Department of
Agriculture and Food
GOVERNMENT OF
WESTERN AUSTRALIA

Identification of high quality agricultural land in the Mid West region:
Stage 1 – Geraldton Planning Region

Second edition

Resource management technical report 386

Supporting your success

Identification of high quality agricultural land in the Mid West region:

Stage 1 – Geraldton planning region

Second edition, replaces
Resource management technical report 384

Resource management
technical report 386

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April 2013

ISSN 1039–7205

Cover photo: Young wheat crop growing on the rich alluvial soils of the Greenough flats.
(Photo: A. Stuart-Street,)

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Acknowledgments

This project has been a multi-agency and multidisciplinary activity and would not have been possible without the generous assistance and feedback from numerous people.

First, we would like to acknowledge the funding for the project provided through the Western Australian Planning Commission by the State Natural Resource Management Program and support provided by the Department of Planning.

The shires involved in this pilot study have provided excellent guidance to the study team to allow us to fit this information into the planning structure. Of particular note are Murray Connell and Andrew Outhwaite, (City of Greater Geraldton); Simon Lancaster and Katherine Jackson, (Shire of Chapman Valley); Hayley Williams (Shire of Northampton); Glen Coaker (Shire of Irwin); Tom Hartman (Shire of Mullewa); and Mike Kendall (Mid West Development Commission).

The Department of Water kindly supplied support and data to assist our project outcomes. Regional-based staff who provided input were Natalie Lauritsen, Craig Scott and Katherine Bozanich, with support from acting Regional Managers Adam Maskew and Katrina Burton. Perth-based staff assisting the project were Laz Leonhard, Sheryl Ryan, Trudy Evans and Chris O'Boy.

Department of Agriculture and Food (DAFWA) staff across all industry areas have been very generous with information, constructive reviews and feedback. Regional staff John Bruce, Peter Gardiner and Ross Upchurch provided support and assistance with GIS program analysis, datasets and software. John Bruce also undertook the land use mapping for the project area.

Regional DAFWA agronomists from the Geraldton office, Andrew Blake, Peter Newman, Rob Grima, Wayne Parker and Marty Harries, reviewed the broadacre agriculture methodology and capability. Planfarm agronomy consultant, Peter Elliot-Lockhart, also provided feedback on the broadacre relative yield mapping.

The DAFWA Hydrology Group, particularly Paul Raper and Russell Speed, as well as Jessica Horstman, Bob Paul, Adele Kendle, Don Bennett and Richard George, assisted with groundwater information and feedback.

The DAFWA Irrigated Agriculture Group, including Rohan Prince, Helen Ramsay, Alec McCarthy, Chris Schelfhout, Manju Radhakrishnan and Allan McKay, gave feedback on irrigation and horticulture potential estimates. Regional economist Peter Gartrell provided input on horticulture assumptions and James Hagen assisted with wheat. Graham Annan assisted with statistical data for the shires.

Peer reviews of sections of the document were carried out by Russell Speed, Mike Clarke, Andrew Blake, Heather Percy, Paul Galloway, Paul Raper, Peter Gardiner, John Bruce, Miriam Lang, Melanie Strawbridge, Peter Gartrell (DAFWA), the Department of Planning, Simon Lancaster, (Shire of Chapman Valley), Hayley Williams (Shire of Northampton), Murray Connell (City of Greater Geraldton), Glen Coaker (Shire of Irwin), and Nat Lauritsen and Trudy Evans (Department of Water). The first edition of the report was edited by Kerry Coyle. This edition was edited by Angela Massenbauer.

Thanks also to Heather Percy for direction and input throughout the project.

The authors gratefully acknowledge the support of all who assisted.

Executive summary

Background and objectives

The future economic development of agriculture is highly reliant on the availability of two crucial natural resources—land and water. Broadacre agriculture requires continued access to large areas of good quality land receiving enough reliable rainfall to produce crops and pastures. Irrigated agriculture needs smaller areas of suitable land but these must be matched with good supplies of water for irrigation, both to preserve existing production and to allow for expansion. Both industries need land with the greatest capacity for flexibility to continually meet the challenge of changing markets and consumer tastes.

Population growth projections mean that we in Australia need to plan for global agricultural requirements. Federal, state and local governments all have their role to play in supporting the continued availability of these resources for agriculture to meet future needs. To ensure the right decisions are made, governments require good quality information about the nature and distribution of these natural resources and their potential.

This project has developed a methodology to identify high quality agricultural land (HQAL) that exhibits a combination of qualities that are valuable to the agricultural industry and worthy of protection for production into the future. This is a pilot project, done at a regional and local scale, for the Geraldton planning region (the Region) within the Mid West.

The methodology is an innovative approach—combining both land and water resources into one outcome—which has been developed to achieve this goal and has injected scientific rigour into the process. The HQAL approach supports the vision of the Department of Agriculture and Food (DAFWA) for a progressive, innovative and profitable agriculture and food sector that benefits WA by ensuring land and water resources meet future industry needs. This vision is fostered by developing strong networks in policy development for water allocation and land use planning with other government agencies.

Current and projected value of agriculture in the Region

The average annual value of the broadacre industry in the Region over the past decade is about $268 million. Irrigated agriculture was valued at about $4 million annually over the same period. This project identified some areas with larger properties and land parcels with water resources and good soils that may be well suited for large-scale irrigation development, as well as numerous smaller properties suited to smaller scale intensive development. Two areas of Unallocated Crown Land with good water and areas of suitable soil with potential for the establishment of horticultural precincts have also been identified.

Additional to these values are the opportunity costs associated with the protection of HQAL. The highest quality agricultural land identified by using this methodology is expected to generate the highest yields and highest returns while incurring minimal or lower costs by avoiding or mitigating environmental damage. Maintaining production in better areas reduces management costs, and economic benefits are realised by limiting environmental degradation due to the lower level of environmental risk in these locations.

The High Quality Agricultural Land (HQAL) approach

The HQAL approach generates not one, but a series of maps and accompanying tables which depict and characterise agricultural land in a way that planners and investors can readily understand. Outputs include relatively detailed maps showing the Region's potential for broadacre and irrigated agriculture, derived from existing information on soils, land capability, water resources and rainfall.

The maps of agricultural potential were the basis for defining Agricultural land areas (ALAs) across the Region. ALAs were generated by subjectively defining reasonably homogeneous units in terms of irrigated and broadacre productive potential, as well as soils, landforms and property sizes. ALAs allow discrete areas to be identified at a suitable scale for strategic planning as well as allowing these areas to be described and characterised. This report contains a two-page information sheet for each ALA that describes its location, characteristics and agricultural importance, as well as listing the opportunities and constraints of each ALA.

Each ALA was then ranked in terms of its potential for both broadacre and irrigated agriculture, using criteria such as yield and water resources. Finally, the ALAs were grouped according to the level of versatility (Figure A).

Securing land and water for agriculture through land use planning

The challenge for planning is how to set aside the most productive and versatile areas of agricultural land identified in this pilot project for long-term food security to meet the needs of projected global, national and state population growth. Planners need to consider the opportunity cost of removing significant land and water resources from future agricultural development. It is important to protect areas of existing production as well as areas that have potential for future development. Climate change, shrinking water resources, increasing urban growth and projected population increases are all competing factors.

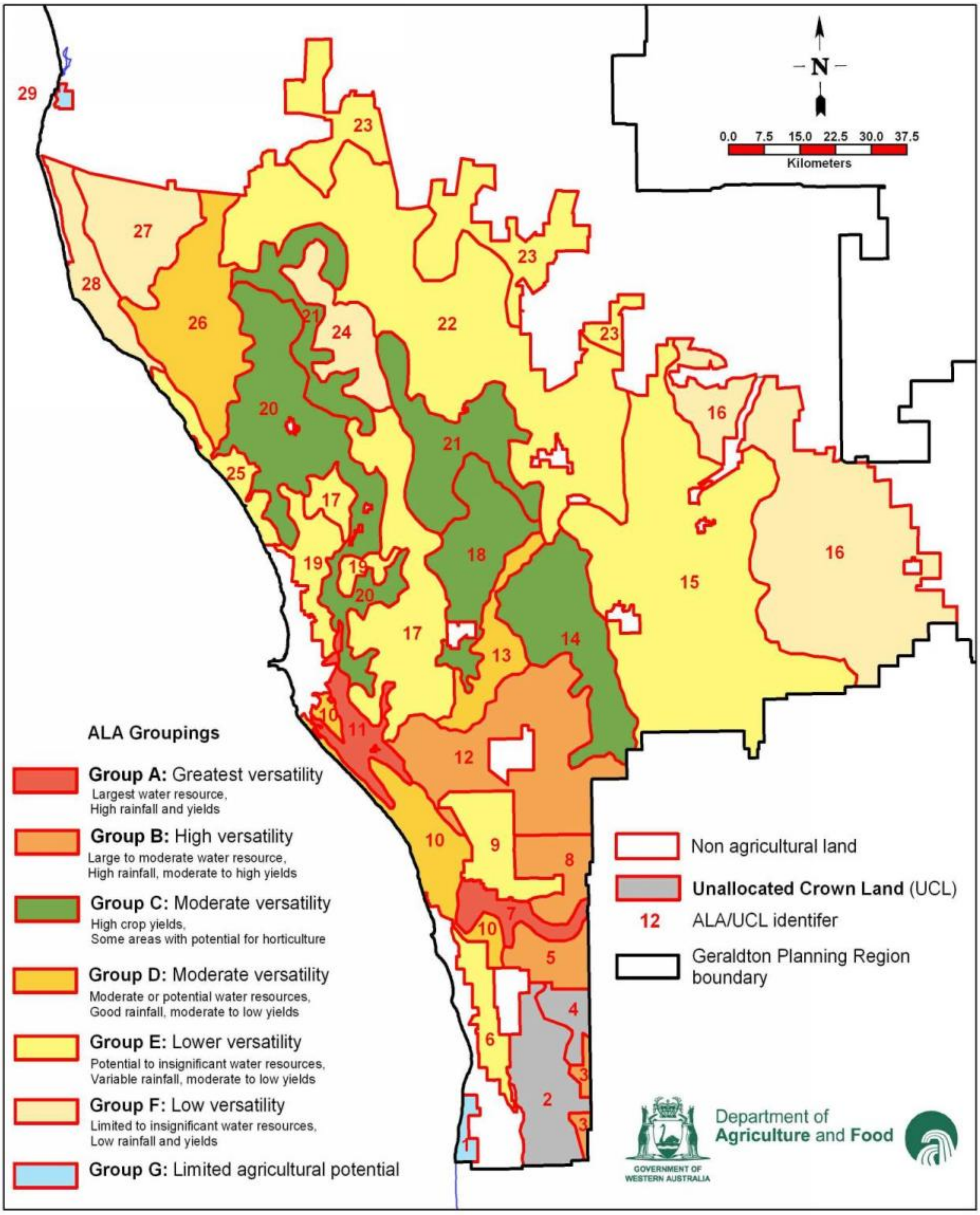

Figure A **Grouping of Agricultural land areas in the Geraldton planning region**

1. Introduction

The concept behind identifying areas of high quality agricultural land (HQAL) is much like highlighting areas of ecological importance or water supply sources. In some instances, land use planning policies and legislation have provided an opportunity for the protection of the unique qualities and special values these areas possess. Protection is also provided to areas of significant mineral resources. Recognition and protection of important areas of agricultural land, however, has been far less robust. This process is about clearly identifying agricultural land that exhibits a combination of special qualities making it valuable to the agricultural industry and worthy of protection for production into the future.

This pilot project is based in the Geraldton planning region (the Region), part of the Mid West region of WA.[1] It includes the shires of Northampton, Chapman Valley and Irwin, as well as the newly formed City of Greater Geraldton (Figure 1.1).[2] It covers an area of 2.88 million hectares. Fifty-seven per cent of the Region is part of the agricultural district.[3] The remainder comprises pastoral leasehold (station country) or urban development. Agricultural activities occur on 49 per cent of the land within the project area.

The purpose of this project is to develop and test a methodology for identifying areas of HQAL at a regional and local planning scale within the Region. The aim is to synthesise a range of land capability, water resource and other data related to land use into a format that is easy to comprehend and incorporate into the planning process. The link to the underlying information should also remain accessible and transparent.

The information presented here will provide justification and background for the identified Agricultural land areas (ALAs) of high value to receive priority consideration for protection in regional and local land use plans. It is important that careful planning is in place at the local level to protect the land and water required for maintaining a strong agricultural industry into the future.

This approach is anticipated to be used for the other subregions of the Mid West and it can also be used for other local government areas in the agricultural regions of WA.

The first edition of this report (Resource Management Technical Report 384) was updated after an error was identified in the calculation of the water requirements for the Tomato/Melon rotation (Table 3.22). This error also flowed into other calculations and while correcting the error did not greatly alter the total water requirements and dollar values from those presented in the first edition, and does not impact on the overall findings, it does affect data throughout the remainder of the report. The irrigation water requirements and irrigated crop dollar values in the first edition are now redundant and only data from this second edition should be used. Other minor editorial changes have also been made to this second edition.

[1] The Geraldton planning region was established in the most recent Geraldton Region Plan (Western Australian Planning Commission 1999). It includes the shires of the Batavia Coast subregion with the former Shire of Mullewa.

[2] The City of Greater Geraldton incorporates the former shires of Mullewa and Greenough.

[3] The cleared area of land used for broadacre or intensive agriculture in the south-west of WA.

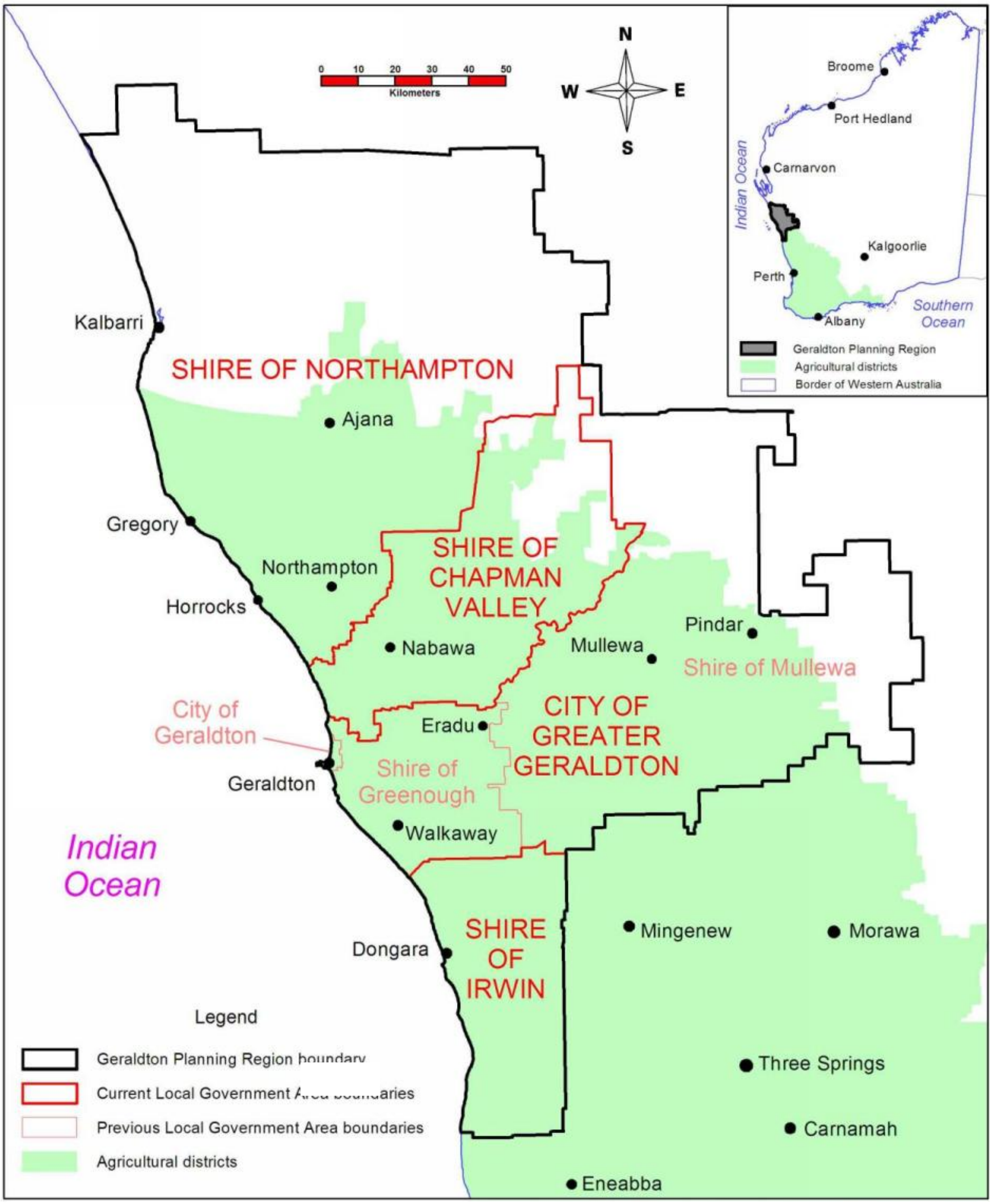

Figure 1.1 **Local government areas of the Geraldton planning region**[4]

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4 Figure 1.1 displays the current local government area boundaries as well as the previous boundaries of the City of Geraldton, Shire of Greenough and Shire of Mullewa that were amalgamated in 2011 to create the City of Greater Geraldton.

1.1 Planning context

Statement of Planning Policy (SPP) 2.5 *Agricultural and Rural Land Use Planning,* gazetted in 2002, states that 'productive agricultural land is a finite National and State resource that must be conserved and managed for the longer term' (Government Gazette WA 2002, p. 1009).[5]

In consultation with industry and farming groups, DAFWA prepared four plans to support industry development for the grains, livestock, food and horticulture industries (DAFWA 2009a, 2009b). A common theme across these plans was the need to provide unconstrained areas of suitable land and water resources to meet the needs of current and future agriculture and food industries. The impact of urban encroachment on existing agribusiness, competition for water and land, and the need to reduce 'red tape' in the approvals process were common issues.

The requirements set out in DAFWA's industry plans are supported by SPP 2.5. DAFWA is working toward identifying demand, trends (such as the expansion of the table grape industry in the Mid West), markets, issues (such as the yield gap in crop production for the higher rainfall shires of Northampton and Chapman Valley), and resources to achieve these goals.

Following a review of the state's rural planning policies, the Western Australian Planning Commission (WAPC) released a draft version of SPP 2.5 renamed *Land use planning in rural areas* for public comment in March 2011 (WAPC 2011). The revised policy has a broader mandate for rural land use planning but retains the protection of agricultural land as a key objective. The draft SPP 2.5 uses the term 'Priority Agricultural Land' which is defined as (p.14):

> Land considered to be of State significance for agricultural purposes due to its collaborative advantages in terms of soils, climate, water (rain or irrigation) and access to services.

Agriculture is considered a key industry by local government authorities within the Region. The authorities acknowledge the requirement to better identify the state, regional and local significance of agricultural land. This project will assist them to protect good quality land through various zoning provisions of local planning schemes. Their planning strategies recognise that existing agricultural areas need to be protected from non-agricultural land use and environmental degradation (Shire of Chapman Valley 2008; Shire of Northampton 2008; Shire of Irwin 2007; City of Geraldton–Greenough 2008).

1.2 Prime, priority or high quality agricultural land?

Identifying important areas of agricultural land is not a new idea. DAFWA documented the requirement to define and identify prime agricultural land in the 1980s. Read (1988) introduced the concept of 'prime agricultural land' in a discussion around the idea of protecting these areas in WA. Information from this report was included in the Western Australian Planning Commission's DC 3.4 Rural Land Use Policy (1992).

The definition compiled by Read (1988, p. 13) included agronomic and environmental factors, but also considered additional details such as infrastructure and the significance of relative location. By 2002 the concept of 'prime agricultural land' had evolved into the term 'priority agricultural land' (SPP 2.5) based on further input from DAFWA (Kininmonth 2000). Essentially, this term was derived from agricultural areas of state or regional significance and was recommended as a zone in town planning schemes to clearly identify and protect such areas.

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5 Although originally gazetted as Statement of Planning Policy 11, this policy is now referred to as SPP 2.5.

In 2009, van Gool and Tille developed a methodology for mapping priority agricultural land, (unpublished DAFWA report) which became the precursor to this project. This methodology was designed to overcome difficulties with incorporating multiple layers of land capability information into the planning process.

The term ‘priority agricultural land’, however, suggested that the mapped information developed by DAFWA provided some level of prioritisation, which is misleading—land areas are prioritised at a higher level by planners at state, regional and local levels. The data provided by DAFWA is just one crucial step in providing information to planners about the relative importance or quality of areas of land to the agricultural industry. Consequently, this project developed the HQAL approach, in which HQAL is defined as:

> Areas of land identified from a combination of soil, land capability, water resource and rainfall data as the most productive and versatile for either irrigated or broadacre agriculture.

There may be some confusion between the terms HQAL and priority agricultural land. Essentially, HQAL identifies the best available land with access to water for agriculture in an area. Priority agricultural land gathers information about land and water availability and combines it with social and economic requirements for the agricultural industry such as distance to market, labour availability and infrastructure. The combination of information is used by planners and helps to determine the relative importance of different areas on a broader state and regional scale.

Many components need to be considered for HQAL to be clearly identified. These include:

- soils and landforms
- land capability
- rainfall for broadacre agriculture
- groundwater and surface water supplies for irrigated agriculture.

As part of this project, we analysed current crop performance across the Region and attempted some predictions in relation to potential trends in the agricultural industry. In the areas of the Region with few groundwater resources, the emphasis is on broadacre cropping—where relative wheat yields are related to growing season rainfall—along with land resources. In areas of moderate to good groundwater allocations, horticultural production becomes more of a focus. When the rainfall and groundwater information is combined with land capability, the areas of higher production potential become more obvious.

Consequently, this project has two themes of land use that focus on agricultural potential and require access to good quality land and water:

- irrigated agriculture
- broadacre cropping.

Land flexibility is also a very important consideration in this approach. Some land may have a high capability for one particular crop or land use but poorer capability for other crops or uses. At times, when a particular crop is popular, the high-capability land may be seen as the most valuable in a region. However, once that crop ceases to perform so well in the marketplace (which is almost inevitable given the cyclical nature of agricultural markets), that land will be seen as a less valuable resource in comparison to land more suited to other crops that are performing well.

1.3 Existing interpretive mapping

Before this project, areas of high quality land were identified by the Department of Agriculture as part of the *Geraldton rural-residential land capability study* (Dye et al. 1990) (Figure 1.2). This capability study was undertaken in response to the State Planning Commission's review of the *Geraldton Region planning study* (GRPSG 1976). The review 'identified a need to assess the existing and potential value of rural activities'.

Detailed soil-landscape mapping (1:50 000 scale) was completed on the outskirts of Geraldton, with local agricultural advisers selecting four of the map units as high quality land. This selection process was not directly related to the land capability ratings assigned to the map units (Dye et al. 1990). The map of high quality land was designed for incorporation into the Geraldton Region Plan (State Planning Commission 1989).[6]

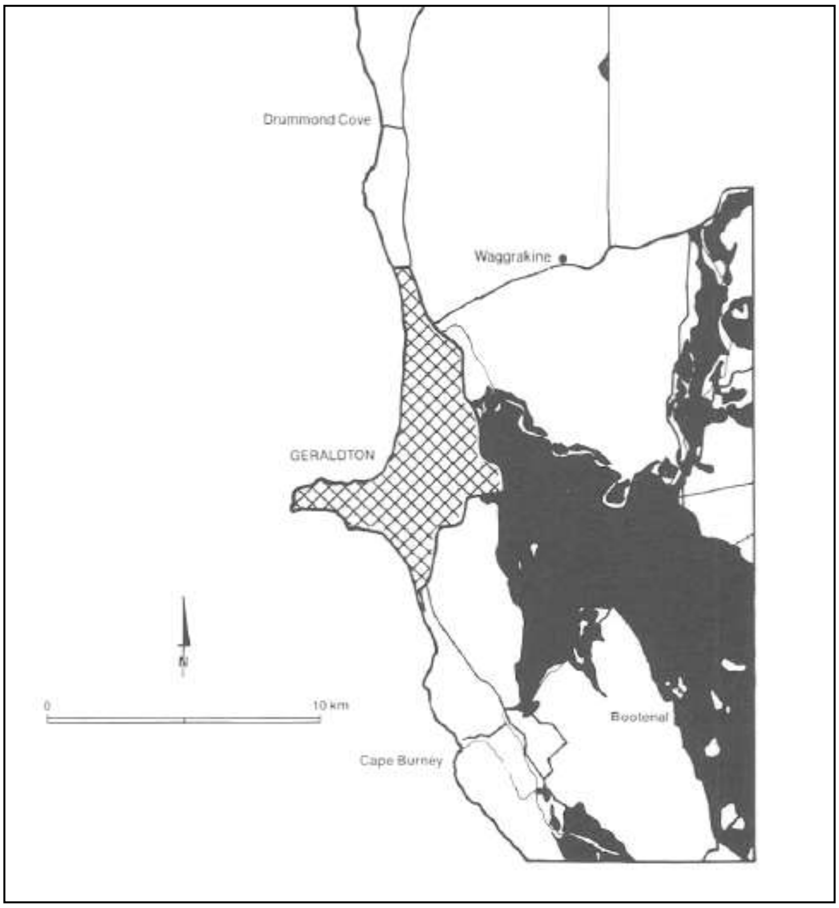

Figure 1.2 **Areas of high quality land (identified in black) on the outskirts of Geraldton. Source: Dye et al. (1990, p. 27).**

In 1992 an interpretive map of the agricultural quality of land in the Shire of Irwin was prepared from draft soil-landscape mapping at a scale of 1:250 000 (Rogers & Frost 1992). This map was incorporated into the shire's Local Planning Strategy as Map 5 (Shire of Irwin 2007).

Following these earlier examples, two different styles of maps showing land of agricultural significance within the Region were developed and have been publicly available for a number of years. These maps exist at dramatically different scales—a complex style and a simplified

6 Figure 1.2 does not actually appear in the 1989 Geraldton Region Plan, as only preliminary mapping from the capability study was available at the time. This mapping, while less detailed, shows the same areas.

style. Both styles have serious limitations when it comes to providing input to the planning process.

The complex style of mapping is based on land capability analyses of DAFWA's soil-landscape mapping (Schoknecht et al. 2004).[7] The map presented in Figure 1.2 shows an early simplified example of this, without the capability analysis component.

More recent examples of the complex style of mapping can be accessed through DAFWA's web page for the Shared Land Information Platform Natural Resource Management (SLIP NRM) program (DAFWA 2012). Here, separate maps of the same area are presented for a variety of land uses (Figure 1.3). Each map is colour-coded according to the proportion of Class 1, 2, 3, 4 and 5 land within each of the soil-landscape mapping units in the manner described by van Gool et al. (2005). By using the SLIP NRM information mapping interface, it is possible to 'drill down' and discover more detail about the individual map unit descriptions and the assumptions on which the capability analyses are based.

While the complex style of mapping can be quite useful when examining individual parcels of land, there are problems in its use for broader scale planning (state, regional or local level) such as:

- The mapping can appear very intricate when viewed at a broad scale, resulting in the big picture getting lost in the detail.
- The capability legend is complex and can be difficult to interpret.
- Assimilating the information provided by a number of different capability maps into a coherent overview of the 'best land' is conceptually difficult.

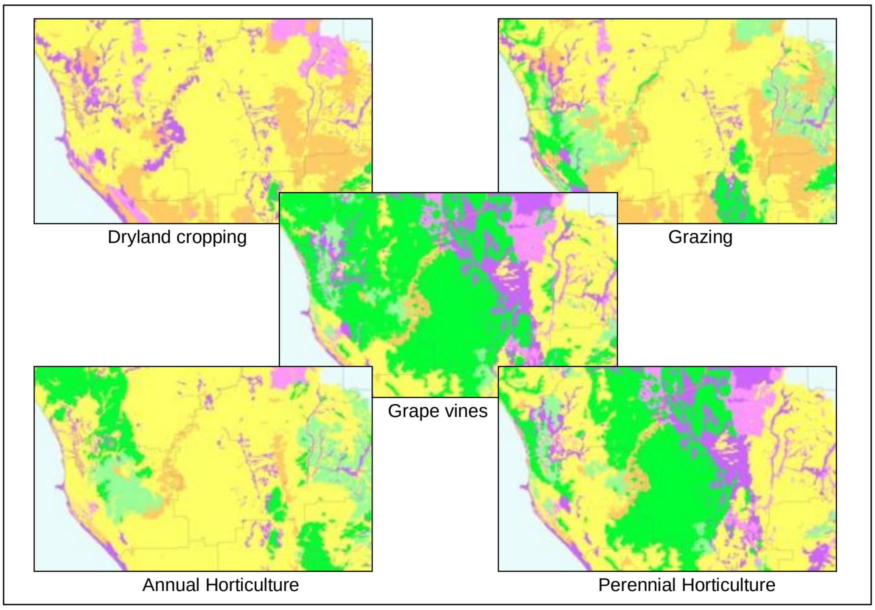

Figure 1.3 **Examples of land capability maps for different land uses. The green areas have the highest capability, yellow and orange are moderate, and purple areas show the lowest capability. Source: SLIP NRM info mapping interface (DAFWA 2011), accessed October 2011.**

7 The scale of this mapping ranges from 1:50 000 to 1:250 000.

At the other end of the scale, the simplified style of mapping identifies Agricultural Priority Management Areas as part of the 2002 SPP 2.5.

The areas identified using the methodology described by Kininmonth (2000) were to be a focus for further detailed investigations to identify land of state and regional significance. Figure 1.4 illustrates the areas identified for the Mid West. During this process, map areas could be expanded or reduced, removed or added as required. The intent was to adjust the Agricultural Priority Management Areas using more detailed or local information where it is readily available. This project provides an opportunity to review mapping for part of the Mid West region.

The map in Figure 1.4 was produced at a very broad scale[8] and, in contrast to the complex mapping described above, this mapping is too simple to be of great use. It only exists as an A4-sized map and difficulties have been experienced when planners have tried to apply this mapping at a regional or local level of planning. In addition, the map is information poor. The three areas shown within the Region are named but not described, other than being placed into one of two categories—existing areas or potential/developing areas.

Neither style of mapping adequately addresses the issue of water resources (rainfall, surface storage or groundwater) that are of such crucial importance to agriculture.[9] Although some of the Agricultural Priority Management Area boundaries appear to have been drawn with reference to the complex style of mapping, there is no direct linkage between the two. This can lead to conflicting interpretations, especially when the complex mapping is updated.

Finally, the assumptions underlying both styles of mapping required review (some of the capability maps shown in Figure 1.3 have errors due to reasons described in s 3.1.1). Neither the simple nor the complex styles of mapping have been readily translated into local, strategic or planning schemes in the Region.

Because of the scale at which this current analysis has been conducted, it is envisaged that HQAL identification will be more suitable to inform local planning strategies and schemes as well as subregional and regional scale assessments and strategies.

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[8] A scale of approximately 1:2 000 000.

[9] Potential water resources were probably considered in identifying the Agricultural Priority Management Areas in Figure 1.4.

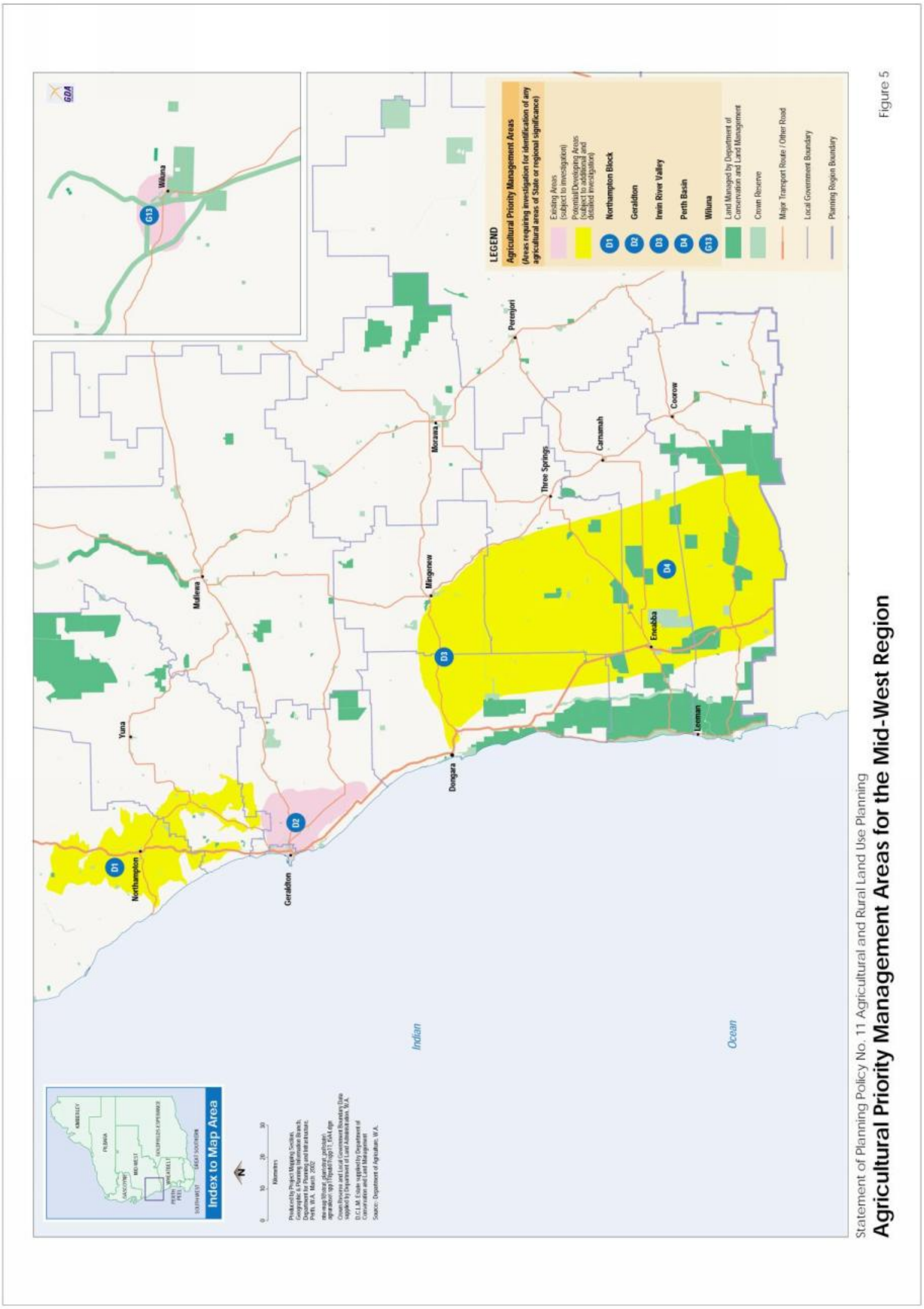


Figure 1.4 **Agricultural Priority Management Areas in the Mid West region. Source: WAPC (2002).**

1.4 The HQAL approach

The approach taken to identify HQAL retains the concept of the two styles of interpretive mapping (described in s 1.3), while incorporating information on water resources (both rainfall and groundwater) with the information on land resources (soil-landscape mapping).

The aim was to reduce the number of complex-style maps, while making the simplified style of mapping more definitive. A direct link between the two styles has been created with the simplified style mapping being derived from the complex style mapping.

In the complex style, the multiple maps showing capability for a variety of land uses have been combined to produce two maps of agricultural potential—one for broadacre agriculture and one for irrigated agriculture. These are described in more detail in s 3.3.1 and s 3.3.2.

Broadacre agriculture encompasses the production of rain-fed field crops (such as wheat, canola, lupins and field peas) as well as raising livestock on rain-fed pastures. Irrigated agriculture tends to be a much more intensive form of production in which horticultural and other crops (such as fruit, vegetables and flowers) are grown with water delivered through irrigation systems (usually sprinklers and drippers).

Both types of agriculture were assessed and mapped separately for the following reasons:

- importance of groundwater supplies to irrigated agriculture compared to broadacre agriculture's sole reliance on rainfall
- likelihood that irrigated agriculture will only ever be likely to occupy a tiny fraction of the region while the bulk of cleared land will remain under broadacre agriculture
- greater variety of production systems falling under the umbrella of irrigated agriculture
- significantly higher monetary value of production of irrigated agriculture on a per hectare basis.

For the simplified style, a map of Agricultural land areas (ALAs) has been created along with a two-page information sheet describing each of the areas identified. This simplified map has been derived from the complex-style maps showing the potential of broadacre and irrigated agricultural areas.

The concept of ALAs was developed during this project and is intended to present broad areas of land that have similar characteristics in terms of rainfall, landform, soils, groundwater supplies and agricultural potential. The similar characteristics often indicate a degree of uniformity in terms of land use patterns and farming systems. These characteristics have also influenced the history of agricultural development, which in turn creates some uniformity in property and lot sizes.

These maps of agricultural potential and ALAs can be used together or separately. The simplified style of mapping provides a broad overview of the Region and highlights the areas of greatest agricultural significance. The accompanying information sheets are designed to assist the planning process, providing information on the natural resources and agricultural potential of each of the ALAs, along with some estimates of their potential economic value.

In addition to providing the basis for the simplified map and accompanying information sheets, the agricultural potential maps can be viewed as stand-alone maps. They provide a visually more complex overview of the Region and can also be used when making planning assessments on a more localised scale. The agricultural potential maps can also inform planners to determine zoning boundaries by matching the land resource boundaries to the most appropriate cadastral data.

Section 5 of this report presents a ranking and a grouping of the ALAs to illustrate agricultural significance. The highest quality agricultural land combines the following characteristics:

- soil-landscapes with a very high capability for irrigated agriculture
- significant volumes of good quality groundwater
- soil-landscapes with a very high capability for broadacre agriculture
- relatively high and reliable growing season rainfall.

It is these areas that are the most productive and versatile for a range of agricultural enterprises. Areas with good potential for irrigated agriculture, but which are not as productive under broadacre cropping, are still ranked in the highest grouping because of the higher value of horticultural produce.

Digital copies of the agricultural potential maps held by DAFWA also provide a link to the underlying map unit and land capability data.

Looking towards the Moresby Range from the Kojarena area in the City of Greater Geraldton

2. Study area

2.1 Local government authorities in the Region

The four local government authorities in the Geraldton planning region are the Shire of Northampton, the Shire of Chapman Valley, the City of Greater Geraldton and the Shire of Irwin.

Northampton – The Shire of Northampton is at the north of the Region. It is bounded by the Indian Ocean on the west and by the shires of Chapman Valley, Shark Bay and Murchison. It contains the townsites of Northampton, Kalbarri, Gregory, Binnu, Ajana, Isseka and Lynton as well as the localities of Horrocks and the Hutt River Province. The main administration centre is in Northampton.

Chapman Valley – The Shire of Chapman Valley is north of the City of Greater Geraldton. It is bounded on the west by the Indian Ocean, on the north by the Shire of Northampton, on the east by the Shire of Murchison and on the south by the City of Greater Geraldton. It contains the townsites of Nanson, Nabawa and Yuna. The main administration centre is in Nabawa.

City of Greater Geraldton – Located in the centre of the Region, the City of Greater Geraldton is bounded by the Indian Ocean on the west, and the shires of Chapman Valley, Murchison, Yalgoo, Morawa, Mingenew and Irwin. It contains the regional city of Geraldton and townsites of Mullewa, Pindar, Tardun, Tenindewa, Wilroy and Narngulu as well as the localities of Drummond Cove, Cape Burney, Walkaway and Greenough. The main administration centre is in Geraldton.

Irwin – The Shire of Irwin is located in the south-west corner of the Region. It is bounded by the Indian Ocean on the west, the City of Greater Geraldton and the shires of Mingenew, Three Springs and Carnamah. It contains the townsites of Dongara, Port Denison and Irwin. The main administration centre is in Dongara.

2.1.1 Agricultural industry in the Region

The Geraldton planning region covers 2 884 000 ha (28 884 sq km) and about 49 per cent of the area is used for broadacre cropping, grazing, horticulture or other agricultural activities (Table 2.1).

The 'leaning trees' at Greenough (River red gums) are a local icon.

Table 2.1 **Summary of local government information and area used for agriculture**

Local Government Area	Population*	Total size '000 ha	Area within agricultural district[†] '000 ha	Agricultural properties[‡] Area '000 ha	Agricultural properties[‡] Proportion of LGA %
Chapman Valley	1 060	398	312	294	74
Geraldton–Greenough[§]	39 370	178	178	146	82
Irwin	3 660	237	237	145	61
Mullewa[§]	900	811	494	474	58
Northampton	3 570	1 260	431	401	32
Total	**46 560**	**2 884**	**1 652**	**1 460**	**51**

* Australian Bureau of Statistics 2010 population data.

† See footnote text 3 on p. 1.

‡ Based on property activities recorded on CRIS data (s 3.1.4), extracted April 2011; excludes areas of road, town and conservation reserves.

§ Data is for the former Shire of Mullewa and former City of Geraldton–Greenough, now districts within the City of Greater Geraldton.

Agriculture is a significant industry for the Mid West. According to the Department of Regional Development and Lands (2011), in 2008–09 the gross value of agriculture for the Mid-West Planning Region was $872 million—second only to the mining industry. Agriculture (with forestry and fishing) is the largest employer in the region with 12.4 per cent of the total workforce—almost twice that of the mining industry (6.7 per cent).

The total value of agricultural production for the Geraldton planning region in 2008–09 was estimated at $418.7 million, almost 6 per cent of the state's total (Table 2.2). Summaries of the value of agricultural crops, livestock and animal products for local governments in the Region (inside the clearing line) are provided in Tables 2.2, 2.3 and 2.4.[10] Details of the national, state and regional significance of the agricultural industry for the Region are presented in s 4.1 and s 4.2.

Hay production on the Greenough Flats, between Geraldton and Dongara

10 The clearing line is a boundary between the land cleared for intensive or broadacre agriculture (freehold land) in the south-west and the uncleared pastoral or rangeland country (leasehold land) to the north and east. It corresponds roughly to the 300 mm rainfall isohyet and runs through the shires of Northampton, Chapman Valley and Mullewa (see Figure 1.1).

Table 2.2 **Estimated total value of agricultural production (2008–09) by local government area, and area of land used for different types of agricultural production**

Local Government Area	Total value of agricultural production (2008–09) $'000	Land used for broadacre agriculture* %	Land used for grazing %	Land used for horticulture %
Mullewa†	123 196	91	69	0.0
Chapman Valley	109 069	86	80	0.5
Northampton	104 718	83	87	0.6
Geraldton–Greenough	47 052	61	86	0.2
Irwin	34 691	50	77	0.03
Total	**418 726**			

* Proportion of properties cleared for broadacre agriculture within the agricultural districts, including areas of remnant vegetation on properties.

† Data is for the former local government area of Mullewa, now a district within the City of Greater Geraldton.

Sources: ABS (2010) and Graham Annan (DAFWA, pers. comm, 2011).

Agricultural activity here is mainly cereal production—dominantly wheat—in rotation with lupins and canola. Other legumes, such as chickpeas and field peas, are grown, mainly in eastern areas. Mullewa district (within the City of Greater Geraldton) and the Shire of Chapman Valley have the largest area of cereals (about 176 000 ha and 121 000 ha respectively in 2008–09).

According to ABS data (accessed 2010), Shire of Irwin and Greenough district (within the City of Greater Geraldton) have the largest vegetable and fruit growing areas with 47 ha and 29 ha respectively planted to vegetables, and 85 ha and 36 ha planted for fruit production in 2008–09. Even though these areas are probably underestimates, horticulture in the Region remains on a small scale. The main irrigated agricultural crops grown include olives, citrus, stone fruit, carob, melons, mangoes, sweet corn, zucchinis, tomatoes and cucumbers (Patterson 2005). Shire of Chapman Valley and Greenough district have the main areas of table grape production.

Table 2.3 **Estimated values of agricultural crops by local government area for 2008–09**

Local government area	Cereals $'000	Legumes $'000	Canola $'000	Vegetables $'000	Fruit $'000	Grapes $'000
Chapman Valley	76 448	10 112	8 811	215	231	19
Geraldton–Greenough	19 837	4 081	6 887	2 947	630	15
Irwin	13 288	4 540	2 257	779	214	n.a.†
Mullewa*	98 296	9 569	7 472	n.a	n.a.	n.a.
Northampton	68 596	12 672	6 269	343	18	n.a.
Total	**276 465**	**40 974**	**31 696**	**4 284**	**1 093**	**34**

* Data is for the former Shire of Mullewa, now a district within the City of Greater Geraldton.

† No information recorded for that land use.

Sources: ABS (2010) and Graham Annan (DAFWA, pers. comm. 2011).

Livestock numbers have been reduced over the past decade due to poor seasons affecting pasture growth in many areas. However, they are still prominent in the mix of many agricultural businesses. In 2007–08 the Shires of Irwin, Chapman Valley and the City of

Geraldton–Greenough had dominant numbers of beef cattle, while the Shire of Northampton had the greatest numbers of sheep and lambs.

Table 2.4 **Estimated value of livestock sales and animal products by local government area for 2007–08**

Local Government Area	Beef cattle sales $'000	Sheep sales $'000	Animal products* $'000
Chapman Valley	5 481	2 390	2 556
Geraldton–Greenough	4 181	1 517	4 261
Irwin	9 624	1 232	1 286
Mullewa†	688	1 518	2 017
Northampton	2 295	3 378	6 882
Total	**22 269**	**10 035**	**17 002**

* Animal products exclude meat—dominantly wool (also includes eggs).

† Data is for the former Local Government Area of Mullewa, now a district within the City of Greater Geraldton.

Sources: ABS (2010) and Graham Annan (DAFWA, pers. comm. 2011).

Grape vines at Chapman Valley Winery

2.2 Land and water resources

2.2.1 Climate

The climate of the Region is semi-arid Mediterranean with mild wet winters and warm to hot, dry summers. The long-term annual average rainfall decreases from just below 500 mm at the north-west of the study area to just over 300 mm inland at Mullewa. June and July usually receive the highest rainfall. Most of the rain relied upon by broadacre agriculture falls during the 'winter' months (April to October).

