Australian Government

Australian Communications and Media Authority

The Australian spectrum map grid 2012

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1. Introduction

Geospatial information (site coordinates) is an important parameter for many radiocommunications licences. Geospatial information is used to define geographic areas for spectrum licences, record the locations of radiocommunications devices in the Register for Radiocommunications Licences (RRL) and define areas where specific rules apply—such as location-based spectrum embargos, band plans and class licences.

Geographic areas are a core condition of spectrum licences under section 66 of the *Radiocommunications Act 1992* (the Act). The geographic area core condition specifies within which area of operation a licensee may deploy a service and helps with spectrum trading. The geographic separation between spectrum licence areas also ensures that incumbent licensees do not cause one another unacceptable levels of interference.

When the spectrum licence regulatory framework was introduced in the 1990s, a spectrum map grid (SMG) was developed to help identify geographic areas for spectrum licences. The SMG used a coordinate reference system based on the datum available at the time, Australian Geodetic Datum 1966 (AGD66).

The ACMA reviewed the SMG as part of its work on the expiring spectrum licence processes and decided that it was timely to provide an update to the grid, including changes to the way it communicates geospatial information on spectrum licences.[1] For example, the ACMA currently uses coordinate references to define the geographic area core condition of a spectrum licence using the AGD66 datum. Any change to another datum would increase the complexity of the coordinates as well as the risk of human error in attempting to transcribe the coordinate references. Instead, the ACMA has decided to apply a different means of describing the geographic area that moves away from the use of coordinates. This approach is intended to simplify the way that geographic areas are defined in spectrum licences and relevant legislation such as designation notices and reallocation declarations.

The purpose of this paper is to explain the changed way in which the ACMA will communicate geospatial information relating to the SMG. These changes are summarised as:

- Updating from AGD66 to the Geocentric Datum of Australia 1994 (GDA94) to align with government policy.
- Improving the existing SMG by:
  - introducing a naming convention that moves away from the use of complex coordinates to define geographic areas for spectrum licences
  - providing a greater level of granularity in the definition of geographic areas.

1.1. Datum change

AGD66 was developed to consolidate all surveying and mapping in Australia to a single datum, replacing a number of datums with applicability to particular jurisdictions. Although a revision to the datum was accepted in 1984 (known as AGD84), many jurisdictions continued to use AGD66 until changing to GDA94 in accordance with Government policy – a process completed in 2000. In order to align with the policy, the ACMA is updating the datum used in its own geospatial information systems from AGD66 to GDA94.

[1] For the purposes of this paper, ‘spectrum map grid’ applies broadly to both the old SMG and the new ASMG.

The datum change is not intended to substantially change spectrum licences but is intended to ensure continuity in the way that geographic areas are defined for both existing and new spectrum licences from 2012. The points on the ground that define an existing spectrum licence will not change, but a transformation method will be applied to ensure that these points are referred to using the updated GDA94 datum instead of AGD66 coordinates. Further information on datums is in Chapter 2 and further information on the transformation method is in Chapter 4.

The ACMA is also updating the RRL so that the geospatial information of licences will use the GDA94 datum. This update is likely to occur over time.

1.2. Improving the spectrum map grid

Although not explicitly stated, the ACMA has been using AGD66 to communicate geospatial information for spectrum and apparatus licensing. The SMG was based on AGD66 and used cells of varying sizes:

> 3x3 degrees
> 1x1 degree
> 5x5 minutes of arc.

The SMG referred to three sizes of cell because access to maps of areas of low population density was limited; consequently, areas with low population density were represented with large cells. This arrangement has limited the flexibility for trading in these areas.[2]

This paper marks an update to the SMG, as the ACMA releases what will now be known as the *Australian spectrum map grid 2012* (ASMG). The ASMG, while aligning with the SMG, will be able to be used with other GDA94 geospatial information. Rather than the three cell sizes on which the SMG relied, the cells of the ASMG will be 5x5 minutes of arc. This consistency simplifies the trading of spectrum between licensees.

