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Working Zones 2016

At a glance

This report provides an overview of the newly developed Australian 'working zone' (WZ) regions which have been compiled by the Bureau of Infrastructure, Transport and Regional Economics (BITRE). WZs are mutually exclusive regions delineated to reflect the commuting patterns of Australian workers. WZs are useful for spatial analysis of economic, social and policy issues at a regional level because they reflect the actual geographic behaviour of individuals, as opposed to other administrative and political boundaries. They are particularly useful for analysing labour markets, because individual WZs have minimal work-based commuting flows either into or out of adjoining WZs.

The BITRE WZs defined here used 'place of usual residence' and 'place of work' data collected in the 2016 Australian Census of Population and Housing as their basis. The baseline dataset contains records for more than 10 million employed persons that enables the calculation of the number of persons who commute for work between origin and destination location 'pairs'. The pairs for this work were based upon the Australian Statistical Geographical Standard (ASGS) Statistical Area Level 2 (SA2) boundaries of which there are 2310 covering the whole of Australia.

Analysis of this commuting flows data was undertaken using a purpose built algorithm which used a multi-staged and stepped approach to build WZs from SA2s. Each stage of the algorithm involved identifying key 'seed' job centres around which WZs would be based before joining other SA2s on the basis of the number of jobs, the distance between and the commuting flows between pairs. It was deemed important to find an approach which could:

- maximise commuting flows within each WZ and minimise flows between WZs
- consider the commuting distances implicit in the size of the WZs
- not result in major urban centres being split into multiple WZs
- permit variation in the size of both the population and area covered by WZs
- prevent cascading uni-directional interactions from building WZs that do not reflect plausible commuting patterns.

The process identified 313 mutually exclusive 'WZs' covering almost all of Australia. The final WZs have resulted in a very high level of overall containment with 95 per cent of the 10 million work commutes in the final dataset occurring within the same WZ. The WZs vary considerably in terms of their physical and population size, reflecting the settlement and distribution patterns of the Australian population. Examination of the characteristics of the 313 WZs revealed that:

- 186 (59 per cent) comprise just a single SA2, while six cover more than 100 SA2s
- most are less than 10 000km^2 in size with some being smaller than 100km^2 and others exceeding 150 000km^2
- total populations range from several hundred in remote communities to several million in major cities

- most WZs have several thousand persons working in them with a range of less than 500 to millions
- self-containment of individual WZs is generally high on both of the key measures used:
    - In nearly 50 per cent of the WZs, more than 90 per cent of employed residents work locally and in 78 per cent of WZs more than 80 per cent work locally.
    - In 80 per cent of WZs, at least 80 per cent of persons working in the WZ also live in the WZ.

The result of this work is a new WZ geography of Australia which reflects the regions within which populations do actually live and travel for work, contains a sufficient number of WZs to conduct detailed spatial analysis of labour markets, and results in most WZs not being so large that they do not reflect realistic labour markets. These boundaries can be used in spatial analysis of social and economic issues, particularly with respect to labour markets and to gain insights into the relative strengths or weaknesses of regional economies. This can assist in understanding and planning for future jobs growth and making associated infrastructure investment decisions.

1. Introduction

There is a long history of literature critical of social and economic analysis that uses geographical units of analysis that do not reflect the behaviour being studied. Critics argue that the spatial level at which the issues of interest operate should form the basis of the analysis (CLG, 2010). It therefore stands that geographical regions defined for political or administrative purposes may not be suitable for analysis of social or economic issues (such as the functioning of labour markets or estimating the regional impact of policy changes). Central to these criticisms are issues associated with the modifiable areal unit problem (MAUP).[1] This is in part because social and economic flows rarely adhere to administrative and political boundaries, meaning the actual areas over which any given issue has an impact is not well represented by those boundaries (CLG, 2010).

Given the above concerns, researchers interested in understanding spatial aspects of social, economic and policy issues have frequently sought to identify alternative methods for delineating regions. In particular, researchers interested in understanding labour markets (the focus of this information sheet) have been proactive in this field. As Mitchell and Watts (2010) argue, spatial units used for analysis of labour markets should be based on informed choice rather than just convenience. That is, the geography used to analyse labour market activity should be based upon the actual behaviour of persons working in the labour markets of interest.

Recognising these issues, BITRE has undertaken such work in the past. In 2003 Australian ‘labour market regions’ were defined based on commuting data[2] from the 2001 Australian Census of Population and Housing (BTRE, 2003). In 2006 the BITRE ‘labour market regions’ were renamed ‘working zones’ (WZs) and updated using 2006 Census data (see Box 1 for a discussion of WZ terminology). Given that commuting patterns change over time (e.g. due to population change, new technology, macro-economic forces or changes to local infrastructure), the boundaries of WZs need periodic updating. For this current work the updated WZs are based on the ABS Australian Statistical Geography Standard (ASGS) and utilise Statistical Area Level 2 (SA2) commuting data from the 2016 Australian Census of Population and Housing. An algorithm-based approach has also been adopted in contrast to the manual methods used previously.

Labour market geography is essentially made up of two sub-geographies – the geography of where people work and the geography of where those people live. The intuition behind the approach taken to create BITRE WZs is to create an approximate geography of the centres where people work, and then join to this the geography of where those people live, to produce a single set of boundaries which define regions in which most of those who live there also work there and vice-versa.

To achieve this, a purpose built algorithm has been used to identify a good model of WZs constructed from SA2s followed by a small number of manual adjustments to deal with unusual cases. It was deemed important to find an approach which could:

- maximise commuting flows within each WZ and minimise flows between WZs

[1] The MAUP refers to the fact that regions used for geographical analysis have not been compiled for the purpose which they are being used and thus are essentially arbitrary in nature (Mitchell and Watts, 2010). The problem arises when results obtained using one set of boundaries are quite different if a similar but different set of boundaries were used in which case the choice of geographical units has an effect on results.
[2] Commuting data is compiled using the ‘Place of Usual Residence’ and ‘Place of Work’ for individuals. With these it is possible to calculate the number of persons who commute between origin-destination pairs.

- consider the commuting distances implicit in the size of the WZs
- not result in major urban centres being split into multiple WZs
- permit variation in the size of both the population and area covered by WZs
- prevent cascading uni-directional interactions from building WZs that do not reflect plausible commuting patterns.

The end result of this process lead to a new WZ geography of Australia which:

- reflects regions within which populations do actually live and travel for work
- contained a sufficient number of WZs to conduct detailed spatial analysis of labour markets and regions
- resulted in WZs that are not so large that they do not reflect realistic labour markets.

The WZs developed are not intended to be a new generic set of boundaries for all regional analysis. They are designed to reflect the labour market geography of Australia as defined by actual commuting patterns and therefore may not necessarily correspond to the movement patterns of populations for other purposes, such as shopping, socialising or education. Furthermore, the WZs may not be appropriate in analysing the behaviour of particular groups in society, for example specialist occupations, workers in particular industry sectors or those using specific modes of transport.

To ensure the final WZs met the key objectives, extensive quality assurance was undertaken including:

- examination of summary statistics to identify anomalies or outliers (e.g. self-containment rates)
- producing results for both 2011 and 2016 Census datasets to test for robustness of the outputs
- sensitivity testing (to examine how outputs differ with minor adjustments to the algorithm parameters)
- visual examination of the results in map format.

This paper provides a detailed overview of the work related to the development of these WZs and includes:

- a discussion on the purpose and potential use of WZs
- an outline of conceptual issues related to the development of WZs
- an overview of some other WZ models and their application in an Australian context
- a discussion of data related issues when developing WZs
- a summary of the methodology taken to develop the current BITRE WZs
- a description of the final WZs and their characteristics
- case study examinations of some of the BITRE WZs.

Box 1 Working Zones Terminology

Although the term 'working zones' (WZs) is used here, in the associated literature there are other terms used for what are conceptually the same type of output. These include 'Functional Economic Regions'; 'Travel to Work Areas'; and 'Labour Market Areas' to name just a few. The common threads are that all:

- are efforts to create new regions with which to understand the functioning of labour markets and local economies
- tend to use commuting data as the basis for the development of their regions
- assume that geographical classifications based upon actual human behaviour will provide new insights to the functioning of labour markets and associated industry development issues (Mitchell and Watts, 2010).

Although these different terms have common threads, BITRE recognises that some may have slightly different underlying concepts and uses. For example, functional economic regions should take into account more than just journeys to work to consider flows of goods and services among other things. In contrast, the term 'Working Zones' is intended to convey the fact that the regions developed reflect the boundaries within which Australia's population tend to both live and work.

2. Policy Value and Purpose

The key purpose for developing WZs is the need to conduct social and economic policy analysis using geography that reflects where people live and work. The broader concept of functional economic regions reflects the notion that geographic areas are linked by the interactions between people across space and that people move between places to access work, services or to buy and sell goods (Productivity Commission, 2017). In the case of WZs, the principal consideration is the movement of workers between where they live and work. As such they are based on the flow of labour between and within regions. However, because people spend so much of their time at either home or work, they also tend to conduct other activities in those regions too. WZs will therefore closely resemble functional economic regions and thus can be used by policy makers to understand the structure and composition of local labour markets and to better reflect the linkages between people across geographic areas (Productivity Commission, 2017). Importantly, they can provide a useful vehicle through which to understand changes and transitions occurring within and between regions. The development of these new BITRE WZs aimed to develop boundaries which:

- reflect the actual patterns of commuting as reported in the 2016 Census
- are largely self-contained and have minimal commuting interactions with other WZs
- are useful for a variety of BITRE and Departmental work, such as:
    - identification of important regional networks and interactions
    - infrastructure and transport planning
- are logical and defensible when taking into account other available information.

A critical issue is that unlike many administrative boundaries, the boundaries of WZ regions will be relatively fluid over time as various forces impact upon where workers live and travel to for employment. Important factors include:

- demographic changes such as population growth/decline, immigration or ageing
- industry changes such as the opening or closure of places of employment
- infrastructure changes such as new roads or public transport services
- broader economic drivers such as booms or recessions
- housing markets
- technology change.

As factors such as these change over time, population commuting patterns will also change. For example:

- new industries could offer increased employment opportunities in a particular location and result in more workers travelling to that location from further away (pull factor), or in locals not needing to travel as far
- closures or declines in certain industries may force residents of some locations to look further afield for employment opportunities (push factor)
- improved transport connectivity may open up potential new employment destinations for workers, and from an employer's viewpoint can tap into a larger pool of potential staff.

As such, by examining the commuting characteristics of workers over time it is possible to gain an insight into the relative strengths or weaknesses of regional economies. This can assist in understanding and planning for future jobs growth and making infrastructure investment decisions to support future changes. WZs also allow for more accurate estimates of the labour market impact of employment shocks like the closure or relocation of existing facilities and industries. For example, in estimating the economic and social impact of a factory closure in a small city it is important to know the area that will be affected (Robison, 2007). Depending on the location of the factory and its size, its closure may have impacts across multiple administrative and political areas.

3. Background Issues

There is a large international literature devoted to the issue of defining WZs and reviewing it in detail is beyond the scope of this report. Nevertheless, the following section details some of the main conceptual, theoretical, methodological and data-related issues which needed consideration prior to undertaking this work. These are issues which provide the basis for understanding the value of WZs and how they can be used, as well as providing insights into the limitations of WZs and problems that can arise when developing or using them. In particular there is a focus on how WZs can be defined and how their quality can be measured. This section is purposely brief, but further information on the issues raised is provided in the Appendices. For ease of presentation headings have been used to separate issues, however, in practice the issues overlap considerably and need to be considered simultaneously when undertaking this work.

Broad Methodologies for Defining Working Zones

There is no universal approach for defining WZs or similar geographic regions (CLG, 2010). Although it can be a complex and difficult task, the underlying intuition is relatively simple. As argued by Robison (2007), an appropriate scale needs to be chosen to ensure the geographies being developed capture the chosen dynamics occurring within an area. If the regions are made too small the impacts of events in an area will flow into other areas and may not be readily identified or understood, and if they are too large, the effects of an event will be lost in the broader noise of occurrences in that area (Robison, 2007). An approach then needs to be developed which will create WZs with weak or no labour market links to adjoining WZs (Casado-Diaz et. al. 2017).

Many recent approaches for defining WZs and similar spatial units have relied heavily on statistical algorithm-based methods. Such methods generally seek to amalgamate smaller spatial units into logical groupings based upon commuting flows. However, despite the benefits of such approaches there are many limitations. As Papps and Newell (2002) note, a drawback of many approaches is that they are often unable to produce meaningful results when applied to a variety of circumstances. A key reason is likely to be that it is not possible to account for all potentially influential variables when developing WZs. That is, the output is a function of the algorithm which has been developed on the basis of the best available knowledge and most critically, the available data sources. It is likely however that key variables are either overlooked or are not available in a suitable format for the analysis. As such, results could occur which do not reflect the functional realities of the place or region and which cannot be reasonably defended given other available knowledge. Additionally, the existing statistical geography of the smaller spatial units being amalgamated will also be inextricably linked to the results.

Within the literature reviewed for this work, a number of different approaches for developing WZs were identified with the main ones falling into one of the following broad groupings:[3]

- **Single-step approaches** construct WZs from smaller geographical units using an algorithm which identifies strong and weak commuting linkages between the spatial units being used.
- **Multi-step approaches** usually start by identifying centres or hubs around which WZs will be based, before moving on to allocate all or most of the surrounding hinterlands to one of the centres/hubs.
- The **merging and building approach** starts with the smallest geographical units available and merge them until further merges do not markedly improve the results, or when some pre-determined thresholds are reached.
- The **splitting regions approach** starts with all baseline units merged into one and progressively divides the regions until some threshold is reached.

[3] A more detailed summary of each of these groupings is contained in Appendix A.

Conceptual Issues

When considering methods and parameters with which to create the new BITRE WZs, there are a wide range of conceptual issues which need to be kept in mind and considered in conjunction with each other at different stages of the process. The main issues are listed below.[4]

- **Working zones are working zones:** It needs to be clearly acknowledged that the WZs developed here are exactly that – Working Zones. They are not functional economic regions and they are not seeking to become a new generic set of regional boundaries for all purposes.
- **Mutual exclusion versus complex realities**: Because WZs are defined to be mutually exclusive regions they do not fully accommodate the complex overlapping geography of labour markets as they exist in reality.
- **Working zone size:** Due to the nature of Australia's geography and population distribution, the final BITRE WZs were always expected to be characterised by a vast array of population and geographical sizes.
- **Contiguity:** Although some approaches to developing WZs do accommodate non-contiguous geographical regions to be joined as a single WZ, it was agreed that non-contiguous areas would generally not be appropriate in this work but may be considered in some circumstances.
- **Cohesiveness:** Some approaches to developing WZs seek to produce regions which have high levels of internal cohesion (i.e. high levels of interaction between individual base units and the rest of the WZ). For this work cohesiveness was not deemed a high priority.
- **Coverage:** Many WZ approaches are designed on the premise that 100 per cent coverage of the country or region in question is necessary. Given Australia's geography which contains many remote communities scattered across vast physical areas, it is recognised that 100 per cent of the country may not be readily assigned to a clear WZ. This is because some individual SA2s contain extremely small populations scattered across vast areas and therefore can't easily be assigned to a WZ but have too few persons in them to stand-alone as a single SA2 WZ.
- **Physical Barriers:** Ideally WZs do not have within them major physical barriers such as rivers or mountain ranges which are difficult for commuters to cross. On occasions however the underlying statistical geography from which WZs are created could unavoidably introduce such barriers.
- **Cascading Interactions:** Some regions, particularly around major cities, may be dominated by one-way commuting flows (i.e. from inner suburban to CBD; from outer suburban to inner suburban and so on) but with little flow in the other direction. In such situation care needs to be taken and processes in place to prevent large unwieldy WZs from developing through cascading relationships.

Definitional Parameters

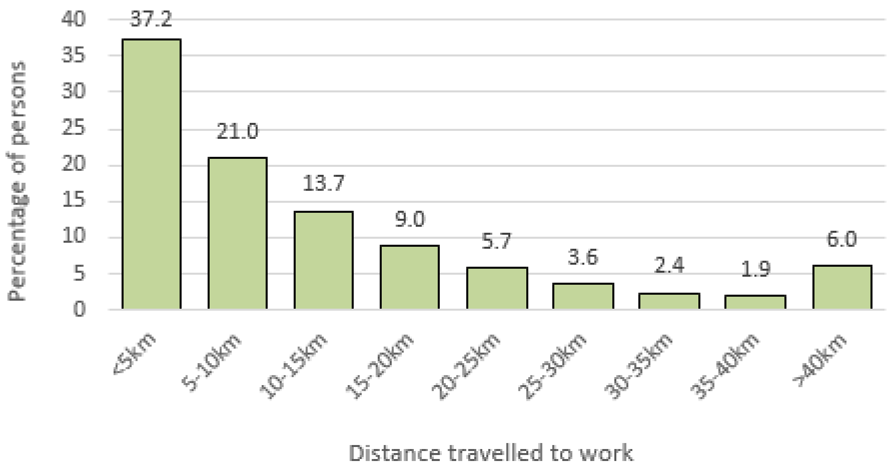
In the wide array of literature devoted to the development of functional economic regions and associated geographical boundary development there are numerous definitional parameters and measures which can be used to feed into the development of WZs. Outlined here are some of the key issues flagged in the literature as well as some of the specific issues taken into account for this work.[5]

- **Commuting inflows and outflows:** Inflow refers to the proportion/numbers of workers coming into an area for work while outflow refers to the numbers/proportion of persons leaving the area in which they live for work purposes. Both can be used to identify WZs and both are important parameters for this work.
- **Self-containment:** This is the most widely accepted principle upon which WZs are defined. The three measures of self-containment used in this work are:
    - Self-containment 1: Percentage of employed residents of a WZ who work in the same WZ as their residence
    - Self-containment 2: Percentage of persons employed in a WZ who also reside in that WZ
    - Joint self-containment: Both of the above measures to give a score out of 200.

[4] More detailed discussion of each of these is contained in Appendix B.
[5] See Appendix C for further discussion of each issue.

- **Overall containment:** Is an extension of self-containment and is one way to test the robustness of the overall set of WZs developed. The overall containment of a set of WZs is the percentage of all persons in the dataset who do not travel outside of their WZ of residence for work as a proportion of all persons in the dataset.
- **Number of Working Zones:** There is no specific number of working zones that should or could exist within any given country, state or region. Rather, the number of WZs defined should be influenced by the commuting patterns identified in the data.
- **Distance:** Distance is also an important factor. Relevant here is time-geography which is a geo-economic concept recognising that on any given day individuals have limited time available in which to undertake the activities they need and choose to do. Analysis of the commuting data being used for this work revealed that most Australian commuters travel short distances for employment. As detailed in Figure 1 over 35 per cent of workers travel less than 5km to work and over 90 per cent travel less than 30km. Only 6 per cent of workers travel further than 40km for their commutes.

Figure 1 Distance travelled to work, Australian employed persons, 2016



Notes: Based on 10 073 246 employed persons in the 2016 Census; Distances are straight-line distances between population-weighted and employment-weighted centroids of SA2s.
Source: BITRE analysis of ABS 2016a.

Data Issues

As touched on above, the most widely used and commonly accepted type of data for developing WZs is commuting data.[6] Commuting data is usually compiled using 'place of usual residence' and 'place of work' at the same geographical scale, which enables calculation of the number of persons who commute between origin-destination pairs. The best available source in Australia for commuting data is from the Census of Population and Housing available through the ABS (2016a) TableBuilder Pro product. Through TableBuilder Pro it is possible to obtain commuting data from the 2006, 2011 and 2016 Census' at a variety of different geographical scales. Despite being the best available source of commuting data in Australia, there are limitations and issues which needed consideration during the earlier stages of this work, some of which are outlined below. A more detailed overview of specific data preparation and analysis procedures is contained in the following chapter.

SA2s as building blocks

The smallest geographical unit for which commuting data is readily available at the same geographical scale in Australia is the Australian Statistical Geographical Standard (ASGS) SA2 level. The 2016 ASGS was thus chosen to underpin this work. There are 2310 SA2s covering the whole of Australia without gaps or overlaps (ABS, 2016b). SA2s range in population from zero to 37 000 persons (most are somewhere between 3000 and 25 000 persons) and have physical areas from less than 0.5km^2 to more than 500 000km^2. By way of comparison, earlier BITRE work which defined labour market working zones relied on the now obsolete Statistical Local Areas (SLAs) of which there were approximately 1400. Despite being the most suitable spatial unit for the

[6] CLG (2010) highlight some other possible data sources including housing markets, supply chains and flow of goods but recognise that all have generally been rejected as inferior when compared to commuting data.

development of nationwide WZs at present, SA2s do still present some problems in this context. These specifically relate to their size (physical and population), shape and location of boundaries, each of which is outlined further below, with more detailed explanations contained in Appendix D.

- **Population size and numbers of employed persons:** The SA2s with zero or very small numbers of residents or employed persons can introduce difficulties when defining WZs, making the flows subject to considerable influence from just a few persons and confidentialisation protocols.
- **Physical size:** The physical size of SA2s is most problematic when they are larger than what would usually be considered suitable for a WZ.
- **SA2 shapes and placement of boundaries:** While SA2s come in all shapes and sizes due to the diversity of ways in which their boundaries are defined (i.e. constructed from the smaller statistical area level 1s [SA1] and take into account existing administrative boundaries, physical features of the environment and population size among other things), there are a number of circumstances which result in shapes or boundary placements that do not reflect actual human behaviour.

In addition to these issues, patterns of commuting flows at the SA2 level can be extremely complex and difficult to disentangle, particularly within major cities. This is because of the larger number of origins and destinations between which workers commute. The Brunswick SA2 in Melbourne for example has a working resident population of just over 13 000 persons and almost 10 000 persons report working within it. There are however just 1551 persons who both live and work within the SA2, while the remainder of Brunswick residents travel to more than 120 different SA2s for work. Persons coming into Brunswick for employment arrive from more than 300 different SA2s. SA2s on the outer edges of major cities are perhaps even more complex, with a variety of factors exerting influences upon where their residents work and where workers travel from to fill the available jobs (e.g. see Box 2).

Place of work data quality

The quality of data can be influenced by a wide range of factors, particularly when it is based upon self-reported responses to questionnaires such as the Census. In particular, missing and incorrect responses can have an impact. With respect to the ABS commuting data, place of work is recorded by asking respondents to provide an address for the main workplace at which they worked in the previous week. In 2016, 10 per cent of eligible persons did not provide an exact location of where they worked, despite having reported being employed. Within this 10 per cent, over half provided no details at all, about 30 per cent provided enough information to identify the SA2 in which they worked while the remainder indicated which capital city or state they worked in. While there are many logical explanations for this (e.g. workers on construction sites in new suburbs, travelling sales people), such responses need to be dealt with when preparing the data for analysis. To this end, the ABS has imputed a location for all such persons, other than those for whom it was clear that they have no fixed place of employment.[7] While it is possible to exclude imputed responses from the dataset, this was not done for this work.[8]

Place of origin data choices

Within the ABS Census data there are two potential sources for the ‘origin’ portion of the commuting pair:

- Place of enumeration: which records where any individual was located on Census night
- Place of usual residence: when individuals report another location as their usual place of residence.

For the vast majority of persons (95 per cent), their usual residence and their place of enumeration is the same. Place of usual residence refers to where respondents expect to spend 50 per cent or more of their time living during 2016. As such, there is considerable scope for persons to report different places of usual residence than where they are enumerated (e.g. on holidays, visiting friends, attending conferences). Given the wording of the place of work question (which focuses on the previous week), there is the possibility for many complications to arise depending on which place-of-origin dataset is used. This is reduced however given that persons who did not go to work that week but usually do, are asked to report where they usually travel.

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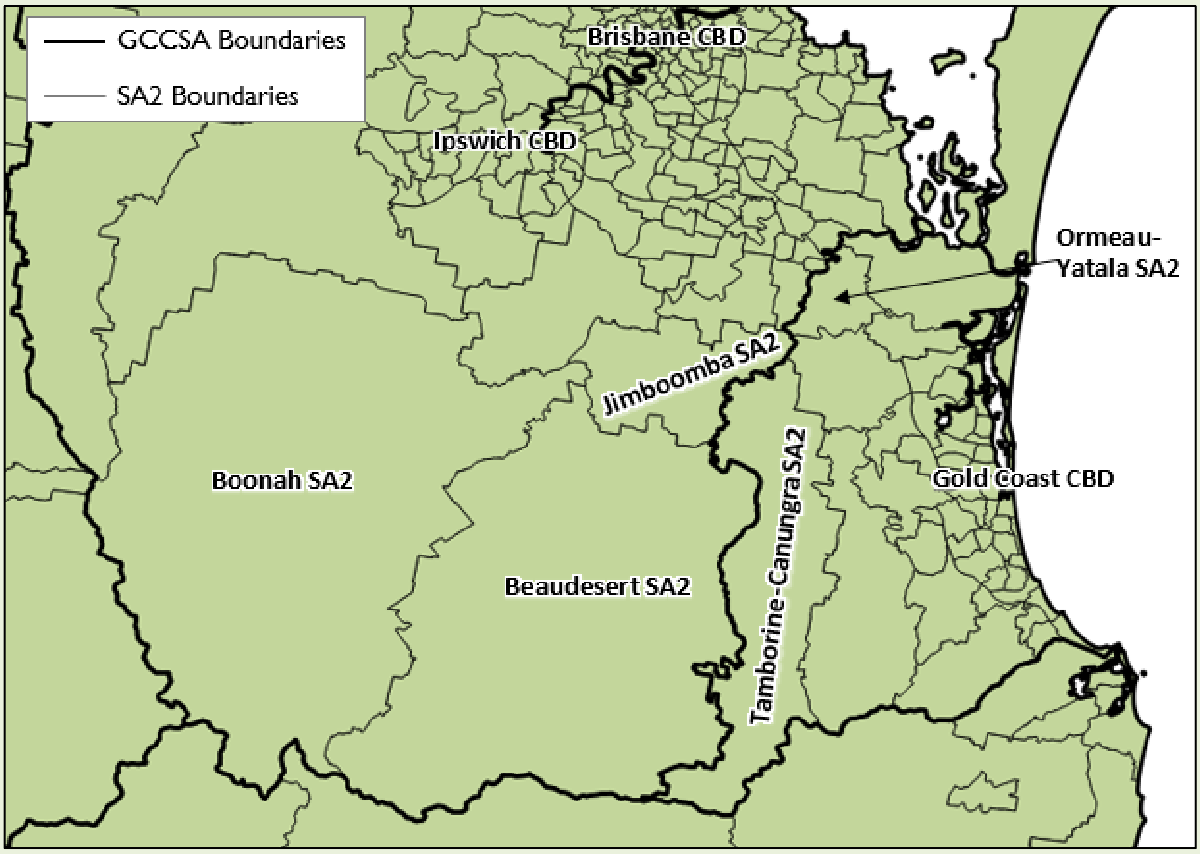
[7] See ABS 2016c for more information about the Place of Work variable and associated imputation.
[8] Testing of the final model was undertaken using non-imputed data and is described later in this report.

Box 2 An SA2 Case Study – Beaudesert

Beaudesert is within the ABS Brisbane Greater Capital City Statistical Area (GCCSA) and approximately one hour driving time from the Brisbane CBD. It is however physically closer to the Gold Coast CBD but road quality and terrain renders the shorter distance more difficult to travel. The Ipswich CBD is also just less than one hour away while the similar sized town of Boonah is about 30 minutes away by road.

In the 2016 Census data 4690 reported working in Beaudesert and it had a resident working population of 4888. Nearly 3000 persons both live and work in Beaudesert meaning that it has a self-containment rate in the vicinity of 60 per cent on both self-containment measures discussed previously. However, with approximately 40 per cent of persons leaving the SA2 for work and about 40 per cent of persons working there coming from outside the SA2, there are likely to be grounds for it to merge with other SA2s.

Examination of Beaudesert's commuting data indicates that residents of Beaudesert travel to more than 120 different SA2s for employment and those coming into Beaudesert arrive from more than 90 different SA2s. Jimboomba SA2 is the most common source of workers as well as the most common destination. Other major sources and destinations of workers travelling to and from Beaudesert are less clear. The second most common source is Tamborine-Canungra SA2 in the Gold Coast hinterland while Boonah SA2 to the west is third. In terms of outflow, Ormeau-Yatala SA2 and Tamborine-Canungra are second and third with Brisbane suburbs occupying the next couple of places before Boonah comes in at fifth on the list. The key point is that it is very difficult to disentangle the commuting patterns both into and out of Beaudesert and whether it should stand alone as a single SA2 WZ, merge with nearby SA2s such as Jimboomba or Boonah, or merge with one of the major metropolitan areas on its doorstep. All possibilities have merit based on the available data and the final decision will depend on definitions influencing the broader development of WZs at the national level.



For example, for some jobs in remote mining areas, many employees fly-in and fly-out of their work location on a rotating roster basis which may involve spending several weeks at a time in a work location followed by several weeks in a usual residence location. Such a person who spent Census night and the preceding week at their work location may have three different locations recorded on their Census form – one for their place of work, one for where they were enumerated (a location near to where their place of work is) and one for their place of usual residence. Such circumstances, whilst rare, may in some cases account for a sizeable portion of the workforce in specific locations. One example can be found in Groote Eylandt (Anindilyakwa SA2), an island community in the Northern Territory. Examination of Census data reveals that of the SA2's workforce of 1484, over 600 have a place of usual residence in a jurisdiction other than the Northern Territory (mostly Queensland) and that more than 400 of them were enumerated in that jurisdiction. Only a few workers were enumerated in a jurisdiction other than the ones they live or work in.

Given that neither of the two dataset options can completely overcome the complexities detailed above, the place of usual residence dataset was chosen. Given that the purpose of this work is to design logical labour market WZs, the basis of the exercise is to identify usual commuting patterns from the usual place of residence to the usual place of work.

Existing Models

Previous BITRE work in this field had defined WZs to reflect the area within which people were willing to commute from their homes to their place of work (BTRE, 2003). These were based upon ABS Statistical Local Areas (SLA) and resulted in 425 'labour market regions' being built from 1350 SLAs. In each 'labour market region' the majority of workers living there also worked in the region. This meant that employment by industry data could be used to provide a reasonable indication of the structure of that region's economy.