Comparisons of long-term average rainfall and the average rainfall received over the past decade (2000–09) show a considerable reduction in annual and 'winter' rainfall in all areas (Table 2.5).

Table 2.5 **Mean annual and 'winter' rainfall over the long-term in comparison with the past decade, 2000–09. Adapted from Bureau of Meteorology (2011)**

Location	Period of rainfall records years	Long-term average annual rainfall mm	Average annual rainfall 2000–09 mm	Decline in annual rainfall %	Long-term 'winter' rainfall (Apr–Oct) mm	Average 'winter' rainfall 2000–09 mm	Decline in 'winter' rainfall %
Northampton	1882–2010	486	397	18.3	440	360	18.2
Nabawa	1905–2010	445	358	19.6	396	304	23.2
Geraldton Airport	1941–2010	443	355	19.7	401	321	20.0
Mullewa	1896–2010	334	248	25.8	270	204	24.4
Dongara	1884–2010	457	347	24.1	417	311	25.4

Summer is normally dry, apart from scattered and irregular thunderstorms or rain from the formation of troughs and moist air from the north-west. Additionally, there are very infrequent events from decaying tropical cyclones.

Growing season rainfall comprises this 'winter' rain in combination with a portion of the rain from preceding months that is assumed to be stored soil moisture (see s 3.3.1 for more details). Average growing season rainfall isohyets for 2000–09 are presented in Figure 3.5.

January is generally the hottest month of the year, except on the coast, where the development of heat troughs in February brings even warmer temperatures. Average daily maximum temperatures range from 32 °C on the coast to 37 °C inland. July is the coldest month with the average daily minimum temperatures ranging from 9 °C on the coast to 7 °C inland. There is a risk of frosts in winter and early spring, although they are not common. The risk of frost increases from the coast to the inland areas: Geraldton averages less than one frost per year; Mullewa two; and Northampton and Nabawa three (Rogers 1996).

The strong south-south-west sea breeze that is part of the summer wind pattern is a feature on the coast. This arrives between 10 am and noon, and can reach 25–28 knots. The sea breeze can move considerable distances inland, often reaching Mullewa by early evening. Winter winds are more variable and are influenced by the movement of cold fronts coming in from the Indian Ocean. The dominant winds are from the east to north-west before the cold fronts. Behind the fronts, the cool, moist winds are generally west to south-west.

Evaporation increases in a north-easterly direction from about 2400 mm per annum at the coast in the south, to 2800 mm per annum in the north and east.

2.2.2 Geology

The geology for the Region is described in detail by Speed (2005a, 2012) and Rogers (1996). The following information is summarised from those reports.

The area has five distinct geological regions. Two of these are crystalline bedrock: first, the Yilgarn Craton on the eastern margin of the area, bounded by the Darling Fault which runs north-south just to the west of Mullewa; and second, the Northampton Block, which is a gneissic inlier stretching north from the vicinity of Walkaway to beyond Northampton. The Northampton Block is partially capped in the west by thin sequences of Jurassic sediments that form the flat-topped Moresby Range near Geraldton.

About 20 km west of the Darling Fault is another fault, the Urella Fault, which runs virtually parallel to the Darling Fault. Between the two faults is a narrow sedimentary basin that is part of the larger Perth Basin, called the Irwin Terrace. This area is noted separately as it is dominated by Permian clay sediments. The remainder of the Perth Basin that lies to the west of the Urella Fault is a deep trough containing sedimentary rocks. This area is characterised by undulating upland and coastal sandplains.

To the north-east of the Northampton Block is the northern-most extent of the Perth Basin. This area is known as the Coolcalalaya sub-basin and consists of Tumblagooda Sandstone. It is a gently undulating sandplain with linear dune ridges and a relict drainage network—a thin sequence of alluvium and colluvium over calcrete and red-brown hardpans. In the north-western corner, extending from the vicinity of Horrocks Beach and across to the western boundary of the Northampton Block, is another area of sedimentary rock which forms the southern portion of the Carnarvon Basin. This area also consists of Tumblagooda Sandstone, partially capped by thin sequences of Mesozoic sediments. It appears as a sandplain plateau dissected by the Hutt River.

2.2.3 Groundwater

This section is a brief summary of the occurrence of groundwater resources in the Region. More detail is presented in s 3.1.3.

The Perth Basin lying west of the Urella Fault and south of the Northampton Block contains significant groundwater resources in large regional aquifers (Speed 2005b). This area is described by the Department of Water (2010) as part of the Arrowsmith Groundwater Area. It covers the northern-most extent of the northern Perth Basin, from Geraldton to Green Head and east to Coorow.

The Arrowsmith Groundwater Area contains sedimentary aquifers and fractured rock aquifer systems. The regional aquifers mainly used for groundwater are the Yarragadee and Leederville–Parmelia. Other sedimentary aquifers are localised and have lower yields, making them less viable. The superficial aquifer is unconfined and widely used for stock, mining and horticulture. Details about the Arrowsmith Groundwater Area are provided by the Department of Water (2010).

Groundwater subareas of the Gascoyne Groundwater Area (lying to the north of Geraldton) include the Casuarinas, Mullewa/Byro, Northampton/Gelena and Yuna/Eradu (Department of Water [DoW] resource allocation database 2010). The hydrogeology for the remaining project area is summarised from Speed (2005b, 2012). On the Yilgarn Craton to the east of the Darling Fault, the yield and quality of groundwater is variable but typically low and of poor quality. Useful supplies of stock-quality water can be obtained higher in the landscape but, generally, the groundwater of valley floors is too saline to be of use.

Groundwater in the Irwin Terrace is typically very saline with negligible yield. This area has very poor hydraulic characteristics due to the clayey Permian sediments.

The Northampton Block has diverse occurrences of groundwater but supplies are limited and typically discrete. It is generally found in fractured rock and the gritty clay saprolite profile. Groundwater also is found in a palaeochannel associated with the Chapman River, and in relict sandplain areas of the Victoria Plateau and underlying Jurassic sediments.

Groundwater supplies of the Carnarvon Basin may be significant in the Tumblagooda Sandstone. Little information is currently available about this area, however, and further investigation is needed.

2.2.4 Soil-landscapes

Soil-landscape zones

Soil-landscape zones are regional units based on geomorphologic or geological criteria (Schoknecht et al. 2004). Eleven have been identified in this Region (Figure 2.1, Table 2.6).

The crystalline basement and eroded sedimentary rock of the Chapman zone (225) is distinct in the Region, associated with the geology of the Northampton Block. The moderately dissected landscape of the Kalbarri Sandplain zone (232) is located in the north-west of the Region. Fringing the coastline along the west of the Kalbarri Sandplain zone are the dunes, cliffs and alluvial plains of the Port Gregory zone (231).

To the south of the Port Gregory zone, the coast is characterised by the undulating dunes, alluvial plains and limestone hills of the Geraldton Coastal zone (221). Extensive sandplain landscapes are a feature of this area. To the east of the Chapman zone are the gently inclined slopes and dune ridges of the Northern Victoria Sandplain zone (223), which is bordered to the south by the alluvial valley slopes and sandplain remnants of the Tenindewa zone (227). To the west of the Tenindewa zone is the undulating and poorly dissected Southern Victoria Sandplain zone (220). Residual sandplain, breakaways and plateau remnants skirt the sandplains. This area is the northern limit of the Arrowsmith zone (224).

Lying between the sandplain landscapes and the Darling Fault are the river valleys and sediments of the Lockier zone (226). To the east of the Darling Fault is the undulating terrain on crystalline basement of the Irwin River zone (271), influenced by the geology of the Yilgarn Craton.

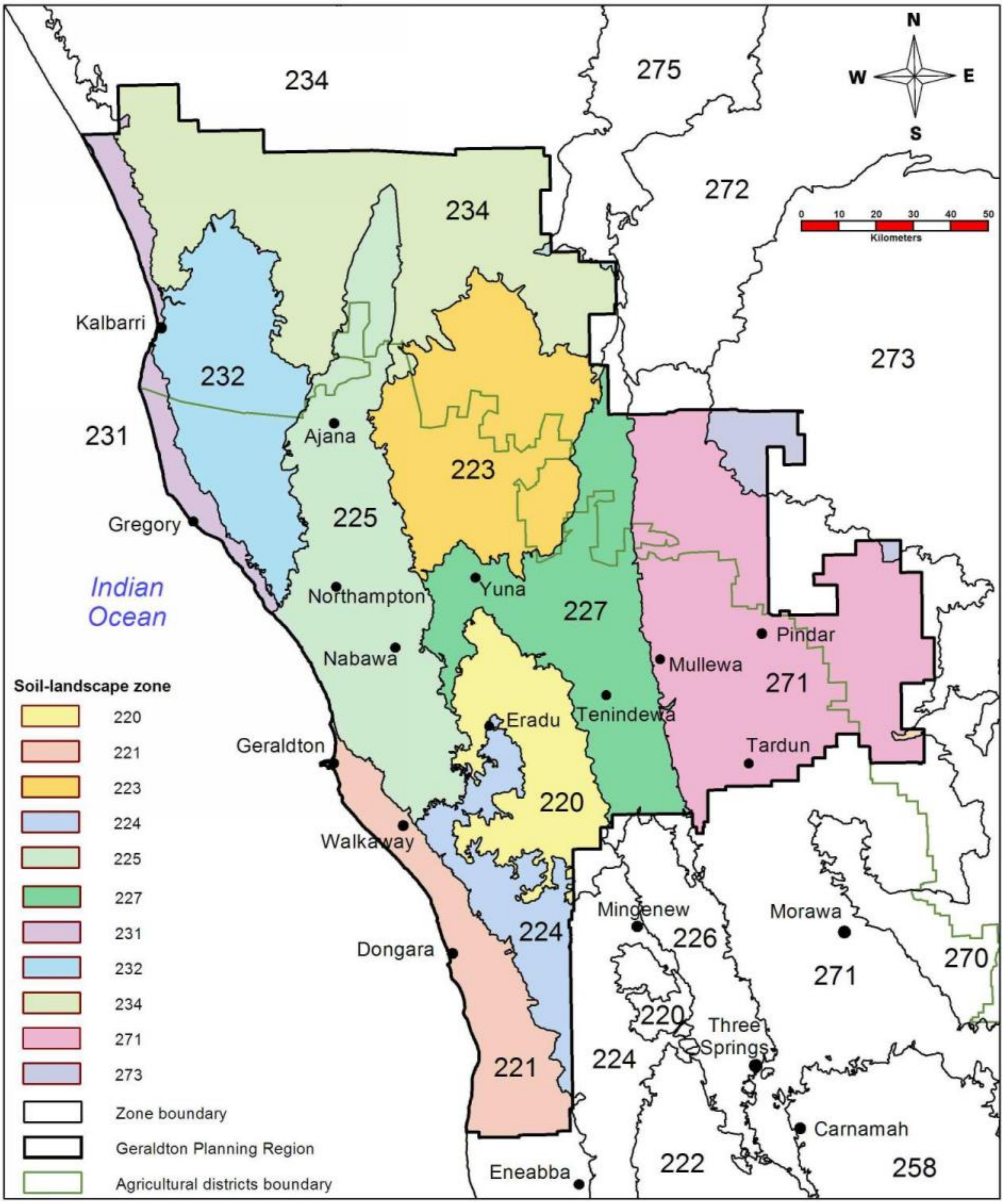


Figure 2.1 **Soil-landscape zones of the Geraldton planning region**

Table 2.6 **Descriptions of soil-landscape zones of the Geraldton planning region**

Soil-landscape zone		Description	Area within Region ha
220	Southern Victoria Sandplain	Gently undulating, weakly dissected sandplain on in-situ weathered Yarragadee sandstone and alluvium. Yellow deep sands with Pale deep sands over gravel. Minor areas of lateritic duricrust occur.	174 500
221	Geraldton Coastal	Low hills of Tamala limestone, recent calcareous and siliceous dunes with alluvial plains and sand sheets. Mainly shallow and deep sands with some Loamy and Sandy earths.	175 700
223	Northern Victoria Sandplain	Weakly dissected sandplain with dune ridges on deeply weathered Carboniferous, Permian and Silurian Perth Basin sedimentary rocks. Yellow deep sands are dominant with some Red deep sand and Red-brown hardpan shallow loams.	234 000
224	Arrowsmith	Dissected lateritic terrain with hills, breakaways, plateau and sandplain remnants on colluvium and deeply weathered mantle over sedimentary rocks. Soils are mainly Pale deep sand (often gravelly), Yellow deep sand, Deep sandy gravel and Grey deep sandy duplex.	132 000
225	Chapman	Mesas on undulating crystalline basement rock with numerous dolerite dykes. Dissected terrain with hills, breakaways, plateau and sandplain remnants. Soils are loamy and sandy duplexes, deep sands, loamy earths and shallow loams.	398 300
227	Tenindewa	Alluvial valley slopes and sandplain remnants with relict hardpan wash plains; on Permian and Carboniferous sedimentary rocks of the Perth Basin. Yellow deep sand and Red-brown hardpan shallow loams with some Yellow and Red sandy earths.	312 000
231	Port Gregory Coastal	Coastal dunes, sea cliffs, undulating sandplain and alluvial plains. Deep and shallow sands are prominent and mainly calcareous.	71 800
232	Kalbarri Sandplain	Moderately dissected undulating sandplain with laterite remnants on sediments of the Carnarvon Basin. Deep sands, Ironstone gravels and Sandy duplexes.	252 900
234	Victoria Red Sandplain	Sandplains with occasional dunes on Quaternary deposits over Permian, Carboniferous and Cretaceous Carnarvon Basin sedimentary rocks in the south-western Gascoyne. Red deep sands are dominant.	489 500
271	Irwin River	The Irwin and upper Lockier catchments within the undulating Yilgarn Craton. Archaean granites, gneisses, metasediments and basic igneous rocks. Soils are shallow loams with loamy and sandy earths, deep sands and sandy duplex.	507 500
273	Yalgoo Plains	Hardpan wash plains (with some sandplains, stony plains, mesas and granite outcrops) on granitic rocks of the Yilgarn Craton. Soils are mainly Red loamy earths and Red shallow loams with Red deep and shallow sands and Red shallow sandy duplex soils.	42 000

WA Soil Groups

Soils across the Region have been classified into WA Soil Groups (Schoknecht 2002). Associated with the extensive sandplain landscapes prominent in the Region, deep sands are prevalent. Yellow deep sand in particular is the dominant soil type. Table 2.7 outlines the dominant and minor soils for each local government area.

Table 2.7 **Dominant and minor WA Soil Groups in each Local Government Area**

Local Government Area	Dominant soil	Minor soils
Chapman Valley	Yellow deep sand	Red shallow loamy duplex; Red-brown hardpan shallow loam
Greenough*	Yellow deep sand	Pale deep sand; Red shallow duplex (sandy & loamy)
City of Geraldton*	Red deep loamy duplex	Yellow deep sand; Calcareous deep sand
Irwin	Yellow deep sand & Pale deep sand	Yellow/brown shallow sand; Calcareous shallow sand
Mullewa*	Yellow deep sand	Red-brown hardpan shallow loam; Red shallow sand
Northampton	Yellow deep sand	Pale deep sand; Red shallow duplex (sandy & loamy)

* Pre-amalgamation Local Government Area boundaries. The City of Geraldton, Shire of Greenough and Shire of Mullewa were amalgamated in 2011 to create the City of Greater Geraldton.

2.2.5 Land degradation risks

A significant limitation to agriculture in most areas is the potential for land degradation. Erosion, acidification, soil compaction and other forms of degradation affect large expanses of the state at a huge cost to farmers and communities.

Interrogation of DAFWA's Map Unit and SoilCalc databases (2012) provides an assessment of areas of degradation hazards for land classed as available for agriculture in the Region, summarised on a local government area basis (Table 2.8). The assessments are based on data collated from regional land resource surveys available from DAFWA (s 3.1.1).

The data in Table 2.8 suggests that susceptibility to subsurface acidification, wind erosion and subsurface compaction are the most widespread land degradation hazards in all shires. Water repellence and soil structure decline are also common issues with land management.

Further information about land degradation hazards on agricultural land and the methodology for the data generation is provided in van Gool et al. (2005, 2008).

Table 2.8 **Percentage estimates of land degradation hazards on land cleared for agriculture for each shire**

	Northampton %			Chapman Valley %			Geraldton–Greenough %			Mullewa %			Irwin %		
Degradation hazard*	**N–L**	**Mod.**	**High**	**N–L**	**Mod.**	**High**	**N–L**	**Mod.**	**High**	**N–L**	**Mod.**	**High**	**N–L**	**Mod.**	**High**
Water repellence	45	39	16	66	29	5	51	30	19	58	38	3	13	45	42
Soil structure decline	71	15	14	67	20	13	62	32	6	53	24	23	95	5	0
Subsurface compaction	13	53	34	6	36	58	11	46	43	5	51	44	6	80	14
Susceptibility to subsurface acidification	6	21	72	2	11	86	18	26	56	6	9	86	20	20	60
Wind erosion†	32	29	39	33	25	42	40	17	42	43	19	38	6	21	73
Water erosion†	77	17	6	83	13	4	66	24	10	94	5	1	81	16	3
Salinity risk‡	98	0	2	98	1	1	100	0	0	95	1	5	100	0	0
Waterlogging	98	0	2	98	1	0	97	2	0	95	4	1	97	3	0

* Degradation hazard categories: N–L = nil to low; Mod. = moderate; High.

† High category includes very high and extreme hazard data.

‡ High category includes estimates of presently saline land.

Source: DAFWA’s Map Unit and SoilCalc Databases (2012).

3. Methods used to evaluate HQAL

The identification of high quality agricultural land (HQAL) in the Region involved creating two styles of interpretive maps (s 1.4). The simplified map of ALAs was derived from two complex-style agricultural potential maps: one showing the potential for broadacre agriculture; the other showing the potential for irrigated agriculture.

Creating the agricultural potential maps involved conducting land capability analyses of the available land resource data across the Region. These analyses were then combined with data on the Region's water resources: rainfall for the map of broadacre agricultural potential; and groundwater resources for the map of irrigated agricultural potential.

These two maps were then used to define the boundaries of, and describe, the ALAs. A number of other datasets (including remnant vegetation, and cadastral and zoning datasets) also informed this process.

The methodology used to identify HQAL is detailed in the following sections:

- Section 3.1 covers the various datasets used in the creation of the interpretive maps, along with some of the modifications made to improve the data quality.
- Section 3.2 covers the system of land capability analysis used.
- Section 3.3 covers the approach to identifying HQAL in more detail.
- Section 3.3.1 describes the creation of the map of broadacre agricultural potential.
- Section 3.3.2 describes the creation of the map of irrigated agricultural potential.
- Section 3.3.3 describes the creation of ALAs.

3.1 Datasets

A range of digital datasets was used to identify HQAL in the Region. These datasets, along with some of the modifications undertaken, are described below.

3.1.1 Land resource data

Land resource surveys

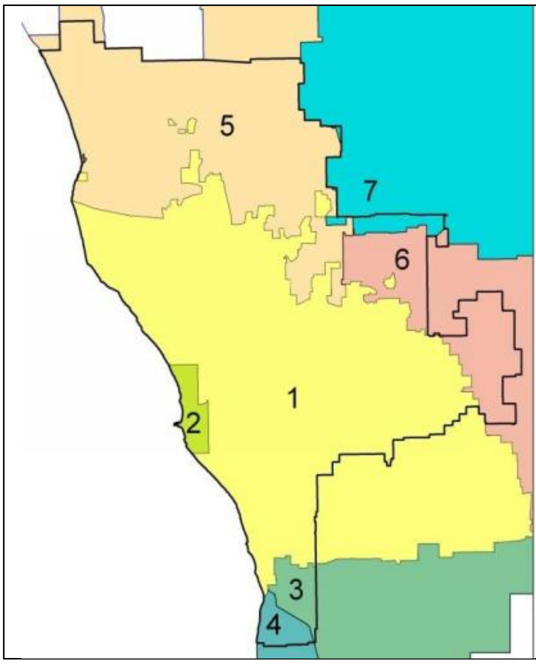
The land resource data used in this project was based on a number of soil-landscape mapping surveys undertaken by DAFWA (Figure 3.1). The surveys covering the agricultural districts within the project area include the:

- *Geraldton Region land resources survey* (Rogers 1996) at a scale of 1:250 000
- *Geraldton rural-residential land capability study* (Dye et al. 1990) at a scale of 1:50 000
- *Three Springs – Latham land resources survey* (Grose in prep.) at a scale of 1:250 000
- *North Coastal Plain land resources survey* (Schoknecht in prep.) at a scale of 1:100 000.

The bulk of the agricultural land is covered by Rogers (1996). In addition to the surveys listed above, the following rangeland surveys (all at a scale of 1:250 000), which fall partly within the Region and cover mostly pastoral land, were also used:

- Lower Murchison (Hennig 2009)
- Murchison River catchment (Curry et al. 1994)
- Sandstone – Yalgoo – Paynes Find (Payne et al. 1998).

The results of these surveys have been incorporated into DAFWA's soil-landscape datasets described by Schoknecht et al. (2004). These datasets include digital copies of the map unit boundaries with descriptions contained in the Map Unit Database.



1. *Geraldton Region land resources survey*
   1:250 000 scale
2. *Geraldton rural-residential land capability study*
   1:50 000 scale
3. *Three Springs – Latham land resources survey*
   1:250 000 scale
4. *North Coastal Plain land resources survey*
   1:100 000 scale
5. *Lower Murchison rangeland survey*
   1:250 000 scale
6. *Sandstone – Yalgoo – Paynes Find rangeland* survey
   1:250 000 scale
7. *Murchison River catchment rangeland survey*
   1:250 000 scale

Figure 3.1 **Soil-landscape surveys covering the Region**

Map unit boundaries were captured via MicroStation design files and are stored in MGE with links to ORACLE. The mapping is usually manipulated using Intergraph GeoMedia^{TM} warehouses. The map unit boundaries from the different surveys have been edge-matched to form (as far as possible) seamless mapping which involved some changes to the published mapping.

In 2004 and 2005, the overlapping (and often conflicting) boundaries of the Geraldton Region survey and the more detailed Geraldton rural-residential survey were correlated. During that process, the boundaries of the Geraldton Regional and Three Springs – Latham surveys were also edge-matched and some previously unmapped areas such as the Wandana Nature Reserve were completed.

Zone land units

At the scales listed above, there is considerable variation in terms of both soils and landforms within the boundaries of the mapped soil-landscape units. The map units have therefore been subdivided into a number of unmapped zone land units (ZLUs) that are suitable for mapping at a very detailed scale (for example, 1:5000). These ZLUs comprise a unique combination of landform and soil type and play an integral role in land capability assessment of the mapping (s 3.2).

A separate set of ZLUs has been created for each of the 31 soil-landscape zones mapped across the entire agricultural region of south-west Australia. Within each zone, the ZLUs consist of three components: a Soil Group of Western Australia (Schoknecht 2002); a Soil Group qualifier (Schoknecht 2002); and a landform position (van Gool et al. 2005).

In the Map Unit Database, the ZLUs are assigned to each soil-landscape mapping unit on a proportional basis. Table 3.1 shows the ZLUs assigned to the Northampton 1 soil-landscape map unit (225No_1) and Figure 3.2 presents a schematic representation of some of these ZLUs within the map unit. See Schoknecht et al. (2004) for more details about ZLUs and soil-landscape map units.

Table 3.1 **Component zone land units (ZLUs) of map unit 225No_1 (Northampton 1)**

Landform component	WA Soil Group component	Soil Group qualifier component	Dominant soil series[11]	Map unit proportion %
Crests & slopes (gradients < 3%)	Bare rock	—	rock outcrop	2
Crests & slopes (gradients < 3%)	Red loamy earth	rock substrate	Kojarena	2
Crests & slopes (gradients < 3%)	Red shallow loamy duplex	rock substrate	Northampton	5
Very gentle slopes (1–3%)	Red shallow loamy duplex	neutral subsoil	Northampton	5
Gentle slopes (3–5%)	Red loamy earth	rock substrate	Kojarena	3
Gentle slopes (3–5%)	Red shallow loamy duplex	rock substrate	Northampton	6
Gentle slopes (3–5%)	Red shallow loamy duplex	neutral subsoil	Northampton	12
Gentle slopes (3–5%)	Self-mulching cracking clay	neutral subsoil	Unnamed soils	5
Gentle slopes (5–10%)	Bare rock	—	rock outcrop	2
Gentle slopes (5–10%)	Red loamy earth	rock substrate	Kojarena	5
Gentle slopes (5–10%)	Red shallow loamy duplex	neutral subsoil	Northampton	14
Gentle slopes (5–10%)	Red shallow loamy duplex	rock substrate	Northampton	15
Gentle slopes (5–10%)	Self-mulching cracking clay	neutral subsoil	Unnamed soils	5
Moderate slopes (10–15%)	Red loamy earth	rock substrate	Kojarena	5
Moderate slopes (10–15%)	Red shallow loamy duplex	rock substrate	Northampton	6
Moderate slopes (15–30%)	Bare rock	—	rock outcrop	1
Moderate slopes (15–30%)	Red shallow loamy duplex	rock substrate	Northampton	5
Well-drained drainage depression	Red shallow loamy duplex	rock substrate	Northampton	2

While the soil series shown in Table 3.1 are not a formal part of the ZLU definitions, there is a field within the Map Unit Database allowing the relevant series to be recorded against the ZLU.

For the three rangeland surveys, only the WA Soil Groups have been allocated in the Map Unit Database at this stage. For these surveys, the Soil Group qualifier and landform components are simply recorded as ‘typical’.

The apparent detail of the ZLU allocations should not be allowed to mask the fact that they can only ever represent a simplification of the natural complexity occurring within the boundary of any map unit. Still, in most cases, the information in the Map Unit Database should present a reasonable description of reality on the ground.

While the proportional allocation of ZLUs to the closest one per cent in Table 3.1 may appear to imply a very high degree of accuracy, in reality these values are approximate only. While there is not enough site data available to assign soil groups to this degree of accuracy, database integrity requires the allocations to add up to 100 per cent and small allocations are included to highlight the presence of minor soil types and landforms.

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[11] Soil series are taxonomic units that define soil with a limited range of morphological, chemical, physical and mineralogical properties that can be managed as a single unit for most present and anticipated land uses (Schoknecht et al 2004).

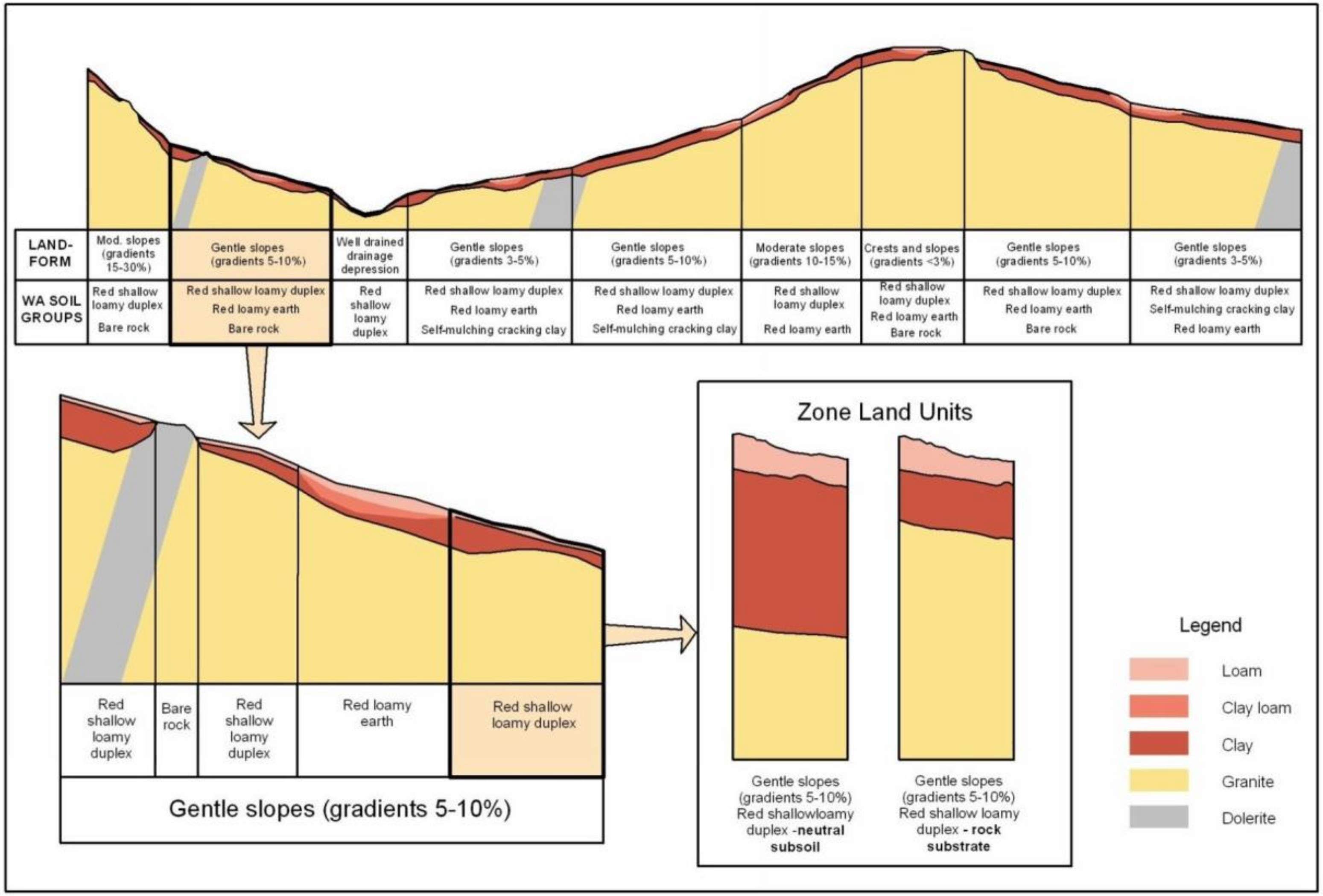

Figure 3.2 **Some zone land units (ZLUs) occurring within Northampton 1 map unit (225No_1)**

The soil-landscape surveys covering most of the Region were undertaken before the Map Unit Database was developed and the ZLUs were introduced. Consequently, in most cases, the person who allocated the ZLUs to the soil-landscape map units was a different person from the one who conducted the survey.

This ‘retro-fitting’ without the benefit of the original surveyors’ input was part of a rapid process to enter data into the database from as many surveys as possible. The results need to be viewed as a first approximation only. The following pages describe some of the modifications made to improve the quality of the ZLU data for the Region.

SoilCalc Database

The SoilCalc Database contains a large array of soil and landform information relating to the ZLUs, including soil layer properties, land characteristics and land quality data that are used in the assessment of land capability.

There are two types of data in the SoilCalc Database: primary data and modelled data. The primary data includes properties that are measurable and are attributed directly to the soil profile or landform. It includes soil layer properties (such as soil textures, pH, gravel content and bulk density) and land characteristics (such as slope gradients). The modelled data is derived from the primary data using pedotransfer functions. For example, soil layer texture and arrangement are used to derive values for hydraulic conductivity and plant available water content. These attributes could be directly measured but the data is currently not available.

The soil layer properties are attributed against modal soil profiles designed to correspond to the qualified Soil Group of WA (Schoknecht 2002) which is intended to represent a ‘typical’ profile. For each soil-landscape zone, a modal profile has been created for each qualified Soil Group present. Each profile consists of five layers extending over the top 200 cm.[12] Soil properties data is attributed to each of the layers.

For any individual attribute, only one value can be assigned to each soil layer for each of the qualified soil groups within a soil-landscape zone. Some of this primary soil layer data is derived directly from field data or laboratory analyses; the remainder is extrapolated from similar profiles. This primary data represents our current best estimates of typical or average values and can never encompass the full degree of natural variation. Further details on soil layer properties, land characteristics and land quality data in the SoilCalc Database can be found in Section 2 and Appendix 2 of van Gool et al. (2005).

Modifications to land resource data

Part of this project involved review of, and modifications to, the existing land resource datasets covering the portion of the Region falling within the agricultural districts. Some modifications involved further changes to the original mapping while others involved improving the contents of the Map Unit Database.

Alterations to soil-landscape map unit boundaries: The southern and south-western boundaries of the Chapman soil-landscape zone (Zone 255) were redefined to match the underlying geology of the Northampton Block. This resulted in the subdivision of some mapping units and the creation of some new soil-landscape subsystems and phases that were entered into the Map Unit Database.

[12] Schoknecht et al. (2004) and van Gool et al. (2005) refer to only four layers in these modal profiles. The fifth layer (typically located in the lower A horizon) has been added since these reports were published to fit in with national standards.

Review of landform component for ZLUs: Slope gradients are an important consideration in the assessment of land capability. For a number of map units, the landform component of the ZLUs recorded in the Map Unit Database did not accurately reflect gradients on the ground. The proportion of map units with steeper gradients was often underestimated. The boundaries of the map units were intersected with maps showing the slope gradient categories used in the Map Unit Database. These slope maps were derived from a digital elevation model (DEM) using elevation data created for the Land Monitor project. The resultant table showing the area of each slope gradient class within each map unit was used to update the landform component of the ZLUs in the Map Unit Database. In most cases, the database allocations now match the DEM categories to within a couple of percentage points.[13]

Review of soil component for ZLUs: WA Soil Group allocations (along with the Soil Group qualifiers) in the Map Unit Database were reviewed against information published in the Geraldton Region and Geraldton- Rural Residential survey reports. The unpublished draft of the Three Springs – Latham survey report was also consulted.

This process included assigning one or more qualified Soil Groups to each of the soil series or soil types described in the reports. This correlation was then used to check the soil component allocations in the database against the percentages shown in the reports. The landscape positions in which the soil series were reported as occurring were also checked.

Where there were discrepancies, the database allocations were adjusted, unless there was information in the Soil Profile Database (Schoknecht et al. 2004), or from local knowledge of DAFWA staff, to confirm the existing allocations. Changes were also made to reduce inconsistencies in soil component allocations between map units originating from adjoining surveys.

Review of zone soil layer properties: The soil layer properties occurring in the SoilCalc Database were reviewed for the soil-landscape zones occurring within the Region based on local experience and data collected, mostly over the past decade. Information in the Soil Profile Database also informed this review. The most significant alterations made were to soil layer depths; texture; arrangement; pH; and organic carbon content for the most common soil series, especially the sandplain soils. These alterations had a major impact on the modelled available water content data.

The process of reviewing the ZLU soil components and the zone soil layer properties also involved an examination of the capability rating for wheat production assigned to the map units (see s 3.2). When compared with the local knowledge of DAFWA staff, this provided an indication of where the proportional allocation of soils in the Map Unit Database, or the information in the SoilCalc Database, required alteration.

3.1.2 Climate data

Climate data was based on daily rainfall records held by the Bureau of Meteorology. Data is available from about 120 stations throughout the Region with some records dating back to the early 1900s. Of these stations, 55 are currently in operation and the remainder have only historical records available. Some of these stations have records covering short periods only.

Data from stations with long-term records have been extrapolated into the Patched Point Dataset by the Queensland Department of Primary Industries (Jeffrey et al. 2001).[14] There

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[13] The DEM slope maps are usually quite accurate except in areas of very low relief. Problems matching map units to the DEM models also exist for very small map units and for long, narrow map units such as those that occur along valley floors.

[14] Now the Queensland Department of Natural Resources and Mines.

are 44 stations used for the patched point dataset within the Region, with another 20 stations sitting just outside the Region. This has resulted in a grid within the Region comprising 3554 points, each about 2.65 km apart, for which daily rainfall and temperatures are interpolated from the closest BoM station.

3.1.3 Groundwater data

Digital copies of the boundaries of the Groundwater Areas (GWAs) and Groundwater Subareas (GWSAs) were obtained from the Department of Water (DoW) in Perth as ESRI shapefiles. Also obtained was an ArcView™ shapefile of aquifer boundaries within the Arrowsmith GWA. Aquifer boundaries for the Gascoyne GWA were obtained from another shapefile with the boundaries of aquifers within each GWSA. All of these shapefiles were transferred into GeoMedia™ Access™ warehouses.

The general licensing components of the groundwater allocation limits by GWSA and aquifer were obtained from the DoW in Perth as a spreadsheet. These data were extracted from the DoW licensing database as part of a Statewide Resource Allocation Report in May 2012.

3.1.4 CRIS property and client data

The DAFWA Client and Resource Information System (CRIS) contains a spatially-linked database of agricultural and other properties in WA to support its biosecurity and regulatory operations. The Client Property database contains property and parcel boundaries that can be interrogated and mapped through GeoMedia™ warehouses. Properties are based on amalgamations of one or more cadastral parcels as supplied by Landgate.[15,16] The data used in this project were based on parcel boundaries supplied by Landgate in 2009.

Parcel data includes area (ha), title owner and parcel address. Property data includes owners' and managers' details, and property and enterprise types (for example, agriculture). For each property, there is also information on primary and secondary activities (that is, crop types and livestock). Data on land ownership and enterprises is compiled from direct contact with landholders through an array of methods, such as mail-outs and attendance at field days.

3.1.5 Remnant vegetation mapping

Digital mapping of the extent of remnant vegetation across WA was prepared by the Department of Agriculture (Shepherd et al. 2002) as part of the National Land and Water Resources Audit (NWLRA).

The mapping shows the presence of remnant native vegetation on private and public land, including native vegetation on farmland, local government reserves, state forest and national parks. This mapping covers all types of remnant vegetation, including heaths, shrublands and native grasslands as well as forests and woodlands. It does not include timber plantations of native or introduced species.

The extent of remnant vegetation was originally compiled on a base of a pre-existing map of vegetative cover compiled from satellite imagery. This map has been modified over time and progressively updated since 2001 by DAFWA, with assistance from the Department of Environment and Conservation (DEC). The most recent revision of the remnant vegetation mapping was undertaken using 2006 digital orthophotography and is suitable for use at a scale of 1:20 000.

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[15] A 'property' is a land management unit defined as one or many contiguous parcels. Property boundary and ownership information is updated on a daily basis by DAFWA in the CRIS Client Property database.

[16] A 'parcel' is a legally defined area of land defined by Landgate's cadastral database. These are often referred to as 'lots'. Parcel data supplied by Landgate is updated twice a year.

3.1.6 Town planning scheme and public drinking water source area maps

ESRI shapefiles of the town planning schemes for the former City of Geraldton – Greenough and Shires of Chapman Valley, Irwin, Mullewa and Northampton were obtained from the Department of Planning in March 2011 (boundaries are prior to the amalgamation of the City of Geraldton – Greenough and the Shire of Mullewa). These files consisted of digital maps showing zoning of the land within the local government areas (into categories such as rural, general farming, small rural holdings, rural residential, residential, retail/business, industrial, and public purposes).

Murray Connell, Manager of Urban & Regional Development for the City of Greater Geraldton, assisted in updating the boundaries between rural and non-rural land on the outskirts of Geraldton.

ESRI shapefiles showing the boundaries and categories of Public Drinking Water Source Areas were obtained from the DoW.

3.1.7 Agricultural production statistics

The estimates of agricultural production used in this report are based on data collated by the Australian Bureau of Statistics (ABS). Agricultural census data were collected from landholders in 2000–01, 2005–06 and 2010–11. This data is available at various scales, with local government areas usually being the most detailed scale. Less intensive agricultural surveys are used by the ABS to extrapolate census data over the intervening years.

Graham Annan (Market Analyst, DAFWA) also provided information, using local knowledge of seasonal weather conditions and crop performance to make his own annual extrapolations of ABS agricultural census data on a local government basis.

Some of the production data presented in this report is sourced solely from the ABS. Much of this data can be viewed at the following website: <http://www.abs.gov.au/websitedbs/c311215.nsf/web/Agriculture>. Elsewhere data provided by Graham Annan has been used. Where this is the case, the data has been attributed to a combination of the ABS and Graham Annan.

3.2 Land capability assessment

The land capability assessments of the soil-landscape mapping units that formed an integral part of the process of identifying HQAL were based on the methodology described by van Gool et al. (2005). Some modifications were made to this methodology to meet the specific requirements of the process and to include land uses not covered by van Gool et al.

Capability classes are assigned to the unmapped ZLUs for individual land uses using a five-class rating system, ranging from Class 1 land (very high capability) to Class 5 land (very low capability) Table 3.2 presents the five capability classes that can be assigned to a ZLU.

Table 3.2 **Land capability classes**

Capability class	General description
1 – Very high	Very few physical limitations present and easily overcome. Risk of land degradation is negligible.
2 – High	Minor physical limitations affecting either productive land use and/or risk of degradation. Limitations overcome by careful planning.
3 – Fair	Moderate physical limitations significantly affecting productive land use and/or risk of degradation. Careful planning and conservation measures required.
4 – Low	High degree of physical limitation not easily overcome by standard development techniques and/or resulting in high risk of degradation. Extensive conservation measures required.
5 –Very low	Severe limitations. Use is usually prohibitive in terms of development costs or the associated risk of degradation.

Source: van Gool et al. (2005).

In the SoilCalc Database, values are assigned to each ZLU for a variety of land qualities that impact on land use. These land qualities include soil pH, soil water storage, salinity, and water erosion hazard. Each quality has a range of values, such as low (L), moderate (M) and high (H).

In capability ratings tables, the values for each land quality are assigned to one of the capability classes for a selected land use. Table 3.3 provides an example of a capability ratings table.

Table 3.3 **Capability ratings table for wheat – production only***

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Inherent fertility	VH, H, M	L	VL		
pH at 0–10 cm	Slac, N	Sac, Mac, Malk	Vsac	Salk	
pH at 15–25 cm	Slac, N	Mac, Malk	Sac, Salk	Vsac	
pH at 50–80 cm	Slac, N	Sac, Mac, Malk	Vsac, Salk		
Rooting depth	VD, D	M	MS		S, VS
Salt spray exposure	N			S	
Soil water storage (0–100 cm)	H, M	ML	L, VL	EL	
Soil water storage (0–50 cm)	H, M	ML, L	VL, EL		
Surface salinity	N	S		M,	H, E
Water repellence susceptibility	N, L	M, H			
Waterlogging / inundation risk	N	VL, L	M	H	VH

* Codes used in Table 3.3 are taken from van Gool et al. (2005) and are listed in Appendix B.

The quality values in the SoilCalc Database are cross-matched with a capability ratings table to determine the capability of the ZLU of that land quality for that land use. For example, if the land quality rooting depth is deep (D) or very deep (VD) for a ZLU, the wheat rating for rooting depth is Class 1. If the rooting depth is moderate (M), the rating is Class 2; if moderately shallow (MS), the rating is Class 3; and if shallow (S) or very shallow (VS), the rating is Class 5.

The overall capability rating for the ZLU is the lowest (most limiting) land quality rating. For example, if one land quality rates Class 4 and all the rest rates Class 1, the overall rating is Class 4. If all land qualities rate Class 4, the overall rating is still Class 4.

The proportion of ZLUs in each map unit then determines the proportion of that map unit having a very high, high, moderate, low or very low capability for the particular land use.

Modifications to capability assessment

The initial results of the land capability assessments tended to show the soils of grey sandplains (Pale deep sands, Gravelly pale deep sands and Grey deep sandy duplexes) rating as highly as those of the yellow sandplains (Yellow deep sands and Yellow sandy earths). This was despite the fact that the yellow sandplains consistently produce higher crop yields and are widely considered to be significantly better agricultural land.

Two main reasons for this discrepancy were identified. First, the land quality ‘soil water storage’ in van Gool et al. (2005) is calculated over the top metre of the profile. While most crops will extract water from this depth once established, the greatest density of roots is close to the surface.

On the sandplains of the northern wheatbelt, many soils have poor topsoil water-storage characteristics. Some of these have heavier textured subsoils that are capable of providing adequate moisture to crops in good seasons. In poorer seasons, however, the topsoil moisture storage may not be enough to allow crops to become properly established and extend their roots into the deeper subsoil. Moisture stored deeper in the subsoil is also not available to shallow-rooted pastures or vegetable crops.

Nutrition is another reason for poorer crop performance on the grey sandplains. Soil fertility was not covered by van Gool et al. (2005). The rationale for this was that soil nutrient status typically reflects the fertiliser history of a paddock as much as any inherent properties of the soil profile. It was also felt that fertility has limited influence on capability as most crops and pastures are fertilised regularly and nutrient deficiencies are easily overcome.

On the Pale deep sands (and other soils with pale coloured sandy topsoils), however, added nutrients can be quickly leached down the profile beneath the reach of the roots of emerging crops. These crops will struggle to produce good yields.

In order to ensure that the capability ratings better reflected the observed situation, two new land qualities were identified for inclusion into the capability ratings tables and the SoilCalc Database.

Soil water storage 0–50 cm: A new quality called ‘soil water storage 0–50 cm’ was created to complement the existing quality ‘soil water storage 0–100 cm’. It is calculated in the same manner described by van Gool et al., only over the top 50 cm rather than the top 100 cm.[17] The land quality value categories are also half those for ‘soil water storage 0–100 cm’:

- Extremely low (EL)—less than 15 mm available water
- Very low (VL)—15–25 mm available water
- Low (L)—25–35 mm available water
- Moderately low (ML)—35–50 mm available water
- Moderately (M)—50–65 mm available water
- High (H)—greater than 65 mm available water.

Inherent fertility: This is based on the soil’s ability to retain nutrients. The assessment of ‘inherent fertility’ incorporates soil layer properties stored in the SoilCalc Database. These are the clay content, organic matter content, and phosphorous retention index of the soil layers. Emphasis is placed on these properties in the topsoil where root activity is greatest.

[17] Or to the root-restricting layer in the top 50 cm.

The method used to calculate inherent fertility in the SoilCalc Database is detailed in Appendix C.

MS-Access™ application

An important component of this project methodology has involved refining an MS-Access™ application already under development. This application (currently named PAL_index8) is designed to take data from the Map Unit and SoilCalc databases and perform the calculations required to produce estimated relative wheat yields (s 3.3.1) and soil-landscape weighted scores for irrigated agriculture (s 3.3.2). As the process of identifying HQAL progressively advanced, there was a continual need for modifications of the application.