1.3. Principles for spectrum management

The ACMA published its *Principles for spectrum management* in 2009 and has since applied these principles to its proposals for regulatory and technical change to licensing frameworks. The key theme of the principles is that maximising the overall public benefit from use of the radiofrequency spectrum requires balanced application of both regulatory and market mechanisms.

More information on the *Principles for spectrum management* may be found on the ACMA website.

The updated ASMG is designed to demonstrate the following principles:

> **To the extent possible, promote both certainty and flexibility**.
In representing Australia's geospatial information with a consistent cell size, the ASMG provides greater granularity of the geographic areas of a spectrum licence. This in turn provides a greater level of certainty and flexibility for licensees wishing to trade.

[2] In some cases, geographic areas of approximately 300 square kilometres were the minimum area that could be traded.

- **Balance the cost of interference and the benefits of greater spectrum utilisation**.
  The ACMA has analysed the benefits of introducing the ASMG versus the potential for impact on normal business practice when applying a new datum. Adopting an improved geographic information model by releasing the ASMG from 2012 (applying it ahead of the re-issued and potentially re-allocated spectrum licences rather than retrospectively to existing licences) means that the necessary changes may be achieved with minimal interference to protocol.

2. Background

Coordinate sets—both geographic coordinates (latitude/longitude) and grid coordinates (zones/eastings/northings)—are on their own insufficient to uniquely define a location. Rather, coordinates must be specified with reference to a datum.

A datum is a mathematical system used to map coordinates to locations on the surface of the Earth. Because the Earth is unevenly shaped, there are numerous different datums that have been created and could be used.

It is important to note that the datum used to define geographic areas for spectrum licences has been superseded during the tenure of existing licences. Therefore, in order to align with government policy, the ACMA will describe the geographic areas in new spectrum licences using the GDA94 datum. As new spectrum licences are expected to be issued from 2012 (resulting from the outcomes of the expiring spectrum licence process and the new allocations from the digital dividend auction in particular) all regulatory and technical frameworks for licences will reflect this change.

The three main datums relevant to Australia are noted below.

2.1. AGD66

Presently, for the purposes of radiocommunications, the ACMA applies spatial data defined using AGD66.[3] AGD66 was the primary datum used between the 1960s and 2000. AGD66 is a local datum that was optimised for the Australian region. This optimisation resulted in a good approximation of the surface of the Earth for the Australian region. However, some limitations were identified (for example, AGD66 is not oriented around the centre of the Earth's mass).

2.2. GDA94

GDA94 was formally defined in 1995, and the Inter-governmental Committee on Surveying and Mapping (ICSM) was charged with coordinating its adoption by Commonwealth and state surveying and mapping agencies.[4] 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).

2.3. WGS84

WGS84 is used by the Global Positioning System (GPS) and is used for surveying and mapping in some parts of the world, such as the polar regions. WGS84 is also used by data suppliers with world-wide scope.

2.4. The challenge of using different datums

The ACMA currently uses AGD66 for geospatial information relating to radiocommunications (including the SMG), unless otherwise noted. For example:

> coordinates of radiocommunications sites in the RRL
> coordinates of sites in spectrum embargoes and class licences
> the ACMA's radiocommunications digital elevation model (RadDEM).

[3] The grid coordinates derived from a Universal Transverse Mercator projection of the AGD66 coordinates, using the Australian National Spheroid, is known as the Australian Map Grid 1966 (AMG66).

[4] The UTM grid coordinate set based on GDA94 is known as the Map Grid of Australia 1994 (MGA94).

The ACMA's use of AGD66 is inconsistent with other Commonwealth and commercial agencies, whose geospatial tools use GDA94 and/or WGS84. For example, new digital elevation models produced by Geoscience Australia use GDA94, while Google Earth and many GPS receivers use the WGS84 datum.

While it is important to update to GDA94 in order to align with mapping and surveying agencies, any update requires a transformation from AGD66. During this transformation some error may occur. This is because the difference between locations with the same coordinates in AGD66 and GDA94 is approximately 200 metres (the exact magnitude and direction of the shift varies depending on location). While this difference is relatively small, the effect may be significant. If, for example, AGD66 coordinates for a site on top of a large hill were used in a GDA94 digital elevation map, the site could appear to be off the peak of the hill and significantly lower than it actually is. Although this potential for error exists, correct use of the transformation method described in Chapter 4 is designed to minimise the potential for misrepresentation.

