

Appendix 1: Catchment Types

Table A1.1: Australian Geological Survey Organisation (Heap *et al.*, 2001, p. 88)
Criteria for Initial Classification of Estuaries.

| | Physical Characteristics | Condition |
|--|---------------------------------|---|
| Near Pristine These estuaries are generally recognised as being in excellent condition with management activities focused particularly on the protection of natural values. These estuaries are likely to provide baselines to judge the condition of other estuaries. | Catchment natural cover | > 90% |
| | Land use | Limited roads & disturbance to natural conditions and processes |
| | Catchment hydrology | No dams or impoundments, virtually nil abstraction |
| | Tidal regime | No impediments to tidal flow, changes from natural morphology (e.g. training walls, barrages, bridges and causeways) |
| | Floodplain | Wetlands intact in vegetation and hydrology, no alterations to flood pattern. |
| | Estuary Use | Extractive activities limited to indigenous or limited & sustainable commercial & recreational fishing, no aquaculture. |
| | Pests & Weeds | Minimal impact on estuary from catchment weeds & limited pests & weeds within estuary. |
| | Estuarine Ecology | Ecological systems & processes intact (e.g. Benthic flora & fauna). |
| Largely Unmodified These estuaries are generally recognised and documented as being in good condition, but with some catchment and estuary use. | Catchment natural cover | ~65-90% |
| | Land use | No known gross impacts from land use (e.g. sediment to waterways to estuary). |
| | Catchment hydrology | No dams or significant impoundments, some abstraction. |
| | Tidal regime | No significant impediments to tidal flow to changes from natural morphology. |
| | Floodplain | Wetlands mostly intact in vegetation & hydrology, no alterations to flood pattern. |
| | Estuary Use | Extractive industries limited to sustainable commercial & recreational fishing, minor aquaculture. |
| | Pests & Weeds | Minimal impact on estuary from catchment weeds & limited pests & weeds within estuary. |
| | Estuarine Ecology | Ecological systems & processes mostly intact (e.g. some changes to Benthic flora & fauna). |

| | | |
|-----------------|-------------------------|---|
| Modified | Catchment natural cover | <65% |
| | Land use | Documented impacts from land use, e.g. sediment & nutrients to waterways. |
| | Catchment hydrology | Dams & impoundments, significant abstraction modifying natural flows. |
| | Tidal regime | Impediments to tidal flow &/or changes from natural morphology, e.g. training walls, causeways, artificial opening of entrance. |
| | Floodplain | Wetlands mostly cleared in vegetation &/or changes in hydrology, e.g. drains, tidal barrages, levees. |
| | Estuary Use | Extractive industries include dredging, extensive aquaculture, habitat modifying fishing methods, e.g. prawn trawling. |
| | Pests & Weeds | Significant impact on estuary from catchment weeds & impact on estuary ecology from pests & weeds within estuary. |
| | Estuarine Ecology | Ecological systems & processes modified (e.g. loss of Benthic flora & fauna). |
| | | |

Appendix 2: Aerial Photograph Index

Table A2.1: Aerial Photographs of Ukerebagh Island, Tweed River.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|-----------------------------------|---|-----------|-----------------|---------|--------------------|--------------------|-----|----------|---|
| Tweed River | | | | | | | | | |
| 1947 | | | | | | | | | |
| Tweed River Entrance, Tweed Shire | | 27.5.1947 | | | SVY 122 | 406 | 2 | | 15,000'; Restricted; Nories Head-Tweed Shire; b&w |
| Tweed River Estuary, Tweed Shire | | 27.5.1947 | | | SVY 122 | 399 | 1 | | 15,000'; Restricted; Nories Head-Tweed Shire; b&w; |
| 1961 | | | | | | | | | |
| Tweed River, Tweed Heads | Sunmap Centre, Surveyor General, Queensland | 1.9.1961 | 1 | 72 | Q1184 | 138 | 10 | | MAG 295; Lens 120; 152.09 mm 8,920; Springbrook; b&w |
| Tweed River, Tweed Heads | Sunmap Centre, Surveyor General, Queensland | 1.9.1961 | 1 | 72 | Q1190 | 52 | 11 | | MAG 294; Lens 120; 152.09 mm 8,920; Springbrook; b&w |
| 1971 | | | | | | | | | |
| Tweed River, Tweed Heads | | | | | | | | | |
| 1983 | | | | | | | | | |
| Tweed River, Tweed Heads | NSW Govt. CMA | 27.1.1983 | 1 | 56 | NSW 3260 | 114 | B | 1:15 000 | 2286m ASL 151.45mm; Tweed I/83; NSW3260 (M1495); colour |
| 1998 | | | | | | | | | |
| Tweed River, Tweed Heads | Surveyor-General's Department | 13.08.98 | | | NSW 4444 | 214 | 1 | 1:20 000 | 152.76mm; in range 210-216; Tweed River 1998; NSW4444 (M2140); colour |

Table A2.2: Aerial Photographs of Tilligerry Creek, Port Stephens.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|--|-------------------------------|------------|-----------------|---------|--------------------|--------------------|-----|----------|--|
| Port Stephens - Tilligerry Creek | | | | | | | | | |
| 1954 | | | | | | | | | |
| Tilligerry Creek, Morna Point, Newcastle | Surveyor-General's Department | ??.9.1954 | 38 | | NSW 257 | 5001 | 1 N | | Lens 267078 152.28mm; 15,500'; colour |
| 1966 | | | | | | | | | |
| Tilligerry Creek, Port Stephens | Surveyor-General's Department | 14.8.1966 | | | NSW 1464 | 5137 | 1N | | 15,500'ASL 114.44mm; Newcastle; b&w |
| Tilligerry Creek, Port Stephens | | | | | | | | | |
| 1975 | | | | | | | | | |
| Tilligerry Creek, Morna Point | Crown Copy NSW Lands Photo | 1.4.1975 | 38 | 8 | NSW 2299 | 113 | 5 | | 6401m ASL 151.45mm; Newcastle; b&w |
| 1983 | | | | | | | | | |
| Tilligerry Creek, Newcastle | Surveyor-General's Department | 20.12.1983 | | | NSW 3358 | 141 | 3 | 1:16 000 | 2896m ASL 151.45mm; Newcastle 1983; NSW 3358 (M1540); colour |
| Tilligerry Creek, Newcastle | Surveyor-General's Department | 20.12.1983 | | | NSW 3358 | 143 | 3 | 1:16 000 | 2896m ASL 151.45mm; Newcastle 1983; NSW 3358 (M1540); colour |
| 1996 | | | | | | | | | |
| Tilligerry Creek, Lower Hunter | Land Information Centre | 8.6.1996 | | | NSW 4314 | 22 | 8 | 1:20 000 | 3070m ASL 152.76mm; Urban Coverage Lower Hunter; NSW4314 (M2033); in range 13-65; colour |

Table A2.3: Aerial Photographs of Black Neds Bay, Lake Macquarie.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|---|----------------------------------|-----------|-----------------|---------|--------------------|--------------------|-----------|----------|--|
| Lake Macquarie - Black Neds | | | | | | | | | |
| 1950 | | | | | | | | | |
| Black Neds Bay, Lake Macquarie, Swansea | | 3.3.1950 | 40 | 2 | 875QUN/ 289 | | 6 (60-75) | | 152.3mm 7500' Restricted; b&w |
| 1961 | | | | | | | | | |
| Black Neds Bay, Lake Macquarie, Swansea | Crown Copy NSW Lands Photo | 23.9.1961 | 40 | 7 | NSW 1076 | 5098 | 9 | | Northumberland Project; 5,900' ASL 114.44mm; NSW 1076/5098; b&w |
| 1974 | | | | | | | | | |
| Black Neds Bay, Lake Macquarie, Swansea | Crown Copy NSW Lands Photo Log-E | 19.6.1974 | 40 | 17 | NSW 2236 | 100 | 1 | | Central Coast June 1974; 1400m ASL 87.80 mm; NSW 2236 (Misc. 883); b&w |
| 1987 | | | | | | | | | |
| Black Neds Bay, Lake Macquarie, Swansea | Crown Copy NSW Lands Photo | 13.4.1987 | 40 | 43 | NSW 3567 | 175 | 18 | 1:16 000 | Newcastle; 2926m ASL 153.10mm; NSW 3567/175 (M1773); colour |
| 1999 | | | | | | | | | |
| Black Neds Bay, Lake Macquarie, Swansea | Surveyor-General's Department | 19.9.1999 | | | NSW 4493 | 98 | 2 | 1:10 000 | 152.76mm; Coastal Surveillance 1999 Wybung Head-Black Head-Swansea-Belmont; in range 90-99; NSW 4493 (M2188); colour |