The approach used by BTRE in 2003 was a manual approach and started with a region being defined for each capital city which typically included the capital city's Statistical Division plus any adjoining SLAs in which fewer than 70 per cent of that SLA's employed persons worked within the same SLA (i.e. 30 per cent or more commuted out of the SLA). The same approach was adopted for regional centres so that SLAs which adjoined regional centres and had fewer than 70 per cent of their employed residents remaining in the SLA for work were attached to the regional centre's labour market region. When there were a number of regional centres in relatively close proximity to each other with multi-directional commuting flows, a broader labour market region was sometimes defined to capture all the centres.

For the current work it was agreed that an algorithm-based approach would be adopted. As such, one goal of the literature review was to identify existing models that may be suitable for use in this project and which could take into account the issues and concepts identified above. From the review, four different models were identified for further assessment and three were then identified for more serious testing for use in this project. The four approaches are briefly outlined here with more detailed discussion of each contained in Appendix E.

- **Intramax:** This was the first model considered for this work. Intramax is a hierarchical clustering algorithm developed by Masser and Brown (1975). It has been widely used in this sort of work, including in Australia. Intramax creates WZs from smaller geographical units using a stepped procedure which merges the two areas with the strongest links at each step of the process (Productivity Commission, 2017). The function for determining links between units is a measure of where journey to work flows exceed what would have been expected if there was no systematic relationship between the two areas (Productivity Commission, 2017).
- **Nordregio:** The Nordregio approach was designed to enable a single methodology of local labour market (LLM) development to be applied across the four continental Europe Nordic countries of Denmark, Finland, Norway and Sweden. It is outlined in more detail in Roto (2012) and involves a stepped process based on identifying LLM centres at the municipality level, and then allocating other municipalities to those centres according to the flows of commuters.
- **Eurostat:** The Eurostat approach is an algorithm-based process designed to delineate labour market areas (LMAs) from commuting matrix data sets at the national level. It emerged from work conducted in the European Commission which sought to harmonise the definition of LMAs across member nations.[9] The Eurostat approach was initially appealing due to the code for implementation of the algorithm being freely available.
- **Network models:** Network models of WZs conceptualise commuting patterns as a network where regions are nodes (vertices) and links (edges) are formed by people commuting from one region to another. The number of people traveling between two regions is typically used as the weight of the link between those two regions. These approaches attempt to separate the networks created by commuting flows into sub-communities which represent WZs.

[9] See Coombes et. al. 2012, Eurostat 2015 and Franconi et. al. 2017 for background information and technical discussion of the algorithm.

Ultimately none of the above approaches were adopted for the current work. Having looked closely at other Australian output using the Intramax approach it was decided not to proceed to testing with it. The other three models all underwent varying levels of testing but none was able to clearly meet the needs of the project.

Background Issues Summary

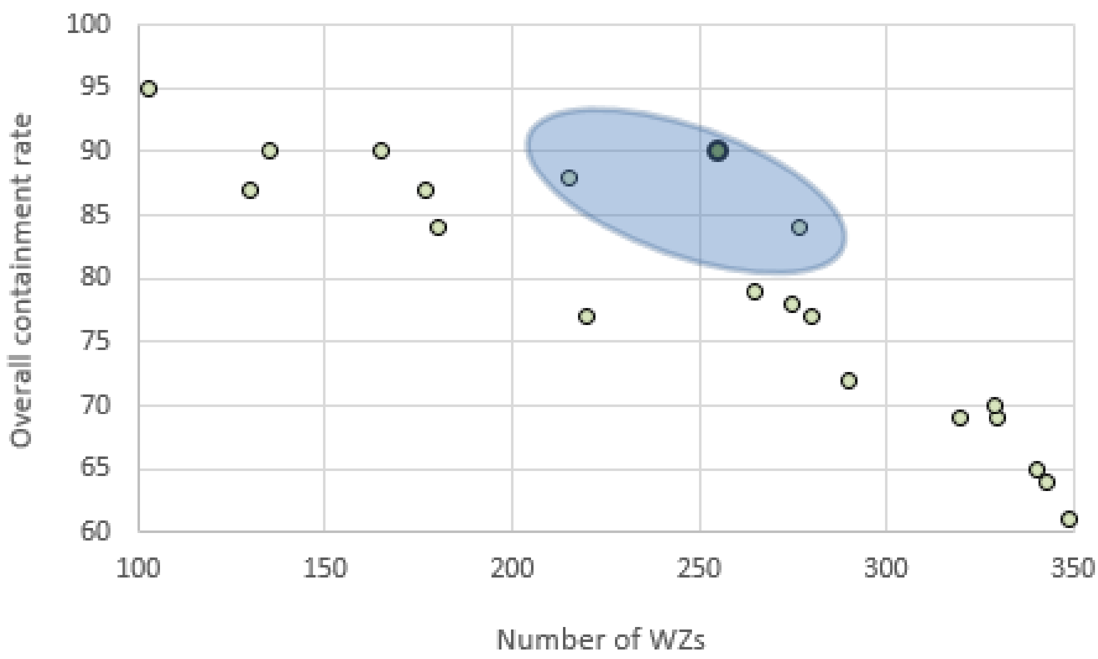
Given the above outline, it is clear that the development of WZs has the potential to be extremely complicated. In particular, it needs to be recognised that while approaches which seek to develop a single algorithm that neatly demarcates the continent into logical WZs to suit all purposes is naturally attractive, it became apparent during the development work for this project that identifying or creating such a 'silver bullet' would not be easy. During the extensive work undertaken for this project, it was never possible to establish a set of algorithm rules which could appropriately assign all regions to a WZ. Slight changes in one parameter designed to correct a problem always resulted in the emergence of a new problem.

In the development of the BITRE WZs, effort was made to produce output which resulted in:

- a sufficient number of WZs to conduct detailed spatial analysis of labour markets and regions across Australia
- a high overall containment rate to provide an indication that the WZs are reflecting regions within which populations do actually live and travel for work
- WZs that are not so large that they do not reflect realistic labour markets.

In one respect the aim was to identify as many WZs as possible whilst simultaneously keeping the overall containment as close to 100 per cent as possible. Such an objective lends itself to the potential for optimisation. For example, Figure 2 plots the overall containment rate by the number of WZs for 20 hypothetical models. Each point represents a different model, with those models to the lower right side of the graph not deemed suitable due to their low containment rates, while those towards the upper left hand side also not deemed suitable due to having too few WZs. Of most interest are the models closest to the upper right hand corner of the graph which have relatively high containment rates as well as relatively high numbers of working zones. In this instance the highlighted model with 90 per cent containment and over 250 WZs is likely to be of most interest. However, selection of models using optimisation methods also needs to consider other objectives outlined earlier (e.g. not having unwieldy regions and developing logical and defensible WZs). As such, a balance between all the competing objectives needs to be sought.

Figure 2 Hypothetical model testing



It was decided that cohesion should be a secondary priority behind self-containment when defining WZs. This is because our purpose was to define WZs which reflect the actual commuting patterns of workers in local labour markets rather than the broader purpose for which many researchers are focused – defining functional economic regions. Many Australian labour markets are likely to contain very complex patterns of commuting and encompass diverse populations in terms of their social, economic and demographic profiles.

Given the settlement geography of Australia which encompasses a vast continental landmass but which has a population largely concentrated in a handful of coastal cities, it is inevitable that commuting patterns and labour markets will reflect this pattern. As such, attempting to produce WZs which are similar in terms of area or population size is not realistic.

The work also recognised the reality that major cities are functional units in themselves. Such realities are evident when examining ABS commuting data for Australia's cities which reveal very complex and multi-directional flows of workers. While there may be some interesting patterns and nuances between different sections of cities, the fact remains that the residents are all part of the same labour market. As such, any single or top tier approaches which result in cities being split into smaller units needs to be treated with great care, with any such splits needing to be very well justified.

At the other end of the scale, it was deemed important to recognise and accommodate the fact that the residents of very remote communities do not tend to commute for work anywhere other than within their own town, even where there are multiple towns in a single statistical geography. Around each centre there is an inescapable distance decay[10] effect which undoubtedly influences commuting patterns and how far people can travel for work on a regular basis. This results in statistical geography which does not reflect an underlying labour market, and such regions need to be identified and should not be considered WZs.

In determining which model to adopt or create for the development of the BITRE WZs, and within the limitations of the baseline SA2 statistical geography with which we were working, it was deemed important to find an approach which could:

- maximise interaction within each WZ and minimise external interaction between WZs
- consider self-containment and overall containment as key measures
- consider the commuting distances implicit in the size of the WZs
- not result in major centres being demarcated into multiple WZs
- permit very large WZs and very small WZs in terms of both population and area
- accommodate areal units with zero jobs or zero population
- prevent cascading uni-directional interactions from building WZs that do not reflect plausible commuting patterns.

These parameters should enable logical and defensible WZs to be developed which reflect the realities of Australian labour markets and associated commuting patterns.

4. Developing the BITRE WZs

Having not had success defining suitable WZs using the existing algorithmic approaches outlined above, a decision was taken to develop our own algorithmic approach. A multi-staged and stepped approach was ultimately used to build WZs from SA2s using 2016 Census commuting data. The approach adopted uses the statistical geography of SA2s and links them into coherent employment hubs and grows the hubs into WZs by joining to them the residential areas with which they have strong commuting flows.

Given the very different types of regions present in the Australian context (i.e. ranging from major cities through to extremely remote outback hamlets) it was decided to break the allocation method up into a number of key stages according to the type of region in question. The different stages/regions are:

- highly self-contained regional centres

[10] Distance decay is a geographical term which describes the effect of distance on spatial interactions – specifically that the interaction between two locales declines as the distance between them increases.

- major cities (which have at least one SA2 which contains more than 100 000 persons working in it)
- secondary cities (at least one SA2 which has more than 10 000 persons working in it)
- smaller centres (at least one SA2 which has more than 1000 persons working in it).

For each of the four stages a three step process was undertaken to construct the WZs.

- Identify the 'seeds' around which individual WZs will be built.
- Construct an approximate employment hub geography around those seeds.
- Merge other SA2s to the employment hubs using commuting flows data.

Following these four stages and associated steps a final stage resulted in the finalisation of WZs through the allocation of unassigned SA2s and manual adjustments to the amalgamation of SA2s.

The remainder of this section provides more detail about each of these stages and steps starting with the data preparation process. Details of the final WZs and their characteristics follow in the next chapter.

Preparing the Data

Preparation of the data and the development of WZs was largely undertaken within the R statistical software package. Prior to entering the R environment, all non-spatial SA2s are removed from the dataset. This includes all 'Migratory - Offshore – Shipping' and 'No usual address' SA2s. A further ten SA2s which have zero resident populations and zero persons working in them are also removed. This reduces the original 2310 SA2s to a matrix containing data for 2282 SA2s. The matrix then needs to be converted to a three column dataframe with over 5 million rows, one for each possible origin and destination pair of SA2s. The three columns are origin (SA2 of usual residence), destination (SA2 of work) and amount (the number of persons who make the journey from origin to destination for work). Each pair of SA2s is present in the dataset twice, once for each direction of travel. For example, in the Central West of NSW there are 335 persons who live in Bathurst SA2 and work in Orange SA2 while a further 152 persons live in Orange SA2 and work in Bathurst SA2. Each has a separate row in the dataset.

Although there are more than 5 million records in the dataset, the vast majority have zero commuting flows between them. All such cases can therefore be removed from the dataset for the analysis. In most cases this is evident for both directions of travel for a given pair of SA2s but in some cases a unidirectional flow is present, particularly in cities. For example, in NSW there are some residents of Braidwood who work in Karabar (an SA2 in Queanbeyan), but no residents of Karabar work in Braidwood. This means that the Braidwood/Karabar pair is only present in the analysis dataset once to indicate the number of persons flowing from Braidwood to Karabar. This step also results in some SA2s being completely removed from the dataframe due to their having no employed residents or employed persons working in them.

Parameters

There are eight parameters which feed into the seeding and allocation process. These parameters are used in various combinations at the various stages of the process to determine which SA2s are seeds and which ones should be allocated to a seed. Each of the parameters is outlined below.

Minimum number of persons working in the SA2

This is a parameter which was established to prevent very small remote area SA2s becoming seeds at Stage 1 of the algorithm. The level was set at 200 employed persons who have that SA2 as a place of work and was determined through examining the SA2 dataset which identified Lord Howe Island as being the SA2 with the fewest number of employed persons by place of work (211), which could logically be considered a stand-alone WZ.

Minimum self-containment

Stage 1 of the algorithm involved identifying SA2s which exceeded the minimum number of employed persons working in the SA2 and were above the minimum self-containment rate. The minimum self-containment rate is the same as the joint self-containment score discussed earlier – that being an aggregation of the two individual self-containment measures to produce a score out of a maximum possible 200. After substantial sensitivity testing, the minimum self-containment rate was set at 160.

Seeds

The first step in each of Stages 1 to 4 of the algorithm was to identify the seed SA2s. As detailed above, four different types of employment hubs were subject to 'seeding' with a single SA2. That is, every WZ starts with a single SA2. Based upon other criteria, remaining SA2s are then allocated to some of the seeds in accordance with the algorithm rules to form WZs. As detailed later in this paper, many of the original WZ seeds never have another SA2 assigned to them and they remain as a single stand-alone SA2 WZ.

The first of the seeds to be identified are those SA2s that are highly self-contained (Stage 1). They are determined by identifying all SA2s which had a joint self-containment score equal to or higher than the minimum self-containment rate (i.e. 160 or higher) as well as having at least 200 persons who have that SA2 as a place of work.

The other three seed types (Stages 2, 3 and 4) are all based upon numbers of persons working in SA2s. The first was set at 100 000 or more which resulted in just five SA2s becoming seeds – those being the SA2s that capture the CBDs of Sydney, Melbourne, Brisbane, Perth and Adelaide. The next two sets of seeds were set at 10 000 and 1000. For both of these seed identification steps, the closest bigger and distance parameters came into play (discussed further below).

Distance

When seeking to amalgamate smaller spatial units into larger commuting regions the underlying aim should be to ensure the final regions reflect the actual commuting patterns of the residents. As outlined earlier, distance is a major factor that needs consideration when defining WZs due to time-space geography related constraints.

Distance can be calculated between two spatial units in numerous ways. For this work distance was calculated as a straight line between the population and employment-weighted centroids of SA2 pairs. As such for each pair of SA2s, there were two distances calculated – one in each direction between the population-weighted centroids and employment-weighted centroids of each. The final distances used in this work were averages of the two distances.

In the development of these BITRE WZs distance was used as a constraining factor in the algorithm in two ways.

- As a proxy for flows to merge smaller spatial units where the statistical geography had arbitrarily split the functional geography and 'fractured' the commuting flows (mostly in cities but also in larger regional centres and regions with polycentric employment centres). As detailed earlier, it was calculated that over 90 per cent of all workers in the dataset were travelling less than 30 kilometres to get to work. This figure was therefore adopted for initial testing of the method. Subsequent optimisation and sensitivity testing resulted in the final distance being revised upwards slightly to 32km. This distance was used at two distinct points in the allocation process of the algorithm as detailed below in the 'closest bigger' section.
- As a limiter at the 'flows' assignment stage to prevent individual WZs from getting too large. This was arbitrarily set at 200km and was measured as the distance between the population-weighted centroids and employment-weighted centroids of existing WZ SA2s and those that could potentially merge with that WZ. That is, only SA2s which were less than 200km from the furthest SA2 of the developing WZ were permitted to merge at a given step.

Closest bigger

An important element of the algorithm is the concept of 'closest bigger'. Using number of employed persons in an SA2 as the measure, every SA2 in the dataset bar one has a single 'closest bigger' SA2. That is, of all the SA2s in Australia which have more employed persons in them, which is closest? This parameter is determined by the dataset and is not subject to arbitrary change. The one SA2 that does not have a closest bigger SA2 is the largest SA2 in the dataset – 'Sydney-Haymarket-The Rocks' which is part of the Sydney CBD.

Distance is not a factor when identifying a closest bigger SA2. For example, there is only one SA2 in Australia which has more employed persons working in it than the Melbourne CBD SA2 – and that is 'Sydney-Haymarket-The Rocks', which is therefore the closest bigger SA2 for the Melbourne CBD. The same applies for the Brisbane CBD, which also has 'Sydney-Haymarket-The Rocks' as its 'closest bigger' SA2. In rural areas the distances are not so great with the nearest town-based SA2 usually being the 'closest bigger' SA2. Within suburban areas the pattern is more mixed with some SA2s having a 'closest bigger' which is adjoining or very nearby, while larger SA2s may be some distance from an SA2 which has more persons working in it. For example in Melbourne, the 'closest bigger' SA2 to Dandenong is Melbourne nearly 30km away while for Dandenong North it is Noble Park North at just 2km away.

When using 'closest bigger' as an assignment tool, it always needs to be used in conjunction with a distance parameter to prevent the merging of SA2s which are too far apart – such as Melbourne and Sydney. As detailed above, the distance parameter used for this work was set at 32km for the final WZ model. There were two distinct applications of 'closest bigger' in conjunction with distance. They are:

- At the 'seeding' stage, when an individual SA2 could only become a WZ seed if it was more than 32km away from its 'closest bigger' SA2
    - 10 000 persons: SA2s which had not yet been assigned to another seed, had more than 10 000 persons working in them and were further than 32km from their closest bigger SA2 became a seed
    - 1000 persons: SA2s which had not yet been assigned to another seed, had more than 1000 persons working in them and were further than 32km from their closest bigger SA2 became a seed
- At the distance allocation stage, an SA2 could only join a WZ seed if it was less than 32km away from that seed.

The 'closest bigger' concept may be useful when looking at how WZs change over time because it is subject to change through a number of different avenues. The main ones are:

- Individual SA2s can increase and decrease their number of employed persons over time
- Given that the distance between SA2s is in this case measured between population and employment-weighted centroids, the location of the centroids in individual SA2s can shift over time.

As such, with these two avenues of potential change, what was the closest bigger SA2 to any given SA2 at one point in time may not necessarily be so at another point in time. For example if one particular SA2 increases its number of jobs substantially, it may become larger than the SA2 which was previously its 'closest bigger'. Its 'closest bigger' would then become a different SA2. With respect to the shifting of centroids, this may occur if for example extensive population growth occurred in one particular part of the SA2 so that the population-weighted centroid of that SA2 would shift towards the area. This may result in the distance to other SA2s either increasing or decreasing resulting in the possibility of change in terms of which SA2 is the closest bigger. As such, when adopting this method it is important to use weighted centroids rather than simple geographic centroids. For this work, straight-line distance was used for the measurements between the centroids however road networks might also be utilised to measure distances between centroids.

Minimum flow rate

The minimum flow rate is used during the 'flows' stages of the algorithm (Step 3 of Stages 1, 2, 3 and 4) to determine whether unassigned SA2s should be assigned to a seed and its WZ on the basis of commuting flows. The flow rate is a calculation incorporating flows in both directions between unassigned SA2s and already identified WZs. The minimum flow rate was set at 35 per cent meaning that at least 35 per cent of the working population of the combined regions needed to be crossing into the other region for work. Flow rates were calculated at each step of the allocation process for all of the existing WZs as they stood at the time.

The SA2 Allocation Process

Box 3 provides an overview of the algorithm which builds WZs from individual SA2s and the various steps involved. As is evident, Stages 1 to 4 follow an almost identical process of identifying seeds, merging SA2s based on 'closest bigger' and distance before finishing with further SA2 allocations based on commuting flows for each of the four region types. Stage 5 also has three steps but they differ in that they are in place to conduct the final refinements of the WZs that have emerged through Stages 1 to 4. Further detail of each of the Stages is provided below.

Box 3 Outline of the BITRE WZ development algorithm

Stage 1: Highly self-contained SA2 seeds

- Step 1: Identify the highly self-contained SA2 seeds
- Step 2: Based on closest bigger and distance, merge SA2s to the seeds to create WZs
- Step 3: Based on commuting flows data, merge SA2s to the WZs

Stage 2: Major city seeds

- Step 1: Identify the major city SA2 seeds
- Step 2: Based on closest bigger and distance, merge SA2s to the seeds to create WZs
- Step 3: Based on commuting flows data, merge SA2s to the WZs

Stage 3: Secondary city seeds

- Step 1: Identify the secondary city SA2 seeds
- Step 2: Based on closest bigger and distance, merge SA2s to the seeds to create WZs
- Step 3: Based on commuting flows data, merge SA2s to the WZs

Stage 4: Smaller employment hub seeds

- Step 1: Identify the smaller employment hub SA2 seeds
- Step 2: Based on closest bigger and distance, merge SA2s to the seeds to create WZs
- Step 3: Based on commuting flows data, merge SA2s to the WZs

Stage 5: Finalise WZ boundaries and coverage

- Step 1: Assign remnant SA2s to existing WZs based on commuting flows
- Step 2: Assign remnant SA2s to WZs based on the SA2 from which they receive the maximum inflow
- Step 3: Manually adjust the assignment of SA2s to finalise the coverage and boundaries of the WZs

Stage 1: Highly self-contained SA2s

Step 1 is to identify SA2s which are very highly self-contained and are far enough from their 'closest bigger' SA2 to become a WZ seed. These are SA2s which have a very high proportion of residents both living and working within the SA2 (i.e. have a minimum self-containment of 160 or higher) and are more than 32km from their closest bigger SA2. The outcomes of this step are largely seen in the remote and outer regional areas where large distances mean that travel outside of the home SA2 for work is relatively uncommon. Six per cent of all SA2s were identified as highly self-contained.

Once the seed SA2s are identified as meeting the highly self-contained parameters, they are considered individual WZs. This stage is conducted at the outset to ensure that SA2s which are highly self-contained do not get 'assigned' to larger centres at later distance-based steps. Early models used for sensitivity testing included in them three distinct self-containment rates that were used to identify these seeds. These were:

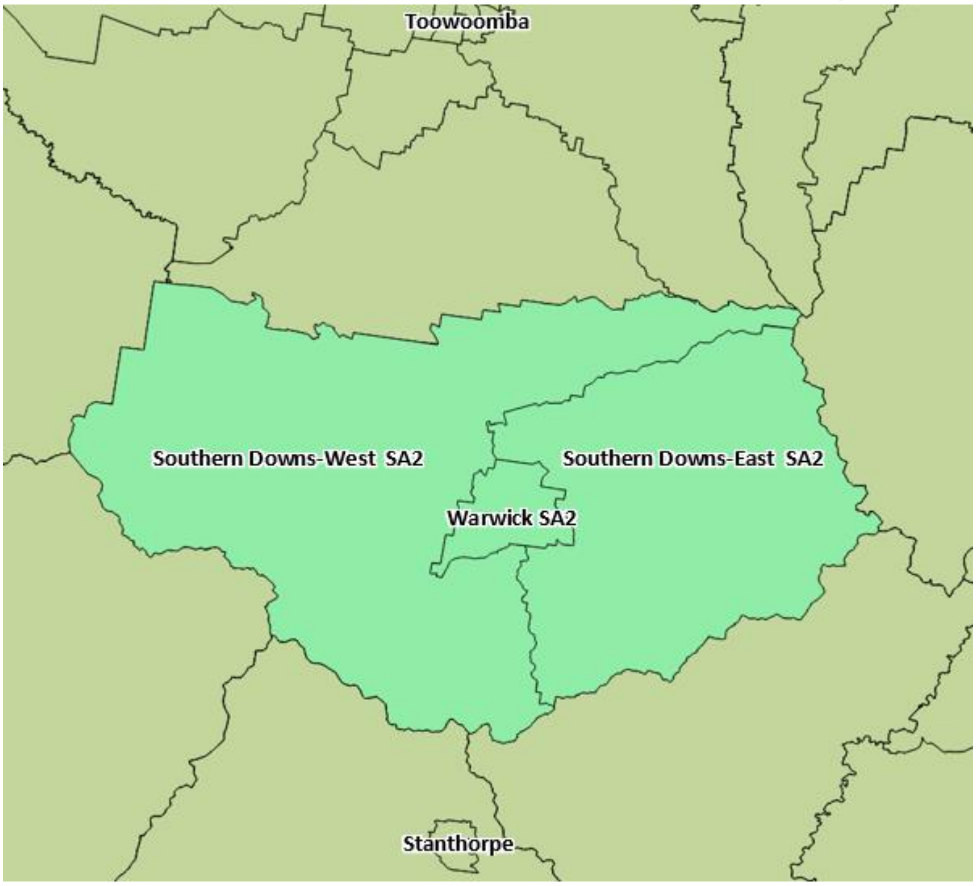
- the percentage of persons living in an SA2 who also worked in that SA2 (usually set in the range 60-80 per cent)
- the percentage of employed person working in an SA2 that also live in that SA2 (usually set in the range 50-70 per cent)
- a combination of the above which was usually set at slightly higher than the lowest possible combined rate of the above two parameters.

Sensitivity testing ascertained that only the combined rate was having a significant impact upon the final results. As such a decision was taken to remove the other two from the seed identification process and the 160 limit was settled upon.

Step 2 of Stage 1 involves merging other SA2s to the previously identified seeds to create employment hubs. These mergers are based upon the 'closest bigger' and distance parameters detailed earlier. As such, all unassigned SA2s which have a 'closest bigger' SA2 that has been identified as a seed, and which is less than 32km away, are merged to that seed. In practice many of these original seeds attract no SA2 merges and at this point remain as stand-alone SA2 WZs. All SA2s that do merge to a seed then become seeds themselves in that WZ. Step 2 is then repeated and repeated as a loop until no further mergers occur. Less than one per cent of all SA2s (20) joined an existing WZ at this step.

The third and final step of Stage 1 is the flows allocation. Any unassigned SA2s which have commuting flows to the existing WZs (i.e. the original seeds and any SA2s that have joined them) that exceed 35 per cent are also assigned to that WZ. The flows assignments were subject to the 200km distance limiter outlined earlier. Again this process occurs as a repetitive loop until no further assignments occur. A visualization of how this process unfolds is provided in Figure 3. In this example the SA2 of Warwick in Queensland is identified as a seed at Step 1 and defined as a WZ. Step 2 resulted in two extra SA2s (Southern Downs-East and Southern Downs-West) joining Warwick to increase the size of the WZ. In the case of Warwick, no further additions occurred during Step 3. Only one SA2 joined a WZ in this step.

Figure 3 SA2s in the 'Warwick and surrounds WZ' and nearby towns



Source: BITRE analysis of ABS 2016a.

Stage 2: Major cities

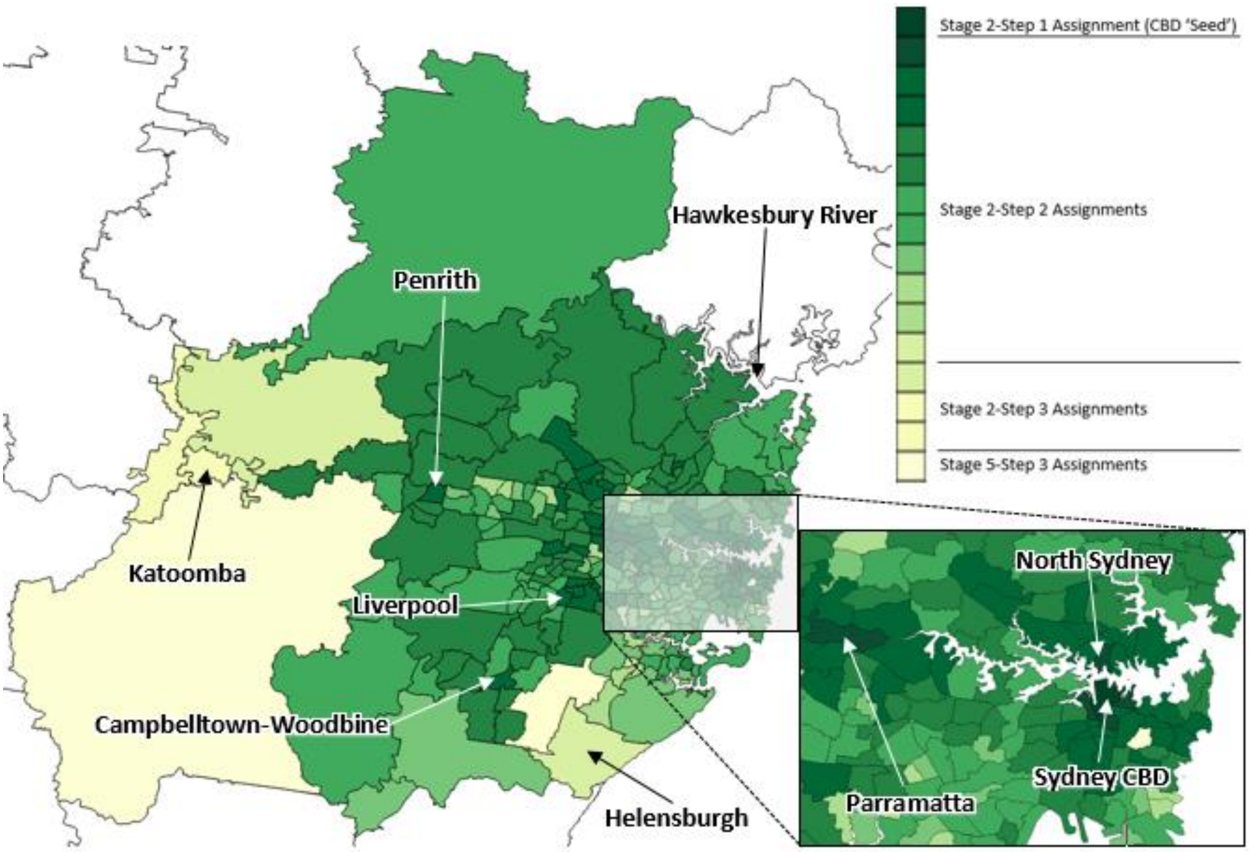
Step 1 of Stage 2 involves planting the five seeds which represent the hubs of the five largest cities in Australia – Sydney, Melbourne, Brisbane, Perth and Adelaide. These cities all have populations in excess of one million persons and central business district SA2s which have more than 100 000 persons working in a single SA2. No other cities in Australia, or CBD SA2s come anywhere near these numbers. It was deemed important to take into account the relative gravity of larger cities over smaller cities and therefore to run this allocation at this stage and distinct from other large cities.