The difference between WGS84 and GDA94 is minor (about one metre), and for many practical applications the two can be considered to be the same.[5]

[5] See www.icsm.gov.au/gda/wgs84fact.pdf for additional information.

3. Australian spectrum map grid 2012

The ASMG takes into account the transition from AGD66 to GDA94 by retaining the locations on the ground, which are used to define a spectrum licence area. As part of the transition to GDA94, a transformation method is applied to the AGD66 coordinates, in order to derive GDA94 coordinates for their respective locations.

The ASMG is created in four steps, by defining:

1. the outer boundary of the ASMG around the Australian land mass
2. the cells of the grid (within the boundary)
3. the transformation methods used to transform between different datum
4. the Hierarchical Cell Identification Scheme (HCIS).

On the basis of these four steps, the ASMG improves on the SMG in the following ways:

> **Cells of the grid—augmentation**. The cell size has been changed to allow for 5x5 minute cells Australia-wide. This allows far greater granularity in the description of areas and, in many cases, the ability to trade smaller areas, particularly in regional Australia.

> **Transformation**. The boundaries of the new ASMG (defined in GDA94) align with the existing spectrum map grid (defined in AGD66). The method used for transformation between AGD66 and GDA94 is identified in Chapter 4. It is possible that GDA94 may be revised during the tenure of the new spectrum licences issued from 2012. In this event, the ACMA would update this document, taking into account the relevant transformation method.

> **HCIS**. The HCIS is a new way of describing geographic areas aligned with the ASMG. This naming convention succeeds in communicating geographic areas in two ways. First, the HCIS removes the need to refer to complex coordinate sets to describe a geographic area (reducing the risk of errors). Second, the HCIS may be used to describe areas regardless of the datum used. This means that although a newer datum may apply in the future, the HCIS will remain consistent in the way areas are described.

4. Transformation between datums

Any transformations between AGD66 and any other datum should use the methods recommended by the Intergovernmental Committee on Surveying and Mapping (ICSM).[6] The ICSM's methods are employed by the ACMA and a number of the Australian and state surveying and mapping agencies. The ACMA relies on the ICSM for its coordination and standards for surveying and mapping national datasets.

4.1 Transformations of points between datums

The *Geocentric Datum of Australia (GDA) Technical Manual* produced by the ICSM recommends the High Accuracy Transformation (Grid Transformation) for transformations between AGD66 and GDA94 in Australia.[7] All transformations of points between AGD66 and GDA94 should be performed using the method identified in the GDA technical manual.[8] Further information on this method, including links to free software to perform the transformations, are available in the GDA manual.

4.2 Transformations of lines from AGD66 to GDA94

The mathematical approximation of the shape of the Earth in GDA94 differs from that used in AGD66. As such, the line across the Earth's surface between two locations slightly differs between the two datums. Provided that the end points are separated by no more than one degree of latitudinal or longitudinal arc, this difference is acceptably small. This is important because, when transforming from AGD66 to GDA94, the boundaries of geographic areas must remain consistent and accurate.

In some uncommon cases the end points may initially be separated by more than one degree of arc. For these cases, following a particular method will allow information to be displayed with minimal difference between AGD66 and GDA94. These methods are:

> The coordinates chosen must be those for corners of cells defined in the ASMG as transformed to GDA94 by the required method.

> If the boundary segment is more than one degree but less than two degrees (in AGD66 coordinate terms) in length, the GDA94 coordinates of the ASMG cell corner nearest the centre of the segment is to be used. If two cell corners are equidistant from the centre of the boundary segment, the GDA94 coordinates of either cell corner may be used.

> If the boundary segment is two degrees or more (in AGD66 coordinate terms) in length, the GDA94 coordinates for each ASMG cell corner along the boundary segment with an integral value (in degrees, in AGD66 coordinate terms) of latitude or longitude (as appropriate for the particular boundary segment) are to be used.