Another PAL_index8 function developed in this project is the creation of soil-landscape map unit capability summaries. These allow the interrogation of the databases to produce an on-screen form. The first part of the form shows the weighted and unweighted capability scores (s 3.3.2) of each of the land uses assessed. It can display up to three selected map units at a time, allowing quick comparisons to be made.

The second part of the form, for a selection of one or two of the land uses, is a summary showing the proportion of the map unit falling into the capability classes:
1–2, 3, and 4–5, along with the main land qualities acting as limiting factors.

The third part of the form comprises the ZLU summary of the selected map units with their capability ratings and limiting land qualities for each of the selected land uses.

These capability summaries proved very useful for checking the capability maps produced, providing a quick explanation of why some map units were rated more highly than others. This helped in updating the ZLU allocations and the review of zone soil layer properties (s 3.1.1). It also assisted in highlighting any modifications of the capability ratings tables required.

While PAL_index8 requires further development to become a user-friendly application, it is hoped that it will prove useful in identifying HQAL in other regions.

A number of GeoMedia™ warehouses are linked to the data generated in PAL_index8 and other digital datasets to produce the maps presented in this report. These are discussed in Appendix A.

3.3 High quality agricultural land

As discussed in s 1.4, HQAL has been identified through the creation of interpretive maps at two different scales.

First, two maps were created at a complex scale showing the potential for broadacre and irrigated agriculture. These maps of agricultural potential can be viewed as stand-alone products, used with their legends. They provide the most detailed line-work and form a point of reference when examining specific locations. The methodology for defining these areas is provided in detail in s 3.3.1 and s 3.3.2.

Second, the information in these two complex maps was combined to produce a broader-scale map of the ALAs. While this map provides a quick stand-alone summary of the Region, it is designed to be used with the accompanying information sheets to produce a description of the areas, their agricultural importance and potential value. The methodology for creating ALAs is detailed in s 3.3.3.

3.3.1 Broadacre agriculture potential

Wheat was selected as the benchmark land use for broadacre HQAL. Wheat is the dominant crop of the Region and contributes close to two-thirds of the total value of agricultural production.[18] The grazing industry (including production from pastoral leases outside the agricultural area) contributes about 15 per cent of the total value, while legumes contribute about 10 per cent.

Wheat grows well in a wide range of soils because it is comparatively tolerant of different situations (Anderson & Moore 1998). Land that produces high wheat yields usually also produces high yields of most of the other crops grown in the district; so good wheat land tends to be the land with the greatest flexibility for broadacre agriculture. There would always be the option of at least a couple of alternative crops on land that is well suited to growing wheat.

Canola, which is one of the two main alternative crops in the Region, has almost identical requirements to wheat. Other common crops have slightly differing requirements. For example, field peas tend to prefer more alkaline conditions than wheat while oats are less tolerant of alkaline conditions. Lupins may not perform so well on soils with poor permeability and barley is better adapted to deal with soil salinity.[19] Pastures also tend to perform best on land with a high capability for wheat.

In comparison to cropping, the grazing industry is relatively small in the Region. It mainly occurs on lower quality land that is never or rarely cropped, primarily as a low-input system on self-sown or volunteer pastures. Current grazing activities do occur post-harvest in permanent rotational cropping situations and as a pasture phase of a crop/grazing rotation. There is also an increasing trend to plant perennial pastures and fodder shrubs for livestock enterprises in the area. Any significant increase in livestock numbers would probably be highly reliant on perennial pastures and fodder crops because of the short growing season.

Over the years, wheat has proved to be the most profitable crop for the Region and remains the basis of most farming enterprises. Benchmarks for the 2008–09 season show that the farming enterprises in which wheat plays the dominant role perform best in financial terms (Bankwest 2010). This trend is also true of previous seasons.

The assessment of the land for growing wheat was based on relative wheat yields estimated from a combination of land capability ratings and growing season rainfall. The calculations were all undertaken using the MS-Access™ application named PAL_index8 (s 3.2).

Land capability ratings

Land capability ratings for wheat were applied to the soil-landscape map units in DAFWA's Map Unit Database (Schoknecht et al. 2004). The capability assessment for wheat comprised two separate ratings.

The first rating was derived from land qualities that relate to the productive potential of the soil and land only (Table 3.3 and Figure 3.3). It does not consider land degradation hazards. Potential soil water storage and pH can have a direct positive or negative effect on wheat growth and production each year and are considered in the rating.[20] Water erosion and salinity hazard are potential future threats that may or may not be realised. They are not

[18] Based on ABS data shown in Tables 2.2, 2.3 and 2.4.

[19] Due to their more restrictive requirement, these crops are not as quite as flexible as wheat. In regions where alternative crops (or pastures) play a more significant role in farming systems, they may need to be considered in the assessment of broadacre HQAL.

[20] The effect of potential soil water storage will vary from year to year depending on the amount and timing of rainfall.

considered as they will not usually have an effect on crop yields in the short-term but could result in long-term yield declines.

The second rating was derived from land qualities that relate to land degradation hazards and other factors that affect crop and land management and assumes that conservation practices (such as minimum tillage, stubble retention, and—for sloping land—sowing on a slight grade off the contour and installing banks) are implemented (Table 3.4 and Figure 3.4).

Table 3.3 **Capability ratings table for wheat—production only***

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Inherent fertility	VH, H, M	L	VL		
pH at 0–10 cm	Slac, N	Sac, Mac, Malk	Vsac	Salk	
pH at 15–25 cm†	Slac, N	Mac, Malk	Sac, Salk	Vsac	
pH at 50–80 cm	Slac, N	Sac, Mac, Malk	Vsac, Salk		
Rooting depth	VD, D	M	MS		S, VS
Salt spray exposure	N			S	
Soil water storage (0–100 cm)	H, M	ML	L, VL	EL	
Soil water storage (0–50 cm)	H, M	ML, L	VL, EL		
Surface salinity	N	S		M,	H, E
Water repellence susceptibility	N, L	M, H			
Waterlogging / Inundation risk	N	VL, L	M	H	VH

* Codes are taken from van Gool et al. (2005) and are listed in Appendix B.

† Very strongly acid (Vsac) conditions in the subsurface (15–25 cm) are considered more limiting in the subsurface than they are on the surface (where it is more practical to ameliorate pH through liming) or in the subsoil (where the feeder roots are less active).

Note: This table is a repeat of Table 3.1 to provide clarity to this discussion.

Table 3.4 **Capability ratings table for wheat—degradation hazards and management***

Land quality	Class 1	Class 2	Class 3	Class 4	Class5
Flood hazard	N, L		M	H	
Land instability hazard	N, VL, L		M	H	
Phosphorus export risk	L	M, H	VH	E	
Salinity hazard	NR		PR	MR, HR	PS
Soil workability	G	F		P	VP
Subsurface acidification susceptibility	L	M, H	P		
Subsurface compaction susceptibility	L	M, H			
Surface soil structure decline susceptibility	L	M	H		
Trafficability	G	F		P	VP
Water erosion hazard	VL	L	M	H	VH, E
Wind erosion risk	L, M	H	VH		E

* Codes are taken from van Gool et al. (2005) and are listed in Appendix B.

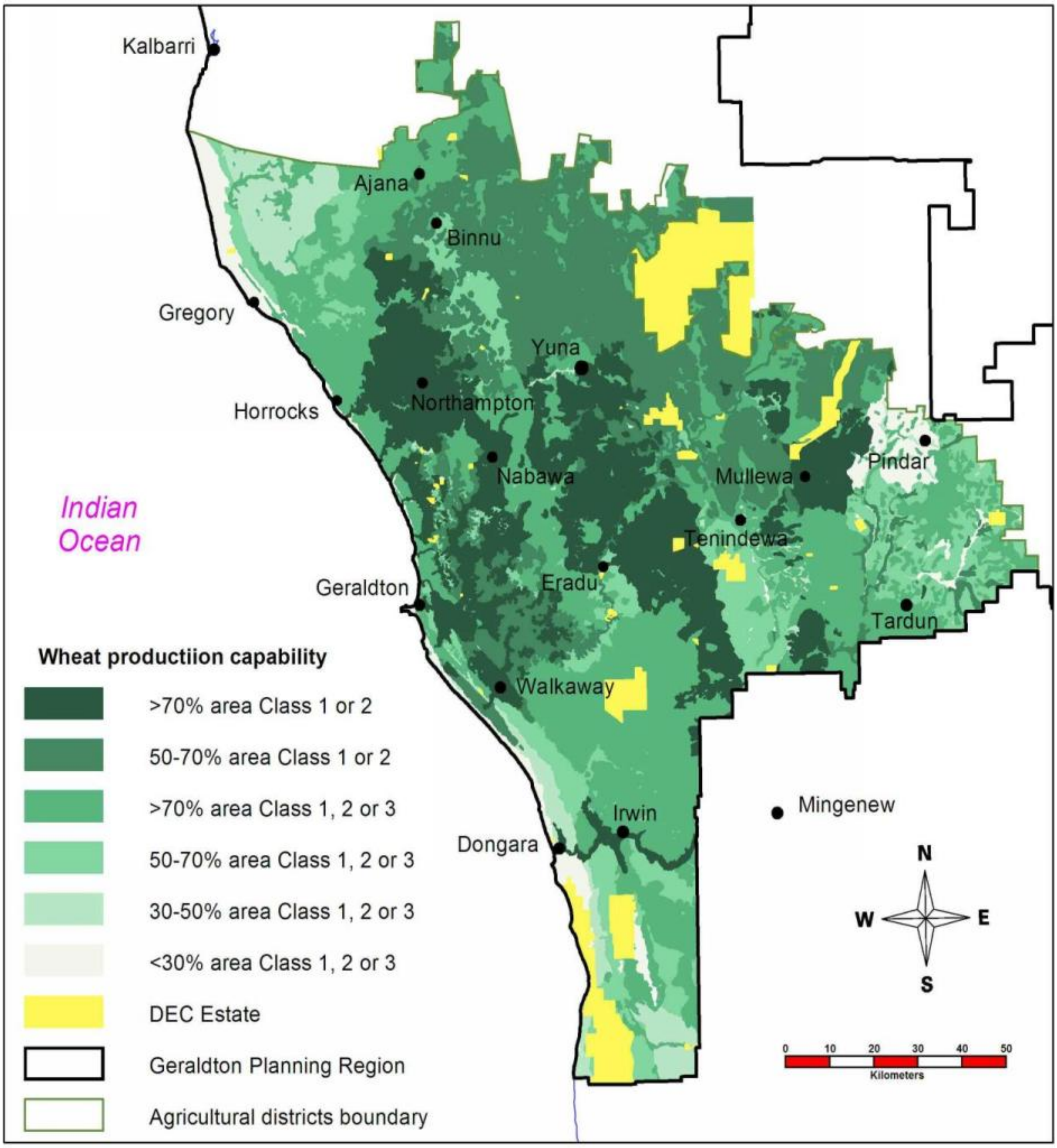


Figure 3.3 **Land capability for wheat—production only in the Geraldton planning region**

Yield constants

Table 3.3 was used to assign a capability class for 'Wheat—production only' to each of the ZLUs that make up the unmapped components of the soil-landscape map units.[21] This capability rating was then converted to a relative wheat yield using a yield constant similar to the land capability constant described by van Gool and Vernon (2005).

Table 3.5 shows the conversion of capability ratings into relative yields. Land with a Class 3 rating was assumed to produce average yields and was therefore assigned a yield constant of 100 per cent.[22] Land with higher capability ratings (classes 1 and 2) have fewer physical and chemical limitations to wheat growth than Class 3 land, so were assumed to produce

[21] For a more detailed explanation of ZLUs, see pp. 30–32 in Schoknecht et al. (2004).

[22] This is the average yield based on average growing season rainfall (see Figure 3.6).

above average yields (that is, the yield constant is greater than 100 per cent). Class 4 and 5 land has more physical or chemical limitations and was assigned yield constants of less than 100 per cent.

Table 3.5 **Conversion of capability rating to relative wheat yield**

Capability ratings for wheat (production only)	Yield constant %	Relative yield (in relation to average yield)
Class 1	180	Well above average
Class 2	140	Above average
Class 3	100	Average
Class 4	60	Below average
Class 5	40	Well below average

Source: Adapted from Table 3 in van Gool and Vernon (2006).

It was assumed that those ZLUs assigned a rating of Class 4 or 5 for ‘Wheat—degradation hazards and management’ (Table 3.4 and Figure 3.4) are not arable and therefore not cropped.[23] This was assumed because either the degradation risk was too great or other management factors (such as machinery access) would be too difficult to overcome. Being considered ‘non-arable’, these ZLUs were assigned a yield constant of zero per cent.

Wheat crop ready for harvest at Chapman Valley, north-east of Geraldton.

[23] There are some examples of land rated as Class 4 and 5 due to degradation hazards constraints being cropped, but this cropping is not considered a sustainable land use.

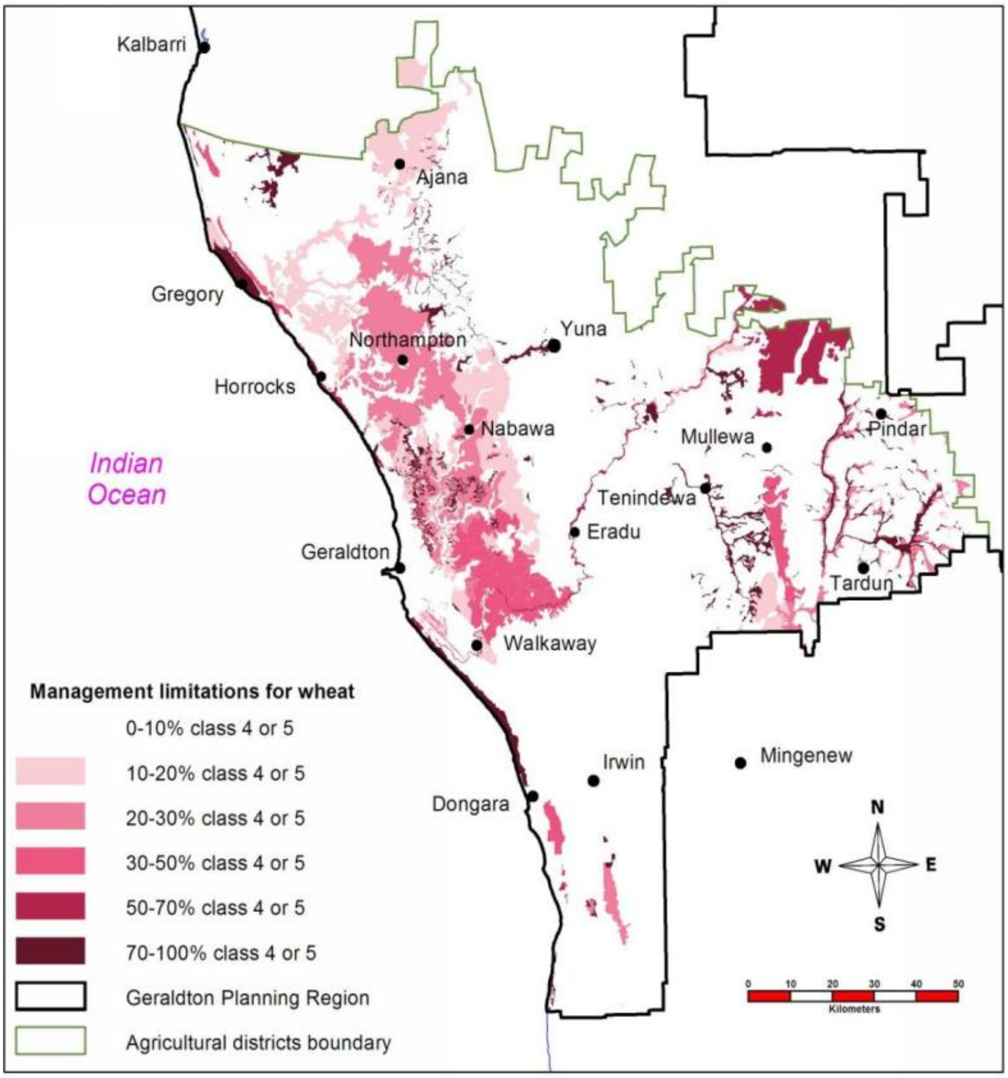


Figure 3.4 **Land rated as capability Class 4 or 5 for wheat (degradation hazards and management only) in the Geraldton planning region**

An example is provided by the Northampton 1 soil-landscape map unit 225No_1 (Table 3.1 and Figure 3.2). In this map unit, the Kojarena soil series (Red loamy earth on a rock substrate) is found on the following three ZLUs: crests and slopes with gradients of less than 3 per cent; gentle slopes with gradients of 3–5 per cent; and moderate slopes with gradients of 5–10 per cent.

As the Kojarena soils are high yielding, each of the three ZLUs in the preceding paragraph has been assigned a rating of Class 2 for 'Wheat—production only'. Where these soils occur on ZLUs with slope gradients in excess of 10 per cent, the water erosion hazard is high and they have been assigned a rating of Class 4 for 'Wheat—degradation hazards and management' and a yield constant of zero per cent. Continual cropping of these soils is likely to result in erosion that not only strips the fertile topsoil but over time reduces soil depth and the ability of the profile to store water and nutrients.

Calculating mean yield constants

The proportional area of each ZLU (as a percentage) within each map unit was multiplied by the yield constant for that ZLU. These resultant values were then added together to determine the mean yield constant for that map unit.

Two map units occurring on the Greenough Flats provide an example of this process. The mean yield constant for the Bootenal well-drained flats (map unit 221Ga_2Bwd) was calculated to be 146 per cent of average yield. This is because all of the ZLUs are rated as Class 1 or Class 2 for Wheat (production only) and none of the ZLUs has a Class 4 or 5 rating for Wheat (degradation hazards and management only).

In contrast, the mean yield constant for the Bootenal poorly-drained flats (221Ga_4Bpd) is only 31 per cent of average yield. ZLUs covering almost three-quarters of the map unit are rated as Class 5 for Wheat (production only) due to waterlogging limitations.

A large proportion of the Greenough Flats contain well-drained Bootenal soils rated as being capability Class 1 or 2 for wheat and producing higher-than-average yields.

The Northampton 1 (225No_1) map unit discussed above provides an example of a map unit with high yielding soils where the mean yield constant has been reduced due to the degradation hazard. The two ZLUs with high yielding Kojarena and Northampton series soils that occur on erosion-prone slopes occupy around one-tenth of the map unit. Although both ZLUs are rated as Class 2 for Wheat (production only), they are rated as Class 4 for Wheat (degradation hazards and management only) and have a yield constant of 0 per cent. If they occurred on slopes with more gentle gradients and an acceptable erosion hazard, their yield constant would have been 140 per cent which reduces the yield constant of the Northampton 1 map unit from 138 per cent to 115 per cent. See Appendix D for further explanation of these calculations.

Growing season rainfall

Growing season rainfall was calculated using the Patched Point Dataset (s 3.1.2). Following the guidelines from Anderson and Garlinge (2000), the growing season rainfall was defined as:

- 100 per cent of April to October rainfall
- 50 per cent of March rainfall
- 25 per cent of January and February rainfall.

Rainfall in the Region over the past decade has been significantly lower than long-term rainfall. The decrease in average annual rainfall for 2000–09 ranges from 18 per cent at Northampton to 26 per cent at Mullewa (Table 2.5). There appears to have been a marked 'step down' in rainfall at the turn of the century. At this stage, it is not yet clear if this reduction is temporary or part of the long-term decline that many climate change models suggest.

The change in the climate makes predicting future rainfall problematic. Erring on the side of caution, rainfall during 2000–09 inclusive was used as a guide for future wheat yields.

The Patched Point Dataset was transformed into a map showing 10 mm growing season rainfall isohyets using ArcView 3.2 and Spatial Analyst (Figure 3.5). These isohyets were intersected with the soil-landscape mapping in Intergraph GeoMedia™ warehouses to create polygons attributed with soil-landscape and growing season rainfall. The new map unit polygon was assigned a rainfall halfway between the two isohyets that bound it. For example, a polygon sitting between the 260 mm and 270 mm isohyets was assigned an average growing season rainfall of 265 mm.

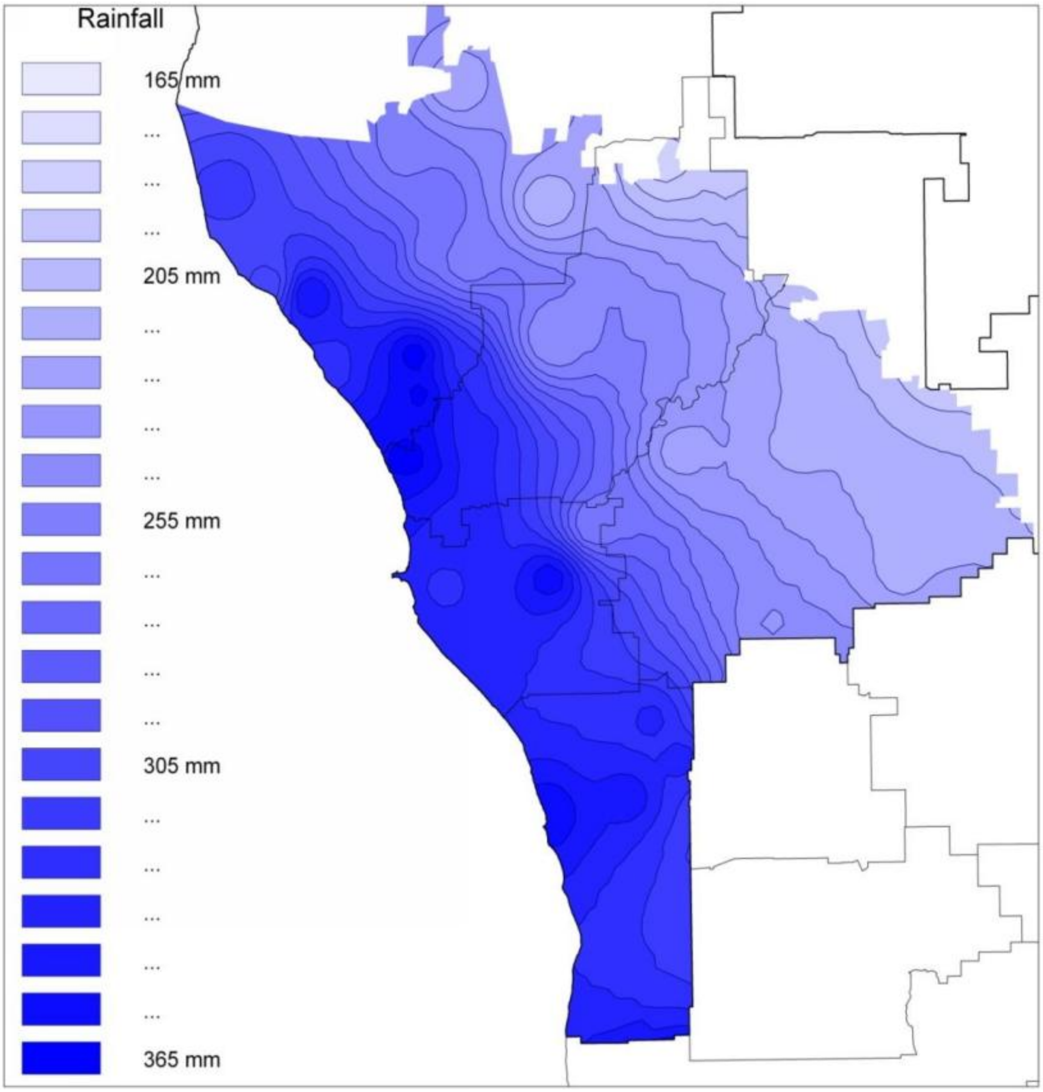


Figure 3.5 **Average growing season rainfall for 2000–09 in 10 mm increments for the agricultural districts of the Geraldton planning region**

Relative yield estimates

For each of the polygons created by intersecting the soil-landscape and growing season rainfall maps, a relative wheat yield was estimated. This estimation was derived from versions of the French and Schultz equation (1984) modified for WA conditions by van Gool and Vernon (2005, 2006).[24]

The French and Schultz equation was modified using the data shown in Figure 3.6. This shows recorded wheat yields over a five-year period plotted against growing season rainfall. The yield data is based on CBH wheat bin receivals for WA for 1995–99.[25] These were summarised for local government areas by DAFWA's Farm Business Development Unit. The average growing season rainfall for local government areas was determined using the Patch Point Dataset (described in s 3.1.2).

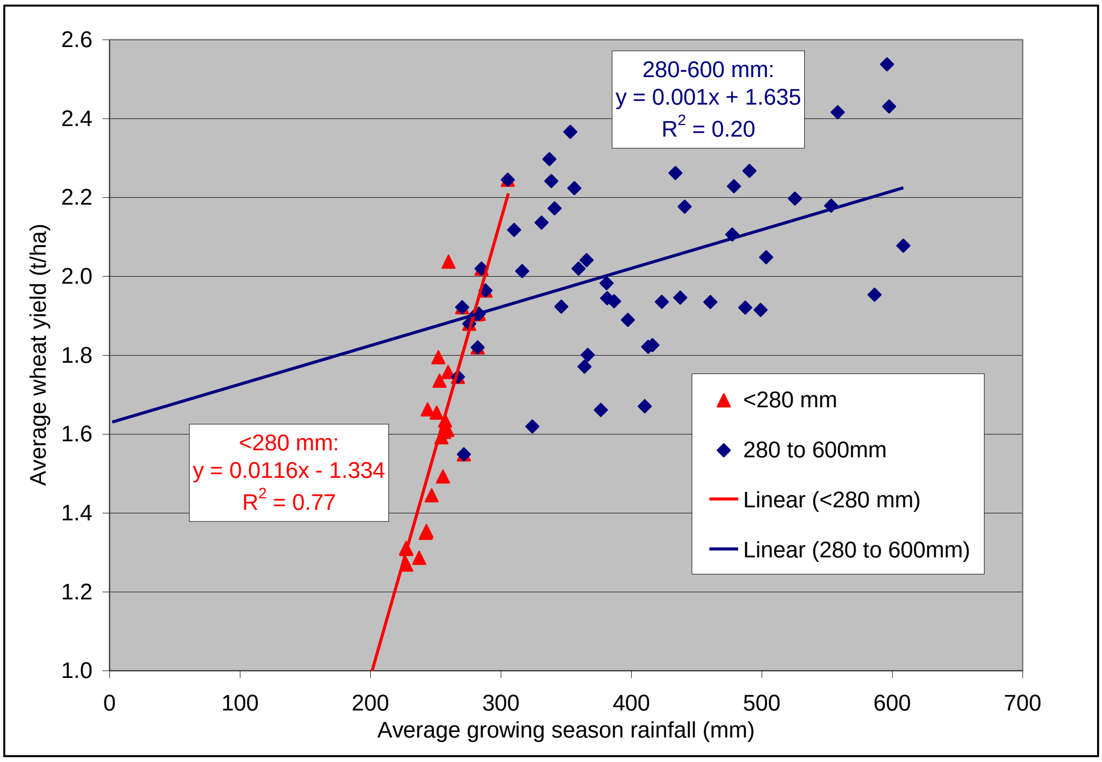


Figure 3.6 **Linear regressions of mean wheat yields 1995–99 based on CBH grain receivals**

The yield by rainfall data were partitioned to create two separate linear regressions.[26] Where growing season rainfall is less than 280 mm, there is a strong linear trend of increasing yield with increasing rainfall. Below 280 mm, water availability is by far the most important factor determining yield. This regression line shows a high water use efficiency of 0.0116 t/ha/mm (11.6 kg/ha/mm), comparable to the water-use efficiency from the French and Schultz (1984) equation.[27]

As growing season rainfall increases above 280 mm, the relationship between rainfall and yield is less clear. Confounding factors (such as nutrients, weeds, disease and waterlogging) have a greater impact on yield, so there is a relatively poor fit between the data and the

[24] The equation that van Gool and Vernon developed for wheat in 2005 was later modified along the lines of their 2006 equation for barley using the regressions in Figure 3.6.

[25] The yield data was from across the entire wheatbelt, from Northampton to Esperance.

[26] The use of two linear regressions instead of a polynomial equation is generally not condoned. However, it is a pragmatic solution for our decision support tool (van Gool & Vernon 2006).

[27] French and Schultz's water use efficiencies tend to be higher but are based on trial data rather than actual on-farm yields.

regression equation. The linear trend line is not nearly as steep, showing much lower water-use efficiency of 0.001 t/ha/mm (1.0 kg/ha/mm). Regardless of the low correlation of yield to increasing rainfall, there is still a trend of increasing yield with increasing rainfall.

The low correlation between yield and rainfall in this latter equation and the use of two linear regressions is not considered problematic in this analysis because the intent is to distinguish grades of land–soil–available water combinations and their relative value for agricultural production.

The modified wheat yield equations are:

1. For growing season rainfall greater than 280 mm:

   $MY = (WUE1 \times GSR \times WLc + Y1) \times Yc$

2. For growing season rainfall of 280 mm or less:

   $MY = (WUE2 \times GSR \times WLc + Y2) \times Yc$

Where:

- MY = average wheat yield in t/ha
- WUE1 = water use efficiency of 0.001 t/ha/mm from the 280–600 linear trend line
- WUE2 = water use efficiency of 0.0116 t/ha/mm from the < 280 linear trend line
- GSR = growing season rainfall in mm
- WLc = waterlogging constant[28]
- Y1 = yield at 0 mm rainfall of 1.635 t/ha (that is, the intercept of the 280–600 mm linear trend line and the ‘Y axis’)
- Y2 = yield at 0 mm rainfall of –1.334 t/ha (that is, the intercept of the < 280 mm linear trend line and the ‘Y axis’)[29]
- Yc = Yield constant

Continuing the examples of the map units discussed in the yield constants section (s 3.3.1), the relative wheat yield for the ‘Bootenal well-drained flats’ map unit (with a mean yield constant of 146 per cent) was estimated at 2.88 t/ha for 335 mm of average growing season rainfall. The relative wheat yield for the ‘Bootenal poorly drained flats’ (with a mean yield constant of 31 per cent) receiving the same rainfall was only 0.62 t/ha.

The relative wheat yield for the ‘Northampton 1 subsystem’ map unit (with a mean yield constant of 115 per cent) ranges from 1.99 t/ha where the average growing season rainfall is 265 mm, up to 2.29 t/ha where 365 mm is received.

The soil-landscape mapping was then colour-coded according to the relative wheat yield estimates (Figure 3.7). The colours were ramped in 0.25 t/ha increments, ranging from a dark green for the highest yielding (> 2.5 t/ha) combinations of soil-landscape and growing season rainfall, to very pale green for the lowest yielding (< 0.5 t/ha) combinations. Non-agricultural land, such as urban areas, industrial land, pastoral leases and major reserves, and areas of remnant vegetation were excluded.

[28] The waterlogging constant was not required for the Region as it only applies where growing season rainfall exceeds 500 mm.

[29] Y2 is a negative value because the < 280 mm linear trend line crosses the X-axis where growing season rainfall equals 155 mm (that is, there is no yield below 155 mm).

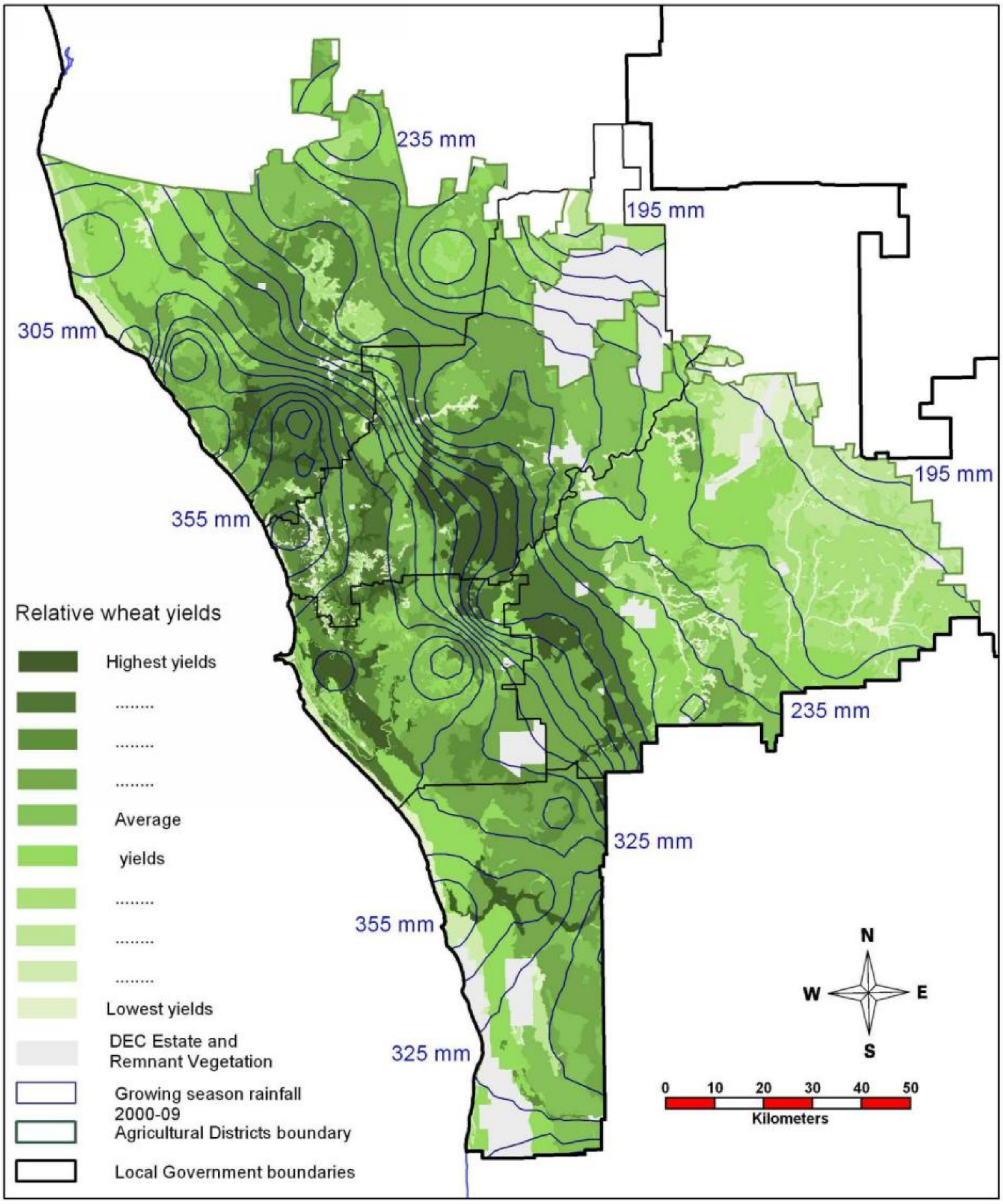


Figure 3.7 **Relative wheat yield for the Geraldton planning region, 2000–09**

3.3.2 Irrigated agriculture potential

The approach taken to identify irrigated HQAL was quite different from the approach for broadacre HQAL for three reasons:

1. There is no single crop like wheat that 'typifies' irrigated agriculture in the Region. Instead, there is a wide range of current and potential irrigated crops (and pastures). Many of these have differing life cycles, requirements, production systems and economic returns.
2. Groundwater supplies, upon which irrigated agriculture in the Region relies, are more complex than rainfall in terms of their spatial distribution, quality, accessibility and allocation.
3. Due to the limited water supplies, irrigated agriculture can only ever occupy a small fraction of the agricultural land in the district.

Capability ratings

To identify the most 'versatile' land for irrigated agriculture, a variety of uses were considered. Capability ratings for nine individual land uses were assigned to each ZLU. These land uses, selected to represent current irrigated crops or potential future crops, were:

- vegetable and melon (general rating for annual species such as cucumbers, zucchini, pumpkins, tomatoes or melons where the harvested crop forms above the ground surface)
- root crops (vegetables such as potatoes and carrots where root or tuber shape is an important consideration)
- stone fruit and nuts (tree crops including stone fruit, almonds and carob)
- avocados
- citrus
- mangoes
- grapevines
- olives
- irrigated pastures (using centre pivots).

While this list is far from exhaustive, it should be representative of land use requirements for irrigated agriculture. If certain crops, such as almonds or chinese red dates, become more important in the future, an individual rating could be generated for them while other crops could be removed if no longer considered significant.[30]

The ratings tables used in calculating capability for vegetables and melons are shown in Table 3.6; and for stone fruit and nuts in Table 3.7. The ratings tables for the other six land uses are presented in Appendix E.[31] These ratings tables are based on the assumption that conservation measures, such as protective groundcover and windbreaks, form part of the farming system. Calculation of land capability ratings were undertaken in the same MS-Access™ application used for the broadacre calculations (PAL_index8.mdb described in s 3.2).

[30] One type of irrigated agriculture not well catered for at this stage is the growing of covered crops (that is, crops grown in glass or shadehouses) or hydroponic crops. Many of the tomatoes grown around Geraldton currently would fit into one of these categories. Ratings tables for these land uses should be developed in the future.

[31] Some of these ratings tables (olives, avocados, mangoes, citrus and irrigated pastures) are only provisional, as further information is required to determine the land use requirements.

Table 3.6 **Capability ratings table for vegetables and melons***

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L	M		H
Inherent fertility	VH, H, M	L	VL		
Land instability hazard	N, VL, L		M	H	
pH at 0–10 cm	Slac, N	Mac	Vsac, Sac, Malk, Salk		
pH at 15–25 cm	Slac, N	Sac, Mac, Malk	Vsac, Salk		
pH at 50–80 cm	Slac, N	Sac, Mac, Malk	Vsac, Salk		
Phosphorus export risk	L, M	H	VH	E	
Rooting depth	VD, D	M	MS	S	VS
Salinity hazard	NR	PR		MR, HR	PS
Salt spray exposure	N			S	
Site drainage potential	R, W, MW	M	P		VP
Soil water storage	H, M, ML	L, VL	EL		
Soil water storage 0–50 cm	H, M, ML	L	VL	EL	
Soil workability	G	F		P	VP
Subsurface compaction	L, M	H			
Surface salinity	N		S	M	H, E
Surface soil structure decline	L, M	H			
Trafficability	G	F		P	VP
Water erosion hazard	VL	L	M	H, VH	E
Water repellence susceptibility	N, L, M	H			
Waterlogging / inundation risk	N, VL	L	M	H	VH
Wind erosion risk	L, M	H	VH		E

Table 3.7 **Capability ratings table for stone fruit and nuts***

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L		M	H
Inherent fertility	VH, H, M	L	VL		
Land instability hazard	N, VL, L		M		H
pH at 0–10 cm	Slac, N	Mac	Sac, Malk	Vsac, Salk	
pH at 50–80 cm	Slac, N	Mac, Malk		Vsac, Sac, Salk	
Phosphorus export risk	L, M	H	VH	E	
Rooting depth	VD, D		M	MS	S, VS
Salinity hazard	NR		PR	MR	HR, PS
Salt spray exposure	N			S	
Site drainage potential	R, W	MW	M	P	VP
Soil water storage	H, M, ML	L	VL	EL	
Soil workability	G	F	P	VP	
Subsurface compaction	L, M	H			
Surface salinity	N		S	M	H, E
Trafficability	G	F		P	VP
Water erosion hazard	VL, L	M, H		VH	E
Water repellence susceptibility	N, L, M	H			
Waterlogging / inundation risk	N, VL		L	M	H, VH
Wind erosion risk	L, M	H, VH		E	

* Codes are taken from van Gool et al. (2005) and are listed in Appendix B.

Land use weightings

The capability ratings for the eight individual land uses were transformed into a single value reflecting the potential of the ZLU for irrigated agriculture in terms of soils and landforms (that is, the potential of the land only, without taking into account the availability of water supplies).

First, the capability rating for each land use was converted to a land use score out of 100 (Table 3.8). Class 1 land was assigned the maximum score of 100. Class 3 land was assigned a score of 50 out of 100 because of likely development/ongoing management costs or lower potential yields. Class 2 land was assigned a land use score of 75 (halfway between classes 1 and 3). Class 4 and 5 land was assigned a score of zero as it is assumed that the production potential would not justify the cost of development.

Table 3.8 **Conversion of capability rating to score**

Land use capability rating	Land use score
Class 1	100
Class 2	75
Class 3	50
Class 4	0
Class 5	0

The score for each land use was then assigned to each ZLU for each map unit. This land use score was multiplied by the map unit proportion of that ZLU to determine the ZLU per cent adjusted score[32] All of the ZLU per cent adjusted scores were then summed to determine the overall land use score for the map unit.

Table 3.9 presents an example of this process for the land use 'vegetables and melons', applied to soil-landscape map unit 255No_1 (see Table 3.1 and Figure 3.2). Table 3.10 presents an example for the land use 'stone fruit and nuts' applied to the same map unit.

The 255No_1 land use score for stone fruit and nuts is 56.5, while for vegetables and melons, it is 49. The lower land use score for vegetables and melons reflects the erosion risk associated with growing annual crops on slope with gradients in excess 10 per cent.

Each land use was then assigned a weighting to reflect its perceived importance in the Region (Table 3.11). The land use weightings are expressed as a percentage and add up to 100 per cent.

[32] This is the proportional area of the map unit that the ZLU occupies, expressed as a percentage.

Table 3.9 **Calculation of land use score for 'vegetables and melons' for map unit 225No_1 (Northampton 1)**

Landform component	WA Soil Group component	Soil Group qualifier component	A Map unit proportion %	B Vege/melon capability rating class	C Vege/melon score*	D ZLU adjusted score†
Crests & slopes (gradients < 3%)	Bare rock	—	2	5	0	0.00
Crests & slopes (gradients < 3%)	Red loamy earth	rock substrate	2	2	75	1.50
Crests & slopes (gradients < 3%)	Red shallow loamy duplex	rock substrate	5	2	75	3.75
Very gentle slopes (1–3%)	Red shallow loamy duplex	neutral subsoil	5	2	75	3.75
Gentle slopes (3–5%)	Red loamy earth	rock substrate	3	2	75	2.25
Gentle slopes (3–5%)	Red shallow loamy duplex	neutral subsoil	12	2	75	9.00
Gentle slopes (3–5%)	Red shallow loamy duplex	rock substrate	6	2	75	4.50
Gentle slopes (3–5%)	Self-mulching cracking clay	neutral subsoil	5	2	75	3.75
Gentle slopes (5–10%)	Bare rock	—	2	5	0	0.00
Gentle slopes (5–10%)	Red loamy earth	rock substrate	5	3	50	2.50
Gentle slopes (5–10%)	Red shallow loamy duplex	neutral subsoil	14	3	50	7.00
Gentle slopes (5–10%)	Red shallow loamy duplex	rock substrate	15	3	50	7.50
Gentle slopes (5–10%)	Self-mulching cracking clay	neutral subsoil	5	3	50	2.50
Moderate slopes (10–15%)	Red loamy earth	rock substrate	5	4	0	0.00
Moderate slopes (10–15%)	Red shallow loamy duplex	rock substrate	6	4	0	0.00
Moderate slopes (15–30%)	Bare rock	—	1	5	0	0.00
Moderate slopes (15–30%)	Red shallow loamy duplex	rock substrate	5	4	0	0.00
Well-drained drainage depression	Red shallow loamy duplex	rock substrate	2	3	50	1.00
Vegetables and melons land use score for map unit 225No_1						**49.00**

* Vegetable/melon score (column C) is the vegetable/melon capability rating class (column B) converted to a land use score, as shown in Table 3.8.

† ZLU adjusted score (column D) is the Vegetables and melons score (column C) multiplied by the map unit proportion (column A).

Table 3.10 **Calculation of land use score 'stone fruit and nuts' for map unit 225No_1 (Northampton 1)**

Landform component	WA Soil Group component	Soil Group qualifier component	A Map unit proportion %	B Stone fruit/nuts capability rating class	C Stone fruit/ nut score*	D ZLU adjusted score† %
Crests & slopes (gradients < 3%)	Bare rock	—	2	5	0	0.00
Crests & slopes (gradients < 3%)	Red loamy earth	rock substrate	2	3	50	1.00
Crests & slopes (gradients < 3%)	Red shallow loamy duplex	rock substrate	5	3	50	2.50
Very gentle slopes (1–3%)	Red shallow loamy duplex	neutral subsoil	5	2	75	3.75
Gentle slopes (3–5%)	Red loamy earth	rock substrate	3	3	50	1.50
Gentle slopes (3–5%)	Red shallow loamy duplex	neutral subsoil	12	2	75	9.00
Gentle slopes (3–5%)	Red shallow loamy duplex	rock substrate	6	3	50	3.00
Gentle slopes (3–5%)	Self-mulching cracking clay	neutral subsoil	5	1	100	5.00
Gentle slopes (5–10%)	Bare rock	—	2	5	0	0.00
Gentle slopes (5–10%)	Red loamy earth	rock substrate	5	3	50	2.50
Gentle slopes (5–10%)	Red shallow loamy duplex	neutral subsoil	14	2	75	10.50
Gentle slopes (5–10%)	Red shallow loamy duplex	rock substrate	15	3	50	7.50
Gentle slopes (5–10%)	Self-mulching cracking clay	neutral subsoil	5	2	75	3.75
Moderate slopes (10–15%)	Red loamy earth	rock substrate	5	3	50	2.50
Moderate slopes (10–15%)	Red shallow loamy duplex	rock substrate	6	3	50	3.00
Moderate slopes (15–30%)	Bare rock	—	1	5	0	0.00
Moderate slopes (15–30%)	Red shallow loamy duplex	rock substrate	5	4	0	0.00
Well-drained drainage depression	Red shallow loamy duplex	rock substrate	2	3	50	1.00
Stone fruit and nuts score for map unit 225No_1						**56.50**

* Stone fruit and nuts score (column C) is the stone fruit and nuts capability class (column B) converted to a land use score as shown in Table 3.8.

† ZLU adjusted score (column D) is the stone fruit and nuts score (column C) multiplied by the map unit proportion (column A).

