Technical Framework Development

Reference Paper: Adoption of GDA94 for spectrum licensing

1. Introduction

The coordinate reference system currently used by the ACMA to reference spatial data is the Australian Geodetic Datum 1966 (AGD66). AGD66 is a local datum optimised for the Australian region and was the primary datum used within Australia from the 1960s until 2000.

Since 2000, all spatial data published by the Commonwealth and state surveying and mapping agencies – excepting unrevised historic data – has used the Geocentric Datum of Australia 1994 (GDA94). GDA94 is an earth-centred datum compatible with satellite-based navigation systems and other major international geographic systems, such as the World Geodetic System 1984 (WGS84).

In order to better align with the general shift in datum use and as part of the development of a new licence management system, the ACMA has formed a view that it should move to GDA94 as the basis for coordinate references for spectrum licensing arrangements as well as other radiocommunications records. The ACMA will consult on the implementation of this change in due course.

Given the impending change the ACMA consider it opportune to review other aspects of spectrum licensing arrangements that rely on the use of the coordinate system such as the Australian Spectrum Map Grid (ASMG) and the digital elevation model (DEM). This paper reports on the proposals developed as a result of these investigations.

At this stage this paper is intended for informational purposes only, however preliminary comment by the Technical Liaison Group (TLG) is welcomed. This work forms part of a larger project investigating the transitioning of all of the ACMA's spatial data to the GDA94 coordinate reference system. As such, it is noted that any changes proposed will ultimately be publicly consulted on outside of the TLG process.

2. Definitions

Datum

A datum is a system which allows the location of latitudes and longitudes (and heights) to be identified onto the surface of the Earth. Basically, a mathematically 'round' surface is created which represents the surface of the Earth (known as a spheroid) and from here, calculations are made to fit this mathematical model to the surface of the Earth.

Spheroid

Because the Earth is wider around the equator than it is between the North and South poles (i.e. the Earth is oblate), a model of the Earth (the spheroid) is made (Figure 1). The spheroid has traditionally been 'positioned' such that it best matches the geoid (the unevenness of the Earth) over the particular area it was specified. This has resulted in the use of local or regional datum, and in the case of Australia, has been AGD66. The centre of the AGD66 spheroid and the centre of the Earth's mass are approximately 200 metres from each other.

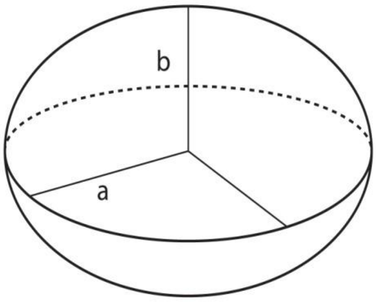


Figure 1: An oblate sphere

3. Overview of Proposed Changes

A high level overview of the changes proposed by the ACMA is as follows:

a) A change from AGD66 to GDA94 for the coordinate reference of device registrations stored in the register of radiocommunications licences (RRL);
b) Amendments to the Australian Spectrum Map Grid (ASMG):
    i. Preserve existing ASMG boundaries in both an AGD66 and GDA94 environment;
    ii. Extend the use of 5' cells across the whole of the ASMG;
    iii. Adopt a hierarchical identifier scheme overlaid on the ASMG; and
    iv. Formalise the ASMG specification
c) A change from RadDEM to the *GEODATA 9 Second Digital Elevation Model Version 3*[1] ()

These proposals are discussed in more detail later in this paper. Of particular note is the development of a formal definition of the ASMG, which will include a definition of the hierarchical identifier scheme and could affect how geographical areas are defined in various facets of spectrum licensing including: spectrum designations/re-allocation declarations made by the Minister, licence instruments, marketing plans and spectrum licence trades.

Ultimately, all the proposed changes will affect how some information is stored and presented in the spectrum licence environment. However, it is anticipated that the changes proposed for the transition to GDA94 by the ACMA will have minimal impact on existing spectrum licensees, since the physical location of licence boundaries and device registrations will remain the same.

In addition to this, the amendments to the ASMG have generally been made to improve flexibility in trading and mitigate the complexity of presenting geographical information in spectrum licence related instruments.

4. Implementation

Before any of these changes are made, the ACMA intends to publicly consult, outside of the TLG process, on the proposed changes in this paper as part of the larger GDA94 adoption process being

[1] Further details are available at: http://www.ga.gov.au/meta/ANZCW0703011541.html

undertaken. This will include the creation and/or modification of any relevant legislative instruments.

At this stage it is proposed that reference coordinates for devices in the RRL be updated when the ACMA's new licensing system comes into effect.

The ACMA will also implement any changes to area definitions for all new, traded, re-allocated and re-issued spectrum licences once final decisions on changes have been made and relevant documentation has been updated/created. As a result, existing licences will be updated in a rolling fashion as they come up for expiry. Relevant changes will also be implemented in spectrum designations/re-allocation declarations made by the Minister, marketing plans and other legislative instruments, as required.