Geospatial data in computerised systems should incorporate each intervening ASMG cell corner along a boundary segment of an area, in order to accurately represent the geographic area in a transformed state.

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[6] See www.icsm.gov.au/.

[7] *Geocentric Datum of Australia Technical Manual* (Version 2.3, amendment 1), ISBN 0-9579951-0-5, www.icsm.gov.au/gda/gdatm/index.html.

[8] As noted above, it is likely that the datum will be updated throughout the tenure period of the spectrum licences issued from 2012. As a result, the transformation method is also likely to be updated at that time.

Attachment A—Australian spectrum map grid

The Boundary of the ASMG

Figure 1 shows the outline of the ASMG. The boundary appears to approach the coast in a number of areas, but this is an artefact of the scale of the map—the boundary typically gets no closer to the coast than 10 kilometres. The ASMG is the area within this polygon. It is important to note that the ASMG does not include the external territories.

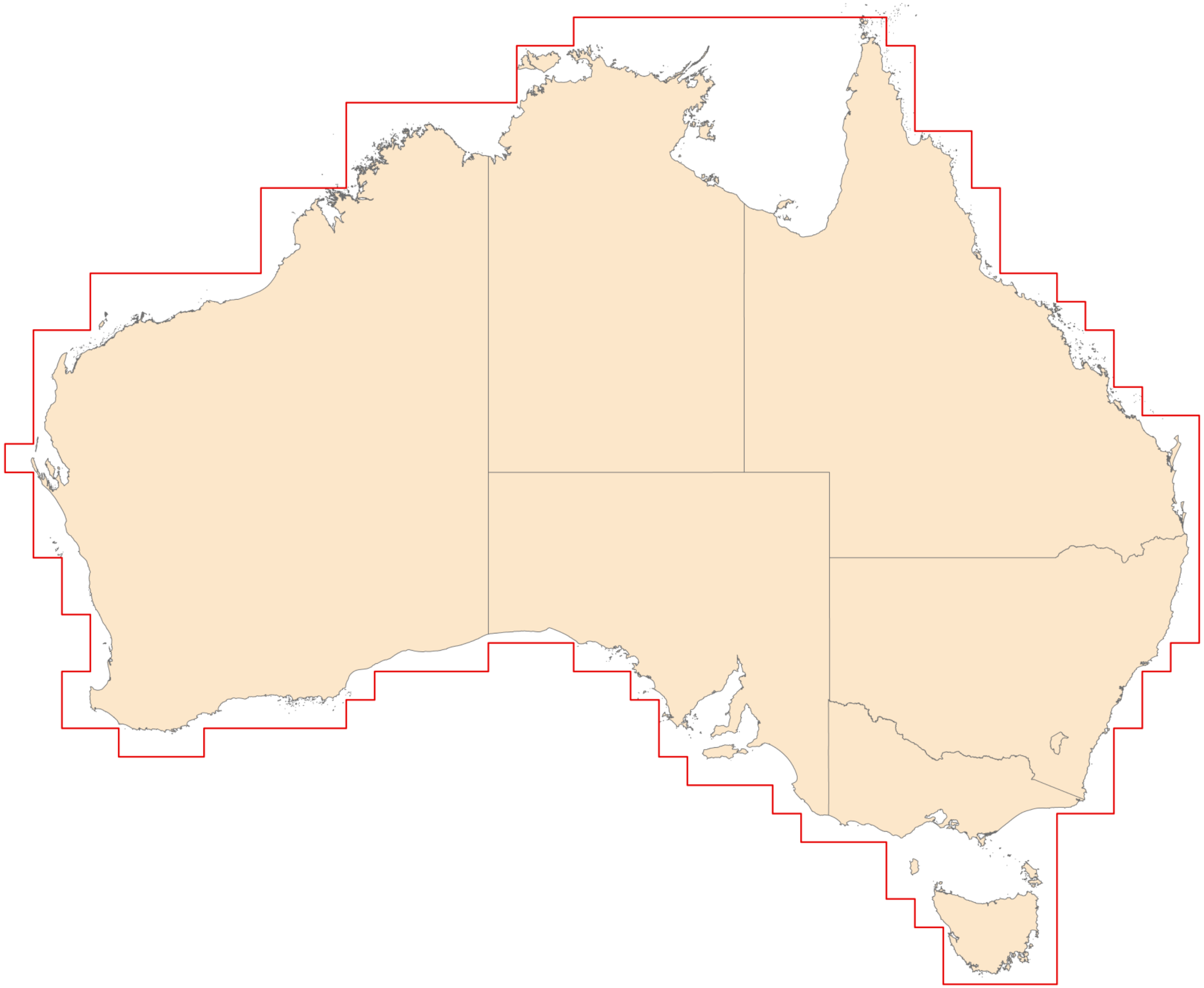
Table 1 lists AGD66 coordinates for the vertices of the ASMG. The boundary of the ASMG is found by joining consecutively numbered points from the table below.