Table 3.11 **Irrigated agriculture land use weightings**

Land use	Land use weighting %	Crop type	Crop type weighting %
Vegetables & melons	33	Annual	50
Root crops	15	Annual	
Irrigated pastures	2	Annual[33]	
Stone fruit and nuts	20	Perennial	50
Mangoes	10	Perennial	
Citrus	8	Perennial	
Grapevines	5	Perennial	
Avocados	5	Perennial	
Olives	2	Perennial	
Total	**100**		**100**

The value of each land use weighting is significant only in relation to the other weightings in the table. For example, the weightings in Table 3.11 suggest that mangoes are likely to be twice as important as grapes or avocados and four times as important as olives in the Region in the future. The weightings for annual and perennial crop types both add up to 50 per cent, suggesting that these two types of horticulture are likely to be of equal importance.

The land use weightings were assigned after consultations with DAFWA staff. These weightings are preliminary as the relatively small scale of the horticultural industry in the Region makes predictions of future trends difficult. These weightings can be reviewed and altered if required as more detailed analysis of potential crops and markets is undertaken.

Land uses that included a variety of crops (vegetables and melons or stone fruit and nuts) received a higher weighting than land uses applying to a single crop only, thereby implying greater flexibility of land use. Low weightings were assigned to land uses deemed likely to make up a small proportion of future irrigated agriculture (in terms of either area planted or economic value). Higher weightings were also assigned to land uses where there was a higher level of confidence in the accuracy of the ratings tables.

For each soil-landscape map unit, the land use weightings (Table 3.11) were multiplied by the land use scores (Table 3.8) to achieve a weighted score for each land use. The individual weighted scores were then summed to determine the overall irrigated agriculture score for the map unit. Table 3.12 presents an example of this process for map unit 225No_1.

[33] Irrigated pastures have been included in the annual category even though perennial pastures may be involved because irrigation systems (for example, centre pivots) are more closely aligned to those used on annual horticultural crops.

Table 3.12 **Calculation of the irrigated agriculture score for map unit 225No_1 (Northampton 1)**

Land use	Land use score	Land use weighting %	Weighted land use score*
Vegetables and melons	49.00	33	16.1700
Root crops	46.25	15	6.9375
Irrigated pasture	66.75	2	1.3350
Stone fruit and nuts	56.50	20	11.3000
Mangoes	30.75	10	3.0750
Citrus	56.50	8	4.5200
Grapevines	68.75	5	3.4375
Avocados	56.50	5	2.8250
Olives	20.50	2	0.4100
Map unit irrigated agriculture score			**50.0100**

* This is the 'land use capability' score multiplied by the 'land use weighting'.

The irrigated agriculture scores were then transformed into categories, as shown in Table 3.13. For example, map unit 225No_1 with a weighted score of 50.01 is placed into category High 1 (H1).

Table 3.13 **Irrigated land categories**

Irrigated agriculture score	Category	Code
70–100	Very high 1	VH1
60–69	Very high 2	VH2
50–59	High 1	H1
40–49	High 2	H2
35–39	Moderate 1	M1
25–34	Moderate 2	M2
< 25	Low	L

The land categories for irrigated agriculture for each map unit are presented in Figure 3.8. This map illustrates potential for irrigated agriculture, assuming that adequate water supplies are available.

Although the maximum irrigated agriculture score is 100, it would be a mistake to think of these scores as a percentage, with a score of 50 representing a 'pass mark'. The scores incorporate the concept of flexibility, with land that has the capacity to support a wide range of crops achieving the highest score.

Land with a score below 50 may still be highly productive horticultural land. An example would be land with good capability for perennial crops but with limitations for annual crops, as these two crop types comprise 50 per cent of the total score each (see Table 3.11). Land with a score over 25 has a reasonable capacity for producing at least some irrigated crops and it may have considerable horticultural potential where good water supplies are available. Such land is productive but not as versatile. It still needs to be identified.

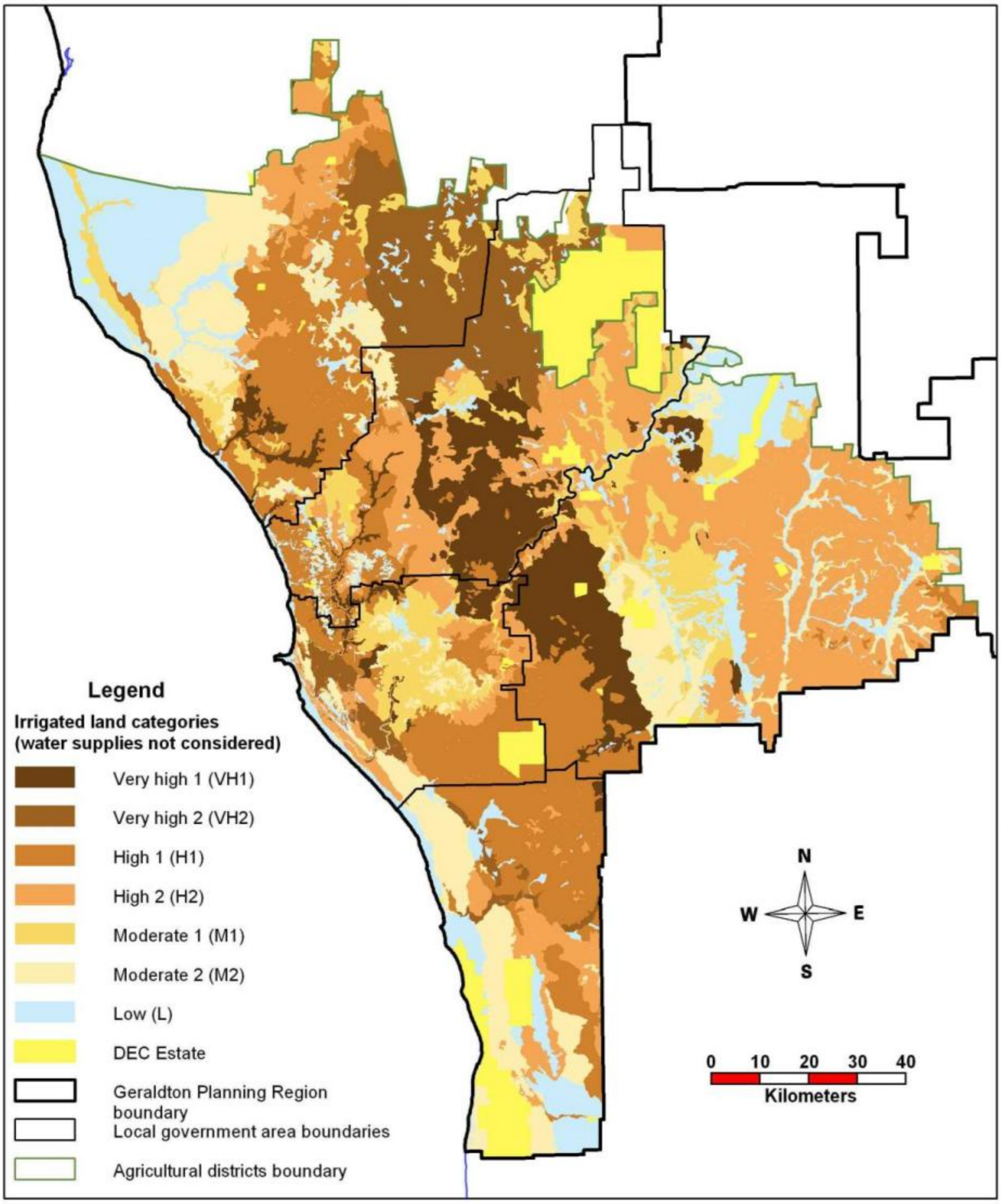


Figure 3.8 **Land categories for irrigated agriculture in the Geraldton planning region (assessment of soils and landforms only; does not consider availability of water supplies)**

Sources of water for irrigation

The availability of water supplies is the single most crucial consideration for the development of irrigated agriculture. Without water, there can be no irrigation. Irrigation water can be supplied from a variety of sources. On-property sources include farm dams, soaks and bores. Water can also be transported to properties (by supply schemes of pipes or channels) from major bore fields or water reservoirs. The desalination of seawater and recycling of wastewater are other possible sources. Table 3.14 summarises the water supply options for irrigated agriculture in the Region.

Table 3.14 **Potential water supply options for irrigated agriculture in the Geraldton planning region**

Potential water source	Advantages	Disadvantages
Surface water (dams, soaks and rivers)	Relatively cheap to access	Limited resource Dependent on annual rainfall, which can be unreliable High evaporation rates Quality can be variable
Scheme water	Good quality Reliable resource	Expensive
Recycled water	Reliable resource	Currently unavailable Expensive Health issues
Desalination	Good quality Reliable resource	Currently unavailable Expensive
Groundwater—local aquifers	Relatively cheap to access	Dependent on annual rainfall, which can be unreliable Quality can be variable
Groundwater—regional aquifers	Relatively reliable resource	Quality can be variable

Currently, the major sources of irrigation water used in the Region are the aquifers of the Perth Basin. For ease and economy, supplies are most likely to be drawn from bores located close to the land being irrigated. There is potential for the future development of supply schemes that pipe irrigation water from bore fields to individual properties or to a horticultural precinct.

Scheme water is intended for highest value end-users, particularly for public drinking water supply. However, shadehouse vegetable growers on the outskirts of Geraldton are currently accessing the local public water supply scheme to irrigate their crops. The future is likely to see more growers with access to scheme water using it for irrigation supplies. One drawback of this is that the cost of scheme water is currently significantly higher than licensed groundwater, limiting its use to efficient, high-value production systems.[34]

Pipelines constructed to supply mining enterprises are another potential means of delivering groundwater supplies to properties not overlying suitable aquifers, especially once mines are decommissioned. This could be a longer term solution but a number of legal and practical issues would need to be addressed.

Desalinated water is currently too expensive to be considered as an irrigation source. Recycled wastewater from Geraldton is currently being used to irrigate a golf course and in other parts of Australia, such water is applied to horticultural crops. Apart from cost, other issues that would need to be considered are water quality, public health, and delivery systems. As with desalination, the cost of the recycled water is likely to be expensive. In South Australia and Victoria, the cost of supply of recycled water for horticulture has been subsidised due to environmental considerations.

Some properties around Northampton and in the Chapman Valley still access surface water supplies for the irrigation of fruit trees and vines. These supplies are highly dependent on seasonal rainfall and are generally unreliable. With high evaporation rates[35] and the current trend of a drying climate (s 2.2.1), surface supplies require supplementation from

[34] The current cost of scheme water for non-residential users around Geraldton is about $1.48/kL, compared with an estimated cost of $0.30–0.50/kL to abstract water from a licensed bore.

[35] Average annual evaporation ranges from 2400 mm in the south-west to 2800 mm in the north-east.

groundwater. Over most of the Region, the rainfall is too low, or the soils too sandy, for the harvesting of surface run-off to be an option for irrigation.

The use of groundwater for irrigated agriculture would need to be licensed by the DoW under the *Rights in Water and Irrigation Act 1914*. The volume of groundwater available for licensing is restricted by the allocation limit for an aquifer. Allocation limits are used to maintain the sustainability of the water resource. The actual volume of water available for licensing varies as licences are issued or amended.

The assessment of irrigated HQAL has focused on groundwater supplies for the reasons discussed in previous paragraphs. Knowledge of groundwater resources in the Region remains relatively broad scale because the area is large and the nature of aquifer systems can be complex.

Almost two-thirds of the Region overlies the sedimentary aquifers of the Perth and Carnarvon Basins. Moderate to high groundwater supplies of good quality are contained in the aquifers in the southern portion of the Perth Basin within the Region. Poor water quality is an issue for aquifers in the northern and eastern portions of the Perth Basin. Detailed investigations of the Carnarvon Basin, in the north-west of the Region, are yet to be undertaken. Groundwater supplies in the remainder of the Region are likely to be small, unreliable and difficult to access, or too poor quality for use in large-scale irrigated agriculture.

Aquifers in the Region can be divided into two categories[36]:

- **Local aquifers**, which have groundwater flow systems that extend over relatively small distances (typically 1–10 km). These aquifers are typically unconfined, connecting directly to the ground surface. Individually, the volumes of water they contain are relatively small and responsive to fluctuations in annual rainfall. In the northern Perth Basin, the numerous local aquifers are referred to collectively as either the Superficial Swan or Perth Surficial aquifers.
- **Regional aquifers**, which have groundwater flow systems that extend over relatively large distances (more than 50 km). Although these aquifers may connect directly to the surface in places, much of the aquifer is often confined.[37] This category includes the aquifers, such as the Yarragadee, that contain the most significant volumes of groundwater in the northern Perth Basin.

Methodology for assessing groundwater resources

In assessing the irrigated agriculture potential of the Region, it was decided to treat groundwater resources of the local and regional aquifers separately. This is because the two categories differ in their characteristics, the nature in which their groundwater resources can be exploited, and the scale at which information about them is relevant.[38]

The primary source of information on groundwater resources used was the general licensing component (GLC) of the allocation limits for the regional aquifers extracted from the DoW licensing database. In addition, estimates of potential annual groundwater recharge from rainfall to local aquifers were undertaken specifically for this project.

With the regional aquifers, it was assumed that most (if not all) of the volume of groundwater available within a groundwater subarea (GWSA) could be abstracted from any part of that

[36] These categories have been adapted from the classification of groundwater flow systems proposed by Coram (1998).

[37] With a piezometric head sitting above the top surface of the aquifer.

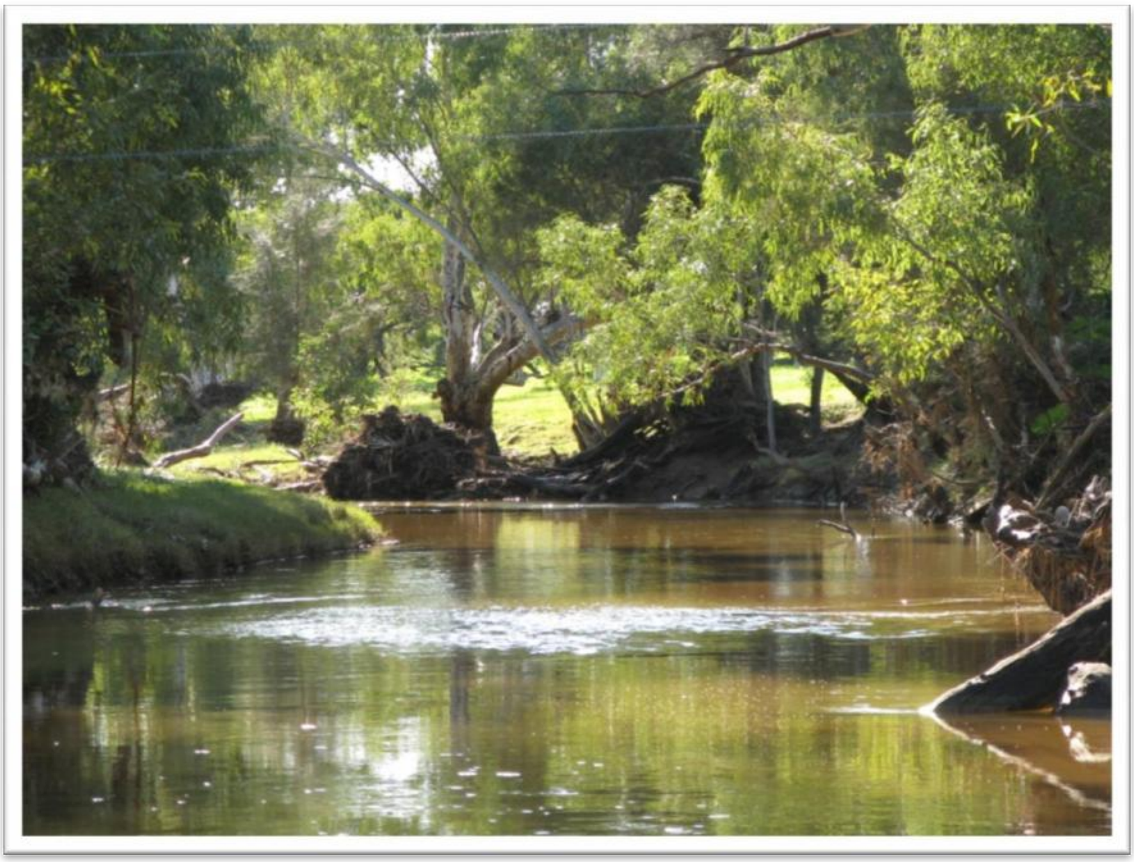
[38] This decision was made in consultation with staff from the DoW.

GWSA underlain by that aquifer.[39] In many cases, the groundwater flow system within the aquifer will extend beyond the bounds of the GWSA. In those aquifers that are confined, abstraction of water will result in a fall in the piezometric head at the point of abstraction. The volume of water located beneath the abstraction point will not decrease in most cases.[40]. Any reduction in the volume of water stored in the aquifer may only be apparent where the aquifer is unconfined, possibly outside the GWSA.

In the case of local aquifers, multiple abstraction points spread across the extent of the GWSA would be required to access the full volume of groundwater available. The watertable will fall as groundwater is abstracted and its replacement will be largely reliant on recharge from rainfall.

The assumptions made in the assessment of groundwater resources for irrigated agriculture are summarised in Box 3.1 and discussed in more detail in the following text. Some of these are 'pragmatic' assumptions and are not necessarily 100 per cent correct. They will warrant review as the methodology continues to be developed. The limitations of the methodology are presented in Box 3.2 at the end of this section.

Figure 3.9 presents a flow diagram summarising the steps undertaken in the assessment of groundwater resources.



Irwin River at Mountain Bridge, east of Dongara

[39] This assumption will not always hold in practice. On-site investigations are required to determine how much groundwater can be abstracted from a regional aquifer at any given point. These investigations may include, but are not limited to, exploratory drilling, geophysical logs, pump tests, hydrogeological reporting, and local groundwater modelling (DoW 2009b).

[40] Even though the volume may not change, the bore water pressure will.

Box 3.1 **Assumptions made in assessing potential water resources for irrigated agriculture**

- Groundwater is the only reliable water source for irrigated agriculture in the Region.
- In the identification of HQAL, the potential for access to groundwater supplies in the longer term should take precedence over the current availability of licensed water entitlements.
- Aquifers designated as 'confined' in the DoW aquifer shapefiles can be treated as regional aquifers. Aquifers designated as 'unconfined' can be treated as local aquifers.
- For regional aquifers, the general licensing component (GLC) provides the best indication of potential groundwater supplies for agriculture in the longer term.
- The full GLC of regional aquifers in the Gascoyne and Arrowsmith GWAs comprises water of a suitable quality for irrigated agriculture.
- For regional aquifers, the full GLC can potentially be abstracted from anywhere within the GWSA that overlies the relevant aquifer. This is not the case with local aquifers.
- The assessment of potential groundwater resources in local aquifers at a scale suitable for identifying HQAL is best achieved by estimating potential recharge.
- Average rainfall over the period from 1975 to 2005 will be representative of future rainfall.
- Maximum recharge under crops and pastures is 8 per cent of rainfall. Maximum recharge under native vegetation is 0.5 per cent of rainfall.
- The reduction in infiltration rates due to run-off can be estimated using soil and landform characteristics.
- DAFWA regolith mapping provides a reasonable estimate of the ability of local aquifers to accept and store water.
- Data from DAFWA soil-landscape mapping provides a reasonable approximation of the distribution of aquifers with saline groundwater.
- Where estimated recharge to fresh aquifers is less than 10 mm/yr, local aquifers will not provide a significant contribution to the total groundwater resource.
- Where estimated recharge to fresh aquifers exceeds 10 mm/yr, the total groundwater resource potentially available for agriculture will exceed the regional aquifer GLC.
- When assessing combined water resources in local and regional aquifers, a greater emphasis should be placed on the GLC of regional aquifers than on recharge estimates for local aquifers.

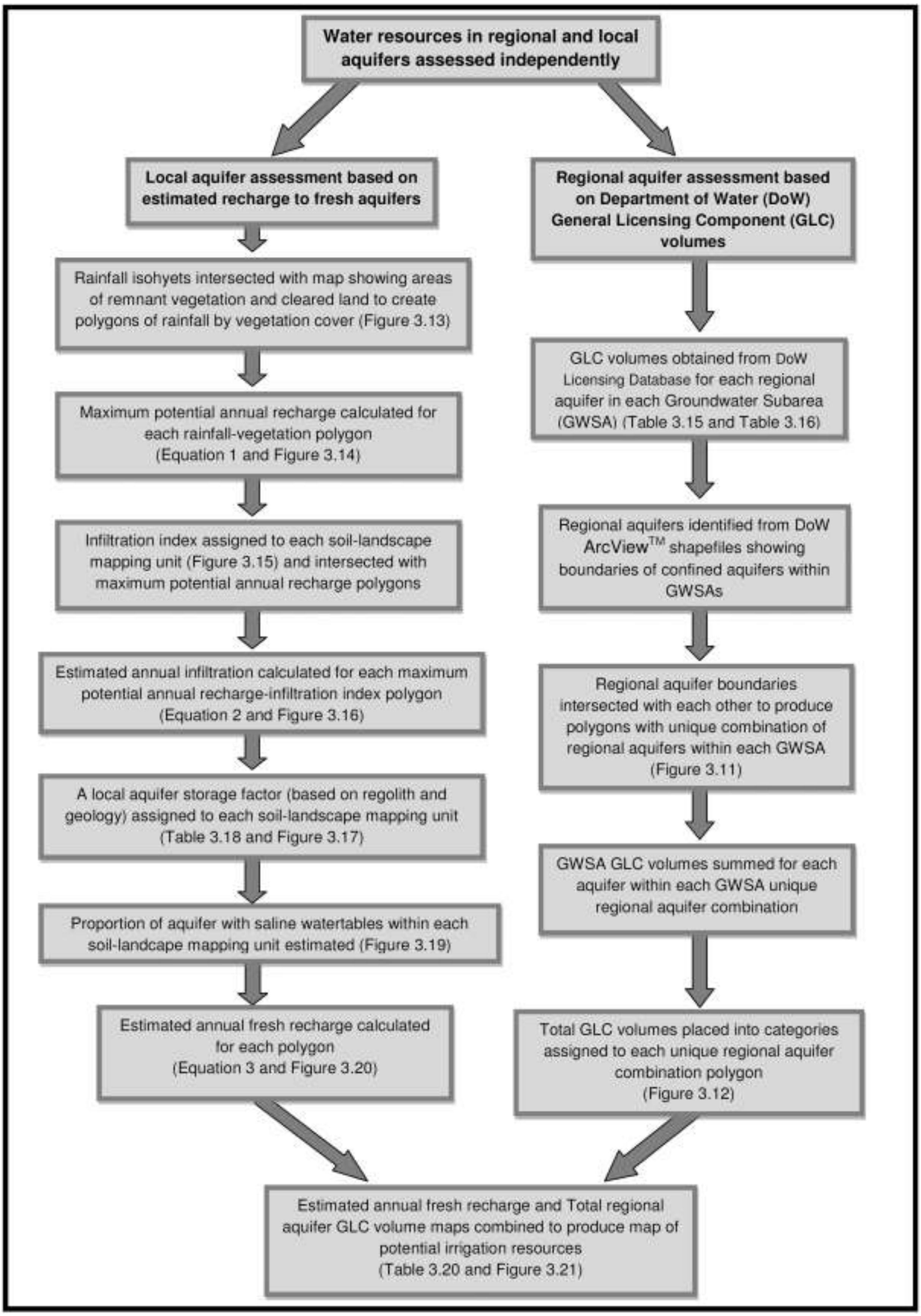


Figure 3.9 **Flow diagram of methodology used to assess groundwater resources**

In Tables 3.15 and 3.16, the aquifers of the GWSAs that overlap the Region are listed by GWSA and categorised as being either regional (shaded grey) or local. Figure 3.10 shows the boundaries of the GWSAs in the Region, and Figure 3.11 shows aquifer boundaries within the GWSAs. This categorisation was based on the DoW shapefile (s 3.1.3) of the Arrowsmith aquifer boundaries in which each aquifer was assigned to one of two aquifer types—'confined' (categorised in this methodology as regional) or 'unconfined' (categorised here as local).[41] These categories were extrapolated to these aquifers where they occurred in the adjoining Gascoyne GWA.[42]

Tables 3.15 and 3.16 also present the GLC of the total allocation limit for each aquifer in each GWSA, as extracted from the DoW licensing database in May 2012.[43] The volume of water set aside by the DoW for general licensing is the volume of water potentially available to irrigated agriculture in the future.

The GLC includes existing licensed entitlements of general licensees (both agricultural and non-agricultural users), as well as water currently available for licensing. It does not include public water supply reserves, current allocations to the Water Corporation, or the exempt unlicensed component (that is, water that is not required to be licensed under the *Rights in Water and Irrigation Act 1914,* such as domestic and stock water).[44]

The full volume of the GLC is assumed to be potentially available for irrigated agriculture in the longer term. This is the case even though some existing licensed entitlements have been allocated by the DoW to non-agricultural users such as mining companies. These existing licensed entitlements could potentially be traded, transferred or leased to agricultural users in the future.

The full volume of the GLC is only potentially available for irrigated agriculture. Currently, licensees may not be willing to trade all or part of their licensed entitlements to agriculture. Water availability for agriculture will actually decline in the future (at least in the short-term) if new licensed entitlements are issued to non-agricultural users.

The full volume of the GLC should not be confused with the volume of water currently available for licensing. In most cases, the volume of water available for licensing will be smaller because some of the GLC is already allocated, committed or requested.

Further information on groundwater allocations and licensing in the Arrowsmith GWA (covering the southern 10 per cent of the Region) can be found in the *Arrowsmith Groundwater Allocation Plan* (DoW 2010). Up-to-date information on the GLC and availability volumes needs to be accessed directly from the DoW.

In contrast to the situation with the regional aquifers, the GLC for local aquifers has not been used when assessing the irrigated agriculture potential of the Region. Groundwater allocations for the local aquifers have been set by the DoW at a broad scale (that is, a single

[41] While many aquifers are clearly confined or unconfined, others fall between these two types. Some portions of the Yarragadee are confined by overlying aquitards while elsewhere the Yarragadee is connected directly to the surface.

[42] Some aquifers, such as the Tumblagooda aquifer, have been designated as local aquifers even though they may be more akin to regional aquifers in parts of the Gascoyne GWA. They can be extensive and may well be confined in places. Gascoyne GWA aquifers with no aquifer type specified have been treated here as local aquifers.

[43] As the southern Gascoyne GWA is yet to be investigated in detail, groundwater allocations (and their general licensing component) for some of the aquifers are nominal and conservative at this stage.

[44] Allocations to the Water Corporation for public water supply are currently not included as part of the general licensing component in the DoW licensing database. In the past, however, they were included as part of the general licensing component in the *Arrowsmith Groundwater Allocation Plan* (DoW 2010).

volume across a GWSA). Mapping HQAL requires a more detailed and local scale assessment of groundwater resources. To resolve this, revised estimates of potential recharge that consider local conditions (rainfall, vegetation, soil and landform variation) were generated as part of this project.

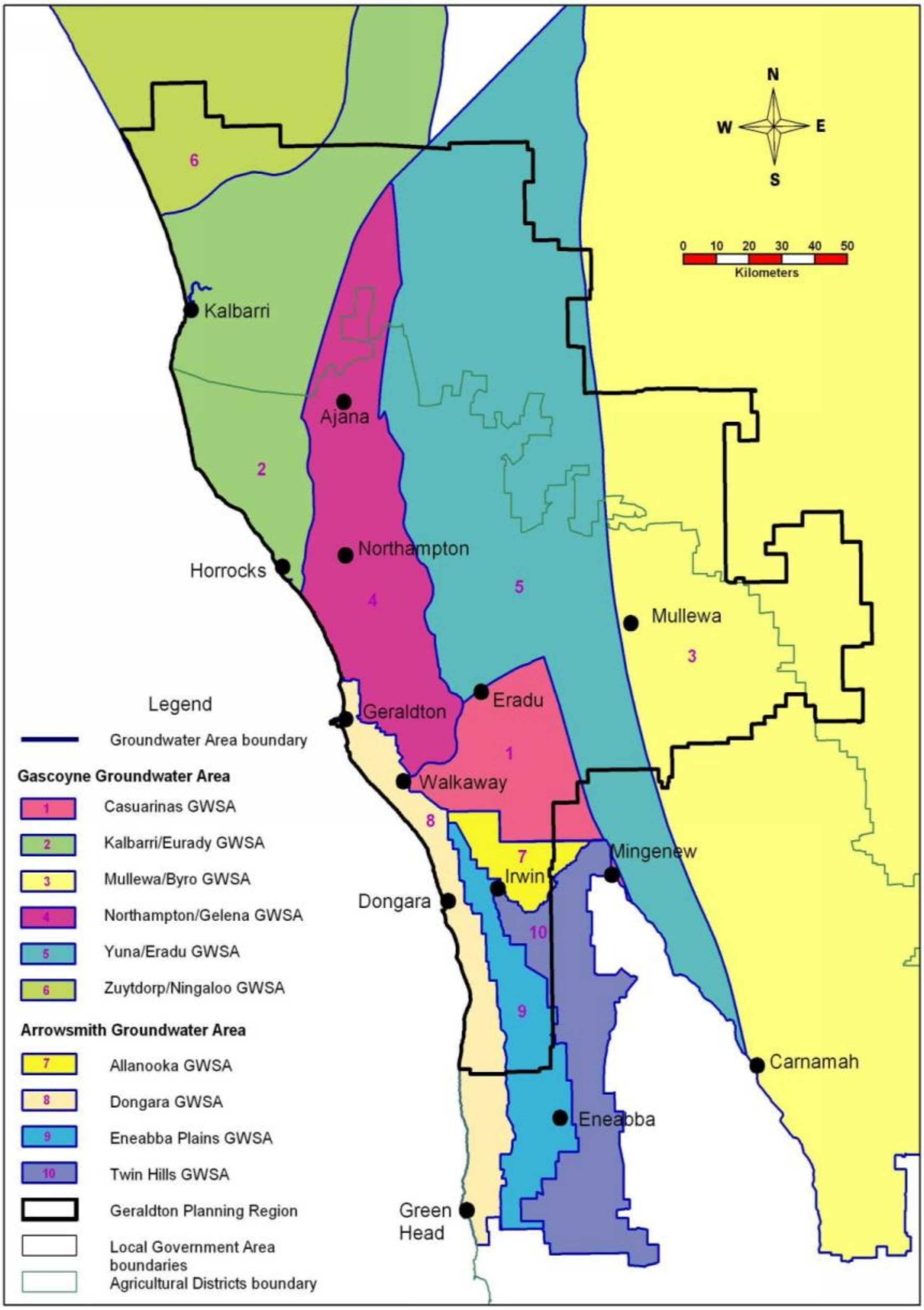


Figure 3.10 **Groundwater subareas of the Geraldton planning region. Source: adapted from DoW shapefiles.**

Table 3.15 **Regional and local aquifers of the Arrowsmith groundwater subareas that overlap the Geraldton planning region, along with the general licensing component of their total allocation limit**

Groundwater area (GWA)	Groundwater subarea (GWSA)	Aquifer type*	Aquifer	GLC ML/yr†
Arrowsmith	Allanooka	Regional	Yarragadee	8 500
	Dongara	Regional	Cattamarra‡	200
			Yarragadee	3 750
		Local	Superficial Swan	6 900
	Eneabba Plains	Regional	Cattamarra‡	100
			Eneabba	2 000
			Yarragadee	20 440
		Local	Superficial Swan	14 470
	Twin Hills	Regional	Cattamarra	500
			Lesueur	200
			Parmelia	3 400
			Yarragadee	42 830
		Local	Perth – Surficial	490

* Based on data in the DoW shapefile of aquifers. Confined aquifers have been designated as regional aquifers here while unconfined aquifers have been designated as local aquifers.

† Extracted from DoW licensing database, May 2012.

‡ GLC is a nominal estimate only.

New vines show expansion of table grape plantings at Walkaway in the City of Greater Geraldton.

Table 3.16 **Regional and local aquifers of the Gascoyne groundwater subareas that overlap the Geraldton planning region, along with the general licensing component of their total allocation limit**

Groundwater area	Groundwater subarea	Aquifer type*	Aquifer	GLC ML/yr†
Gascoyne	Casuarinas	Regional	Yarragadee	4 600
		Local	Cockleshell Gully	5 000
			Permian Sandstone	290
			Superficial Swan	100
	Kalbarri/ Eurardy	Unspecified	Sandstone	1 000
		Local	Carnarvon – Surficial	100
			Sedimentary	1 000
			Tumblagooda	4 300
	Mullewa/Byro	Local	Combined Fractured Rock – Alluvium	10 000
			Combined Fractured Rock – Calcrete	10 000
			Combined Fractured Rock – Fractured Rock	9 925
			Combined Fractured Rock – Palaeochannel	10 000
	Northampton/ Gelena	Local	Fractured Rock	4 950
			Sedimentary	2 000
			Superficial Swan	200
			Surficial	5 000
			Tumblagooda (Carnarvon Basin)	100
			Tumblagooda (Perth Basin)	1 000
	Yuna/Eradu	Regional	Yarragadee	500
		Local	Cockleshell Gully	1 000
			Combined Fractured Rock	100
			Northampton Fractured Rock	100
			Permian Sandstone	5 000
			Perth – Surficial (north)	435
			Sedimentary	1 000
	Zuytdorp/ Ningaloo	Local	Carnarvon – Alluvium	12 200
			Carnarvon – Sedimentary	5 000
			Carnarvon – Superficial	5 000
			Carnarvon – Tumblagooda	0
		Unspecified	Carnarvon – Birdrong	29 370
			Carnarvon – Windalia	0

* Based on data in the DoW shapefile of aquifers. Confined aquifers have been designated as regional aquifers here while unconfined aquifers have been designated as local aquifers.

† Extracted from DoW licensing database, May 2012.

Assessment of groundwater resources in regional aquifers

The digital boundaries of the aquifers listed in Tables 3.15 and 3.16 were intersected with each other to produce a GeoMedia™ warehouse feature class comprising polygons with unique combinations of regional aquifers within each GWSA. The distribution of these unique regional aquifer combinations is shown in Figure 3.11.

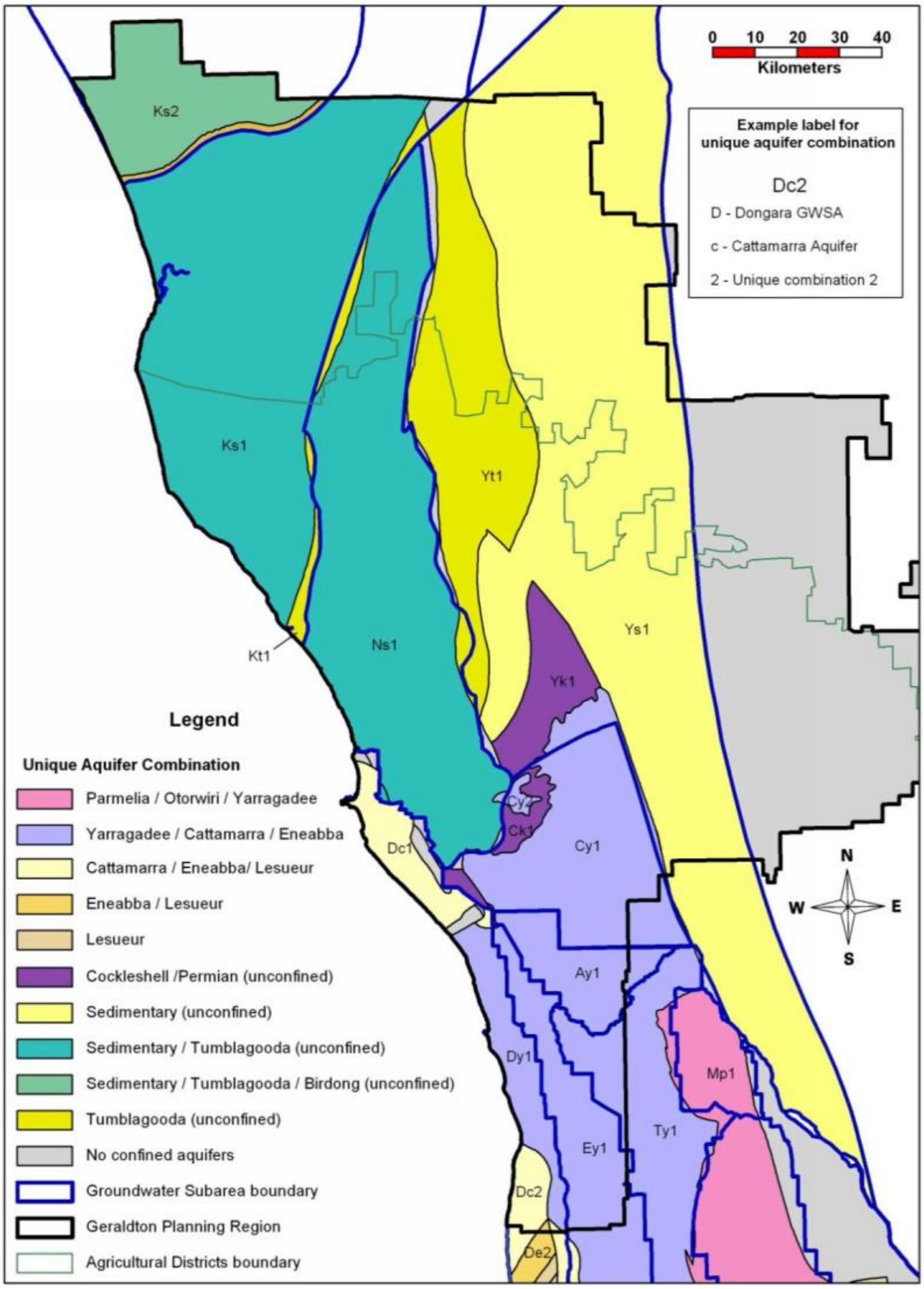


Figure 3.11 **Unique regional aquifer combinations for groundwater subareas of the Geraldton planning region (adapted from DoW shapefiles)**

The original DoW mapping was modified slightly in the northern Casuarina GWSA and the adjoining portion of the Yuna/Eradu GWSA to reflect more recent mapping of the extent of the Yarragadee aquifer (Laz Leonhard, DoW, pers. comm. 2011).

At this stage, no attempt has been made to exclude groundwater resources of unsuitable quality for irrigation, as there is insufficient water quality data. Most of the GLC within the

Yarragadee aquifer would appear to be of suitable quality, while the poorer quality GLC in the Cattamarra aquifer is relatively small.

In the GeoMedia™ warehouse, the GWSA GLCs were assigned to each unique regional aquifer combination polygon containing the relevant aquifer. This is because (in theory at least) the full GLC can be abstracted from any portion of that aquifer.

The GLCs for each regional aquifer in the polygon were then summed to determine the total GLC for that polygon.[45] The results are presented in Figure 3.12.

Extensive area of shadehouses for vegetable growing adjacent to the Geraldton Airport at Moonyoonooka

[45] In most cases, summing was not necessary as there was only one regional aquifer with a general licensing component present in the unique regional aquifer combination.

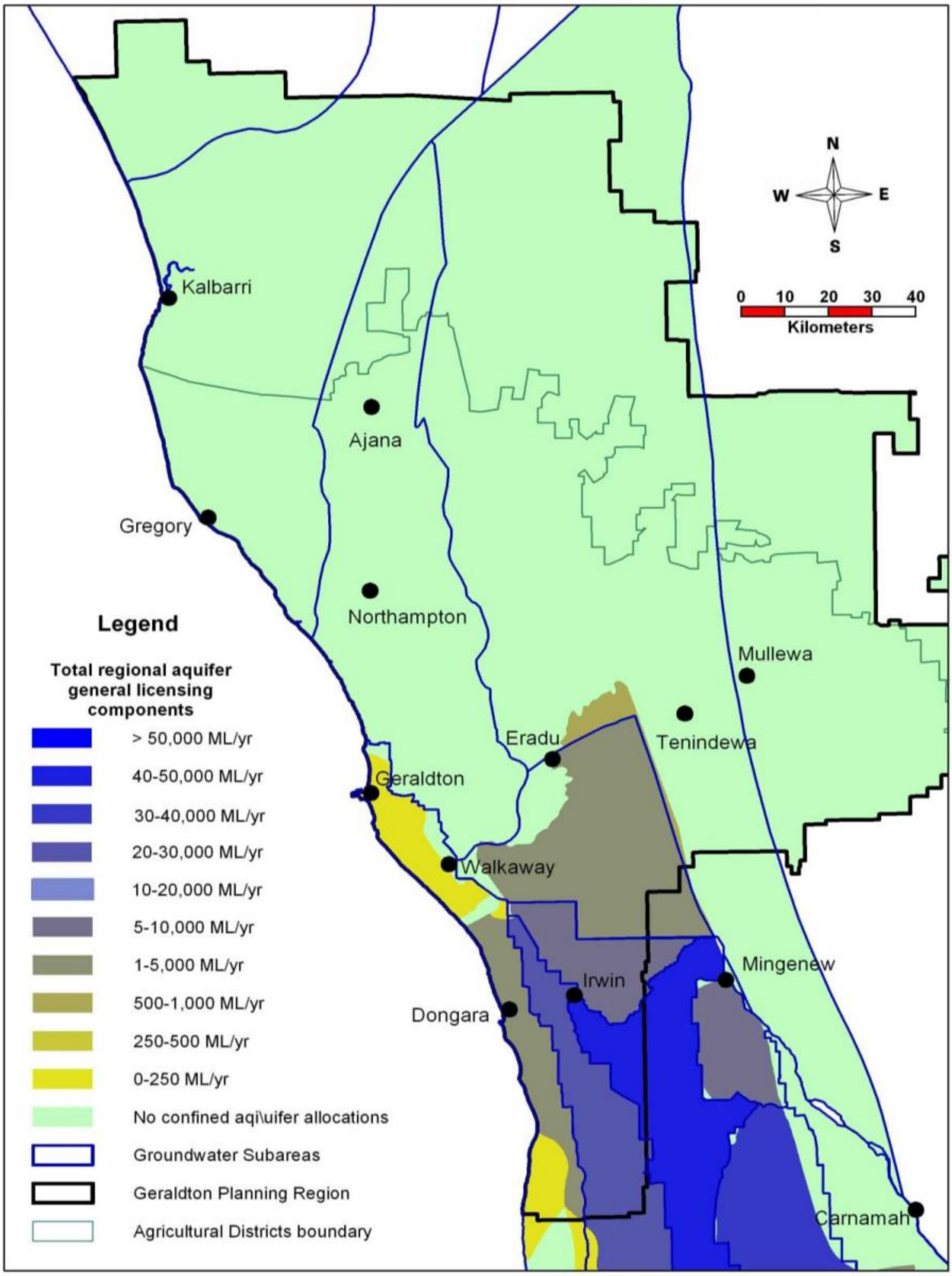


Figure 3.12 **General licensing component of the allocation limit for regional aquifers**

As the GWSA boundaries differ from those of the Region (Figure 3.10), many of the regional aquifers with GLCs extend beyond the Region. Table 3.17 shows the proportion of each regional aquifer underlying the Region.

Table 3.17 **Areas of regional aquifers and general licensing components in the Geraldton planning region**

GWSA		Regional aquifer			Within Geraldton planning region		
	A		B	C	D	E[46]	F[47]
Name	Total area ha	Name	GLC ML/yr	Total area ha	Area ha	Proportion of aquifer %	Proportion of GWSA %
Allanooka	54 100	Yarragadee	8 500	53 882	46 908	87	87
Casuarinas	175 113	Yarragadee	4 600	151 265	129 321	85	74
Dongara	171 699	Cattamarra	200	63 681	28 394	45	17
		Yarragadee	3 750	51 221	35 715	70	21
Eneabba Plains	151 073	Cattamarra	100	17 845	92	1	0
		Yarragadee	20 440	113 603	67 512	59	45
Twin Hills	231 252	Yarragadee	42 830	215 954	26 246	12	11
Yuna/Eradu	1 034 351	Yarragadee	500	16 212	15 305	94	1

Column E in Table 3.17 shows the proportion of regional aquifers located within the Region, providing an indication of the potential for competing claims (from both agricultural and non-agricultural users) to the groundwater resource from outside the Region. This does not equate to a proportion of the resource set aside for users within the Region.

From Table 3.17 it can be seen that the largest regional aquifer GLC (column B) accessible from within the Region is 42 830 ML from the Yarragadee aquifer in the Twin Hills GWSA. Only 12 per cent of this aquifer lies beneath the Region, the bulk of its area being located to the south. While (in theory at least) the entire GLC could be abstracted by licensees located within the Region, it cannot be assumed that they will have exclusive access to the water. Indeed, it is possible for the entire GLC to be allocated to users from outside the Region.

Assessment of groundwater resources in local aquifers

The methodology for assessing potential groundwater supplies from local aquifers is a modification on the methodology used by DoW (2009a) to calculate total allocations for aquifers. It concentrates on potential recharge from rainfall and incorporates annual rainfall, vegetation cover, land surface conditions, and aquifer properties. This methodology is still being developed but provides an indication of potential superficial and surficial water resources.

The formula used by DoW to calculate groundwater allocations in 1995 and 2002 was:

Total gross recharge (ML/yr) = Area (km^2) x Rainfall (mm/yr) x Recharge rate (%)[48]

This basic formula was adopted in this project, with modifications to the method of calculating the 'recharge rate' using geographic information system (GIS) datasets of the factors listed in the formula.

The first step in assessing potential groundwater supplies in local aquifers was to combine the digital datasets of rainfall and vegetation cover in a GeoMedia™ warehouse. Isohyets of average annual rainfall for 1975–2005 (with a 25 mm interval) were intersected with polygons

46 Column E (proportion of aquifer) = column D (area of aquifer within Geraldton planning region [ha]) divided by column C (total area of regional aquifer [ha]).

47 Column F (proportion of GWSA) = column D (area of aquifer within Geraldton planning region [ha]) divided by column A (total area of GWSA [ha]).

48 See tables in Appendixes A and B of the *Review of Jurien and Arrowsmith groundwater limits* (DoW 2009a).

showing remnant vegetation with an area in excess of 100 ha (Figure 3.13).[49,50] Each polygon was assigned a value for annual rainfall that was halfway between the two isohyets that bounded it. For example, a polygon sitting between the 300 mm and 325 mm isohyets was designated as receiving 312.5 mm average annual rainfall.