5. Detail of Proposed Changes

5.1 Changes to Device Registrations

Coordinates contained in the publically available RRL are currently recorded with reference to AGD66. It is proposed that these be transformed to GDA94 when the ACMA moves to its new licensing management system.

This transformation will be performed using the most accurate method available, documented in the *GDA Technical Manual*[2] published by the Intergovernmental Committee on Survey and Mapping (ICSM), which is by application of a grid shift transformation using published grid shift files in NTv2 format.

The ICSM has published an AGD66 to GDA94 transformation grid for the whole of Australia. Software is widely available which supports the use of this method of transforming AGD66 coordinates to GDA94 coordinates.

5.2 Changes to the ASMG

a) Preserve existing ASMG boundaries in both an AGD66 and GDA94 environment

The ACMA proposes to preserve the existing ASMG boundaries and define an appropriate transformation to use that will allow the ASMG to be accurately interpreted in either AGD66 or GDA94 coordinate systems. This ensures that there will be no shift in the location of the existing Standard Trading Units (STUs) defined in the ASMG or the current definition of spectrum licence boundaries in relation to the ASMG.

The ACMA proposes that the approach adopted for transforming the existing ASMG AGD66 coordinates to GDA94 be the most accurate transformation method identified in the GDA Technical Manual**Error! Bookmark not defined.** (see "changes to Device Registrations" for more detail). It is also proposed that this transformation be described in the formal ASMG specification, to ensure that the appropriate method is applied.

[2] The *GDA Technical Manual* and other relevant information can be found on the ICSM website at http://www.icsm.gov.au/gda/gdatm/index.html.

The coordinates used for describing ASMG aligned boundaries in AGD66 will be recorded in latitude and longitude, defined in degrees, minutes and seconds of arc. When transforming coordinates to GDA94, latitude and longitude should be quoted in decimal degrees to 6 decimal places to retain transformation accuracy.

As the AGD66 to GDA94 transformation is not uniform across Australia, there may be a discrepancy between arcs constructed in AGD66 terms and arcs constructed in GDA94 terms. For example, coordinates specifying particular locations on the ground in AGD66 that are at the same latitude are unlikely to be at exactly the same latitude when transformed to GDA94 reference system. As a result boundary segments in GDA94 cannot be interpreted to follow lines of constant latitude or longitude when constructed between sequential pairs of coordinates in a boundary description.

In order to limit this discrepancy between a boundary represented in GDA94 terms and a boundary as defined in AGD66 terms a process known as densification[3] can be employed. Using this process, an accuracy of $\pm$ 0.5m can be achieved by recording intermediate coordinate pairs at no more than 1 degree latitude or longitude spacing along the perimeter of the boundary. The ACMA proposes to include these densification criteria into the formal specification described at 4.2(d).

b) Extend use of 5’ cells across the whole of the ASMG

The ACMA proposes that the use of 5’ cells (or STUs) be extended across the whole of the ASMG (as formally defined) to allow for finer definition of areas and subsequently reduce some of the inherent trading restrictions for spectrum licences in regional and remote Australia.

The use of 5’ cells across the whole ASMG also has the benefit of providing a natural densification of the ASMG boundaries and therefore improves the ability to preserve the “on the ground” boundary representation of the original ASMG in the GDA94 environment.

Extending the ASMG this way would also facilitate the adoption of a hierarchical identifier scheme (see below).

[3] Densification is the process of increasing the number of vertices along an arc that defines a line or geographical boundary. The smaller the distance between the vertices that define an arc the higher the accuracy of the line/boundary being replicated in the transformation.

c) Adopt a hierarchical identifier scheme overlaid on the ASMG

The ACMA proposes that the ASMG specification be expanded to incorporate a hierarchical identifier scheme for cells in the grid. This approach simplifies the description of spectrum licensing areas by giving each cell in the ASMG a unique identifier. An area can then be described by listing the identifiers of all cells comprising the area.

The ACMA proposes the use of a four level hierarchical identifier scheme aligned with a 3°, 1°, 15’ and 5’ of arc ASMG cell structure. This provides for more succinct descriptions of geographical areas through aggregation of smaller cells into complete larger blocks of cells. Appendix B describes how such a hierarchical identifier scheme could be overlaid on the ASMG and provides an example of the application of this scheme to define an area.