Table A2.4: Aerial Photographs of Brisbane Water Islands.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|--|-------------------------------|-----------|-----------------|---------|--------------------|--------------------|-----|----------|--|
| Brisbane Water | | | | | | | | | |
| 1954 | | | | | | | | | |
| Pelican/ Rileys/ St Huberts Islands, Gosford | Surveyor-General's Department | 16.5.1954 | | | NSW 136 | 5010 | 14 | | 11,000' 10"; Gosford; Lens 157564; b&w |
| Pelican/ Rileys/ St Huberts Islands, Gosford | Surveyor-General's Department | 16.5.1954 | | | NSW 136 | 5012 | 14 | | 11,000' 10"; Gosford; Lens 157564; b&w |
| Pelican/ Rileys/ St Huberts Islands, Gosford | Surveyor-General's Department | ???.1954 | | | NSW 132 | 5052 | 15G | | 11,000' 10"; Gosford; Lens 157564; b&w |
| 1965 | | | | | | | | | |
| Pelican/ Rileys/ St Huberts Islands, Gosford | Surveyor-General's Department | 3.10.1965 | | | NSW 1412 | 5008 | 5 | | 8,350' ASL 114.44mm; Cumberland 1965 Series; b&w |
| 1975 | | | | | | | | | |
| Pelican/ Rileys/ St Huberts Islands, Gosford | Surveyor-General's Department | 4.6.1975 | | | NSW 2317 | 9 | 8 | | 6401m Asl 151.45mm; b&w |
| 1986 | | | | | | | | | |
| Pelican/ Rileys/ St Huberts Islands, Gosford | Crown Copy NSW Lands Photo | 20.8.1986 | | | NSW 3537 | 09 | 5 | 1:16 000 | 2652m ASL 153.10mm; Sydney ISG 1986; NSW 3537 (M1742); colour |
| 1998 | | | | | | | | | |
| Pelican/ Rileys/ St Huberts Islands, Gosford | CaLM Land Information Centre | 30.9.1998 | | | NSW 4454 | 85 | 1 | 1:25 000 | ASL 152.76mm; Sydney; in range 71-91; NSW 4454 (M2136); colour |

Table A2.5: Aerial Photographs of Courangra Point, Hawkesbury River.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|-----------------------------------|-------------------------------|-----------|-----------------|---------|--------------------|--------------------|-----|----------|---|
| Hawkesbury River - Spencer | | | | | | | | | |
| 1954 | | | | | | | | | |
| Spencer, Gosford | Surveyor-General's Department | 19.3.1954 | | | NSW 131 | 5110 | 13G | | 11,000; 10"; Gosford; Lens 157564; b&w |
| Spencer, Gosford | Surveyor-General's Department | 19.3.1954 | | | NSW 131 | 5112 | 13G | | 11,000; 10"; Gosford; Lens 157564; b&w |
| 1966 | | | | | | | | | |
| Spencer, Gosford-Lake Macquarie | Surveyor-General's Department | 8.3.1966 | | | NSW 1439 | 5006 | 11 | | 15,500' ASL 114.44mm; b&w |
| Spencer, Gosford-Lake Macquarie | Surveyor-General's Department | 8.3.1966 | | | NSW 1439 | 5008 | 11 | | 15,500' ASL 114.44mm; b&w |
| 1975 | | | | | | | | | |
| Spencer, Gosford | Surveyor-General's Department | 4.6.1975 | | | NSW 2317 | 13 | 8 | | 6401m ASL 151.45mm; b&w |
| 1986 | | | | | | | | | |
| Spencer | Crown Copy NSW Lands Photo | 20.8.1986 | | | NSW 3536 | 146 | 4 | 1:16 000 | 2652m ASL 153.10mm; Sydney ISG 1986; NSW 3537 (M1742); colour |
| 1994 | | | | | | | | | |
| Spencer, Gosford | CaLM Land Information Centre | 12.9.1994 | | | NSW 4238 | 29 | 13 | 1:25 000 | 4115m ASL 152.7mm; in range 23-41; colour |

Table A2.6: Aerial Photographs of Careel Bay, Pittwater.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|-------------------------------|----------------------------------|-----------|-----------------|---------|--------------------|--------------------|----------|----------|--|
| Pittwater - Careel Bay | | | | | | | | | |
| 1940 | | | | | | | | | |
| Careel Bay, Broken Bay | | 29.9.1940 | 44 | 1 | SVY 3175 | 73 | | | 13,400'; Restricted; b&w |
| 1965 | | | | | | | | | |
| Careel Bay, Cumberland | Land Information Centre | 23.9.1965 | 45 | 11 | NSW 1408 | NSW 1408 5247 | 11 | | 8,350 ASL 114.44mm; Cumberland 1965 Series; NSW 1408/5247; b&w |
| 1974 | | | | | | | | | |
| Careel Bay, Central Coast | Crown Copy NSW Lands Photo Log-E | 19.6.1974 | 45 | 38 | NSW 2236 | NSW 2236 53 | 4 | | 1400m ASL 87.80mm; NSW 2236/53 Central Coast July 1974 (MISC. 883); b&w |
| 1986 | | | | | | | | | |
| Careel Bay, Collaroy - Avalon | NSW Govt. C.M.A. | 18.8.1986 | 45 | 40 | NSW 3533 | NSW 3533 232 | - | 1:10 000 | 1533m ASL 153.10mm; Collaroy-Avalon; NSW 3533 (M1747); colour |
| 1996 | | | | | | | | | |
| Careel Bay, Whale Beach | Land Information Centre | 31.5.1996 | 44 | 115 | NSW 4311 | 0197 | M203 112 | 1:8 000 | 1230m ASL; Run M203112 152.76mm; in range 192-201; C.S. Wybung Head-Pt. Hacking, Whale Beach; NSW 4311 (M2031); colour |

Table A2.7: Aerial Photographs of Towra Point, Botany Bay.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|---------------------------------|-------------------------------|-----------|-----------------|---------|--------------------|--------------------|-----|-------|--|
| Botany Bay - Towra Point | | | | | | | | | |
| 1956 | | | | | | | | | |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5065 | 29 | | 6,400' 115.00mm; Port Hacking; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5048 | 30 | | 6,400' 115.00mm; Port Hacking; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5050 | 30 | | 6,400' 115.00mm; Port Hacking; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5052 | 30 | | 6,400' 115.00mm; Port Hacking; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5147 | 30 | | Cumberland County; Lens 32; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5149 | 30 | | Cumberland County; Lens 32; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5151 | 30 | | Cumberland County; Lens 32; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5153 | 30 | | Cumberland County; Lens 32; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5075 | 31 | | 6,400' 115.00mm; Port Hacking; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 2.1.1956 | | | NSW 235 | 5077 | 31 | | 6,400' 115.00mm; Port Hacking; b&w |
| 1961 | | | | | | | | | |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 834 | 5007 | 44 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 834 | 5009 | 44 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 834 | 5011 | 44 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 834 | 5013 | 44 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 836 | 5029 | 46 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 836 | 5031 | 46 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 1043 | 5160 | 45 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 1043 | 5162 | 45 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| Towra Point, Port Hacking | Surveyor-General's Department | 25.6.1961 | | | NSW 1043 | 5163 | 45 | | 9,200' ASL 209.74mm; Cumberland 1961 Series; b&w |
| 1970 | | | | | | | | | |
| Towra Point, Kurnell | Surveyor-General's Department | 6.7.1970 | | | NSW 1906 | 5198 | 24 | | 7,500 ASL 152.37mm; Cumberland 1970 Series; b&w |
| Towra Point, Kurnell | Surveyor-General's Department | 6.7.1970 | | | NSW 1906 | 5200 | 24 | | 7,500 ASL 152.37mm; Cumberland 1970 Series; b&w |
| Towra Point, Kurnell | Surveyor-General's Department | 6.7.1970 | | | NSW 1906 | 5202 | 24 | | 7,500 ASL 152.37mm; Cumberland 1970 Series; b&w |
| Towra Point, Kurnell | Surveyor-General's Department | 6.7.1970 | | | NSW 1906 | 5204 | 24 | | 7,500 ASL 152.37mm; Cumberland 1970 Series; b&w |
| Towra Point, Kurnell | Surveyor-General's Department | 6.7.1970 | | | NSW 1908 | 5007 | 23 | | 7,500 ASL 152.37mm; Cumberland 1970 Series; b&w |
| Towra Point, Kurnell | Surveyor-General's Department | 6.7.1970 | | | NSW 1908 | 5009 | 23 | | 7,500 ASL 152.37mm; Cumberland 1970 Series; b&w |
| 1983 | | | | | | | | | |