The vegetation cover factor was then determined as follows. For areas of predominantly cleared land (that is, under crops or pasture), it was assumed that a maximum of 8 per cent of average annual rainfall would become recharge (for example, the maximum recharge would be 16 mm for an area receiving 200 mm average annual rainfall).[51] For areas of remnant native vegetation, it was assumed that a maximum of 0.5 per cent of average annual rainfall would become recharge (for example, 1 mm recharge with 200 mm of rainfall). The average annual rainfall was then multiplied by the vegetation cover factor to derive the maximum potential recharge.

Equation 1: Maximum potential recharge (mm) = Average annual rainfall (mm) x Vegetation cover factor (%)

Where:

Vegetation cover factor for crops and pastures = 8.0%

Vegetation cover factor for remnant vegetation = 0.5%

The maximum potential recharge calculated by these means is shown in Figure 3.14.

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49 As this methodology for assessing local aquifer groundwater supplies is still under development it was decided to trial it with relatively simple datasets. Post-1975 rainfall is commonly used in WA for assessments of water supplies. In future iterations of the model these could be replaced with lower interval rainfall isohyets generated from the patched point dataset for a period more reflective of the recent climate. It should also be possible to generate data for effective rainfall events.

50 See s 3.1.2 and s 3.1.5 for more information on source data. The 100 ha size limitation was partly a pragmatic decision to limit the number of polygons involved but it was also considered that pockets of remnant vegetation smaller than 100 ha would have a limited effect on recharge.

51 According to the *Arrowsmith groundwater allocation plan* (DoW 2010) there have been no direct measurements of recharge rates in the Arrowsmith GWA. Recharge rates used to calculate allocation limits in the Arrowsmith GWA ranged from 5 to 10 per cent of mean annual rainfall and were based on extrapolation from estimates elsewhere in the Perth Basin. The vegetation cover factors used in this project were selected after consultation with DAFWA and DoW hydrogeologists.

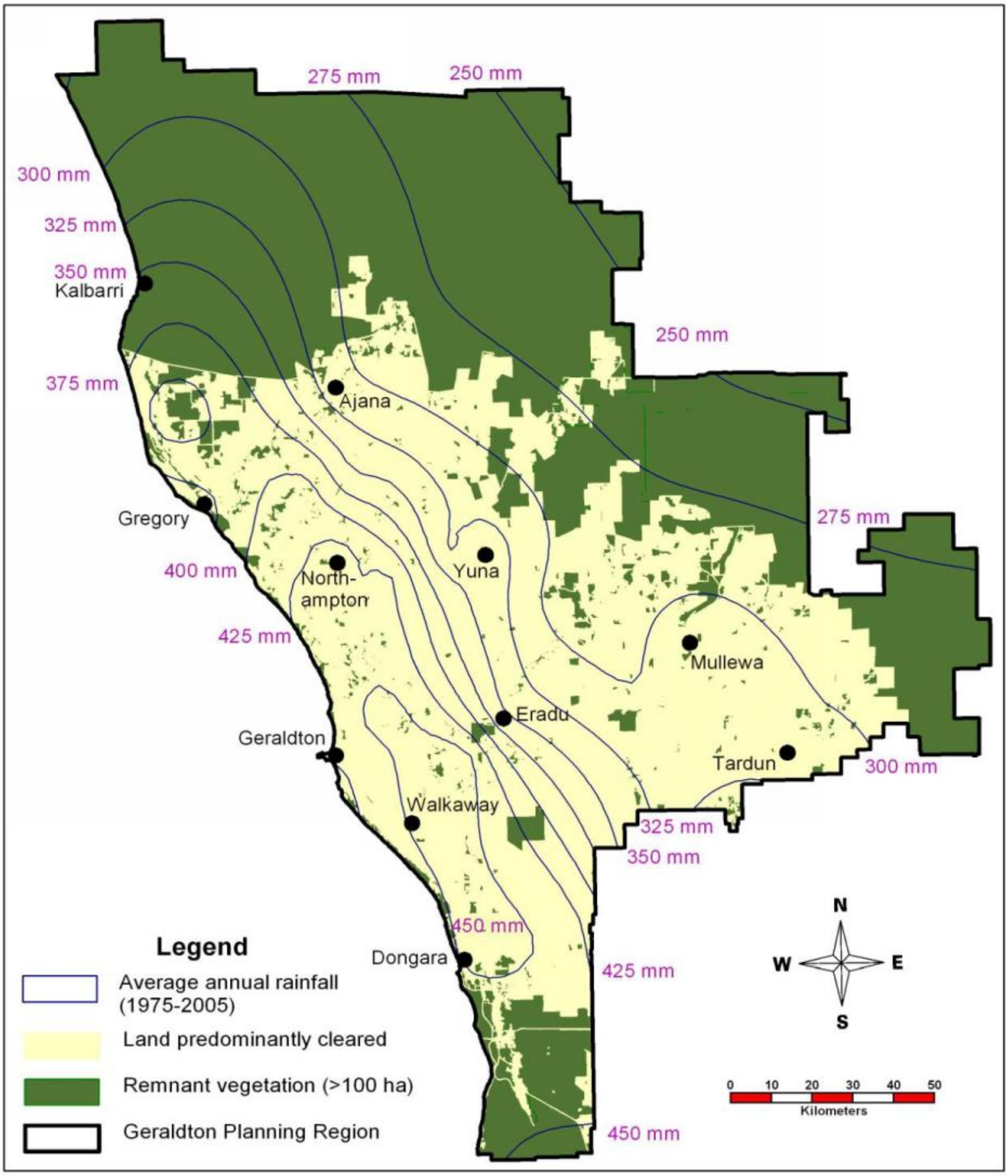

Figure 3.13 **Average annual rainfall (1975–2005) and remnant vegetation (> 100 ha) across the Geraldton planning region**

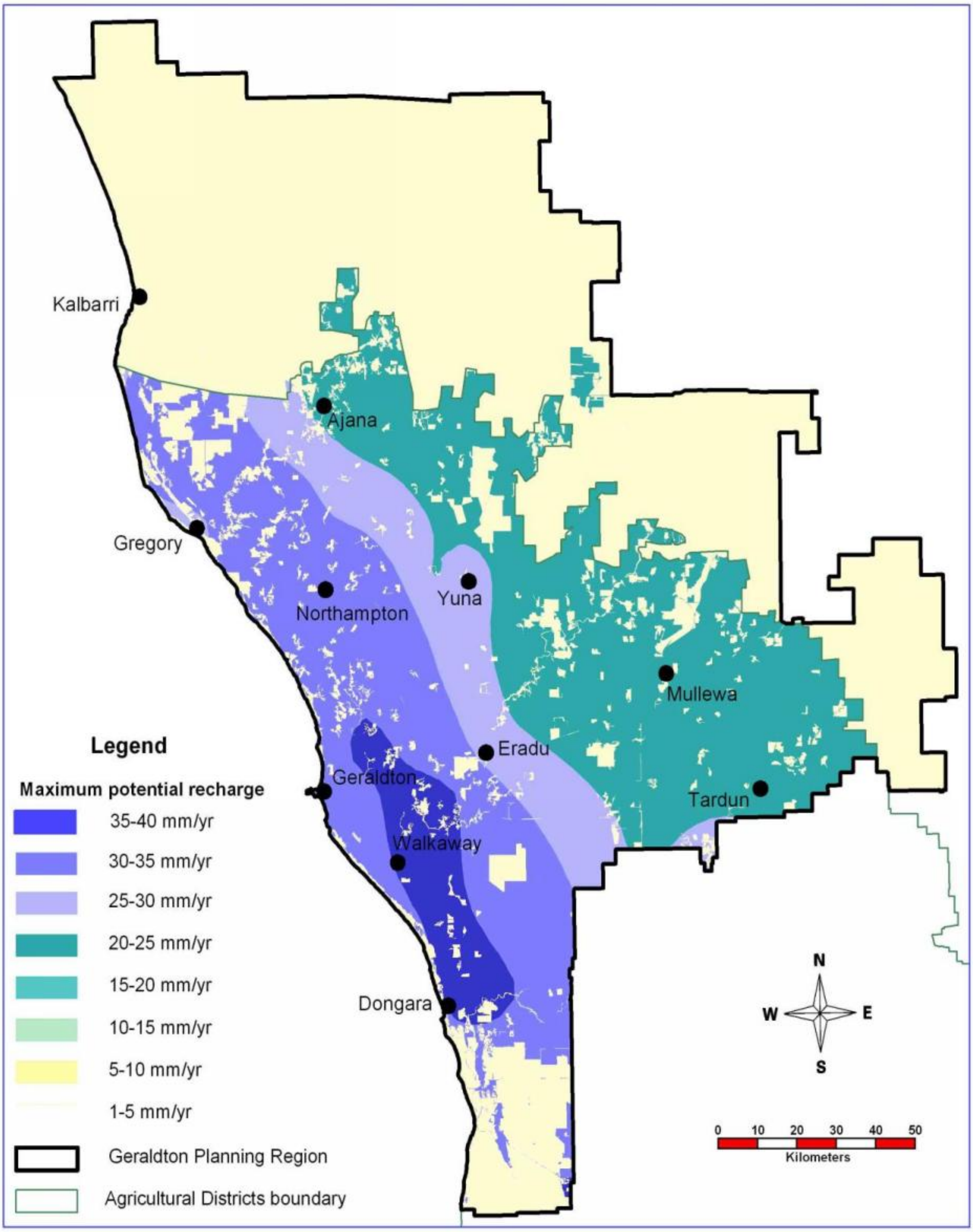

Figure 3.14 **Maximum potential annual recharge based on rainfall and vegetation cover across the Geraldton planning region**

The second step in assessing potential groundwater supplies in local aquifers involved intersecting the polygons of maximum potential annual recharge with the polygons of the soil-landscape map units (s 3.3.1). This was done to incorporate soil and landform factors that would influence run-off and infiltration into the assessment of potential recharge.

An infiltration index, representing the proportion of the maximum potential recharge likely to infiltrate into the soil profile—as opposed to becoming run-off—was assigned to each soil-landscape map unit.

The infiltration index was determined from the soil properties and landform characteristics of its component ZLUs of the soil-landscape map units (see s 3.1.1). It takes into account factors affecting both infiltration excess (slope gradient and topsoil texture, condition and water repellence) and saturation excess (soil permeability and texture contrast as well as the potential for waterlogging).

The infiltration index is the inverse of the run-off index used in the South-West Run-off Estimator (Westrup et al. 2007, Tille et al. forthcoming). An exception to this relationship is the case of water bodies and swamps where it is assumed that rainfall will contribute to run-off but recharge rates are also likely to be high.

The infiltration index is highest (in excess of 90 per cent) on relatively flat map units with sandy soils. Examples are 223Bn_1 (Binnu 1 sandplain) and 220Ca (Casuarina sandplain). The index is lowest (50–60 per cent) on steeper map units with shallow soils (for example, 225Mo_1ss – Moresby sideslopes) or flats with heavy textured soils (221Ga_1 – Greenough 1). Figure 3.15 shows the infiltration index applied to map units across the Region.

Irrigated pasture in the Irwin Valley, east of Dongara

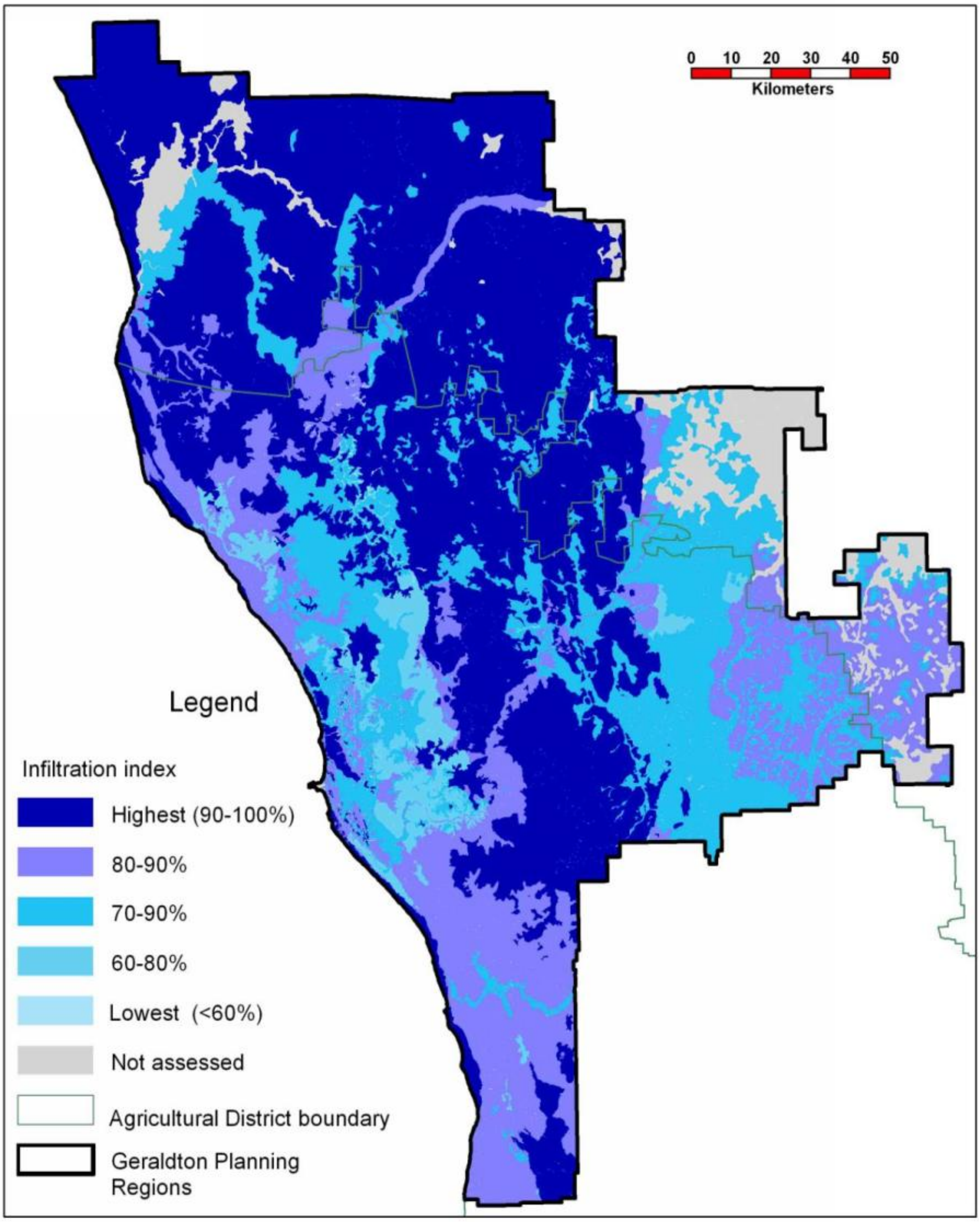

Figure 3.15 **Soil-landscape map unit infiltration index across the Geraldton planning region**

For each polygon created by intersecting the rainfall, vegetation cover and soil-landscape maps, the estimated infiltration was calculated using the following formula:

Equation 2: Estimated annual infiltration (mm) = maximum potential recharge (mm) x infiltration index (%)

The estimated annual infiltration is shown in Figure 3.16.

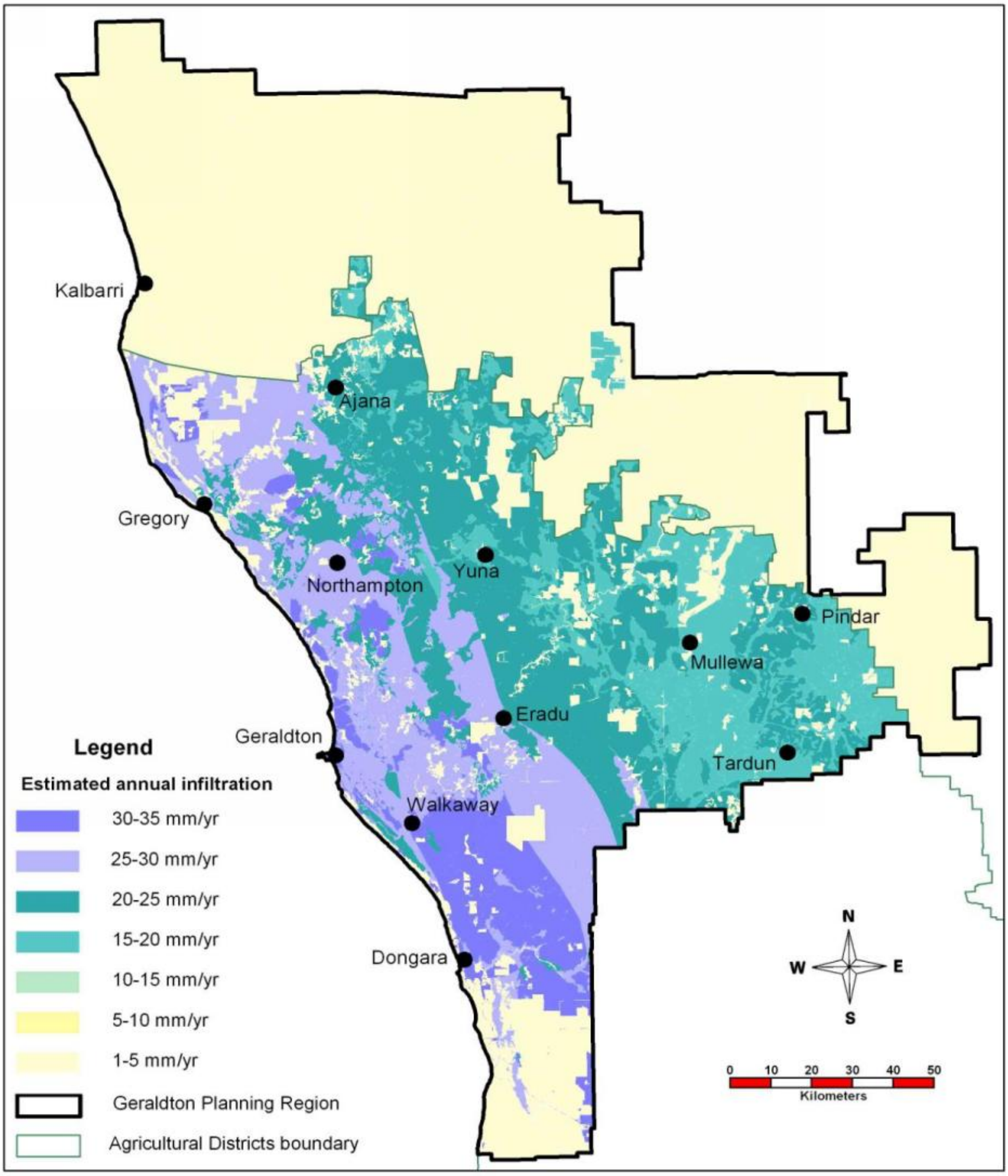

Figure 3.16 **Estimated annual infiltration based on rainfall, vegetation cover and soil infiltration across the Geraldton planning region**

The third step in assessing potential groundwater supplies in local aquifers involved assessing an aquifer's ability to accept, store and yield water. This is a function of the thickness and composition of the aquifer.

In an area underlain by unconsolidated sandy sediments greater than 10 m thick, the aquifer should be capable of storing all rainfall that infiltrates and percolates beyond the root zone. While clayey sediments tend to have a higher porosity than sandy sediments, they have lower permeability because the pores are smaller and many are not interconnected. This means that clays have a reduced capacity to accept and store infiltrated rainfall. It also means that groundwater is more difficult to abstract from clays than from sandy sediments.

A shallow aquifer overlying impermeable bedrocks will have a limited capacity to store infiltrated rainfall. In areas where the aquifer consists of about 50 cm of weathered granite (including much of the land around Northampton), infiltrated water will return to the surface as seepage once all the pore spaces have been filled.

In the absence of detailed mapping of local aquifers, the soil-landscape mapping has been used as a substitute. The soil and landforms are heavily influenced by the nature of the underlying materials. Three descriptors of substrate materials (potential aquifers) have been assigned to each soil-landscape unit in the Region to categorise the materials occurring beneath the top 1.5 m of the soil profile.[52]

The first descriptor categorises the unconsolidated regolith material on which the soil profile sits. The second categorises the 'hard rock' geology underlying this regolith. The third categorises a second geological layer.[53] The categories have been kept reasonably broad and no attempt has been made to capture the full complexity of the geological strata.

An example from the Moresby Range is the map unit 255Mo_1Mt (Moresby mesa tops). Here the regolith has been categorised as 'shallow weathered profile', the first geological layer has been categorised as 'sedimentary rocks' and the second geological layer has been categorised as 'crystalline rocks'.

Figure 3.17 shows the regolith category applied to the map units of the Region, and Figure 3.18 shows the combined geology categories. These maps combine to form a surrogate local aquifer map.

Each unique combination of these three substrate materials has been assigned a local aquifer storage factor reflecting the expected ability to accept, store and yield water. These are presented in Table 3.18.[54]

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[52] This data is yet to be incorporated into the DAFWA Map Unit Database and currently sits in an offline database.

[53] In some cases, the second geological layer will be the same as the first geological layer.

[54] The local aquifer storage factor assignments are very preliminary at this stage. A more robust method of dealing with the storage factor may be developed in the future.

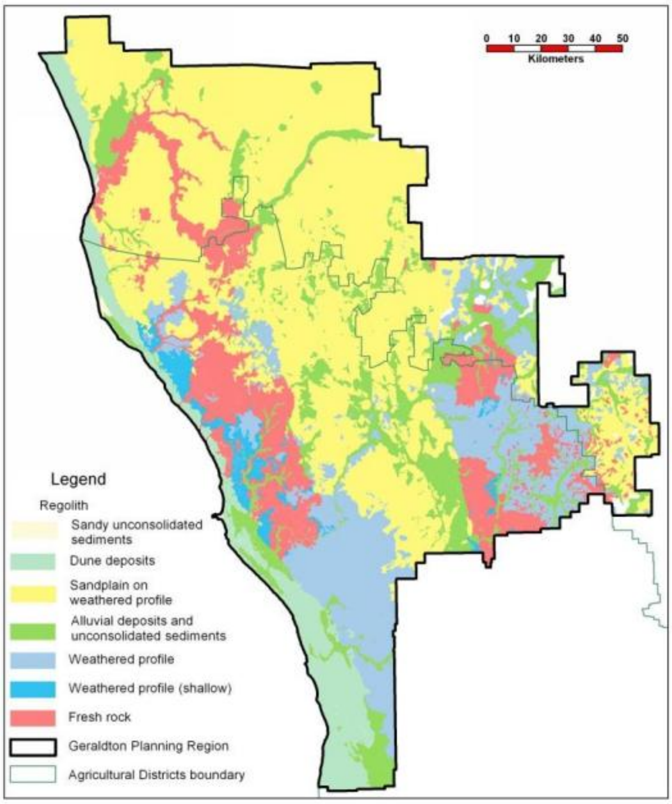

Figure 3.17 **Regolith categories across the Geraldton planning region**

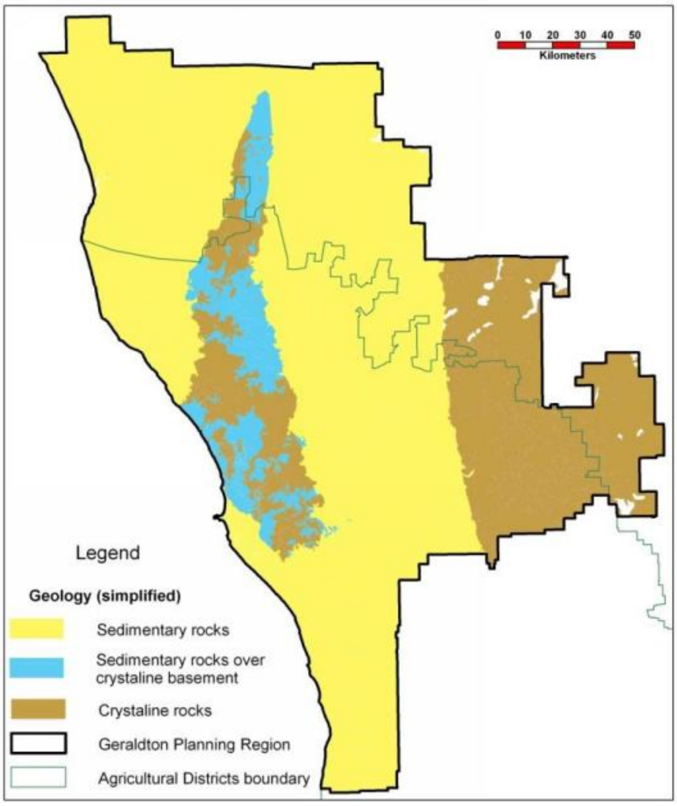

Figure 3.18 **Simplified geology across the Geraldton planning region**[55]

55 In combination, the mapping in Figures 3.17 and Figure 3.18 form a surrogate unconfined aquifer map that is too detailed to be presented at a scale that fits on an A4 page.

Table 3.18 **Local aquifer storage factors applied to the types of regolith mapped in the Geraldton planning region**

Local aquifer storage factor %	Regolith	Geology 1	Geology 2
100	Dune deposits	Sedimentary rocks	Sedimentary rocks
100	Sandy unconsolidated sediments		
95	Sandplain on weathered profile		
90	Alluvial deposits		
90	Unconsolidated sediments		
90	Weathered profile		
80	Fresh rock		
80	Weathered profile (shallow)		
50	Dune deposits	Sedimentary rocks	Crystalline rocks
50	Sandy unconsolidated sediments		
50	Weathered profile		
48	Sandplain on weathered profile		
45	Alluvial deposits		
45	Unconsolidated sediments		
40	Fresh rock		
40	Weathered profile (shallow)		
40	Dune deposits	Crystalline rocks	Crystalline rocks
40	Sandy unconsolidated sediments		
30	Sandplain on weathered profile		
25	Alluvial deposits		
25	Unconsolidated sediments		
10	Weathered profile		
5	Weathered profile (shallow)		
1	Fresh rock		

The final step in assessing potential groundwater supplies in local aquifers involved excluding recharge feeding saline aquifers. This was achieved by estimating the proportion of the soil-landscape units underlain by saline watertables.[56]

For each soil-landscape unit, the proportional area of the ZLUs recorded in the Map Unit Database as being saline or having a salinity risk was summed. For some map units, this value was increased manually to include areas known to be underlain by saline watertables but in which this salinity is unlikely to develop a surface expression. This adjustment was based on data presented in Bairstow et al. (2006).[57] Figure 3.19 presents the estimates of map unit surficial groundwater salinity based on the soil-landscape mapping units.[58]

56 This includes groundwater that would be classified as brackish (1500–5000 mg/L), saline (5000–50 000 mg/L) or hypersaline (> 50 000 mg/L) by DoW.

57 These adjustments are listed in Appendix F.

58 These estimates will require future review. They could be modified or replaced by mapping of salinity in superficial and surficial aquifers if available.

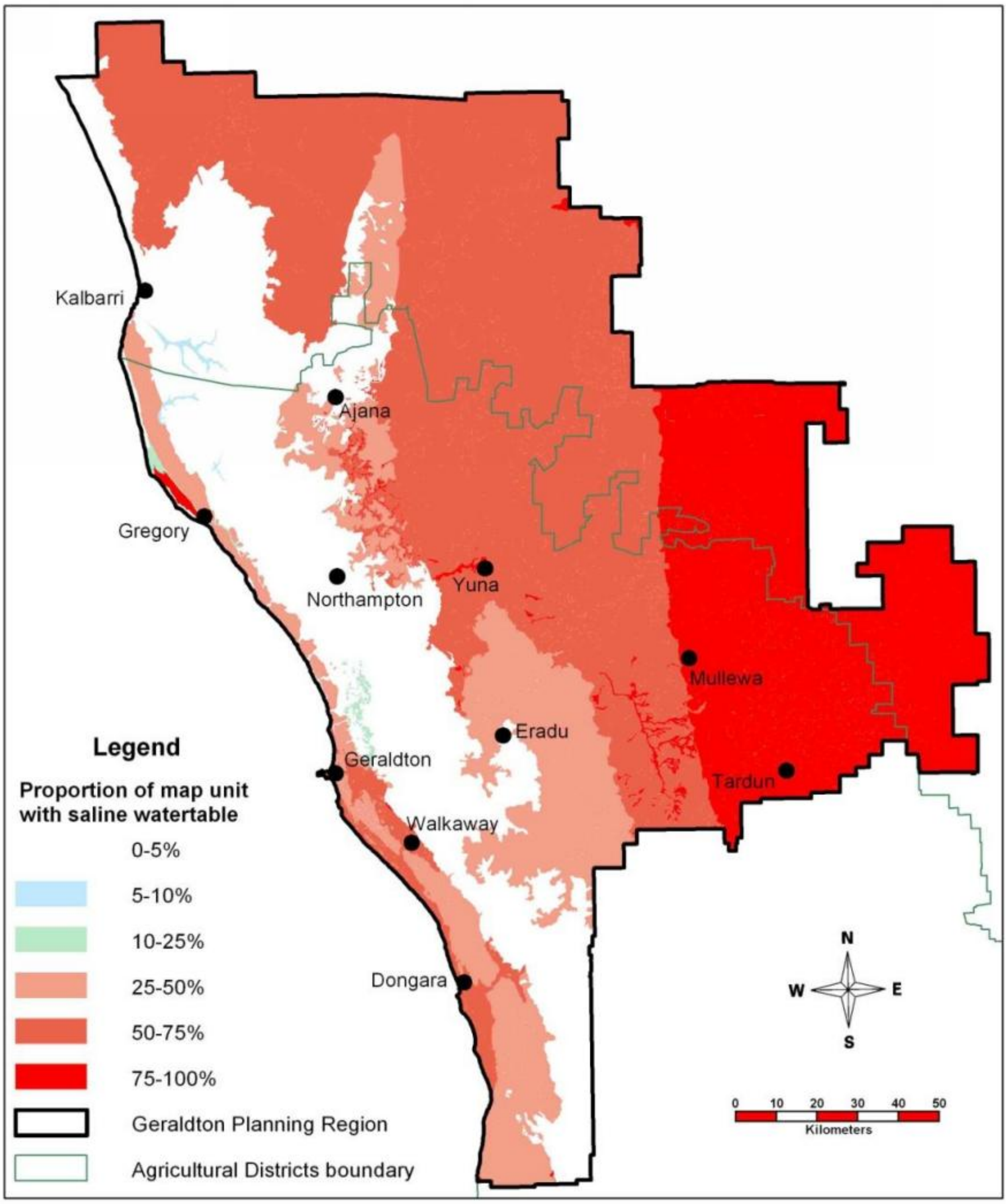

Figure 3.19 **Estimated proportion of saline watertables across the Geraldton planning region**

The estimate of recharge to fresh aquifers was calculated using the following formula:

Equation 3: Estimated annual fresh recharge (mm) = estimated annual infiltration (mm) x local aquifer storage factor (%) x map unit salinity (%)

This estimate of recharge can be expressed in millimetres (mm) or megalitres per hectare (ML/ha). Figure 3.20 presents the estimated annual recharge of fresh aquifers.[59]

[59] In some cases, such as along the coastal strip south of Geraldton, areas are highlighted in Figure 3.20 as receiving lower recharge not because of low recharge rates but because a significant proportion of the aquifers being recharged are likely to be saline (as highlighted in Figure 3.19).

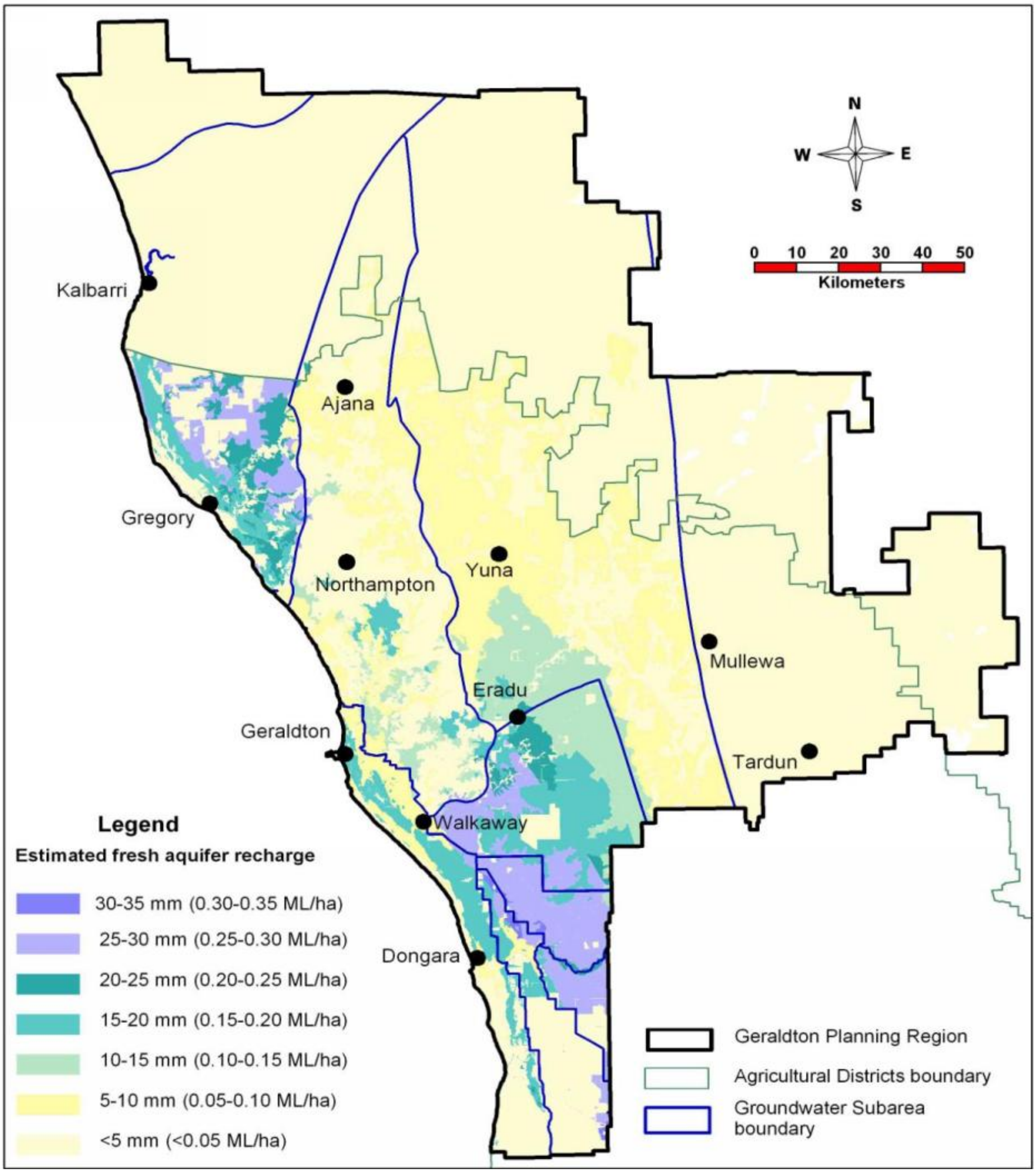

Figure 3.20 **Estimated annual recharge to fresh aquifers across the Geraldton planning region**

The estimate of annual recharge to fresh aquifers is a preliminary assessment only, requiring review and possible modification. It is yet to be tested against field data from bores drilled into local aquifers. This estimate of annual recharge to fresh aquifers does not replace the GLC of the allocation limit for local aquifers.

Where local aquifers exist, the mapped fresh aquifer recharge is a first-order approximation of the potential yield of the aquifer. This does not exclude water that is or will be allocated to the environment and public water supply. Where confined aquifers outcrop or are recharged by leakage from an overlying unconfined aquifer, the mapped fresh aquifer recharge represents the total recharge to all aquifers (local and regional) under that area.

Combining regional and local aquifer groundwater data

The use of two methods for assessing groundwater in regional and local aquifers resulted in the creation of two datasets with significant differences. Table 3.19 summarises some of these differences that are explained in more detail below.

Table 3.19 **Summary of differences between methods used to assess regional and local aquifer groundwater resources**

Difference	Method for regional aquifers	Method for local aquifers
Unit of measure	Total volume of GLC (ML/yr)	Volume by area of recharge (ML/ha/yr)
Uses of water resource considered	Yes*	No
Relationship to DoW groundwater allocations	Derived from GLC	Not directly related to groundwater allocations
Impact of groundwater abstraction from any given point	Likely to affect the aquifer across the entire extent of GWSA	Effects are likely to be localised and not impact other local aquifers within the GWSA

* Environmental water, public water supply and future water reserves are already subtracted from the volume of the GLC.

The assessment of groundwater supplies in regional aquifers is based on the GLC determined by the DoW (Figure 3.12). It is expressed as a volume of water that can be abstracted on an annual basis (ML/yr) without adversely affecting the groundwater resource or the environment. This volume applies (in theory at least) across the full extent of each individual aquifer within the GWSA. Abstraction from any given point will reduce the volume of water available for licensing over the remainder of the aquifer.

In contrast, the assessment of groundwater supplies in local aquifers is based on an estimate of annual recharge to fresh aquifers (Figure 3.20). It is expressed in millimetres of average annual recharge (mm/yr) and can be converted into a volume per given area (ML/ha/yr). Having been determined at a local scale, these recharge estimates can be matched to parcels of land with soils suitable for irrigation.

Some problems arise in using these recharge volumes to calculate the water that is potentially available for abstraction from aquifers. The recharge volume will be an overestimate of the volume of water available for abstraction because no water has been set aside for the environment or for infiltration into the regional aquifers below. These recharge estimates are an indicative guide only.

Accessing the local aquifers is still a valid option but there is and always will be limitations and constraints. There are often numerous local aquifers within a GWSA and these individual aquifers contain only small volumes of water compared to the regional aquifers. Bore yields are often low and will vary at different locations depending on site-specific conditions. A volume of water that could be abstracted from one location within a GWSA may not exist at another location.

Furthermore, bore yields decline as the watertables of the unconfined local aquifers fall, limiting the spatial impact of over-pumping at a single location. Drawing down all the local supplies from one location may have little or no effect on local groundwater in another location as they may not be connected, or there may be no piezometric gradient between the locations.

Bores that exploit local aquifer groundwater resources usually need to be widely spaced. In some instances, pumping rules will need to be applied to any abstraction from unconfined aquifers to avoid impacts on the resource (such as salt recycling and watertable declines) and on other users.

The GLC in regional aquifers is unrelated to the recharge estimates. For the resource to be sustained into the future, water abstracted from regional aquifers will need to be replaced by surficial recharge, either directly or indirectly. Recharge may come from overlying local aquifers via preferred pathways in the separating aquitard or from remote locations where the aquifer is directly connected to the surface (that is, where the aquifer itself is unconfined). Either way, some of the annual recharge of local aquifers will be required for future recharge of regional aquifers. This water cannot be used twice.

To combine the regional and local aquifer data and create a single estimate of groundwater resources, the maps presented in Figures 3.12 and 3.20 were intersected in GeoMedia™ to create a new map with polygons attributed by both datasets. The potential irrigation resource was then determined according to the criteria in Table 3.20. These criteria are discussed below.

Table 3.20 **Potential irrigation resource, based on a combination of regional aquifer general licensing component and estimated recharge to fresh aquifers**

	Estimated recharge to fresh aquifers (mm/yr)			
Regional aquifer GLC (ML/yr)	**> 25**	**15–25**	**10–15**	**< 10**
> 30 000	A. Largest groundwater resource	A. Largest groundwater resource	A. Largest groundwater resource	A. Largest groundwater resource
20 000–30 000	A. Largest groundwater resource	A. Largest groundwater resource	B. Relatively large groundwater resource	B. Relatively large groundwater resource
10 000–20 000	B. Relatively large groundwater resource	C. Moderately large groundwater resource	C. Moderately large groundwater resource	D. Moderate groundwater resource
5 000–10 000	C. Moderately large groundwater resource	D. Moderate groundwater resource	D. Moderate groundwater resource	D. Moderate groundwater resource
2500–5000	D. Moderate groundwater resource	D. Moderate groundwater resource	E. Reasonable potential for groundwater	F. Fair potential for groundwater
< 2500	E. Reasonable potential for groundwater	F. Fair potential for groundwater	G. Limited or unknown groundwater	G. Limited or unknown groundwater

In Table 3.20, the main emphasis was placed on the regional aquifer GLCs, with six basic categories being recognised. The first was areas of land overlying regional aquifers with a total GLC in excess of 30 000 ML/yr, characterised as having the largest groundwater resource. This is enough water to irrigate more than 2500 ha of the horticultural enterprise mix shown in Table 3.24.

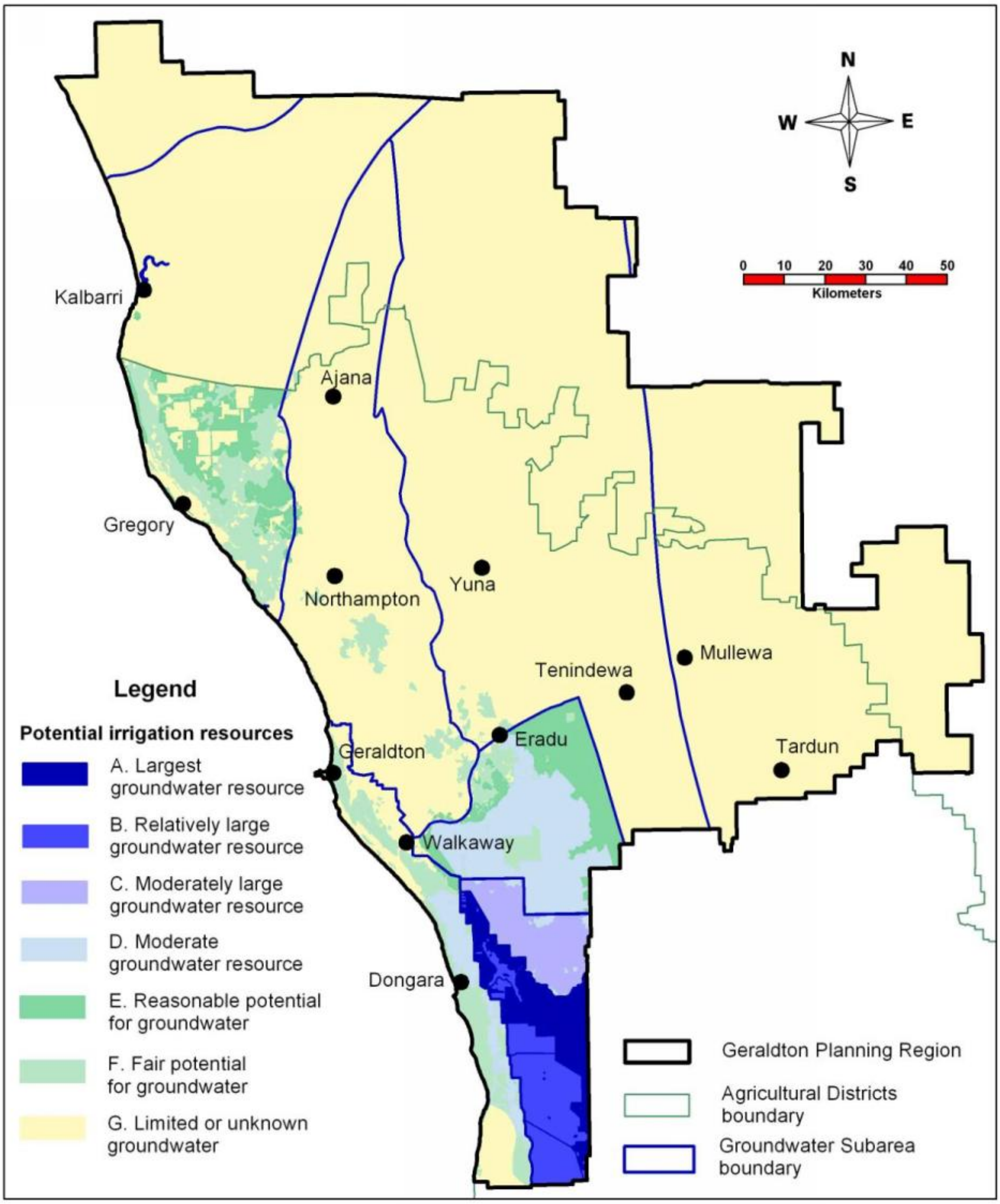

Figure 3.21 **Potential irrigation resources across the Geraldton planning region**

The second category was land overlying total GLCs of 20 000 ML/yr to 30 000 ML/yr, enough to irrigate more than 1500 ha of the horticultural enterprise mix.

The third category comprised land overlying total GLCs of 10 000 ML/yr to 20 000 ML/yr, enough to irrigate about 800 ha.

The fourth category comprised land overlying total GLCs of 5000 ML/yr to 10 000 ML/yr, enough to irrigate about 400 ha.

The fifth category comprised land overlying total GLCs of 2500 to 5000 ML/yr, enough to irrigate around 200 ha.

The final category comprised land overlying total GLCs of less than 2500 ML/yr, which were not significant in terms of irrigation potential.

As shown in Table 3.20, the recharge estimates were used to modify the categories for total GLCs. For land receiving lower rates of recharge, the total GLC category was downgraded. This partly reflected the reduced opportunity of supplementing water abstracted from the regional aquifers with water abstracted from local aquifers. It also reflects the reduced potential for direct recharge of the regional aquifers.

Where the total GLC is less than 5000 ML/yr, the recharge estimates used in Table 3.20 indicate areas where groundwater supplies may potentially exist. This was based on the assumption that the higher the recharge, the greater the chance of exploitable volumes of groundwater occurring.

Figure 3.21 displays the distribution of potential irrigation resources, as defined in Table 3.20, across the Region. It is important to realise that the full volume of the GLC upon which this map is based are not set aside exclusively for the use of irrigated agriculture. Nor is access to water restricted to licensees located within the Region. Indeed, significant volumes of the resource shown are currently being abstracted by licensees located in the Shires of Three Springs, Carnamah and Coorow to the south and east of the Region.

Figure 3.21 provides an indication of the potential groundwater resources for irrigation in the longer term. It does not show the volumes of water currently available for licensing. The volumes of groundwater available to potential irrigators (and other users) are subject to continual change.

