LAND USE MANAGEMENT MAPPING FOR THE MURRAY-DARLING BASIN

PHASE 1

Queensland Pilot Study
St George 8641 1:100 000 Map Sheet

Prepared for the

Landmark Project
Murray-Darling Basin Commission

by

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ABSTRACT

A methodology for land use management mapping for the Murray-Darling Basin was assessed. A pilot study of land use mapping was conducted across the St George 1:100,000 mapsheet in southwest Queensland. The use of a combination of remotely sensed satellite imagery, datasets containing land use information, field verification and expert local knowledge was evaluated.

Satellite imagery and datasets containing land use information were interpreted using image processing software in a GIS and land use type polygons identified. These were assigned land use classes according to a modified version of the Baxter & Russell land use classification (Bureau of Rural Sciences and State agencies, 1999) and a draft land use map (as at 1997) produced. This was field verified by visual inspection and expert local knowledge from land extension and protection officers as well as land managers. The draft map was updated using field data followed by final editing and quality assurance checks.

Although no independent validation of the final dataset was conducted, thorough checking of virtually all land use polygons resulted in an estimated accuracy of 90% or better.

Improved efficiency could be gained by using as much locally available data as possible both in the initial interpretation and field verification stages. Land use classifications must be robust and sufficiently flexible to accommodate modifications to class descriptors as well as addition and removal of classes according to local mapping requirements. Independent validation is essential for a meaningful and useful land use dataset.

INTRODUCTION

Land use has the single biggest impact on the state of Australia’s natural resource base. It is increasingly likely that changes to land uses and land management practices will be required if we are to move towards sustainable agricultural systems, reduce rates of environmental degradation and effectively manage land based greenhouse gas emissions.

Information on land use and land management practices is essential for the sustainable management and economic development of natural resources. Information regarding the current state of resources and how they are being managed is required to predict future states. It is also crucial to the understanding of land degradation processes, predicting their potential outcomes as well as for the evaluation of natural resource and agricultural investment strategies.

Policy makers and land management agencies now appreciate the spatial and temporal heterogeneity in the Australian landscape, and the extent to which this needs to be accounted for in developing solutions for sustainable land management. Research activity has resulted in improved understanding of many of the processes that control landscape functioning and affect the status of Australia’s natural resource base. However, to apply the results of this research at a range of locations, we need to take into account the factors controlling regional or catchment scale heterogeneity. These factors include topography, soils, climate, hydrogeology, land cover, land uses and land management practices.

Integrated modelling, which combines models of processes (eg erosion) with spatially explicit information, such as topography, offers the best opportunity to predict the behaviour of a catchment under different conditions, for example the impact of changing land uses or land management practices on rates of salinisation. This capacity to examine complex biophysical systems and their interactions with economic and social environments will be central to the effective management of Australia’s land, water and vegetation resources. The integration of process and spatial models to investigate potential policy options and predict the likely impact of changes will provide a powerful range of tools for future natural resources managers. While there is room for improvement in most of the data sets and models available for integrated modelling, land use and land management practice data sets are the most important information still to be developed.

This study is the first phase of a two phase project, Task 6, which is a component of the Landmark project being undertaken by the Murray-Darling Basin Commission (MDBC) to advance the development of sustainable dryland agricultural farming systems. Phase 1 consists of concurrent pilot studies in selected 1:100,000 map sheet areas of Queensland, New South Wales and South Australia. The primary objectives are to develop and test cost effective methods for mapping land use as a basis for future monitoring of land use changes and provide preliminary costings for mapping land use in the Basin. Progression to Phase 2, which may include Basin-wide mapping, will be dependent on the outcomes from Phase 1.

The project is being undertaken by state agencies and coordinated and managed by the Bureau of Rural Sciences (BRS) for the MDBC.

The project will build on existing state and nationally coordinated projects which have assessed land use & land cover change as well as providing an ongoing management tool to facilitate the acquisition of land use management data by remote sensing techniques. Methods recently developed by the Queensland Department of Natural Resources (QDNR) for land use mapping of the Fitzroy Catchment in central Queensland (Calvert *et al*, 2000) will be applied to map the St George 1:100,000 scale map sheet at the same scale using remotely sensed imagery, land use datasets, expert local knowledge and field observations.

Key outcomes will be a repeatable and cost-effective method for mapping and monitoring changes in broadacre dryland land uses at bioregional or catchment level as well as a dataset and map showing principal land uses according to a nationally agreed classification scheme across the extent of the St George 1:100,000 map sheet.

Study Area

The St George 1:100,000 map sheet area is located approximately 500 kilometres south-west of Brisbane, close to the state border with New South Wales (Figure 1). It spans the confluence of three biogeographic regions, the Brigalow Belt Southern, Mulga Lands & Darling Riverine Plain, and is traversed by the catchments of two locally significant rivers, the Balonne and Moonie. Topography is essentially flat across the map sheet as much of it is located within the floodplains of the Balonne and Moonie Rivers. Climate is hot and dry with a cool winter. Mean annual rainfall at St George, the major regional centre, is 500 millimetres.

The St George map sheet was chosen for pilot project mapping primarily as it possesses a mix of dryland agricultural uses common in the Basin, these being predominantly cattle and sheep grazing as well as broadacre cropping. The St George Irrigation Area, which supports cotton, cereals, oilseeds, grapes and fodder crops is also located within the study area. Established in 1956, it covers approximately 9,500 hectares with an additional 5,000 hectares planned for future expansion (D. Kann, pers. comm. March 2000).

Over the last forty to fifty years the area has been subject to extensive clearing of native vegetation for agriculture and the last decade has seen the Queensland Murray-Darling Basin sustain some of the highest clearing rates in the state (SLATS, 2000). Gordon *et al* (2000) identified areas of the Basin subject to saline discharges as a result of land clearing and highlighted that increasing use of saline groundwater in irrigation areas greatly increases the risk of salinity.

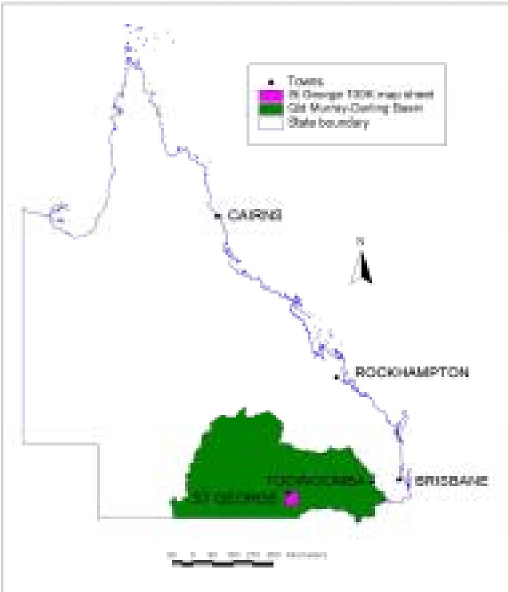

Figure 1: The Qld Murray-Darling Basin & St George 1:100,000 map sheet

METHODOLOGY

This project adopts and builds on the land use mapping methodology developed for the Fitzroy Catchment Land Use Mapping Project (Appendix D). Key steps in the process are shown in Figure 2. They include integration & interpretation of primary and ancillary datasets to produce a draft land use map, field attribution and verification, updating and GIS editing, validation, and production of the final dataset.

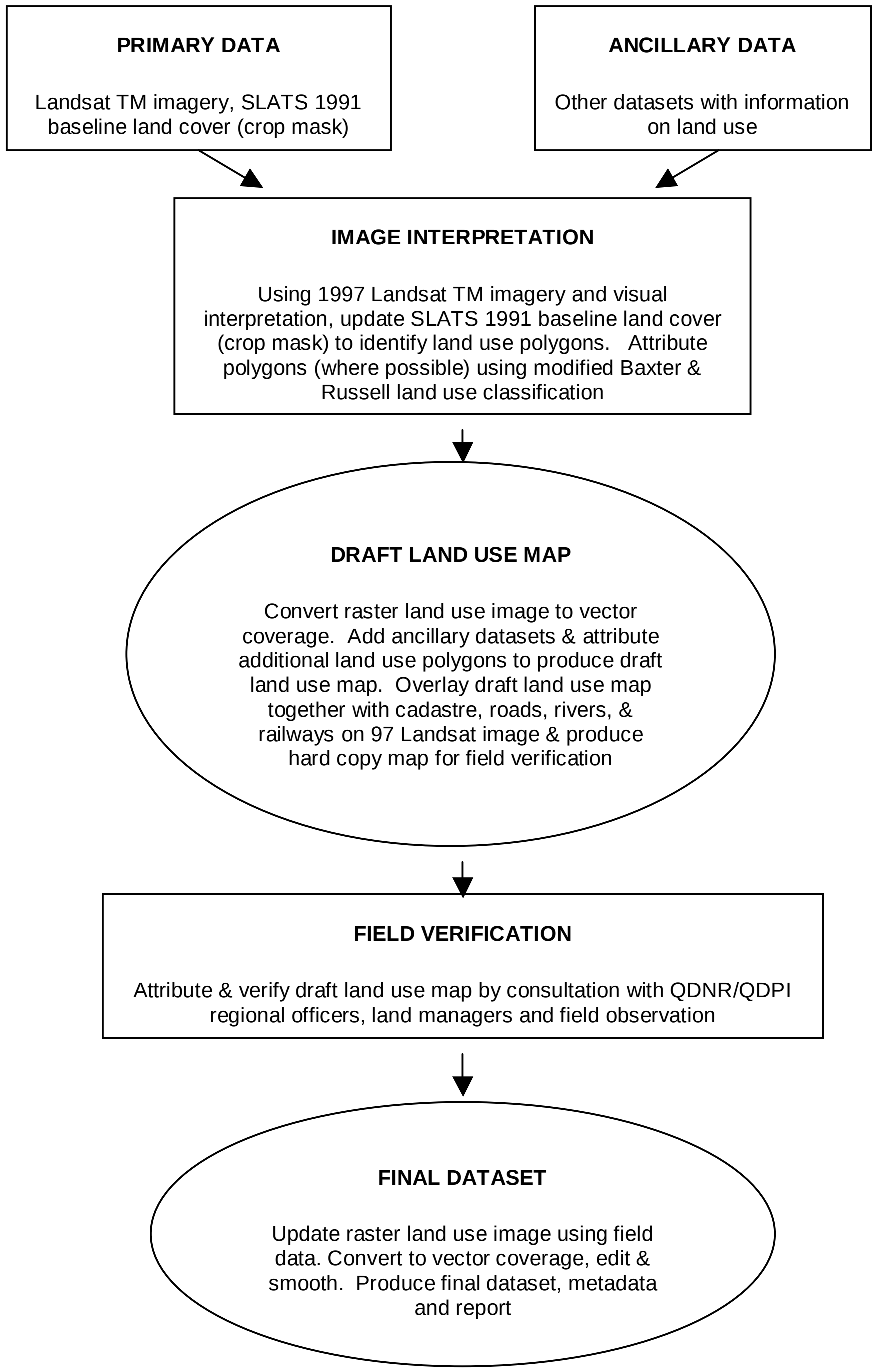

Figure 2: Procedure for St George land use mapping

Land use types are assigned according to a modified and expanded version of the Baxter & Russell (1994) classification developed at a joint Commonwealth-State workshop in February 1999. It is an hierarchical scheme which assigns a specific land use type to a class according to its 'level-of-intervention' into an assumed unaltered 'natural' landscape. Five primary levels of intervention (land use classes) are distinguished ranging from essentially undisturbed natural environments through to intensive and highly intrusive uses. Each primary level is subdivided into secondary and tertiary classes describing land use in increasing levels of detail. The St George map sheet was classified to secondary level as this is the highest level possible at the selected mapping scale (1:100,000) using Landsat TM imagery.