The use of a hierarchical identifier scheme also has the following advantages:

- Areas identified in spectrum trading, spectrum auctions and geographical areas defined on spectrum licences can be more easily described by using identifiers than by having to transcribe AGD66 or GDA94 coordinates. Publication of reference material (maps, shapefiles, etc.) including the identifiers would facilitate the objective of making areas easier to describe, and therefore reduce error rates and the resource intensity associated with processing licence area changes as part of spectrum trades.
- Cell identifiers work well in automated systems – lists of identifiers are simple to store and easily formulated into queries from which spatial data records for boundaries can be created.
- Cell identifiers can be easily overlaid on the ASMG as they are universal, meaning they can be used in both the AGD66 and GDA94 reference systems as they describe the same physical area in each case.
- Cell identifiers facilitate a smoother transition to future reference systems (e.g. future revisions to GDA to account for the movement of the Australian Tectonic Plate). With the identifier scheme in place, spectrum licensing instruments, marketing plans and determinations can, where appropriate, be varied to support use of the identifiers in describing geographic areas for spectrum licensing as an alternative to the use of coordinate references. Although the reference datum used (and the resulting coordinates) may change, the cell identifier references to locations on the ground do not.

d) Formalise the ASMG specification

The ACMA proposes to publish a formal definition of the ASMG. This will provide an explicit point of reference for spectrum licensing instruments and licences as well as facilitating the description of areas for trading by licensees. The ACMA will also make available spatial data (including hierarchical identifiers) for the ASMG in GIS-ready format both the AGD66 and GDA94 datum.

The formal ASMG definition will:

- define the current ASMG with reference to AGD66, including how STUs (individual 5' cells) are defined;
- define the hierarchical identifier scheme and associated naming convention;
- define the transformation methodology from AGD66 to GDA94;
- define the accuracy to which coordinates are to be recorded; and
- define how and to what accuracy arcs between AGD66 coordinates should be constructed in a GDA94 (or other) coordinate space to replicate the same "over the ground" boundaries as described in AGD66 terms;

Any future datum change can then be accommodated by incorporating the appropriate transformation information into the ASMG specification.

This is essentially the same procedure that was applied to the boundaries of land parcels by State government land titles administrations in the course of the transition from AGD66/AGD84 to GDA94.

5.3 Changes to the Digital Elevation Model

To coincide with the release of the 700 MHz and 2.5 GHz spectrum licences, updating the technical frameworks for the 800 MHz and 1800 MHz and the change to GDA94, the ACMA has worked to identify whether an appropriate update to the digital elevation model is also applicable.

The *GEODATA 9 Second Digital Elevation Model Version 3* (DEM9S) is the latest 9-second DEM to be released by Geoscience Australia (with elevation gridding performed by ANU) and is the proposed DEM to be incorporated in the updated and new spectrum licence technical frameworks.

DEM9S is a gridded digital elevation model computed from continent-wide topographic data including point elevations, streamlines, water body boundaries and cliff lines. The data included in DEM9S was collected between 1 July 2005 and 30 June 2008.

Estimates based on residuals from points selected on a finer scale than DEM9S show that for 50% of the DEM, heights do not vary more than 4 metres with a standard deviation of 10 metres, and for 80% of the DEM, heights do not vary more than 13 metres with a standard deviation of 15 metres.

The primary reason for the ACMA to adopt the DEM9S is that conversion between the current RadDEM in AGD66 and GDA94 is a rather complex operation which requires the RadDEM raster to be re-sampled using some interpolated function to form a grid of heights in the new datum (GDA94). Whilst this process is possible, it is not desirable as the underlying effect of applying the interpolated function are unknown and beyond the realms of ACMA study.

The ACMA has chosen to remain with a 9-second DEM even though there are other more dense DEMs (including a 1-second DEM using data based on the Shuttle Radar Topography Mission – SRTM) available from Geoscience Australia. The averaging already used in the device boundary process, for which the DEM is most required, means there is no need for the ACMA to adopt a denser DEM because the averaging area would likely remain a similar size in order to maintain results like those already being achieved.

The ACMA has determined that in order for the DEM to be used for spectrum licensing, it needs to be a product that can be maintained and easily obtained by the licensee and other parties as well as being a proven and mature release rather than the dense DEMs which are only a first release. In addition, RadDEM and DEM9S both fit onto a standard CD-ROM and therefore make re-distribution a lot simpler.