For up-to-date information on the volumes available for licensing, contact the DoW in Geraldton.

The limitations of this methodology of assessing groundwater resources presented on the preceding pages are summarised in Box 3.2.

Box 3.2 **Limitations of the methodology to assess potential water resources for irrigated agriculture**

- The methodology does not consider the water currently available for licensing or the water that can be accessed at individual properties.
- The methodology does not consider the economics of groundwater use in terms of the number and depth of bores required to access water for irrigation.
- The methodology cannot account for the licensing process which must consider water availability, impacts to the aquifer, environment and other users.
- Groundwater resource data at two differing scales have been combined into one dataset.
- Some aquifers designated and assessed as local (for example, Tumblagooda) may actually be regional aquifers.
- Groundwater allocation limits for some regional aquifers, especially those within the Gascoyne GWA, are nominal only and may over or underestimate the volume of the resources.
- It may not be physically possible to abstract the full volume of an aquifer’s GLC from any given location above that aquifer.
- Variation in groundwater quality in regional aquifers is not considered.
- As groundwater allocation limits are subject to future review and amendment, the volumes presented in the report may not reflect future allocations.
- It cannot be assumed that future water entitlements will be allocated exclusively for irrigators within the Region.
- Rainfall recharge estimates do not translate directly into volumes of water stored in regional aquifers.

Matching land and water data

To determine the overall potential for irrigated agriculture, the groundwater availability and land capability datasets were matched. Since Figure 3.21 incorporates the soil-landscape mapping units, it was possible to attribute the irrigated land categories (Table 3.13) directly to each polygon, along with the groundwater availability category (Table 3.20).

The criteria in Table 3.21 were then used to determine the irrigated agriculture potential of each polygon in Figure 3.21, to then create Figure 3.22 which presents the potential irrigated agriculture categories for the agricultural districts within the Region.

Table 3.21 **Determining potential for irrigated agriculture**

Potential irrigation resource	**Land category for irrigated agriculture**			
	Very high (VH1, VH2)	**High (H1, H2)**	**Moderate (M1, M2)**	**Low (L)**
Large groundwater resources (A, B)	1. Large water resources – Best land	2. Large water resources – Good land	3 Large water resources – Fair land	6. Large to moderate water resources – Poor land
Moderate groundwater resources (C, D)	4. Moderate water resources – Best land	5. Moderate water resources – Good to fair land	5. Moderate water resources – Good to fair land	6. Large to moderate water resources – Poor land
Potential groundwater resources (E, F)	7. Potential water resources – Best land	8. Potential water resources – Good to fair land	8. Potential water resources – Good to fair land	10. Limited potential for irrigation
Limited or unknown groundwater resources (G)	9. Limited or unknown water resource – Best land	10. Limited potential for irrigation	10. Limited potential for irrigation	10. Limited potential for irrigation

The categories are numbered in descending potential for irrigated agriculture.

- **Category 1** areas have the greatest potential for irrigated agriculture. They have large groundwater resources and the land has a very high capability—being the most versatile and productive. These areas are most likely to be suited to larger scale horticultural developments. As discussed above, access to water cannot be guaranteed.
- **Category 2** also has large groundwater resources, with the land capability being high. While the land is not the best category, it is still good horticultural land.
- **Category 3** has large groundwater resources and moderate land capability. Such land is suitable for development.
- **Category 4** has moderate groundwater resources and very high land capability.
- **Category 5** has moderate groundwater resources and high or moderate land capability.
- **Category 6** has moderate to high groundwater resources, but low land capability. Some development of irrigated agriculture may occur due to the water resources—but the land would be expensive to develop or crop yields are likely to be lower than on the above categories.
- **Category 7** has potential groundwater resources and very high land capability. Groundwater resources under these areas warrant further investigation.

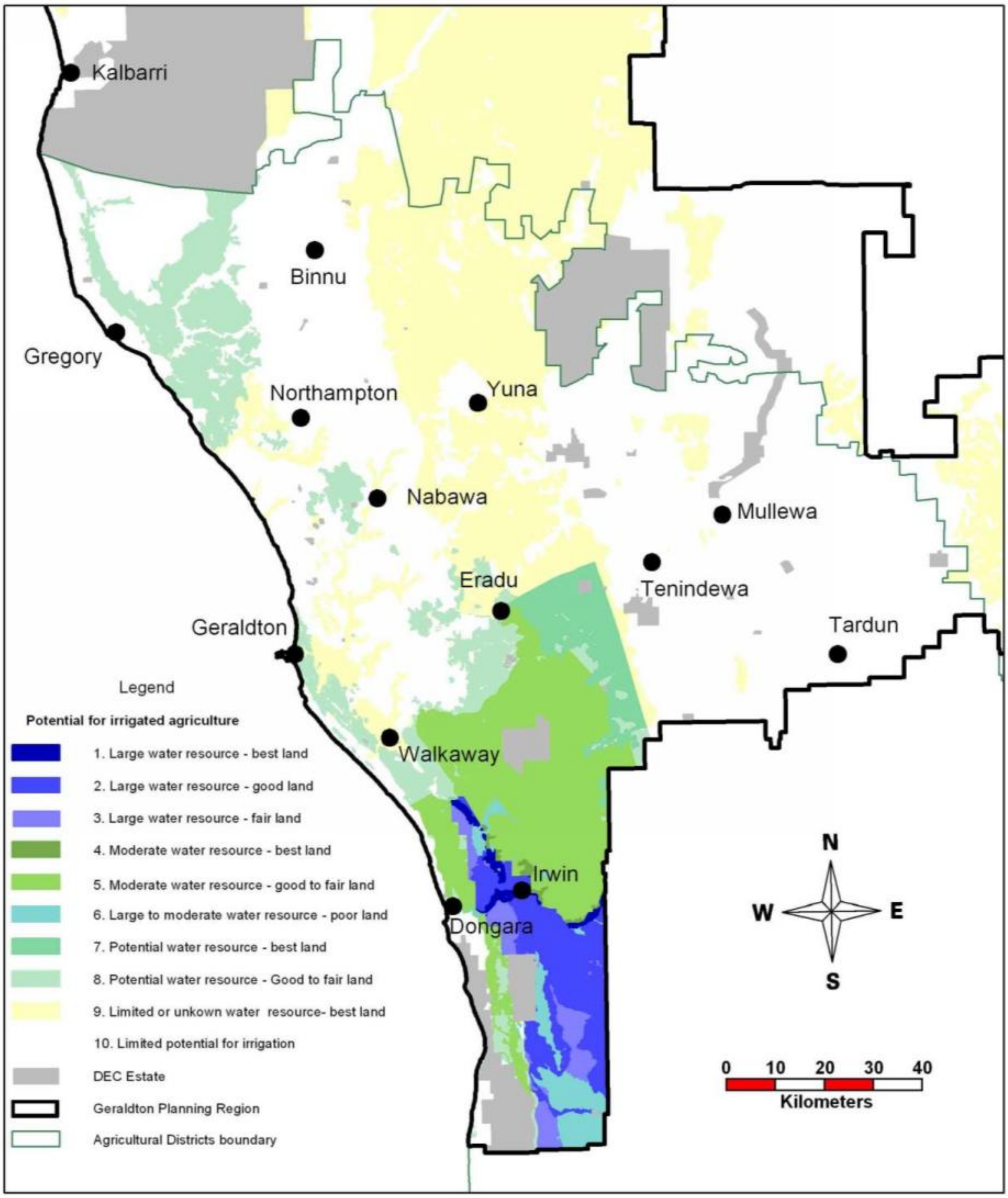

Figure 3.22 **Irrigated agriculture potential of the Geraldton planning region**

- **Category 8** has potential groundwater resources and high or moderate land capability.
- **Category 9** has limited or unknown groundwater resources but very high land capability. Land in this category has good potential for development if future investigations identify sizeable groundwater resources. Another possibility is the development of schemes to pipe water to this land.
- **Category 10** has the lowest potential for irrigated agriculture. These areas either have potential groundwater resources but low land capability or limited or unknown groundwater supplies (with high to low land capability). While some niche development of irrigated agriculture may develop here it is likely to be on a very small scale.

3.3.3 Agricultural land areas

Agricultural Land Area (ALA) maps

The development of Agricultural land areas evolved from feedback from local government planners at a workshop held in March 2011. In addition to the detailed maps of the broadacre and irrigated land potential, the planners outlined a need for a less detailed (or 'blobby') map for the whole region, with minimal mapped details.

The upshot was the creation of a simplified map showing ALAs. Each ALA has been populated with information to outline its characteristics and agricultural significance (s 4.3). Planners can readily refer to these maps and their associated information in a format that is easily understood.

ALAs were determined mainly through a visual assessment of the maps of relative wheat yields (Figure 3.23) and irrigated agriculture potential (Figure 3.24).[60] The boundaries were drawn by hand on-screen in an Intergraph GeoMedia™ warehouse.

In addition to the patterns shown on the agricultural potential maps, consideration was given to growing season rainfall, soil-landscape units, property sizes, and current land use zoning. Areas of non-agricultural land were also mapped as part of this process. These included urban areas, industrial land, rural residential areas, major reserves and pastoral leases.

[60] Figure 3.24 includes the pipeline that delivers water from the Allanooka bore field to Geraldton. Water delivered through this pipeline is currently being used for irrigated crops around Geraldton.

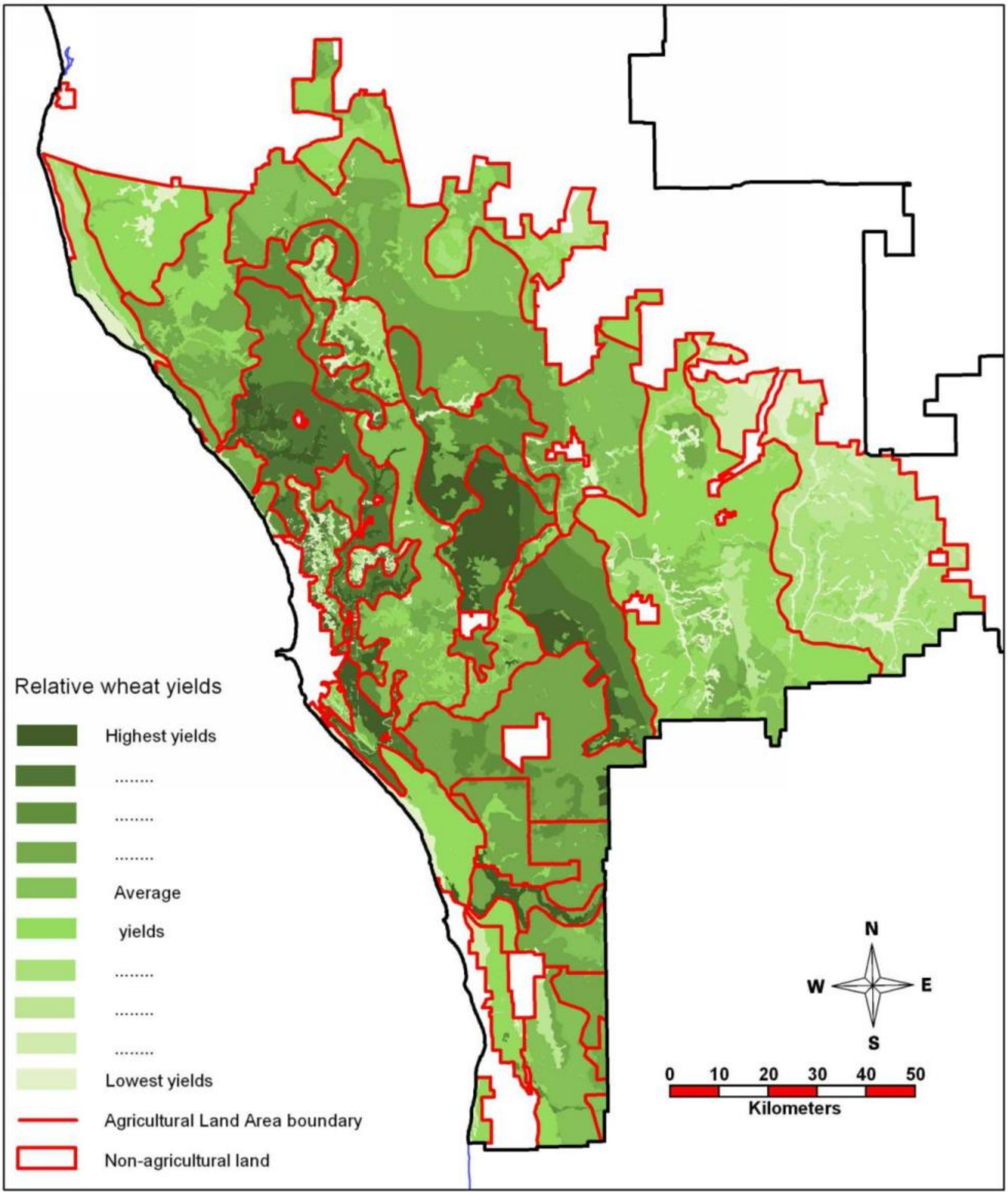

Figure 3.23 **Agricultural land areas and relative wheat yields, 2000–09**

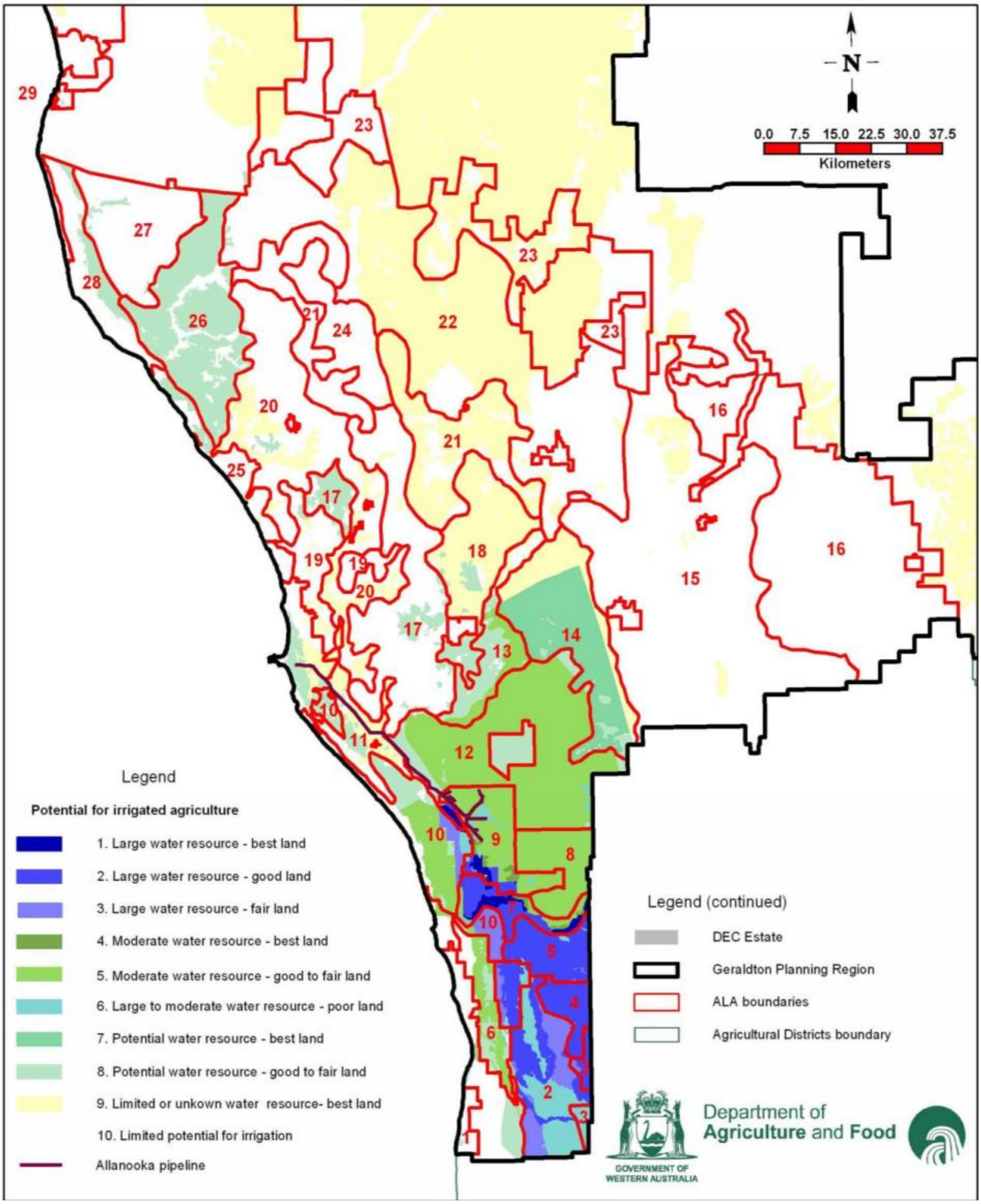

Figure 3.24 **Agricultural land areas and irrigated agriculture potential**

The intention was to identify areas of land that were reasonably homogeneous in terms of irrigated and broadacre potential as well as soils, landforms and property sizes at a broad scale rather than to accurately define boundaries at a property scale.

The boundaries between these ALAs need to be viewed as ‘fuzzy’ boundaries. They often simplify complex patterns of soil distribution. Where they are based on growing season rainfall isohyets, they represent a transition rather than a sudden change, as rainfall and yield decrease gradually over an area rather than change suddenly.

Agricultural land area characterisation

Once the boundaries of the ALAs were captured digitally, it was possible to intersect them with the other digital datasets (s 3.1) in GeoMedia™ warehouses to generate the data used to typify and describe the areas. Queries in MS-Access™ were then used to create summary tables showing data on a variety of themes for each ALA (Tables G.1 to G.5 in Appendix G).

The summary tables were based on the intersection of the ALA boundaries with the following:

- soil-landscape mapping to calculate the area of the various soil types and landforms along with the range of slope gradients
- remnant vegetation mapping to calculate the area of cleared land
- growing season rainfall isohyets (Figure 3.5) to calculate the rainfall range and average rainfall
- CRIS client property data to calculate number and sizes of parcels and properties and the main land use allocated to each property
- relative wheat yield maps (Figure 3.7) to calculate total potential wheat harvest and average relative wheat yield
- potential irrigation resources (Figure 3.21) to calculate the volume of the GLC of the allocation limit; estimated recharge to fresh aquifers; and the potential area of crops that could be irrigated and their value.

The data in the summary tables were used to compile a two-page information sheet for each ALA (s 4.3.1 to s 4.3.29). The first page includes a map of the ALA along with a description of its location, characteristics, agricultural importance, and the agricultural opportunities and constraints. The second page presents a tabular summary of the data in Tables G.1 and G.5 specific to that area, along with some brief descriptions of characteristics.

Property and parcel statistics

Table G.1 contains data on the properties and their component parcels occurring within each ALA. This data was created to provide an indication of the scale of agricultural operations in each ALA. It also provides a guide to the range of parcel (lot) sizes potentially on the current market. This provides some indication of whether or not further subdivision of rural land is required for future agricultural development.

As the ALA boundaries are not based on cadastral boundaries, there are some considerable overlaps. Many properties fall within two ALAs. Some larger properties were spread across more than three ALAs with a significant proportion of the property in each ALA. Three properties are spread across five ALAs. The data in Table G.1 should therefore be viewed as indicative only.

DAFWA's CRIS client property database was intersected with the boundaries of the ALAs. Only properties recorded as enterprise types 'A' (agriculture) or 'L' (lifestyle) in the CRIS database were included. Each property was allocated to the ALA containing the greatest area of that property. In some cases, this resulted in a significant proportion of that property or parcel being located outside the ALA to which it was allocated. The properties allocated to each ALA were then counted and their average size calculated.

A similar process was undertaken for parcels (lots). Each parcel was allocated to the ALA in which the greatest area of that parcel was located. Parcel types '3' (reserves) and parcels for which the state or Commonwealth government agencies were recorded as the owner in the

CRIS database were excluded. Again, some parcels occurred in multiple ALAs but this involved smaller areas than for the properties.

The outcome was that quite a few parcels were allocated to a different ALA than their parent property. When the average number of parcels per property was calculated, each parcel was allocated to its parent property (and therefore to the same ALA allocated to the parent property). For this reason, the data in the average parcels per property column of Table G.1 is sometimes different to the value that would be calculated by dividing the number of parcels by the number of properties.

Groundwater data

Table G.2 contains data on the GLC of regional aquifers that can potentially be accessed from each of the ALAs. Table G.3 contains estimates of recharge to fresh aquifers in the ALAs. This data was created to provide an indication of groundwater availability in each of the ALAs, and therefore the potential for the development of irrigated agriculture.

The data in Table G.2 was created by intersecting the map of regional aquifer GLCs (Figure 3.12) with the ALA boundaries. The area of each GSWA – aquifer combination within the ALA was measured in hectares. This area was then calculated as a percentage of the total area of the ALA, the GWSA, and the extent of aquifer within that GWSA.

All of those GWSA – regional aquifer combinations that occupied more than 5 per cent of the total area of the ALA were included in Table G.1 along with their total volume of the regional aquifer GLC. Where more than one aquifer or GSWA occurred within the boundaries of the ALA, these figures were then added together to calculate the combined regional aquifer GLC accessible from the ALA.[61]

In Table G.3 the estimated annual recharge to fresh aquifers across each of the ALAs is presented. This was calculated by intersecting the ALA boundaries with the estimated recharge (Figure 3.20). The estimated recharge (in ML/ha/yr) assigned to each polygon was multiplied by the area of that polygon to obtain a recharge figure in megalitres. The values for each polygon within each ALA were then added together.

Table G.4 contains a simplified summary of the data in Tables G.2 and G.3, with the regional aquifer GLCs and recharge estimates summed to provide a total volume of water potentially available for irrigation. This total is expressed both as a maximum volume (assuming all the water is obtainable and licensed for irrigation) and a smaller volume amount (taking into account some of the practicalities of obtaining the water and the likelihood of licensed entitlements being allocated to non-agricultural users). This process is described in more detail in s 4.3.

Potential value of agricultural produce

Tables G.1 and G.5 provide summarised estimates of the potential value of agricultural produce for each ALA. These are intended as indicative values only.

Broadacre agriculture: To represent the value of broadacre agriculture, a crop value for each ALA was calculated by multiplying the relative average annual wheat yield in tonnes by the average IMF (International Monetary Fund) international monthly wheat price for the past decade (IMF 2012). These values were converted into Australian dollars using monthly conversion data (Reserve Bank of Australia 2012).

[61] It was considered that including those aquifers occupying less than 5 per cent of the ALA's area would artificially inflate the general licensing component assigned to the ALA. Such a small proportion of the ALA should not be used to typify the ALA.

The resultant average wheat price of $264.67/t (AUD) for the decade December 2000 to December 2009 is similar to the ABS average gross unit value of $262/t for a tonne of WA wheat over the same period.[62]

The average annual yield is based on the data generated for the 2000–09 growing seasons that are described in s 3.3.1 and shown on Figure 3.23. The calculations assume all arable cleared land within the ALA is planted to wheat. These figures may overestimate the value of broadacre agriculture as on any given year a certain proportion of the land is not in production or is producing alternative crops or livestock.

Irrigated agriculture: Estimations of the potential value of irrigated agriculture were more complex. The potential value is largely determined by available water resources. There is also a wide range of crops that can be grown, each with differing water requirements and market values. Prices of individual crops fluctuate significantly throughout the course of the year depending on seasonal demand and supply. The current small scale of the existing horticultural enterprises also presents some difficulties in developing verifiable assumptions for the Region.

To demonstrate the potential value of irrigated agriculture, a variety of irrigated crop types were selected to represent a range of options. This selection comprised five tree crops, one vine crop and eight annual crops grown as part of four rotations (Table 3.22).

The selection was based on existing enterprises and crops believed to have future potential and complements the irrigated land uses for which capability analysis was undertaken (Table 3.11).[63] Also influencing the selection was the availability of data on the crop water use and yield potential in a local context. No attempt was made to cover the full range of options for irrigated agriculture. The selected crops are only intended to provide some indication of the range of potential value of irrigated agriculture.

The first step in estimating the potential value was to calculate the water requirement of each crop using the Irrigation Calculator (DAFWA 2010). Based on the crop, irrigation period, irrigation proportion and irrigation efficiency selected, this program calculates the water requirement for a number of locations across the state (including Geraldton) in megalitres per hectare per year (ML/ha/yr) for both sandy soils and loamy or clayey soils.

Table 3.22 shows the water requirements of the selected crops and rotations for the Geraldton locality, along with the underlying irrigation assumptions. The water requirements of sands and loams or clays have been averaged and converted from ML/ha/yr to ha/ML/yr to show the average areas of crop or rotation that could be irrigated with one megalitre of water.

[62] Calculated for the financial years 2000–01 to 2009–10.

[63] Irrigated pastures were excluded from this selection as the value of production relates not to the pastures grown but to the livestock grazing on them.

Table 3.22 **Water requirements of selected crops/rotations for the Geraldton locality***

Crop/ rotation	Irrigation period	Irrig- ation prop- ortion	Irrigation effic- iency	Water required Sand ML/ha/yr	Water required Loam or clay ML/ha/yr	Water required Average† ML/ha/yr	Area irrigated by 1 ML‡ ha/ML/yr
Avocado	Aug–May§	1.00	1.1	25.5	25.1	25.3	0.04
Citrus (oranges)	Sep–Apr§	0.75	1.1	11.4	11.2	11.3	0.09
Mangoes		1.00	1.1	20.0	19.7	19.9	0.05
Olives	Sep–Mar§	0.55	1.1	4.8	4.8	4.8	0.21
Peaches (early)	Aug–Apr§	0.70	1.1	7.9	7.8	7.8	0.13
Table grapes	Aug–Mar§	1.00	1.1	7.9	7.8	7.9	0.13
Carrots‖	Mar 1–Jul 22	1.00	1.2	7.6	6.6	7.1	0.14
Onions‖	Aug 15–Feb 1	1.00	1.2	20.6	20.2	20.4	0.05
Carrot / Onion						27.5	0.04
Potatoes‖	Mar 15–Jul 13	1.00	1.2	6.7	5.8	6.3	0.16
Sweet corn	Aug 15–Nov 18	1.00	1.2	8.0	7.9	8.0	0.13
Potato / Corn						14.3	0.07
Cucumbers	Mar 15–Jul 18	1.00	1.2	8.7	8.3	8.5	0.12
Rock melons	Sep 1–Jan 9	1.00	1.2	13.1	13.1	13.1	0.08
Cucumber / Melon						21.6	0.05
Tomato Transplants	Mar 15–Aug 22	1.00	1.1	8.8	8.4	8.6	0.12
Watermelon‖	Oct 1–Jan 19	1.00	1.2	14.2	14.1	14.1	0.07
Tomato / Melon						22.7	0.04

* Data in the shaded rows of these tables relates to the irrigated land uses shown in Table 3.11. The data in the unshaded rows is for the individual crops that make up the vegetable rotations from Table 3.11

† Average water requirement = (water required sand + water required loam or clay) divided by 2. For the vegetable rotations the requirements for the individual crops have been summed.

‡ The number of hectares that can be irrigated by 1 ML of water each year. This value is the inverse of the average water requirement in ML/ha/yr.

§ Irrigation Calculator data includes small water requirements for these crops throughout all of the winter months.

‖ Irrigation data for these crops at Geraldton is not available in the Irrigation Calculator (DAFWA 2010). Water requirements were calculated by multiplying Gingin values by 1.25 to allow for the evaporation difference between Gingin and Geraldton.

For the vegetable and melon rotations (where on one piece of land a first crop is grown and harvested and is then followed by a different crop in the same year), the water requirements of the two individual crops were added together to calculate a total yearly water requirement.

It needs to be noted that these water requirement values are for the Geraldton district and based on evaporation data from Geraldton Airport. They are probably reasonably applicable to the coastal portions of the Region but less applicable for inland areas where higher evaporation and lower rainfall is experienced.

The second step was to estimate the potential yields and values of the selected crops and rotations. These were originally based on ABS data for WA (the yields being based on Midlands data where it was available) but were later amended in consultation with DAFWA staff to reflect more realistic values for the Geraldton area.

Estimated yields and values of the selected crops and rotations are presented in Table 3.23. This data has been combined with the water requirement data in Table 3.22 to calculate potential crop and rotation values, both in dollars per hectare planted and dollar per megalitre of water used. Using the same data, Table 3.23 also shows for each crop and rotation the area of land that can be irrigated by 250 megalitres of water and its estimated dollar value.

Table 3.23 **Irrigated crop/rotation yield and value calculations for the Geraldton locality***

				Crop value			Irrigated by 250 ML	
Crop/ rotation	**Irrigation period**	**Water ha/ML/yr†**	**Yield t/ha**	**$/kg**	**$/ha**	**$/ML**	**Area ha**	**Value $ million**
Avocado	Aug–May	0.04	18	2.25	40 500	1 603	9.9	0.40
Citrus (oranges)	Sep–Apr	0.09	40	1.40	56 000	4 940	22.1	1.24
Mangoes		0.05	20	2.50	50 000	2 518	12.6	0.63
Olives	Sep–Mar	0.21	10	0.50	5 000	1 042	52.1	0.26
Peaches (early)	Aug–Apr	0.13	25	2.85	71 250	9 111	32.0	2.28
Table grapes	Aug–Mar	0.13	15	3.00	45 000	5 732	31.8	1.43
Carrots	Mar 1–Jul 22	0.14	66	0.66	43 824	6 178	35.2	1.54
Onions	Aug 15–Feb 1	0.05	60	1.04	62 400	3 055	12.2	0.76
Carrot / Onion		0.04			106 224	3 860	9.1	0.97
Potatoes	Mar 15–Jul 13	0.16	49	0.67	33 026	5 284	40.0	1.32
Sweet corn	Aug 15–Nov 18	0.13	25	2.62	64 976	8 132	31.3	2.03
Potato / Corn		0.07			98 002	6 882	17.6	1.72
Cucumbers	Mar 15–Jul 18	0.12	23	3.82	86 370	10 203	29.5	2.55
Rock melons	Sep 1–Jan 9	0.08	21	1.05	21 840	1 668	19.1	0.42
Cucumber / Melon		0.05			108 210	5 019	11.6	1.25
Tomato Transplants	Mar 15–Aug 22	0.12	70	1.52	106 470	12 402	29.1	3.10
Watermelon	Oct 1–Jan 19	0.07	40	1.24	49 600	3 516	17.7	0.88
Tomato / Melon		0.04	0		156 070	6 878	11.0	1.72

* Data in the shaded rows of these tables relates to the irrigated land uses shown in Table 3.11. The data in the unshaded rows is for the individual crops that make up the vegetable rotations from Table 3.11

† This is the 'Area irrigated by 1 ML' appearing in the last column of Table 3.22.

The crop values are initially expressed in dollars per kilogram of crop produced. As previously stated, it is much harder to place a definite value on horticultural crops than it is for a crop such as wheat that is largely centrally handled and marketed. Horticultural produce prices vary rapidly and markedly with seasonal supply and demand, as well as with the varieties and quality of the produce. A viewing of the Perth Market City price reports (http://www.perthmarket.com.au/produce-information-database-0.) can be obtained, which will show the complexity of produce values. Data to estimate horticultural crop values over the past decade are not easily accessible.

Prices presented here are estimates of current wholesale prices in the Perth Market City. An exception is the value assigned to carrots, which are more closely aligned to export prices as this was considered the most likely market for any carrot industry that may develop in the Region. No attempt is made to consider the value-added prices of any of the crops.

The third step was to take the data presented in Tables 3.22 and 3.23 to calculate an area and single dollar value of irrigated agriculture per megalitre of water. This was based on a mix of enterprises reflecting the land use weightings in Table 3.11.

Table 3.24 shows the calculation of the single area and dollar value. First, each crop or rotation was assigned a weighted enterprise score out of 100, expressed as a percentage (column A). As in Table 3.11, the sum of the land use weightings for vegetable and melon rotations is 50 per cent while the score for the perennial tree and vine crops also add up to 50 per cent.

For each crop or rotation these weighted scores (column A) were then multiplied by the area in hectares of that crop/rotation that can be irrigated by one megalitre of water per year (column B—taken from the last column in Table 3.22) to produce a weighted area irrigated (column C).

For each crop or rotation these weighted scores (column A) were also multiplied by crop/rotation value in $/ML (column D—taken from Table 3.23) to produce a weighted crop/rotation (column E).

Table 3.24 **Calculations of area irrigated by one megalitre of water and its value for the selected mix of enterprises**

		Column				
		A	B	C	D	E
		Enterprise weighting score	Area irrigated ha/ML/yr		Crop/rotation value $/ML/yr	
Crop type	**Crop/rotation (enterprise)**	**%**	**Unweighted**	**Weighted**	**Unweighted $**	**Weighted $**
Perennial tree and vine crops	Avocado	5	0.04	0.0020	1 603	80
	Citrus (oranges)	10	0.09	0.0088	4 940	494
	Mangoes	10	0.05	0.0050	2 518	252
	Olives	5	0.21	0.0104	1 042	52
	Peaches (early)	10	0.13	0.0128	9 111	911
	Table grapes	10	0.13	0.0127	5 732	573
Annual crop rotations	Carrot / Onion	12.5	0.04	0.0045	3 860	483
	Potato / Corn	12.5	0.07	0.0088	6 882	860
	Cucumber / Melon	12.5	0.05	0.0058	5 019	627
	Tomato / Melon	12.5	0.04	0.0055	6 878	860
Total (per ML)		**100**		**0.0764**		**5 192**

The weighted area (column C) and dollar values (column E) were then summed to calculate the area of mixed enterprises irrigated per megalitre of water (0.0764 ha) and the potential dollar value per megalitre ($5192). This represents a horticultural enterprise mix production value of $67 956 per hectare per year.

These values were then multiplied by the total volume of potential water for irrigation for each of the ALAs. For example, in an ALA with access to a total volume of 10 000 ML/yr of water, it would potentially be possible to irrigate about 765 ha of the enterprise mix, producing crops with an annual value of $51.9 million. With a total volume of 250 ML/yr of water, it would be possible to irrigate about 20 ha, producing crops to the value of $1.3 million.

4. Outcomes

4.1 Broadacre agriculture

The map of estimated relative wheat yields for the Region between 2000 and 2009 is shown in Figure 4.1. Most of this map is suitable for presentation at a scale of 1:250 000, with some areas suitable for presentation at more detailed scales (see Figure 3.1).

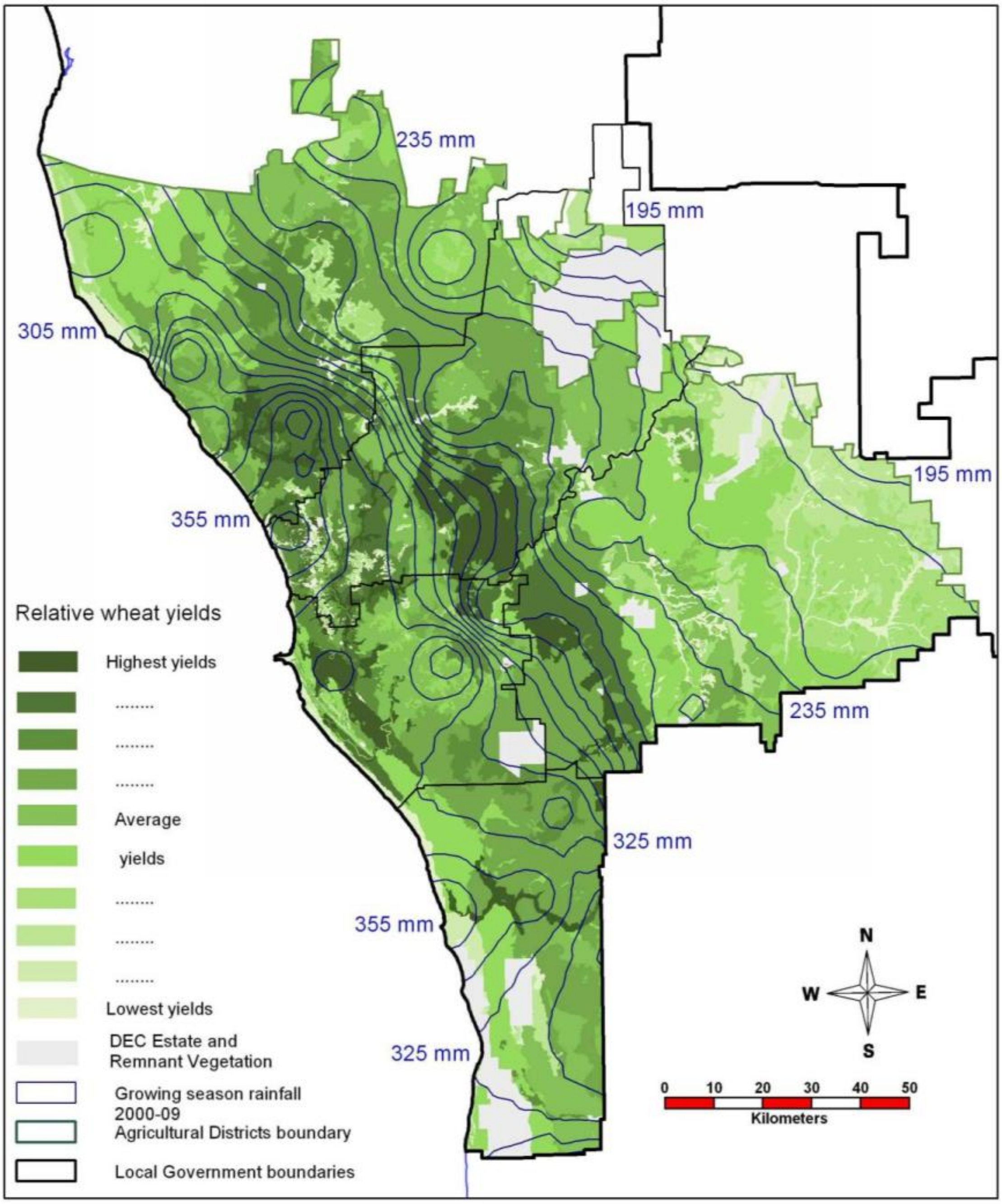

Figure 4.1 **Relative wheat yield for the Geraldton planning region, 2000–09**

The soil-landscape mapping that forms the basis for this map can be viewed on the SLIP NRM Program web page (DAFWA 2012 http://spatial.agric.wa.gov.au/slip/program.asp). The individual map unit descriptions can also be accessed through this portal.

Figure 4.1 shows the highest yields (average > 2 t/ha) being confined to areas receiving an average of 250 mm or greater growing season rainfall. Within this rainfall zone, the main high yielding soils are:

- the yellow sandplain soils stretching from Binnu to Eradu and south towards Mingenew
- the red loamy soils of the granitic hills around Northampton and through the Chapman Valley
- the alluvial soils of the Greenough Flats and Irwin Valley.

While Figure 4.1 shows relative average yields, actual yields will vary greatly from year to year and from property to property. Seasonal conditions, the timing of rainfall, disease, and management practices all play an important role in determining yield but are beyond the scope of this project.

Areas other than those mentioned above are capable of producing high yields in favourable seasons. For example, many crops around Pindar yielded over 3 t/ha in 2011 but this was after several years of significantly lower production.

Figure 4.2 shows relative wheat yields (calculated using the method described in s 3.1[64]) for 2005, the wettest year of the decade between 2000 and 2009. Growing season rainfall in that year was in excess of 250 mm across the entire agricultural part of the Region and ranged up to 425 mm around Geraldton and Northampton. This contrasts with Figure 4.3 for 2006, the worst year of the decade, with growing season rainfall ranging from 200 mm in the south to 100 mm in the north.

Wheat harvest underway in Chapman Valley

[64] The exception being that 25 mm rather than 10 mm growing season rainfall intervals were used in the calculations.

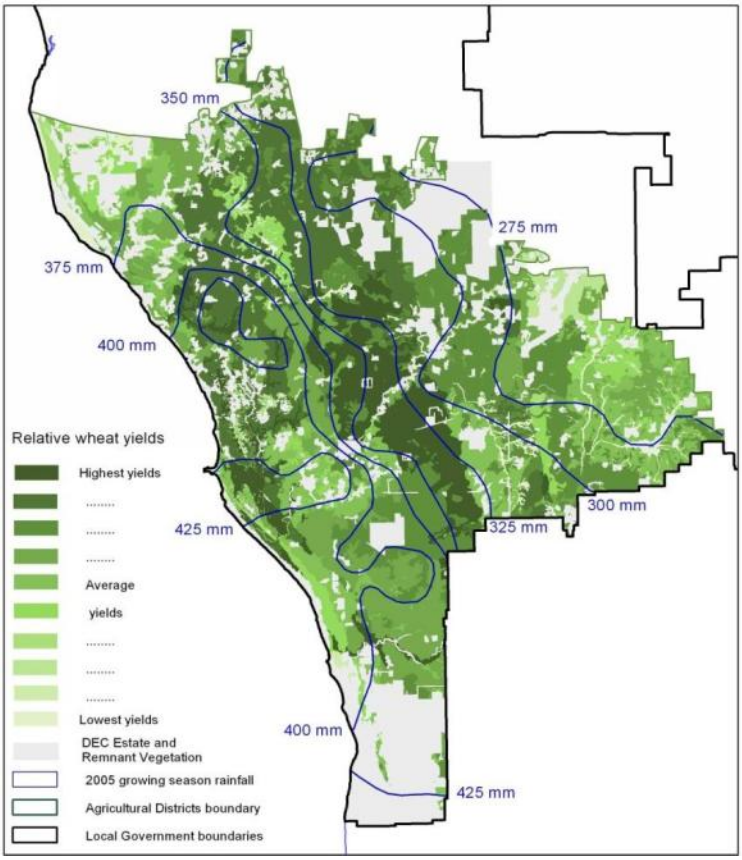

Figure 4.2 **Relative wheat yield for 2005**

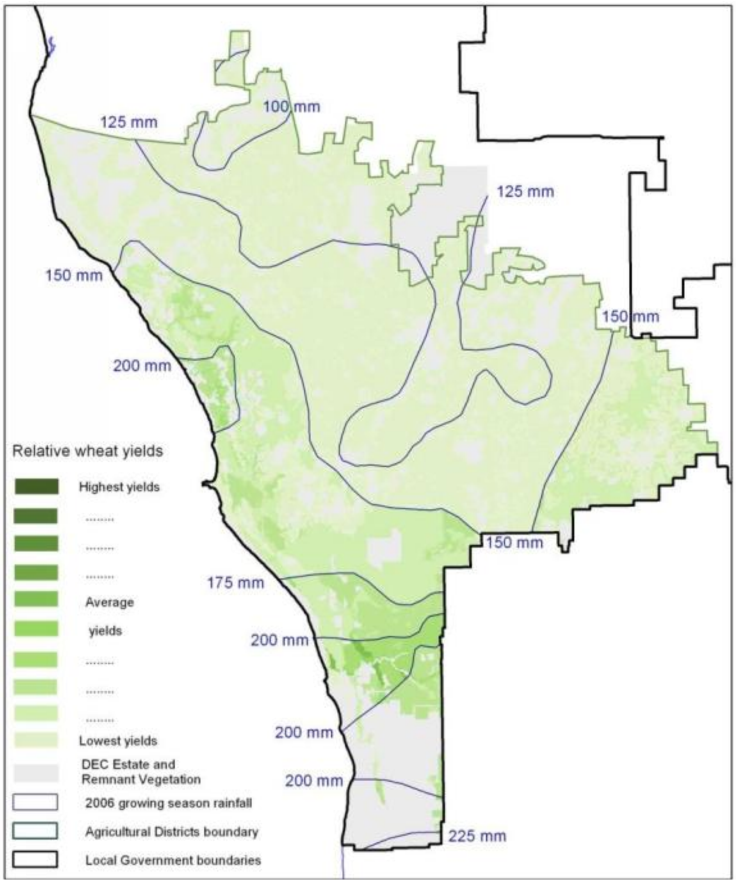

Figure 4.3 **Relative wheat yield for 2006**

It is also worth considering the interaction between seasonal conditions, soil type and crop performance. While the heavier soils at Greenough and Northampton usually outperform the yellow sandplain soils in higher rainfall years, the reverse tends to be the case for years of below average rainfall.[65] From a regional perspective, production on these two soil types complement each other, to a certain extent evening out fluctuations in harvest from year to year.

The method used to estimate relative wheat yields is relatively simple. It does not take into account these soil-related differences in crop performance in seasons of below and above average rainfall.

The model is also not sophisticated enough to deal with variations in timing of rainfall during the growing season, dealing only with the total growing season rainfall. While growing season rainfall across the Region was highest in 2005, the average yield for that year (2.04 t/ha) was lower than that for 2008 (2.16 t/ha). In 2008 timing was an important factor with good finishing rains.

For these reasons the relative yield estimates are more applicable when calculated for longer term averages, where seasonal variations tend to be ‘smoothed out’, than for individual years.

The model may underestimate production on the best quality soils. For example, on some parts of the Greenough Flats, yields of 3–4 t/ha are normal but the maximum decade average was calculated at just under 3 t/ha.[66]

Additionally in the model some limitations (such as soil pH) reduce yields in the same way that moisture-holding properties do. In the real world, suboptimal moisture conditions will result in reduced yields. In contrast, suboptimal soil pH may incur an additional cost in liming but with good management the highest yields can still be achieved.

The relative yield maps are definitely not intended to be used to assess the productivity of individual properties. In addition to the limitations discussed in the preceding paragraphs, the mapping scale is not detailed enough for property assessments. It is to be expected that individual growers may achieve higher yields than the maps suggest.

Furthermore, the maps should not be interpreted as a guide to farm profitability. Although average yields are lower in the north-east, farming enterprises can be more profitable than in higher rainfall areas because input costs, such as weed control, are often lower.[67]

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[65] In the wetter years, the heavy soils are more likely to retain rainfall within the rooting zone than sandy soils. In high rainfall years, nutrient leaching can also reduce crop yields on lighter textured sandplain soils. In drier seasons, the greater crop lower limit (CLL) of the heavier soils means that less of the stored soil water is available to crops while a greater proportion of the rainfall is likely to be stored and available within the rooting zone of sandy profiles.