As occurred in Stage 1, once the individual SA2 seeds representing the five major city CBDs were planted, Step 2 involved building the employment hub geography through use of the closest bigger and distance parameters. As such, all unassigned SA2s that were within the required distance of the five seeds and had a 'closest bigger' SA2 identified as one of those seeds, were then assigned to those seeds to increase the size of the respective WZs. Those newly assigned SA2s then become seeds of a WZ themselves and Step 2 repeated over and over as a loop until no further assignments are possible given the rules of the algorithm. Just over 47 per cent of all SA2s joined one of the five major city WZs in this step.

As for Stage 1, Step 3 of Stage 2 involves allocating any unassigned SA2s which have sufficiently strong commuting flows to the existing WZs. This is also iterative and ends when no further allocations are possible. In the final model adopted this resulted in a handful of outer suburban SA2s being merged to the big five cities WZs. For example the Blue Mountains SA2s of Katoomba-Leura and Blackheath-Megalong Valley were allocated to the Sydney WZ during this allocations step. One per cent of all SA2s (26) joined a WZ during this step.

By way of example, Figure 4 provides an overview of the development of Sydney's WZ through the three steps of Stage 2. The SA2 containing the Sydney CBD (Sydney–Haymarket–The Rocks) was first assigned as a seed at Step 1. At the first iteration of Step 2 just five SA2s joined the Sydney seed to start the growth of the WZ – North Sydney, Potts Point, Surry Hills, Pyrmont-Ultimo (all adjacent to the CBD) and Parramatta. At this point these five SA2s become seeds themselves. At the next iteration of Step 2, 15 more SA2s joined the WZ and then became seeds themselves. Most of these 15 were adjacent to the existing WZ SA2s (e.g. close to the CBD or Parramatta) but at this step Liverpool also became a seed. At the next iteration a further 34 SA2s joined the WZ – most being adjacent to either the CBD, Parramatta or Liverpool but with some new non-contiguous seeds emerging including Penrith and Campbelltown-Woodbine SA2s. This allocation process repeats until no more allocations are possible. Then Step 3 commences through the allocation of SA2s to the WZ based upon commuting flows. This again continues as a loop until no further assignments are made to any of the five major city WZs.

Figure 4 The Sydney and surrounds WZ showing the progressive assignment of SA2s



Source: BITRE analysis of ABS 2016a.

Stage 3: Secondary cities

An identical process as was undertaken for Stages 1 and 2 then occurs for secondary cities. Step 1 defines the seeds based on number of employed persons working in a single SA2 (this time 10 000 employed persons) and being far enough away from their 'closest bigger'. The 32km distance parameter was very important at this step because it prevented SA2s that were close to each other from becoming seeds at the same time. For example, Robina SA2 and Southport-North SA2 in south east Queensland both have more than 10 000 persons working in them and were unassigned prior to this stage. They are however less than 32km apart and with Southport-North being Robina's closest bigger SA2, Southport-North became the first seed for the Gold Coast WZ. Robina then joined Southport-North at Step 2. A further 35 SA2s (1.5 per cent of all SA2s) were identified as seeds at this step and started new WZs.

Once Step 1 had identified the seeds for the WZs, Steps 2 and 3 build the employment hub geography and assign SA2s to the WZs based on commuting flows until no further assignments occur. Step 2 of this stage resulted in 27 per cent of all SA2s joining a WZ and Step 3 linked a further 12 SA2s through commuting flows.

Stage 4: Smaller employment hubs

Stage 4 repeated the same pattern as occurred in the previous three stages – Step 1 identifying seeds (unallocated SA2s that have at least 1000 persons working in them and are further than 32km from their closest bigger SA2), Step 2 assigning SA2s to the seeds to create larger WZs and Step 3 further growing the WZs based on commuting flows. In this stage 123 new WZs were created at Step 1 with seven per cent of SA2s (156) joining these WZs at Step 2 and just 2 SA2s joined at Step 3.

Stage 5: Final allocations

Following Stage 4 just 51 (2 per cent) of the 2282 SA2s had not been assigned to a WZ. Stage 5 includes three steps to complete the allocations and to finalise the coverage and boundaries of the WZs.

Step 1 is a final flows allocation step similar in nature to those used in Step 3 of Stages 1 through 4 but with slightly relaxed criteria to allow remnant unassigned SA2s to 'find a home'. Specifically the requirement that SA2s only assign to WZs for which their flow exceeds the minimum flow rate is removed. Furthermore, SA2s can assign to any WZ and not just those that have been created during the most recent seeding stage. Step 1 assigned 12 more SA2s to WZs.

Many of the remaining 39 SA2s had similar characteristics in that they had zero or few residents in them and therefore did not have outflows of workers, although in many cases they did have inflows. Due to not having any or sufficient outflows, the algorithm did not assign them. Step 2 of Stage 5 deals with these SA2s by assigning them to the WZ from which the majority of their worker inflows are sourced. A further 23 of the remaining 39 SA2s found a WZ home at this point leaving 16 still unassigned.

By the end of Step 2 of Stage 5 the algorithm had resulted in 314 WZs and an overall containment rate of 95.1 per cent. Step 3 of Stage 5, the final step of assignments, is a manual assignment process. This was deemed necessary after extensive testing of different models and parameters determined that no single model would ever be able to produce a set of working zones which met all of our criteria perfectly. When one parameter was adjusted slightly to rectify a given problem, another problem eventuated. As such it was decided to identify a very good model and then to make manual adjustments based on close examination of commuting flows.

Through careful examination of the results a number of manual adjustments were identified which were made before the final WZs were agreed upon. At the end of this final step the number of WZs decreased to 313 and the overall containment rate increased to 95.2 per cent. The adjustments made fell into a handful of categories listed below, with full details contained in Appendix F.

- Unassigned SA2s: which due to a unique combination of parameters had not been assigned to a WZ.
- Demerging: a qualitative assessment of the WZs identified a small number of cases where SA2s had been assigned to a WZ based on distance but flows data suggested another allocation was more appropriate.
- Merging: when stand-alone single SA2 WZs were merged with a neighbouring WZ.
- Non-Contiguous: when non-contiguous components of WZs were deemed more appropriately joined to an adjoining WZ.

- Surrounded SA2s: unassigned SA2s (most with zero or few residents) that had not been assigned to a WZ but were completely surrounded by a WZ were assigned to that WZ.

Unassigned SA2s

At the end of this set of procedures there remained ten SA2s which for various reasons were not assigned to any WZs. The unassigned SA2s are Ashendon-Lesley (WA), Avon Valley National Park (WA), Lake King (Vic), Lamb Range (Qld), Malmalling-Reservoir (WA), Stirling Range National Park (WA), Western (SA), Wilderness–West (Tas), Wollangambe-Wollemi (NSW) and Wooroonooran (Qld).

The most notable of these is the SA2 of Western which covers a vast area of South Australia but has just 26 employed residents and 29 persons recording it as a place of work. As such it is too small to be a WZ but does not have sufficient flows to any WZ to join another one. All other unassigned SA2s are national parks, lakes or wilderness areas which do not have any residents, persons working in them, or are not surrounded by a WZ.

Sensitivity testing

Extensive sensitivity testing was undertaken at all steps of the development process as different models and parameters were evaluated. During the final stages of developing the model using 2016 Census data, the model was also applied to:

- corresponding 2011 Census commuting data
- non-imputed 2016 Census commuting data.

Both sets of testing produced results which did not raise major concerns about the model and the final parameters being used. Summary results and how they differ from the final 2016 BITRE WZs are detailed in Appendix G. In both cases these differences are reported as they stood after the algorithm had completed running, but before manual adjustments were made to the final model.

5. The 2016 BITRE Working Zones Described

There are 313 BITRE WZs Australia wide (see Appendix H for the detailed list of the WZs as well as maps and summary statistics). The WZs have been named according to a series of conventions designed to allow a reader to relatively easily understand something of the nature of any given WZ. The conventions are also designed to ensure that WZ names do not correspond to ASGS names which may have different boundaries. For example the major cities are not named 'Greater….' to ensure they are not interpreted as having the same boundaries as their corresponding city in the ABS Greater Capital City Statistical Area (GCCSA) classification system. The naming conventions are:

- WZs which have just a single SA2 have usually retained the name of that SA2. Exceptions are only made when SA2s have names which are based on a town which is not included in the WZ. For example, the Deniliquin Region SA2 (NSW) has become a stand-alone WZ but it does not include the town of Deniliquin. In such circumstances, a new name is created based upon the main towns in the WZ and the SA2 name is included in brackets. For example, the WZ which is based on the Deniliquin Region SA2 is named Moulamein-Barham (Deniliquin Region).
- WZs compiled from two SA2s have been given a name which corresponds to the two individual SA2s (e.g. Margaret River SA2 and Augusta SA2 have been joined to become Margaret River and Augusta WZ). In those cases when a town-focused SA2 merges with a 'donut region' style SA2 with the same name (e.g. Busselton and Busselton Region) only 'region' is retained (e.g. Busselton and Region WZ).
- WZs which have three or more SA2s within them have usually been named after the major centre/centres around which they are focused and with the words 'and surrounds' added (e.g. Sydney and surrounds, Perth and surrounds, Albury-Wodonga and surrounds). There are a number of such cases however when multiple SA2s have combined to form a WZ which is essentially urban in nature. In such cases just the name of the major centre/centres are given to the WZ (e.g. Geraldton WZ contains 4 SA2s but these are focused on the town while the surrounding area is in another WZ).

As detailed in Table 1, most WZs are in NSW which has 81, followed by Queensland (69) and Victoria (48). There are five cross-border WZs, all of which include parts of NSW. They are:

- Gold Coast-Tweed Heads and surrounds is largely in Queensland but with some SA2s in northern NSW
- Canberra and surrounds includes some NSW SA2s in the Queanbeyan and Yass areas
- Mildura and Wentworth includes SA2s in and around Wentworth, NSW
- Albury-Wodonga and surrounds straddles the Murray River with SA2s in both Victoria and NSW
- Corowa, Yarrawonga, Rutherglen and surrounds also straddles the Murray River on the Victoria/NSW border.

Table 1 State and territory distribution of working zones

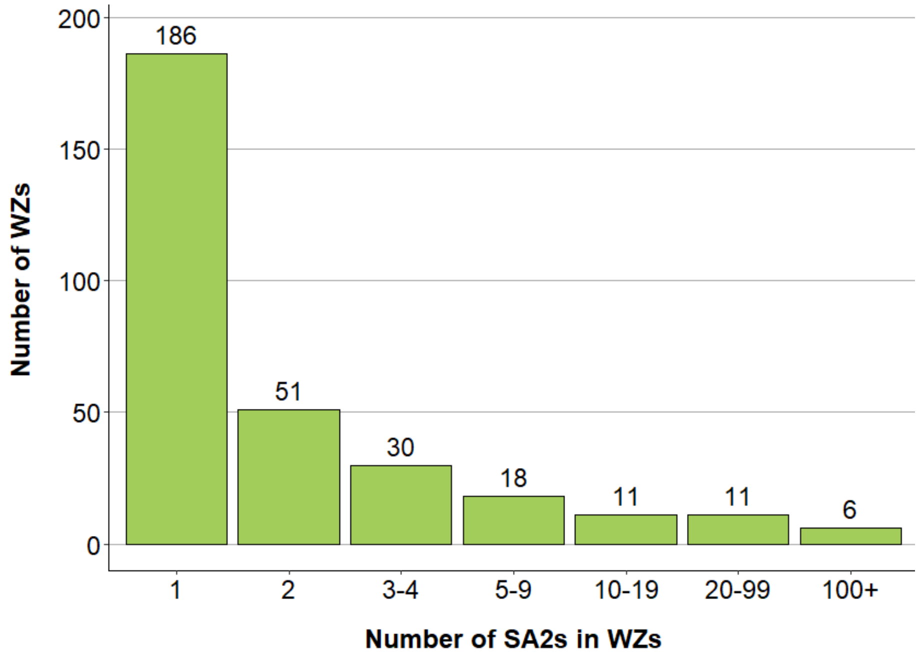
	Number of WZs
New South Wales	81
Victoria	48
Queensland	69
South Australia	35
Western Australia	44
Tasmania	13
Northern Territory	19
Australian Capital Territory	1
Other Territories	3
Total	313

Note: The five cross-border WZs have been assigned to the jurisdiction in which the majority of employed persons are located: 2 to NSW, 1 to Queensland, 1 to Victoria and 1 to the ACT.

Source: BITRE analysis of ABS 2016a.

In terms of the construction of WZs, Figure 5 provides an overview of the number of SA2s which contribute to individual WZs. As indicated, 186 (almost two thirds) of the 313 WZs are stand-alone SA2s and a further 51 are compiled of just 2 SA2s. Only 28 of the WZs (less than ten per cent) contain more than ten SA2s. The WZs with the largest number of SA2s are the major cities with Melbourne and Surrounds containing 314 SA2s, Sydney and Surrounds containing 282 and Brisbane and Surrounds 235. The WZs focused on Perth, Adelaide and Canberra are the only others which have more than 100 SA2s within their boundaries. Gold Coast-Tweed Heads is seventh on this measure but it has just 53 SA2s in it.

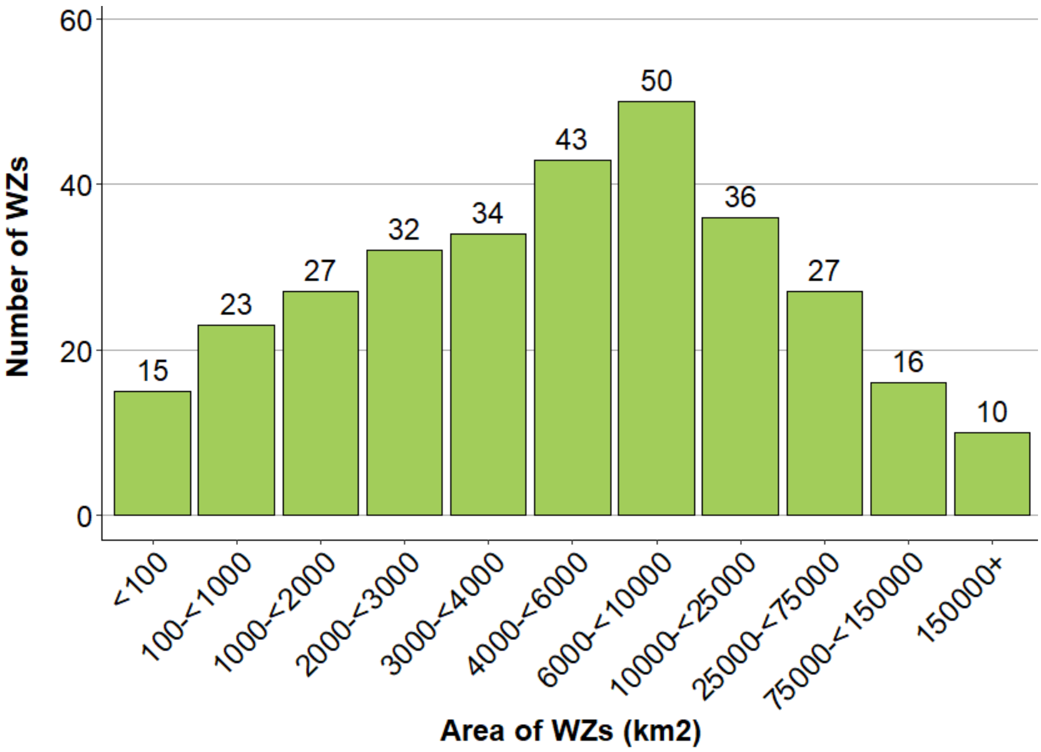
Figure 5 Number of SA2s in each WZ



Source: BITRE analysis of ABS 2016a.

When the physical size of the WZs are considered in terms of square kilometres covered, Figure 6 provides an overview. As expected, there is enormous variability in the size of the WZs ranging from less than 10km^2 (Nhulunbuy) to more than 500 000km^2 (Outback [SA]). The majority of WZs however cover an area of several thousand square kilometres. As indicated in Figure 6, there are just 53 WZs which are larger than 25 000km^2 and 65 under 2000km^2 with the remainder being between 2000 and 25 000. All the major capital cities as well as many of the major regional centres, are within this middle range – for example Sydney covers 10 700km2, Melbourne 12 700km2, Brisbane 7600km^2, Perth 10 300km^2, Adelaide 7700km^2 and Darwin 3100km^2.

Figure 6 **Physical area of WZs (km^2)**

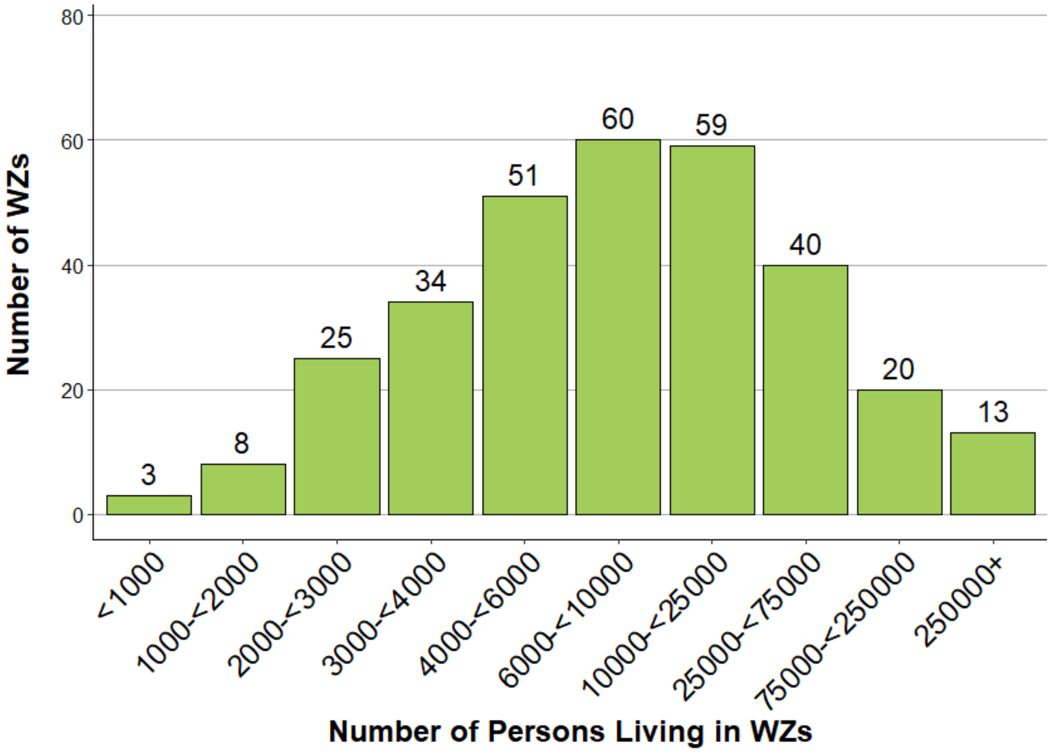


Source: BITRE analysis of ABS 2016a.

When attention is turned to the size of the population, workforce or numbers of persons working in them, again there is great variety but without correspondence to the physical size of the WZ. Figures 7, 8 and 9 provide an overview of the total population, number of resident workers and number of persons working in each WZ respectively. As Figure 7 indicates, most WZs have total populations smaller than 25 000 residents but larger than 2000 residents. Melbourne and Surrounds WZ has the largest population with over 4.5 million residents closely followed by Sydney and Surrounds, also with just over 4.5 million. Brisbane (2.3 million), Perth (1.9 million) and Adelaide (1.3 million) follow. At the other end of the scale, the smallest WZs in resident populations are Lord Howe Island with 381 residents, Cocos (Keeling) Islands with 541 and Flinders and Cape Barren Islands with 899 residents.

When we consider the size of the labour force and the number of persons working in each WZ, Sydney takes out top spot on both measures with more than 2 million residents being in the labour force and also more than 2 million persons working in the WZ. The Melbourne WZ also exceeds 2 million resident workers and persons working in it, but both figures are slightly lower than recorded for Sydney. As Figures 8 and 9 reveal, the labour force of most WZs is substantially smaller than the two major cities, with numbers of workers in the 1500 to 10 000 range much more common. This is also the case for the numbers of persons working in individual WZs with most having several thousand in them, with small numbers of very large and very small work centres. The WZ with the fewest persons working in it is Lord Howe Island with 211 followed closely by Cocos (Keeling) Islands with 228 and Aurukun with 252. The mean size of the WZs is 32 080 persons working but the median is just 3294, reflecting that the vast majority of WZs are quite small. This is not surprising given the geography of Australian settlement which for most of the land mass contains quite small towns separated by large distances. Due to the time-space geographies residents of such towns are subject to, it is not practical to travel anywhere else for employment.

Figure 7 **Total population of each WZ**



Source: BITRE analysis of ABS 2016a.

Figure 8 **Total employed persons resident in each WZ**

Source: BITRE analysis of ABS 2016a.

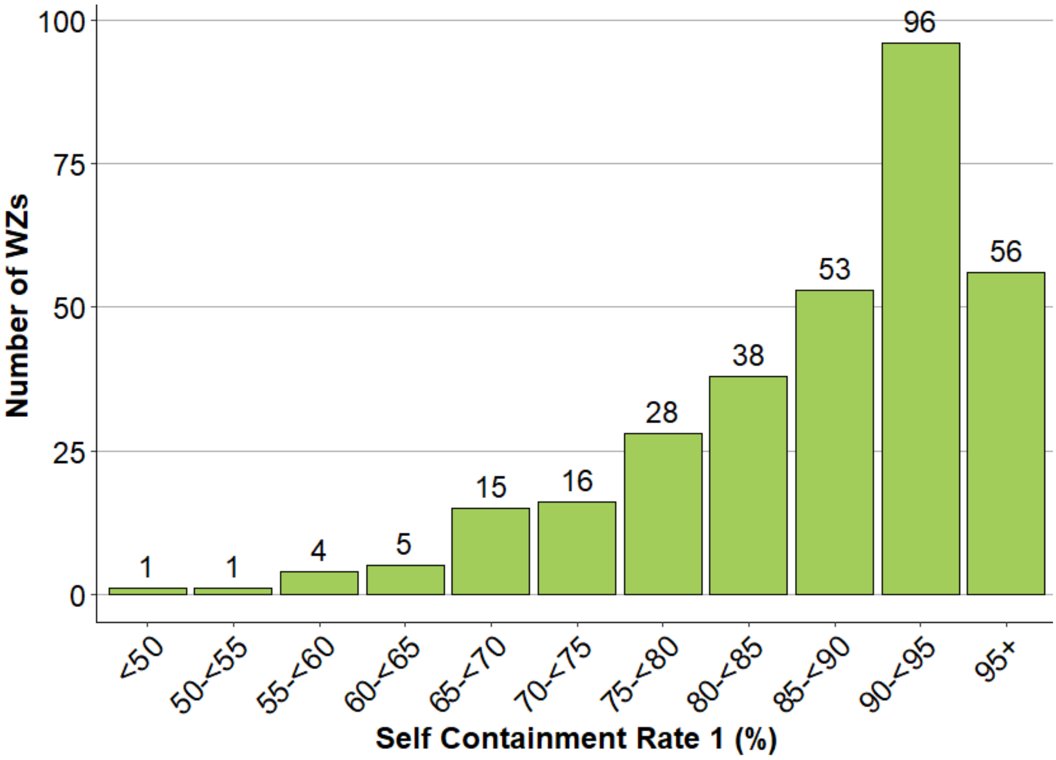
Figure 9 **Total employed persons who have a place of work in each WZ**

Source: BITRE analysis of ABS 2016a.

The overall containment rate of the BITRE WZs is 95.2 per cent. This means that of the 10 million employed persons used to develop these WZs, just 4.8 per cent live in a different WZ to which they work. As discussed earlier, this is an unavoidable outcome given the reality that labour markets are not mutually exclusive regions with clear boundaries but are complex interactions of overlapping groups of people and places of employment. Nevertheless, obtaining a rate of over 95 per cent provides confidence that the WZs are robust and can safely be used to understand patterns of industry and employment issues and how they affect different populations on the ground. The largest absolute outflow of residents occurs from the Gold Coast-Tweed Heads WZ with over 38 000 (14.6 per cent) persons leaving the WZ for work, mostly to Brisbane. A similar situation is evident for the Central Coast with 33 000 residents (25.8 per cent) working elsewhere, mostly Sydney and Newcastle. Perth and Brisbane also have outflows exceeding 30 000 persons but proportionally these outflows represent less than 4 per cent in each case.

Across the WZs there are also generally high rates of self-containment. As indicated in Figure 10 which shows the self-containment 1 (percentage of residents working locally) scores for all WZs, there are few WZs with rates below 65 per cent. Over 240 WZs (76 per cent) have self-containment 1 rates over 80 per cent and over 150 (nearly 50 per cent) have rates over 90 per cent. Two WZs (Anindilyakwa and Lord Howe Island) record 100 per cent on this measure meaning that all employed persons who live in those WZs also work there too. A further 8 WZS have scores of 99 per cent including Sydney, Melbourne, Canberra and Hobart as well some smaller island communities. At the other end of the spectrum, Weipa records a self-containment 1 rate of just over 47 per cent. This appears to be due to many Weipa residents travelling to work in nearby mining operations that are situated in the Cape York WZ. The two did not merge due to distance related issues with the major population centre of Cape York being several hundred kilometres away and therefore few persons travel from Cape York into Weipa. Bulahdelah-Stroud (54.9 per cent), Glenelg (Vic.) (56.1 per cent), Yeppoon and Surrounds (56.7 per cent), Mannum (59.1 per cent) and Yea (59.8 per cent) were the only other WZs to score below 60 per cent on this measure.

Figure 10 Self-containment 1 (percentage of residents working locally) of each WZ



Source: BITRE analysis of ABS 2016.

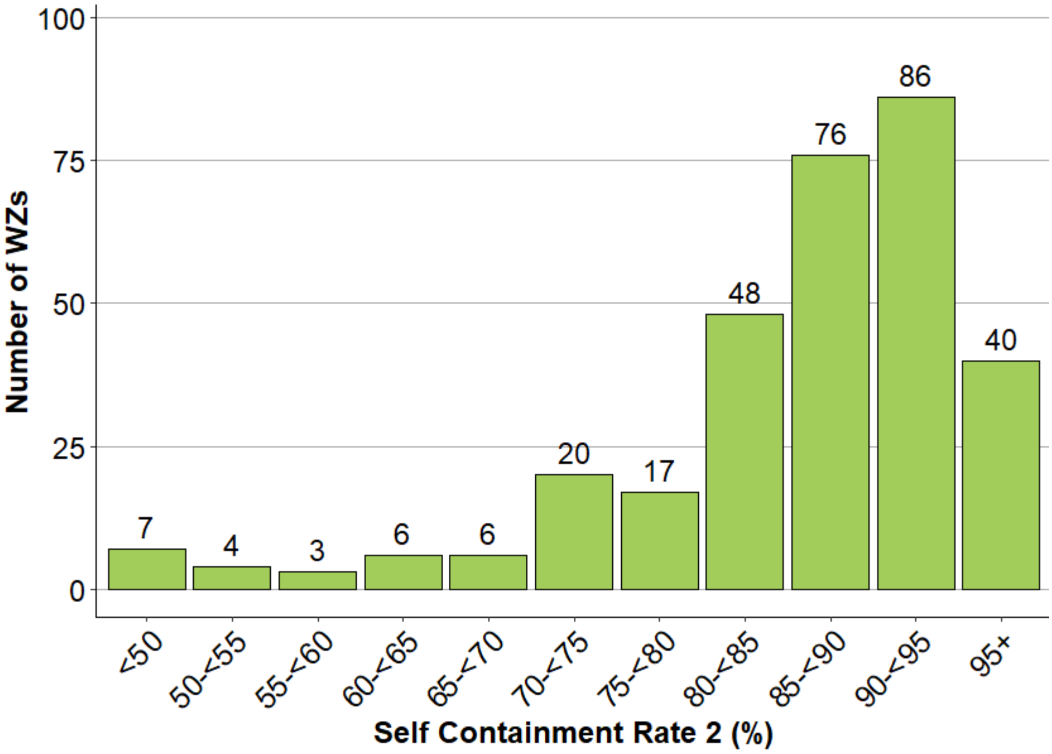
On the other measure of self-containment - self-containment 2 (percentage of workers residing locally) - there are no 100 per cent scores but both Perth and Hobart scored 99 per cent. A further six WZs recorded self-containment 2 rates in the 98 per cent range (Norfolk Island, Adelaide, Kangaroo Island, Maryborough, Hervey Bay and Surrounds, Melbourne and Canberra). At the other end of the scale, seven WZs have scores below 50 per cent, the lowest of which is East Pilbara at 21.9 per cent. All of these seven WZs are remote and have an industry profile dominated by mining operations and are therefore subject to high levels of fly-in and fly-out or drive-in and drive-out employees. Such workers do not typically reside within the WZ but travel in for periods of work before returning to their place of usual residence (see Box 4 for a case study of the East Pilbara workforce). Figure 11 highlights the distribution of self-containment 2 scores which is similar to that recorded for self-containment 1 (percentage of residents working locally). Over 40 per cent of WZs (126) scored at least 90 per cent on this measure and almost 80 per cent (250) scored over 80 per cent.

Box 4 East Pilbara SA2 Workforce – Place of Usual Residence

East Pilbara SA2 has a workforce of 11 900 persons but just 2500 of these persons identify East Pilbara as their place of usual residence. A further 500 report living in Newman SA2 which is completely surrounded by East Pilbara. The third, fourth and fifth most common SA2s of usual residence are all in the south west of Western Australia over 1000km away. Indeed over 50 per cent of persons working in East Pilbara SA2 report a place of usual residence in one of the Perth region SA4s (Perth-North West, Perth-South East, Perth-South West, Perth-North East and Mandurah).