Appendix A – Current ASMG

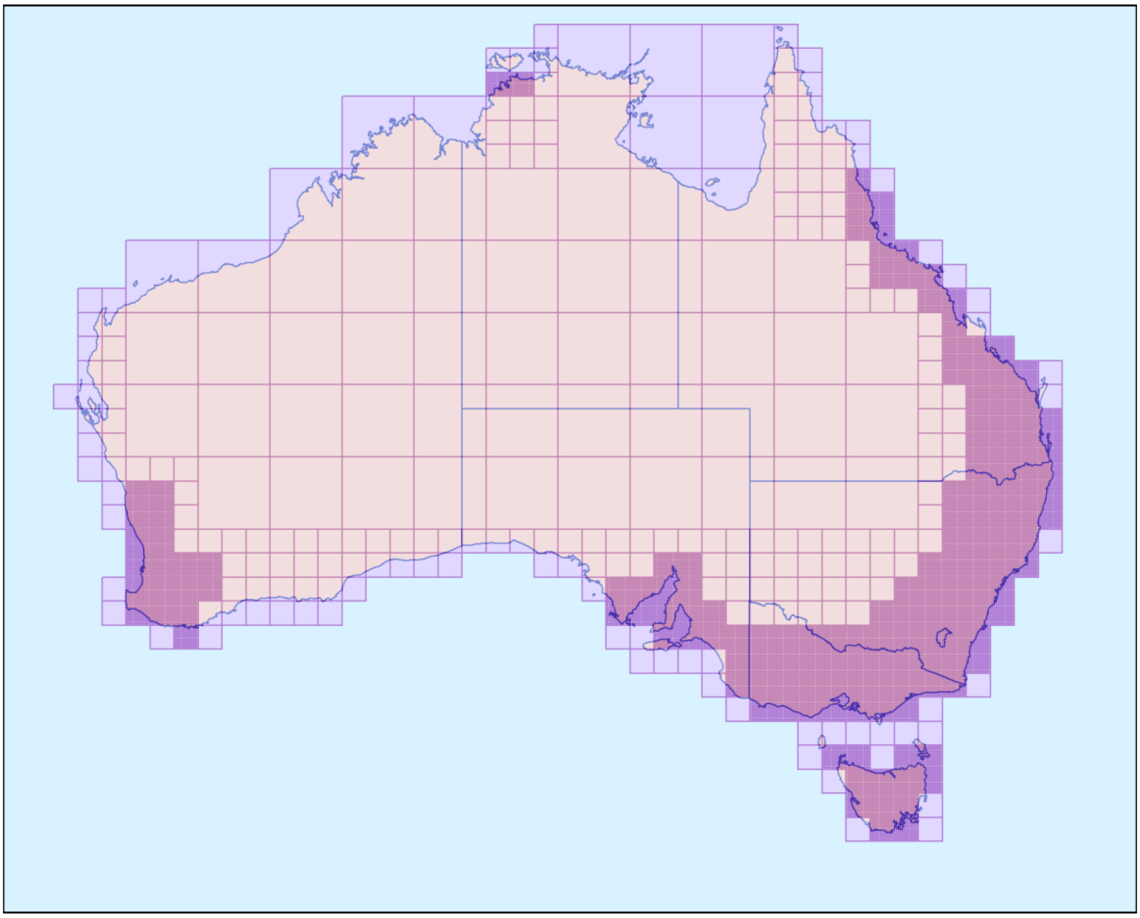
The current ASMG is referenced to the Australian Geodetic Datum 1966 (AGD66) and is illustrated in Figure 2. It has three different resolutions aligning with the typical density of radiocommunications services across Australia:

- In remote areas the grid is 3 degrees of arc dividing the geographic area into cells approximately 330 km along each edge.
- Regional areas are covered by a 1 degree grid or cell approximately 110 km along each edge.
- The state capitals and much of the south east coast of Australia is covered by a grid of 5 minutes of arc or areas approximately 9 km along each side.

Boundary segments are interpreted to follow lines of constant latitude or longitude when constructed between sequential pairs of coordinates in a boundary description.

Individual cells define the current geographical standard trading unit (STU) for spectrum licences across Australia.

Figure 2: Current ASMG



The coordinate list for the outer boundary of the current ASMG referenced in AGD66 is contained in the table below:

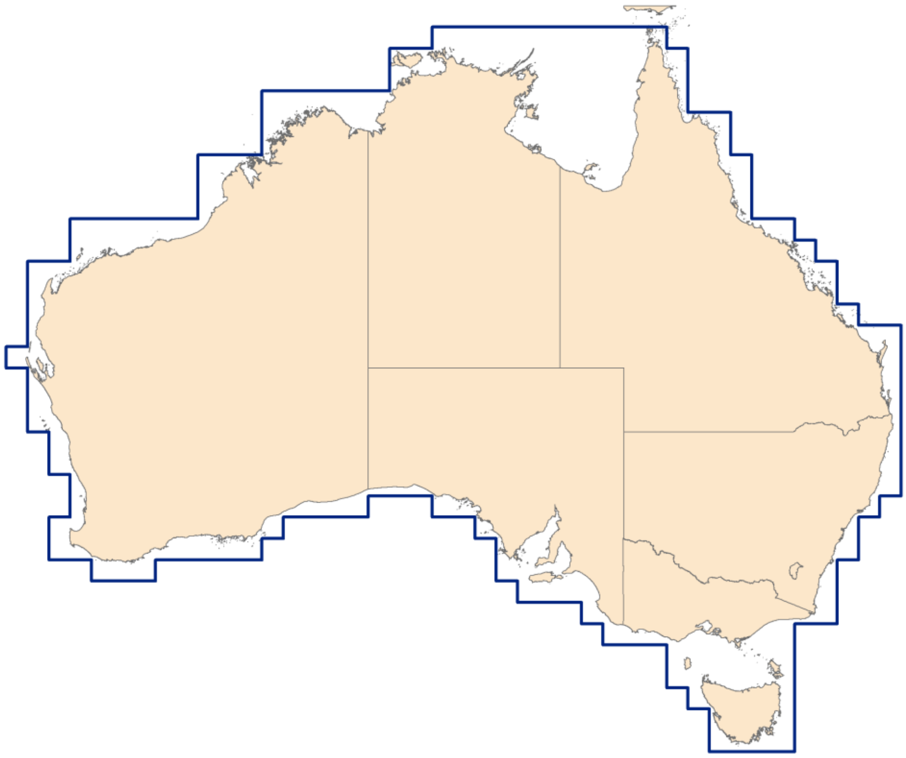
° ' " South	° ' " East
21 00 00	113 00 00
21 00 00	115 00 00
19 00 00	115 00 00
19 00 00	121 00 00
16 00 00	121 00 00
16 00 00	124 00 00
13 00 00	124 00 00
13 00 00	130 00 00
11 00 00	130 00 00
11 00 00	132 00 00
10 00 00	132 00 00
10 00 00	143 00 00
11 00 00	143 00 00
11 00 00	144 00 00
14 00 00	144 00 00
14 00 00	146 00 00
16 00 00	146 00 00
16 00 00	147 00 00
19 00 00	147 00 00
19 00 00	149 00 00
20 00 00	149 00 00
20 00 00	150 00 00
21 00 00	150 00 00
21 00 00	151 00 00
23 00 00	151 00 00
23 00 00	152 00 00
24 00 00	152 00 00
24 00 00	154 00 00
32 00 00	154 00 00