| | | | | | | | | | |
|-----------------------|-------------------------------|-----------|--|--|----------|-----|---|----------|---|
| 1983 | | | | | | | | | |
| Towra Point, Cronulla | C.M.A. Photo | 19.9.1983 | | | NSW 3337 | 272 | 3 | 1:16 000 | 2576m ASL 151.45mm; Harris Forest-Cronulla ISG; NSW3337 (M1548); b&w |
| Towra Point, Cronulla | C.M.A. Photo | 19.9.1983 | | | NSW 3337 | 276 | 3 | 1:16 000 | 2576m ASL 151.45mm; Harris Forest-Cronulla ISG; NSW3337 (M1548); b&w |
| Towra Point, Cronulla | C.M.A. Photo | 19.9.1983 | | | NSW 3337 | 280 | 3 | 1:16 000 | 2576m ASL 151.45mm; Harris Forest-Cronulla ISG; NSW3337 (M1548); b&w |
| Towra Point, Cronulla | C.M.A. Photo | 19.9.1983 | | | NSW 3337 | 284 | 3 | 1:16 000 | 2576m ASL 151.45mm; Harris Forest-Cronulla ISG; NSW3337 (M1548); b&w |
| 1999 | | | | | | | | | |
| Towra Point, Kurnell | Surveyor-General's Department | 20.6.1999 | | | NSW4481 | 131 | 3 | 1:20 000 | 152.76mm; in range 130-136; NSW4481 (M2148); Coastal Surveillance 1998 Wybung Head-Port Hacking; colour |
| Towra Point, Kurnell | Surveyor-General's Department | 20.6.1999 | | | NSW4481 | 132 | 3 | 1:20 000 | 152.76mm; in range 130-136; NSW4481 (M2148); Coastal Surveillance 1998 Wybung Head-Port Hacking; colour |
| Towra Point, Kurnell | Surveyor-General's Department | 20.6.1999 | | | NSW4481 | 133 | 3 | 1:20 000 | 152.76mm; in range 130-136; NSW4481 (M2148); Coastal Surveillance 1998 Wybung Head-Port Hacking; colour |
| Towra Point, Kurnell | Surveyor-General's Department | 20.6.1999 | | | NSW4481 | 134 | 3 | 1:20 000 | 152.76mm; in range 130-136; NSW4481 (M2148); Coastal Surveillance 1998 Wybung Head-Port Hacking; colour |

Table A2.8: Aerial Photographs of Currumbene Creek, Jervis Bay.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|---|-------------------------------|-----------|-----------------|---------|--------------------|--------------------|-----|----------|--|
| Jervis Bay - Currumbene Creek | | | | | | | | | |
| 1949 | | | | | | | | | |
| Currumbene Creek, Jervis Bay, Currarong | | 4.4.1949 | 56 | 29 | SVY 562 | 5085 | 1 | | 25,000' 153.0mm; Restricted; SVY562.156-13/449; in range 5078-5093; Jervis Bay; b&w; 4 photos in the set |
| 1961 | | | | | | | | | |
| Currumbene Creek, Jervis Bay, Currarong | Crown Copy NSW Lands Photo | 21.9.1961 | 56 | 8 | NSW1074 | 5040 | 1 | | 15,200' ASL 114.44mm; Jervis Bay; NSW 1074; b&w |
| 1975 | | | | | | | | | |
| Currumbene Creek, Jervis Bay, Currarong | Crown Copy NSW Lands Photo | 26.2.1975 | 56 | 22 | NSW 2361 | 54 | 1 | | 6401m ASL 151.45mm; Jervis Bay; NSW 2361; b&w |
| 1993 | | | | | | | | | |
| Currumbene Creek, Jervis Bay, Currarong | Surveyor-General's Department | 22.2.1993 | | | NSW 4106 | 117 | 1 | 1:25 000 | 3932m ASL 151.45mm; in range 109-125; Jervis Bay; colour |
| 1997 | | | | | | | | | |
| Currumbene Creek, Jervis Bay | Land Information Centre | 5.1.1997 | | | NSW 4337 | 86 | 1 | 1:50 000 | 8188m ASL 152.76mm; Jervis Bay; in range 82-89; NSW 4337 (M2053); colour |

Table A2.9: Aerial Photographs of Cararma Inlet, Jervis Bay.

| Location | Copyright | Date | DLWC Sector No. | Set No. | Photo No. (Series) | Photo No. (Indiv.) | Run | Scale | Miscellaneous |
|--------------------------------------|-------------------------------|------------|-----------------|---------|--------------------|--------------------|-----------|----------|---|
| Jervis Bay - Cararma Inlet | | | | | | | | | |
| 1948 | | | | | | | | | |
| Cararma Inlet, Jervis Bay, Currarong | | 2.12.1948 | 56 | 5 | SVY 492 | 5014 | C/ KEY | | SVY 492. I56-13; Restricted; in range 5012-5024; Jervis Bay-Nowra; 15,000'; b&w |
| 1961 | | | | | | | | | |
| Cararma Inlet, Jervis Bay, Currarong | Crown Copy NSW Lands Photo | 21.9.1961 | 56 | 8 | NSW 1074 | 5051 | 6N | | 15,200' ASL 114.44mm; NSW 1074; b&w |
| 1974 | | | | | | | | | |
| Cararma Inlet, Jervis Bay, Kiama | Crown Copy NSW Lands Photo | 29.12.1974 | | | NSW 2288 | 3 | 8 | | 6401m ASL 151.45mm; Kiama NSW 2288; b&w |
| 1981 | | | | | | | | | |
| Cararma Inlet, Jervis Bay, Currarong | Crown Copy NSW Lands Photo | 28.6.1981 | | | NSW 2928 | 73 | 60 | 1:25 000 | 3810m ASL 152.02mm; NSW Coastal Wetlands; NSW 2928/73 (MISC. 1309); colour |
| 1997 | | | | | | | | | |
| Cararma Inlet, Jervis Bay, Kiama | Land Information Department | 20.1.1997 | | | NSW 4344 | 34 | 7 | 1:50 000 | 8188m ASL 152.76mm; in range 28-34; Kiama; NSW 4344 (M2053); colour |
| 1999 | | | | | | | | | |
| Cararma Inlet, Jervis Bay, Currarong | Surveyor-General's Department | 10.3.1999 | 55 | 104 | NSW 4474 | 101 | 3 | 1:12 000 | 152.76mm; in range 98-104; Cabbage Tree Swamp; NSW4474 (M2167); colour |

Appendix 3: Instructions for Coastal Wetland Habitat Dynamics Analyses Using the ArcView® GIS 3.2

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Data Input

Scanning the image

Click onto the *HP scanner icon*, and scan the aerial photograph at 300 dpi, 'Best Colour Photograph'. Use the border tool to outline the relevant section of the photograph. Save the image as a JPEG file (*.jpg or *.jpeg). A JPEG is a standard compression technique for storing full colour and grey scale images (ESRI, 1996).

Starting ArcView and its Extensions

Open the ArcView program by navigating through the ESRI icon until you find the icon *ArcView® GIS 3.2*. Start with a *Blank Project* and open a *New View*. The first thing to do is ensure that the *Image Analysis* extension is activated. To do this:

1. Go to *File ► Extensions*.
2. Put a tick next to the *Image Analysis* extension and select *OK*.

Also, ensure that you have set the correct projection. To do this:

1. Go to *View ► Properties*. The *View Properties* dialog box will be displayed.
2. Press the *Projection* button. *ArcView®* displays the *Projection Properties* dialog box.
3. Choose the projection you want to use. In the case of this study, *UTM 1983* was used. Also select the projection's zone, which in this case was *Zone 56*.
4. Set the other two parameters (*Map Units*, *Distance Units*) both to *metres*.
5. Press *OK* on the *View Properties* dialog box. *ArcView®* redraws the view using the new projection.

Also ensure that the *Spatial Analyst* extension is also activated for use later. Set both *Image Analysis* and *Spatial Analyst* as defaults.

A map projection is a mathematical formula used for representing the curved surface of the earth on a flat map or on your screen. The default projection used in *ArcView®* is decimal degrees or Latitude and Longitude Co-ordinates. Since we want to make accurate measurements of shape, area, distance and direction from our image, we need to specify a co-ordinate system that allows these measurements in suitable units (i.e. measurements in metres rather than degrees). Universal Transverse Mercator is a good international co-ordinate system for use within Australia. It is important that the correct zone is selected. For South-east Australia, it is generally Zone 56 from Sydney until Bega where it changes to Zone 55.