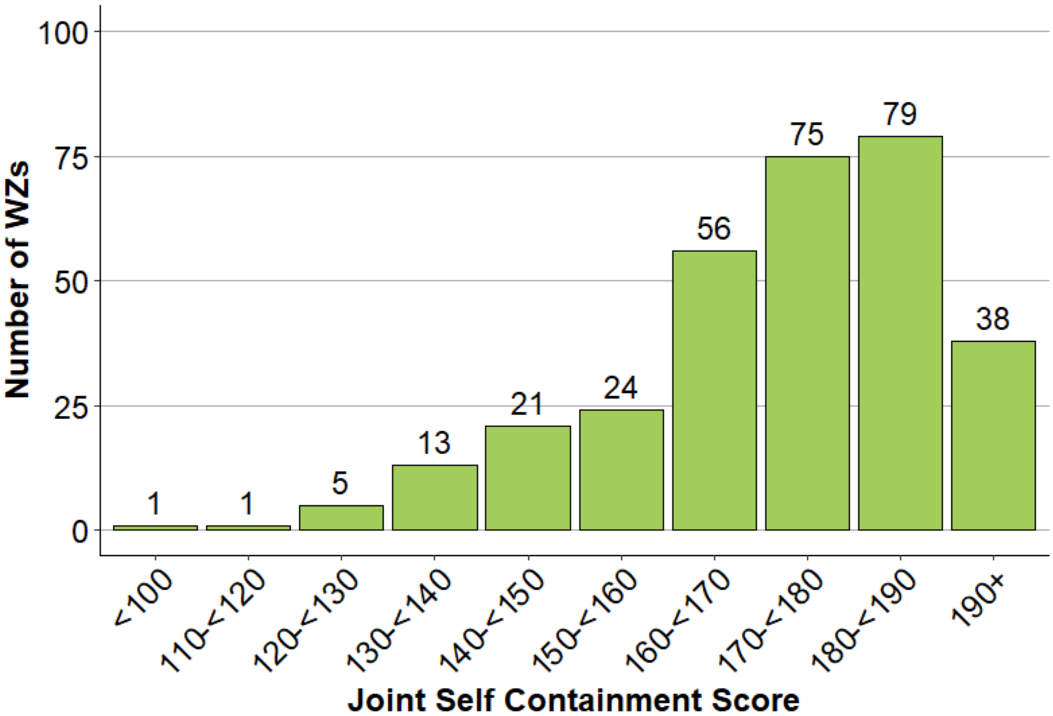
The final measure of self-containment examined here is the combined scores of both self-containment 1 (percentage of residents working locally) and self-containment 2 (percentage of workers residing locally) which provides an overall indication of the containment of individual WZs. Figure 12 reveals the distribution of results with only one WZ scoring below 100 (East Pilbara) and one other falling below 120 (Outback [SA]). Over 270 WZs (87 per cent) have a score of at least 150 on this measure and 158 WZs (just over 50 per cent) have a joint self-containment score exceeding 175. The highest scoring WZ on this measure is Hobart with over 198, followed by Canberra, King Island, Norfolk Island, Adelaide and Melbourne (all with 197).

Figure 11 Self-containment 2 (percentage of workers residing locally) of each WZ



Source: BITRE analysis of ABS 2016a

Figure 12 Joint self-containment score of each WZ



Source: BITRE analysis of ABS 2016a.

Box 5 Comparing BITRE WZs to other Australian zones

The two other relatively recent efforts to demarcate Australia into labour market areas have been undertaken by the Productivity Commission (see Productivity Commission, 2017) and researchers at the University of Newcastle's Centre of Full Employment and Equity (CofFEE) (see Stimson et. al. 2016). Both of these groups made use of 2011 Census data at the SA2 level, both utilised the Intramax algorithm for all or some of their work (detailed in Appendix B) and both groups called their zones Functional Economic Regions (FERs). Despite these similarities each had a different set of objectives, neither of which align with the objectives driving the development of the BITRE WZs.

The Productivity Commission was clear that their FERs were for illustrative purposes only to demonstrate a possible approach that could be built upon by others. Although they used commuting flows, they also took into account additional factors including access to services and governance issues. In contrast, the CofFEE FERs rely entirely on commuting flows data and the Intramax algorithm (the Productivity Commission only used Intramax for part of their process). The key objective for this and earlier versions of the CofFEE work was to derive new regions which reflect actual economic behaviour and that overcome issues associated with the 'modifiable areal unit problem' (mentioned briefly earlier in this paper). Despite the various differences between these two approaches and the BITRE approach, it is worth undertaking a brief comparison of the three sets of outputs.

The main difference in the output of the three approaches is in the number of zones created. Specifically, in contrast to the 313 WZs created by BITRE, the other approaches resulted in substantially fewer FERs – the Productivity Commission produced 89 and CofFEE finished with 159 (although as noted by Stimson et. al., [2016] 25 of the CofFEE regions have no commuting flows (e.g. National Parks and Wilderness areas) and should therefore not be analysed as FERs. In terms of their overall containment, the CofFEE FERs figure was 73 per cent which is somewhat lower than obtained for the BITRE WZs (95 per cent), while the Productivity Commission's rate was slightly higher at 97 per cent.

In terms of size, at a national level, the BITRE WZs tend to be smaller than the CofFEE FERs and considerably smaller than the Productivity Commission's FERs. One major difference between the Productivity Commission's FERs and the other two approaches is that theirs did not allow cross-border regions to emerge (except for NSW and the ACT) and nor did they allow 'greater' capital city regions (as defined by the ABS) to be demarcated or merged. In contrast, CofFEE and BITRE both have zones which cross state borders and capital city areas which do not adhere exactly to the ABS 'greater' city regions. Furthermore, in part due to their having extra objectives which resulted in additional merging steps, the Productivity Commission's regions are also generally larger than the other two sets of output with very few 'stand-alone' SA2s – something which is very common in the BITRE output and reasonably common in the CofFEE output. With respect to the city areas, while the Productivity Commission approach was to adhere precisely to ABS boundaries, the CofFEE approach has generally resulted in the major metropolitan areas being demarcated into smaller FERs. In contrast, the BITRE approach has generally produced larger capital city regions without demarcations within them, but which differ slightly around the edges to the ABS 'greater regions'. In regional areas the BITRE approach has clearly resulted in generally smaller areas than both the

Working Zones Examined

The final section of this report takes some time to examine specific WZs as well as some groups of interesting WZs. By far the largest WZs in terms of their number of persons working in them and resident working populations are Sydney, Melbourne, Brisbane, Perth and Adelaide. These are examined first and of interest is that the none of these five cities have WZ boundaries which align neatly with their respective ABS Greater Capital City Statistical Areas (GCCSAs).[11] The remaining capital cities, including Canberra, are then looked at, followed by two other interesting case study groups of WZs.

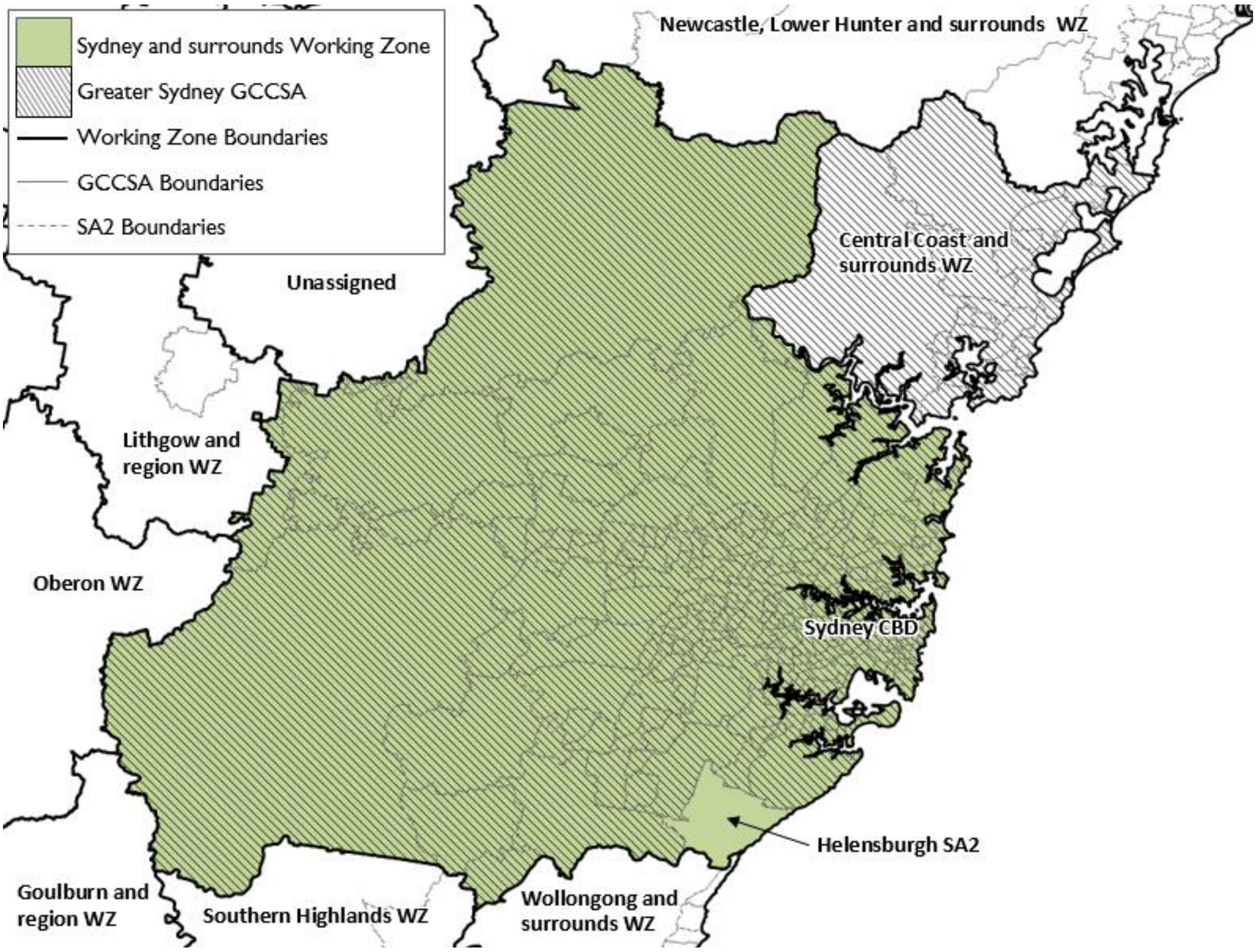
[11] Noting that GCCSAs are built from SA4s rather than SA2s and their development is subject to a number of criteria which limit the possibility of their boundaries exactly matching the respective WZ boundaries.

Sydney

The Sydney WZ is considerably smaller than its corresponding ABS GCCSA (Figure 13). The principal difference is that the Sydney WZ does not extend north of the Hawkesbury River except to include the thinly populated Bilpin-Colo-St Albans SA2 in the north west. In contrast, the Sydney GCCSA includes within its bounds the broad area north of the Hawkesbury encompassing the Central Coast. The northern boundary of the Sydney GCCSA corresponds exactly with the northern boundary of the Central Coast WZ where it meets the Newcastle WZ. Based on commuting data flows, this outcomes appears justifiable with more than 74 per cent of residents in the Central Coast WZ also working in the Central Coast WZ. Furthermore, more than 90 per cent of persons working in the Central Coast WZ are also residents of the Central Coast WZ.

In addition, Sydney also includes the coastal SA2 of Helensburgh in the south, which in the GCCSA classification falls outside of Sydney. Commuting data indicates that more than 60 per cent of employed Helensburgh residents travel to the Sydney CBD or suburbs for work.

Figure 13 Sydney and surrounds WZ compared to the Sydney GCCSA

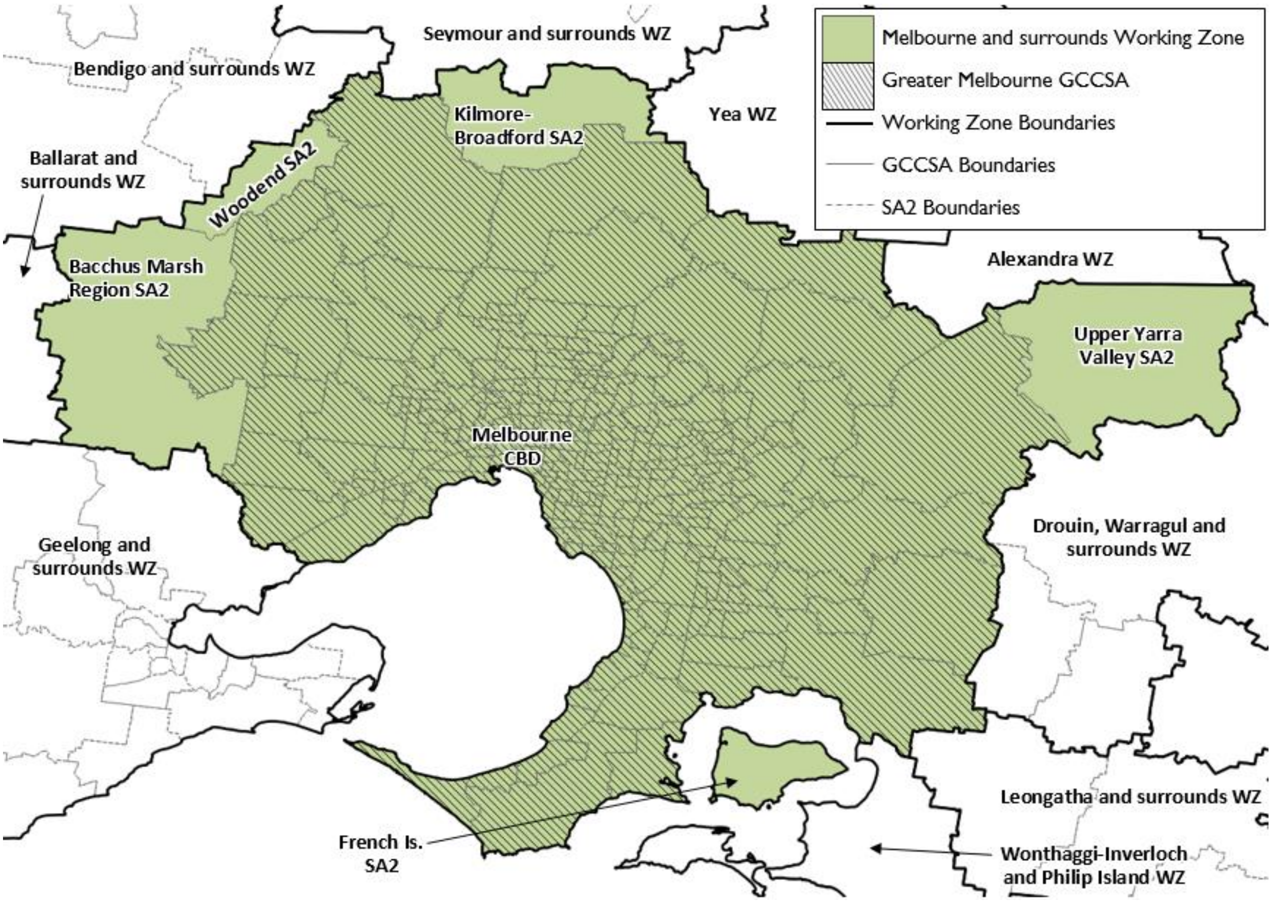


Source: BITRE analysis of ABS 2016a.

Melbourne

The Melbourne WZ closely matches the ABS Melbourne GCCSA but has five extra SA2s included within it – Bacchus Marsh region to the west, Woodend to the north west, Kilmore-Broadford to the north, Upper Yarra Valley to the east and French Island to the south east (Figure 14). With regard to the Bacchus Marsh Region SA2, travel data indicates that commuters head in two main directions – east towards Melbourne and west towards Ballarat - with a smaller number heading south to Geelong. Of the two major flows, it is evident that the eastbound traffic is largest with just over 50 per cent heading in that direction. Kilmore-Broadford is similar with a sizeable portion of its population of workers either working locally or travelling north for work, but with 46 per cent heading south to Melbourne for work is has attached to that WZ. Upper Yarra Valley has just 45 employed residents and attaches to Melbourne rather than elsewhere on the basis of workers travelling to the nearby Yarra Valley SA2 for work.

Figure 14 Melbourne and surrounds WZ compared to the Melbourne GCCSA



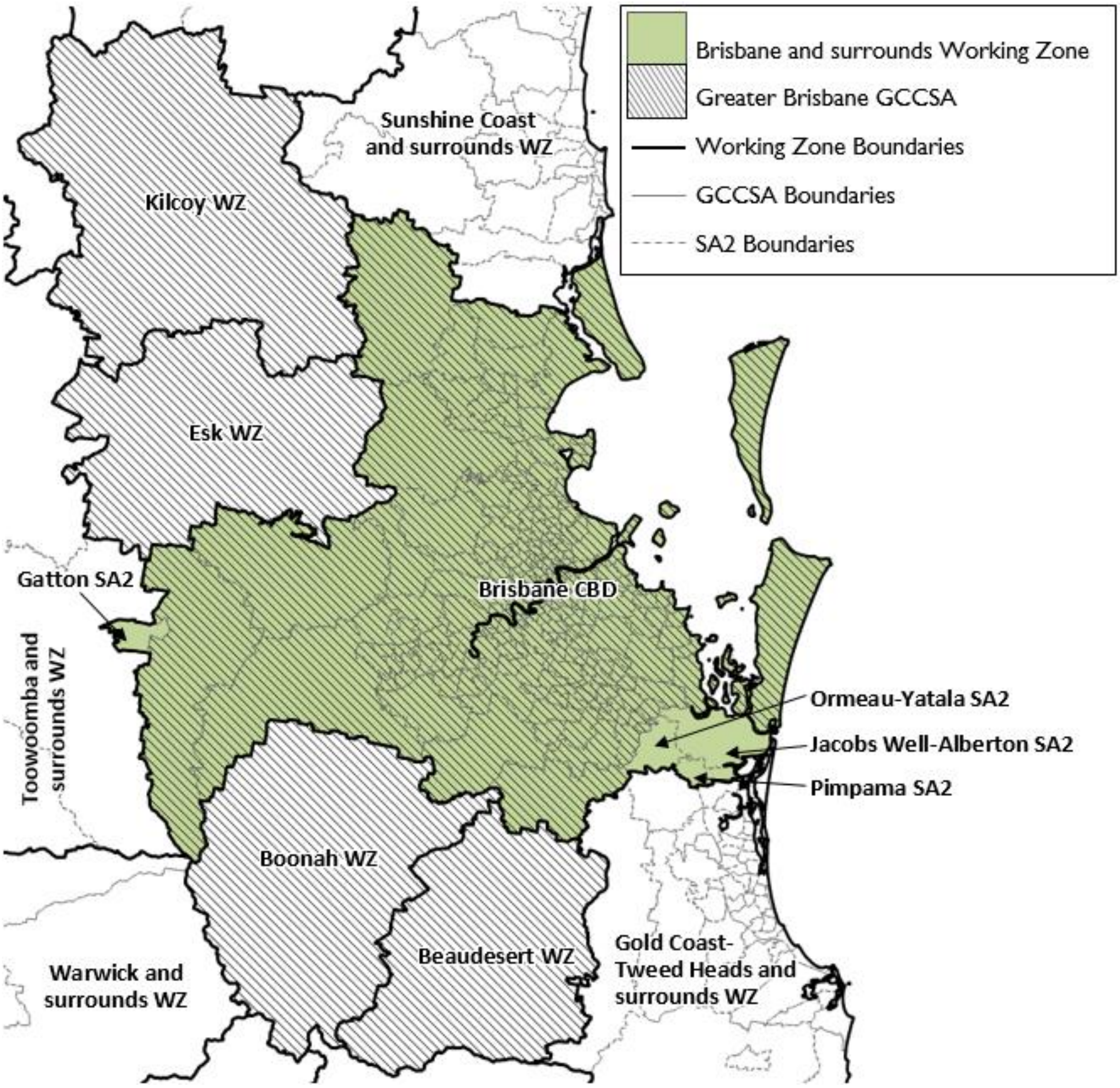
Source: BITRE analysis of ABS 2016a.

Brisbane

In contrast to Melbourne, for which the WZ is somewhat larger than its corresponding GCCSA, the Brisbane WZ is smaller than the Brisbane GCCSA (Figure 15). Of note are that the SA2s of Kilcoy and Esk to the north west, and Boonah and Beaudesert to the south west have not been assigned to the Brisbane WZ. In all four cases these SA2s stand alone as individual WZs. Given that all have significant flows of workers to Brisbane, they were all examined closely at the final manual assignment stage but it was decided not to merge any of them. All four have self-containment rates exceeding 60 per cent on both measures, and in the case of Boonah, over 84 per cent of persons working in the region live in the region. Another factor was that when the outflows were examined, although Brisbane was the main destination, there were significant flows in other directions too – particularly in the case of Beaudesert to the Gold Coast and Kilcoy to the Sunshine Coast. As such, rather than manually assign them to Brisbane where their flows were at best marginal, it was decided to retain them as stand-alone WZs.

The Brisbane WZ also picked up some areas which fall outside of the Brisbane GCCSA. These are Gatton SA2 to the west and Ormeau-Yatala, Jacobs Well-Alberton and Pimpama SA2s to the south.

Figure 15 Brisbane and surrounds WZ compared to the Brisbane GCCSA

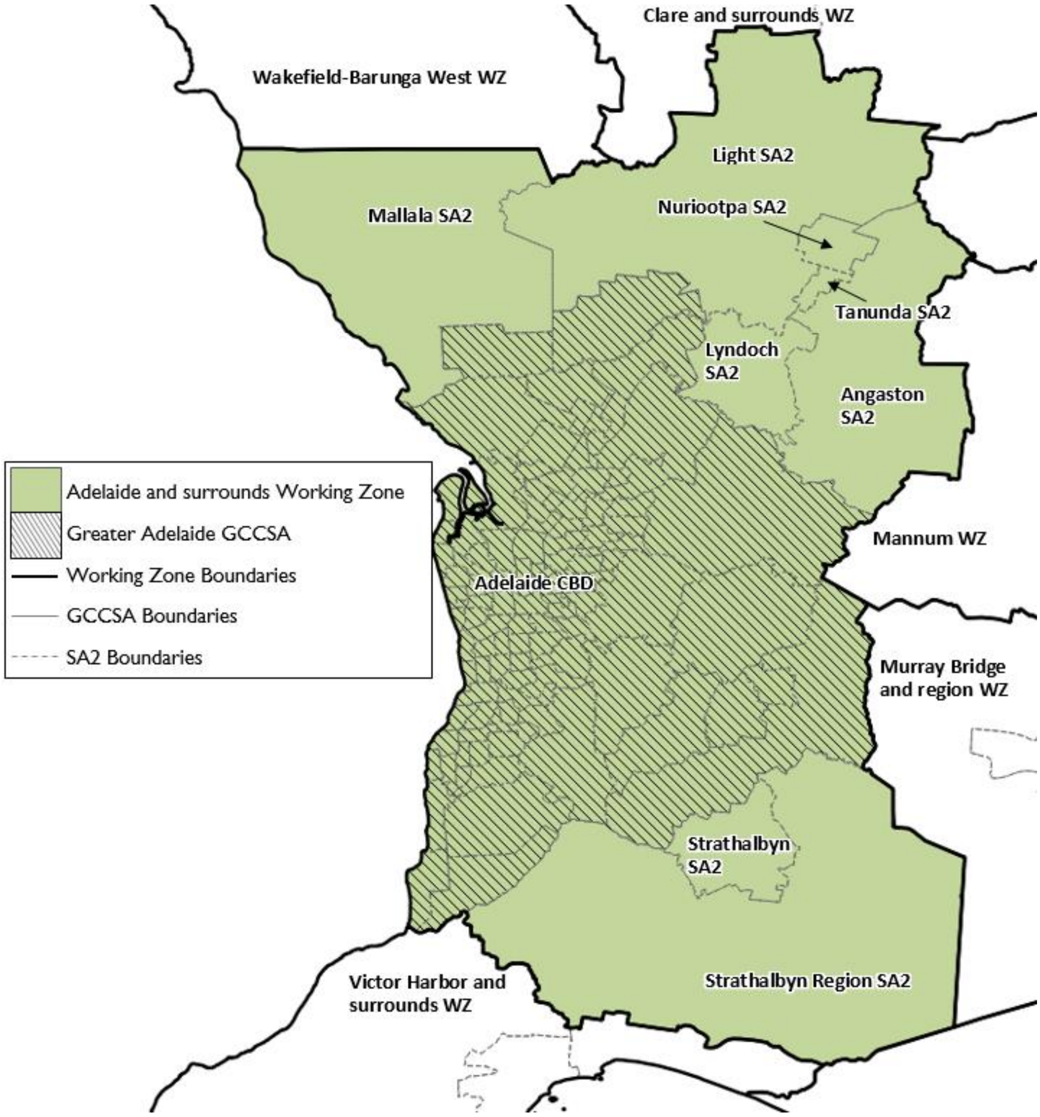


Source: BITRE analysis of ABS 2016a.

Adelaide

The Adelaide WZ is somewhat larger than the Adelaide GCCSA in two key areas – to the north where it captures a number of SA2s in the Barossa Valley and some adjoining coastal area and to the south in the area around Strathalbyn (see Figure 16). This WZ boundary remained solid throughout the sensitivity testing phase of the project and therefore was not considered for manual adjustment.

Figure 16 Adelaide and surrounds WZ compared to the Adelaide GCCSA

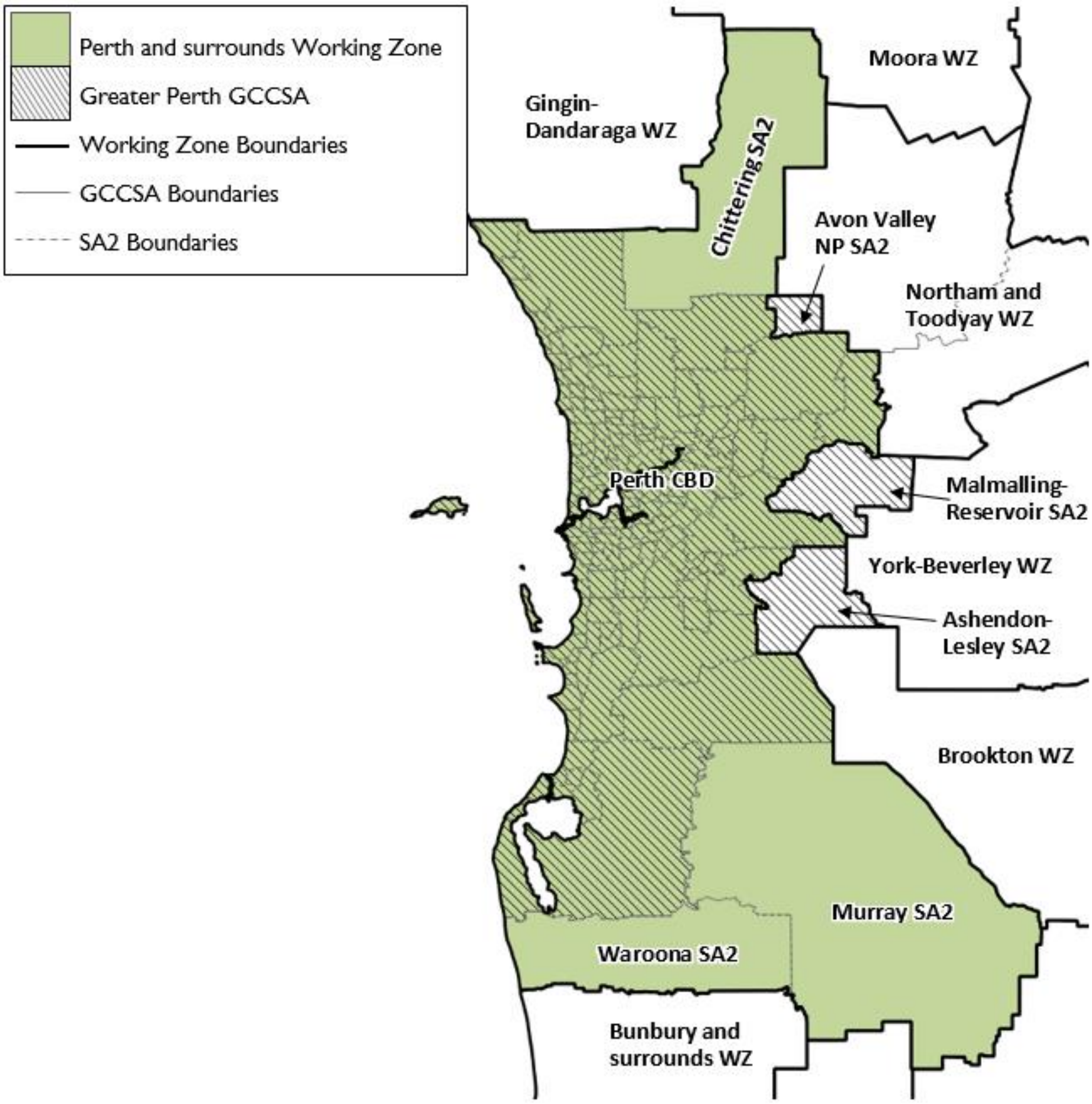


Source: BITRE analysis of ABS 2016a.

Perth

The Perth WZ includes extra SA2s, albeit fewer than Adelaide, on both the northern and southern outskirts of the city which are not part of the Perth GCCSA (Figure 17). The SA2s of Chittering to the north of Perth and Waroona and Murray to the south have been included in the Perth WZ despite not being part of the Perth GCCSA. Of these Murray is perhaps the most interesting and was considered as a possible stand-alone WZ on the basis that more than 76 per cent of its residents work in the SA2. In contrast, however, there is a sizeable inflow of workers to Murray with just 34 per cent of persons working in Murray also living in Murray. This is likely to be due to the large mining operations in the area which are drawing many workers from the Mandurah and Rockingham regions of Perth. As such Murray joins Perth and surrounds WZ on the basis of a strong inflow rather than strong outflow (which is usually the case).