° ' " South	° ' " East
32 00 00	153 00 00
33 00 00	153 00 00
33 00 00	152 00 00
35 00 00	152 00 00
35 00 00	151 00 00
38 00 00	151 00 00
38 00 00	149 00 00
44 00 00	149 00 00
44 00 00	145 00 00
42 00 00	145 00 00
42 00 00	144 00 00
41 00 00	144 00 00
41 00 00	143 00 00
39 00 00	143 00 00
39 00 00	140 00 00
38 00 00	140 00 00
38 00 00	139 00 00
37 00 00	139 00 00
37 00 00	136 00 00
36 00 00	136 00 00
36 00 00	135 00 00
34 00 00	135 00 00
34 00 00	134 00 00
33 00 00	134 00 00
33 00 00	132 00 00
32 00 00	132 00 00
32 00 00	129 00 00
33 00 00	129 00 00
33 00 00	125 00 00

° ' " South	° ' " East
34 00 00	125 00 00
34 00 00	124 00 00
35 00 00	124 00 00
35 00 00	119 00 00
36 00 00	119 00 00
36 00 00	116 00 00
35 00 00	116 00 00
35 00 00	114 00 00
33 00 00	114 00 00
33 00 00	115 00 00
31 00 00	115 00 00
31 00 00	114 00 00
29 00 00	114 00 00
29 00 00	113 00 00
26 00 00	113 00 00
26 00 00	112 00 00
25 00 00	112 00 00
25 00 00	113 00 00

It is proposed that the boundary of the ASMG be preserved, and represented in GDA94. This boundary is shown in Figure 3. Because of the scale, the cells are not shown

Figure 3: Boundary of proposed ASMG



Below is the boundary of the ASMG in GDA94 (note: where the boundary spans more than 1 degree between vertices intermediate points have been added at 1 degree increments).

Row	Latitude (° South)	Longitude (° East)
1	24.998757	112.001377
2	24.998744	113.001346
3	23.998738	113.001340
4	22.998729	113.001347
5	21.998721	113.001338
6	20.998713	113.001332
7	20.998705	114.001326
8	20.998698	115.001297
9	19.998688	115.001319
10	18.998681	115.001312
11	18.998673	116.001310
12	18.998666	117.001309
13	18.998658	118.001306
14	18.998650	119.001304
15	18.998642	120.001301
16	18.998630	121.001292
17	17.998630	121.001289
18	16.998626	121.001281
19	15.998622	121.001274
20	15.998616	122.001271
21	15.998607	123.001262
22	15.998601	124.001256
23	14.998601	124.001255
24	13.998599	124.001249
25	12.998597	124.001244
26	12.998592	125.001239
27	12.998586	126.001234
28	12.998581	127.001229
29	12.998576	128.001224
30	12.998571	129.001218
31	12.998580	130.001200
32	11.998567	130.001205
33	10.998568	130.001202
34	10.998567	131.001191
35	10.998568	132.001181
36	9.998561	132.001184
37	9.998558	133.001177
38	9.998554	134.001170
39	9.998550	135.001162
40	9.998546	136.001154
41	9.998543	137.001145
42	9.998539	138.001137
43	9.998535	139.001128
44	9.998532	140.001118
45	9.998528	141.001108
46	9.998510	142.001113
47	9.998506	143.001104
48	10.998494	143.001114
49	10.998513	144.001081
50	11.998507	144.001084
51	12.998499	144.001091
52	13.998493	144.001090
53	13.998490	145.001081
54	13.998488	146.001070
55	14.998483	146.001074
56	15.998478	146.001078
57	15.998474	147.001067
58	16.998469	147.001072
59	17.998465	147.001078
60	18.998465	147.001089
61	18.998456	148.001071
62	18.998451	149.001058
63	19.998451	149.001064
64	19.998441	150.001050
65	20.998438	150.001056
66	20.998432	151.001042
67	21.998429	151.001049
68	22.998434	151.001058
69	22.998420	152.001041
70	23.998428	152.001046
71	23.998411	153.001033
72	23.998405	154.001018
73	24.998402	154.001025
74	25.998401	154.001033
75	26.998397	154.001041
76	27.998398	154.001049
77	28.998397	154.001059
78	29.998395	154.001068
79	30.998395	154.001078
80	31.998395	154.001088
81	31.998405	153.001103
82	32.998404	153.001116
83	32.998415	152.001132
84	33.998414	152.001145
85	34.998416	152.001158
86	34.998426	151.001172
87	35.998427	151.001188
88	36.998431	151.001203
89	37.998434	151.001218
90	37.998444	150.001236