[66] In part this may be due to the regression equations in Figure 3.6 being based on average LGA yield data that to some extent masks the best and worst performing crops. The capability ratings table for wheat (production only) may also be a bit restrictive when it comes to identifying Class 1 land.

[67] Bankwest (2011) concluded that, of all the broadacre farming districts in the state, the north-eastern wheatbelt (located to the north of Perenjori and east of Mullewa) showed the highest level of profit over the six-year period 2005–10. The average return on capital was 5.9 per cent, with a return of 9.27 per cent for the top quartile of enterprises. This compared with an average return on capital of 0.99 per cent (and 3.89 per cent for the top quartile) for the higher yielding district that included Northampton and Geraldton.

4.1.1 Statewide significance of broadacre agriculture in the Region

Broadacre crops grown in the Region are of statewide significance and even register on a national scale. According to the ABS (2010), the Region's wheat harvest for the decade 2000–01 to 2009–10 was 6.2 million tonnes, valued at $1554 million. This represents more than 8 per cent of WA's total wheat production for that decade, and just over 3 per cent of the national production.

Annual wheat production from the Region ranged from 193 000 tonnes in 2006 (3.8 per cent of statewide production) to 872 000 tonnes in 2003 (11.3 per cent of statewide production).

Over the same decade, the Region also produced 1.8 million tonnes of lupins, valued at $405 million (24 per cent of the total state crop and 20 per cent of the national crop); 329 000 tonnes of canola, valued at $135 million (5 per cent of the total state crop and 2.5 per cent of the national crop); 550 000 tonnes of barley valued at $104 million (2 per cent of the total state crop); and 15 000 tonnes of field beans and chick peas valued at $5 million (about 13 per cent of the total state crop).

Livestock products were of lesser economic significance. Over the decade, wool production was valued at $198 million (3.9 per cent of the state total); sheep sales were valued at $145 million (4.5 per cent of the state total); and cattle sales valued at $136 million (3 per cent of the state total). The above data is summarised in Table 4.1.

Table 4.1 **Value of broadacre production in the Geraldton planning region over the past decade**

		Value			
Crop	**Production ‘000 t**	**Total for 2000-01 to 2009–10 $m**	**Annual average $m**	**Proportion of total WA value %**	**Proportion of national value %**
Wheat	6 200	1 554	155.4	8	3
Lupins	1 800	405	40.5	24	20
Canola	329	135	13.5	5	2.5
Barley	550	104	10.4	2	n.a.
Chick peas, field peas & beans	15	5	0.5	13	n.a.
Wool	n.a.	198	19.8	4	n.a.
Sheep sales	n.a.	145	14.5	4	n.a.
Cattle sales	n.a.	136	13.6	3	n.a.
Total		**2 682**	**268.2**		

n.a. not available

Source: ABS (2010).

4.1.2 Comparison of relative wheat yield and ABS production data

To test the validity of the methodology used to estimate relative wheat yields (s 3.3.1), the estimates were compared with ABS data. The map of average relative yields over the past decade (Figure 4.1) was intersected with the shire boundaries to calculate the potential wheat yield per shire, based on the assumption that all cleared arable land was planted.

These were compared to the average production for each shire over 2000–01 to 2009–10 according to the ABS data. The ABS average area cropped in each shire over the decade was divided by the total cleared area in each shire. The potential yield for each shire was multiplied by this fraction to derive an adjusted potential yield. The difference between this and the ABS production was then calculated. The results of this analysis are presented in Table 4.2.

Table 4.2 **Comparison of estimated potential wheat yields and ABS production data**

Local Government Authority	ABS wheat harvest t	Adjusted potential wheat yield t	Differ-ence %	Cleared land ha	Potential cleared land yield t	ABS wheat area ha	Cleared land with wheat crop %
Chapman Valley	157 943	200 257	27	255 082	496 611	102 861	40
Greenough*	56 412	69 603	23	128 817	269 736	33 240	26
Northampton	159 267	162 477	2	323 188	559 927	93 781	29
Mullewa*	217 081	218 941	1	413 542	575 921	157 211	38
Irwin	31 015	26 209	–15	117 419	208 982	14 726	13
Total	**621 718**	**677 486**	**9**	**1 238 048**	**2 111 177**	**401 819**	**32**

* Data is for the former shires of Greenough and Mullewa that are now districts within the City of Greater Geraldton.

For the Region, the average adjusted potential yield for the decade was 9 per cent higher than the average production recorded by the ABS. The potential and ABS figures are very similar for the Shire of Northampton and the Mullewa district. The most significant differences are for the Shire of Chapman Valley and the Geraldton–Greenough district where the adjusted potential yield is 27 and 23 per cent higher respectively than actual production.[68]

A likely explanation for the actual production from the Shire of Irwin being 15 per cent higher than the estimated yield is that cropping is concentrated in the higher yielding soils in the east of the shire. The estimated yields are lower as they include the poorer sandy soils of the coastal strip.

Cattle grazing on the fertile floodplains of the Irwin River

68 There is no immediately apparent explanation for this discrepancy.

4.2 Irrigated agriculture

4.2.1 Current extent of irrigated agriculture in the Region

Areas of intensive land use, including irrigated agriculture, were mapped by DAFWA as part of this project. This mapping is a preliminary assessment only and was undertaken using 2006 aerial photo ortho-mosaics. This mapping does not capture crops planted after 2006. A summary of this mapping is presented in Table 4.3.

Table 4.3 **Extent of intensive agricultural land uses in the Geraldton planning region**

	Local Government Area				
Intensive land use	**Chapman Valley ha**	**Northampton ha**	**Greater Geraldton ha**	**Irwin ha**	**TOTAL ha**
Olives	92	46	46	52	**236**
Annual crops	31	17	108	24	**180**
Stone fruit and nuts*	10	33	61	64	**168**
Irrigated pasture	0	0	0	139	**139**
Grapes (table & wine)	12	12	39	3	**66**
Other irrigation†	3	10	42	0	**55**
Aquaculture	14	542	35	5	**596**
Animal‡	0	6	26	0	**32**
Abattoir	0	0	12	0	**12**
TOTAL	**162**	**666**	**369**	**287**	**1484**

* Includes mangoes, macadamia, carob, neem, stone fruit, citrus and figs.

† Includes turf, floriculture, nurseries and sandalwood.

‡ Includes cattle feedlot and poultry/egg farms.

Almost 1500 ha of intensive agricultural land use were mapped, although more than one-third of this area (535 ha) comprises a single algae farm at Gregory. Other uses not considered irrigated agriculture include abattoirs, feedlots, poultry farms, and aquaculture for fish and crustaceans.

Of the 844 ha of irrigated agriculture, more than one-quarter of the area was planted to olives (236 ha). Other tree crops include mangoes (53 ha); carob (52 ha); stone fruit (25 ha); and sandalwood (23 ha). Of the 66 ha of grapes, only 12 ha were wine grapes and the remainder were table grapes. The 180 ha of annual crops included 24 ha of melons. Three centre-pivots in the Irwin Valley irrigate about 140 ha of pasture.

4.2.2 Statewide significance of irrigated agriculture in the Region

Horticultural crops in the Region currently contribute only a small fraction of the total WA production of fruit and vegetables. According to the ABS (2010), for 2000–01 to 2009–10, the value of the Region's vegetable production was $33 million. This represents about 150 ha of crop planted a year (mostly in the former Shire of Greenough and the Shire of Irwin) and comprises only 1.3 per cent of WA's total vegetable production for the decade. Fruit production was even less significant, valued at $7.6 million or 0.4 per cent of WA's annual production.

While not technically a form of irrigated agriculture, egg sales represent a form of intensive agricultural production reliant on good-quality water supplies. Production from the Region was valued at $28 million over the decade, which represented 7.4 per cent of the state total.

Even allowing for the fact that the ABS data often underestimates actual horticultural production, the Region cannot be considered a major contributor to WA's total production. It is not in the same league as Carnarvon to the north or Gingin to the south.

4.2.3 Future potential of irrigated agriculture

While Geraldton is highly unlikely to become a major player in the horticulture industry in the near future, in the longer term its importance may increase, especially as WA's population grows. Along with increasing demand for WA produce, continued population growth is likely to force horticultural enterprises to relocate from the fringes of the Perth metropolitan area. Increased demand for local produce as the population of Geraldton and surrounding districts grows is another consideration.

The soils and landforms over much of the Region have good potential for the development of irrigated agriculture. Figure 4.4 shows about 20 per cent of the land occurring within all of the ALAs (almost 300 000 ha) as having a very high capability for irrigated agriculture.[69] A further 45 per cent (over 720 000 ha) has a high capability for irrigated agriculture, with 22 per cent (about 350,000 ha) having a moderate capability. Only 13 per cent of the land in the ALAs (about 200 000 ha) has a low capability.

If all of the very high capability land was planted to the mix of enterprises shown in Table 3.24, the irrigation water requirement would be in the order of 3.5 million megalitres (3500 GL). If all of the high and moderate capability land were also planted, this requirement would increase to around 16 million megalitres (16 000 GL).

The *Arrowsmith groundwater allocation plan* shows total allocation limit of the Arrowsmith GWA is only 189 250 ML (189 GL), including water for public water supply and water in aquifers located entirely outside the Region (DoW 2010). This total Arrowsmith allocation would only be enough to irrigate around 16 000 ha of the mix of enterprises shown in Table 3.24. Clearly, it is the availability of irrigation water, rather than the availability of suitable land, that will present the major limitation to the development of irrigated agriculture.

Melons growing on the productive soil of the Greenough Flats

[69] This figure is based on land located within the ALAs shown in Figure 4.6.

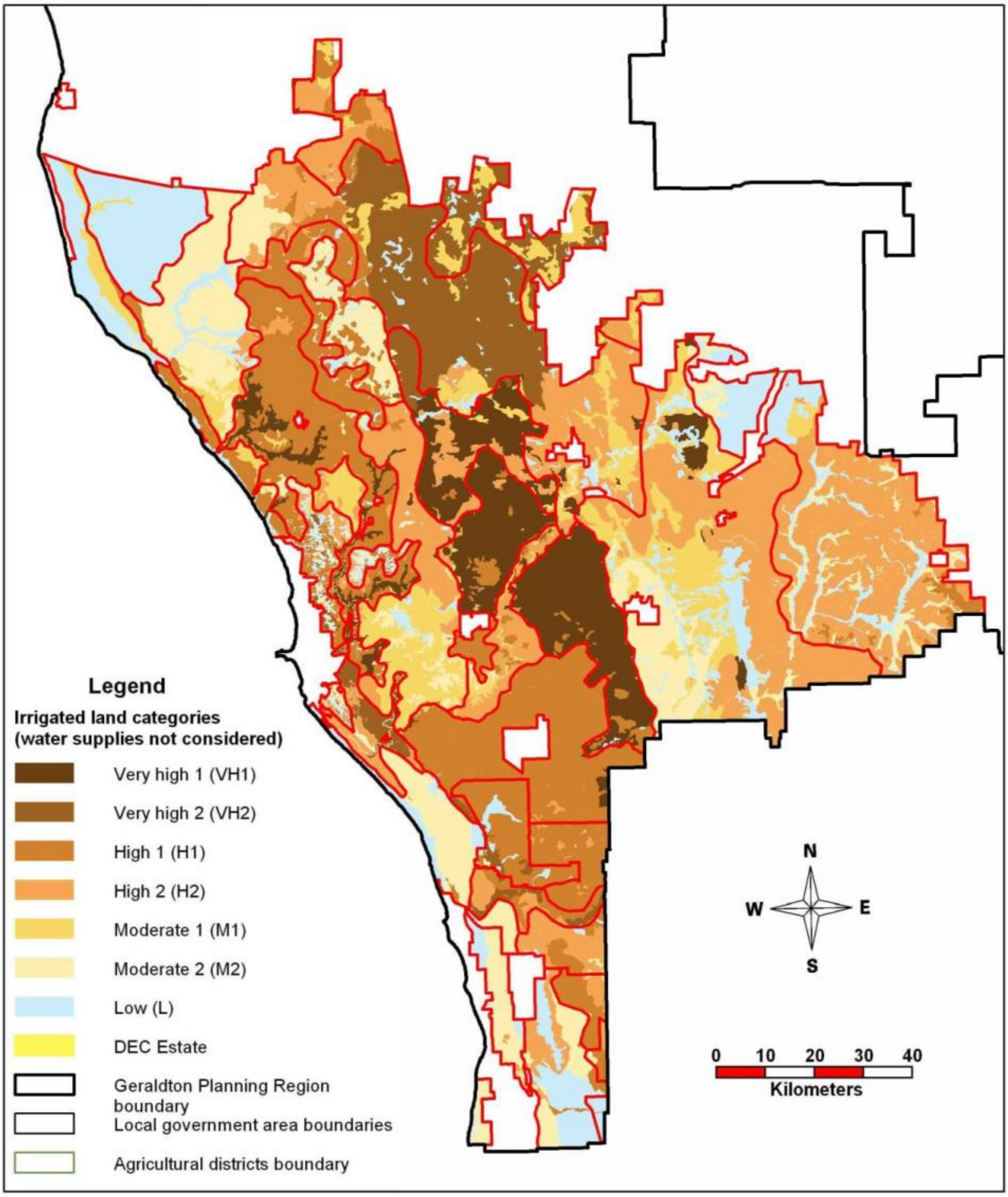

Figure 4.4 **Land capability for irrigated agriculture within the ALAs of the Geraldton planning region[70]**

70 The soil-landscape mapping that formed the basis for this map can be viewed on the SLIP NRM Program web page (DAFWA 2012 http://spatial.agric.wa.gov.au/slip/program.asp). The individual map unit descriptions can also be accessed through this portal.

4.2.4 Water supplies

Determining the amount of water available for irrigated agriculture remains problematic. Only limited groundwater investigations have been conducted in the Gascoyne GWA in which most of the Region falls.[71] Even in the southern portion of the Region, where more detailed studies have been undertaken in the Arrowsmith GWA, there are difficulties interpreting groundwater allocations, partly because the groundwater allocation boundaries are not aligned to the boundaries of the Region. It is also difficult to predict the future allocation of water resources to competing users, such as urban demand, mining and industry.

As shown in Table 4.4 and Figure 4.5, the Region overlies regional aquifers with a combined general licensing component (GLC) of 80 920 ML (81 GL). If all of this water was licensed to agriculture, it would be enough to irrigate about 6180 ha of the mix of enterprises shown in Table 3.24. These crops would have an annual value of about $420 million.

This annual value is an order of magnitude larger than the total value of fruit and vegetable production (excluding egg production) in the Region (s4.2.2) as reported by the ABS over the past decade ($40.6 million over the decade) or around 100 times greater than the ABS annual average ($4 million).

This potential value of irrigated crops is also one and a half times greater than the combined annual value of all the broadacre enterprises ($268 million) as reported by the ABS over the past decade (Table 4.1).

Table 4.4 **Regional aquifer general licensing components in the Geraldton planning region**

				Within Geraldton planning region			
GWSA	**Aquifer**	**Area ha**	**GLC ML/yr***	**Area ha**	**Proportion of aquifer %**	**Proportional adjustment ML/yr†**	**Further 50% adjustment ML/yr‡**
Allanooka	Yarragadee	53 882	8 500	46 908	87	7 400	3 700
Casuarinas	Yarragadee	151 265	4 600	129 321	85	3 933	1 966
Dongara	Cattamarra	63 681	200	28 394	45	89	45
Dongara	Yarragadee	51 221	3 750	35 715	70	2 615	1 307
Eneabba Plains	Cattamarra	17 845	100	92	1	1	0
Eneabba Plains	Yarragadee	113 603	20 440	67 512	59	12 147	6 074
Twin Hills	Yarragadee	215 954	42 830	26 246	12	5 205	2 603
Yuna/Eradu	Yarragadee	16 212	500	15 305	94	472	236
Total		**683 663**	**80 920**	**349 493**		**31 861**	**15 931**

* These general licensing components have been modified to exclude current allocations to the Water Corporation (for public water supply) and reserves (for example, future public water supply reserves).

† The modified GLC multiplied by the percentage area of the aquifer situated within the Region.

‡ The proportional adjustment value divided in half to exclude assumed allocations to non-agricultural users (including mining, industrial and recreational).

[71] Most of the investigations in the Gascoyne GWA to date have concentrated on the Carnarvon district, well to the north of the Region.

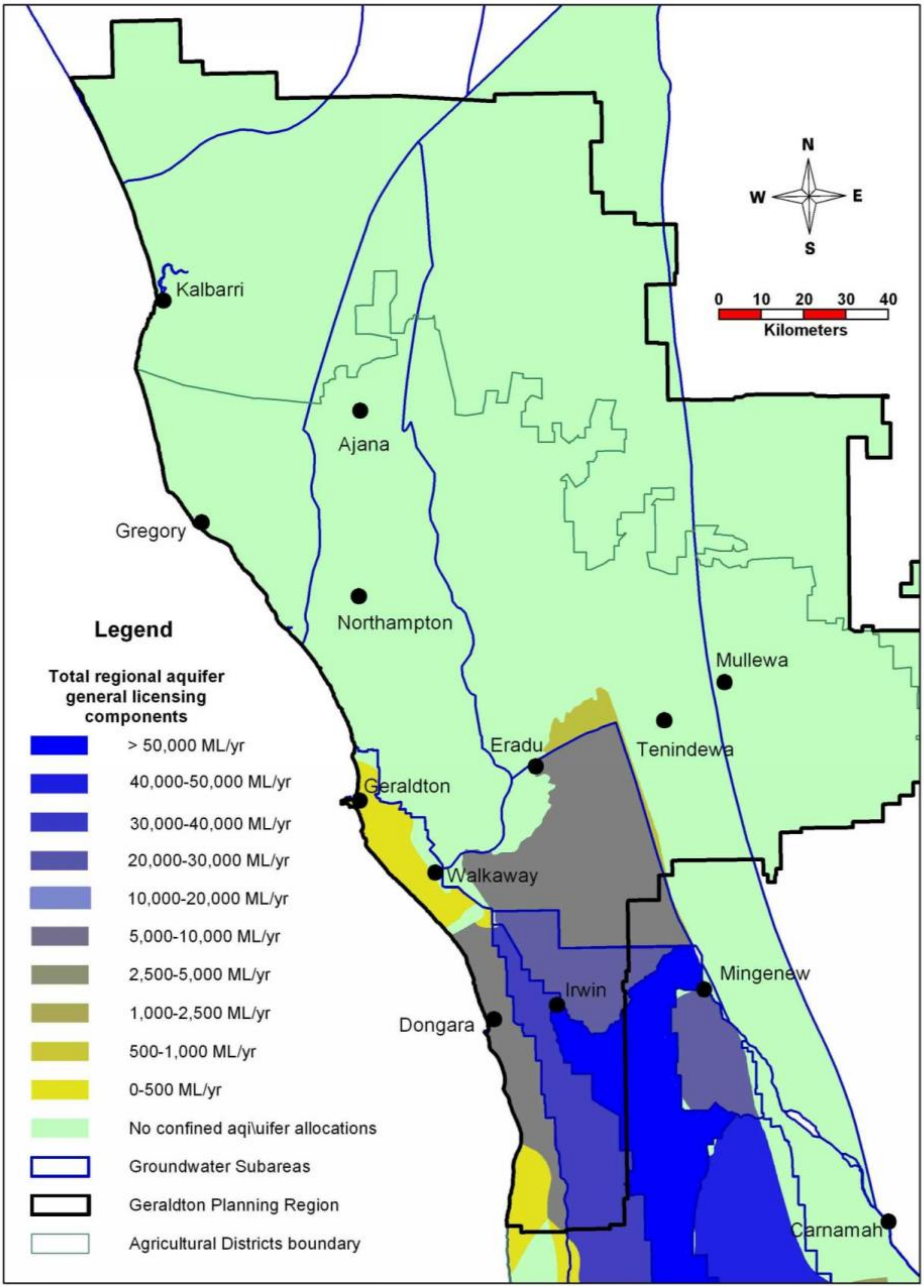

Figure 4.5 **Total regional aquifer general licensing components in the Geraldton planning region**

It is quite unrealistic to assume that the total GLC from these aquifers will be exclusively for the use of agriculture in the Region. As shown in Table 4.4 and Figure 4.5, a large proportion of some of these aquifers lie outside the Region. Water is currently being extracted from these aquifers in the shires to the south and east.

The aquifer GLCs have been multiplied by the proportion of the aquifer that lies within the Region to provide a nominal figure indicating the amount of water likely to be extracted within the Region. For example, 59 per cent of the Yarragadee aquifer in the Eneabba Plains GWSA lies within the Region. The GLC of 20 440 ML has been multiplied by 59 per cent to create an adjusted GLC of 12 147 ML.

A further adjustment has been made to the allocations in Table 4.4. The proportionally adjusted GLC has been halved to allow for a 50 per cent allocation to non-agricultural uses. These would include mining, industry or recreational use (such as playing fields and golf courses) but not public water supply allocations which were excluded from the original modified GLC.

These adjusted figures are notional only. They do not reflect current DoW policy, nor is it suggested that they should. In practice, the licensing of water will vary from area to area and aquifer to aquifer. In some areas, most of the water may be used for agriculture; elsewhere it could be mainly allocated to mining. Similarly, most of an aquifer’s allocation may be extracted from one or two locations.

The adjusted figures in Table 4.4 represent an attempt to give a more realistic picture of future water use. The total proportionally adjusted GLC for the Region is about 31 860 ML which would irrigate almost 2430 ha of the mix of enterprises and produce crops to the annual value of about $165 million.

Halving this volume to allow for licensing to non-agricultural users still leaves about 15 930 ML, which would irrigate 1220 ha at an annual value of almost $83 million. This would represent a significant increase in the value of agricultural production in the Region, lifting the total annual production value to over $350 million. This would represent an increase of about 30 per cent on the existing value of broadacre production ($268 million as shown in Table 4.1).

The figure of $83 million is a nominal farm gate value only—it does not consider the output multiplier impact of this production on the local economy, nor the potential for value-adding of products through downstream processing. The real value to the economy is likely to be much greater.

Stonefruit orchard at Bowes River near Northampton

4.2.5 Other considerations

The availability of water resources is crucial to the future development of irrigated agriculture in the Region but development will not occur solely on this basis. A number of other factors need to be considered.

An important factor warranting further investigation in relation to crop selection is climatic parameters. Some areas of the Region will be better suited to certain crops than others. It would be helpful in the future to create climatic profiles, (including timing of rainfall events, evaporation rates, temperate averages and extremes, chilling hours, frost risk and exposure to wind) of the ALAs, which would help identify the crops most suited to each area.

Examples of this include avocados, which may struggle away from the coast where mid-summer temperatures and low humidity may cause excessive moisture stress. Mangoes would also probably do better in coastal locations where the frost risk is low. Low-chill stone fruit would be better suited to soil on inland sites with greater chill accumulation.

Identifying crops that will prove competitive in terms of price, quality and timing of availability is also important. While avocado trees may yield well in the Region, the fruit would come on the market at the same time as those from Bundaberg—Australia's largest production region. Consequently, there may not be much interest in Geraldton produce at this time and prices are likely to be low. Early peaches and nectarines may have better potential in the Perth market.

For many of the crops suited to the Region, the season for produce from Carnarvon merges into that of Gingin as well as areas on the northern and eastern fringes of the Perth metropolitan area (Swan Valley, Perth Hills, Wanneroo–Carabooda). There would appear to be no particular market niche opportunities for these crops.

The scale of production also needs to be considered. The significant expansion in the production of oranges near Moora could provide opportunities for Geraldton if it results in the development of export markets, but it could equally lead to a local over-supply, reducing demand and prices. There may be potential for export vegetables, such as onions or carrots, but only if sufficient tonnage of crop is produced to interest overseas buyers. For these industries to develop, access to sufficient water supplies would need to be assured.

Other considerations include the size and price of properties, the presence of infrastructure (transport, power supplies) and the availability of labour supply. Sweet potato, a crop currently imported in considerable volume from Queensland, has been identified as an opportunity for the Carnarvon district. Given the larger property sizes inland from Geraldton, this Region may provide better opportunities.

Proximity to the larger population centres of Geraldton and Dongara – Port Denison not only provides better access to infrastructure but also increases the chances of securing a workforce.[72] Crops for which planting and harvesting can be mechanised (such as potatoes and carrots) and for which the labour requirement is lower, may be more suitable for areas further away from population centres.

[72] The popularity of the Batavia coast with windsurfers from all over the world presents possibilities of a casual labour supply interested in morning work before the 'sea breeze' kicks in and consumes their full attention.

4.2.6 Other findings

It is worth noting that almost 20 per cent (35 ha) of the vegetable crops mapped in the Region are located on land where rural activities are no longer considered as the primary land use (Murray Connell pers. comm.).[73,74] This includes a number of tomato (and other) crops produced in shadehouses using scheme water.

Shadehouse production is an intensive and high-value form of horticulture and has increased significantly on the outskirts of Geraldton since 2006 (images A and B).

There is a possibility that horticultural production may not continue on this non-rural land in the future, which could lead to a significant decline in the volume and value of vegetable produce from the Region. To ensure continued production, provision needs to be made for suitable land that is zoned rural and has good access to water supplies and labour.

This project has identified a few possibilities for irrigation developments on non-agricultural land in the north and south of the Region. These may warrant further investigation.

A sizeable area of Unallocated Crown Land (UCL) is located to the south-east of Dongara, extending to the north and south of the Brand Highway. This land was previously considered unsuitable for release for broadacre agriculture (Ted Griffin, DAFWA, pers. comm.). While most of the area has limited agricultural potential, it overlies some of the Region's more significant groundwater resources. The soil-landscape mapping indicates some areas of soils suited to horticulture.[75] This land is shown as the Arrowsmith River and Tompkins Road UCLs (UCL 2 and UCL 4) on Figure 4.6.[76]

There may be a future opportunity to develop a small-scale horticultural precinct within one of these areas, with only the most suitable soils being selected and cleared. The water supplies and soils would require thorough investigation for development to occur. Issues that need to be addressed before the release and clearing of any portion of this UCL include native title status, biodiversity/environmental values, existing mining tenements, and securing water entitlements. Tompkins Road UCL appears to have the better potential of the two, both in terms of soils and water supplies.

Much of the northern portion of the Region is currently under pastoral lease. This includes extensive areas of red (and some yellow) sandplains overlying the sedimentary rocks of the Carnarvon Basin. While many of these soils are likely to be suited to horticultural production, the current knowledge of groundwater resources is limited. These areas may be worth investigating in the future.

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73 A further 24 ha of other horticultural crops (such as olives and mangoes) are also located on non-rural land around Geraldton.

74 Some of this land is already zoned residential, rural residential, special use, or light industrial in the *City of Geraldton–Greenough town planning scheme* (City of Geraldton 2008). Other areas are identified for future non-rural zoning.

75 As unallocated crown land, these areas may have received less attention than adjoining agricultural land when the original soil-landscape surveys were conducted. A re-examination of the soils of these areas would be advisable.

76 Though not currently agricultural land, these have been designated as ALAs due to their horticultural potential.

Image A 2006

Image B 2011

Aerial photos showing increase in shadehouse production at Moonyoonooka (between the Chapman River and Geraldton Airport) on the Greenough Flats ALA between 2006 and 2011 (©2011 Google).

4.3 Agricultural land areas

Understanding the ALA concept

It is important to understand what the ALAs are and what they are not. They were created to present a broad overview of the agricultural land in the Region and are designed for presentation at a mapping scale in the order of 1:500 000 to 1:1 000 000.

The ALAs are by nature subjective creations. Multiple, and sometimes conflicting, factors[77] were considered when identifying the ALAs and determining their boundaries. In many cases, there is no single ‘correct’ ALA to which any given piece of land belongs and therefore the ALAs are not set in concrete and their boundaries need to be viewed as ‘fuzzy’ rather than ‘hard’.

In most cases, there was no single ‘right place’ to draw the ALA boundaries and they are definitely **not intended for** direct use as planning or zoning boundaries. As discussed in s 3.3.3, the ALA boundaries are deliberately not aligned with cadastral boundaries. This was a deliberate tactic to provide a gap between the conceptual ALAs and statutory planning zones.

Rather than attempting to be the sole basis of land use planning, the ALA map provides one layer of information that assists the process of identifying planning boundaries.[78] The intention is that the accompanying information sheets will provide part of the rationale for planning policies.

It would be a mistake to think that the ‘value’ of a parcel of land should be judged on the basis of which particular ALA it was located in. There will be a fair degree of internal variation within each of the ALAs. Soil types, landforms, rainfall and groundwater resources are rarely consistent across an entire area. Each ALA will contain parcels of land that are significantly higher yielding than is typical for that ALA, as well as some that are lower yielding.

While the ALA will provide a useful context for individual parcels of land, the detailed maps will provide a better indication of that parcel’s potential. Even these detailed maps have their scale limitations and there is no substitute for on-site investigation.

ALA maps, descriptions and data

The maps of broadacre and irrigated agriculture potential (Figures 4.1 and 4.4) have been simplified and combined to produce the map of the ALAs (Figure 4.6).

This map has been designed for use with the ALA descriptions contained in the information sheets presented in s 4.3.1 through to s 4.3.29. The ALA number shown on the map relates to the final portion of the section number. For example, the information sheet for ALA No. 17 (Naraling Hills) is presented in s 4.3.17.

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77 These include rainfall, soil, landforms, land capability for a variety of crops, groundwater availability, and existing land use.

78 Many other factors (such as industrial, urban growth, and environmental considerations) should be considered along with transport corridors and existing cadastral boundaries when determining planning boundaries.

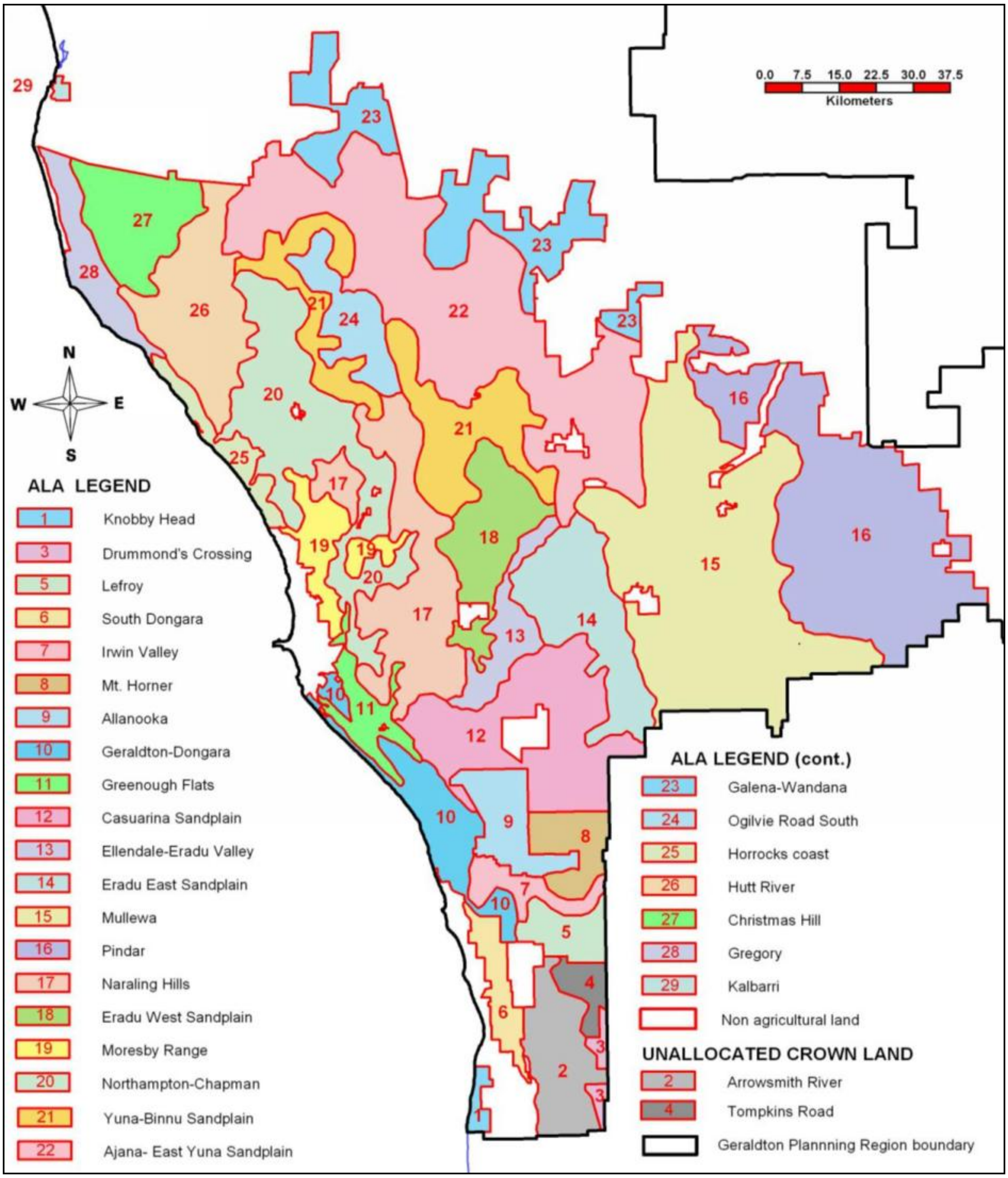


Figure 4.6 **Agricultural land areas for the Geraldton planning region**

Each ALA information sheet consists of two pages. The first page provides a description of the ALA in terms of location, characteristics and agricultural importance. There is also a map of the ALA and a list of opportunities and constraints.

The second page is in tabular form and provides a mix of brief descriptions and data for the following:

- landforms and gradients
- remnant vegetation cover
- soils
- growing season rainfall

- broadacre agriculture (includes potential wheat production in tonnes and dollars)
- groundwater resources (includes maximum and conservative volume estimates)
- horticultural potential
- maximum and conservative estimates of the potential value of irrigated crops
- number and sizes of properties and parcels.

Table 5.1 provides a summary of some of this data, allowing for quick comparisons between individual ALAs to be made. More detailed ALA data is presented in Appendix G.

Interpreting the ALA data

The intention is to provide a consistent assessment of potential production across the Region, allowing for a broad-scale comparison of the different ALAs. Much of the data only provides an indication of potential value of production rather than being definitive. The methods used to derive the data are detailed in s 3. Caution needs to be exercised when interpreting the data in these information sheets and tables. It is important to understand what they do and do not show.

The ALA data is not intended for use when making farm-scale assessments or decisions. There is a degree of internal variation within each ALA that is beyond the scope of these data summaries.

Some important points to keep in mind when interpreting the ALA data are:

- Wheat crop yields, tonnages and values are based on the unrealistic assumption that all cleared arable land is planted to wheat. These values are intended to provide an indication of productive capacity for a range of broadacre land uses rather than to capture actual wheat production.
- Individual properties within ALAs will achieve higher or lower yields than the relative wheat yield presented, depending on seasons, soils and management.
- Estimates of recharge are untested estimates only. While they provide an indication of potential local groundwater resources, they do not replace DoW local aquifer allocations.
- It is not possible to indicate the precise amount of groundwater available for licensing within an ALA. This will be determined by a complex variety of factors and will be highly dependent on existing licensed water entitlements in other areas.
- It is quite possible that in some ALAs overlying regional aquifers with significant GLC volumes, no water will actually remain available for licensing and water would only be available through water entitlement transactions.
- Estimates of the area of land that can be irrigated with the water volumes and the value of the crops are totally dependent on the availability of the water.
- The irrigable area and value of crops are based on a specific mix of enterprises. A change in this mix will alter water requirements and the area that can be irrigated, as well as the value of the produce. Larger areas of low water use crops could be irrigated but only smaller areas of high water use crops.
- All dollar values presented relate to the price of agricultural produce and do not include the full value of production to the economy.
- To ascertain the current availability of groundwater in any of the ALAs, it will be necessary to contact the DoW in Geraldton.

- The water use and dollar values presented are based on some very broad assumptions and are totally unsuitable for use in farm budgeting.

Each of the tables is followed by further information to assist in the interpretation of the data. The columns in the tables are numbered for easy reference.

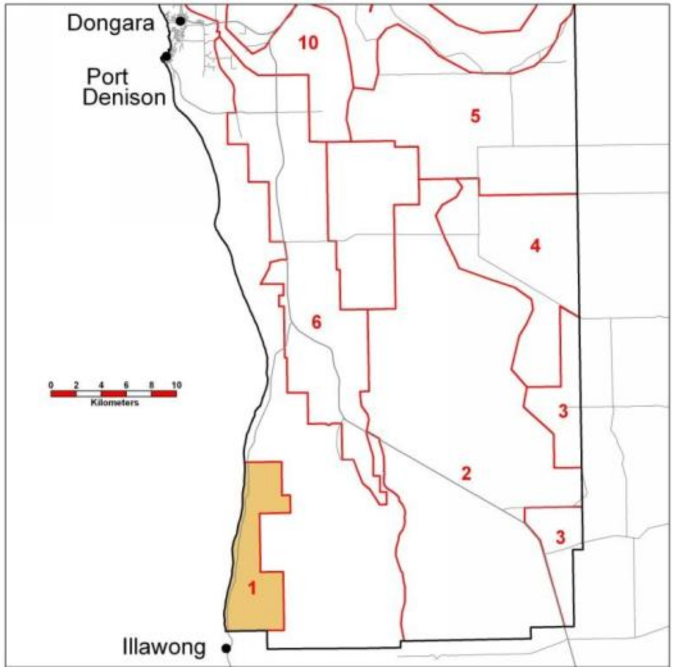
Lupin crop in flower on the Casuarina Sandplain ALA

Agricultural land area information sheets

Sandy soils and larger parcels of land are features of the Lefroy ALA

4.3.1 Knobby Head ALA

Location: The Knobby Head ALA covers about 4360 ha along the coast in the south-west corner of the Irwin Shire between Freshwater Point and Knobby Head.



Characteristics: This area has a narrow strip of coastal dunes parallel to the coast, backed by low dunes on limestone. Most of the area has gentle slopes, interspersed with flat land. Soils are mainly deep and shallow sands. Currently the area is used mainly for grazing sheep. No irrigated agriculture currently exists. There is only one property that comprises four parcels (lots). About 95 per cent of the area remains uncleared. Cleared land is mainly on flatter areas with less than 3 per cent slopes.

Agricultural importance: Despite the relatively high rainfall, the shallow and sandy soils tend to have very low productivity. The combination of poor quality soils and limited groundwater resources make large-scale irrigation developments unlikely.

Opportunities:

- relatively high rainfall.

Constraints:

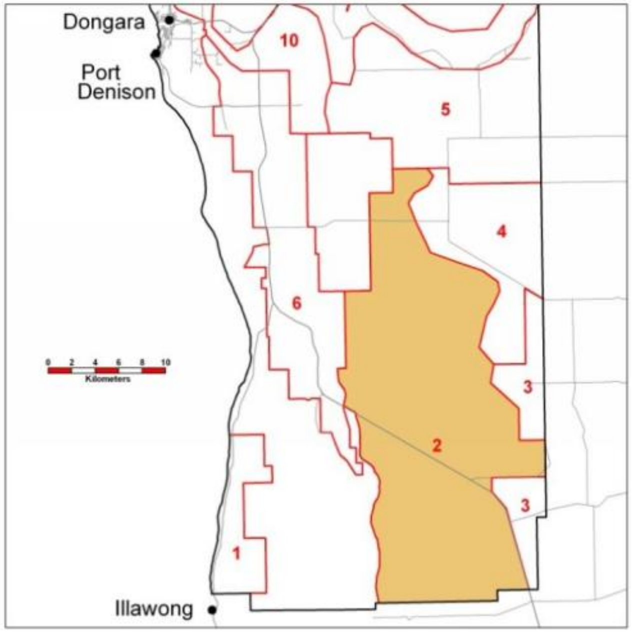
- poor quality soils
- limited groundwater supplies
- permission to clear remnant vegetation required before most of the area could be used for agriculture.

Knobby Head ALA (4360 ha)

Landform	This area has a narrow strip of coastal dunes backed by low dunes on limestone. Most of the land has gentle slopes but there are significant areas of flat land.		**Gradients:** Mainly 1–5% slope	**Remnant vegetation:** 94%
Soils	The dominant soils are Calcareous shallow and deep sands (Bookara series). There are also some Yellow/brown shallow sands, Yellow deep sands (Teakle series) and patches of Red shallow sands (Menai series).			
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 335 mm			
	Potential wheat production from all arable cleared land: 180 t		**Average potential yield:** 0.8 t/ha	**Value:** $0.05 million/year
	Despite the relatively high rainfall, the shallow and sandy soils tend to have very low productivity.			
Groundwater resources	**Estimated recharge to fresh aquifers:** 2 mm/yr contributing to potential groundwater resource of around 30 ML/yr (spread across 180 ha).			
	Regional aquifer general licensing component: 200 ML/yr—from 7% of the Cattamarra aquifer in the Dongara GWSA (covering 4300 ha).			
	Current knowledge suggests that groundwater supplies are small and of questionable quality.			
Irrigated agriculture	**Horticulture potential:** Poor quality soils and limited groundwater resources make large-scale irrigation developments unlikely.			
	Potential water for irrigated agriculture:		**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume	230 ML/yr	20 ha (< 1% of ALA)	$1.5 million/year
	Conservative volume	15 ML/yr	1 ha (< 1% of ALA)	$0.1 million/year
Property analysis	**No. of properties:** This area contains just one property comprising four parcels (lots) with an average size of 979 ha.			

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.2 Arrowsmith River UCL



Location: Arrowsmith River UCL covers about 38 400 ha of Unallocated Crown Land (UCL) between the Yardanogo and Beekeepers Nature Reserves and the eastern boundary of the Irwin Shire. It extends to the north and south of the Brand Highway.

Characteristics: This area is dominated by a level to very gently sloping coastal sandplain dominated by sandy soils. Further inland the sandplain is dissected with minor areas of low gravel ridges and laterite breakaways. It is currently uncleared.

Agricultural importance: This land (and the adjoining Tompkins Road UCL) was previously considered unsuitable for release for broadacre agriculture (Ted Griffin, DAFWA pers. comm.). While most of the area has limited agricultural potential, it is underlain by relatively good groundwater resources and some pockets of soil may be suitable for horticultural crops.

There may be a future opportunity for the development of a small horticultural precinct within this UCL. Issues that would need to be addressed before the release and clearing of any portion of this UCL include native title status, biodiversity/environmental values, existing mining tenements and obtaining of water entitlements.

The location of land for release could be carefully selected to maximise productivity and reduce environmental risks. Any enterprise established would be well buffered from surrounding agricultural land uses. Native fauna and vermin from surrounding bushland may prove problematic. Careful management of irrigation and fertilisers would be required to maintain production, particularly on any areas with ‘poorer’ sands.

Opportunities:

- may have potential for the development of a small horticultural precinct
- possibility of groundwater abstraction
- flat landscape lends itself to centre-pivot irrigation
- some pockets of higher productivity sands
- surrounds transport corridor (Brand Highway).

Constraints:

- UCL currently unavailable for agriculture
- existing mining tenements and environmental or native title considerations
- current allocation of water entitlements
- many of the sands have low productivity
- distance from labour supply and infrastructure
- wildlife and vermin may reduce crop potential.

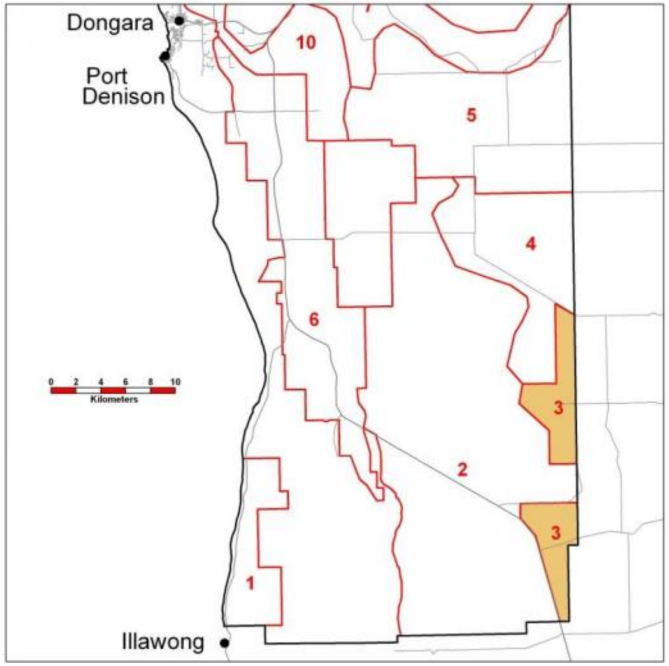
Arrowsmith River UCL (38 400 ha)

Landform	This area is dominated by level to very gently sloping coastal sandplain.		**Gradients:** Mainly < 3%	**Remnant vegetation:** 99%
Soils	The dominant soils are a mix of Pale deep sands and Yellow deep sands, with some Yellow/brown shallow sands (Teakle series). The quality of these sands for agriculture has a fair degree of variation due to grain size and clay content.			
Broadacre agriculture	**Growing season rainfall over past decade:**	Average: 326 mm	Geographical range: 320–350 mm	
	Currently this area is uncleared Unallocated Crown Land. It is not used for agriculture and is unlikely to be released for broadacre development			
Groundwater resources	**Estimated recharge to fresh aquifers:** 2 mm/yr contributing to potential groundwater resource of around 100 ML/yr (spread across 380 ha).			
	Regional aquifer general licensing component:	20 440 ML from 33% of the Yarragadee aquifer in the Eneabba Plains GWSA (covering 38 000 ha).		
	This ALA occurs within a GWSA with relatively large volumes of regional groundwater. Most of the general licensing component is currently allocated to existing water licensed entitlements located outside of this ALA. Native vegetation limits recharge to local groundwater.			
Irrigated agriculture	**Horticulture potential:** There should be some pockets areas of moderate to good quality sandy soils suitable for horticultural development. Most of the sandy soils are freely drained and easy to work but in many of the soils, the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these 'poorer' sands.			
	Potential water for irrigated agriculture:		**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume	20 540 ML/yr	1560 ha (4% of ALA)	$105 million/year
	Conservative volume	3450 ML/yr	260 ha (1% of ALA)	$20 million/year
Property analysis	**No. of properties:** This area contains just one property comprising one parcel (lot). The remainder is currently in state ownership (UCL).			