Table 2 lists GDA94 coordinates for the vertices of the ASMG, along with necessary intermediary points to preserve accuracy.

The Cells of the ASMG

The area bound by the outer limits (illustrated in Figure 1) is subdivided into cells to form the ASMG. The cells have boundaries at five-minute arc intervals of both latitude and longitude (in AGD66), originating at the northernmost and westernmost edges of the ASMG outer boundary respectively. These points can be transformed into GDA94 using the method described in Chapter 4.

Figure 1 ASMG outline



Attachment B—ASMG boundary in AGD66

The outer limit of the ASMG is illustrated in Figure 1. The outer limit of the ASMG is represented by a line that starts at the location specified by the first set of AGD66 coordinates and passes sequentially through the locations specified by each subsequent set of coordinates, to the location of commencement.

Table 1 ASMG boundary vertices in AGD66

Vertex no.	Latitude (degrees minutes and seconds) South	Longitude (degrees minutes and seconds) East
1	25 00 00	112 00 00
2	25 00 00	113 00 00
3	21 00 00	113 00 00
4	21 00 00	115 00 00
5	19 00 00	115 00 00
6	19 00 00	121 00 00
7	16 00 00	121 00 00
8	16 00 00	124 00 00
9	13 00 00	124 00 00
10	13 00 00	130 00 00
11	11 00 00	130 00 00
12	11 00 00	132 00 00
13	10 00 00	132 00 00
14	10 00 00	143 00 00
15	11 00 00	143 00 00
16	11 00 00	144 00 00
17	14 00 00	144 00 00
18	14 00 00	146 00 00
19	16 00 00	146 00 00
20	16 00 00	147 00 00
21	19 00 00	147 00 00
22	19 00 00	149 00 00
23	20 00 00	149 00 00
24	20 00 00	150 00 00
25	21 00 00	150 00 00
26	21 00 00	151 00 00
27	23 00 00	151 00 00
28	23 00 00	152 00 00
29	24 00 00	152 00 00
30	24 00 00	154 00 00
31	32 00 00	154 00 00
32	32 00 00	153 00 00
33	33 00 00	153 00 00
34	33 00 00	152 00 00
35	35 00 00	152 00 00
36	35 00 00	151 00 00
37	38 00 00	151 00 00
38	38 00 00	149 00 00
39	44 00 00	149 00 00
40	44 00 00	145 00 00
41	42 00 00	145 00 00
42	42 00 00	144 00 00
43	41 00 00	144 00 00
44	41 00 00	143 00 00
45	39 00 00	143 00 00
46	39 00 00	140 00 00
47	38 00 00	140 00 00
48	38 00 00	139 00 00
49	37 00 00	139 00 00
50	37 00 00	136 00 00
51	36 00 00	136 00 00
52	36 00 00	135 00 00
53	34 00 00	135 00 00
54	34 00 00	134 00 00
55	33 00 00	134 00 00
56	33 00 00	132 00 00
57	32 00 00	132 00 00
58	32 00 00	129 00 00

59	33 00 00	129 00 00
60	33 00 00	125 00 00
61	34 00 00	125 00 00
62	34 00 00	124 00 00
63	35 00 00	124 00 00
64	35 00 00	119 00 00
65	36 00 00	119 00 00
66	36 00 00	116 00 00
67	35 00 00	116 00 00
68	35 00 00	114 00 00
69	33 00 00	114 00 00
70	33 00 00	115 00 00
71	31 00 00	115 00 00
72	31 00 00	114 00 00
73	29 00 00	114 00 00
74	29 00 00	113 00 00
75	26 00 00	113 00 00
76	26 00 00	112 00 00
77	25 00 00	112 00 00

Attachment C—ASMG boundary in GDA94

The points in Table 2 have been transformed using the method in Chapter to create the AMSG boundary in GDA94.