Image manipulation & processing was performed on UNIX & Windows NT workstations using ERDAS Imagine 8.3.1 & 8.4 software. GIS operations were performed primarily on a UNIX workstation using ARC/Info 7.2 and Arcview 3.2 & 3.2a.

Datasets

The datasets used in this project have been categorised into primary and ancillary types. This is principally in recognition of the types of land use information each provides. Primary datasets are fundamental and essential components in the land use mapping process and contain information mainly regarding landscape-scale land use such as types of agriculture. Ancillary datasets contain useful information on smaller scale land use such as production forests, protected areas, urban and other types.

A key element in keeping data acquisition costs as low as possible is to utilise as much locally available existing data as possible. Through the Statewide Landcover & Tree Study (SLATS), QDNR has acquired an extensive inventory of multi-date Landsat Thematic Mapper (TM) imagery covering the entire state and produced a range of land cover and land cover change datasets. The project had access to these as well as QDNR's large archive of spatial datasets many of which contain land use information (Table 1).

Primary data

SLATS provided Landsat TM imagery (non-standard full scene, path 92, rows 79 & 80, September 1991, July 1995, August 1997) and the 1991 baseline land cover (crop mask). The imagery was converted to reflectance units and registered to the 1991 scene by SLATS. The crop mask identifies cropping areas at 1991 in five broad classes, broadacre cropping, sugar cane, horticulture, orchards and miscellaneous crops (Kuhnell et al. 1996). Both the St George and Fitzroy Catchment land use mapping projects have updated and modified the 1991 baseline land cover (crop mask) over their respective extents according to the modified Baxter & Russell classification.

Ancillary data

Other datasets containing land use information were sourced from QDNR spatial databases. They provided a detailed representation of non-cropping areas including protected areas, water bodies, water storage, irrigation areas, state forests & timber reserves, urban areas, aerodromes & airfields.

LAND USE TYPE	DATASET NAME	SCALE	CURRENCY
All	Landsat TM imagery	1:100,000	1991, 1997
Land cover types	SLATS 1991 Baseline Land Cover Data (crop mask)	1:100,000	1991
Cadastre	Qld Digital Cadastral Data Base DCDB	1:2,500 to 1:250,000	Updated daily
Production forest	State Forests and Timber Reserves - QLD_STATEFORESTS_DBASE	1:250,000	Jan 2000
Protected areas	Protected Areas of Queensland (Estates v6.3), National Parks QLD_NATIONALPARK_250K	1:250,000	1997
Water bodies	AUSLIG water body 250K Geodata - QLD_WATERBODY_250K	1:250,000	1996
Irrigation areas	Boundary of Gazetted Irrigation Areas in Queensland (irr_area)	1:25,000 to 1:100,000	Current
Urban	AUSLIG built up areas 250K Geodata - QLD_BUILTUP_250K	1:250,000	1993, updated as required
Water storage	Dams and Weirs in Queensland (dam_weir)	1:250,000	Current
Airfields	AUSLIG aeronautical 250k Geodata - QLD_AERONAUT_250K	1:250,000	1996

Table 1: Ancillary datasets used for St George land use mapping

Image Interpretation

Landsat TM imagery was clipped to the extent of the St George 1:100,000 topographic map sheet. Bands 2, 3, 4, and 5 were used to maximise differences between land use classes. The clipped crop mask was overlaid in semi-opaque mode on the 1997 image and land use polygons identified by visual interpretation using the standard cues of shape, size, colour, texture, tone, and location.

These were manually digitised on-screen using the ‘select polygon’ and ‘recode’ tools in Imagine.

Cropping areas were identified from the crop mask and visual interpretation. The 1991 and 1995 scenes were used to compare changes in vegetation. This was particularly useful for crop/pasture rotation which is effectively a temporal class not readily identified from single date imagery. Natural and constructed water bodies (lakes, billabongs, dams, weirs, etc.) were distinguished using visual interpretation (size, shape and context) and reference to AUSLIG 1:250K Geodata water body and Dams and Weirs in Queensland (QDNR) coverages. Urban residential and urban industrial were identified with reference to AUSLIG 1:250K Geodata built up areas and the Queensland Digital Cadastral Database (DCDB). Rural residential was a problem class & determined by reference to the DCDB as well as field inspection. Aerodromes & airstrips were identified by visual interpretation and AUSLIG 1:250K Geodata aeronautical. Mining & waste treatment areas were identified by visual interpretation. State Forests were extracted from the QDNR State Forests and Timber Reserves database.

Classification

Land use polygons were assigned a land use class to the secondary level of the modified Baxter and Russell classification. Landsat TM imagery does not support mapping at scales smaller than about 1:100,000 therefore classification to tertiary (commodity) level was not attempted for all classes. Furthermore, tertiary level classification, whilst desirable and achievable for some land use classes, was not a project requirement.

Draft land use map

The raster land use image was converted to a vector coverage. Ancillary datasets were overlaid on the land use coverage and additional land use classes and polygons identified, digitised and attributed. A hard copy map at 1:100,000 scale showing 1997 Landsat imagery (bands 2, 4 & 5), vector polygon coverage of the draft land use classification, cadastral information, a 1,000 metre graticule, rivers, main roads, protected areas & state forests was produced for field verification & attribution.

Field verification and attribution

Verification of the draft land use map was performed during a field trip to the study area. Land use polygons which had been assigned a land use class were checked by visual inspection, expert local knowledge provided by regional land protection officers, extension officers and land managers, or both.

Mis-classified, omitted and unattributed land use polygons were identified and corrections noted on the field map.

Additional information which may have assisted with clarification of problem classes was acquired for interpretation in conjunction with primary and ancillary data. Positional information of land use polygons and point sources was checked using differential GPS.

Validation

No independent validation process was undertaken primarily due to time & resource constraints. However, virtually every land use polygon was verified by either field inspection, expert local knowledge, or both.

Final dataset production

The draft land use raster image was corrected, updated and attributed using information from the field map. The updated raster image was converted to a vector coverage and underwent smoothing, final editing and re-projection in a GIS. The final dataset was reclassified according to the Australian Land Use and Management Classification, metadata was produced and quality assurance checks performed.

RESULTS and DISCUSSION

Image interpretation

Six hundred & forty five polygons in sixteen land use classes were identified during this phase. Issues and problems relating to interpretation, classification & attribution of polygons as well as specific land use classes and how these were approached are discussed below.

Native pasture is not distinguishable from improved pasture using Landsat TM imagery, and is very time-consuming to distinguish by fieldwork. Therefore these classes have been classified jointly. Whilst it is recognised that improved pasture implies a higher level of intervention into the landscape than native pasture, it could be argued that improved pasture promotes soil retention and increases soil organic matter, thus reducing potential impact on land degradation. In any event, the differences between native and improved pasture should be investigated before a decision is made as to whether or not they warrant distinction for the purposes of land use mapping. Some QDNR/QDPI land suitability surveys include cleared land, improved pasture and (grazed) native vegetation. It would be possible to complete an inventory of these projects, which would be useful in future land use mapping work, however, they have been surveyed over a number of years and are focused specifically on high quality agricultural land. In the Fitzroy Catchment study improved pastures were identified by the presence of cleared areas.

Dryland rotation cropping/pasture and irrigated rotation cropping/pasture were separated to better reflect actual and observed land management. For example, 1997 dryland cropping (pasture rotation) was separated from 1997 pasture (dryland cropping rotation).

Green cropped and ploughed areas were readily identifiable. Mature crops are also distinguished by uniform colour, size, shape and proximity to other cropping areas. However, cropping stubble is more easily confused with dry grass and should be confirmed by fieldwork. Permanent cropping cannot be separated from cropping rotation without confirmation by fieldwork.

Pasture cannot be identified as rotation with crops unless confirmed by expert local knowledge (land manager/extension officer). Also, there are likely to be unidentified areas of pasture that rotate as crop. Temporal mapping (with a three to five year period, for example) would build a more complete picture of rotation cropping areas, as well as giving some indication of the nature of the rotations, and hence an indication of land management practices.

Horticulture (vegetables, grapes, citrus, peanuts) has reflectance values and appearance similar to immature broadacre crops. Size and association indicate can facilitate distinguishing these but classification requires confirmation by fieldwork.

Irrigation areas should be confirmed by field verification. The Boundary of Gazetted Irrigation Areas in Queensland database is useful for establishing major irrigated areas and could be used to define mapping at 1:25,000 scale.

Some classes such as intensive primary production, waste treatment and disposal sites and other small scale intensive land uses are difficult to identify using Landsat TM but can be confirmed using appropriate datasets and field validation. Most of these operations are too small to map at 1:100,000 scale, however their potential environmental impact is sufficient to warrant recognition. Such sites may be mapped as point coverages and this should be considered for future land use mapping work.

Rural residential, urban residential and urban industrial are difficult to identify and separate using Landsat TM imagery and were confirmed by fieldwork and consultation with Local Government Authorities.

Water was separated into two broad categories (natural and built water bodies) according to the modified Baxter and Russell classification. However, this scheme is unclear: dams are included as a tertiary class under water, but are also included as a tertiary class under utilities (as water storage and treatment). In recognition of its dual character as both a land cover type and land use type, water has been treated separately within the new Australian Land Use and Management Classification.

The modified Baxter and Russell land use classification was used for all stages of this project with the exception of the final dataset. It has recently been reviewed, amended and renamed the Australian Land Use and Management Classification in the light of experience gained in Landmark & NLWRA land use mapping work. The final dataset has subsequently reclassified according to the new classification.

Field verification and attribution

A field trip to the study area was conducted in March 2000 during which virtually all land use polygons identified on the draft land use map were verified either by visual inspection, consultation with land protection & extension officers as well as land managers, or both. Polygons unable to be attributed during the image interpretation & classification phase as well as classes which proved difficult to identify or separate were also verified. These include irrigated and dryland cropping, pasture and cropping rotations, horticulture, waste treatment, urban and rural residential and urban industrial. Local expert knowledge provided by QDNR/QDPI officers and land managers regarding land use types and their locations facilitated the verification process and significantly reduced the requirement for visual checking and hence travel.

Positional information was collected using a differential GPS and manually transferred to the field map. It was intended to use a laptop computer linked to a differential GPS navigation system using proprietary software to provide real-time tracking capability for location and recording of the position & attributes of land use polygons. This system has been used with great success for other land use mapping work as well as other projects requiring real-time positional information and tracking (for example, acquisition of SLATS field data). Unfortunately, unexpected software problems precluded this from being undertaken for the present project.

Access to a significant proportion of the study area was not possible due to unseasonally wet conditions. Verification of these areas was obtained primarily from information supplied by QDNR regional extension officers.