- *Important: Ensure you do this at the beginning of any activity in ArcView®, or your time and effort could be lost.*

Importing the Image into Arc View®

To import the *.jpeg file that you have scanned:

1. Go to *File* ► *Import*.
2. Click the *List of Files of Type* drop-down menu and select the file type *County DOQ (JPEG)*.
3. In the *Select File to Import* dialogue box, use your mouse to navigate to the directory where you have saved your scanned image and select the file that you have scanned from the list of *File Names*. Press *OK*.

After some processing time, the imported image and a list of 3 bands will appear in the *View's Table of Contents* on the left side. Tick the box next to imported image, and the image will appear in the view.

- *NB: The image colours may appear different to what you have scanned. These can be adjusted later.*

Saving the Imported Image

First you have to make the imported image active by ticking the *imported image* box in the *View's Table of Contents* on the left side. A dashed line will appear around the image name – this indicates the theme is active and editable.

1. Go to *Theme* ► *Save Image As*.
2. In the *Save As* dialogue, navigate to the directory that you wish to save the image in.
3. Click the *List of Files* drop-down menu and select the file type *Imagine Image Format*.
4. Type the name that you want to save the image as in the *File Name* text box and select *OK*.

After a few moments you will be asked whether to add the new image to the view. Select *Yes* and the image name will appear in the *View's Table of Contents* on the left side. Tick the box to make the newly saved image appear in the view.

Deleting the Imported Image

The imported image should still be active and have an outline around the title. If not:

1. Click on *Imported Image* in the *View's Table of Contents* on the left side.
2. Go to *Edit* ► *Delete Themes*, then select *Yes* when asked about deleting the imported image theme.

Georectification and Registering the Image to Australian Map Grid (AMG) Co-ordinates and from Image to Image

Specifying a Map Projection

Once again, the map projection must be confirmed before you begin the georectification process. To do this:

1. From the *View* menu choose *Properties*. The *View Properties* dialog box will be displayed.
2. Press the *Projection* button. *ArcView*® displays the *Projection properties* dialog box.
3. Choose the projection you want to use. In the case of this study, *UTM 1983* was used. Also select the projection's zone, which in this case was *Zone 56*.
4. Set the other two parameters (*Map Units*, *Distance Units*) both to *metres*.
5. Press *OK* on the *View Properties* dialog box. *ArcView*® redraws the view using the new projection.

Ground Control Points

We firstly need to identify points common to the scanned image (aerial photograph) and the topographic map. These are known as ground control points (GCPs). Ideally these will be fixed features that are easily identifiable, such as road intersections and boat ramps. Control points are used in image rectification to transform an image from a pixel coordinate system to a map coordinate system. The complexity of the calculations required to transform an image from the pixel coordinate system to the map coordinate system is called order of transformation. The number of control point pairs you collect determines the order of transformation. You need three sets of control points for a first order transformation and six sets of control points for a second order transformation. The *ArcView*® *Image Analysis* extension uses first or second order transformations only.

To do this:

1. Make sure that the saved image is active by ticking its box in the *View's Table of Contents* on the left side.
2. Go to *View ► Align*. You are now ready to identify your first GCP.
3. Move the cursor over the image until you find a suitable GCP. You may need to use the *zoom to image resolution* feature to see the area more clearly. To do this click the right mouse button and select *Zoom to Image Resolution*.
4. Click on the GCP that you have identified. This point is the “*from point*”.
5. You will notice a rubber-banding line from your cursor to the first GCP. This indicates that *ArcView*® is waiting for a “*to point*”. Click the right mouse button and select *enter* to co-ordinate. A “*to point*” dialogue box will appear and you can enter the corresponding X and Y map co-ordinates and select *OK*.
6. You are now ready to enter your second GCP. Move your cursor over the image until you identify your second GCP.
7. Click on the GCP.
8. Again you will notice that *ArcView*® is waiting for a “*to point*”. Click the right mouse button and select *Enter to Point*. Enter the corresponding X and Y map co-ordinates into the dialogue box and select *OK*.
9. Repeat this process until 6 GCPs have been identified.

- *NB: Make sure that the co-ordinates are entered in metres. Otherwise the projection will have to be adjusted to suit the units.*

After 4 GCPs are collected an RMS error, or root mean squares error, can be determined by clicking the right mouse button and selecting *Display Link Error*. The total RMS error will appear in the status area of the *ArcView*® window. Make a note of the RMS for each image (based on at least 6 GCPs). If the RMS error is 5, for example, it means the rectified pixel is within 5 pixels of the desired location.

Saving Control Points and Creating a New Image

By saving the control points and subsequently making a copy of the original scanned image, a process known as resampling, you will save a copy of the altered image without changing the original image. To do this:

1. Again, ensure that the saved image is active by ticking the name of the image in the *View's Table of Contents* on the left side.
2. Go to *Theme ► Save Image As*.
3. In the *Save Control Points* dialogue box select *Yes*.
4. Then navigate to the place that you want the GCPs file to be saved.
5. Type the name of the GCPs file in the *File Name* text box and click *OK*.
6. In the *Add to View* dialogue box select *Yes* and a new control points theme will appear in the view.
7. In the *Save As* dialogue that appears, navigate to the directory that you want to save the rectified image in.
8. Select *IMAGINE* from the *List Files of Type* drop-down menu.
9. Type the name of the rectified image in the *File Name* text box and select *OK*.
10. In the *Add to View* dialogue, select *Yes* and the rectified image will appear in the view.

- *NB: You may wish to delete the unrectified image from the view. To do this, click on imported image in the View's Table of Contents on the left side. Go to Edit ► Delete Themes, then select Yes when asked about deleting the imported image theme.*

Image to Image Rectification

Scanning the image

Click onto the HP scanner icon, and scan the aerial photograph at 300 dpi. Use the border tool to outline the relevant section of the photograph. Save the image as a **.jpg* or **.jpeg* file.

Importing the Image into ArcView®

To import the **.jpeg* file that you have scanned:

1. Go to *File ► Import*.

2. Click the *List of Files of Type* drop-down menu and select the file type *County DOQ (JPEG)*.
3. In the *Select File to Import* dialogue box, use your mouse to navigate to the directory where you have saved your scanned image and select the file that you have scanned from the list of *File Names*. Press *OK*.

After some processing time, the imported image and a list of 3 bands will appear in the *View's Table of Contents* on the left side. Tick the box next to *imported image*, and the image will appear in the view.

- *NB: the image colours may appear different to what you have scanned, these can be adjusted later*

Saving the Imported Image

First you have to make the imported image active by ticking the *imported image* box in the *View's Table of Contents* on the left side. A dashed line will appear around the image name – this indicates the theme is active and editable.

1. Go to *Theme ► Save Image As*.
2. In the *Save As* dialogue, navigate to the directory that you wish to save the image in.
3. Click the *List of Files* drop-down menu and select the file type *Imagine Image Format*.
4. Type the name that you want to save the image as in the *File Name* text box and select *OK*.

After a few moments you will be asked whether to add the new image to the view. Select *Yes* and the image name will appear in the *View's Table of Contents* on the left side. Tick the box to make the newly saved image appear in the view.

Deleting the Imported Image

The imported image should still be active and have an outline around the title. If not, click on *Imported Image* in the *View's Table of Contents* on the left side.

1. Go to *Edit ► Delete Themes*, then select *Yes* when asked about deleting the imported image theme.

Aligning the Two Images

Initially you will not be able to see both images at once, and they need to be aligned. You use the *Align* tool when you have loaded two themes of overlapping geographic extent such as each of the periodical aerial photographs from which you are digitising habitat areas. When you are conducting Image to Image Rectification, one of the images has already been registered.

To start:

1. Click the *Align* tool to display two themes together. Ensure that the unrectified image (the one to be aligned) is active by ticking the image name box. We

firstly need to identify points common to both images (GCPs). Ideally these will be fixed features that are easily identifiable, such as road intersections and boat ramps.

2. Press the *Align Tool* button on the toolbar and click your mouse on the first GCP on the unrectified image.
3. Click a known point on the image. A rubber-banding line appears indicating that you are to click the corresponding point in the reference theme. This creates the “*from point*”.
4. Click the right mouse button and select *Image to Bottom*. This will bring the rectified image to the top.
5. Use the *Pan* feature when clicking the right mouse button to find the same place in the rectified image.
6. Click the left button on the mouse to create a “*to point*”.
7. Click the right mouse button and choose *Image to Top* to bring the unrectified image to the top.
8. Identify the second GCP and click the left mouse button on this location.
9. Again click the right mouse button and select *Image to Bottom* so that the rectified image is visible.
10. Use the *Pan* to find the same GCP and click the left mouse button to create a “*to point*”.
11. Continue this process until a minimum of 4 GCPs is selected (although a minimum of 6 GCPs is recommended in the Protocol). You may want to re-do GCPs which make your RMS error unacceptably high.
12. You are now ready to save the newly aligned image.