The outer limit of the ASMG is illustrated in Figure 1. The outer limit of the ASMG is represented by a line that starts at the location specified by the first set of GDA94 coordinates and passes sequentially through the locations specified by each subsequent set of coordinates, to the location of commencement.

Table 2 ASMG boundary vertices in GDA94

Vertex no.	Decimal degrees South	Decimal degrees 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
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
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

Attachment D—the Hierarchical Cell Identification Scheme

The Hierarchical Cell Identification Scheme (HCIS) is a naming convention developed by the ACMA that applies unique 'names' to each of the cells of the ASMG. Each five minute of arc square cell in the ASMG is assigned a unique identifier, derived from the cell's position in a hierarchically arranged grouping of cells. The hierarchy has four levels.

An illustration of the HCIS is at Figure 2.

The use of the HCIS permits the description of areas that align with ASMG cells to be made independent of coordinate and datum references, by listing the identifiers of cells within the area.

Descriptions for each level of grouped cells are in Table 3.

Figure 2 Illustration of the HCIS

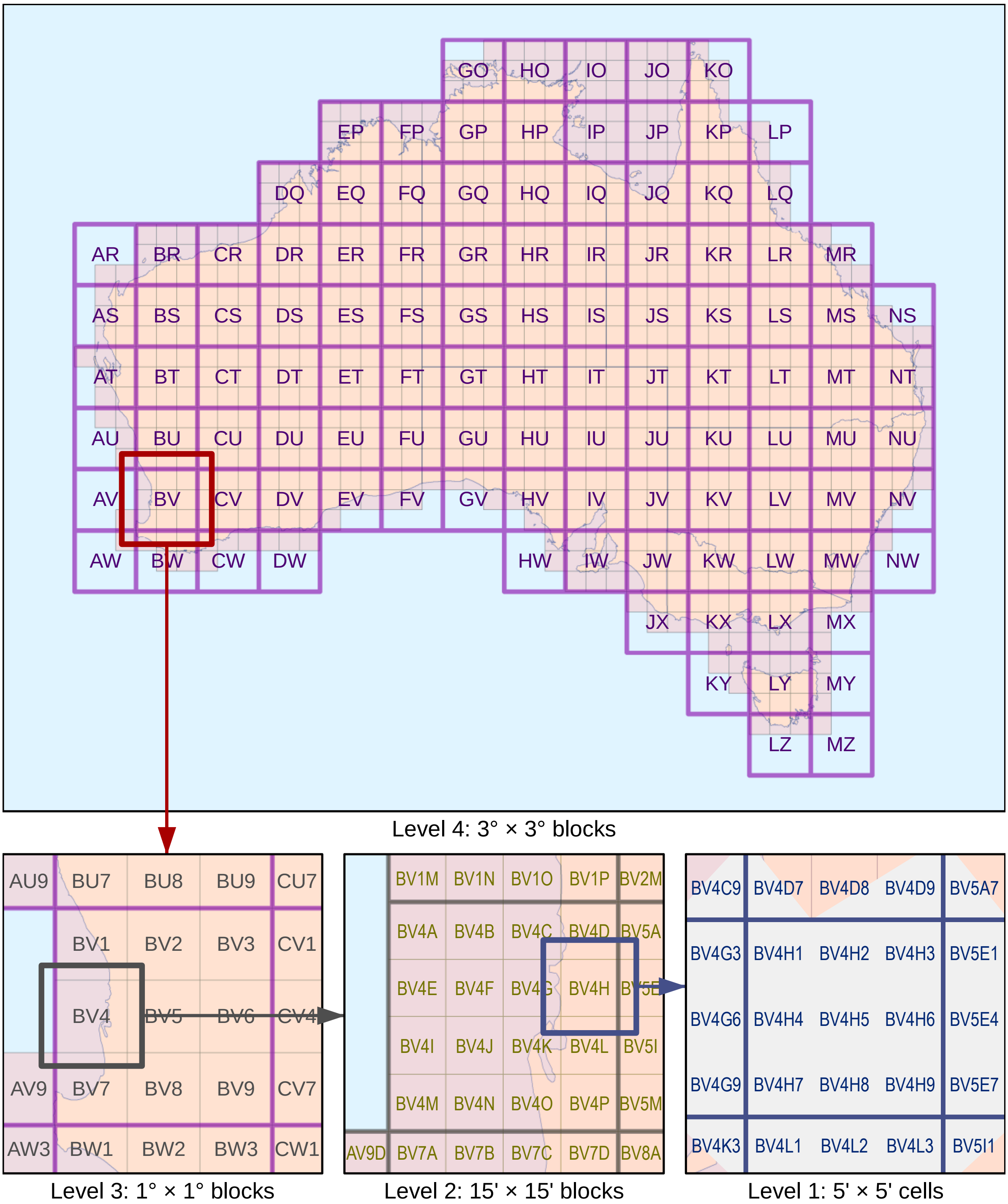


Table 3 HCIS levels

Level	Description
4	> The highest level in the hierarchy is formed by grouping cells into blocks 3° east to west by 3° north to south, commencing at the westernmost and northernmost edges of the ASMG outer boundary respectively.[9] > Each block is assigned a two-letter identifier, with the first letter in the range A through N according to the block's position from the westernmost edge of the ASMG, and the second letter in the range O through Z according to the block's position from the northernmost edge of the ASMG. > Blocks not completely within the ASMG outer boundary (e.g. the block with identifier AR) are defined only for the purpose of providing identifier structure to blocks at lower levels in the hierarchy, and their identifiers are not valid in area descriptions.