Row	Latitude (° South)	Longitude (° East)
91	37.998457	149.001255
92	38.998459	149.001268
93	39.998464	149.001286
94	40.998469	149.001304
95	41.998475	149.001323
96	42.998481	149.001343
97	43.998488	149.001364
98	43.998499	148.001382
99	43.998511	147.001401
100	43.998522	146.001418
101	43.998534	145.001436
102	42.998527	145.001413
103	41.998522	145.001384
104	41.998531	144.001408
105	40.998524	144.001387
106	40.998536	143.001403
107	39.998529	143.001383
108	38.998522	143.001358
109	38.998534	142.001379
110	38.998546	141.001393
111	38.998557	140.001407
112	37.998545	140.001384
113	37.998562	139.001401
114	36.998554	139.001381
115	36.998567	138.001396
116	36.998578	137.001408
117	36.998590	136.001420
118	35.998576	136.001402
119	35.998595	135.001413
120	34.998583	135.001401
121	33.998570	135.001397
122	33.998586	134.001398
123	32.998580	134.001383
124	32.998595	133.001387
125	32.998608	132.001394
126	31.998594	132.001397
127	31.998606	131.001396

Row	Latitude (° South)	Longitude (° East)
128	31.998614	130.001404
129	31.998623	129.001413
130	32.998642	129.001419
131	32.998653	128.001427
132	32.998664	127.001435
133	32.998675	126.001445
134	32.998686	125.001456
135	33.998699	125.001467
136	33.998715	124.001479
137	34.998719	124.001489
138	34.998731	123.001496
139	34.998749	122.001505
140	34.998756	121.001505
141	34.998769	120.001510
142	34.998788	119.001513
143	35.998793	119.001533
144	35.998806	118.001537
145	35.998819	117.001541
146	35.998832	116.001543
147	34.998831	116.001528
148	34.998841	115.001532
149	34.998846	114.001528
150	33.998836	114.001511
151	32.998821	114.001492
152	32.998823	115.001497
153	31.998805	115.001478
154	30.998801	115.001459
155	30.998798	114.001458
156	29.998789	114.001441
157	28.998773	114.001422
158	28.998787	113.001428
159	27.998776	113.001417
160	26.998768	113.001394
161	25.998754	113.001362
162	25.998767	112.001389
163	24.998757	112.001377

Appendix B – Hierarchical Cell Identification Scheme (HCIS)

The HCIS comprises four levels, as described below, and illustrated in figure B-1:

Level 4: The highest level in the hierarchy is formed by grouping cells into "square" blocks of 3° each side. These are assigned a two letter identifier, commencing from the north-westernmost (upper left) corner, where the first letter (in the range A-N) refers to the horizontal position in the grid, and the second letter (in the range O-Z) refers to the vertical position.

Level 3: Each Level 4 block of cells is subdivided into nine "square" blocks of 1° each side. Each block is assigned an identifier composed of the identifier of the Level 4 block and a numeric suffix. The numeric suffix is in the range 1 through 9, assigned sequentially from the north-westernmost (upper left) corner.

Level 2: Each Level 3 block of cells is subdivided into sixteen "square" blocks of 15' each side. Each block is assigned an identifier composed of the identifier of the Level 3 block and an alphabetic suffix. The alphabetic suffix is in the range A through P, assigned sequentially from the north-westernmost (upper left) corner.