Final dataset production

The updated raster draft land use image was converted to a vector coverage and subjected to several GIS operations to produce the final dataset. The key steps in this process are de-pixelation (smoothing) of the coverage to remove the rasterised edge on polygons, editing to remove node and label errors, and elimination of polygons whose area is smaller than the acceptable minimum mapping unit for 1:100,000 scale mapping (four hectares). Care was taken to ensure that BRS specified tolerances (fuzzy, dangle, edit, node, snap, weed, grain) were maintained throughout all GIS operations. The procedures used were similar to those applied in the Fitzroy Catchment project (Appendix D).

Following GIS operations, the final dataset was reclassified according to the Australian Land Use & Management Classification. The overall effect of this on the dataset was minimal, the principal outcome being the creation of new classes by re-aggregation and re-attribution of some polygons. Reclassification was considered desirable as the existing modified Baxter & Russell classification had undergone a review and significant modification in the time between field verification of the draft land use map and production of the final dataset. Changes resulting from the review include elimination, redefinition & simplification of several classes. Water has been recognised as both a land use and land cover type and categorised independently within the classification. The new scheme is both simpler & a more accurate representation of actual land use types encountered in the field. Similarly to the land use mapping process itself, classification schemes will require ongoing review and modification if they are to remain useful and relevant as categorisation tools for land use data. Both the modified Baxter & Russell and Australian Land Use & Management Classification schemes are attached (Appendices A & B). Further information regarding these as well as land use mapping and related work undertaken by the BRS in collaboration with state agencies can be obtained from http://www.brs.gov.au/land&water/landuse/landuse.html

The final dataset comprises a thematic land use map in vector coverage format with 290 polygons (Figure 3) in fourteen land use classes (Table 2). Metadata at ANZLIC page 0 level was created (Appendix C) and data quality checks were applied to ensure compliance with BRS data quality specifications (Appendix E).

Accuracy assessment

No formal accuracy assessment (independent validation) was undertaken for this project.

However, detailed manual image interpretation followed by an extensive field verification process involving checking virtually all land use polygons ensures that classification accuracy is high. It is estimated that map reliability is 90% or better.

LAND USE CLASS	**TERTIARY CODE**	**AREA** (hectares)	**PERCENTAGE OF MAP SHEET**
Livestock grazing	2.1.0	223,766	74.13
Grazing improved pasture	3.3.0	9,515	3.15
Cropping	3.4.0	43,843	14.53
Irrigated improved pasture	4.3.0	32	0.01
Irrigated cropping	4.4.0	20,670	6.85
Irrigated perennial horticulture	4.5.0	640	0.22
Manufacturing & industrial	5.3.0	39	0.01
Urban residential	5.4.1	297	0.09
Rural residential;	5.4.2	67	0.02
Airports/aerodromes	5.7.1	44	0.01
Mining	5.8.1	6	0.00
Waste treatment & disposal	5.9.0	8	0.00
Agricultural water supply	6.2.2	2268	0.75
Rivers	6.3.0	652	0.23
TOTAL		**301,847**	**100.00**

Table 2: Land use classes identified in the St George 1:100,000 map sheet (Australian Land Use & Management Classification)

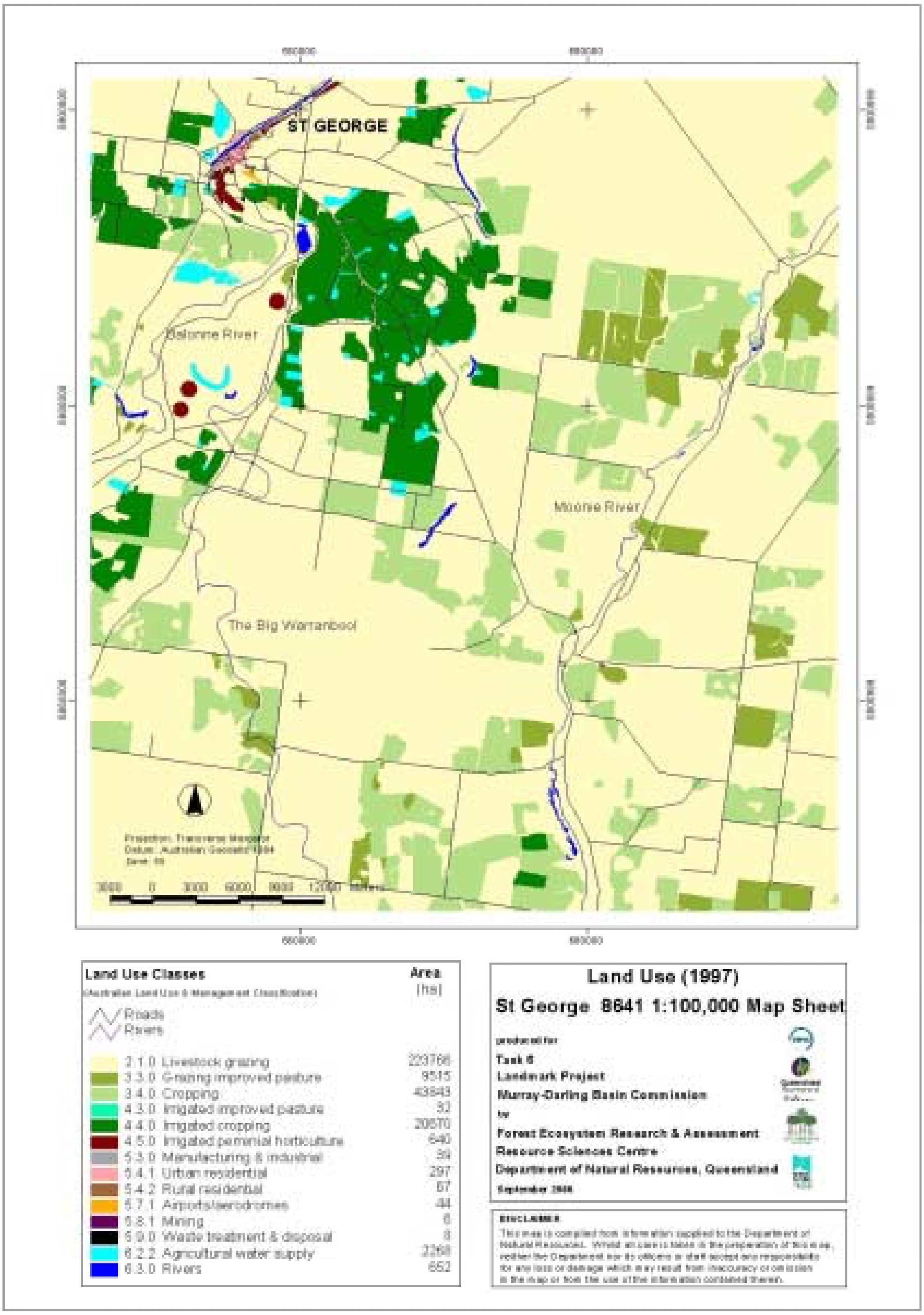

Figure 4: Land use map of St George 1:100,000 map sheet

CONCLUSIONS and RECOMMENDATIONS

- An efficient & effective methodology has been demonstrated for mapping land use at 1:100,000 scale in the Queensland Murray-Darling Basin utilising Landsat TM satellite imagery, land use datasets, expert local knowledge and field verification.

- Use of existing datasets containing land use information facilitates & enhances the quality and utility of land use mapping.

- The extensive expert local knowledge base available in regional areas should be utilised to maximise information collection efficiency and minimise travel.

- Use of a laptop computer linked to a differential GPS to provide real-time positional information & facilitate editing of spatial data sets should be a component of future land use mapping work.

- Independent validation of mapping accuracy is essential for land use datasets to be meaningful and applicable. This should be undertaken as soon as possible following final map editing by personnel who were not part of the field verification team.

- Land use is not static – it is a dynamic activity and possesses a temporal component. Accurate baseline mapping as well as an on-going commitment to re-mapping at regular intervals is required if changes and patterns in land use and land use management practices are to be identified.

- Land use classification schemes should be robust and sufficiently flexible to sustain periodic review and amendment as new classes are identified and descriptors require modification.

FUTURE WORK

In addition to the development & testing of a methodology for catchment scale land use mapping, a requirement of the project is to prepare preliminary costings for Basin-wide mapping (Appendix F).

Estimated cost and time to map the remainder of the Queensland Murray-Darling Basin is approximately $200,000 and 4.9 years respectively. It should be noted that these figures are preliminary estimates based on costs & timeframe associated with the present study. The Fitzroy Catchment project demonstrated that when land use mapping is undertaken over an area of significant size, ‘economies of scale’ should reduce the time and cost figures substantially. It is anticipated that similar reductions could be expected for catchment scale mapping in the Murray-Darling Basin.

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APPENDICES

APPENDIX A: Baxter and Russell Land Use Classification

(modified by BRS/States, February 1999)

DRAFT LAND USE CLASSIFICATION - Summary			
Primary class		**Secondary class**	**Tertiary class**
I Conservation	1.1	Strict nature reserves	Marine and estuarine reserves
(predominantly natural vegetation			Land reserves
minimal management)	1.2	Wilderness area	
	1.3	National Park	
	1.4	National monument	
	1.5	Habitat/species management area	
	1.6	Protected landscape	Marine
			Land
	1.7	Managed resource protected area	Biodiversity
			Surface water supply
			Groundwater
			Landscape
	1.8	Unmanaged land	Vacant Crown lands
			Aboriginal lands
			Defence lands
			Rehabilitated lands
			Stock routes
	1.9	Water	Lakes/dams
			Rivers

			Wetlands
			Coastal
II Production from relatively natural	2.1	Grazing	Shrubland
environments			Grassland
(predominantly natural vegetation			Grassy woodlands
intermittent intervention)			Tablelands
			Alpine
			Riverine
			Montane
	2.2	Production Forests	Commercial native forest production
			Native forest nurseries and services
III Primary production from dryland agriculture	3.1	Plantations	Plantation forest production
and plantations			Plantation nurseries and services
(predominantly introduced vegetation	3.2	Grazing improved and fertilised pastures	Pure lucerne
single and multiple uses)			Lucerne/pasture mixtures
			Pasture legumes
			Perennial grasses/lucerne mixture
			Annual grasses/lucerne mixture
			Sown grasses
	3.3	Farm forestry	Windbreaks
			Woodlots
			Production of trees and crops
	3.4	Cropping/pasture rotations	Crop/pasture rotations
	3.5	Permanent cropping	Cereals
			Beverage and spice crops

			Hay and silage
			Oil seeds
			Sugar Cane
			Tobacco
	3.6	Horticulture	Vegetables
			Fruit
			Nuts
			Oleaginous fruits
			Flowers and bulbs
IV Primary production from irrigated agriculture	4.1	Irrigated Plantations	Irrigated plantations
and plantations			Irrigated plantation nurseries
predominantly introduced vegetation	4.2	Irrigated improved and fertilised pastures	Irrigated pure lucerne
			Irrigated lucerne/pasture mixtures
			Irrigated pasture legumes
			Irrigated perennial grasses/lucerne mixture
			Irrigated annual grasses/lucerne mixture
single and multiple uses			Irrigated sown grasses
hydrological intervention	4.3	Irrigated Farm Forestry	Irrigated production of trees and crops
	4.4	Irrigated Cropping/pasture rotations	
	4.5	Irrigated Permanent cropping	Irrigated cereals
			Irrigated beverage and spice crops
			Irrigated hay and silage
			Irrigated oil seeds
			Irrigated sugar cane
			Irrigated tobacco