3	> Each Level 4 block of cells is subdivided into blocks 1° east to west by 1° north to south, commencing at the westernmost and northernmost edges of the Level 4 block respectively. > 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 left to right and top to bottom.
2	> Each Level 3 block of cells is subdivided into blocks 15' east to west by 15' north to south, commencing at the westernmost and northernmost edges of the Level 3 block respectively. > 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 left to right and top to bottom.
1	> Each five-minute of arc cell is assigned an identifier composed of the identifier of the Level 2 block that encloses it and a numeric suffix. > The numeric suffix is in the range 1 through 9, assigned sequentially from left to right and top to bottom according to the cell's position within the Level 2 block.

[9] The westernmost edge is 112° E, and the northernmost edge is 10° S (in AGD66).

Attachment E—working example of a sample licence

Table 4 and Figure 3 demonstrate the way in which HCIS information appears in a sample licence for an area within Adelaide.

Part 3 – Geographic Area

For core condition 2, the area within which operation of radiocommunications devices is authorised by this licence is, with respect to the HCIS in the ASMG, as follows:

Table 4 HCIS for example area

HCIS identifiers
IW3J, IW3K, IW3L, IW3N, IW3O, IW3P, IW6B, IW6C, IW6D, IW6F, IW6G, IW6H, IW3E5, IW3E6, IW3E8, IW3E9, IW3F4, IW3F5, IW3F6, IW3F7, IW3F8, IW3F9, IW3G4, IW3G5, IW3G6, IW3G7, IW3G8, IW3G9, IW3H4, IW3H5, IW3H6, IW3H7, IW3H8, IW3H9, IW3I2, IW3I3, IW3I5, IW3I6, IW3I8, IW3I9, IW3M2, IW3M3, IW3M5, IW3M6, IW3M8, IW3M9, IW6A2, IW6A3, IW6A5, IW6A6, IW6A8, IW6A9, IW6E2, IW6E3, IW6E5, IW6E6, IW6E8, IW6E9, JW1E4, JW1E7, JW1I1, JW1I4, JW1I7, JW1M1, JW1M4.

Figure 3 HCIS—map of example area