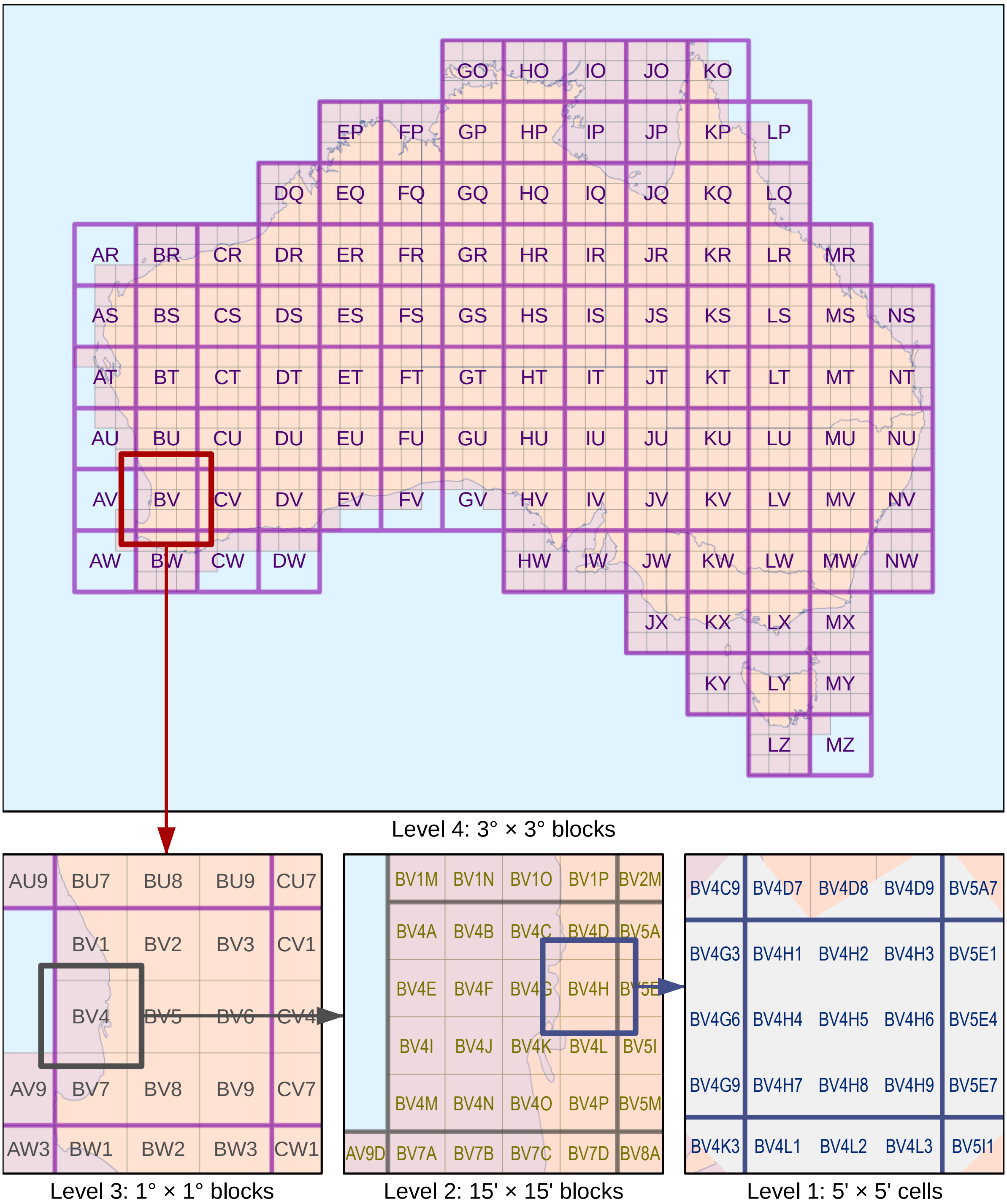
Level 1: Each 5' square cell is assigned an identifier composed of the identifier of the Level 2 block containing it and a numeric suffix. This numeric suffix is in the range 1 through 9, assigned sequentially from the north-westernmost (upper left) corner of the Level 2 block.

Where a block does not fall entirely within the existing ASMG it would not be valid in an area description, however it may be retained if levels lower in the hierarchy are contained within it, such as the Level 4 block with identifier AR in Figure 4.

Descriptor for an example illustrated in Figure 4

Level 4		Level 3	Level 2	Level 1
[A-N]	[O-Z]	[1-9]	[A-P]	[1-9]
Horizontal position (in 3° blocks)	Vertical position (in 3° blocks)	Sequential position (in 1° blocks)	Sequential position (in 15' blocks)	Sequential position (in 5' cells)cells)
B	V	4	H	6