Figure 17 Perth and surrounds WZ compared to the Perth GCCSA



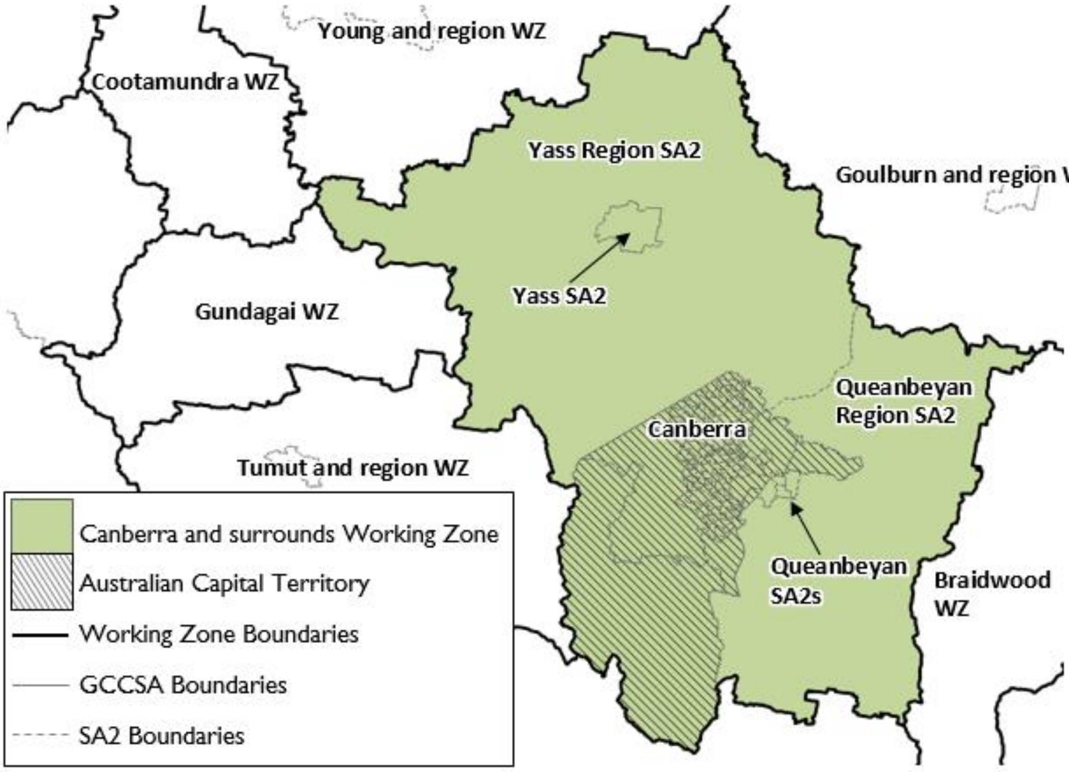
Note: Avon Valley NP SA2, Malmalling-Reservoir SA2 and Ashendon-Lesley SA2 are not part of any WZ.

Source: BITRE analysis of ABS 2016a.

Canberra

The Canberra GCCSA equates exactly to the boundaries of the Australian Capital Territory (ACT). This is despite commuting flows data revealing strong flows of nearby residents from NSW working in the ACT as well as smaller flows heading in the opposite direction. The Canberra and surrounds WZ recognises these flows and encompasses all of the ACT as well as a number of adjoining areas of NSW, notably the SA2s which include Queanbeyan and Yass and their surrounding regions (see Figure 18).

Figure 18 Canberra and surrounds WZ compared to the Canberra GCCSA



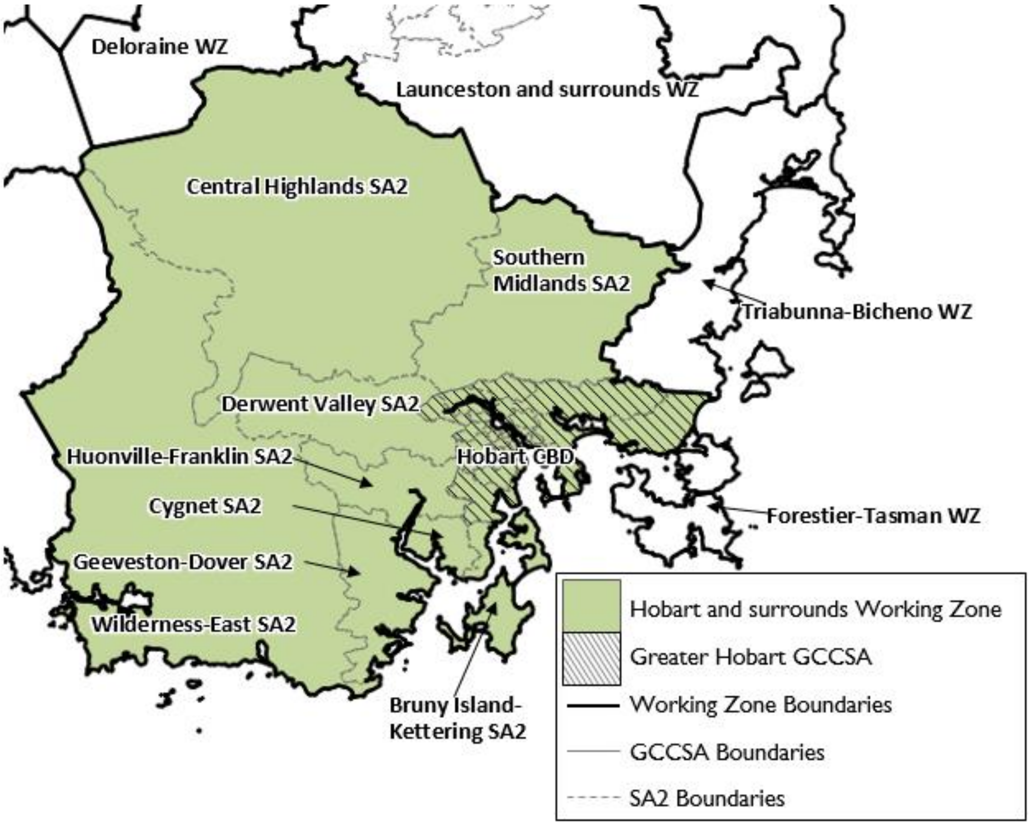
Note: Queanbeyan SA2s are Queanbeyan, Queanbeyan-East, Karabar and Queanbeyan West-Jerrabomberra

Source: BITRE analysis of ABS 2016a.

Hobart

Of all the capital city WZs, Hobart and surrounds is the largest in terms of area and is several times larger than the area of its corresponding GCCSA (see Figure19). Besides having within it the entire GCCSA, Hobart and surrounds WZ also contains eight extra SA2s, some of which are relatively large compared to the Hobart GCCSA. These SA2s however have relatively small populations and the data shows that the populations they do have largely work in the Hobart region. For example, over 75 per cent of employed residents of the Derwent Valley SA2 have a place of work in the Hobart GCCSA, as do 61 per cent of those in the Southern Midlands SA2, 55 per cent of Bruny Island-Kettering SA2 residents and 48 per cent of those living in Huonville-Franklin SA2. One of the reasons for the large area of Hobart and surrounds WZ is the presence of Wilderness-East SA2 which has only nine residents living in it, all of whom work there, but it also has a small number of people who work there but live in Hobart. Given it has too few persons working there to be a WZ in its own right and that it does have some inflow from Hobart, the algorithm merged it to the Hobart and surrounds WZ. The other very large SA2 contributing to the size of the WZ is Central Highlands. A major reason for this is that the vast majority of the population of this SA2 live in the south east corner of the SA2 less than 100km from the Hobart CBD. As such, over 30 per cent of the Central Highlands SA2 working population travel to the Hobart GCCSA for work and a further 7 per cent travel to either Derwent Valley or Southern Midlands SA2s, both of which joined the Hobart WZ at an earlier step. In the opposite direction, although 68 per cent of persons working in Central Highlands SA2 are local residents, the main source of inflow is from suburbs in the Hobart GCCSA as well as from the Southern Midlands and Derwent Valley SA2s.

Figure 19 Hobart and surrounds WZ compared to the Hobart GCCSA

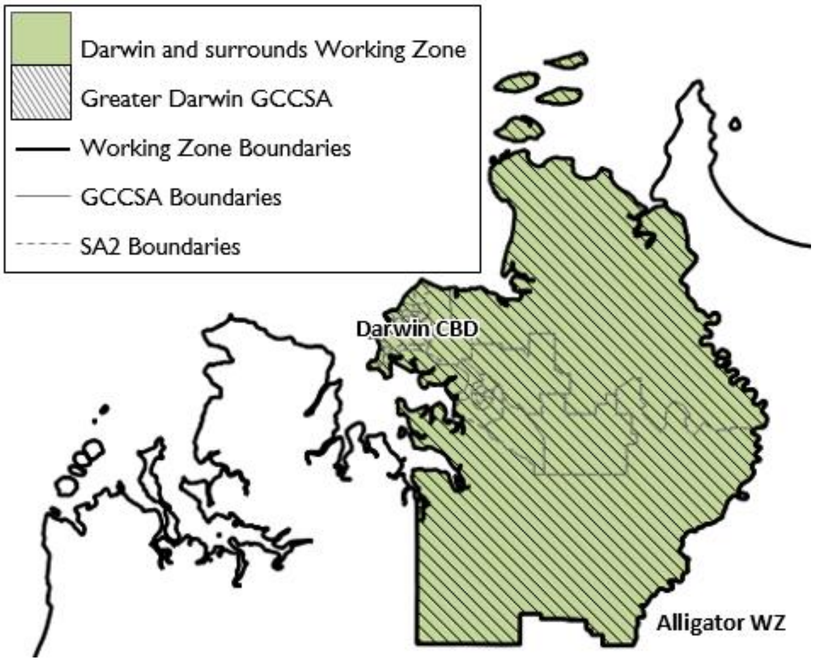


Source: BITRE analysis of ABS 2016a.

Darwin

Darwin is the only capital city which has a WZ that exactly adheres to its corresponding GCCSA boundary (see Figure 20). Almost all of the working population of the WZ lives in the urban SA2s close to the centre of Darwin or in the suburbs to the south around Palmerston. Besides Darwin and Palmerston, the other main work destination in this WZ is in the SA2 of Weddell which contains significant gas processing infrastructure employing more than 7,000 persons at the time of the Census. A large proportion of these workers reside in Darwin and its suburbs.

Figure 20 Darwin and surrounds WZ compared to the Darwin GCCSA



Source: BITRE analysis of ABS 2016a.

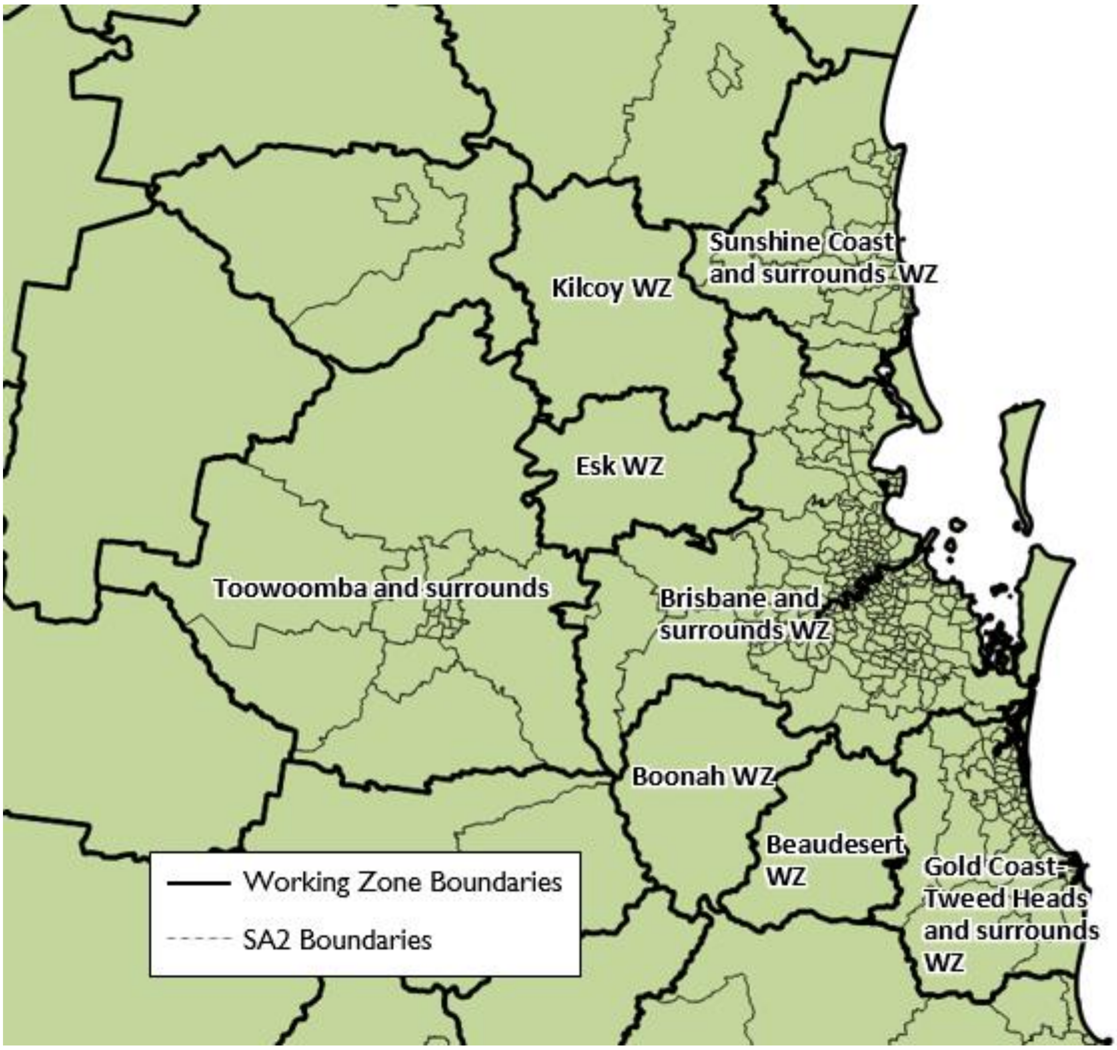
South East Queensland

The WZs of interest here are Brisbane and seven WZs which surround it – Gold Coast, Sunshine Coast, Toowoomba, Kilcoy, Esk, Boonah and Beaudesert (see Figure 21). During the development process, it was noted that the boundaries of these WZs were relatively fluid depending upon the specific parameters in use. In contrast WZ boundaries in the Adelaide region remained extremely stable during the sensitivity testing process.

In large part this instability can be attributed to the presence of a number of major job centres in the region which has resulted in very complex patterns of commuting between regions. Furthermore, the growth of these large job centres in recent years has resulted in urban boundaries extending outwards to a point that they now either merge into each other or are very close to doing so.

Table 2 presents the flows of commuters between these eight WZs. As indicated, for all eight WZs the self-containment rate is in excess of 60 per cent (shaded cells) and over 85 per cent for the four largest WZs (Brisbane, Gold Coast, Sunshine Coast and Toowoomba). Flows of commuters from those larger centres to smaller centres is extremely minimal. In contrast, the flows from the smaller WZs of Beaudesert, Boonah, Esk and Kilcoy to the larger centres is more noteworthy, particularly to Brisbane. Nearly 36 per cent of Boonah's resident workers work in the Brisbane WZ. As such it might appear appropriate to merge Boonah into the Brisbane WZ. However, Boonah's job market is relatively highly contained with a self-containment 2 (percentage of workers residing locally) rate of nearly 85 per cent. Furthermore, Boonah is more than 32km from its closest bigger SA2.

Figure 21 South East Queensland WZs



Source: BITRE analysis of ABS 2016a.

Table 2 Commuting matrix for South East Queensland WZs

Place of Usual Residence	Brisbane	Gold Coast	Sunshine Coast	Toowoomba	Beaudesert	Boonah	Esk	Kilcoy
Place of Work	*Percentage of persons*							
Brisbane	97.6	13.0	8.0	4.4	28.3	35.8	27.3	26.8
Gold Coast	1.5	86.7	0.2	0.2	5.8	0.7	0.5	0.2
Sunshine Coast	0.4	0.1	91.6	0.1	0.1	0.1	0.6	1.9
Toowoomba	0.3	0.1	0.2	95.2	0.1	0.4	3.9	0.9
Beaudesert	0.1	0.2	0.0	0.0	64.9	3.0	0.0	0.0
Boonah	0.0	0.0	0.0	0.0	0.9	60.1	0.0	0.0
Esk	0.0	0.0	0.0	0.0	0.0	0.0	63.2	3.6
Kilcoy	0.0	0.0	0.1	0.0	0.0	0.0	4.5	66.5

Source: BITRE analysis of ABS 2016a.

Weipa

Only one WZ has recorded a self-containment 1 (percentage of residents working locally) rate of lower than 50 per cent (47.4 per cent). This is the Weipa WZ in far north Queensland. The major factor underpinning this result is the presence of two major work destinations (the Rio Tinto bauxite mine and RAAF Base Scherger) immediately adjacent to the Weipa SA2 but over the border in the Cape York SA2. Weipa is also physically close to Aurukun WZ but there is a water barrier between the two and very few flows of employed persons between the two. The algorithm did not merge Weipa and Cape York SA2s due to the distance between the centroids being beyond the allowable limit. This is because the major population centre of the Cape York SA2 is Cooktown which is several hundred kilometres to the south east of Weipa (see Figure 22). While consideration was given to manually merging Weipa SA2 with Cape York SA2, this was rejected given that Weipa's self-containment 2 (percentage of workers residing locally) rate exceeded 90 per cent indicating a very small commuting flow into Weipa from Cape York.

Figure 22 Cape York Peninsula WZs

Source: BITRE analysis of ABS 2016a.

6. Summary and Conclusion

This information sheet provides an overview of newly developed Australian 'working zones' (WZ) which have been prepared by BITRE. WZs are mutually exclusive regions delineated from each other partly on the basis of the actual commuting behaviour of the employed persons living and working within them. The aim was to demarcate Australia into regions which have boundaries within which the vast majority of people both live and work, with few persons crossing a boundary to get to work. The outcome is 313 WZs covering almost all of Australia. The overall containment rate (percentage of all persons living and working within the same WZ) exceeds 95 per cent.

BITRE has previously conducted work similar to this using 2001 and 2006 Australian Census of Population and Housing data. For the first time, 2016 Census data was used in conjunction with 2016 ASGS SA2 level data. Following extensive testing of existing methodologies, a decision was taken to develop a new algorithm-based approach. The method used 'place of usual residence' and 'place of work' data collected in the Census – a dataset that contains more than 10 million commuting records of employed Australians. Such data enabled the calculation of the number of persons who commute for work between origin and destination locations. The algorithm was a stepped approach which identified 'seed' SA2s and then assigned other SA2s to the seeds over multiple steps to create the final WZs. The identification of seed SA2s and the assignment of other SA2s by the algorithm was based upon variations of the following three variables:

- the numbers of people working in individual SA2s
- the distance between SA2s
- the flows of commuters between SA2s.

As outlined in the earlier sections of this report, WZs are a useful tool with which to analyse spatial patterns related to labour markets because they reflect the actual geographical behaviour of individuals and have minimal work-based commuting flows to adjoining WZs. WZs can essentially be used for analysis in the same way as any other boundaries used for social and economic analysis. Specifically, because the BITRE WZs use SA2s as their basis, any data which is currently available at the SA2 level can easily be examined at the WZ level. One of the recognised benefits of WZs and other similarly derived regions (such as travel to work areas or functional economic regions) is that their boundaries have been influenced by the actual economic behaviour of their residents. An example of how administrative boundaries and WZ boundaries differ and produce different outcomes when answering labour market questions is provided in Box 6. As is evident in that case focused on Launceston, existing administrative boundaries do not fully capture the actual population flows for work purposes in the broader Launceston region.

As also detailed in this report, despite providing an improved means by which to understand labour market related research issues, BITRE WZs are still subject to a number of constraints that should be understood by users of the zones. In particular the existing statistical geography used to construct the WZs (ASGS SA2s), brings with it a number of problems which could not easily be resolved with the methods employed here. In particular the size and shape of some SA2 boundaries means that some WZs will be less useful for understanding labour market dynamics than with other WZs. These problematic WZs are however largely in very remote and sparsely populated parts of Australia, with the vast majority of Australia's working population being within a WZ that is logical and defensible based upon the available knowledge, and reflects the actual commuting patterns of the region.

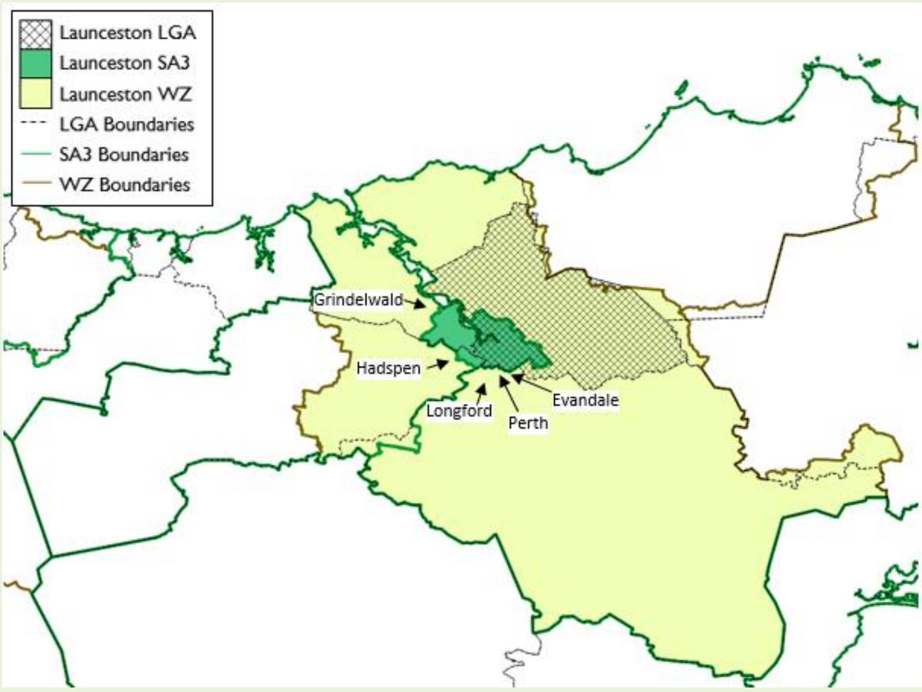
Further information related to the WZs and their development is available on the BITRE website. This includes:

- an excel spreadsheet containing all the information provided in the table in Appendix H as well as extra summary statistics
- an excel spreadsheet containing the SA2 to WZ concordance details
- a shape file of the WZs.

Box 6 Using WZs - defining the Launceston employed labour force

The Launceston region provides a useful case study for how WZs can be used to understand labour market issues. If for example we wanted to know the size of the currently employed Launceston labour force using 2016 Census data, there are a number of ways we could define Launceston (e.g. Launceston Local Government Area [LGA] or Launceston ASGS SA3, among others) and we could get different results depending on the specific data used. A quick examination of labour force numbers and commuting flows using these different boundaries reveals that there are some inconsistencies that would need resolving. For example, the Launceston LGA had a resident employed labour force of just over 30 000 persons but over 34 000 persons nominate their place of work as being in the Launceston LGA. Cross-tabulating the place of residence and place of work data reveals that only 21 600 persons both live and work in the Launceston LGA – which means over a quarter of the LGA's residents work elsewhere while over a third of persons working in the LGA live in other LGAs. As such, determining the 'size' of the Launceston employed labour force using this method does not produce a clear answer. When the data is examined at an SA3 level, a similar story is evident – about a quarter of Launceston SA3 employed residents leave the SA3 for work and about a quarter of those who work in the SA3 live elsewhere.

One of the reasons for these outcomes is that neither of the boundaries used above reflect the true nature of the local labour force. As the map below reveals, the Launceston SA3 is fairly tightly defined in comparison to Launceston LGA which partly overlaps with the SA3 but also includes a much larger area to the east and north east. A key issue in both cases is that within 20km of the Launceston CBD there are a number of relatively large communities which have strong links to Launceston, including: Evandale, Perth, Longford, Hadspen and Grindelwald. None of these towns are part of the Launceston SA3 or LGA.



To overcome this issue, and to gain a more accurate measure of the size of the Launceston labour force it is necessary to extend the boundaries of Launceston far enough to ensure that most of the 'inflow' and 'outflow' workers from these nearby areas are included, but not so far that areas without commuting links to Launceston are captured. This is not possible using LGAs or SA3s. In both cases appending adjoining regions to Launceston results in the capture of much larger areas for which commuting data suggests there are limited links to Launceston.

As such, to get a better picture of the size of the 'Launceston labour force' a WZ built up from smaller SA2s provides a solution. The Launceston WZ contains 26 individual SA2s including some in each of the adjoining SA3s and some of the adjoining LGAs, but without capturing all of those regions. The result is a WZ which has just over 120 000 residents of whom 48 000 are currently employed and which has about 48 000 persons working in it. The two self-containment measures are both close to 97 per cent meaning that few workers flow out of or in to the WZ. As such the clear answer to how large the Launceston labour force is that it would be about 48 000 persons.

Appendix A. Main identified approaches for developing working zones

While most modern approaches use some form of statistical algorithm to help identify and delineate WZs, they vary considerably in terms of their underlying assumptions and conceptual approach. Casado-Diaz et. al. (2017) provide a good overview of different algorithmic approaches and their various pros and cons. A key difference between many approaches is that some rely entirely on a single algorithm to demarcate the country/region of interest, while others will take a stepped approach.

Single step approaches

Single-step approaches construct WZs from smaller geographical units using an algorithm which identifies strong and weak commuting linkages between the spatial units being used. Such approaches could be based on merging smaller units which have strong commuting links and/or separating larger regions where weak commuting links are evident. Applications of such approaches include work by Mitchell and Stimson (2010) in Australia and by Farmer and Fotheringham (2011) in Ireland.

Multi-step approaches

In contrast, multi-step approaches usually start by identifying centres or hubs around which WZs will be based, before then moving on to allocate all or most of the surrounding hinterlands to one of the centres/hubs. Sometimes the identification of centres/hubs might also involve multiple steps, particularly if polycentric centres of economic activity are evident. Examples of multi-stepped approaches are outlined by the OECD (2013) and Roto (2012).

The merging and building approach

This approach appears to be the most common and could be used in both single and multi-step applications. It involves starting with the smallest geographical units available and merging them until further mergers do not markedly improve results, or when some pre-determined thresholds are reached (e.g. distance, or population size). This is the approach taken by the most active Australian WZ researchers – a team based at the University of Newcastle working in the Centre of Full Employment and Equity (CofFEE).[12] Their approach is based on a statistical algorithm which identifies neighbouring areal units which have strong commuting linkages and joins them first to create larger units. It then examines the commuting flows to/from neighbouring areal units and so on. Previous WZ development by BITRE adopted a similar approach, albeit manually rather than through an algorithm.

Splitting regions

Another approach which is less well known, but which has been tested in some contexts is a demarcation approach. While the method for identifying where demarcations can occur vary, the overall approach is to start with all baseline units merged into one and progressively dividing into two through steps. Most studies using this approach use theories and methods first proposed by Newman and Girvan (2004) for finding community structures in networks. It has been applied to WZ development by Farmer and Fotheringham (2011) in Ireland and by Rae and Nelson (2018) in the United States. In these studies the objective has been to continue splitting until the least random allocation of groups is found.

[12] See for example Mitchell and Stimson, 2010.

Appendix B. Key conceptual issues for developing working zones

Working zones are working zones

It needs to be clearly acknowledged that the WZs developed here are exactly that – working zones. They are not functional economic regions and they are not seeking to become some new generic set of regional boundaries. They are designed to reflect the travel patterns of commuters and therefore the boundaries may not necessarily correspond to the movements of individuals for other purposes, such as shopping, socialising or education.

Furthermore, WZ development such as this does not take into account the nuances of different types of labour markets which may exist for different groups, including different occupations, industry sectors and transport modes. The one size fits all approach for WZs does not acknowledge that for highly specialised occupations and industries, labour markets will function very differently to those at the other end of the spectrum in low skill and routine type roles. As such, the socio-spatial relationships within and between regions will vary accordingly. Nevertheless, WZs such as those defined here do have their place in researching and understanding regional socio-economic dynamics particularly if the limitations of the WZs are recognised and understood when interpreting the results.

Mutual exclusion versus complex realities

Although the need for WZs and related conceptual spatial products (e.g. Travel to Work Areas and Functional Economic Regions) are in part based upon the premise that the use of administrative regions for spatial analysis is flawed, it needs also to be recognised that WZs and other such boundaries are in themselves artificial and do not fully reflect the realities of local, regional and broader labour markets. A key issue is that WZs are defined to be mutually exclusive regions. While this is necessary for conducting most types of spatial analysis, such an approach does not accommodate the reality that most labour markets overlap with other labour markets regardless of the scale of analysis. For example, metropolitan areas are not neatly arranged clusters of discrete labour markets with residents of dormitory suburbs travelling to work in their nearest 'jobs hub'. Rather, they are more akin to a tangled web of inter-twined pathways of workers travelling within and across suburbs. Nevertheless, within major cities there are likely to be major flows of workers to and from certain areas and fewer flows between other areas. These are the patterns that analysis of commuting data can detect and which can then be used to inform the development of WZs. They therefore will provide an indication of where certain job centres draw most of their labour from and where the workers of residential neighbourhoods tend to travel for work. Although they will be designed as mutually exclusive regions, it needs to be acknowledged that they are overlooking the true overlapping complexity of the actual geography.

Working zone size

An objective of many European WZ models is to achieve WZs with similar population and area size. For example, Franconi et. al. (2017) highlight preventing WZs from being too large in terms of size or population as a principle. Similarly Casado-Diaz et. al. (2017) view homogeneity as a key goal, alongside self-containment and cohesion (see below), to enable statistical comparability and this can be achieved by establishing a minimum population or area size.

Whilst such an objective has merits, particularly for comparison purposes, it is an objective that was recognised early as being unlikely to be feasible in many contexts, including Australia. As recognised in work conducted in eastern Canada, and which has application in the Australian context, the settlement pattern is such that some small isolated communities are too far from any other community to allow for commuting and as such may need to be defined as functional labour markets themselves, despite having very small populations (Freshwater et. al. 2014). In Australia, which is a vast continental landmass but which contains a highly urbanised population concentrated largely in a handful of major cities in the south and east, it needed to be recognised at the outset that homogeneity is not an objective that should be deemed necessary. As such it was agreed that the final BITRE WZs would be bound to have very different population sizes and job numbers (subject to a minimum size threshold) and also different physical sizes. The main criteria was that they needed to be logical and defensible given other available information.