	4.6	Irrigated Horticulture	Irrigated vegetables
			Irrigated fruit
			Irrigated nuts
			Irrigated oleaginous fruits
			Irrigated flowers and bulbs
V Intensive uses	5.1	Intensive primary production and processing	Intensive animal production
(landscape modification			Processing plants
extensive management and intervention)	5.2	Rural residential living	
	5.3	Urban uses	Residential
			Manufacturing and industrial
			Commercial services
			Public services
			Recreation and culture
	5.4	Institutional uses	Defence facilities
			Research facilities
	5.5	Utilities	Electricity generation/transmission
			Water storage and treatment
			Gas treatment, storage and transmission
	5.6	Transport and communication	Airports/aerodromes
			Roads
			Railways
			Ports and water transport
			Navigation and communication
	5.7	Mining	Mines
			Quarries
			Tailings

	5.8	Waste treatment and disposal	Stormwater
			Landfill
			Solid garbage
			Incinerators
			Sewage
			Evaporation basins

APPENDIX B: Australian Land Use and Management Classification

Australian Land Use and Management Classification (Version 4)

Minimum expected level of attribution

s-code	Secondary class	t-code	Tertiary class
	I Conservation and Natural Environments		
1.1	Nature conservation[1]		
		1.1.1	Strict nature reserves
		1.1.2	Wilderness area
		1.1.3	National park
		1.1.4	Natural feature protection
		1.1.5	Habitat/species management area
		1.1.6	Protected landscape
		1.1.7	Other conserved area
1.2	Managed resource protection[1]		
		1.2.1	Biodiversity
		1.2.2	Surface water supply
		1.2.3	Groundwater
		1.2.4	Landscape
		1.2.5	Traditional indigenous uses
1.3	Other minimal use		
		1.3.1	Defence
		1.3.2	Stock route
		1.3.3	Remnant native cover
		1.3.4	Rehabilitation[2]
	2 Production from Relatively Natural Environments		
2.1	Livestock grazing[3]		

s-code	Secondary class	t-code	Tertiary class
2.2	Production forestry[4]		
3	**Production from Dryland Agriculture and Plantations**		
3.1	Plantation forestry		
		3.1.1	Hardwood plantation
		3.1.2	Softwood plantation
		3.1.3	Plantation forest nurseries
3.2	Farm forestry		
		3.2.1	Woodlots
		3.2.2	Windbreaks
		3.2.3	Tree and crop production
3.3	Grazing modified pastures[5]		
		3.3.1	Native/exotic pasture mosaic
		3.3.2	Woody fodder plants
		3.3.3	Legumes
		3.3.4	Legume/grass mixtures
		3.3.5	Sown grasses
3.4	Cropping[6]		
		3.4.1	Cereals
		3.4.2	Beverage & spice crops
		3.4.3	Hay & silage
		3.4.4	Oil seeds & oleaginous fruit
		3.4.5	Sugar
		3.4.6	Cotton
		3.4.7	Tobacco

s-code	Secondary class	t-code	Tertiary class
3.5	Perennial horticulture[6]		
		3.5.1	Tree fruits
		3.5.2	Oleaginous fruits

		3.5.3	Tree nuts
		3.5.4	Vine fruits
		3.5.5	Shrub nuts fruits & berries
		3.5.6	Flowers & bulbs
		3.5.7	Vegetables & herbs
3.6	Seasonal horticulture[6]		
		3.6.1	Fruits
		3.6.2	Nuts
		3.6.3	Flowers & bulbs
		3.6.4	Vegetables & herbs

4 Production from Irrigated Agriculture and Plantations

4.1	Irrigated plantation forestry		
		4.1.1	Irrigated hardwood plantation
		4.1.2	Irrigated softwood plantation
		4.1.3	Irrigated plantation nurseries
4.2	Irrigated farm forestry		
		4.2.1	Irrigated woodlots
		4.2.2	Irrigated windbreaks
		4.2.3	Irrigated tree and crop production
4.3	Irrigated modified pastures		
		4.3.1	Irrigated woody fodder plants
		4.3.2	Irrigated pasture legumes
		4.3.3	Irrigated legume/grass mixtures
		4.3.4	Irrigated sown grasses
4.4	Irrigated cropping[6]		
		4.4.1	Irrigated cereals
		4.4.2	Irrigated beverage & spice crops
		4.4.3	Irrigated hay & silage
		4.4.4	Irrigated oil seeds & oleaginous fruit
		4.4.5	Irrigated sugar
		4.4.6	Irrigated cotton
		4.4.7	Irrigated tobacco

s-code	Secondary class	t-code	Tertiary class
4.5	Irrigated perennial horticulture[6]		
		4.5.1	Irrigated tree fruits
		4.5.2	Irrigated oleaginous fruits
		4.5.3	Irrigated tree nuts
		4.5.4	Irrigated vine fruits
		4.5.5	Irrigated shrub nuts fruits & berries
		4.5.6	Irrigated flowers & bulbs
		4.5.7	Irrigated vegetables & herbs
4.6	Irrigated seasonal horticulture[6]		
		4.6.1	Irrigated fruits
		4.6.2	Irrigated nuts
		4.6.3	Irrigated flowers & bulbs
		4.6.4	Irrigated vegetables & herbs
	5 Intensive Uses		
5.1	Intensive horticulture		
		5.1.1	Shadehouses
		5.1.2	Glasshouses
		5.1.3	Glasshouses (hydroponic)
5.2	Intensive animal production		
		5.2.1	Dairy
		5.2.2	Cattle
		5.2.3	Sheep
		5.2.4	Poultry
		5.2.5	Pigs
5.3	Manufacturing and industrial[7]		
5.4	Residential		
		5.4.1	Urban residential
		5.4.2	Rural residential

s-code	Secondary class	t-code	Tertiary class
5.5	Services		
		5.5.1	Commercial services
		5.5.2	Public services

		5.5.3	Recreation and culture
		5.5.4	Defence facilities
		5.5.5	Research facilities
5.6	Utilities		
		5.6.1	Electricity generation/transmission
		5.6.2	Gas treatment, storage and transmission
5.7	Transport and communication		
		5.7.1	Airports/aerodromes
		5.7.2	Roads
		5.7.3	Railways
		5.7.4	Ports and water transport
		5.7.5	Navigation and communication
5.8	Mining		
		5.8.1	Mines
		5.8.2	Quarries
		5.8.3	Tailings
5.9	Waste treatment and disposal		
		5.9.1	Stormwater
		5.9.2	Landfill
		5.9.3	Solid garbage
		5.9.4	Incinerators
		5.9.5	Sewage
6 Water[8]			
6.1	Lake		
		6.1.1	Lake - conservation
		6.1.2	Lake - production
		6.1.3	Lake - intensive use
6.2	Reservoir		
		6.2.1	Water storage and treatment
		6.2.2	Reservoir - intensive use
		6.2.3	Evaporation basin
		6.2.4	Effluent pond

	6.3	River			
				6.3.1	River - conservation
				6.3.2	River - production
				6.3.3	River - intensive use
	6.4	Channel/aqueduct			
				6.4.1	Supply channel/aqueduct
				6.4.2	Drainage channel/aqueduct
	6.5	Marsh/wetland			
				6.4.1	Marsh/wetland - conservation
				6.4.2	Marsh/wetland - production
				6.4.3	Marsh/wetland - intensive use
	6.6	Estuary/coastal waters			
				6.6.1	Estuary/coastal waters - conservation
				6.6.2	Estuary/coastal waters - production
				6.6.3	Estuary/coastal waters - intensive use

Notes –

The definitions for each class are being updated from those contained in the draft land use classification (6 May 1999) used in mapping projects for the National Land and Water Resources Audit (Gippsland, Victoria and the Fitzroy Basin, Qld), and the Murray Darling Basin Commission's Landmark Project (St George, Qld, Cootamundra, NSW and Swan Reach, SA).

1 Nature conservation - **Tertiary classes are based on the Collaborative Australian Protected Areas Database (CAPAD) classification except 1.1.7 'Other conserved area' and 1.2.5. 'Traditional indigenous uses'. Class 1.1.7 includes forms of nature conservation outside the IUCN definition such as heritage agreements, voluntary conservation, registered property agreements etc.**

2 Rehabilitation **– This tertiary class includes areas that are under active rehabilitation or are unused because of weed infestation, salinisation, scalding and similar hazards.**

3 Livestock grazing (natural environments) - *Optional* **Tertiary classes provide an opportunity to link the land use classification with NVIS native vegetation classes. The classification at this level could be attributed by a simplified structural formation classification of the dominant native vegetation (NVIS level II), as shown below, if these data are available.**

- Forest
- Woodland
- Open woodland
- Shrubland
- Grassland
- Other

4 Production forestry (relatively natural environments) - *Optional* **Tertiary classes provide an opportunity to link the land use classification with NFI forest types. The classification at this level could be attributed by NFI forest type, as shown below, if these data are available.**

- Rainforest
- Callitris forest
- Tall eucalypt forest
- Acacia forest
- Medium eucalypt forest

5 **Grazing improved pastures -** ***Optional*** Tertiary classes for legume and grass pasture types can be fitted to the pasture attributes collected through the ABS Agricultural Census. Attribution to the classification at this level is likely to be facilitated when census geocoding is completed.

6 **Cropping/ Perennial Horticulture / Seasonal Horticulture –** ***Optional*** attribution of agricultural commodities and commodity classes at the Tertiary level of the classification is likely to be facilitated when the geocoding of the Agricultural Census is completed. States may wish to map the distribution of important crops such as sugar, cotton and rice.

7 **Manufacturing and Industrial–** ***Optional*** attribution at the tertiary level includes abattoirs and other agricultural processing activities. Agricultural production facilities such as feedlots, piggeries etc are included as Tertiary classes under 5.2 Intensive animal production.

8 **Water–** Water is regarded as an essential aspect of the classification, but its inclusion is complicated as it is normally classified as a land cover type.

At the secondary level the classification identifies water features, both natural and artificial.

At the tertiary level natural water features are classed according to levels of use. *'Conservation'* accounts for features associated with land uses included in 1. Conservation and Natural Environments. *'Production'* accounts for features associated with land uses included in 2. Production from Relatively Natural Environments, 3. Production from Dryland Agriculture and Plantations, and 4. Production from Irrigated Agriculture and Plantations. *'Intensive use'* accounts for features associated with land uses included in 5. Intensive Uses.

The classification of water features will be reviewed after the next round of land use mapping

APPENDIX C: Metadata

ANZLIC Page 0 Metadata

Dataset

Title: Land Use in the St George 1:100 000 Map Sheet, Murray-Darling Basin, Queensland

Custodian: Queensland Department of Natural Resources (QDNR)

Jurisdiction: Queensland

Description

Abstract: This dataset is a digital land use map of the St George 86411:100 000 topographic mapsheet. As nearly as possible it shows land use in 1997. The dataset is a product of Phase 1 of Land Use Management Mapping for the Murray-Darling Basin. This is a pilot study being undertaken by the Bureau of Rural Sciences (BRS), QDNR and other state agencies for the Murray-Darling Basin Commission. The dataset comprises one digital map in vector format at a nominal scale of 1:100 000 and is accompanied by a detailed technical report. Coordinates are geographic referred to the Geocentric Datum of Australia 1994 (GDA94) on the Geodetic Reference System 1980 (GRS80) ellipsoid. The map is a polygon coverage with each polygon having an attribute representing a land use code. Land use is classified according to the Australian Land Use & Management Classification (October 2000). Further details of this and related land use mapping information can be found at http://www.brs.gov.au/land&water/landuse/techspecs.html.