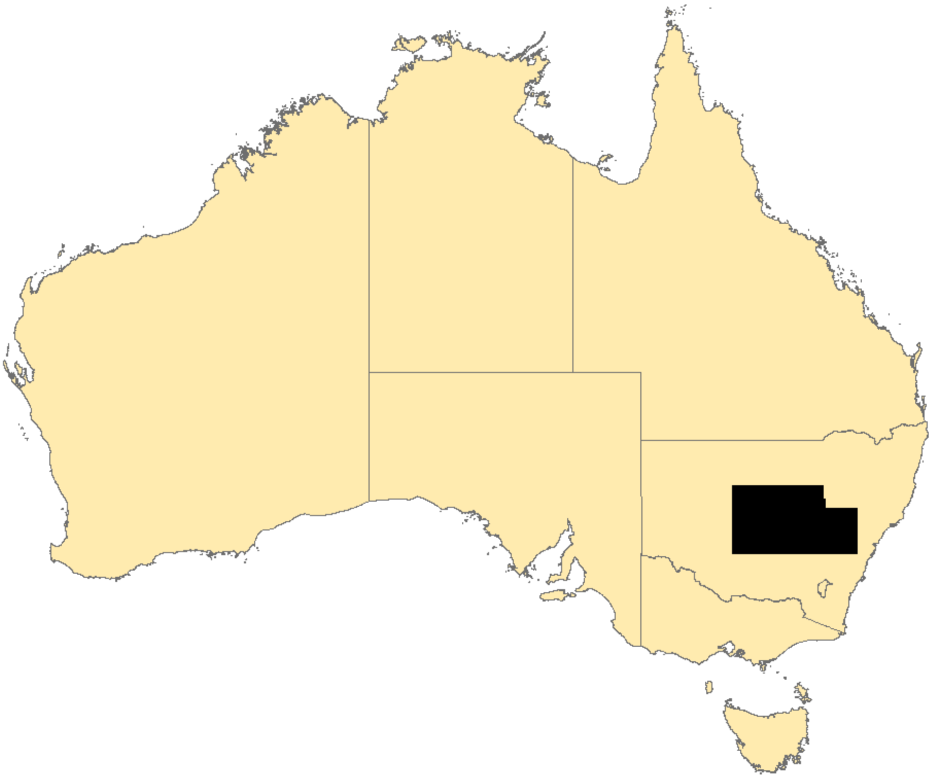
Figure 4: Illustrated representation of the HCIS



Example implementation of the HCIS

Although an area can be defined by any combination of hierarchical identifiers (level 1 and higher), the general method will be to use the most succinct description available. As an example of how this would be applied, consider the area shaded in purple in the map of Figure 5.

Figure 5: Example Area (shaded black)



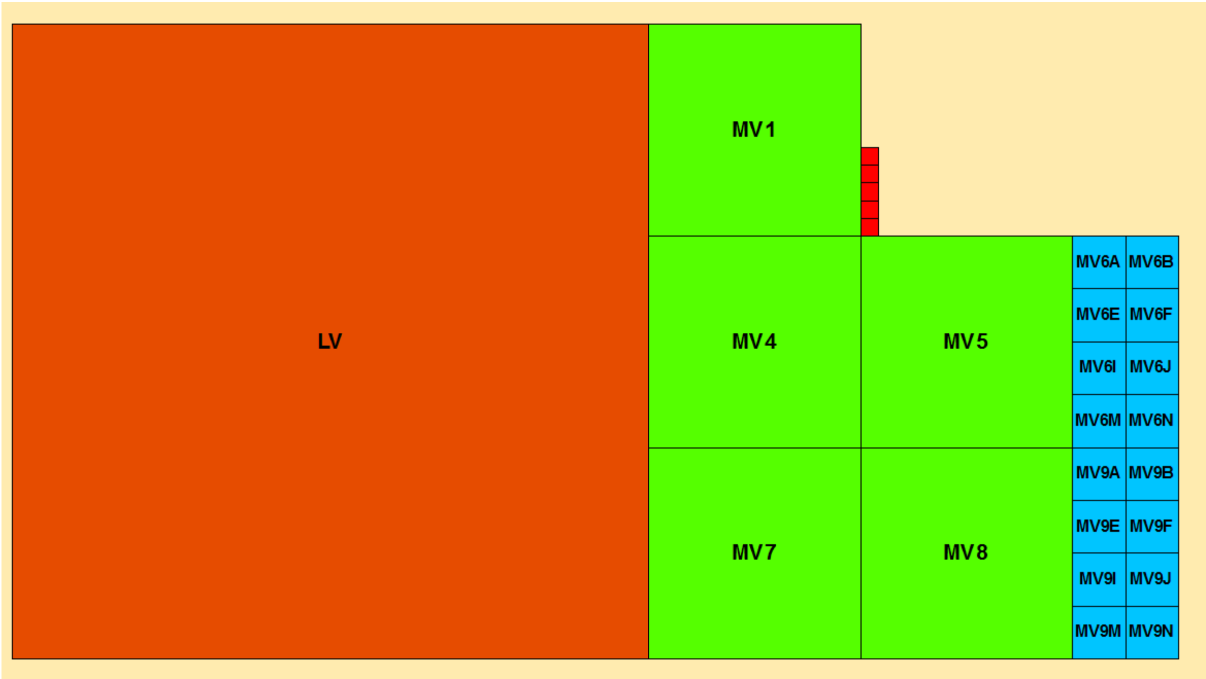
The most succinct description of this example area in terms of hierarchical identifiers is:

LV, MV1, MV4, MV5, MV7, MV8, MV6A, MV6B, MV6E, MV6F, MV6I, MV6J, MV6M, MV6N, MV9A, MV9B, MV9E, MV9F, MV9I, MV9J, MV9M, MV9N, MV2I4, MV2I7, MV2M1, MV2M4, MV2M7

This is pictorially displayed in Figure 6 (i) and Figure 6 (ii).

Figure 6: Highest level identifiers that compose the example area

(i)



(ii)