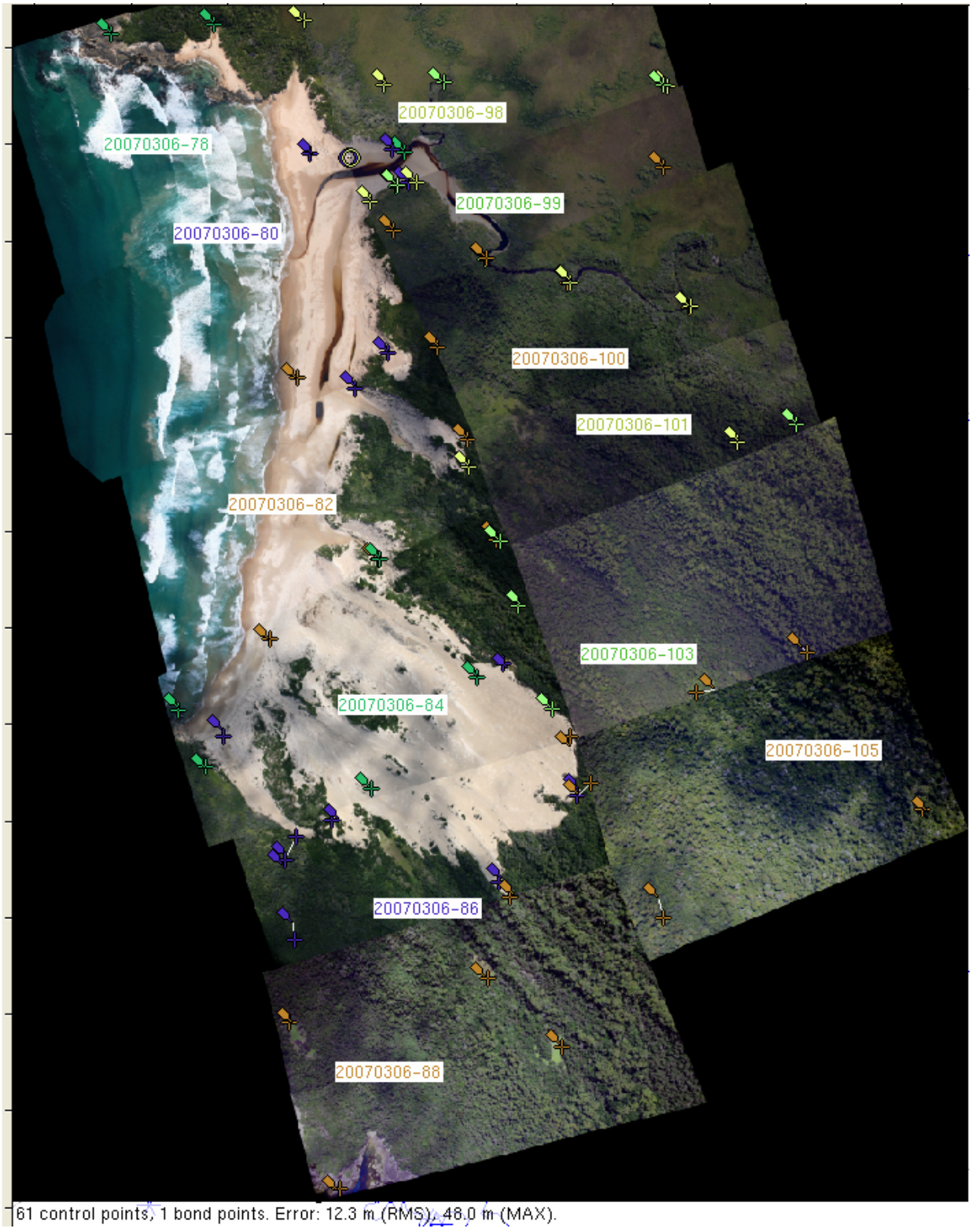
NEW HARBOUR 2007 digital images



TOWTERER BEACH 1:25000 1988 aerial photograph



TOWTERER BEACH 2007 digital images



APPENDIX 2
DGPS points positional uncertainty

Positional uncertainty for each differential GPS point collected at Cox Bight and New Harbour. Positional Uncertainty is defined by the 95% confidence interval.

GPS Point ID	Positional Uncertainty
P1	0.27
P2	0.52
P3	0.22
P4	0.5
P5	0.75
P6	0.19
P7	0.17
P8	0.17
P9	0.36
P10	0.2
P11	0.44
P12	0.19
P13	0.37
P14	0.26
P15	0.13
P16	0.23
P17	0.08
P18	0.47
P19	0.22
P20	0.33
P21	0.09
P22	0.34
P23	0.21
P24	0.1
P25	0.1
P26	0.19
P27	0.21
P28	0.43
P29	0.64
P30	0.18
P31	0.67
P32	0.3
P33	0.3
P34	0.18
P35	1.31
P36	0.19
P37	0.49
P38	0.27
P39	0.43
P40	0.31

GPS Point ID	Positional Uncertainty
P41	1.55
P42	0.49
P43	0.61
P44	0.23
P45	0.79
P46	0.49
P47	0.49
P48	0.27
P49	0.36
P50	0.08
P51	0.19
P52	0.16
P53	0.39
P54	0.2
P55	0.26
P56	0.3
P57	
P58	0.11
P59	0.29
P60	0.24
P61	0.12
P62	0.36
P63	0.17
P64	0.22
P65	0.24
P66	0.23
P67	
P68	
P69	0.25
P70	0.22
P71	0.16
P72	0.21
P73	0.32
P74	0.18
P75	0.42
P76	0.65
P77	0.77