Search Words: LAND

LAND Use

LAND Use Classification

Geographic Extent: St George 8641 1:100 000 Map Sheet

Data Currency

Beginning Date: 01JAN1991

Ending Date: 30SEP2000

Dataset Status

Progress: Complete

Maintenance and Update Frequency: Not planned

Access

Stored Data Format: DIGITAL ARC/Info 8.0.2 under SunOS, vector coverage, geographic, 290 polygons

Available Format Types: DIGITAL ARC/Info Coverage

Access Constraints: Conditions of use, copyright & charges apply

Data Quality

Lineage: Source data includes the following datasets: QDNR - SLATS processed Landsat TM imagery (1991 & 1997), Statewide Landcover & Tree Study (SLATS) baseline land cover (1991) & land cover change (1999), Digital Cadastral Database (DCDB) (2000), Protected Areas of Queensland (Estates v6.3) (1999), State Forest & Timber Reserve Boundaries (2000), Boundary of Gazetted Irrigation Areas in Queensland (1998), Dams and Weirs in Queensland (2000), AUSLIG - waterbody 250K geodata (1996), built up areas 250K geodata (1996), aeronautical 250k geodata (1996). All datasets were in digital format.

Landsat TM scenes (non-standard full scene, path 92, rows 79 & 80 (Dirranbandi), 1991 & 1997) and SLATS baseline land cover mapping (1991) raster image were clipped to the extent of the St George 1:100,000 map sheet. The land cover image was overlaid on the 1997 Landsat image and land use polygons identified & digitised on-screen. The 1991 Landsat and land cover change images were used to determine the nature & extent of temporal changes in land use types between 1991 & 1997. Additional land use information from QDNR & AUSLIG Geodata ancillary data sets was incorporated. This included production forests, dams & weirs, protected areas, water bodies, irrigation areas, urban, water storage and airfields. Polygons were assigned to classes according to the Baxter & Russell (1994) land use classification scheme, as modified by BRS (2000). This process produced a raster image of land use polygons which was converted to a vector coverage in Arc/INFO. The coverage was overlaid on the 1997 Landsat TM scene together with the DCDB, roads, towns & other major features to produce a draft land use map. Detailed field checking of the draft map was undertaken to verify classification of land use polygons & attributes. This involved visual inspection of individual land use polygons where access was possible and acquisition of best available local knowledge from land protection & extension officers as well as land owners & managers.for those polygons where access was not possible. Positional information of polygons & features was checked using differential GPS. Field data & corrections were incorporated into the draft map followed by GIS manipulation & editing. The final dataset was reclassified according to the Australian Land Use & Management Classification (October 2000) and quality assurance checked to ensure compliance with specified data quality standards.

Positional Accuracy: Positional accuracy is largely determined by the accuracy of the source data sets. Positional accuracy of the ancillary data sets used is variable ranging from approximately 56 metres for information derived from 1:100,000 scale source maps to 140 metres for information derived from 1:250,000 scale maps. SLATS Landsat TM imagery has a positional accuracy of two pixels (50 metres) or better. Field acquired GPS positional information has a horizontal accuracy of ten metres or better.

Attribute Accuracy: Attribute accuracy is determined by the accuracy of source data sets, classification methodology and the land use classification scheme used. Assignment of land use types according to the modified Baxter & Russell land use classification was based on visual interpretation of imagery as well as ancillary data sets where these were available.

Where no ancillary data was available, a preliminary assignment based solely on visual interpretation of imagery was made & subsequently field checked.

Wherever access permitted, individual land use type polygons were field checked for classification, attribute & positional accuracy. Expert local knowledge from land managers, land extension and land protection officers was used where access was not possible. Whilst no independent quantitative accuracy assessment was undertaken, it is estimated that attribute accuracy is greater than 90%.

Logical Consistency: Logical consistency is determined by the logical consistency of the source data & subsequent GIS operations performed on this data. Arc/Info was used to perform topological consistency checks to detect errors in the spatial data structure. These confirmed that all polygons are closed & possess only one label; nodes are formed at the intersection of lines; there is no overshoot, undershoot, unintentionally crossed or duplicated lines & all points, lines & polygons are topologically related.

Completeness:

Completeness of coverage – all spatial & attribute data are complete for the entire dataset.

Completeness of classification – The draft map was produced by mapping to the smallest discrete unit able to be visually interpreted from the imagery (approximately 0.0625 hectares) using the visual cues of colour, texture & pattern as well as ancillary data. Field verification was conducted at this level of detail wherever possible. Subsequent GIS manipulation, smoothing (using GENERALIZE in Arc/INFO) & editing operations (using ERDAS Imagine, Arc/Info & ArcView software) which were applied to ensure compliance with the required data quality standards resulted in polygons smaller than four hectares being eliminated in the final dataset.

Application of the modified Baxter & Russell classification in this as well as other land use mapping work has highlighted the need for on-going development & modification to suit the requirements of individual projects. The classification has recently undergone a review resulting in the creation of a new primary class, modifications to secondary & tertiary classes as well as increased flexibility in class descriptors to more accurately reflect specific land use types and been renamed the Australian Land Use & Management Classification. It is likely that the present classification & land use mapping methodology in general will undergo modification & refinement as national land use mapping programs progress.

Completeness of verification – field verification was undertaken to validate polygon classification, attributes & spatial data. Individual polygons were checked in the field wherever access to these was possible. Polygons unable to be field checked were verified to the extent of best available knowledge. Spatial verification was performed using differential GPS derived positional information with a horizontal accuracy of approximately ten metres or better.

Contact Information

Contact Organisation: Department of Natural Resources

Contact Position: Data Coordinator

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Metadata Date

Metadata Date: 30SEPT2000

Additional Information

Additional Information: Refer to AUSLIG Metadata web page – http://www.auslig.gov.au/meta.htm#dm and the contact position for additional information regarding source data.

File Transfer Details

Files Name(s) and size(s) used in this Transfer:

Number of Records in each file:

File Format:

Field Name Definitions:

Fields Names in each File:

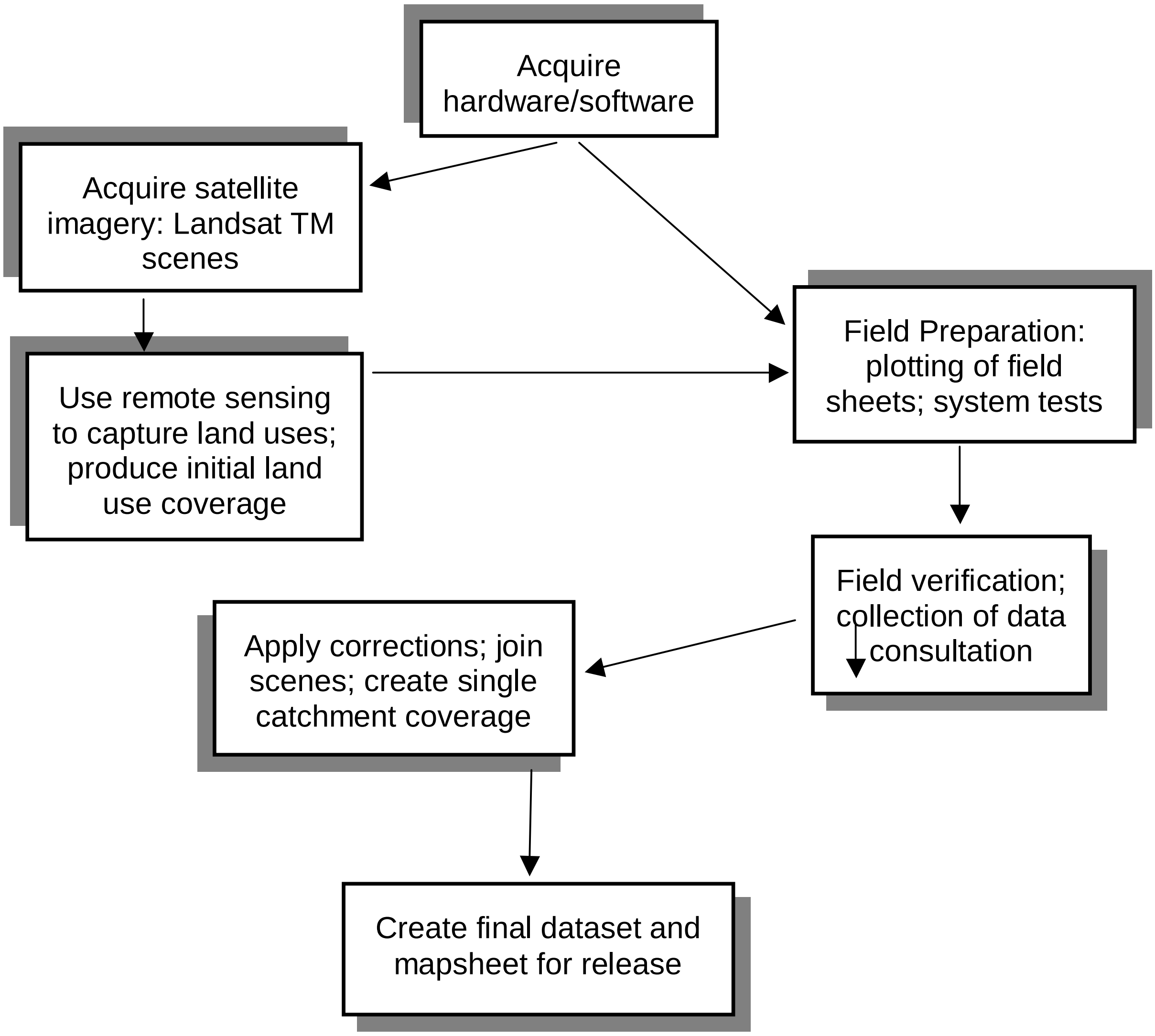
Update: Full or Partial

Date of Creation of Transfer File(s):

APPENDIX D: Methods - Land Use Mapping of the Fitzroy Catchment

The procedures and methods for the capture and processing of data for land use mapping within the catchment are summarized in figure 2.

The land uses in the catchment were mapped from remote sensing coverage for the winter months of 1997 using Landsat TM imagery. Remotely sensed areas and land use classifications obtained from the Queensland Digital Cadastral Data Base (QDCDB) were verified in the field along with consultation with landholders, local authorities and DPI/DNR district officers. After field verification, corrections and changes were applied during a final edit. The final mask was then manipulated and converted into a classification coverage displaying the fields required by the NLWRA, and prepared for release.



Flow chart, showing progressive steps undertaken for land use mapping in the Fitzroy catchment.

Preparation: equipment and software

Prior to the actual collection and creation of datasets classifying land use in the catchment, dedicated hardware/software and specific equipment was purchased or leased and prepared for service.

Pre-project preparation included:

- A dual-cab Mitsubishi Triton tray back 4WD vehicle was leased from Q Fleet for 12 months/50,000 kilometres for the field verification operation of the project.

- An additional 12 volt battery was installed to allow for two additional electrical ports to be added to prevent unintentional shut-down of positioning and navigational units.

- A Global Positioning System (GPS) receiver and Differential GPS receiver were purchased and mounted in the vehicle for navigation and positioning of features/land uses.