Saving Control Points and Creating a New Image

By saving the control points and subsequently making a copy of the original scanned image, a process known as resampling, you will save a copy of the altered image without changing the original image.

Again, ensure that the saved image is active by ticking the name of the image box in the *View's Table of Contents* on the left side.

1. Go to *Theme ► Save Image As*.
 2. In the *Save Control Points* dialogue box select *Yes*.
 3. Then navigate to the place that you want the GCPs file to be saved.
 4. Type the name of the GCPs file in the *File Name* text box and click *OK*.
 5. In the *Add to View* dialogue box select *Yes* and a new control points theme will appear in the view.
 6. In the *Save As* dialogue that appears, navigate to the directory that you want to save the rectified image in.
 7. Select *IMAGINE* from the *List Files of Type* drop-down menu.
 8. Type the name of the rectified image in the *File Name* text box and select *OK*.
 9. In the *Add to View* dialogue, select *Yes* and the rectified image will appear in the view.
- *NB: You may wish to delete the unrectified image from the view. To do this, click on imported image on the left side of the screen. Go to Edit ► Delete Themes, then select Yes when asked about deleting the imported image theme.*

Saving the Project

A *Project* is a file in which you store the work you do with *ArcView*®. A *Project* contains all the views, tables, charts, layouts and scripts that you use for a particular *ArcView*® application or set of related applications. In this way your work is stored in one convenient place.

Saving a *Project* enables you to re-open an *ArcView*® project to the status at which you last left it.

1. Go to *File* ► *Save Project As*.
2. In the *Save Project As* dialogue box navigate through to the place where you want to save the project.
3. Give the project an appropriate *File Name* and select *OK*.

Opening a Project

After exiting *ArcView*® a *Project* may be reopened by:

1. Selecting the *Open an Existing Project* on the *Welcome to ArcView*® *GIS* dialogue box, then pressing *OK*.
2. Navigate through the directories until you find the place where you saved the *Project*.
3. Select the *Project* you wish to open and press *OK*. The *Project* will then appear on the screen as you last left it.

Adjusting the Appearance of the Georectified Image

With the *Image Analysis* extension you have the opportunity to adjust the appearance of an image so that the image can be displayed in different ways. It enables you to change the brightness and contrast of an image and apply different stretches to the image to emphasise different features or de-emphasise other features.

To adjust the appearance of an image, double-click on the image name on the left side and the *Legend Editor* box will appear on the screen. By clicking on the *Legend Type* drop-down menu you can change the appearance of the image from colour to black and white by selecting *Multi-Band* or *Single Band* respectively. The *Brightness* and *Contrast* can be adjusted by sliding the toggles from left to right. You can change the combination of data bands assigned to Red, Green and Blue to display data in different ways. Clicking on the Red Band, Green Band and Blue Band drop-down menus and changing between Layers 1, 2 and 3 can do this. The best option for this particular project is to have the Red Band as Layer 1, the Green Band as Layer 2 and the Blue Band as Layer 3, so that the image on the screen is as close as possible to the actual aerial photograph.

The range of raw data file values that makes up an image is usually not the same as the range of brightness values of the display. The image can be enhanced by

spreading the range of raw data values over the full range of brightness values of the display. To do this a stretch can be applied to the data. The stretches that can be applied to data include: Standard Deviations, Histogram Equalise, Minimum-Maximum, and Level Slice.

Additionally, you have the option to not apply a stretch to the original image. This will make it look as close to the original aerial photograph as possible.

To adjust the *Stretches*, click on the *Stretch* drop-down menu and select the appropriate stretch.

For this particular project the *Histogram Equalize* option is the most appropriate. This will redistribute the data so that there is roughly the same number of data points in each display value bin. This makes it easier to distinguish between habitats.

Once all changes have been made select the *Apply* button, and close the *Legend Editor* box.

Creating Themes and Digitising Boundaries

Creating a New Theme

To create a new theme:

1. Go to *View ► New Theme*.
2. In the *New Theme* dialogue box that appears choose the type of features you want your new theme to contain. Selecting the Feature Type that you wish to make the theme in the drop-down menu does this. For example, for mapping vegetation units, the *Feature Type* would be *Polygon*, and the dowel tidal height data used later would be a *Line*. Select *OK*.
3. In the *New Theme* dialogue box, navigate to the directory you wish to save the new theme in, type in the file name, and select *OK*.
4. Then the new theme will appear in the *View's Table of Contents* on the left side with a dashed line around the ticked box, which indicates it is ready for editing. You are now ready to begin digitising.

Digitising Boundaries and Polygons

Firstly ensure that the theme is editable and has a dashed line around the ticked box. If the theme is not editable, make the theme active by double clicking on the theme name. Before you start creating polygons, decide whether they should be perfectly aligned. As it is important not to have gaps or overlap, you must set the *snapping environment*. If you create a polygon near another polygon that is within the snap tolerance, this new polygon will get snapped to the other polygon, eliminating gaps and overlap.

Snapping

When you use *Snapping*, ArcView® moves the vertices of a feature to align with the vertices of another feature that are within a specified distance. This specified distance is known as the *Snap Tolerance*. Initially you need to set the *Snapping Environment*.

1. Ensure that a *shape file* (polygon, line or point) is editable and has the dashed line around the ticked box. If it is not editable make sure the *Theme* is active by pressing on the *Theme* name, then go to *Theme ► Start Editing*. A dashed line will then appear around the ticked box.
2. Click on the right mouse button in the *View* and select *Enable Interactive Snapping*. A *Snap* button will then appear on the toolbar.
3. To set the *Snap Tolerance*, press the *Snap* button and drag out a circle of a particular (user-specified) radius, as shown in the status bar.
4. To snap the vertex of one polygon to another while digitising, select the *Draw Line to Append Polygon* from the *Draw* palette.
5. Click on the vertex where you want the polygon to begin.
6. Draw the independent boundary until you come to the vertex of the shared boundary you want to snap to.
7. Double click at this vertex and the polygon will then close by following the boundary of the adjacent polygon.

Digitising

1. Go to *Theme ► Start Editing*.
2. Click the drawing tool palette on the toolbar and scroll down to the appropriate shape (which is called *Draw Polygon*).
3. In the *View*, click the left mouse button where you want the polygon to start, click each vertex around the polygon's boundary, and then double click the final vertex. Draw your polygon by clicking around the boundary of the feature you are digitising. When you create a new polygon feature in the theme, a corresponding new record is automatically added to the theme's attribute table. While you are editing a theme, its table is also in edit mode. You can add data for this record anytime by entering new values in the table.

If you have set the interactive snap environment, then while you are adding your polygon, you can hold down the right mouse button to display the popup menu, and choose one of the snapping options from this menu (i.e. *General Snapping*) to control how the next vertex you add to the boundary will be snapped to existing polygons in the theme.

You are now ready to develop your attributes table.

1. Click on *Open Theme Table* on the toolbar. The attributes will show one *record* and two *field names* (*Shape* and *ID*).
2. To add more field names go to *Edit ► Add Field*.
3. In the *Field Definition* dialogue type in the name of the field (i.e. 'vegetation category', 'area', or 'perimeter'), and select the *Field Type* from the drop-down menu. If you select the *Number Field Type* (i.e. for 'area' and 'perimeter') you will have to type in a field width and the number of decimal places that the field displays. If you select a *String Field Type* (i.e. 'vegetation category') you will again have to type in the field width. The other two field types are *Boolean* and *Date*.

4. Continue adding more records in this manner until you are happy with the setup of the attributes table.

Measurements can be made as you progress, to help determine the distance between vegetation units in order to determine what category an area fits into (i.e. saltmarsh, mixed or mangrove).

To add the information related to the digitised polygon, press the *Edit* button on the toolbar and click in the cell that you want to edit. You can now type in that cell to fill in the relevant information (i.e. vegetation category). Continue this process until all the information is supplied for the polygon.

You are now ready to add another polygon.

1. Go to *Window* ► *View 1*. The screen will then switch back to the *View* screen.
2. Go to the *draw button* and scroll down to the appropriate *shape* (which is called *Draw Polygon*).
3. Begin drawing your polygon by clicking around the boundary of the feature you are digitising, and double click to close the polygon.
4. You are now ready to edit your attributes table. Go to *Window* ► *Attribute Table* of the editable theme.
5. Clicking on the *Open Attributes Table* icon on the toolbar can also do this.
6. Again select the *Edit* button on the toolbar and add the relevant information to the cells.
7. Continue to add polygons and edit the *Attribute Table* until you are ready to save the work.