Contiguity

Many other approaches suggest a need for the final WZ regions to be contiguous. As Franconi et. al. (2017) argue, each WZ needs to be a single contiguous territory which may involve some checks, balances and adjustments to the results output from algorithms. Others, however, are not so rigid in their approach. The work of Papps and Newell (2002) provides a useful example in that they did not require their algorithm to retain only contiguous entities in their work in New Zealand. Their output resulted in 140 WZ areas of which 14 had non-contiguous components. Although they retained all of these as valid outputs, they recognised that examination of such results could be conducted to identify invalid outcomes which required reallocation (Papps and Newell, 2002). Examples of non-contiguous areas might include islands, satellite towns connected by a major transport link, or cases where large numbers of workers fly-in and fly-out. For this work it was agreed that non-contiguous areas would generally not be appropriate but may be considered in some circumstances. As such contiguity was not a criteria included in the algorithm.

Cohesiveness

As a number of authors have pointed out (e.g. Rowe, 2017; Casado-Diaz et. al., 2017; Franconi et. al., 2017) there are two key conflicting objectives when creating WZs – on one hand the goal is to identify self-contained regions which have little interaction with other WZs, whilst on the other hand identification of cohesive regions which have strong internal integration is important. The conflict arises because as WZs become larger in size they tend to become more self-contained but simultaneously become less cohesive (Casado-Diaz et. al., 2017). As such there is a need to identify a suitable balance between the two priorities. Casado-Diaz et. al. (2017) note that in many cases, although noted as an issue, cohesion is not actually measured and tested in the results. To address this, Casado-Diaz et. al. (2017) put forward an interaction index which measures the level of commuting interaction between individual base units and other units in the final WZs developed. For this work, cohesiveness was not deemed a high priority and was therefore not used as an input parameter or output measure.

Coverage

Many WZ approaches are designed on the premise that 100 per cent coverage of the country or region in question is necessary. That is, all parts of the country/region will be part of a WZ. One exception identified to date is work conducted in Nordic Europe and detailed by Roto (2012). Their approach recognised that some parts of Nordic Europe are so sparsely populated that labour markets do not exist in the standard economic sense. In their model such regions are identified and are not subsequently classified as being their own labour market or belonging to another labour market.

In contrast, similar work from Eastern Canada (Freshwater et. al. 2014) recognised that some small isolated communities are too far from any other community to allow for commuting. However, their approach was to have 100 per cent coverage of their study region and therefore identified such communities as being their own labour markets, despite having tiny populations potentially spread across vast areas.

Our approach was to keep the option of 100 per cent coverage open whilst acknowledging that there are likely to be a cases for which assignment of an SA2 to a WZ is not possible or not suitable.

Physical barriers

A functional WZ would ideally not have major physical barriers within it. For example, major rivers or mountain ranges with no easy crossing points. In such cases, some populations of the unit must head in one direction for social and economic functions whilst others in the region head a different direction due to logistical and time issues associated with the physical barrier. WZs based on commuting flows take into account natural barriers where they prevent people from commuting. Issues however arise where these barriers are within the underlying statistical geography from which WZs are created.

Cascading interactions

Care needs to be exercised with larger regions which may have very complicated flows of workers. In particular the potential for uni-directional cascading interactions to emerge between regions could heavily influence the output. In such scenarios regions may be linked with nearby regions on the basis of dominant one-way in-flows of workers (i.e. from inner suburban to CBD; from outer suburban to inner suburban and so on). The key is that all of these interactions are largely one-way with very few workers heading in the opposite direction. In some respects this is an undesirable outcome because it could result in WZs emerging which are extremely large and reflect a series of overlapping labour markets. In other respects this is a reflection of reality. The outer suburban dormitory suburb peri-urban fringe regions from which people travel to the city or suburban areas for work is a feature of Australian labour markets and should not be ignored because it results in unwieldy regions.

For example, as the largest work destination in the country, the CBD of Sydney attracts workers from a very large suburban metropolis surrounding it. Towards the edges of the metropolis there are satellite job hubs (e.g. Hornsby, Penrith, Campbelltown) which themselves attract workers from a broad surrounding region. In the case of Melbourne this might include Dandenong to the south east, Tullamarine and Campbellfield-Coolaroo to the north and Bacchus Marsh to the west. Such regions are themselves job destinations whilst simultaneously being contributors to the Melbourne workforce. Beyond each of those places are other job centres which attract workers from further away whilst simultaneously supplying workers to the more inner regions.

Whilst not ignoring their reality in the labour market, a potential difficulty is having a clear process to ensure that WZs were not derived which were so large that workers could not commute from one side of the region to the other due to these one-way cascading relationships. Careful checking of results from such areas during the early stages of testing and generating output can help to identify emerging issues and minimise any problems at later stages of the work. In addition, WZs in this project were constrained so no WZ exists where the distance between the population-weighted centroid and employment-weighted centroid of any underlying region is greater than 200km.

Appendix C. Key definitional issues

Commuting inflows and outflows

Inflow and outflow of commuting trips are major issues that are taken into account by most researchers developing WZs. Inflow refers to the proportion/numbers of workers coming into an area for work while outflow refers to the numbers/proportion of persons leaving the area in which they live for work purposes. Both inflows and outflows can be used to identify WZs and both will be important parameters for the purposes of this work. This is because:

- some regions will have large inflows relative to outflows (e.g. CBDs)
- others will have large outflows relative to inflows (e.g. outer suburban locations)
- some regions are likely to have high rates of both inflow and outflow while also having a high rate of within region commuting.

As such, the relative inflow, outflow and within-region commuting is the most important consideration. CBD areas, for example, have a high level of inflow from surrounding regions, but also a high proportion of residents who work locally. The important feature to measure is the inflow and outflow relative to the resident workers.

Self-containment and overall containment

Self-containment is the most widely accepted principle upon which WZs are defined and is the main basis for many approaches. Most of the approaches outlined in this paper take self-containment into account to some extent including Mitchell and Watts (2010), Franconi et al. (2017) and Papps and Newell (2002), among others. Although self-containment is a relatively straightforward concept which takes into account inflows, outflows and within-region commuting, in the literature it is evident that it can be measured in different ways. For example, some approaches rely more upon the level to which a region's jobs are filled by local workers, while others focus more on the levels of outflow relative to intra-regional commuting.

A fully self-contained WZ is one which sees no inflows of workers from another WZ or any outflows of residents to another WZ. In such a case all available jobs within a given WZ are filled by residents of that WZ and none of the residents of that WZ commute elsewhere for work. While such scenarios may be evident in very remote isolated communities such as islands, in reality most WZs will have some level of commuting to and from other WZs. The issue is then how to measure self-containment and where thresholds should be placed to deem a WZ self-contained or not. The three measures of self-containment being used in this work are:

- self-containment 1: Percentage of employed residents of the WZ who work in the same WZ as their residence
- self-containment 2: Percentage of persons employed in a WZ who are also residents of that same WZ

- joint self-containment: Both of the above measures to give a score out of 200.

It is quite possible for individual WZs to have self-containment 1 and self-containment 2 rates which are either very similar to each other or completely different. For example, some remote WZs which have little flows of workers either to or from them will have high self-containment rates on both measures. Alternatively, WZs which have more employed residents than available jobs will have higher self-containment 2 rates than self-containment 1 rates because many local residents commute to neighbouring WZs for employment. Similarly, other WZs may be home to some major employment opportunities which attract many employees from surrounding WZs meaning they may have higher self-containment 1 rates than self-containment 2 rates.

An extension of self-containment is 'overall containment' which is one way to test the robustness of the overall set of WZs developed. The overall containment of a set of WZs is the percentage of persons in the entire dataset who do not travel outside of their WZ of residence for work. A high overall containment figure reflects that the boundaries of the WZs are closely reflecting the overall commuting flows within the region of interest. If no person in the dataset works in a WZ in which they do not live, the overall containment is 100 per cent. Alternatively if no person lives in the WZ in which they work, the overall containment is 0 per cent. The overall containment tends to increase as the number of working zones falls, and will always have a perfect score where there is only one WZ for the entire population in question (i.e. the whole of Australia).

Overall containment can also be used as a target parameter when developing the boundaries. One model utilised in much European WZ development (the Eurostat model discussed further below) uses overall containment as one of the parameters feeding into their algorithm.

One issue that is of interest in Australia, which has a large proportion of the population concentrated in a handful of major cities, is that it is relatively easy to increase the overall containment rate by expanding the physical area covered by the major cities of Sydney, Melbourne, Brisbane, Adelaide and Perth WZs. Depending upon the purposes of the work this may be a positive or negative outcome.

Containment issues therefore have the potential to be used as input parameters (e.g. to establish a target containment rate or set a minimum containment rate) but also to test the robustness of individual models. This can be done by using the overall containment rate detailed above as a useful single figure of how different models compare against each other. Overall containment however should not be used in isolation to assess the value of the WZs. In part this is because it can be influenced by high rates of self-containment in the major cities where the majority of the population is concentrated. That is, if a given model allows cascading effects to occur around major cities and they grow to such an extent that they capture other large centres within their WZ boundaries, the overall containment rate will increase. As such, it is always important to consider self-containment rates simultaneously when assessing model performance. The minimum self-containment rate across all individual WZs for example gives one aspect to a model's performance while the average self-containment rate for all the WZs can also be useful.

Number of working zones

In conjunction with containment rates, the number of WZs also needs to be considered when assessing the performance of a WZ model. There is no specific number of working zones that should or could exist within any given country, state or region. Nevertheless, because the WZs being developed are based upon the notion of regular commuting behaviour, there must be time and space constraints upon what is possible. That is, because individuals have limited time within their day which can possibly be devoted to commuting, there will be barriers to how large individual WZs can be. As such, the number of WZs likely to emerge in any given context will in part be driven by the size of the entire region in question. A physically large country like Australia will likely have hundreds of WZs while smaller countries will have fewer.

Distance

Distance is also an important factor. Relevant here is time-geography which is a geo-economic concept recognising that on any given day individuals have limited time available in which to undertake the activities they need and choose to do. As such the decisions they make in terms of where they work, where they live, where they socialise and so on, is inescapably influenced by their time and space constraints.

In some approaches to defining WZs distance is used as an early parameter to ensure that regions which are too far apart to enable logical regular commuting cannot be merged into a single WZ. BITRE (2015) for example used a threshold of 250km road distance travelled to exclude flows between origin and destination pairs.

Anything over this distance was not considered reasonable to commute on a daily basis. Allowing long-distance commutes to remain in the data can impact upon averages to an extent that they can be distorted in some regions – particularly those with smaller populations.

In Australia, very long-distance commutes are often associated with mining industry employment – particularly fly-in-fly-out operations. As such, distance was always going to be a key parameter in this work to prevent the results being influenced too greatly by such circumstances. For example, Groote Eylandt is an island in the Northern Territory which has a large inflow of workers from Cairns in Queensland – several hundred kilometres away over mountains, jungles and water. This is due to fly-in-fly-out workers to mining operations on the island.

As a consequence it is clear that if WZs are to reflect underlying worker movements, they cannot be too large, and that some distance threshold is appropriate.

Appendix D. SA2s as building blocks

Physical size, numbers of residents and numbers of employed persons

According to the ABS (2016b), SA2s are designed to reflect functional areas that represent a community that interacts together socially and economically. Despite this claim, SA2s come in an enormous range of 'shapes and sizes'. They range in population from zero to 37 000 persons (most are somewhere between 3000 and 25 000 persons) and have physical areas from less than 0.5km^2 to more than 500 000km^2. In the context of this work, the number of employed persons in SA2s is extremely important and that varies even more than the number of residents - from zero in some SA2s to more than 320 000 in a single SA2 encompassing the Sydney CBD. Furthermore, the numbers of employed persons and the numbers of residents in individual SA2s do not always correspond to each other. Some SA2s have boundaries capturing only industrial suburbs with many thousands of employed persons but zero or few residents (e.g. Port Melbourne Industrial SA2 has 22 000 employed persons and 15 residents) while others have thousands of residents but few employed persons (e.g. Dunlop SA2 in Canberra has more than 7000 residents but fewer than 200 employed persons). There are numerous SA2s with zero employed persons and zero residents and others with less than 200 of each.

In terms of being problematic, it is the SA2s with very small numbers of residents or employed persons that can introduce difficulties when defining WZs. In particular when identifying SA2s which have strong commuting flows between each other it is usual to look at the rate of flow rather than the actual numbers flowing. As such, for SA2s which have very small populations or very few employed persons – possibly very specialised – the rates of flows to or from other SA2s are subject to considerable influence from just a few persons. Furthermore, confidentialisation protocols[13] adopted by the ABS means that data from SA2s with small absolute numbers of residents or employed persons can only be treated as a guide.

The physical size of SA2s is also a problem when they are larger than what would usually be considered suitable for a final WZ. In particular there are some remote area SA2s exceeding 100 000km^2 in size, with some in excess of 400 000km^2. Large SA2s such as these are likely to contain within them multiple discrete townships which have minimal or no commuting flows between each other due to the long distances involved. Using SA2 data it is not possible to identify residents of one town as distinct from residents of other towns because they are all contained within the same SA2.[14] An example of this situation is the SA2 of 'Outback' which covers over 500 000km^2 in the north of South Australia. Outback had 2600 residents recorded in the 2016 Census but these residents are scattered across multiple small towns and farms including Leigh Creek, Andamooka, Woomera, Yunta, Oodnadatta, Maree and Marla. Distances between communities are in the hundreds of kilometres extending to more than 1000km by road between those towns at the extremities of the SA2.

SA2 shapes and placement of boundaries

SA2s come in all shapes and sizes due to the diversity of ways in which their boundaries are defined. They are constructed from the smaller SA1s and take into account existing socio-political boundaries, physical features

[13] For further information about these protocols see ABS 2016d.
[14] A work-around is technically possible using place of residence data at the smaller ASGS SA1 scale in conjunction with place of work data at the ABS Destination Zones (DZN) scale. Such an approach would however be complicated and the results obtained would not have direct utility for Departmental analysis to be undertaken using the final WZs developed due to the limited data available at this scale.

of the environment and population size among other thing. There are a number of circumstances which can pose problems when seeking to amalgamate SA2s into WZs.

One particular shape of SA2 which is relatively common in regional Australia and causes difficulties when defining WZs can best be described as a 'donut' type SA2. 'Donut' SA2s usually encompass a large sparsely populated region surrounding a more densely populated town (see Figure D.1). Sometimes these towns contain just a single SA2 (as is the case in Figure 3 while in other cases the town contains multiple SA2s (e.g. the Wagga Wagga township contains four adjoining SA2s which are all surrounded by a single 'Wagga Wagga Region' SA2).

Figure D.1 Example of a 'donut' SA2, Yass Region SA2 which surrounds Yass SA2

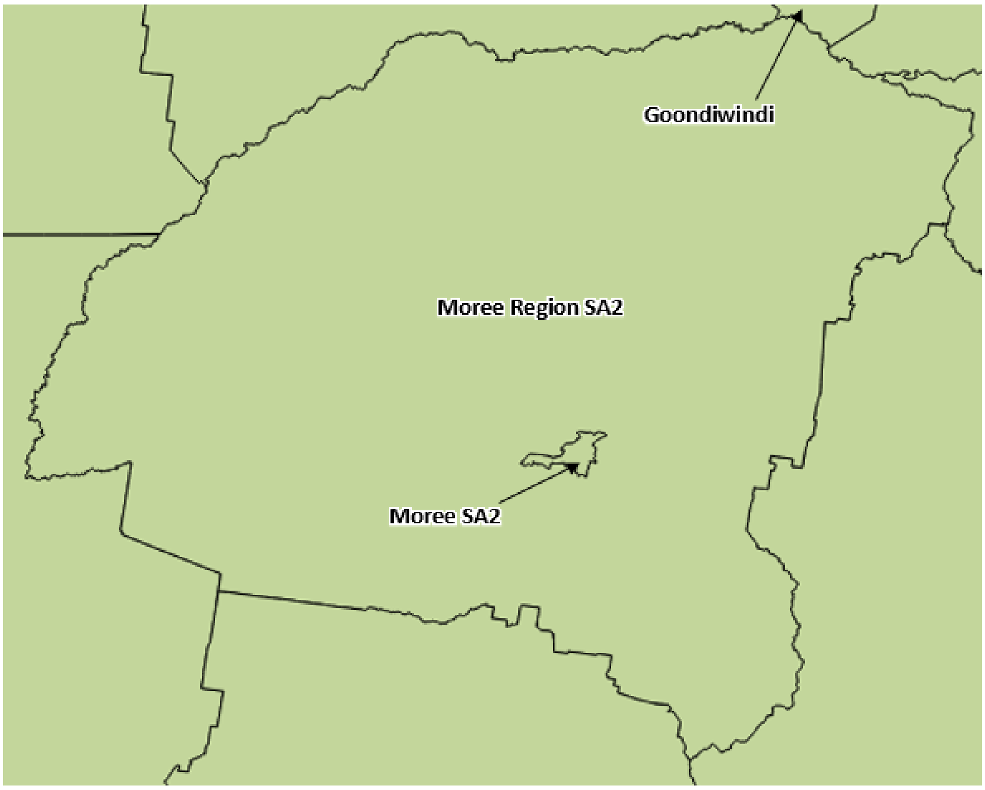
Source: BITRE analysis of ABS 2016a.

The key problem with these 'donut' SA2s is that they sometimes have more than one population centre within them. As such, there may be considerable numbers of residents living close to the township which they surround but there can also be other residential centres considerable distances from that town. Sometimes these more distant towns may be located close to the outer edge of the 'donut' and indeed in closer proximity to other centres than the one around which the 'donut' is placed.

A good example of this is Moree Region SA2 which surrounds Moree SA2 (see Figure D.2). Examination of commuting data at the ABS Destination Zone (DZN) and SA1 level for 'Moree Region' SA2 reveals that workers in the north of the SA2 are more likely to cross the border to Queensland for work than they are to head south towards Moree. There are four DZNs in the combined Moree and Moree Region SA2s, the northern most of which has within it five SA1s and a combined working population exceeding 450 persons. For all five SA1s the most common destination DZN is the one in which they live. The next most common (for the DZN and each of the five SA1s in it) is across the border to the DZN capturing Goondiwindi. More than 90 persons travel there for work compared to less than half this number travelling south to the other three 'Moree' and 'Moree Region' DZNs combined. Highlighted by this simple example is that this part of the Moree Region SA2 has few commuting flows to other parts of Moree Region or to Moree itself.

The key problem with SA2s such as this is that they frequently do not have self-containment rates to warrant standing alone as a single SA2 WZ (because there are residents commuting to the town around which the donut sits as well as commuting out of the donut into other SA2s) but they do not have commuting flows to another single SA2 which are strong enough to warrant joining. In the case of Moree Region SA2, there are many residents who live and work within the SA2, many others who travel into the Moree township for work, as well as many more who travel into other SA2s for work – in this case likely to be over the border into Queensland.

Figure D.2 Moree Region SA2 and Moree SA2, and key population centres



Source: BITRE analysis of ABS 2016a.

Situations like this are however not confined to 'donut' SA2s. There are other examples of SA2s which capture within their boundaries what appear likely to be discrete communities with little evidence of commuting flows between them. The SA2 of 'Outback' described above provides one example which through its sheer size includes within its boundaries numerous small towns that are each separated by many hundreds of kilometres. Another example is the Mildura Region SA2 which covers a large region of north western Victoria extending to the South Australian and NSW borders, but not including Mildura itself. Examination of commuting flows data at the smaller DZN and SA1 levels reveals that the SA2 has two distinct parts which have few commuting flows between them - a northern region which captures small communities near to Mildura and the Murray River fruit growing areas and a southern region which includes the small grain growing communities of Ouyen, Murrayville and Underbool among others. The outcome is that the Mildura SA2 captures two spatially distinct populations of similar sizes which have few commuting flows between them, but for the purposes of this work must be treated as a single unit.

Appendix E. Existing algorithm-based approaches

Intramax

Intramax is a hierarchical clustering algorithm developed by Masser and Brown (1975). It has been widely used in this sort of work, including in Australia by Mitchell and Stimson (2010), Stimson et. al. (2016) and the Productivity Commission (2017). The Intramax approach creates WZs from smaller geographical units using a stepped procedure which merges the two areas with the strongest links at each step of the process (Productivity Commission, 2017). The function for determining links between units is a measure of where journey to work flows exceed what would have been expected if there was no systematic relationship between the two areas (Productivity Commission, 2017).

Although this was the first model seriously examined for use in this work, it did not ultimately proceed to testing stage. The decision to exclude it from consideration was based upon examination of previous results of the model using Australian data – notably work undertaken in the Centre of Full Employment and Equity (CofFEE) at the University of Newcastle using 2006 and 2011 Census data (Mitchell et. al., 2007; Mitchell and Stimson, 2010; Mitchell and Watts, 2010; Stimson et. al., 2016). Of concern was that the algorithm appeared to be producing output which resulted in Functional Economic Regions (FERs) in regional areas which were relatively large and in metropolitan areas relatively small. Examples of this occurring in CofFEE output using 2011 data include:

- In Victoria, the Melbourne FER is very small relative to its neighbouring FERs and extends only into the very inner northern and eastern suburbs. This is despite the relevant Census data revealing that the vast majority of persons working in the Melbourne FER come from outside of the FER. The region which encompasses the inner western suburbs of Melbourne (immediately adjacent to the CBD) extends west to include the eastern suburbs of Ballarat. Census data reveals very few flows of persons to Melbourne and its suburbs from eastern Ballarat and even fewer persons heading to eastern Ballarat from suburban Melbourne.
- Darwin and its surrounding area has been demarcated into three FERs – inner Darwin; northern suburbs; and a broader region encompassing areas south of Darwin including the major centre of Palmerston. An examination of Census data indicates a high degree of commuting between the three regions suggesting that they could be merged into a single FER – for example, about 30 per cent of Palmerston workers travel to inner Darwin for work and a further 20 per cent work in Darwin's suburbs. About 80 per cent of workers from Darwin's suburbs work either in Darwin suburbs or city.

Given the above results, it was decided not to follow through with testing of this model as the output did not appear to be compatible with the range of objectives outlined for this project.

Nordregio

The Nordregio approach was designed to enable a single methodology of local labour market (LLM) development to be applied across the four continental Europe Nordic countries of Denmark, Finland, Norway and Sweden. It is outlined in more detail in Roto (2012) and involves a stepped process based on identifying LLM centres at the municipality level, and then allocating other municipalities to those centres according to the flows of commuters. The steps and thresholds being used are outlined in Box E.1.

The Nordregio approach underwent considerable testing, first with 2011 commuting data for Tasmania before extending to 2011 national level data and then 2016 data when it became available. Results at the Tasmanian level proved promising, with output having high levels of overall containment and WZs which were in accordance with expectations given the settlement geography of Tasmania. Initial testing adopted the percentage parameters used by Nordregio but adjustments were made during later phases to ascertain whether results could be improved.

When the approach was extended to the national level the output was not as encouraging. The model was having difficulty assigning many of the SA2s, particularly those in fringe locations with multi-directional commuting flows or SA2s which had very small population or job numbers. The result was that although the major cities appeared to have been identified reasonably well, on their outskirts and in some industrial areas, allocations had not occurred well, resulting in many small WZs emerging. In some cases the visual representation was akin to a patchwork quilt.

While some of these sorts of outcomes were expected, and it was assumed that manual adjustments may be necessary, in this case the outputs in early testing did not lend enough confidence to push forward with the approach. It was thought that the manual adjustment process would be extensive and alternative approaches could perform better.

Box E.1 The Nordregio Allocation Process

A. Defining the LLM Centres

In order to be classified as a centre:

1. The municipality's share of out-commuters shall not be over 20% of its employed population, OR
2. there should be more places of employment than employed residents AND the highest single out-commuting flow to another municipality shall not be over 10% of the sending municipality's employed population

B. Municipalities are defined as belonging to a LLM when

3. They have a single out-commuting flow to another municipality that is over 7.5% of the sending municipality's employed population.

C. Defining secondary LLM centres

4. A municipality can also be defined as a LLM centre if the share of out-commuters is max 25% of the municipality's employed population AND the highest single out-commuting flow to another municipality is below 7.5% of sending municipality's employed population AND the municipality has its own LLM, meaning municipalities fulfilling rule 3.

Source: Roto, 2012.

Eurostat

The Eurostat approach is an algorithm-based process designed to delineate labour market areas (LMAs) from commuting matrix data sets at the national level. It emerged from work conducted in the European Commission which sought to harmonise the definition of LMAs across member nations.[15] The Eurostat approach was initially appealing due to the code for implementation of the algorithm using R statistical software being available online. See Box E.2 for more information about the algorithm.

As occurred for the Nordregio approach, testing of the Eurostat algorithm was first undertaken with 2011 Census data for selected states (Tasmania and Western Australia), before progressing to national data and then 2016 data. Sensitivity testing was undertaken throughout to understand the impact of adjustments to the four Eurostat parameters detailed in Box 1. Early results were promising, particularly in Tasmania but less so for Western Australia. For example, using 2011 data, some sets of parameters resulted in the algorithm clustering Tasmania's 95 SA2s into 15 WZs with an overall containment of over 94 per cent. Slight adjustments to the model could increase the overall containment to nearly 97 per cent but this reduced the number of WZs. When the same sets of parameters were applied to Western Australian data, overall containment rates was substantially lower.

Having observed that the Eurostat model was sometimes merging SA2s which were hundreds of kilometres apart, a distance limiting parameter was implemented for some testing so that the algorithm only used commuting flows which were below a specific threshold distance (100km, 150km and 200km were all tested).

Regression analysis of the output was also undertaken at this stage as well as simulations to better understand the relative influence of the individual parameters. Regression results indicated that the minimum self-containment parameter was the critical variable influencing the overall containment measure while the number of WZs is influenced by target size and to a lesser extent minimum self-containment. Further testing was then undertaken focusing more upon these two parameters. The aim being to improve the overall WZ numbers and overall containment through making minor adjustments to the parameters. While it was tempting to increase the target self-containment parameter into the 90 per cent or more range a consequence of increasing the minimum and target self-containments too high was that major cities tended to capture surrounding regions to an extent that they become implausibly large and the number of WZs declined.

[15] See Coombes et. al. 2012, Eurostat 2015 and Franconi et. al. 2017 for background information and technical discussion of the algorithm.

Box E.2 The Eurostat Algorithm

The Eurostat algorithm is a clustering approach which seeks to group municipalities into LMAs based on self-containment and number of persons employed. As detailed by Franconi et. al. (2017), the algorithm relies on the setting of four parameters, two for self-containment and two for number of workers:

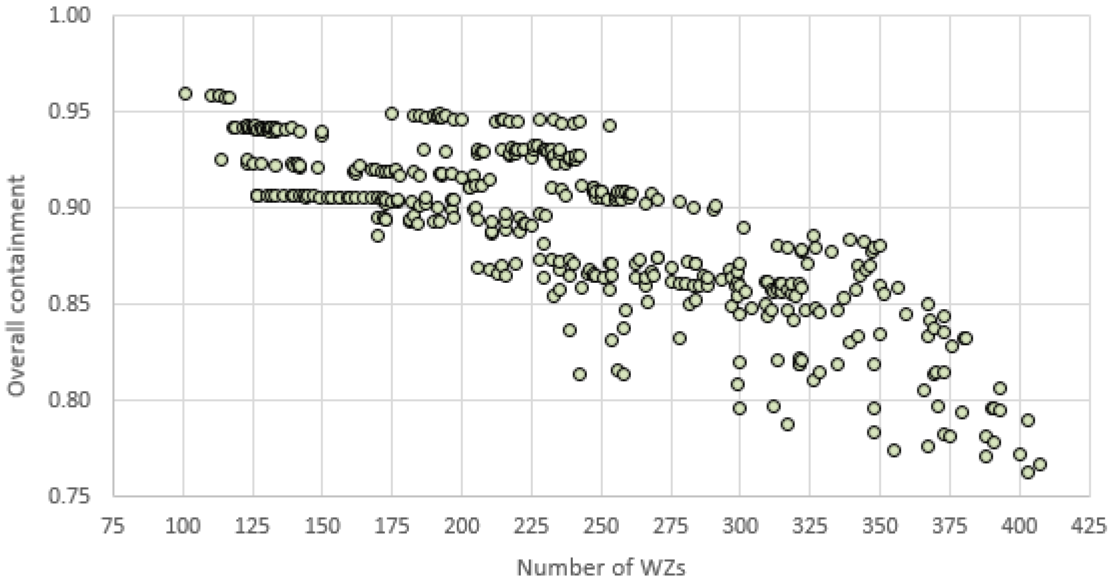
- Minimum self-containment (minimum level of self-containment for a cluster that has a size at least of target size to be considered a LMA)
- Target self-containment (Level of self-containment which is necessary for a cluster with minimum size in order to be considered a LMA)
- Minimum size (Minimum size [number of workers] of a cluster in order to be considered a LMA)
- Target size (Size of a cluster [number of workers] for which the minimum level of self-containment is adequate for the cluster to be considered a LMA)

The first step of the algorithm tests the self-containment rate and size of working population for every base unit. Any base units found not to meet the defined self-containment criteria are then assessed against other base units to identify the one with which the most important commuting flows are evident[1]. This occurs one base unit at a time starting with the lowest ranked on the initial self-containment measure. Once two base units are merged they are treated as a single unit by the algorithm and the process starts again. As this process continues, grouped units are continually subject to re-testing against the first self-containment criteria and when they fail are un-grouped and the original base units re-enter the process. The process stops when all base units and grouped LMAs meet the initial self-containment criteria.

Source: Eurostat, 2015.

Testing of Eurostat with 2016 national data was extensive and involved sensitivity testing of hundreds of models with slight variations to the four parameters. On some occasions parameter selection was random and on others it was structured using the earlier regression and simulations to guide the structuring. Figure E.1 provides an example of the output from 400 randomised Eurostat models (within structured 'sensible' parameters). The number of WZs in this output varied from 101 to 407 and the overall containment varied from over 96 per cent to less than 76 per cent. What is clear overall is that as the numbers of WZs increased the overall containment rate decreased as expected.

Figure E.1 Overall containment and number of WZs from 400 Eurostat models



Source: BITRE analysis of ABS 2016a.