- A laptop with a 5Gb hard drive and 12 volt transformer were purchased with the transformer mounted in the vehicle.

- A mobile phone for communications dedicated to the land use mapping project.

- Specific tracking/logging software, Computerized Information Gathering System (CIGS) was purchased and loaded on the laptop.

- A dedicated PC and ERDAS Imagine imaging software package and license were purchased for the remote sensing applications of the project.

- Landsat TM imagery for 1991, 1995 and 1997 along with crop masks for 1991 were acquired from Statewide Land Cover and Trees Study (SLATS).

Remote sensing preparation and methodologies

Naming conventions

3 basic stages are required using Erdas Imagine software to produce a land use mask for a raster or vector coverage in the Fitzroy LUMP. The naming convection should reflect each stage. The first stages are temporary (such as initial raster editing) and are deleted as they are superseded by updated images.

Storing files

Files created or used by remote sensing officer are stored on the local D drive under Fitzroy. Each scene has its own folder and all files relating to that scene are placed in this file. There are several extra folders:

- Coverages: generally vector coverages created in ArcInfo.

- Reports
- SLATS additional data from the slats file store, and updated crop masks using slats methodology.

Files created by remote sensing officer are also stored on a separate drive:

- Rsk_fera on 'indplly7'/habitat and resource assessment/projects/Fitzroy/draft_3s5c.

SLATS will store the updated crop masks but the classifications will be altered as per SLATS methodology. Currently, these updated crop masks reside in rsk_fera on 'indplly7'/habitat and resource assessment/projects/Fitzroy/slats97_m0f0.

Naming structure

Naming structure follows the SLATS structure, as it is practical and easy to follow.

f	b	l	a	9	7	a	u	_	1	f	0	c	.	i	m	g

The file name is broken into 'f' (c1), unique scene id (c3), scene date (n2, c2), an underscore to visually break scene information from processing information, scene processing stage (n1) and scene coordinate information (c1, n1). Compressed scenes are tagged with a 'c' (final letter). Compression has been applied to the projected scenes to decrease storage space.

fbla97au_1f0.img

To avoid confusion with SLATS, every file generated by myself for the Fitzroy LUMP starts with 'f'.

fbla97au_1f0.img - *unique scene id*

Represents the 1st 3 letters of the scene name, eg bla is for blackwater. The Fitzroy catchment only contains 13 scenes, and there is no duplication of id's.

fbla97au_1f0.img - *scene date*

Obtained from SLATS files, all image data is named according to the year and month of data capture. The 1st 2 numerics are the year of data capture (97 = 1997) and the last 2 characters are the month (ju = june).

Codes for months that conflict are as follows:

June = ju

July = jy

fbla97au_1f0.img - *scene processing steps*

The processes used in the Fitzroy LUMP are fully described in stage 1 methods. There are 3 main steps which are numerically labelled. These are as follows:

Fsssyymm_1f0 - initial raster edit of land use mask.

Fsssyymm_2s5c - projection into zone 55 of initial raster edit

Fsssyymm_3s5c – amended land use mask after field editing

fbla97au_1f0.img - *scene co-ordinate information*

Lets the user know what co-ordinate system the data is in.

f = file based or 'raw' pixel/row coordinates

s = GPS ground surveyed GCP's in AMG coordinates (Australian National Spheroid, AGD84 Transverse Mercator Projection) to provide the transformation parameters for final re-sampling.

The second numeric field is for AMG zone information. The possible entries for this field are:

0 = not on the AMG

5 = AMG zone 55

6 = AMG zone 56

SLATS naming conventions

Several files are used from SLATS in order to generate these files. Contact SLATS to gain access to the SLATS homepage: http://atrax.dnr.qld.gov.au/ciss/slats for a description of SLATS naming conventions.

Raster editing land use mask

Raster editing involves modifying the existing 1991 SLATS crop mask to the Baxter and Russell land use classification scheme used by the NLWRA and Fitzroy LUMP. The SLATS crop mask classification is as follows:

SLATS crop mask classes

Class no.	Class name
3	Miscellaneous crop
4	Sugar
5	Broadacre
6	Horticulture
16	Orchard

The Baxter and Russell (B&R) land use scheme is a more detailed system. 3 tiers of classifications were developed based on mapping scale, and on the level of land use detail (Appendix I). A mapping scale of 1:100,000 was decided for the Fitzroy LUMP, based on catchment size and the use of Landsat TM imagery.

Step 1

- Output name: fsssyymm_1f0.img

- In windows explorer: copy SLATS raster crop mask, named ssss91mm_m0f0.img and rename as fsssyymm_1f0.img. Close.

Define classes:

- In Erdas Imagine 8.3.1, open 1f0.img in viewer 1. Open AOI tool box and use polygon or box tool to select an AOI in the mask that is currently classed '1'. Under Raster ⇒ Tools select either Fill Area icon or Recode area icon to reassign a class value of '25'. Save image then close. It will take a few seconds to process statistics.

- Re-open 1f0.img. Under Raster ⇒ Attributes add another column (column icon ⇒ choose 'new', click 'editable, title = class; type = string, display width = 15. OK. Recode '25' back to original code. The idea behind assigning an area to code '25' is to allow all land use codes between 1and 25 to be attributed colours.

- To copy colours from one mask to another, open viewer ⇒ 1f0.img (a mask previously assigned these colours) ⇒ Raster ⇒ Raster Attribute box. Right click on head of column, copy. Right click on head of column of new mask, paste; colours should be copied from old to new file. Class names can be copied the same way (ensure that column attributes are the same).

- Assign an opacity value of 0.5 for all colours except class 0 and 1 (assign zero for these 2 classes). This allows the satellite scene to be seen.

- Save Raster Attribute Editor then close.

Raster Editing:

- Open 3 or 4 viewers.

- In viewer 1, open slats ssssyymm_l0f0.img (or q1f0.img if 1997 or later): file ⇒ open ⇒ raster layer. Go to raster options, select bands 2, 4, and 5 OR bands 3, 4 and 5. OK. These bands distinguish between cropping and grazing better than any other combination. Bands can be changed during raster editing by selecting View ⇒ arrange layers, right click on file layer to be changed ⇒ band combinations. Overlay with 1f0.img: file ⇒ open ⇒ raster layer: go to raster options and de-activate 'clear display', OK.

- Open viewers 2, 3 and 4 with 91, 95 and 97 l0f0/q1f0.imgs from SLATS (to enable a temporal comparison between land uses, which is important for distinguishing between rotation and permanent cropping). Geo link all viewers (right click on viewer ⇒ geo link/unlink, click on image to be linked). Increase scale to see detail clearly (view ⇒ scale ⇒ scale tool, enter ~ 1500 to 2000, whatever; but always work in the same scale).

- ➢ Scan image by working across scene (use hand icon to move scene), keep a tab on coordinates, and overlap each scan to avoid missing any areas.

Digitising

- ➢ Select AOI ⇒ tools. Polygon AOI is the most useful tool, also Rectangle AOI and Polyline AOI. Digitise area to be changed. Go to Raster ⇒ tools ⇒ select recode area icon, change new value to the preferred class (eg for an airstrip, change class 1 to class 13). Note: AOI must be selected. If you apply recode values and an AOI is not selected, the entire scene will be recoded (you can cancel this operation by pressing the cancel button that appears at the bottom of the viewer). Several AOI's can be selected at the same time by selecting the Box select AOI icon. You can also use 'fill area' tool in the raster tools to change class values, but the 'recode area' icon allows you to change several values at once.

Region grow tool

Water can be selected using the region grow tool; it is quicker and more accurate than digitising. Go to AOI ⇒ seed properties. De-select area and distance. Set spectral euclidean distance at 50 (you may need to experiment with this number). Close. Go to View, change layering so that l0f0.img or q1f0.img is the top layer. Select 'region grow AOI' icon in AOI tool box, and click inside a water area. The AOI will take a few seconds to form. Go back to View and change layering so that 1f0.img is on top. Recode AOI.

Step 2

Output name = fsssyymm_2s5.img

The raw coordinate mask is projected into zone 55 of the Australian Geodetic Datum (AGD 84), to enable field checking.

Zone 55

In the Fitzroy catchment, the Landsat TM scenes mackay, moranbah, st lawrence, alpha, emerald, blackwater, carnarvon, injune, roma and yeppoon are in zone 55.

- ➢ In Imagine 8.3., go to Data Prep ⇒ Image Geometric correction, select 'From Image File', click 'Open File' icon and find 1f0.img file to be projected, OK.

- ➢ In Set Geometric Model box select "Polynomial', OK. In Polynomial Model Properties box select Projection ⇒ Add/Change Projection. In Projection Chooser box select Custom. Enter following (check this coz geocentric datum gets changed in 2000):

    - Projection type = Transverse Mercator
    - Spheroid name = Australian National
    - Datum name = AGD 84
    - Scale factor at central meridian = 0.9996

- Longitude = 147.0 E (zone 55 – for *)
- Latitude = 0 N
- False Easting = 500,000 meters
- False northing = 10,000,000 meters

➢ OK, close.

➢ In GCP Tool Reference Setup box: select Keyboard only, OK. A 'GCP Tool : (input : file name (Reference : No File)' box will appear. Highlight X Input Y Input X Ref Y Ref columns (click and drag), right click, select Import. In Import Column Data box, click 'open file' icon and select l3s5.dat file for scene. (l3s5.dat files are SLATS files of differential GPS control points collected in the field – 5 represents zone 55, hence 6 represents zone 56).

➢ Select Options. In Import Column Options, change Separator Character to comma, and change column / field table (table 3). OK.

Column / field table numbers.

Column name	Default column no.	New column no.
X Input	1	2
Y Input	2	3
X Ref	3	4
Y Ref	4	5

➢ Check that GCP's are accurate (total RMS Error should be < 0.7. If RMS error is large, delete any rows that have zero coordinates. If RMS error is still > 0.7, delete rows with largest RMS error, ie >1. BUT: 1st check that GCP is not essential by referring to image and proximity of other GCP's. If GCP is an isolated point, best to leave it. To delete, highlight entire row, right click – choose delete).

➢ In Geo Correction Tools box, select 'resample' (coloured squares) icon. In Resample box, enter output file name (fsssyymm_2s5.img); in resample method, choose 'cubic convolution' if resampling a satellite image; choose 'nearest neighbor' for a mask ('cubic convolution' takes a lot longer to process). Adjust Output Corners to nearest multiple of 25 (eg, 745 887 ⇒ 745 875), adjust Output Cell Sizes to 25, activate 'ignore zero in stats', OK.

Processing will take a few minutes to complete.

Zone 56

3 Landsat TM scenes (chinchilla, monto and gladstone) are positioned in zone 56 by SLATS, and need to be re-projected to zone 55 in order to be used in the Fitzroy LUMP.