Saving Themes

1. Go to *Attributes* ► *Table* ► *Stop Editing*.
2. In the *Stop Editing* dialogue box select *Yes* to save edits.
3. Then switch to the *View* by going to the *Window* field on the menu bar and selecting the appropriate view. The dashed line around the ticked box should have disappeared, indicating that the theme is saved and is no longer editable.

Enhancing the Visual Attributes of Your New Theme

1. Double click on the *Theme Name* in the *View's Table of Contents* on the left side and the *Legend Editor* box should appear. You then have the option of selecting the *Legend Type* from the drop-down menu. *Single Symbol* displays all polygons, regardless of attribute type, as a single colour. The *Unique Value* legend type enables you to display the polygons based on an attribute, so that different attributes are displayed in different colours. For example, different vegetation types could be displayed in different shades of green. If you choose *Unique Value* from the *Legend Type* drop-down menu, you will then have to select a field from the *Values Field* drop-down menu, to identify the field upon which a different colour is used to symbolise each value in that particular field. Selecting a predefined colour scheme from the *Colour Schemes* drop-down menu may change the colour scheme of the theme. Alternatively, you can

customise the colour scheme by double clicking on the symbol you wish to customise. The *Fill Palette* will then appear on the screen.

2. From the options you are presented with choose an appropriate fill pattern.
3. Then select the *Colour* palette from this particular toolbar, and select an appropriate colour.
4. From the colour drop-down menu select *Foreground* and select an appropriate colour, likewise with *Background* and *Outline* (and *Text* if required).
5. Close the *Colour* palette and press the *Apply* button on the *Legend Editor*, then close the *Legend Editor* box.

Calculating Areas

Setting the Script Default

1. If the *A* button does not appear by default on the toolbar, shrink the *View* facility, until you come to the *Project Page*.
2. Select the *Scripts* button on the left hand side and press *New* on this toolbar to create a new script.
3. A textbox will appear entitled *Script1*. Enlarge, and then press *Load Text File* from the toolbar.
4. Navigate through to c:\esri\av_gis30\arcview\samples\scripts\calcapl.ave. The *Script* will then appear on the screen.
5. By pressing the *Compile* button (a tick) on the toolbar, the *Script* will become readable by the computer.
6. The *Script* window can then be closed.
7. Open the original *View* and double click on an empty spot on the toolbar. A *Customize* dialogue box will appear.
8. From the *Type* drop down menu choose *View*.
9. From the *Category* drop down menu choose *Buttons*, and then press the *New* button. This allows you to add a new button to the toolbar.
10. Double click on *Click*, and scroll down to and select *Script1* from the *Script Manager* dialogue box, and press *OK*.
11. Double click on *Icon* and select the icon you wish to be used on the toolbar (in this case, *A*), and then press the *Make Default* button and close the *Customise Dialogue* box.

If the *A* button does appear by default on the toolbar, ignore the previous two paragraphs.

Calculating Individual Areas (i.e. by individual polygon)

1. Activate the *Theme* of the area you wish to calculate, then press the *A* button on the toolbar.
2. Then press the *Open Theme* button on the toolbar, and you will see two new fields have been added, *Area* and *Perimeter*. These fields will calculate the area and perimeter in the units specified by the *Projection* earlier in the work.

Calculating Categorised Areas (i.e. by habitat type or attribute)

1. Open the *Attribute Table* of the *Theme* you want to calculate areas of by pressing the *Open Theme* button on the toolbar.
2. Make the field active that you want to categorise the areas by (i.e. attribute) by pressing on the field name.
3. Press the *Summarise* button on the toolbar and navigate to where you wish to save the *Summary Table*. Specify the name of this new file and where you want to save it.
4. From the *Field* drop down menu select *Area*.
5. From the *Summarise By* drop down menu select *Sum*, press the *Add* button, and *Sum Area* will appear on the right hand side. Press *OK*. A new table will appear which will summarise the area of the different attributes.

Each *Theme* has 3 file types associated with it, with the extensions .shp, .shx, and .dbf., the last of which can be viewed and manipulated in Excel, once it has been exported as a *.txt file. To export a table from the *Summarised Areas* tool:

1. With the *Summarised Areas* table open, go to *Edit* ► *Select All*. This will highlight the whole table.
2. From the *Summarise Areas Results* dialog, click the *Export to Table* button.
3. Type the file name of your choice (e.g. test86-96.txt) ► *OK* in the *Export Table to Text File* dialog.
4. Close the *Summarise Areas Results* dialog by clicking *Close*.

Analysis of Areas of Habitat Change

Consolidation of Habitat Categories

In order to determine habitat change from one date to another, each individual theme must be altered from the original data set. Check that the *Spatial Analyst* extension is still selected, following the previous instructions. *Spatial Analyst* facilitates the conversion of feature themes to cell-based raster data (grid themes), contouring, Boolean query on grid themes, and grid classification and display.

- *NB: Before proceeding with this step, it is important that each of the original themes, containing individual polygons, be copied and saved in either a different directory or on a separate disk. This is because this consolidation of habitat categories process saves over the original files that delineate individual polygons, and there is no going back.*

The first step is to consolidate the habitat categories in each map. For example, each individual mangrove polygon will be combined to effectively form one polygon. In order to do this, the appropriate theme must be opened, having ensured that the *View Properties* have been set: *Map Units: Meters*, *Distance Units: Metres*, and the *Projection* at *UTM-1983, Zone 56*.

1. Go to *Theme* ► *Start Editing* to make the theme editable.
2. In order to consolidate each habitat category, select the *Query Builder* (a hammer with a question mark) icon on the toolbar.

3. In the *Field* field, double click on 'Veg', then double click on '=' in the centre, then double click on the value (i.e. habitat type) in the right field. This will be shown in the bottom field as:

([Veg] = ["mangrove"])

4. Following this, click on *New Set* to the right. Close the box.
 5. Move the cursor to *Edit* ► *Combine*.
 6. Move to the *Attribute Table*, and you will notice that the last row is now blank. Fill this field with the name of the habitat category that has just been combined, i.e. 'mangrove'.
 7. Repeat this for each habitat category.
- *Note that if there is a problem with this process, it is useful to skip between the View and Attribute Table. Once completed, go to Theme ► Stop Editing, and save.*

The theme must then be converted from a vector image to a raster image, in order to compare habitat change between each theme's grids.

1. Click on the feature theme you want to convert to a grid theme.
 2. Go to *Theme* ► *Start Editing*.
 3. Go to *Theme* ► *Convert to Grid*. If the *View*'s analysis properties haven't been set to a specific value, then you'll be prompted to set the extent and cell size for the output grid theme. Do so in the *Conversion Extent* dialog (i.e. 'Same as Display') and press *OK*.
 4. In the *Conversion Field* dialog, choose a field in the feature theme that will be used to give values to the cells in the output grid theme (i.e. 'Veg'). Press *OK*.
 5. Save the image with a new, yet related name, for example, save the 1996 habitat theme as 'test96grid'. A grid theme represents a geographic layer where space is partitioned into square cells in a view. Each cell stores a numeric data value that conveys information about the geographic layer it represents. A grid theme created out of integer values (as in this project) can have an associated table that summarised the attributes it contains. Cells that have the same value will have the same attributes. A grid theme merely points to the geographic data it represents; it does not contain the data itself.
 6. Choose to add the new grid to the *View*.
- *NB: Save this file at the very top of C: drive. The Spatial and 3D Analysts have the ability to create grid data sets and work with them. A grid data set is stored in a directory called a workspace. Each grid data set is stored as a separate directory with associated tables and files that contain specific information about the grid. Each grid data set also stores some files in an INFO directory found in the workspace. All output grid data sets are created in the project's working directory. By default this is the user's home directory and can be set using the Project Properties dialog or by choosing Set Working Directory from the View window's File menu. It has been found that this should only be done in the C: drive.*

Once saved:

1. In the *Conversion Extent* box select *Same as Display* in the drop-down menu and select *OK*.
2. Then in the *Conversion Field* box select *Veg*.
3. Follow the *Convert to Grid* box prompts, by selecting *Yes* when it asks you to *Add grid as theme to the View?*
4. Go to *Theme ► Stop Editing*.

Start editing the other theme, and follow the same steps as above, but:

1. In the *Conversion Extent* box change the *Output Grid Extent* drop down menu to *Same as testgrid96*. This ensures that the pixel sizes in the grid match.
2. Go to *Theme ► Stop Editing*.
3. For each consecutive theme, select *Same as [the first one]* to ensure that the grids are of equal size in order for the software to compare habitat change on a raster-by-raster basis. Un-tick each of the original shape files, and tick each of the new grids, i.e. 'testgrid96' and 'testgrid86'.