Those models which produced promising looking summary statistics (i.e. high overall containment rates and higher numbers of WZs [towards the upper right of Figure E.1]) were examined in more detail with the aid of maps. Although maps of the better performing Eurostat models confirmed that the approach was working reasonably well and producing WZs which mostly appeared defensible given other available information, it also confirmed the tendency of it to produce some WZs which did not appear logical. For example, one of the best performing models which had an overall containment of 93 per cent and 256 WZs, had merged the Gold Coast and Toowoomba into a single non-contiguous WZ. Examination of commuting flows data was not able to determine why this occurred and could not support it being retained. Other unusual output included models that split Brisbane into a northern and southern component divided by the Brisbane River and a similar situation in Perth with the northern and southern suburbs separated into different WZs by the Swan River. Neither of these could be supported by the commuting data with both cities having very strong flows of workers in both directions across their respective rivers.

One possible problem with the Eurostat algorithm for this work is that it is a condition of the algorithm that a 'target' size is specified. This is difficult in an Australian context because it would be expected our final WZs would range in size from just several hundred persons in remote outback areas to several million in regions surrounding major cities. It is therefore difficult to set a sensible 'target'.

Another key issues was that the two key variables which appeared to exert the greatest influence upon the model – minimum self-containment and target size – appeared to be pulling in opposite directions. The minimum self-containment parameter is highly correlated with the overall containment, however, as overall containment rises the number of working zones tends to fall. If the minimum self-containment is set low, the model would give more working zones but then it is quite likely to give some unusual and small regions. By setting a high target size the model tends to merge regions excessively, resulting in a cascading effect as it seeks to merge to meet the target size parameters. If a high overall containment was sought by increasing the minimum self-containment and target self-containment (which must be set higher than the minimum), then a reduction in the number of WZs and excessively large regions was a result. Aiming for more working zones by keeping the target size low tended to result in a lower overall containment rate and major cities delineated into smaller WZs which could not be supported by the underlying commuting data (such as occurred on occasions in Brisbane and Perth).

Given some of the unusual results emerging from the Eurostat algorithm and an inability to identify a set of parameters which produced an overall good outcome without the presence of problematic results, a decision was taken to abandon testing and move onto examination of other alternatives. Had other suitable alternatives not been identified, it was thought that Eurostat could be revisited later for further testing.

Network models

The final existing approach considered for the development of BITRE WZs is best described as a 'Network Model'. A network model of WZs, or functional economic regions more broadly, conceptualises commuting patterns as a network where regions are nodes (vertices) and links (edges) are formed by people commuting from one region to another. The number of people traveling between two regions is typically used as the weight of the link between those two regions.

As discussed earlier, the complicated and overlapping nature of commuting flows means that very few individual areas would be identifiable as a separate network. In the Australian context, when only commutes of under 250km (measured as a straight line) are considered, there are three large networks: The East Coast (which includes Tasmania), West Coast (centred on Perth) and Northern (centred on Darwin) networks. These networks are shown below in Figure E.2. As can be seen in the figure, there are also a small number of completely isolated regions.

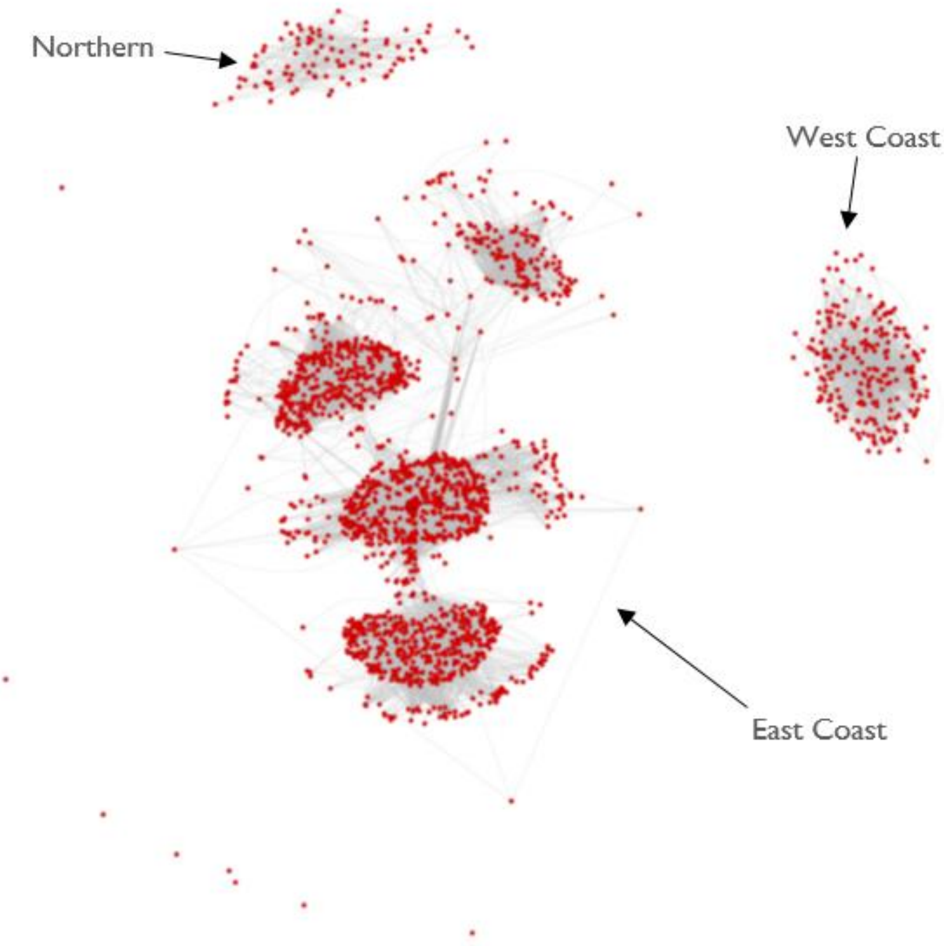
These approaches attempt to separate the networks created by commuting flows into sub-communities which represent WZs. This requires an objective criteria on which to decide upon an optimal split. The few published studies using a network approach (e.g. Farmer and Fotheringham, 2011; Rae and Nelson, 2018) have attempted to split the network of regions into sub-communities so that the sub-communities that remain are those that are least likely to be random. In network terminology they have attempted to maximise modulatory, which can be described as:

> *"A multiplicative constant, the number of edges falling within groups minus the expected number in an equivalent network with edges placed at random."* (Newman, 2006)

The intuition behind using modularity is that if the number of links between sub-communities of nodes is significantly different from what would be expected had the links been randomly distributed, then the communities are valid. In practice the highly non-random sub-communities from networks of commuting flows are very large, much larger than any individual would realistically travel from home to work. This is due to the highly interwoven and overlapping nature of commuting patterns. For example, in the case of Australia there are overlapping labour markets all the way along the east coast from Geelong to Townsville. However, no person undertakes this 2700km commute daily. For this reason, while the sub-communities generated through this approach are interesting and statistically non-random, they do not accurately represent the concept of WZs that this project seeks to identify.

BITRE has undertaken research into alternative ways of splitting networks into sub-communities which maximises overall containment, rather than modularity. The heuristic algorithm developed by BITRE split the network based on iteratively removing the weakest links between regions until no region was larger than 200km across (from any population-weighted centroid to any to employment-weighted centroid). The weakest link was defined in absolute terms as the smallest number of commuting flows between any pair of regions in the network or in relative terms as the smallest flow between any pair of regions within the network as a proportion of the total number of flows from the sending region. This resulted in realistically sized WZs, however the overall containment of the WZs created never reached above 85 per cent which was substantially lower than the approach ultimately used.

Figure E.2 Networks of Australian Commuting Flows, 2016



Note: The networks identified do not correspond to the physical geography of Australia.

Source: BITRE analysis of ABS 2016a limited to 250km straight line distance. Layout: Kamada-Kawai algorithm at 1000 iterations, generated using the igraph R package.

Appendix F. List of manual adjustments at Stage 5 – Step 3

Unassigned SA2s

- Lithgow SA2 and Lithgow Region SA2 (NSW) remained unassigned due to a unique combination of parameters. Neither of the SA2s met any parameters to become a seed but neither did they meet the criteria to merge with another WZ. Examination of flows data indicated that combined they could become a WZ.

Demerging

- Gatton SA2 (Qld) had been allocated to Toowoomba on the basis of closest bigger and distance. Flows data indicated it should be assigned to the Brisbane WZ.
- Lockyer Valley-East SA2 (Qld) had been allocated to Toowoomba (via Gatton) on the basis of closest bigger and distance. It was reassigned to Brisbane WZ on the basis of commuting flows.
- Seymour, Seymour Region and Nagambie SA2s (all Vic) had all merged with Melbourne in Step 1 of Stage 5. Examination of flows data suggested they could split from Melbourne and form their own WZ.
- Tanami SA2 had been merged with Petermann-Simpson SA2 during the final flows stage. Examination of the distance parameter indicated this merger should be wound back.
- Tocumwal-Finley had merged with Cobram to become a WZ. Examination of flows data suggested Tocumwal Finley should stand alone as an independent WZ and Cobram should then merge with Numurkah.

Merging

- Stand-alone SA2 WZ Crows Nest (Qld) was merged with Toowoomba WZ.
- Stand-alone SA2 WZ Broadsound-Nebo (Qld) was merged with Mackay WZ.
- Stand-alone SA2 WZ Collinsville (Qld) was merged with Bowen WZ.
- Sandover-Plenty WZ (NT) was merged with Alice Springs WZ which it completely surrounds.
- Kambalda-Coolgardie-Norseman WZ (WA) was merged with Kalgoorlie which it completely surrounds.

Non-contiguous

- Shoalwater Bay SA2 was a non-contiguous part of Rockhampton WZ. It was merged to Yeppoon WZ.
- Tea Gardens-Hawks Nest SA2 was assigned to Nelson Bay WZ on the basis of distance despite being non-contiguous (water separation). Examination of flows data indicated an assignment to Newcastle WZ was logical.
- Ettrema-Sassafras-Budawang SA2 (NSW) (9 residents) had been assigned to the Sydney WZ despite being non-contiguous. Examination of data indicated that Nowra was a more logical WZ to which it should be assigned.
- Phillip Island (Vic) had been merged with Melbourne despite a water barrier. Examination of flows data suggested it should merge with Wonthaggi.

Surrounded SA2s

- A number of SA2s mostly in the ACT and having zero or few residents or workers in them, had not been assigned but were completely surrounded by a WZ. These SA2s were assigned to those WZs and are:
  - Holsworthy Military Area SA2 was assigned to Sydney and surrounds WZ.
  - Enoggera Reservoir SA2 was assigned to Brisbane and surrounds WZ.
  - Mount Wellington SA2 was assigned to Hobart and surrounds SA2.
  - Ashendon-Lesley SA2 and Melaleuca-Lexia SA2 were assigned to Perth and surrounds WZ.
  - Gooroomon SA2, Lake Burley Griffin SA2, Gungahlin-East SA2, Gungahlin-West SA2, Taylor SA2, Tuggeranong-West SA2, Molonglo SA2 and Molonglo-North SA2 were all assigned to Canberra and surrounds WZ.

Appendix G. Sensitivity testing: 2011 Census data and 2016 non-imputed Census data

2011 Census data

Testing with 2011 data resulted in 324 WZs being identified and an overall containment rate of 95.6 per cent (compared to 313 WZs and overall containment of 95.2 per cent using 2016 data). With 11 extra WZs there were naturally some minor differences identified, some of which can be attributed to SA2 boundary changes and others which may indicate changes in commuting behaviour over time. The main point of interest is that the 2016 WZs appear to have slightly increased their size when compared to the 2011 output. There were no differences between the 2011 and 2016 WZs in the Northern Territory but all other jurisdictions had some differences. The main differences are outlined below.

New South Wales/ACT:

- In 2011, the western boundary of the Sydney and surrounds WZ did not extend as far as it did in 2016. In 2011 the four western-most SA2s in the Sydney and surrounds WZ merged with the two Lithgow region SA2s to form a broader Blue Mountains/Lithgow WZ.
- The 2011 Newcastle and surrounds WZ covers slightly less territory than in 2016. In the south of the 2016 WZ, two SA2s (Morrisett-Cooranbong and Bonnells Bay-Silverwater) were in the Central Coast and surrounds WZ in 2011.
- In 2011, Junee SA2 stood alone as a WZ, but in 2016 it has joined the Wagga Wagga and surrounds WZ.
- Braidwood was merged with Canberra WZ in 2011, but stands alone as a WZ in 2016.
- Mudgee Region-East SA2 stood alone as a WZ in 2011 but has merged with Mudgee WZ in 2016.
- In 2011, South West Rocks SA2 appeared as a non-contiguous component of the Macksville-Scotts Head WZ, but in 2016 it was a contiguous part of the Kempsey WZ.
- In 2011 Kyogle SA2 stood alone as a WZ but in 2016 it has merged with Lismore.

Victoria:

- The SA2s of Yea and Alexandra formed a WZ in 2011 but in 2016 they have split into two individual WZs.
- Beechworth and Myrtleford SA2s were in 2011 combined as a WZ. In 2016 they both joined with the Wangaratta and surrounds WZ.
- In 2011, Moira and Yarrawonga SA2s merged to create a WZ with two SA2s on the south side of the Murray River. In 2016 they are part of a broader WZ with five SA2s straddling the NSW/Victoria border.

Queensland:

- Yarrabah SA2 stood alone as a WZ in 2011, but in 2016 is part of the Cairns and surrounds WZ.
- Herberton stood alone as a single SA2 WZ in 2011 but joined Atherton WZ in 2016.

South Australia:

- In 2011, the Yankalilla SA2 was merged with the Adelaide WZ, but in 2016 it has merged with Victor Harbor SA2 and Goolwa SA2 to form a WZ with three SA2s.
- In 2011 the SA2 of Goyder stood alone as a WZ, but in 2016 it has merged with the Clare and surrounds WZ.

Western Australia:

- Donnybrook-Balingup SA2 was in 2011, a stand-alone WZ but in 2016 had joined Bunbury.
- Wagin SA2 was in 2011 a standalone 'donut' WZ surrounding Narrogin SA2, but in 2016 they have merged.

Tasmania:

- George Town SA2 was in 2011 a stand-alone WZ but in 2016 has been merged with the Launceston and surrounds WZ.
- In 2011 Penguin-Sulphur Creek SA2 was part of Burnie WZ but in 2016 joins Devonport and surrounds WZ.

Non-imputed 2016 Census data

When testing the final model using non-imputed 2016 Census data, again the results are very similar but with some minor variations. With this dataset, the output was 309 WZs and an overall containment of 95.4 per cent (compared to 313 WZs and overall containment of 95.2 per cent using imputed 2016 data). Examination of the output found that there were no differences in the final WZs in any of South Australia, Western Australia and the Northern Territory. The key differences in the other states are outlined below.

New South Wales:

- Braidwood SA2 merges with the Canberra and surrounds WZ rather than standing alone as a single SA2 WZ.
- Nelson Bay SA2 and Anna Bay SA2 merge with the Newcastle, Lower Hunter and surrounds WZ rather than standing together as a WZ with two SA2s.

Victoria:

- Rather than being a stand-alone SA2 WZ, Yea SA2 is merged with the Melbourne and surrounds WZ.
- Cobram SA2 stands alone as a single SA2 WZ rather than being merged with Numurkah SA2.

Queensland:

- Two SA2s in the far south of the Brisbane and surrounds WZ (Pimpama and Jacobs Well-Alberton) are part of the Gold Coast WZ rather than with Brisbane.
- Weipa SA2 merges with Aurukun SA2 to create a non-contiguous WZ with two sections.

Tasmania:

- Deloraine SA2 merged with the Devonport and surrounds WZ instead of standing alone as a WZ.

One issue associated with using the non-imputed data is that the seed thresholds and minimum sizes will have had an effect. For example, the minimum size was set at 200 persons working in an SA2 to ensure that Lord Howe Island and Cocos Islands were each found to be stand-alone WZs but smaller places were not. When the non-imputed data is used, all SA2s lose some employed persons – in the case of Lord Howe and Cocos Islands, they both fell below 200. At the other end of the scale, Adelaide slipped below 100 000 persons so does not become a seed until the next possible opportunity.

Appendix H. The BITRE WZs 2016 – Key data and maps

Table H.1 The BITRE WZs and key data

Map Key	Working Zone Name	State	No. of SA2s	Employed persons, place of usual residence in this WZ	Employed persons, place of work in this WZ	Self-cont. 1: Employed persons who live in this WZ, per cent who work in this WZ	Self-cont. 2: Employed persons who work in this WZ, per cent who live in this WZ
1	Adelaide and surrounds	SA	118	576 063	573 807	98.4	98.8
2	Agnes Water-Miriam Vale	QLD	1	1961	1447	66.6	90.3
3	Albany and surrounds	WA	5	15 082	14 655	91.7	94.4
4	Albury-Wodonga and surrounds	VIC/ NSW	9	47 154	47 986	94.2	92.6
5	Alexandra	VIC	1	2432	2372	84.7	86.9
6	Alice Springs and surrounds	NT	7	12 897	13 070	98.0	96.7
7	Alligator	NT	1	1686	1762	74.2	71.0
8	Anindilyakwa	NT	1	701	1335	100.0	52.5
9	APY Lands	SA	1	504	550	97.8	89.6
10	Ararat and region	VIC	2	4379	4726	87.0	80.6
11	Armidale and surrounds	NSW	3	13 703	13 904	96.5	95.2
12	Ashburton (WA)	WA	1	7902	22 896	94.0	32.5
13	Atherton and surrounds	QLD	5	15 180	14 619	90.3	93.8
14	Aurukun	QLD	1	227	252	91.2	82.1
15	Avoca, Maryborough and surrounds	VIC	3	5239	4961	81.2	85.7
16	Ayr and Burdekin	QLD	2	7447	7263	91.8	94.1
17	Bairnsdale, Lakes Entrance and surrounds	VIC	4	13 691	13 471	94.0	95.6
18	Ballarat and surrounds	VIC	12	51 807	49 593	89.6	93.6
19	Ballone	QLD	1	2032	2029	95.0	95.2
20	Balranald-Euston (Wentworth-Balranald Region)	NSW	1	1520	1597	74.6	71.0
21	Banana	QLD	1	4162	5095	75.2	61.4
22	Barcaldine-Blackall	QLD	1	2270	2246	94.5	95.5
23	Barkly	NT	1	589	509	77.1	89.2
24	Batemans Bay, Moruya and surrounds	NSW	5	9977	9943	92.7	93.0
25	Bathurst and surrounds	NSW	3	17 649	17 291	87.4	89.2
26	Beaudesert	QLD	1	4929	5070	65.0	63.2
27	Bega, Merimbula, Eden and surrounds	NSW	4	11 487	11 265	95.9	97.8
28	Benalla and region	VIC	2	5311	5047	78.1	82.2
29	Bendigo and surrounds	VIC	15	60 269	58 340	90.1	93.1
30	Berri, Renmark, Loxton and surrounds	SA	6	10 957	10 862	97.0	97.8
31	Biloela	QLD	1	2785	2872	70.1	67.9
32	Bombala	NSW	1	990	1003	88.8	87.6

(continued)

Map Key	Working Zone Name	State	No. of SA2s	Employed persons, place of usual residence in this WZ	Employed persons, place of work in this WZ	Self-cont. 1: Employed persons who live in this WZ, per cent who work in this WZ	Self-cont. 2: Employed persons who work in this WZ, per cent who live in this WZ
33	Boonah	QLD	1	4801	3409	60.3	84.9
34	Bourke-Brewarrina	NSW	1	1363	1399	97.2	94.7
35	Bowen and Collinsville	QLD	2	5024	5591	92.1	82.8
36	Braidwood	NSW	1	1472	1013	63.2	91.9
37	Bridgetown-Boyup Brook	WA	1	2499	2304	79.2	85.9
38	Bright - Mount Beauty	VIC	1	3353	3664	81.7	74.8
39	Brisbane and surrounds	QLD	236	1 011 827	1 035 497	97.0	94.8
40	Broken Hill	NSW	1	6697	6680	96.9	97.2
41	Brookton	WA	1	1408	1386	86.9	88.3
42	Broome and Roebuck	WA	2	7000	7074	96.3	95.3
43	Bulahdelah-Stroud	NSW	1	1691	1240	54.9	74.8
44	Buloke	VIC	1	2355	2395	90.5	89.0
45	Bunbury and surrounds	WA	13	40 064	36 943	85.9	93.1
46	Bundaberg and surrounds	QLD	11	30 650	29 639	94.1	97.4
47	Burnie and surrounds	TAS	8	13 461	14 382	85.1	79.6
48	Busselton and region	WA	2	14 900	13 500	80.3	88.7
49	Cairns and surrounds	QLD	21	69 025	67 131	94.6	97.2
50	Camperdown and Corangamite-North	VIC	2	3494	3585	75.9	74.0
51	Canberra and surrounds	ACT/ NSW	138	230 716	233 753	99.3	98.0
52	Cape York	QLD	1	2280	3675	97.0	60.2
53	Carnarvon	WA	1	2036	2046	93.7	93.2
54	Carpentaria	QLD	1	1502	1624	96.0	88.8
55	Ceduna	SA	1	1123	1257	93.0	83.1
56	Central Coast and surrounds	NSW	30	128 410	103 269	74.2	92.3
57	Central Highlands-East (Qld.)	QLD	1	3215	5415	90.8	53.9
58	Charleville	QLD	1	1949	1912	94.7	96.5
59	Charters Towers and Dalrymple	QLD	2	4335	4125	87.8	92.2
60	Chinchilla	QLD	1	3250	3629	87.4	78.3
61	Christmas Island	OT	1	802	891	99.6	89.7
62	Clare and surrounds	SA	3	5404	5341	82.8	83.8
63	Clermont	QLD	1	1679	2593	92.0	59.6
64	Cloncurry-Camooweal (Mount Isa Region)	QLD	1	1611	3465	94.0	43.7
65	Cobar	NSW	1	1928	2128	96.3	87.2
66	Cobram and Numurkah	VIC	2	7419	7444	76.9	76.7
67	Cocos (Keeling) Islands	OT	1	222	228	97.3	94.7
68	Coffs Harbour and surrounds	NSW	8	31 326	31 277	94.3	94.5
69	Colac and region	VIC	2	7621	7904	89.8	86.6
70	Collie	WA	1	3127	4427	84.4	59.6

(continued)

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71	Condobolin	NSW	1	2514	2469	90.5	92.2
72	Coober Pedy	SA	1	606	647	95.9	89.8
73	Cooloola	QLD	1	1312	1182	74.4	82.6
74	Cooma and region	NSW	2	4132	3991	85.5	88.5
75	Coonabarabran	NSW	1	2744	2609	89.9	94.6
76	Coonamble	NSW	1	1470	1483	89.8	89.0
77	Cootamundra	NSW	1	2644	2664	86.7	86.1
78	Corangamite-South	VIC	1	3319	3357	78.1	77.2
79	Corowa, Yarrawonga, Rutherglen and surrounds	NSW / VIC	5	10 088	9392	78.3	84.1
80	Cowra and region	NSW	2	5306	5217	91.0	92.5
81	Croydon - Etheridge	QLD	1	450	449	84.4	84.6
82	Cunderdin	WA	1	1551	1528	87.2	88.5
83	Daly	NT	1	489	557	91.2	80.1
84	Darwin and surrounds	NT	44	68 094	70 280	97.5	94.5
85	Deloraine	TAS	1	2071	2077	71.3	71.1
86	Deniliquin	NSW	1	2939	3186	91.3	84.2
87	Denmark	WA	1	2163	1883	77.3	88.7
88	Derby-West Kimberley	WA	1	2269	2412	96.5	90.8
89	Devonport, Ulverstone and surrounds	TAS	11	22 920	21 243	84.2	90.8
90	Dorrigo	NSW	1	1070	945	76.6	86.8
91	Dowerin	WA	1	1718	1665	87.7	90.5
92	Drouin, Warragul and surrounds	VIC	3	16 715	13 822	63.6	76.9
93	Dubbo and surrounds	NSW	4	18 576	19 274	94.6	91.2
94	East Arnhem	NT	1	1228	1727	95.5	67.9
95	East Pilbara	WA	1	3541	11 514	71.3	21.9
96	Echuca, Moama and surrounds	VIC	4	11 589	11 870	88.4	86.3
97	Elsey	NT	1	488	530	88.1	81.1
98	Emerald and Central Highlands-West	QLD	2	9813	10 535	86.0	80.1
99	Esk	QLD	1	1488	1230	64.3	77.8
100	Esperance	WA	1	5101	4944	92.1	95.0
101	Euroa	VIC	1	2417	2062	70.9	83.1
102	Exmouth	WA	1	1975	2390	92.1	76.1
103	Eyre Peninsula	SA	1	2700	2213	69.4	84.6
104	Far Central West (Qld.)	QLD	1	1045	1116	94.7	88.7
105	Far South West (Qld.)	QLD	1	1340	1375	92.7	90.3
106	Far West (NSW)	NSW	1	897	961	87.4	81.6
107	Flinders and Cape Barren Islands	TAS	1	390	399	99.0	96.7

(continued)

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108	Forbes	NSW	1	3994	3943	86.2	87.3
109	Forestier-Tasman	TAS	1	711	697	79.3	80.9
110	Forster, Tuncurry and surrounds	NSW	3	7477	7615	82.8	81.3
111	Gayndah-Mundubbera	QLD	1	2679	2701	93.9	93.1
112	Geelong and surrounds	VIC	20	117 228	106 154	84.6	93.4
113	Geraldton	WA	4	15 387	14 859	91.2	94.5
114	Gilgandra	NSW	1	1743	1585	83.8	92.2
115	Gin and North Burnett	QLD	2	1460	1274	67.0	76.8
116	Gingin-Dandaragan	WA	1	3289	3265	75.4	76.0
117	Gladstone and surrounds	QLD	9	23 821	24 375	95.7	93.6
118	Glen Innes	NSW	1	3022	2998	93.0	93.8
119	Glenelg (Vic.)	VIC	1	3646	2527	56.1	80.9
120	Gloucester	NSW	1	1675	1718	87.5	85.3
121	Gnowangerup	WA	1	1392	1469	93.0	88.1
122	Gold Coast-Tweed Heads and surrounds	QLD/ NSW	53	265 486	242 560	85.4	93.5
123	Goondiwindi	QLD	1	2852	2976	91.0	87.2
124	Goulburn and region	NSW	2	14 455	13 133	84.6	93.1
125	Grafton and region	NSW	2	11 387	11 205	86.6	88.0
126	Grenfell	NSW	1	1339	1210	81.0	89.7
127	Griffith (NSW) and region	NSW	2	14 214	14 593	96.6	94.1
128	Gulf	NT	1	843	1065	95.1	75.3
129	Gundagai	NSW	1	1488	1428	81.1	84.5
130	Gunnedah and region	NSW	2	5518	5883	92.1	86.4
131	Gympie and surrounds	QLD	4	14 861	14 332	84.6	87.7
132	Halls Creek	WA	1	687	825	94.3	78.5
133	Hamilton (Vic.) and Southern Grampians	VIC	2	6890	7091	93.5	90.8
134	Hay	NSW	1	1220	1290	95.3	90.2
135	Hobart and surrounds	TAS	43	105 228	105 373	99.2	99.1
136	Horsham and region	VIC	2	8735	8818	92.7	91.8
137	Ingham and region	QLD	2	4334	4250	93.3	95.1
138	Inglewood-Waggamba	QLD	1	1719	1693	85.6	86.9
139	Innisfail and surrounds	QLD	3	8411	7734	84.2	91.5
140	Inverell and Inverell Region-East	NSW	2	6083	6289	93.2	90.1
141	Irwin	WA	1	1253	1007	74.7	92.9
142	Jamestown	SA	1	1888	1684	75.7	84.9
143	Jindabyne-Berridale	NSW	1	3591	4082	84.3	74.2
144	Kadina and surrounds	SA	3	4591	4287	85.5	91.5
145	Kalgoorlie and Nullarbor Plain	WA	6	15 965	16 967	97.0	91.3

(continued)

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146	Kangaroo Island	SA	1	2013	1999	97.8	98.5
147	Karoonda-Lameroo	SA	1	1353	1392	89.9	87.4
148	Karratha and Roebourne	WA	2	10 233	12 391	92.8	76.7
149	Katanning	WA	1	1866	1978	91.9	86.7
150	Katherine	NT	1	3995	4145	95.5	92.0
151	Kempsey, South West Rocks and surrounds	NSW	3	8774	9176	91.1	87.1
152	Kerang and Gannawarra	VIC	2	4179	3870	82.7	89.3
153	Kilcoy	QLD	1	2039	1968	65.4	67.7
154	Kimba-Cleve-Franklin Harbour	SA	1	1865	1914	92.8	90.4
155	King Island	TAS	1	731	743	99.5	97.8
156	Kingaroy, Nanango and surrounds	QLD	3	8248	8389	91.3	89.8
157	Kingston-Robe	SA	1	1603	1520	88.0	92.8
158	Kojonup	WA	1	1826	1785	84.9	86.8
159	Kowanyama-Pormpuraaw	QLD	1	437	450	93.8	91.1
160	Kulin	WA	1	2177	2381	93.7	85.6
161	Kununurra	WA	1	3136	3451	96.7	87.9
162	La Trobe Valley	VIC	6	31 120	32 014	87.6	85.1
163	Launceston and surrounds	TAS	26	48 380	48 135	96.6	97.1
164	Le Hunte-Elliston	SA	1	1038	1077	95.6	92.1
165	Leeton	NSW	1	4108	4196	86.1	84.2
166	Leinster-Leonora	WA	1	1696	5462	91.6	28.5
167	Leongatha and surrounds	VIC	4	11 444	10 558	76.3	82.8
168	Lismore and surrounds	NSW	14	56 755	56 848	95.9	95.7
169	Lithgow and region	NSW	2	7357	7226	80.5	82.0
170	Loddon	VIC	1	2494	2435	73.5	75.2
171	Longreach	QLD	1	1844	1830	94.7	95.4
172	Lord Howe Island	NSW	1	202	211	100.0	95.7
173	Mackay and surrounds	QLD	18	53 814	54 383	92.2	91.3
174	Macksville, Nambucca Heads and surrounds	NSW	3	5711	5425	81.2	85.5
175	Maclean-Yamba-Iluka	NSW	1	4839	4746	83.2	84.9
176	Magnetic Island	QLD	1	862	651	69.0	91.4
177	Manjimup and Pemberton	WA	2	4421	4526	92.6	90.4
178	Mannum	SA	1	2154	1700	59.1	74.9
179	Mansfield (Vic.)	VIC	1	3585	3824	90.0	84.4
180	Margaret River and Augusta	WA	2	6323	5754	81.7	89.8
181	Maryborough, Hervey Bay and surrounds	QLD	11	30 048	28 751	94.2	98.5
182	Meekatharra	WA	1	1260	3528	90.6	32.3