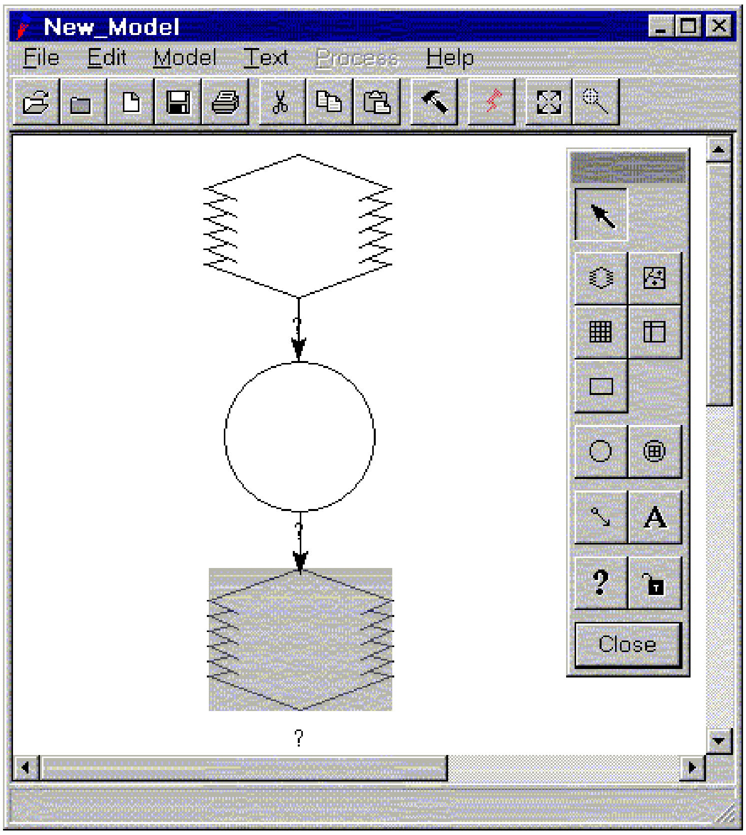
Follow the same procedure as above but with the following differences:

- In Projection Chooser box, Custom, enter Longitude = 153.0 E (instead of 147.0 E).
- In Import Column Data box, file is called ssss91mm_ l3s6.dat instead of l3s5.dat
- Go to Session ⇒ Tools ⇒ Coordinate calculator. Co-0ordinate Calculator box will appear. In GCP Tool box, highlight X ref and Y ref columns (click and drag). Right click then click 'copy'. In Coordinate calculator box, highlight input X and input Y. Right click then click 'paste'. Check that input numbers have been copied correctly and ignore output numbers. Go to 'projection' ⇒ 'set input projection', change projection parameters to zone 56. Go to 'projection' ⇒ 'set output projection', change projection parameters to zone 55. Copy and paste output X and output Y columns into X ref and Y ref columns in CCP Tool box.
- Check RMS error. It will probably be > 2. If it is < 0.7 it is ok, but anything bigger than that needs to be corrected. To correct RMS error, go to 'Display Model Properties' in Geo Correction Tools box. Under 'Parameters', change polynomial order to 2, then apply. This should reduce RMS error to < 0.7.

Step 3: Mask size compression

Output name = fsssyymm_3s5c.img

Projected mask size is ~80Mb but can be compressed to ~1Mb by running through the modeller. Open Modeller ⇒ model maker. Create a simple model as shown in figure 3. Double click on input raster, enter input file, OK. Double click on function circle, Function definition box opens, double click on available input (your file name), OK. Double click on output raster, call output file fsssyydd_2s5c. Ensure output layer is thematic and 'ignore zero in stats' is activated. Hit lightening bolt icon in top tool box, model takes a little time to run. Colour values and descriptions will need to be re-assigned as they revert to grey scale and descriptions get dropped. The mask is then ready for field editing.



Compression model of land use mask.

Field verification.

Preparation for the field verification of the land use classifications involved the creation and production of various scripts, datasets and map-sheets for data collection

- Trialling of methodologies for the collection of data and testing of software and related equipment

- Contact made with the district and field officers from the Department of Natural Resources (DNR) and Primary Industries (DPI) and representatives from local authorities, to arrange meetings for collection of information in local areas.

Catchment boundary

As a dataset of the Fitzroy Catchment and major sub-catchment boundaries conforming with 1:100000 specifications did not exist, a new dataset was created by firstly defining the boundaries from existing 1:100000 topographical mapsheets. This dataset was digitized into an ArcInfo coverage.

- Use the ArcInfo command : *clip* to create a dataset of cadastral information within the confines of the catchment and use ArcEdit command ; *select area gt 250000* (select area greater than 250000 square meters or 25 hectares) to produce a workable dataset, uncongested within town areas.

- Using the ArcEdit command: *select tenure*, State Forests and National Parks were extracted from the QDCDB and put into separate ArcInfo coverages.

- Satellite images were converted to.tif files using bands 5 4 2 for compatibility with the CIGS software used for navigation and data collection, using ERDAS Imagine version 8.3

- Create ArcInfo coverage of remotely sensed land use mask (in.img format) received from the remote sensing officer by using the Arc commands: *imagegrid* and *gridpoly* to convert the.img file into a coverage.

- To enable ArcInfo coverages of the QDCDB, catchment / sub-catchment boundaries and land use classifications to be compatible with the CIGS software on the laptop, use the Arc command: *ungenerate* to create a.lin2 file which is peculiar to that particular software.

- Prepare Applied Macro Language (AML) script to create 1:100000 field verification sheets with image, DCDB, catchment/sub-catchment boundaries, classification coverage, national parks and state forest coverages, grid and legend.

- Print all 1:100000 field verification map sheets.

- Become familiar with and amend Baxter and Russell guidelines to suit the region.

Field Verification: data collection.

Field Preparation

83 field verification sheets covering the Fitzroy catchment were printed at 1:100000 scale, showing the satellite image, 10km co-ordinates, DCDB polygons larger than 10ha, main roads, and national park and state forest boundaries. A field laptop was installed with the CIGS software tracking system. Satellite images were installed in geotiff format, and relevant coverages (DCDB, land use classifications and catchment boundaries) were installed as .lin2 files (table 4). Zonal changes occur within the catchment and particular care was taken to ensure the images are projected in their particular zone.

The procedures for field verification are:

Convert the raster mask (in .img format) into an ArcInfo coverage using the Arc commands *imagegrid* and *gridpoly*.

Images and coverages used in CIGS software.

Input file/Coverage	Output file	Description
chin97ju_q3s6.img	rgb_chin97_55.tif	Satellite image
97/98_2s5.img	97/98_2s5.tif	Land use mask (raster)
refitcat (Coverage)	refitcat.lin2	Land parcels > 25ha (vector)
chincov	chin.lin2	Land use mask (vector)

subcatbdy	catch.lin2	Catchment/sub catchment boundary

Use the Arc command *ungenerate* to create a.lin2 file of the DCDB, catchment /sub-catchment boundaries and the land use coverage and load on the laptop. Satellite images, in .geotiff format were also written to CD as backup and as a space saving measure.

District officers and local authorities were contacted at least one week prior to the field work commencing in their area and arrangements made for data gathering meetings. Local authorities supplied information on waste disposal, rural residential areas and the general infrastructure of their shires.

All land use classifications were visited excepting for those noted on the field sheets, where it was not possible to gain access to acquire a visual sighting or confirmation from landholders. The laptop, GPS and DGPS were connected and input data into the CIGS software.

Two methods of confirming/logging data were utilized. The codes allocated to the Baxter& Russell classifications for this project were marked/verified on the hard copy field sheets & the information was also logged in the CIGS software.

Configuring.txt files (also refer to CIGS User Guide V1.1.5)

The CIGs User Guide gives a detailed explanation of configuring.txt files in notepad. The following is an example of field definition information used to capture data for the Fitzroy LUMP. It is a very basic set of function commands to enable data to be entered into the laptop software.

In notepad, enter on 1st line:

- $f1,Landuse,2,5
    - $f1 = configuring data for F1 key
    - Landuse = type of information gathered
    - ,, = (2 commas) indicates that anyone can enter information; alternately enter MC, - initials and comma – to signature personalized entry
    - 2 = marker colour
    - 5 = marker size (1 – 10)
- on 2nd line: Types,L,16, 2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
    - Types = types of landuse
    - L = list
    - 16 = number of fields/classes

- 2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18 = number assigned to each land use class (eg 2 represents improved pasture, 16 represents water).

- On 3rd line: Description,A,200
  - Description = additional information you may wish to add
  - A = alphabetical characters (N = numerics)
  - 200 = limit to number of characters that can be entered.

Refer to CIGs user guide for general use of CIGs software. Field data entered into the CIGs software is recorded as.log files.

Logged data showed but was not restricted to the following information :

- Year
- Month
- Day
- Hour
- Minute
- Second
- Easting
- Northing
- Number of satellites
- Field (Classification code)
- Operator

The two methods were used in case of hardware/software failure and for the ease of in-field editing and final product editing. Each days' data log was downloaded onto floppy disks as a further back-up precaution.

On completion of each satellite scene, editing of the log file and hard copies was carried out in office before dispatching the data on disk for conversion into vector coverages for use by imaging software. This process was repeated until all land use classifications on all scenes (7,273 polygons) had been verified/checked in the field.

Amendments to land use mask using field data

After field editing, hard copy maps and.log files are used to amend 2s5c.img files.

- In ArcInfo, .log files are converted to vector coverage:

- Open log file in excel and delete 1st column plus any others that are blank or meaningless. Save as text file.

- In Arcview go to Project Window ⇨ Table ⇨ Add, to open text file.

- New view: View ⇨ Add Event Theme and select text file, easting and northing.

- Theme ⇨ Convert to Shapefile

- In Arcinfo, convert shapefile to point coverage.

- In Imagine 8.3.1, project SLATS q1f0.img into zone 55, and rename fsssyymm_q1s5.img.

- In Windows explorer, copy 2s5c.img and re-name 3s5c.img.

- Open viewer and load q1s5.img, overlaid by 3s5c.img. Raster edit using hard copy maps and converted.log files (arc coverages).

Both 1f0.img's and 2s5c.img's should be deleted when 3s5c.img's and 4f0.img's are complete, as they contain incomplete and incorrect data.

Stitching together scene masks

Output file name f_final_97.img

- Go to modeler ⇨ model maker.

- In New Model box, go to file ⇨ open, and open file named moya.gmd. This model contains 2 raster inputs connecting to a function as follows:

- CONDITIONAL { ($n2_*input2*== 0) $n1_*input1*, ($n1_*input1*==0) $n2_*input2*, ($n1_input1 == 1)$n2_*input2*, ($n2_*input2*)$n1_*input1* }

- Input 1 and input 2 are the 2 scene masks to be stitched together.

- The function is connected to a raster output.

- To use model, double click on raster inputs and find appropriate file ⇨ OK. Double click on raster output and enter new file name (temp file), change file type to thematic & ignore zero in stats ⇨ OK. Press lightning bolt icon from tool menu, model should take a while to run. The last file to be added will create the final mask; name this output file f_final_*yy*.img.

- Colours and descriptions will be lost when run through the modeller, so, they need to be re-added. Open final mask in Imagine viewer. Open a mask (pre-stitched) in another viewer. Open attributes under raster for both. Copy colours and descriptions across from original mask to final mask.

- Note: all scene masks must be projected into the same zone.

- To reproject zone 66 to 55, de-project file to raw co-ordinates 1st, then reproject into zone 55. It doesn't seem to fall in the right spot if its projected straight from 56 to 55 (for some strange reason).

Generation of final dataset, database integration and production of map sheets.