Once this has been completed, it is necessary to make some notes as to *ArcView*®'s numeric classification of each habitat category. To do so, double click on the grid theme box on the left hand side, i.e. 'test96grid'. This will open the attribute table. Make a note of the classifications. Do the same for the map to which this theme is being compared, i.e. 'test86grid'. One of these themes will have to be reclassified, in order to determine new 'habitat change categories'. This is done by assigning new values to this reclassified theme. Such a table, following the steps in this paragraph, should look as follows:

| value | 96grid | value | 86grid | new value for 86grid |
|-------|-------------|-------|-------------|----------------------|
| 1 | Mangrove | 1 | Mangrove | 10 |
| 2 | Mixed | 2 | Mixed | 20 |
| 3 | Reclaimed | 3 | Reclaimed | 30 |
| 4 | Saltmarsh | 4 | Saltmarsh | 40 |
| 5 | Terrestrial | 5 | Terrestrial | 50 |
| 6 | Catchment | 6 | Catchment | 60 |
| 7 | Waterway | 7 | Waterway | 70 |

This table should be prepared as a note for the operator, and is not entered into the program in this form. The values and habitat categories will not always correlate from grid to grid, but the map calculation to follow will pick up on this.

A key decision rule in this process was always to reclassify the older theme, allowing the most recent theme to remain the same.

Once these notes are made, activate theme being changed (i.e. 86grid):

1. Go to *Analysis ► Reclassify*, and then select *OK*.
2. In the right hand column, under *New Value*, change the numbers to the new values, as in the right hand column of the table above. This will create a new grid for 'test86grid', i.e. 'new test86grid'.
3. Tick this and de-tick the original 'test86grid.'

It is at this point that the *Map Calculator* is used to determine habitat (grid) change:

1. Activate both 'test96grid' and 'reclass of test86grid' (by holding the *Shift* key).
2. Go to *Analysis ► Map Calculator*. The *Map Calculator* dialog aids in the creation of an expression that produces a new output grid theme. The expression can be based on a single grid theme or multiple grid themes (as in this case). To aid in the creation of the expression, there are five groups of inputs in the *Map Calculator* dialog. The first is the *Layers* scrolling list which identifies the available grid layers in the active view; the second, arithmetic buttons; the third, a keypad of numbers; the fourth, a group of relational and Boolean operators; and the fifth, a series of mathematical functions.
3. To do this, you are going to subtract the reclassified theme (i.e. 'new test86grid'), from the most recent theme (i.e. 'test96grid').
4. Double click on a layer from the *Layers* scrolling list (i.e. 'reclass of test86grid', the reclassified and older theme).
5. Choose an arithmetic operator (i.e. '-').
6. Double click on the other appropriate layer from the *Layers* scrolling list (i.e. 'test96grid', the most recent, original theme).
7. The *Map Calculator* dialog should look like:

([Reclass of test86grid] – test96grid)

8. Select *Evaluate*, and immediately go to *Theme ► Save Dataset*, and save once again at the top of the C: drive. Save the new grid with an appropriate title, such as 'reclass86-96'.

De-tick the two grid themes, and activate the reclassified grid, i.e. 'reclass86-96':

1. Selected the grid's attribute table.
2. Go to *Table ► Start Editing*.
3. To add a new field, i.e. 'change', go to *Edit ► Add Field*.
4. In the *Field Definition* box add the label 'Change' in the *Name* field, change the *Type* to *String* in the drop-down menu, and make the *Width* 30, then select *OK*.

The new classification system, of habitat change, needs to be determined according to the notes previously tabulated. This is done by subtracting the value for each habitat type in 'test96grid' from the new value assigned to each habitat type in 'test86grid'. For example, based on the information in the previous table, this table can be created as follows:

| Value | Count | NewField1 |
|-------|-------|-------------------------|
| 3 | | Mangrove to waterway |
| 4 | | Mangrove to catchment |
| 5 | | Mangrove to terrestrial |
| 6 | | Mangrove to saltmarsh |
| 7 | | Mangrove to reclaimed |
| 8 | | Mangrove to mixed |
| 9 | | Mangrove to mangrove |
| 14 | | Mixed to catchment |
| 15 | | Mixed to terrestrial |
| 16 | | Mixed to saltmarsh |
| 18 | | Mixed to mixed |
| 19 | | Mixed to mangrove |
| 24 | | Reclaimed to catchment |
| ... | | ... |

This needs to be continued until new classifications are assigned to all the values. Once finished:

1. Go to *Table* ► *Stop Editing*.
2. In the *Save Edits?* box, select *Yes*.
3. Close the *Attribute Table*, double click on the active reclassified grid (i.e. ‘Map Calculation 1’) to open the *Legend Editor*.
4. In the *Legend Type* drop down menu, select *Unique Value*.
5. In the *Values Field* drop down menu, select *New Field 1*, which is a reflection of the habitat change classifications you just assigned. Select *Apply*. This provides the map of areas of habitat change. *Unique Value* maps display data values such that the symbol for one value is no more or less prominent than the symbols for any other value (i.e. best for categorical maps, such as these).
6. Some cosmetic tips are to remove the black boundary on each legend classification, and to make categories such as ‘mangrove to mangrove’ transparent, as there has actually been no habitat change in such areas.

Calculating Areas of Habitat Change

This is similar to calculating areas of habitat types. Keep open the previous grid of habitat change. This needs to be converted back to a vector map. To do this:

1. Click on the name of the theme you want to convert to make it active.
2. Go to *Theme* ► *Convert to Shapefile*.
3. In the dialog that appears, specify a name and location for the shapefile, such as ‘86-96.shp’, and press *OK*.

This allows you to convert a grid theme to a feature theme so that you can work with the raster data in vector format. By default, the shapefile that is created is in the same map units and coordinate system as the data source of the theme you converted. If your view is projected (as ours is), you will be prompted if you want the output shapefile to be in projected units or in the same units as the data source.

1. Follow the prompts in the *Convert to Shapefile* box by selecting *Yes*.
2. Tick this new theme, and un-tick all others.
3. Open this new theme’s *Attribute Table* and reclassify the new values, as before, although this will have to be done for multiples of each value (representing

multiples of new polygons of change), whereas previously there was just one instance of each new value to label.

4. Once this is completed, go to *Theme* ► *Stop Editing* and save, then close.
5. Double click on the theme's box on the left to open the *Legend Editor*.
6. In the *Legend Type* drop down menu, select *Unique Value*.
7. In the *Values Field* drop down menu, select *New Field 1*, which is a reflection of the habitat change classifications you just assigned. Select *Apply*. This provides the final shapefile (vector) map of areas of habitat change. Repeat the cosmetic tips from above.

Repeat the process previously used to calculate areas. That is:

Setting the Script Default

1. If the *A* button does not appear by default on the toolbar, shrink the *View* facility, until you come to the *Project Page*.
2. If the *A* button does not appear by default on the toolbar, shrink the *View* facility, until you come to the *Project Page*.
3. Select the *Scripts* button on the left hand side and press *New* on this toolbar to create a new script.
4. A textbox will appear entitled *Script1*. Enlarge, and then press *Load Text File* from the toolbar.
5. Navigate through to c:\esri\av_gis30\arcview\samples\scripts\calcapl.ave. The *Script* will then appear on the screen.
6. By pressing the *Compile* button (a tick) on the toolbar, the *Script* will become readable by the computer.
7. The *Script* window can then be closed.
8. Open the original *View* and double click on an empty spot on the toolbar.
9. A *Customize* dialogue box will appear. From the *Type* drop down menu choose *View*. From the *Category* drop down menu choose *Buttons*, and then press the *New* button. This allows you to add a new button to the toolbar.
10. Double click on *Click*, and scroll down to and select *Script1* from the *Script Manager* dialogue box, and press *OK*.
11. Double click on *Icon* and select the icon you wish to be used on the toolbar (in this case, *A*), and then press the *Make Default* button and close the *Customise Dialogue* box.

If the *A* button does appear by default on the toolbar, ignore the previous two paragraphs.

Calculating Individual Areas (i.e. by individual polygon)

1. Activate the *Theme* of the area you wish to calculate, then press the *A* button on the toolbar.
2. Then press the *Open Theme* button on the toolbar, and you will see two new fields have been added, *Area* and *Perimeter*. These fields will calculate the area and perimeter in the units specified by the *Projection* earlier in the work.

Calculating Categorical Areas (i.e. by habitat type or attribute)

1. Open the *Attribute Table* of the *Theme* you want to calculate areas of by pressing the *Open Theme* button on the toolbar.
2. Make the field active that you want to categorise the areas by (i.e. attribute) by pressing on the field name.
3. Press the *Summarise* button on the toolbar and navigate to where you wish to save the *Summary Table*.
4. Specify the name of this new file and where you want to save it.
5. From the *Field* drop down menu select *Area*.
6. From the *Summarise By* drop down menu select *Sum*, press the *Add* button, and *Sum_Area* will appear on the right hand side. Press *OK*. A new table will appear which will summarise the area of the different attributes.