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183	Melbourne and surrounds	VIC	314	2 012 947	2 030 366	99.0	98.2
184	Merredin	WA	1	2186	2224	93.4	91.8
185	Mildura and Wentworth	VIC/ NSW	6	21 947	21 298	94.7	97.6
186	Miles-Wandoan	QLD	1	1856	3264	89.7	51.0
187	Millicent and Wattle Range	SA	2	3300	2927	76.4	86.2
188	Millmerran	QLD	1	1300	1485	86.6	75.8
189	Monto-Eidsvold	QLD	1	1422	1513	89.6	84.2
190	Moora	WA	1	2185	2358	93.5	86.6
191	Moranbah	QLD	1	4131	7413	86.6	48.3
192	Morawa	WA	1	1767	2246	91.9	72.3
193	Moree	NSW	1	3144	3673	90.6	77.6
194	Moulamein-Barham (Deniliquin Region)	NSW	1	2873	2738	64.8	68.0
195	Mount Gambier and surrounds	SA	3	14 733	14 764	92.9	92.7
196	Mount Isa	QLD	1	8750	8331	90.8	95.4
197	Mudgee and surrounds	NSW	3	9556	9761	95.1	93.1
198	Mukinbudin	WA	1	1450	2240	93.6	60.6
199	Mungindi-Boggabilla (Moree Region)	NSW	1	2381	2142	66.2	73.6
200	Murgon-Wondai (Kingaroy Region - North)	QLD	1	2892	2742	78.3	82.6
201	Murray Bridge and region	SA	2	8151	8967	80.7	73.3
202	Muswellbrook, Scone and surrounds	NSW	4	12 457	14 224	91.5	80.1
203	Naracoorte and region	SA	2	3953	3982	90.8	90.1
204	Narooma-Bermagui and Deua-Wadbilliga	NSW	2	2542	2427	81.1	85.0
205	Narrabri and region	NSW	2	4965	4965	94.0	94.0
206	Narrandera	NSW	1	2290	2045	75.7	84.8
207	Narrogin and Wagin	WA	2	3895	3979	93.4	91.4
208	Narromine	NSW	1	2473	2268	73.6	80.3
209	Nelson Bay Peninsula and Anna Bay	NSW	2	9395	7469	65.9	82.9
210	Newcastle, Lower Hunter and surrounds	NSW	47	233 236	230 768	93.6	94.6
211	Newman	WA	1	2206	2542	70.0	60.7
212	Nhill Region	VIC	1	2765	2654	86.9	90.6
213	Nhulunbuy	NT	1	1510	1098	67.6	93.0
214	Norfolk Island	OT	1	956	950	98.3	98.9
215	Northam and Toodyay	WA	2	5762	5144	69.6	78.0
216	Northampton-Mullewa-Greenough	WA	1	2374	2113	71.3	80.1

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217	Northern Highlands (Qld.)	QLD	1	1645	2636	91.3	57.0
218	Northern Peninsula	QLD	1	766	802	98.6	94.1
219	Nowra, Jervis Bay and surrounds	NSW	11	26 869	27 711	90.3	87.6
220	Nyngan-Warren	NSW	1	1994	2193	93.5	85.0
221	Oberon	NSW	1	1794	2016	82.8	73.7
222	Orange and surrounds	NSW	4	24 573	24 759	93.5	92.8
223	Orbost and Alps-East	VIC	2	2112	2039	87.7	90.8
224	Otway	VIC	1	1442	1334	80.3	86.8
225	Outback (SA)	SA	1	1296	2785	78.0	36.3
226	Ouyen-Murrayville (Mildura Region)	VIC	1	1672	1901	77.2	67.9
227	Palm Island	QLD	1	474	575	99.4	81.9
228	Parkes (NSW) and region	NSW	2	5437	5413	88.6	89.0
229	Penola	SA	1	1416	1586	77.9	69.5
230	Perth and surrounds	WA	173	874 078	849 096	96.3	99.1
231	Peterborough-Mount Remarkable	SA	1	2022	1649	72.0	88.2
232	Petermann-Simpson	NT	1	1082	1079	95.2	95.5
233	Plantagenet	WA	1	1991	1976	73.0	73.6
234	Port Augusta and Quorn-Lake Gilles	SA	2	5774	6087	90.7	86.0
235	Port Douglas and Daintree	QLD	2	5038	5415	91.5	85.1
236	Port Hedland and South Hedland	WA	2	6494	8399	93.7	72.5
237	Port Lincoln	SA	1	6493	6723	91.8	88.7
238	Port Macquarie and surrounds	NSW	5	27 606	27 158	93.8	95.4
239	Port Pirie and region	SA	2	6242	6533	92.4	88.3
240	Portland	VIC	1	4250	5137	90.2	74.6
241	Proserpine and Airlie-Whitsundays	QLD	2	9630	8994	89.1	95.4
242	Quirindi	NSW	1	2824	2607	79.0	85.6
243	Ravensthorpe (Esperance Region)	WA	1	1662	1903	86.2	75.2
244	Robinvale	VIC	1	1177	1210	76.9	74.8
245	Rockhampton and surrounds	QLD	16	37 848	38 287	88.4	87.3
246	Roma and region	QLD	2	6019	6628	92.8	84.3
247	Roxby Downs	SA	1	2130	3391	98.6	61.9
248	Sale and surrounds	VIC	5	14 719	14 827	88.2	87.6
249	Scottsdale-Bridport	TAS	1	2377	2238	85.7	91.0
250	Seymour and surrounds	VIC	3	5867	5907	75.1	74.6
251	Shepparton and surrounds	VIC	7	31 579	32 660	92.4	89.4
252	Smithton and North West	TAS	2	3416	3585	94.9	90.4

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253	Southern Highlands (NSW)	NSW	6	18 845	17 546	77.2	82.9
254	St Arnaud	VIC	1	1377	1339	85.2	87.6
255	St Helens-Scamander	TAS	1	1732	1665	92.2	95.9
256	Stanthorpe and region	QLD	2	3987	4030	93.1	92.1
257	Stawell	VIC	1	3230	3324	84.5	82.1
258	Sunshine Coast and surrounds	QLD	33	138 814	129 104	89.3	96.0
259	Swan Hill and region	VIC	2	7018	7481	93.0	87.3
260	Sydney and surrounds	NSW	283	2 034 612	2 082 384	99.3	97.0
261	Tamworth and surrounds	NSW	4	24 702	24706	95.6	95.6
262	Tanami	NT	1	555	986	90.6	51.0
263	Tara	QLD	1	1293	1242	83.1	86.5
264	Taree and surrounds	NSW	4	15 520	14 804	85.8	89.9
265	Tatiara	SA	1	3281	3392	95.3	92.2
266	Temora	NSW	1	2566	2476	86.7	89.9
267	Tennant Creek	NT	1	1120	1258	96.8	86.2
268	Tenterfield	NSW	1	2212	2059	82.1	88.2
269	Thamarrurr	NT	1	321	346	98.4	91.3
270	The Coorong	SA	1	2141	2007	78.4	83.6
271	Tiwi Islands	NT	1	516	540	98.6	94.3
272	Tocumwal-Finley-Jerilderie	NSW	1	3666	3177	74.1	85.5
273	Toowoomba and surrounds	QLD	18	70 679	69 314	92.7	94.5
274	Torres	QLD	1	1325	1411	96.0	90.1
275	Torres Strait Islands	QLD	1	952	963	92.4	91.4
276	Townsville and surrounds	QLD	24	81 241	79 621	95.1	97.1
277	Towong	VIC	1	2490	1977	66.9	84.3
278	Triabunna-Bicheno	TAS	1	1521	1407	83.7	90.5
279	Tully	QLD	1	4303	4526	89.5	85.1
280	Tumbarumba	NSW	1	1360	1423	87.6	83.7
281	Tumut and region	NSW	2	4294	4334	91.6	90.8
282	Ulladulla and region	NSW	2	6507	5735	82.7	93.8
283	Victor Harbor and surrounds	SA	3	9288	8400	76.7	84.8
284	Victoria River	NT	1	589	555	86.1	91.4
285	Wagga Wagga and surrounds	NSW	6	33 337	33 419	96.0	95.8
286	Waikerie	SA	1	2551	2289	80.6	89.9
287	Wakefield-Barunga West	SA	1	3549	3378	69.6	73.1
288	Walcha	NSW	1	1374	1409	90.4	88.1
289	Walgett-Lightning Ridge	NSW	1	2059	2060	93.7	93.6
290	Wambo	QLD	1	7305	7557	90.0	87.0
291	Wangaratta, Beechworth and surrounds	VIC	4	15 719	15 562	85.5	86.3

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292	Warialda-Bingara (Inverell Region - West)	NSW	1	2238	1709	70.1	91.8
293	Warrnambool and surrounds	VIC	4	22 086	21 689	93.9	95.6
294	Warwick and surrounds	QLD	3	9299	9071	91.1	93.4
295	Weipa	QLD	1	2023	1061	47.4	90.4
296	Wellington	NSW	1	2673	2276	69.6	81.8
297	West Arnhem	NT	1	786	834	97.8	92.2
298	West Coast (SA)	SA	1	1458	1281	81.0	92.2
299	West Coast (Tas.)	TAS	1	1418	1877	97.8	73.9
300	West Wimmera	VIC	1	1230	1150	81.7	87.4
301	West Wyalong	NSW	1	2413	2520	92.5	88.6
302	Whyalla and Whyalla North	SA	2	7991	7799	92.7	94.9
303	Wollongong and surrounds	NSW	23	115 529	98 600	80.7	94.6
304	Wonthaggi-Inverloch and Philip Island	VIC	2	11 306	10 057	77.3	86.9
305	Yarram	VIC	1	1981	1767	78.4	87.9
306	Yarriambiack	VIC	1	2466	2489	84.0	83.2
307	Yea	VIC	1	1246	1003	59.8	74.3
308	Yeppoon and surrounds	QLD	3	9076	6281	56.7	81.9
309	York-Beverley	WA	1	1902	1461	69.3	90.3
310	Yorke Peninsula - North	SA	1	2450	2506	85.5	83.6
311	Yorke Peninsula - South	SA	1	1275	1148	80.3	89.2
312	Young and region	NSW	2	6795	6641	89.9	92.0
313	Yuendumu-Anmatjere	NT	1	385	414	92.7	86.2

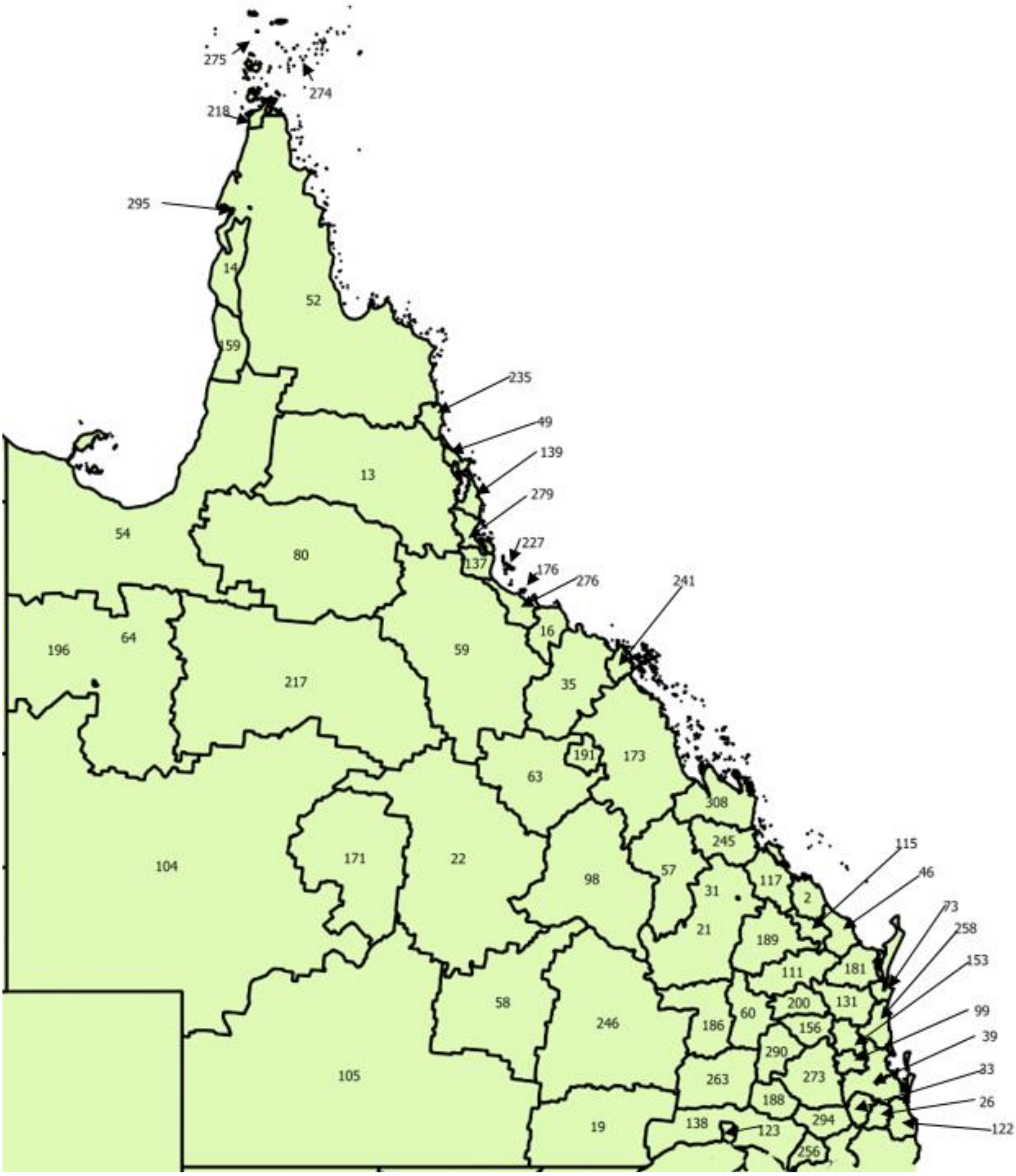
Note: Christmas Island, Cocos (Keeling) Islands, Lord Howe Island and Norfolk Island are not shown on the maps below.

Source: BITRE analysis of ABS 2016a.

Figure H.1 New South Wales, Victoria and the Australian Capital Territory WZs

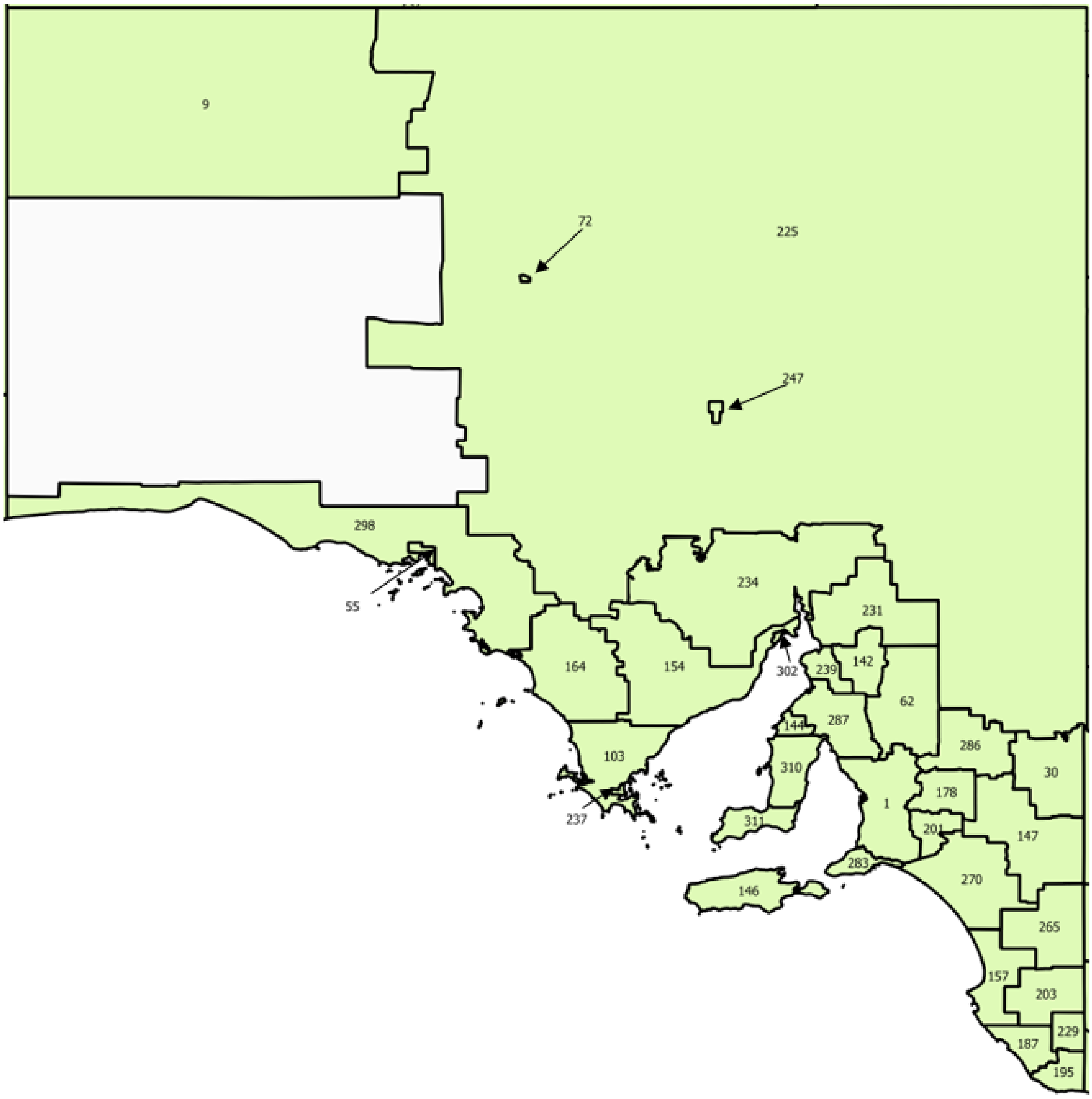
Source: BITRE analysis of ABS 2016a.

Figure H.2 Queensland WZs



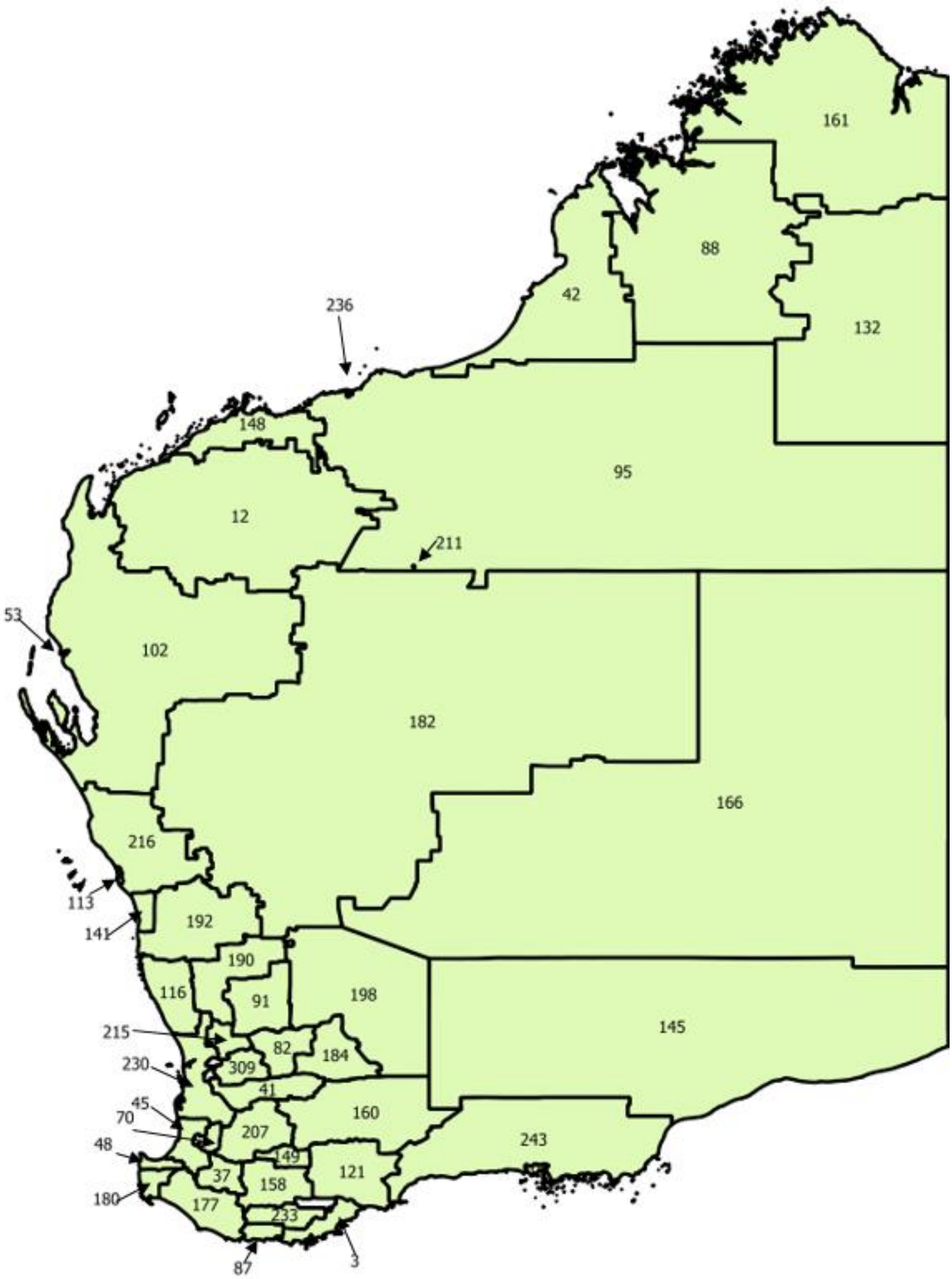
Source: BITRE analysis of ABS 2016a.

Figure H.3 South Australia WZs



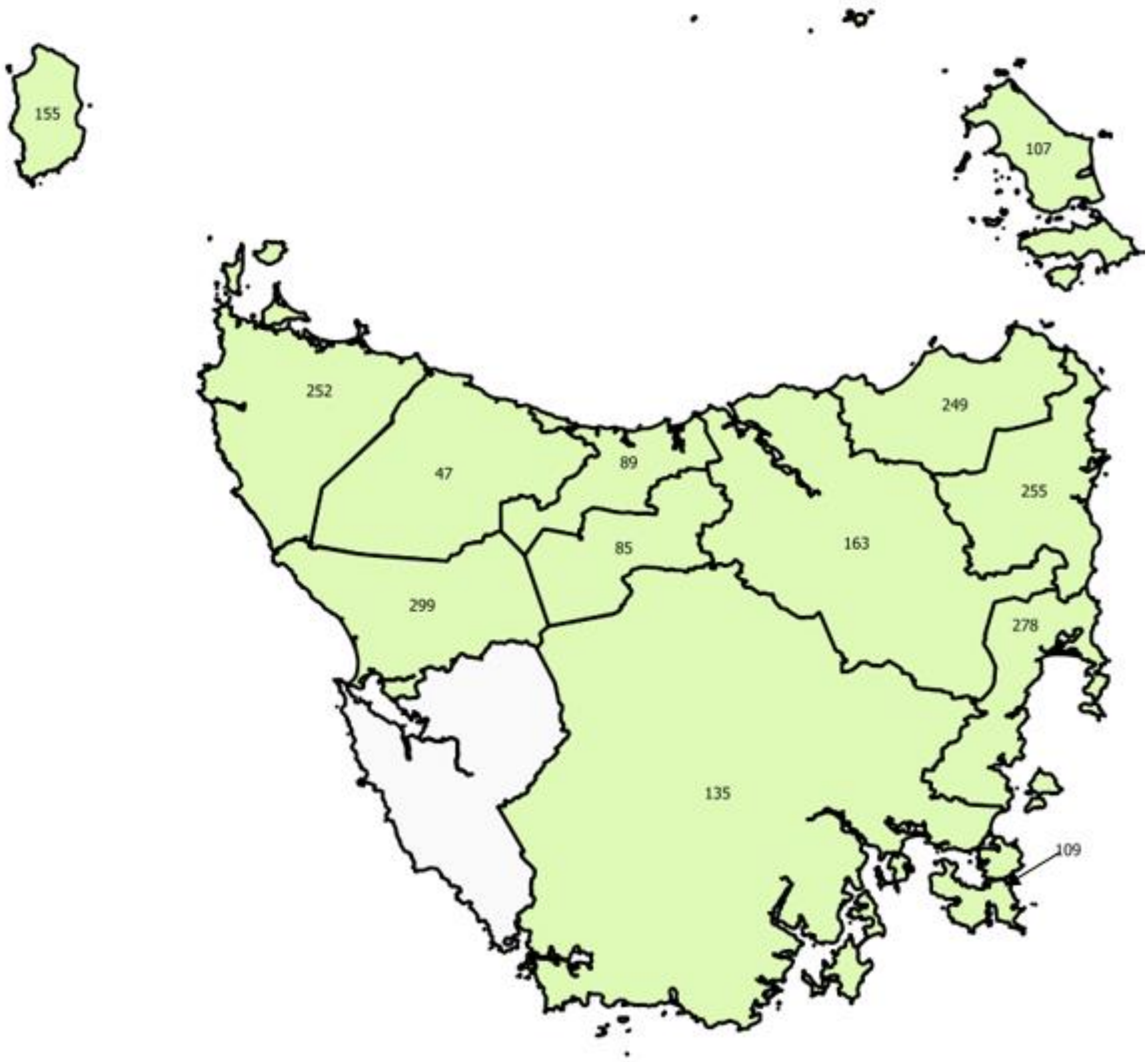
Source: BITRE analysis of ABS 2016a.

Figure H.4 Western Australia WZs



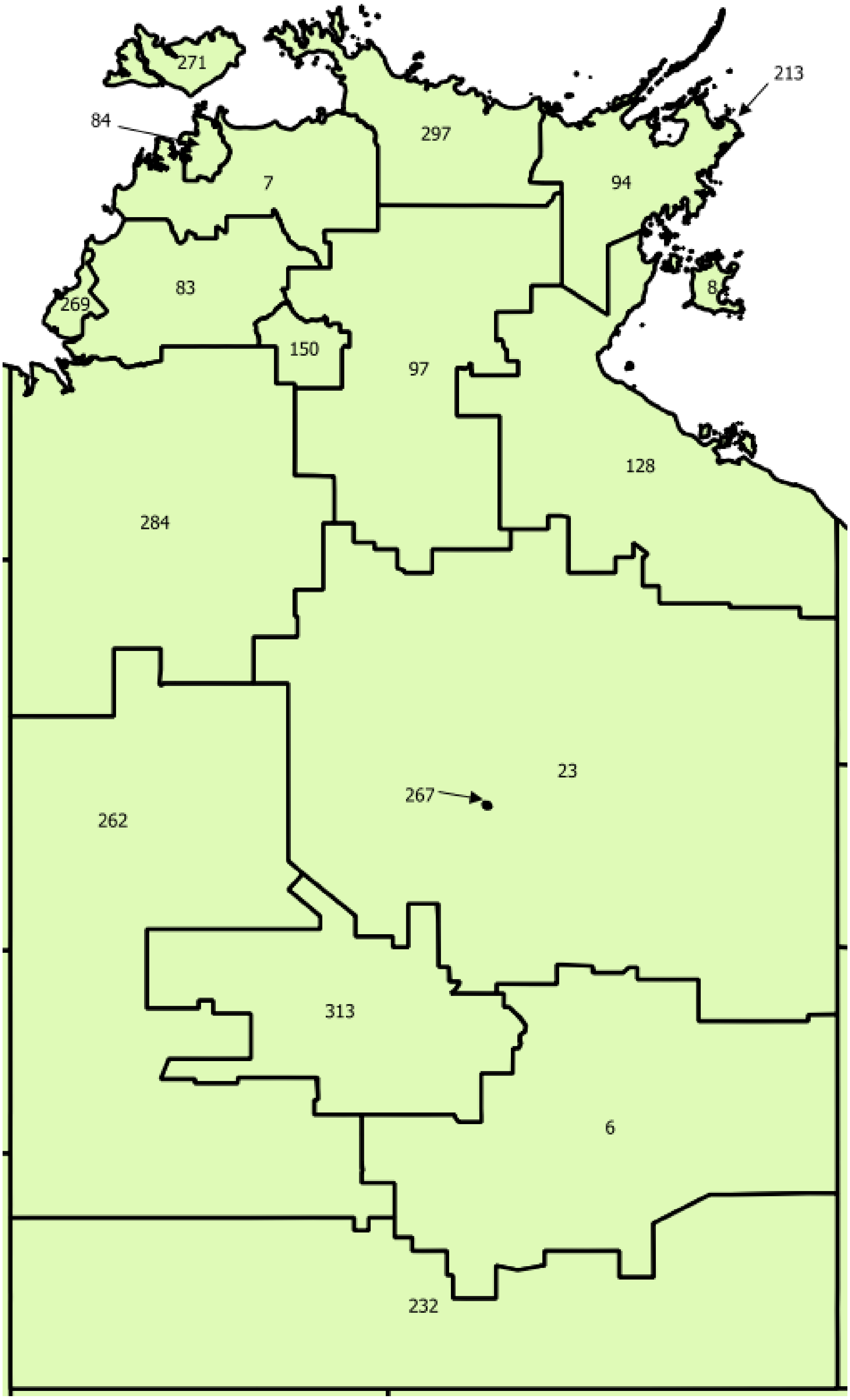
Source: BITRE analysis of ABS 2016a.

Figure H.5 Tasmania WZs



Source: BITRE analysis of ABS 2016a.

Figure H.6 Northern Territory WZs



Source: BITRE analysis of ABS 2016a.

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