APPENDIX 3
Metadata

Metadata – Mapinfo tables

Table name	Description of table
coastal_veg_comm_class	Field survey quadrats locations and vegetation classification by dominant species.
sampling_locs_Mar07	Quadrat and transect locations from field work.
veg_07APl	Vegetation mapping from photo interpretation of 2007 project digital photographs. Shows undefined polygons enclosing different vegetation communities at Cox Bight, New Harbour and Towterer Beach.
veg_85APl	Vegetation mapping from photo interpretation of 1,5000 1985 aerial photograph. Shows undefined polygons enclosing different vegetation communities at Cox Bight.
veg_07APl_MUdefn	Vegetation mapping from photo interpretation of 2007 project digital photographs. Shows defined polygons and map units for different vegetation communities at Cox Bight, New Harbour and Towterer Beach.
Geomorph_classification	Shows locations of all geo-reference points collected along Cox Bight and New Harbour. Shows geomorphic process classification for each point based on developed score system.
Coast_erosionfront	Lines linking geo-reference points with colours indicating the general geomorphic process of the scarp at Cox Bight and New Harbour.

Metadata - Mapinfo Aerial Flightline

Data Name	WHA Coast 07 flightline & WHA Coast 2007 images
Data Location	WHA Coast 07 flightline: H:\GIS_Resources\GIS_Datasets\Mapinfo_Datasets\Digital aerial photos flightlines
Description	WHA Coast 07 flightline : Aerial photography flight file detailing image name. location, elevation, direction , time, camera etc.
Data custodian	Tim Rudman
Division	RMC
Branch	BCO
Contact details	Ph: 6233 3912, 134 Macquarie st Hobart
Business purpose	Vegetation monitoring
Clients	RMC, PWS
Software tools used to maintain the system	Mapinfo
Data storage formats	Mapinfo tables
Projections used	GDA 94
Coverage/geographical region	Selected beaches from Towterer to Lion Rock. Coverage of individual beaches is not always complete.

SizeMB	<1 MB
Currency/last updated	June 2007
lens	35mm Canon
Camera	Canon 5D
CCD	35mm
Photo Elevation	600-900m
Photographer	Photographs taken by hand by Stewart Wells Photography. DPIW holds ownership over the photographs.
Flight path map	WHA coast 2007
Location accuracy	Image locations recorded in the flight file are estimated to be mostly within 100m ± 50m of the centroid of the photograph. No ground controls are in place for the images.

Metadata – Orthomozaic low altitude digital photography

Data Name	WHA coast 07 Orthomozaics
Location	H:\GIS_Resources\GIS_Datasets\Mapinfo_Datasets\Raster_Images\WHA_Aerial_Photographs
Description	Small format Digital Aerial Photographs orthomozaics.
Division	RMC
Branch	BCO
Data custodian	Tim Rudman
Contact details	Ph: 6233 3912, 134 Macquarie St Hobart
Business purpose	Vegetation monitoring
Clients	RMC, PWS
Software tools used to maintain the system	Landscape mapper, Mapinfo
Data storage formats	ecw, tiff and Mapinfo table
Projections used	GDA 94
Coverage/geographical region	Selected beaches; Cox Bight, New Harbour, Towterer Beach.
SizeMB	
Currency/last updated	June 2007
lens	35mm Canon
Camera	Canon 5D
CCD	35mm
Photo Elevation	See flightlines.tab
Georeferencing method	Georectification and orthorectification was undertaken using Landscape Mapper. Lens correction and 10m DEM correction was undertaken. Rectification was done against the 1:25,000 scale 1988 WHA aerial photography rectified imagery. and limited on-ground submetre differential GPS controls for New Harbour and Cox Bight.
Spatial accuracy	Variable over the mozaic depending on availability of corresponding image control points on the 1:25,000 images. At the very best equivalent to the 25,000 mapping base layer accuracy of 90% points within >12.5m of the true position. Poorly controlled areas could conceivably be double or more this error, particularly away from the beach on the photograph edges where rectification was less.

	Examination of errors against submetre GPS control points indicated 8-14 ? metre errors in the rectification
Notes	

Metadata - Unprocessed aerial photographs

Data Name	WHA Coast 2007 images
Data Location	WHA Coast 2007 images:
Description	WHA Coast 2007 images : Vertical (approximately) small format digital aerial photographs, unrectified and unedited.
Data custodian	Tim Rudman
Division	RMC
Branch	BCO
Contact details	Ph: 6233 3912, 134 Macquarie st Hobart
Business purpose	Coastal monitoring programs – vegetation change
Clients	RMC, PWS
Software tools used to maintain the system	Non specific image software
Data storage formats	jpg image files
Projections used	none
Coverage/geographical region	Selected beaches from Towterer to Lion Rock. Coverage of individual beaches is not always complete.
SizeMB	
Currency/last updated	June 2007
lens	35mm Canon
Camera	Canon 5D
CCD	35mm
Photo Elevation	600-900m
Photographer	Photographs taken by Stewart Wells Photography. DPIW holds ownership over the photographs.
Flight path map	WHA coast 2007, Mapinfo file
Location accuracy	Image locations recorded in the flight file are estimated to be mostly within 100m ± 50m of the centroid of the photograph. No ground controls are in place for the images.

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