Each *Theme* has 3 file types associated with it, with the extensions .shp, .shx, and .dbf., the last of which can be viewed and manipulated in Excel, once it has been exported as a *.txt file.

Creating 3D Images

Creating the Tidal Height (Dowel) Theme

3D images are created using tidal reference data collected in the field. To do so, open the appropriate rectified image, i.e. 'new_careel96.img'.

1. Go to *View* ► *New Theme*, and select the *Point* feature type, and select *OK*.
2. Save this with an appropriate name, i.e. 'careeldowels.shp'.
3. Click the *Drawing* Tool palette on the toolbar and move the cursor to select the *Draw Point* icon on the toolbar.
4. Using the cursor and the left mouse button, mark on the image in the *View* where the location of each dowel.
5. Go to the *Attribute Table*, move to *Edit* ► *Add Field*, name the new field *Dowel Number*. Add another field, and name it *Tidal Height*. Fill the values appropriately, with the tidal height data in metres (this value was calculated by subtracting the depth of immersion of each dowel from the known Spring High Tide level).
6. Go to *Theme* ► *Stop Editing* to save the theme.

Creating a 3D Image

Open a new project page.

To create contours for an entire (grid or TIN) theme:

1. Activate the grid or TIN theme from which to create the contours in a view or 3D scene.
2. Go to *Surface* ► *Create Contours*.
3. Enter the contour interval in the *Contour interval* type-in box.
4. Specify the contour value to start contours in the Base contour type-in box. Contours will be created above and below the base contour. Press *OK*.

For a point or multipoint theme:

1. Activate the point or multipoint theme from which to create the contours in a *View* or *3D Scene*.
2. Go to *Surface* ► *Create Contours*.
3. If the *View's* analysis properties haven't been set to a specific value, or if the points were activated in a *3D Scene*, then you'll be prompted to set the extent and cell size for the output grid theme. Do so in the *Surface Grid Specification* dialog and press *OK*.
4. Specify the interpolation parameters necessary to create the temporary surface that contours will be created from, and press *OK*.
5. Enter the contour interval in the *Contour Interval* type-in box.
6. Specify the contour value to start contours in the Base contour type-in box. Contours will be created above and below the base contour. Press *OK*.

Smaller contour intervals create more contours. The optimum contour interval is a matter of the elevation change in the input grid or TIN theme, the amount of area covered by the theme, the analysis to follow, and the desired aesthetics of the output line theme.

To trace the contour passing through a selected point:

1. In a *View*, click on a grid or TIN theme to make it active. Use only grid themes representing a continuous attribute, such as elevation in this case.
2. Click on the *Contour* tool.
3. Click on a location on the grid or TIN theme to see its contour.

The contour is drawn on the *View* as a graphic line. Its value is displayed on the left side of the status bar. The contour graphic lines are added to the graphics list for the grid or TIN theme that they were created from. They will only be displayed when this theme is displayed. The current line symbol is used to draw the graphic contour lines. You can change the line symbol used to draw the graphic contour lines by first making sure that no graphics are selected and then choosing *Show Symbol Window* in the *Window* menu.

You can also put the contour lines directly into another theme and write the colour values to the table of that theme.

To put contour lines directly into a new theme:

1. Go to *View* ► *New Theme*.
2. Choose the *Line* as the feature type and press *OK*.
3. Provide the directory and file name for the new theme, and press *OK*.
4. Click on the grid or TIN theme you want to trace contours from, to make it active.
5. Click on the *Contour* tool.
6. Click on the location on the grid or TIN theme that you want to create a contour for.

The contour is placed into the new theme. A field is added to the new theme with the value of the contour. To stop placing contours into the new theme, click on the theme to make it active. Go to *Theme* ► *Stop Editing*. When prompted, press *Yes* to save edits.

To calculate summary attributes for features using a grid theme:

1. Activate a zone theme (an integer grid or feature theme) on which to summarise the zones.
2. Go to *Analysis* ► *Summarise Zones*.
3. In the *Summarise Zones* dialog, choose the field defining the zones in the input theme from the drop down list (i.e. 'tidal height'). Press *OK*.
4. From the drop down list, choose the value grid theme defining the cell values to summarise within each zone defined by the zone theme. Press *OK*.
5. Choose a statistic to chart from the drop down list. In this case choose area, minimum, maximum, range, mean, standard deviation, sum.

Summarise Zones computes a chart and a table. The output values are a function of the value of the cells in an input value grid theme found within each zone in the zone theme. The values of the input grid theme represent habitat elevation. In the output table, the number of rows is equal to the number of zones defined in the input zone theme; each row value represents the corresponding zone.

Appendix 4: Root Mean Square Error Values for Georectified Aerial Photographs

Table A4.1: Root Mean Square Error Values for Georectified Aerial Photographs.

| Site | Image Name | RMS |
|------------------------|-------------|-------|
| Ukerebagh Island | tweed98 | 7.84 |
| | tweed83 | 13.88 |
| | tweed79a | 11.25 |
| | tweed79b | 7.16 |
| | tweed61a | 7.02 |
| | tweed61b | 8.59 |
| Tilligerry Creek mouth | tillig96a | 6.75 |
| | tillig96b | 15.32 |
| | tillig96c | 14.85 |
| | tillig96d | 9.11 |
| | tillig83a | 5.03 |
| | tillig83b | 4.26 |
| | tillig83c | 11.18 |
| | tillig83d | 9.01 |
| | tillig83e | 18.43 |
| | tillig83f | 13.66 |
| | tillig75a | 1.67 |
| | tillig75b | 10.07 |
| | tillig75c | 9.11 |
| | tillig66a | 5.31 |
| | tillig66b | 11.00 |
| | tillig66c | 4.67 |
| tillig54a | 14.25 | |
| tillig54b | 12.88 | |
| tillig54c | 4.14 | |
| Black Neds Bay | blackneds99 | 10.76 |
| | blackneds87 | 6.53 |
| | blackneds74 | 15.23 |
| | blackneds61 | 9.37 |
| | blackneds50 | 17.94 |
| Brisbane Water | bris94 | 7.00 |
| | bris86 | 13.81 |
| | bris75 | 1.76 |
| | bris65 | 4.88 |
| | bris54c | 6.36 |
| | bris54b | 5.47 |
| Courangra Point | bris54a | 4.79 |
| | spenc94a | 21.04 |
| | spenc94b | 4.39 |
| | spenc94c | 5.92 |
| | spenc86a | 3.23 |
| | spenc86b | 2.56 |
| | spenc86c | 15.82 |
| | spenc75a | 10.26 |
| | spenc75b | |
| | spenc66a | 1.51 |
| spenc66b | 20.00 | |
| spenc54m | 4.94 | |
| spenc54c | 2.66 | |

| Site | Image Name | RMS |
|------------------|--------------|-------|
| Careel Bay | careel96 | 13.70 |
| | careel86 | 12.61 |
| | careel74 | 6.96 |
| | careel65 | 10.18 |
| | careel40 | 1.97 |
| Towra Point | towra99a | 5.45 |
| | towra99b | 12.88 |
| | towra99c | 9.98 |
| | towra99d | 7.21 |
| | towra83a | 6.25 |
| | towra83b | 4.03 |
| | towra83c | 9.52 |
| | towra83d | 7.63 |
| | towra83e | 1.61 |
| | towra70a | 7.78 |
| | towra70b | 2.22 |
| | towra70c | 5.59 |
| | towra70d | 2.88 |
| | towra70e | 4.02 |
| | towra61a | 6.86 |
| | towra61b | 11.84 |
| | towra61c | 5.25 |
| | towra61d | 10.25 |
| | towra61e | 13.42 |
| | towra61f | 11.58 |
| | towra61g | 5.19 |
| | towra61h | 4.81 |
| | towra61i | 3.04 |
| | towra56a | 4.47 |
| | towra56b | 3.22 |
| | towra56c | 4.28 |
| | towra56d | 4.55 |
| towra56e | 3.05 | |
| towra56f | 3.45 | |
| towra56g | 5.00 | |
| Currambene Creek | currambene93 | 4.79 |
| | currambene87 | 5.00 |
| | currambene75 | 5.41 |
| | currambene61 | 1.59 |
| | currambene49 | 4.06 |
| Cararma Inlet | cararma99 | 16.00 |
| | cararma81 | 18.21 |
| | cararma74 | 14.41 |
| | cararma61 | 2.34 |
| | cararma48 | 1.35 |