1:100 000 land use classification dataset

Upon completion of corrections to the mask, imaging software was utilized for the creation of one raster mask covering the catchment. This final mask (.img format) was converted into ArcInfo coverage, edited, manipulated and converted into a final dataset in Geographic projection ready for distribution to clients. Eight (8) 1:250000 sub catchment map sheets using 1:100000 data and two (2) 1:50000 irrigation area map sheets using 1:25000 data were produced.

Procedures for database integration and production of map sheets are as follows:

- Convert the final mask (in.img format) into an ArcInfo coverage using the Arc commands *imagegrid* and *gridpoly*.

- De-pixelize the coverage using the Arc command *generalize* ensuring the weed tolerance is 50.

Editing of the final coverage to check each individual poly for correctness was carried out in ArcEdit.

A look-up table was created for the master dataset to show the fields to secondary classifications. Using the Arc command *info*, a tabular data file called LUMP.INFO was defined with four fields, GRID-CODE, PRIMARY, SECONDARY and DESCRIPTION using the specifications in table 5 for the parameters.

Specifications for building look-up table for the land use classifications.

Parameters	Description
Item name	Any name (up to 16 alphanumeric characters – must begin with an alpha character)
Item width	Number of spaces (or bytes) used to store the item values.
Item output width	Number of spaces used to display item values.
Item type	Data type of the item. The most common item types are :
C	Character-any combination of alphanumeric characters
I	Integer-any characters that make up a valid integer
B	Binary integer-an integer number stored in binary format
N	Number-any characters that make up a valid decimal number

F	Binary floating point-a decimal number stored in binary format
D	Date-stored as 8 bytes : displayed as 8 or 10 spaces

The parameters used are demonstrated below.

GRID-CODE

- Item name > GRID-CODE
- Item width > 4
- Item output width > 8
- Item type > B

PRIMARY

- Item name > PRIMARY
- Item width > 4
- Item output width > 8
- Item type > B

SECONDARY

- Item name > SECONDARY
- Item width > 2
- Item output width > 4
- Item type > B

DESCRIPTION

- Item name > DESCRIPTION
- Item width > 50
- Item output width > 50
- Item type > C

The 24 grid-codes, related Baxter & Russell codes, and land use classification descriptions were entered into the LUMP.INFO look-up table using the *add* command as per the example below.

Enter command > add

- Grid-code > 4

- Primary > 3
- Secondary > 5
- Description > Permanent cropping

Continue entering the classifications

The LUMP.INFO table for the 1:25000 dataset has been formatted the same way and shows 43 grid-code features at a tertiary level.

To allow user access to the fields determined by the .info table, an association had to be made between the actual polygon coverage .pat file and the LUMP.INFO table. The table and the coverage were joined using the Arc command *joinitem.*

Because map sheets are to be produced using the final dataset, a colour table was created using a colour scheme related to the GRID-CODE to depict the different classifications. Using the Arc command *info*, a colour look-up table, COLOR.LUT was defined to reference the grid-code with a colour symbol. The parameter specifications were determined as with the LUMP.INFO table and are demonstrated as follows.

GRID-CODE

- Item name > GRID-CODE
- Item width > 4
- Item output width > 8
- Item type > B

SYMBOL

- Item name > SYMBOL
- Item width > 3
- Item output width > 3
- Item type > I

Once the COLOR.LUT table had been defined, the 24 colours were entered in ArcInfo using the *add* command.

Enter command > add

- Grid-code > 4
- Symbol > 180

Continue entering the symbols.

The COLOR.LUT table for the 1:25000 dataset has been formatted the same way and shows 43 colours.

1:25 000 and 1:50 000 datasets

To produce the 1:250000 and 1:50000 map sheets, a script was written using AML which combined the following information/datasets.

- A DCDB base showing polygons greater than 25 hectares
- The land use classification coverage
- Drainage patterns showing major streams and rivers
- A road center line coverage showing highways and major roads
- Reference and legend
- Australian Map Grid in specific zones
- Internal text
- North point
- Title
- Scale bar
- Projection information
- Appropriate logos
- Locality map
- Relevant notes pertaining to each map sheet
- Disclaimer
- Unique map number and associated text

Local Authority or Shire boundaries have also been added to map sheets to assist local government officers in determining infrastructure needs.

Draft copies of each sheet are created for editing prior to a final copy being produced.

Final datasets and metadata

The final datasets and metadata produced are as follows:

- The Fitzroy catchment and major sub catchment 1:100000 boundary in Geographic projection.

- The final Land Use cover of the catchment, in Geographic projection.
- The Emerald Irrigation Area 1:25000 Land Use coverage in Geographic projection.
- The Dawson valley Irrigation Area 1:25000 Land Use coverage in Geographic
- Projection.

All 100000 coverages used in the creation of the final dataset have the folllowing tolerances:

- Fuzzy : 3.28
- Dangle 0.0
- Edit : 50.0
- Node : 50.0
- Snap : 50.0
- Weed 50.0
- Grain 50.0

All 25k coverages used in the creation of the final dataset have the following tolerances:

- Fuzzy : 1.27
- Dangle 0.0
- Edit : 12.0
- Node : 12.0
- Snap : 12.0
- Weed 12.0
- Grain 12.0

It is important for users of the land use datasets to use this information in conjunction with the Baxter and Russell guidelines and not to use individual interpretations of classifications.

APPENDIX E: BRS data quality statement proforma

DATA QUALITY STATEMENT

Data set details

Coverage name:	Type:
Stored on:	Size:
Date:	Custodian:
Contact officer:	Contact telephone:
Contact address:	E-mail:

Compliance with specifications

(see www.brs.gov.au/land&water/landuse/techspecs.html for more detail)

		Details of Compliance	✓/✗
Metadata	ANZLIC Page 0		
	ANZLIC Page 1		
	Report		
	Map		
Spatial data standards	Topology		
	Attributes		
	Labelling		
	Errors		
	Lookup tables		
	Tolerances		
	Unique IDs		
Classification (see page 3)	Classes		
Spatial referencing systems	Projection		
	Position		
	Overlap		
Data transfer standards	Transfer file		
	Media		
Validation	Data		
	Currency		

Assessment of data formats and structure:

Assessment of classification:

Compliance requirements:	✓/✗

Data compliance

Compliant / not yet compliant

Checked by:	XXXXXX	Date:	X/X/XX

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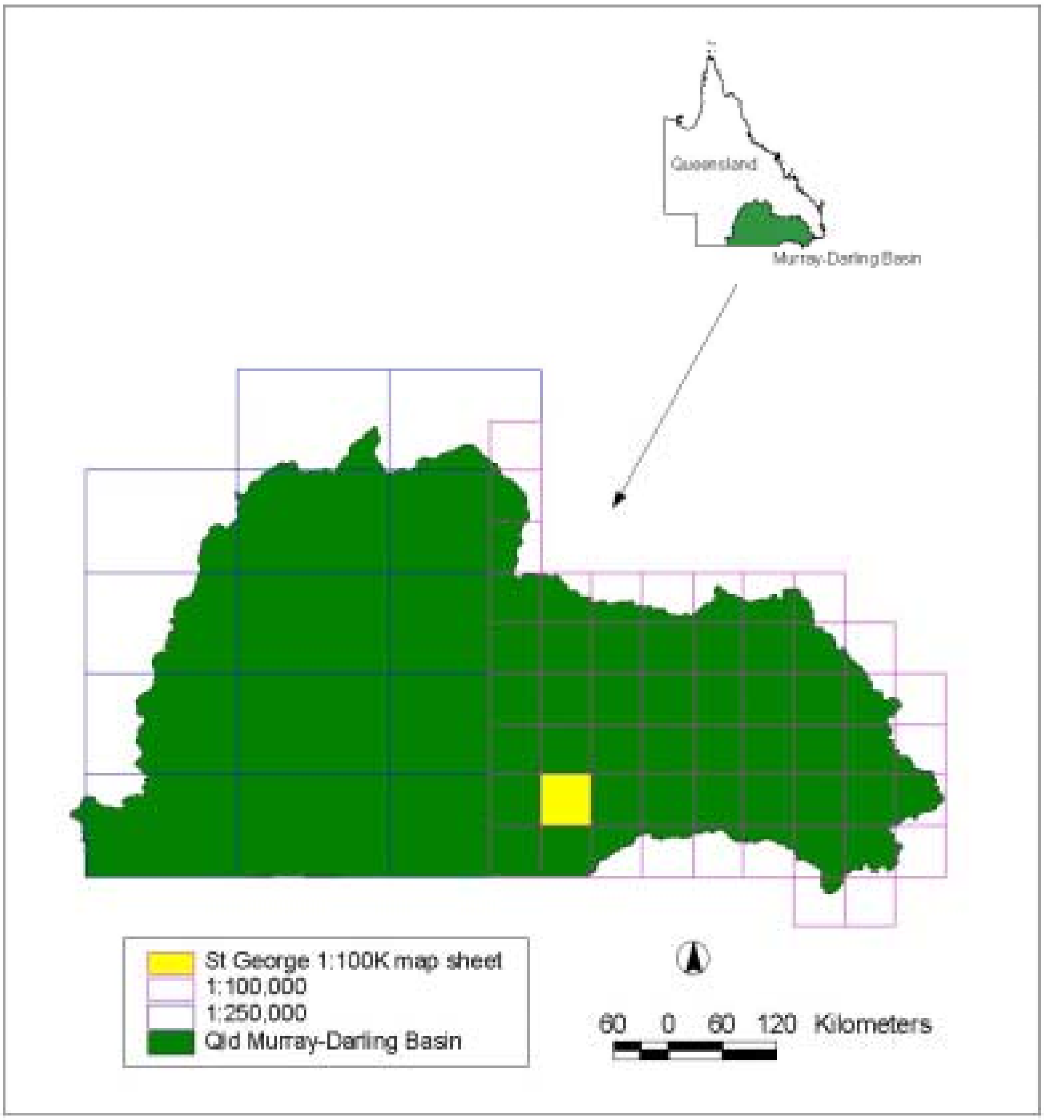
APPENDIX F: Costings for land use mapping across the Qld Murray-Darling Basin

TASK	TIME (days)	COST
Dataset acquisition, image interpretation, draft land use map	**2**	-
PC & software charges	-	In-kind
Salaries	2	460
Field Verification	**5**	-
Vehicle hire	5	300
Travelling allowance	2 x 5	1,100
Salaries	2 x 5	2,300
GIS editing, final dataset, metadata, quality assurance	**15**	-
Salaries	15	3,450
TOTAL	**22**	**7,610**

Estimated costs & time (single mapsheet) for 1:100,000 and 1:250,000 scale pilot project land use mapping in Queensland

An adjusted cost of $3,800 – 4,800 would apply when mapping is extended to adjacent mapsheets. This could possibly be further reduced if mapping was undertaken over an area of significant size.

The map below shows the extent of the Queensland Murray-Darling Basin together with costings based on adjusted cost of mapsheets.



Proposed mapping scales and their extent for land use mapping across the Murray-Darling Basin in Queensland

Cost calculations

Number of 1:100K map sheets is 29 full + 26 part (approx. 13 full) = 42 equivalent full sheet
Number of 1:250K map sheets is 3 full + 11 part (approx. 6 full) = 9 equivalent full sheets
Cost per mapsheet (same for both 100K & 250K) = $3,800 (see table)
Total cost = $3,800 x 51 sheets = $193,800

Assuming 22 days per mapsheet:

Total time = 22 x 51 mapsheets = 1,122 days (224.4 weeks or 4.9 years)