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting

4.3.3 Drummonds Crossing ALA

Location: The Drummonds Crossing ALA covers about 5200 ha, comprising two discrete subareas: 2300 ha in the south-east corner of the Irwin Shire near where Corey Road leaves the Brand Highway; and 2900 ha approximately 30 km to the north. These two subareas have been combined due to their small area and similarity in rainfall, soils and groundwater supplies. They are separated by an area of Unallocated Crown Land (see Arrowsmith River UCL s 4.3.2).



Characteristics: The southern portion is on the coastal plain and predominantly level to very gently inclined. The northern portion extends from the coastal plain upward to gently dissected slopes with low gravel ridges and minor breakaways. Sandy soils are dominant throughout. Currently this area is used mainly for grazing sheep and cattle and for cropping wheat. No significant irrigated agriculture currently exists. This area is typified by relatively large properties with fairly large parcels (lots). Most of it is cleared, with about one-quarter of the land covered by remnant vegetation. The cleared areas are mainly on gentle slopes.

Agricultural importance: While rainfall is moderately high, the variable nature of the sandy soils results in wheat yields that are lower than those achieved from 'better quality' sandplain to the east. Despite its small size this area appears to be underlain by relatively good groundwater resources. There are some areas of moderate to good quality sandy soils suitable for horticultural development. Careful management of irrigation and fertilisers would be required to maintain production particularly on any areas with 'poorer' sands.

Opportunities:

- relatively high rainfall
- some areas of higher productivity sands
- some potential for groundwater abstraction
- property and parcel (lot) sizes allow for larger scale agricultural developments.

Constraints:

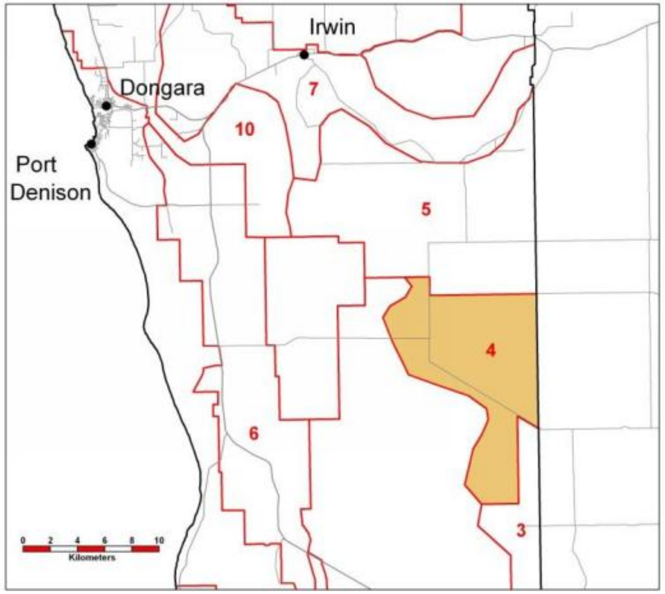
- current allocation of water entitlements
- many of the sands of lower productivity
- careful management of irrigation and fertilisers would be required to maintain production, particularly on any areas with 'poorer' sands.

Drummonds Crossing ALA (5200 ha)

Landform	There are two discrete subareas here—in the south is the level to very gently inclined coastal plain; in the north, the coastal plain transforms eastward up into gently dissected sandy slopes.	**Gradients:** South: mainly 0–3%; North: mainly 1–5%	**Remnant vegetation:** 25%
Soils	Most of the area in the south has mainly Pale deep sands with some Yellow deep sands and Grey deep sandy duplexes. In the north, there is a mix of Pale deep sands and Yellow deep sands with some Gravelly pale deeps sands, Deep sandy gravels and Grey deep sandy duplexes.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 322 mm	Geographical range: 315–340 mm	
	Potential wheat production from all arable cleared land: 6800 t	**Average potential yield:** 1.7 t/ha; yields range up to 2 t/ha on better sandplain soils	**Value:** $2 million/year
	While rainfall is moderately high, the variable nature of the sandy soils results in yields that are lower than those achieved from ‘better quality’ sandplain to the east.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 24 mm/yr contributing to potential groundwater resource of around 1250 ML/yr (spread across 4360 ha).		
	Regional aquifer general licensing component:	20 440 ML from 4% of the Yarragadee aquifer in the Eneabba Plains GWSA (covering 4100 ha). 42 830 ML from 1% of the Yarragadee aquifer in the Twin Hills GWSA (covering 1150 ha).	
	This area straddles two GWSAs with relatively large volumes of regional groundwater. Much of the general licensing component is currently allocated to existing water licensed entitlements located outside of this ALA.		
Irrigated agriculture	**Horticulture potential:** There are some areas of moderate to good quality sandy soils suitable for horticultural development. They are freely drained and easy to work but in many of the soils the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these ‘poorer’ sands.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 64 520 ML/yr	4930 ha (94% of ALA)	$335 million/year
	Conservative volume 800 ML/yr	60 ha (1% of ALA)	$4 million/year
Property analysis	**Average property size:** 2339 ha	**Average parcel (lot) size:** 1735 ha	
	No. of properties: 5	**No. of parcels (lots):** 6	**Average no. of parcels per property:** 2

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.4 Tompkins Road UCL



Location: Tompkins Road covers about 10 200 ha of Unallocated Crown Land (UCL) between the Yardanogo Nature Reserve and the eastern boundary of the Irwin Shire.

Characteristics: This area is dominated by very gently sloping sandy terrain dissected in places with low gravel ridges. It has mainly deep yellow and pale gravelly sandy soils. It is currently uncleared. No agriculture currently exists.

Agricultural importance: This land (and the adjoining Arrowsmith River UCL) was previously considered unsuitable for release for broadacre agriculture (Ted Griffin, DAFWA, pers. comm.). While most of the area has limited agricultural potential, it is underlain by relatively good groundwater resources and some soils may be suitable for horticultural crops.

There may be a future opportunity for the development of a small horticultural precinct within this UCL. Issues that would need to be addressed before the release and clearing of any portion of this land include native title status, biodiversity/environmental values, existing mining tenements, and obtaining of water entitlements.

The location of land for release could be carefully selected to maximise productivity and reduce environmental risks. Any enterprise established would be well buffered from surrounding agricultural land uses. Native fauna and vermin from surrounding bushland may prove problematic. Careful management of irrigation and fertilisers would be required to maintain production particularly on any areas with ‘poorer’ sands.

Opportunities:

- may have potential for the development of a small horticultural precinct
- possibility of groundwater abstraction
- flat landscape lends itself to centre-pivot irrigation
- some pockets of higher productivity sands.

Constraints:

- Unallocated Crown Land currently unavailable for agriculture
- existing mining tenements and environmental or native-title considerations
- current allocation of water entitlements
- many of the sands have low productivity
- distance from labour supply, infrastructure and transport
- wildlife and vermin may reduce crop potential.

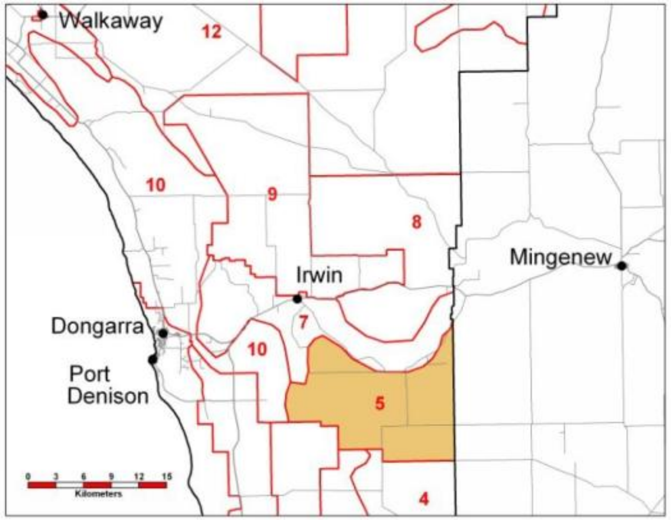
Tompkins Road UCL (10 200 ha)

Landform	The area is dominated by very gently sloping sandy terrain	**Gradients:** Slopes are mainly < 5%	**Remnant vegetation:** 100%
Soils	The dominant soils are a mix of Yellow deep sands (Eramba, Teakle & Eradu series), Gravelly pale deep sands (Casuarina series) and Pale deep sands (Allanooka & Tabletop series). The quality of these sands for agriculture has a fair degree of variation due to grain size and clay content.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 316 mm	Geographical range: 310–320 mm	
	Currently this area is uncleared UCL. It is not used for agriculture and is unlikely to be released for broadacre development.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 2 mm/yr contributing to potential groundwater resource of around 10 ML/yr (spread across 35 ha).		
	Regional aquifer general licensing component:	42 830 ML from 3% of the Yarragadee aquifer in the Twin Hills GWSA (covering 5700 ha). 20 440 ML from 4% of the Yarragadee aquifer in the Eneabba Plains GWSA (covering 4400 ha).	
	This area straddles two GWSAs with relatively large volumes of regional groundwater. Much of the general licensing component is currently allocated to existing water licensed entitlements located outside this UCL. Native vegetation limits recharge to local groundwater.		
Irrigated agriculture	**Horticulture potential:** There are some areas of moderate to good quality sandy soils suitable for horticultural development. They are freely drained and easy to work but in many of the soils the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these 'poorer' sands.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 63 280 ML/yr	4840 ha (48% of ALA)	$330 million/year
	Conservative volume 970 ML/yr	75 ha (1% of ALA)	$5 million/year
Property analysis	This land is currently in state ownership (UCL)		

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.5 Lefroy ALA

Location: Lefroy ALA covers about 16 900 ha, to the south of the Irwin River and against the eastern boundary of the Irwin Shire.



Characteristics: This area appears as gently undulating sandy terrain dissected in places by low gravelly ridges. Currently it is used mainly for cropping (mostly wheat in rotation with lupins and canola) and grazing livestock (mainly sheep, with some cattle and a few goats). No areas of significant irrigated agriculture exist. This area is typified by relatively large properties comprising relatively large parcels (lots). Most of this area is cleared; only about 10 per cent is remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance: While rainfall is relatively high, the variable nature of the sandy soils results in yields that (while still above the district average) are considerably lower than those achieved from 'better quality' sandplain. These soils perform best in average to just below average rainfall years with regular falls. Too much rain leads to leaching of nutrients which impacts on yields.

This area appears to be underlain by relatively good groundwater resources. There are large areas of moderate to good quality sandy soils suitable for horticultural development. They are freely drained and easy to work. The low clay content of these soils may limit moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these 'poorer' sands.

Opportunities:

- relatively high rainfall
- some areas of higher productivity sands
- potential for groundwater abstraction
- property and parcel (lot) sizes allow for larger scale agricultural developments.

Constraints:

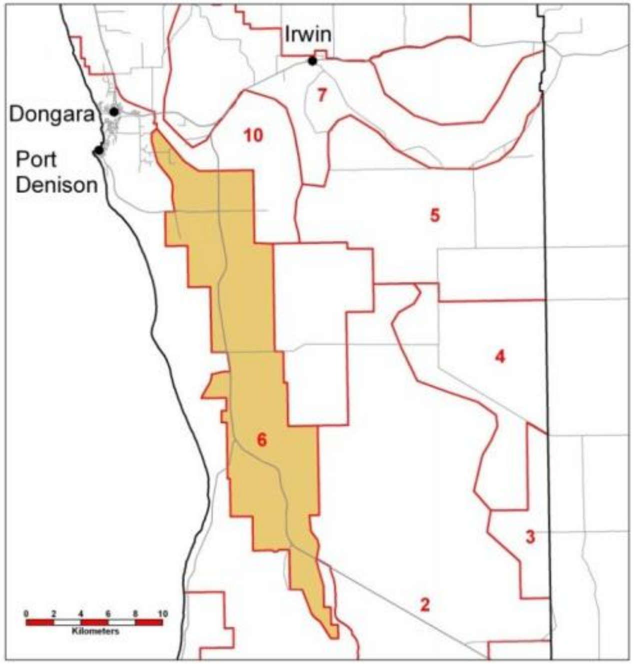
- current allocation of water entitlements
- many of the sands of lower productivity
- careful management of irrigation and fertilisers would be required to maintain production.

Lefroy ALA (16 900 ha)

Landform	This area is dominated gently undulating sandy terrain	**Gradients:** dominantly < 5% with some areas at 5–10%	**Remnant vegetation:** 10%
Soils	There is a variety of soils including Yellow deep sands (Teakle & Eurangoa series); Cracking clays (Fraser & Greenough series); Red sandy and Loamy earths (Bowes & Bootenal series); Yellow/brown shallow sandy duplexes (Moresby series); and Pale deep sands (Allanooka series).		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 324 mm	Geographical range: 310–340 mm	
	Potential wheat production from all arable cleared land: 27 200 t	**Average potential yield:** 1.8 t/ha	**Value:** $7 million/year
	While rainfall is relatively high, the variable nature of the sandy soils results in yields that (while still above the district average) are considerably lower than those achieved from ‘better quality’ sandplain.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 24 mm/yr contributing to potential groundwater resource of around 4080 ML/yr (spread across 15 410 ha).		
	Regional aquifer general licensing component:	42 830 ML from 7% of the Yarragadee aquifer in the Twin Hills GWSA (covering 15 600 ha). 20 440 ML from 1% of the Yarragadee aquifer in the Eneabba Plains GWSA (covering 1300 ha).	
	This ALA straddles two GWSAs with relatively large volumes of regional groundwater. Much of the general licensing component is currently allocated to existing water licensed entitlements located outside of this ALA.		
Irrigated agriculture	**Horticulture potential:** There are large areas of moderate to good quality sandy soils suitable for horticultural development. They are freely drained and easy to work but in many of the soils the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these ‘poorer’ sands.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 67 350 ML/yr	5150 ha (30% of ALA)	$350 million/year
	Conservative volume 2690 ML/yr	200 ha (1% of ALA)	$14 million/year
Property analysis	**Average property size:** 2613 ha	**Average parcel (lot) size:** 561 ha	
	No. of properties: 10	**No. of parcels (lots):** 38	**Average no. of parcels per property:** 10.5.

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.6 South Dongara ALA



Location: The South Dongara ALA covers about 17 000 ha, forming a long strip of land that roughly follows the Brand Highway from the Irwin River south to Arrowsmith.

Characteristics: This area is dominated by low, gently undulating dune systems with limestone outcrop. Currently this area is used mainly for cropping (wheat, lupins and canola) and grazing livestock (mainly cattle and sheep with a few horses, goats and pigs). This area typically has small properties and parcels. Over half remains uncleared—mainly areas of shallow soils and steep rocky terrain.

Agricultural importance: This area tends to have 'mid-range to poor quality' sands, with low water-holding capacity and fertility. While rainfall is relatively high, the 'poorer quality' sandy soils result in yields that are considerably lower than those achieved from adjoining areas of loamy and clayey soils. It is more comparable with yields from lower rainfall areas inland.

This area appears to have moderate groundwater resources. The volume of the general licensing component for the Yarragadee aquifer is considerably smaller here than for the ALAs to the east. Water quality is likely to be an issue, especially in the western portion of this ALA. The moderate quality sandy soils would not be considered 'optimal' for horticulture. Nor are the large areas of poorer quality sands highly suited to horticultural development. Most of the soils have low moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production.

Opportunities:

- relatively high rainfall
- some areas of moderately productive sands
- some potential for groundwater abstraction
- well-established transport routes
- numerous small properties suitable for intensive agricultural development.

Constraints:

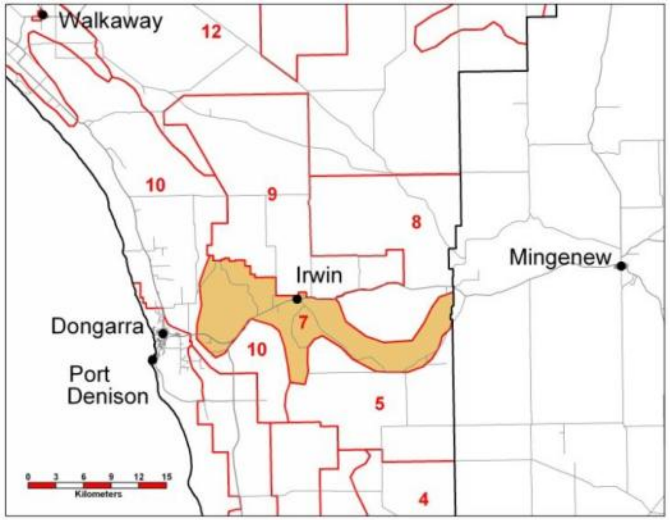
- groundwater resources unproven
- many of the sands have poor productivity
- careful management of irrigation and fertilisers is required to maintain productivity
- exposed to strong coastal winds—wind protection required
- small parcels and dissected landscape can limit the scale of operations.

South Dongara ALA (17 000 ha)

Landform	This area is dominated by low, gently undulating dune systems with limestone outcrop.	**Gradients:** Dominantly < 5%; some steeper areas 5–30%	**Remnant vegetation:** 62%
Soils	The dominant soils are a mix of Yellow deep sands and Yellow/brown shallow sands (Teakle series) with Calcareous deep sand and Calcareous shallow sands (Bookara & Quindalup series). These tend to be 'mid-range to poor quality' sands, with low water-holding capacity and fertility.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 335 mm	Geographical range: 325–355 mm	
	Potential wheat production from all arable cleared land: 7700 t	**Average potential yield:** 1.3 t/ha	**Value:** $2 million/year
	While rainfall is relatively high, the 'poorer quality' sandy soils result in yields that are considerably lower than those achieved from adjoining areas of loamy and clayey soils, and more comparable with yields from lower rainfall areas inland.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 8 mm/yr contributing to potential groundwater resource of around 1140 ML/yr (spread across 6330 ha)		
	Regional aquifer general licensing component:	3750 ML from 33% of the Yarragadee aquifer in the Dongara GWSA (covering 16 850 ha).	
	This ALA occurs within a GWSA with relatively small volumes of regional groundwater. Only a small portion of the general licensing component is currently allocated to existing licensed water entitlements. There is some potential for irrigation supplies in the local aquifers. Water quality may be an issue due to salinity.		
Irrigated agriculture	**Horticulture potential:** While there are significant areas of moderate quality sandy soils suitable for horticultural development, most would not be considered 'optimal' horticultural soils. There are large areas of poorer quality sands not highly suited to horticultural development. Most have low moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production. Wind protection is required.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 4890 ML/yr	370 ha (2% of ALA)	$25 million/year
	Conservative volume 900 ML/yr	70 ha (< 1% of ALA)	$5 million/year
Property analysis	**Average property size:** 951 ha	**Average parcel (lot) size:** 254 ha	
	No. of properties: 17	**No. of parcels (lots):** 61	**Average no. of parcels per property:** 5.4

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.7 Irwin valley ALA



Location: The Irwin Valley ALA covers about 15 000 ha, extending along the Irwin River from the outskirts of Dongara to the eastern Irwin Shire boundary.

Characteristics: This area is dominated by the fertile alluvial flats of the Irwin River. There is an area of low limestone hills with leached sands on the western edge and the adjoining lower slopes of the upland sandplain to the north and south, all surrounding the alluvial plain. The terrain is dominantly flat or gently sloping. Currently this area is used mainly for cropping and grazing livestock (mainly sheep and cattle with some goats). Minor areas of horticulture include avocados, irrigated pastures, olives, viticulture, mangoes and citrus. Small properties and parcel (lot) sizes are typical here. Most of this area is cleared; about 10 per cent is covered by remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance: The combination of relatively high growing season rainfall and 'rich' alluvial soils places the river flats as the highest yielding country for broadacre agriculture in the Region. Wheat yields range from > 2.5 t/ha on alluvial soils with minimal constraints (about one-third of the area) to < 1.5 t/ha on the poorer sands of the limestone hills closer to the coast.

This ALA has potential access to some of the better groundwater resources in the Region. The alluvial soils with their good moisture and nutrient retention are well suited to many horticultural crops. Groundwater salinity levels may be may be a bit higher along the Irwin River than they are underneath sloping terrain to the north and south. Water quality may also be an issue in the west of the ALA.

Opportunities:

- relatively high rainfall
- highly productive soils on alluvial flats with no constraints, especially in good rainfall years
- good groundwater resources
- well-established transport routes (Brand Highway and Midland Road)
- small properties suitable for intensive development.

Constraints:

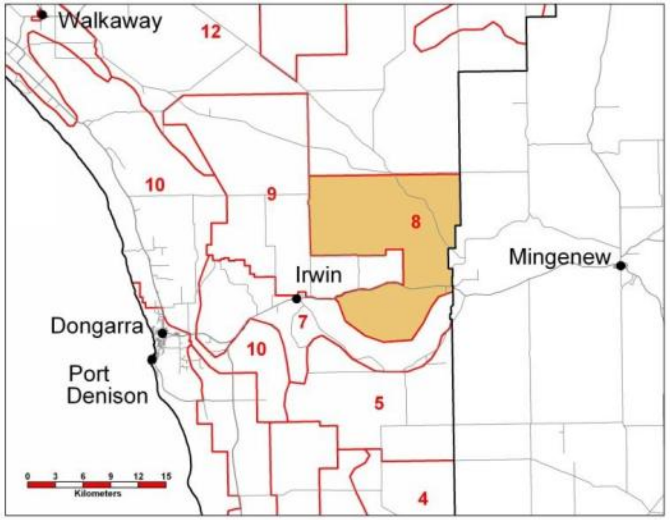
- current allocation of water entitlements
- small lots can limit the scale of operations
- high land prices
- flood risk and waterlogging along the Irwin River can lead to crop losses and damage to infrastructure.

Irwin valley ALA (15 000 ha)

Landform	This ALA contains the alluvial flats of the Irwin River and the adjoining lower slopes. In the west are low dunes on limestone. This is flat or gently sloping terrain.	**Gradients:** Mainly < 3% with lower slopes at 3–10%.	**Remnant vegetation:** 10%
Soils	There are a variety of soils including Yellow deep sands (Teakle & Eurangoa series); Cracking clays (Fraser & Greenough series); Red sandy and Loamy earths (Bowes & Bootenal series); Yellow/brown shallow sand duplexes (Moresby series); and Pale deep sands (Allanooka series).		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 339 mm	Geographical range: 315–355 mm	
	Potential wheat production from all arable cleared land: 29 000 t	**Average potential yield:** 2.1 t/ha reaching > 3 t/ha for better soils;	**Value:** $8 million/year
	The combination of relatively high growing season rainfall and ‘rich’ alluvial soils places the river flats among the highest yielding land in the district. Somewhat lower yields are obtained from the sandy soils on the adjoining slopes and coastal dune area. Waterlogging and flood risk in wet years.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 18 mm/yr contributing to potential groundwater resource of around 2460 ML/yr (spread across 10 390 ha).		
	Regional aquifer general licensing component:	42 830 ML from 2% of the Yarragadee aquifer in the Twin Hills GWSA (covering 3700 ha). 20 440 ML from 6% of the Yarragadee aquifer in the Eneabba Plains GWSA (covering 6900 ha). 8500 ML from 6% of the Yarragadee aquifer in the Allanooka GWSA (covering 3350 ha). 3750 ML from 2% of the Yarragadee aquifer in the Dongara GWSA (covering 1150 ha).	
	This ALA has potential access to the greatest volumes of groundwater in the Region. It overlies the junction of four GWSAs, three with sizeable general licensing components. Almost half of this water is currently allocated to existing water licensed entitlements, most located outside this ALA.		
Irrigated agriculture	**Horticulture potential:** The alluvial soils with their good moisture and nutrient retention are well-suited to many horticultural crops. The heavier clays present some problems for trees requiring free drainage (for example, citrus) and root vegetables where tuber shape is important (for example, carrots). Such crops may be better suited to the sandy soils on the adjoining slopes. Flood risk is a consideration.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 77 980 ML/yr	5960 ha (40% of ALA)	$405 million/year
	Conservative volume 1910 ML/yr	150 ha (1% of ALA)	$10 million/year
Property analysis	**Average property size:** 200 ha	**Average parcel (lot) size:** 50 ha (most are < 20 ha)	
	No. of properties: 31	**No. of parcels (lots):** 264	**Average no. of parcels per property:** 4.

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.8 Mt Horner ALA



Location: The Mt Horner ALA covers about 20 700 ha, sitting to the north of the Irwin River valley at the eastern boundary of the Irwin Shire.

Characteristics: This area appears as long gentle slopes dominated by sandy terrain with lateritic breakaways and low gravel ridges. Currently it is used mainly for cropping (mostly wheat in rotation with lupins and canola) and grazing livestock (mainly sheep with some cattle and a few goats). No areas of significant irrigated agriculture exist. This area is typified by relatively large properties comprising relatively large parcels (lots). Most of this area is currently cleared; only about 9 per cent is covered by remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance: While rainfall is relatively high, the variable nature of the sandy soils results in yields that (while still above the district average) are considerably lower than those achieved from 'better quality' sandplain. These soils perform best in average to just below average rainfall years with regular falls. Too much rain leads to leaching of nutrients which impacts on yields.

This ALA has access to moderate volumes of regional groundwater. There are large areas of moderate to good quality sandy soils suitable for horticultural development. They are freely drained and easy to work. The low clay content of these soils may limit moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on areas of 'poorer' sands.

Opportunities:

- relatively high rainfall
- some areas of higher productivity sands
- some potential for groundwater abstraction
- property and parcel (lot) sizes allows for larger scale agricultural developments

Constraints:

- current allocation of water entitlements
- many of the sands have lower productivity

Mt Horner ALA (20 700 ha)

Landform	This area is dominated by long gentle slopes dominated by sandy terrain with lateritic breakaways and low gravel ridges **Gradients:** Mainly 1–5% **Remnant vegetation:** 9%
Soils	The dominant soils are a mix of Pale deep sands (Allanooka & Tabletop series) and Yellow deep sands (Eurangoa, Teakle, Eramba & Eradu series). The quality of these sands for agriculture has a fair degree of variation due to grain size and clay content. Other soils present include Gravelly pale deep sands and Deep sandy gravels (Casuarina series) as well as Grey deep sandy duplexes (Heaton Series).
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 331 mm; Geographical range: 320–340 mm **Potential wheat production from all arable cleared land:** 34 300 t; **Average potential yield:** 1.8 t/ha; **Value:** $9 million/year While rainfall is relatively high, the variable nature of the sandy soils results in yields that (while still above the district average) are considerably lower than those achieved from ‘better quality’ sandplain.
Groundwater resources	**Estimated recharge to fresh aquifers:** 26 mm/yr contributing to potential groundwater resource of around 5410 ML/yr (spread across 20 360 ha). **Regional aquifer general licensing component:** 8500 ML from 38% of the Yarragadee aquifer in the Allanooka GWSA (covering 20 700 ha). This ALA occurs within a GWSA with relatively large volumes of regional groundwater but most of it is allocated to public water supply. Only a small portion of the general licensing component is currently allocated to existing licensed water entitlements. There is currently no general licensing component for local aquifers.
Irrigated agriculture	**Horticulture potential:** There are large areas of moderate to good quality sandy soils suitable for horticultural development. They are freely drained and easy to work but in many of the soils, the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on areas of ‘poorer’ sands.

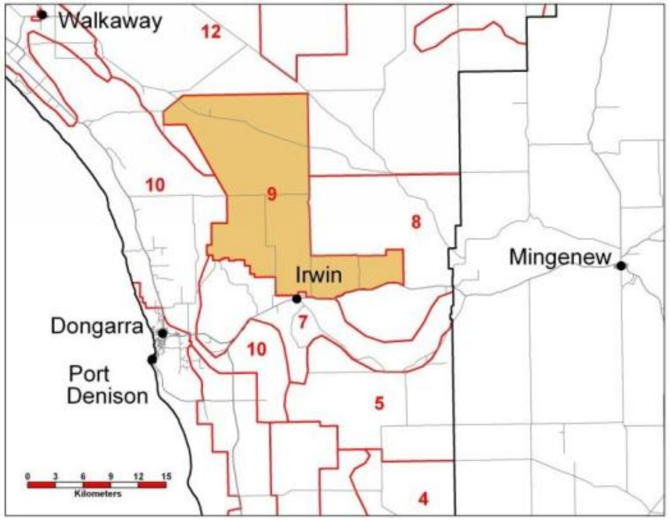
Potential water for irrigated agriculture:		Area of mix of enterprises irrigated by potential water:	Potential value of irrigated crops:
Maximum volume	13 910 ML/yr	1060 ha (5% of ALA)	$70 million/year
Conservative volume	2980 ML/yr	230 ha (1% of ALA)	$15 million/year

Property analysis	**Average property size:** 3053 ha	**Average parcel (lot) size:** 777 ha	
	No. of properties: 9	**No. of parcels (lots):** 29	**Average no. of parcels per property:** 11.8.

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.9 Allanooka ALA

Location: The Allanooka ALA covers about 26 300 ha. It is located to the north of the Irwin Valley ALA. It is defined by a Public Drinking Water Source Area boundary and land use restrictions apply.[79]



Characteristics: This area is dominated by long gentle slopes of sandy terrain broken by low gravel ridges and open depressions. Currently it is used mainly for cropping (mostly wheat in rotation with lupins and canola) and grazing livestock (mainly sheep with some cattle and a few goats). No areas of significant irrigated agriculture exist. This area is typified by relatively large properties comprised of relatively large parcels (lots). Most of this area is currently cleared; only about 7 per cent is covered by remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance: While rainfall is relatively high, the variable nature of the sandy soils results in yields that (while still above the district average) are considerably lower than those achieved from 'better quality' sandplain. These soils perform best in average to just below average rainfall years with regular falls. Too much rain leads to leaching of nutrients which impacts on yields.

This ALA has access to relatively large volumes of regional groundwater but as this is a Public Drinking Water Source Area, restrictions on development for intensive agriculture or other agricultural land uses may apply. There are large areas of moderate to good quality sandy soils suitable for horticultural development. They are freely drained and easy to work. The low clay content of these soils may limit moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on 'poorer' sands.

Opportunities:

- relatively high rainfall
- some areas of higher productivity sands
- some potential for groundwater abstraction
- property and parcel (lot) sizes allow for larger scale intensive agricultural developments.

Constraints:

- restrictions on intensive land use apply due to Public Drinking Water Source Area status
- current allocation of water entitlements
- many of the sands of lower productivity.

79 Identified by the Department of Environment Water Protection Plan in the Shire of Irwin Local Planning Strategy 2007.

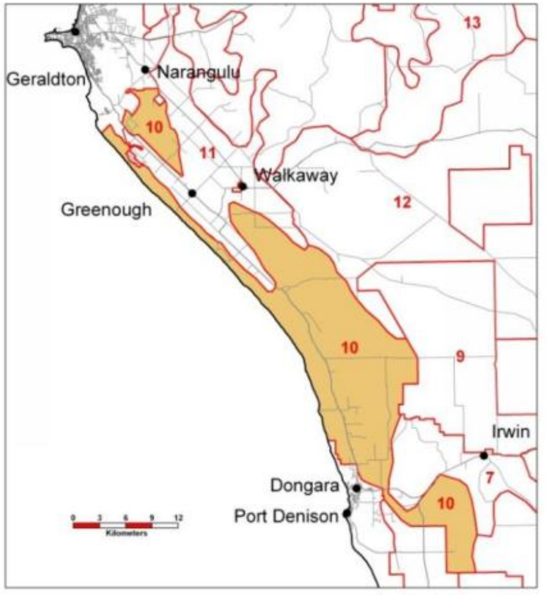
Allanooka ALA (26 300 ha)

Landform	This area is dominated by gently sloping sandy terrain	**Gradients:** dominantly 1–5% with some slopes to 10%	**Remnant vegetation:** 7%
Soils	The dominant soils are a mix of Pale deep sands (Allanooka & Tabletop series) and Yellow deep sands (Eurangoa, Teakle, Eramba & Eradu series). The quality of these sands for agriculture has a fair degree of variation due to grain size and clay content. Other soils present include Gravelly pale deep sands and Deep sandy gravels (Casuarina series) as well as Grey deep sandy duplexes (Heaton Series).		
Broadacre agriculture	**Growing season rainfall over past decade:**	Average: 332 mm	Geographical range: 320–350 mm
	Potential wheat production from all arable cleared land: 43 700 t	**Average potential yield:** 1.8 t/ha	**Value:** $12 million/year
	While rainfall is relatively high, the variable nature of the sandy soils results in yields that (while still above the district average) are considerably lower than those achieved from ‘better quality’ sandplain.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 28 mm/yr contributing to potential groundwater resource of around 7210 ML/yr (spread across 25 440 ha).		
	Regional aquifer general licensing component:	20 440 ML from 3% of the Yarragadee aquifer in the Eneabba Plains GWSA (covering 3350 ha). 8500 ML from 42% of the Yarragadee aquifer in the Allanooka GWSA (covering 22 800 ha).	
	This ALA occurs within a GWSA with relatively large volumes of regional groundwater but most of it is allocated to public water supply. Most of the general licensing component is currently allocated to existing licensed water entitlements located outside this ALA.		
Irrigated agriculture	**Horticulture potential:** This area is unlikely to be developed for intensive agriculture because it occupies a restricted land use area due to its Public Drinking Water Source Area status.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 36 150 ML/yr	2760 ha (11% of ALA)	$190 million/year
	Conservative volume 3900 ML/yr	300 ha (1% of ALA)	$20 million/year
Property analysis	**Average property size:** 1089 ha	**Average parcel (lot) size:** 439 ha	
	No. of properties: 26	**No. of parcels (lots):** 48	**Average no. of parcels per property:** 5.2.

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.10 Geraldton–Dongara ALA

Location: The Geraldton–Dongara ALA covers about 38 700 ha, comprising two discrete subareas that occupy the coastal strip between Geraldton and Dongara. These subareas are separated by the Greenough Flats. The larger subarea to the south-east is about 35 600 ha and includes the coastal dunes to the west of the Brand Highway but also extends inland at Bookara. The smaller subarea to the north-west is about 3 100 ha and extends south-east from Geraldton between Narngulu and Greenough.



Characteristics: High coastal dunes are backed by lower dunes on limestone. Deep sands are the dominant soil and most of the land is gently sloping. Currently it is generally used for grazing sheep and cattle, and cropping. Other livestock include deer, horses and goats. Main crops are wheat, oats and lupins. Current irrigated agricultural includes nuts, olives and melons. The area is typified by small properties and parcel sizes. About 43 per cent remains uncleared including most of the coastal dunes.

Agricultural importance: While rainfall is relatively high, the 'poorer quality' sandy soils result in wheat yields that are considerably lower than those achieved from adjoining areas of loamy and clayey soils. Yields are more comparable to those from lower rainfall areas inland. The low clay content of these soils may limit moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these 'poorer' sands.

South of Dongara, this ALA has potential access to good water supplies. Over the remainder, groundwater supplies are more limited and salinity is an issue in places, especially closer to the coast. Some soils have potential for horticultural crops.

Opportunities:

- relatively high rainfall
- close to potential labour supply and infrastructure in Geraldton and Dongara
- well-established transport routes
- numerous small properties suitable for intensive development
- potential access to good groundwater resources in the south.

Constraints:

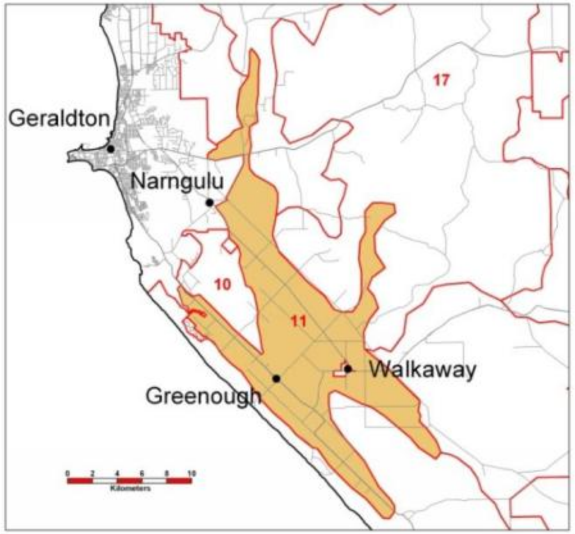
- poorer quality soils—careful management of irrigation and fertilisers would be required to maintain production
- limited rotation options
- limited groundwater resources and water quality issues over much of the ALA
- exposed to very strong winds
- small parcels limit scale of operation
- high land prices
- potential for conflicts along urban interface and with 'rural life-stylers'.

Geraldton–Dongara ALA (38 700 ha)

Landform	This area includes the high coastal dunes as well as lower inland dunes formed on limestone. Most of the land features gentle slopes but there are significant areas of moderate slopes along the coast and level to very gently sloping terrain inland	**Gradients:** Mainly up to 10%, with some dunes at 10–30%	**Remnant vegetation:** 38%
Soils	Calcareous deep sands (Quindalup and Southgates series) are found on the coastal dunes. Inland on the low dunes over limestone are Yellow deep sands with Yellow/brown shallow sands (Teakle series) and Calcareous shallow sand (Bookara series). There are also patches of Red shallow and deep sands (Menai series).		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 338 mm	Geographical range: 320–350 mm	
	Potential wheat production from all arable cleared land: 33 400 t	**Average potential yield:** 1.4 t/ha	**Value:** $9 million/year
	While rainfall is relatively high, the 'poorer quality' sandy soils result in yields that are considerably lower than those achieved from adjoining areas of loamy and clayey soils and more comparable with yields from lower rainfall areas inland.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 14 mm/yr contributing to potential groundwater resource around 5190 ML/yr (spread across 27 440 ha).		
	Regional aquifer general licensing component:	20 440 ML from 7% of the Yarragadee aquifer in the Eneabba Plains GWSA (covering 8150 ha). 3 750 ML from 34% of the Yarragadee aquifer in the Dongara GWSA (covering 17 350 ha). 200 ML from 16% of the Cattamarra aquifer in the Dongara GWSA (covering 10 300 ha).	
	Potential access to relatively large volumes of regional groundwater south of Dongara. Most of the general licensing component is currently allocated to existing licensed water entitlements located outside of this ALA. Underneath the remainder of the ALA are relatively small volumes of regional groundwater and salinity levels may be high. There is some potential for irrigation supplies in local aquifers.		
Irrigated agriculture	**Horticulture potential:** The soils are freely drained and easy to work but in many of the soils, the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these 'poorer' sands. .		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 29 580 ML/yr	2260 ha (6% of ALA)	$155 million/year
	Conservative volume 2690 ML/yr	210 ha (1% of ALA)	$14 million/year
Property analysis	**Average property size:** 193 ha	**Average parcel (lot) size:** 92 ha	
	No. of properties: 190	**No. of parcels (lots):** 393	**Average no. of parcels per property:** 2.7

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.11 Greenough Flats ALA



Location: The Greenough Flats ALA covers about 19 700 ha, mostly to south-east of Geraldton. It occupies the current and past floodplains of the lower Greenough and Chapman Rivers, including areas of parallel strips (known as the front and back flats) divided by a limestone ridge. It runs along the Brand Highway and Edward Road up to Moonyoonooka, encompassing the town of Walkaway and the Greenough Hamlet and the localities of Bootenal, Bradleys, Georgina and Crampton.

Characteristics: This area is dominated by floodplains and very gently sloping terrain featuring alluvial soils with small areas of low hills of leached sands over limestone. **The Greenough Flats currently has some of the more significant horticultural activity in the Region.** Table grapes, olives, carob, vegetables and melons are some of the produce grown here. Flood risk and wind exposure are management considerations. Small lot sizes and proximity to Geraldton make this area attractive for people seeking rural lifestyle blocks and there is a potential for conflicts with agricultural activities.

Agricultural importance: Good growing season rainfall combines with the rich alluvial soils to make this **some of the highest yielding land in the Region**. Half of the area has a relative average wheat yield potential of > 2.5 t/ha.

The alluvial soils with their good moisture and nutrient retention are well suited to many horticultural crops. While groundwater resources in this area may only provide a patchy contribution to future irrigated agricultural development, some existing growers are sourcing water from nearby sources. Scheme water is currently being used by shadehouse growers on the outskirts of Geraldton and this industry has expanded markedly in the past five years. Table grapes are irrigated in Walkaway using a dedicated pipeline from the Allanooka GWSA. In the future, there may be potential to tap further supplies from this GWSA. McGhie and Meaton (1999) estimated that up to 1000 ha could be irrigated from the existing pipeline. Another possible source of irrigation water is recycled wastewater from Geraldton.

Opportunities:

- relatively high rainfall
- highly productive soils (areas of both heavy and light land)
- close to potential labour supply and infrastructure in Geraldton
- well situated to supply Geraldton with fresh food
- well-established transport routes
- access to scheme water and other potential alternative irrigation sources
- numerous small properties suitable for intensive agricultural development.

Constraints:

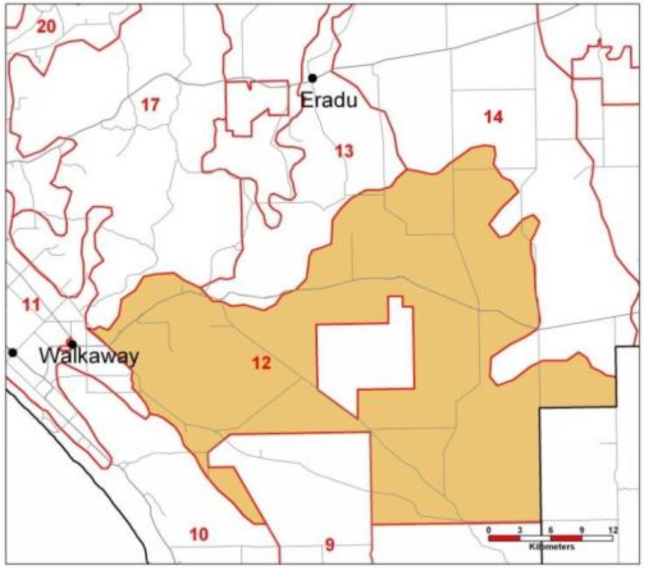
- limited groundwater resources
- relatively high cost of scheme water
- flooding along the Greenough River (partially mitigated by levees)
- exposed to very strong winds (especially on the ‘Front Flats’)
- small lots limit scale of operation
- high land prices
- potential conflicts along urban interface and with ‘rural life-stylers’.

Greenough Flats ALA (19 700 ha)

Landform	Alluvial flats and very gently sloping terrain	**Gradients:** Dominantly 0–3%	**Remnant vegetation:** 6%
Soils	Alluvial soils are dominant. They include Cracking clays (Greenough and Fraser series), Red shallow and deep loamy and sandy duplexes with some Red loamy earths (Bowes series) and Red sandy earths and Deep sands (Bootenal series). Most of these soils are reasonably well drained. The limestone ridge separating the alluvial soils of the front and back flats is mainly Yellow deep sand and Yellow/brown shallow sands (Teakle series).		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 334 mm	Geographical range: 320–340 mm	
	Potential wheat production from all arable cleared land: 44 900 t	**Average potential yield:** 2.4 t/ha; up to > 3 t/ha on better soil	**Value:** $12 million/year
	Good growing season rainfall combines with the rich alluvial soils to make this some of highest yielding land in the region.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 9 mm/yr contributing to potential groundwater resource 630 ML/yr (spread across 3630 ha).		
	Regional aquifer general licensing component: 200 ML from 20% of the Cattamarra aquifer in the Dongara GWSA (covering 12 500 ha).		
	There is limited potential for groundwater abstraction directly within this ALA. Water quality in the underlying aquifers is generally brackish to saline. McGhie and Meaton (1999) estimated that up to 1000 ha of the Greenough Flats could be irrigated from the pipeline carrying groundwater from Allanooka.		
Irrigated agriculture	**Horticulture potential:** The alluvial soils with their good moisture and nutrient retention are well suited to many horticultural crops. The heavier clays present some problems for trees requiring free drainage (for example, citrus) and root vegetables where tuber shape is important (for example, carrots). Such crops may be better suited to the sandy soils on the limestone ridge. While groundwater resources underneath this ALA are limited, there are alternative sources including scheme water upon which the shadehouse industry is currently based. Flood risk is a consideration along the Greenough River.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 835 ML/yr	65 ha (< 1% of ALA)	$4 million/year (see text below)
	Conservative volume 175 ML/yr	15 ha (< 1% of ALA)	$1 million/year (see text below)
	The current value of irrigated crops produced in this ALA would exceed the maximum potential value shown above, even without taking into account prospects for future expansion. As growers on the Greenough Flats access water from alternative sources, the potential water volumes, irrigated crop areas and values above, are underestimates. Currently there are over 250 ha of irrigated crops within the ALA and adjoining land within Geraldton. Intense shade house production generates significantly higher income than the enterprise mix used for calculations in this report		
Property analysis	**Average property size:** 105 ha	**Average parcel (lot) size:** 35 ha	
	No. of properties: 162	**No. of parcels (lots):** 455	**Average no. of parcels per property:** 3.4

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.12 Casuarina Sandplain ALA



Location: The Casuarina Sandplain ALA covers about 86 400 ha, extending from the east of Walkaway to the vicinity of Erangy Spring Road.

Characteristics: This area is predominantly a combination of sandplain and gently undulating sandy slopes with occasional low gravelly rises. Currently this area is used for cropping with some grazing of livestock. Main crops grown are wheat, lupins and canola. Livestock are mainly sheep with some cattle and a few horses, goats and pigs. Small areas of olives, mangoes and macadamia are present, but no significant irrigated agriculture currently exists. This area is typified by relatively large properties and parcels (lots). Most of it is cleared; only about 7 per cent is remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance: These are generally 'mid-range' sandplain soils with reasonable moisture- holding and fertility. While rainfall is moderately high, the variable nature of the sandy soils results in yields that are lower than those achieved from 'better quality' sandplain to the east. Wheat yield potentials range from over 2 t/ha on better sandplain soils to < 1.5 t/ha on poorer soils on residual slopes. There are large areas of moderate quality sandy soils suitable for horticultural development with significant pockets of better quality sands. They are freely drained and easy to work but in many of the soils the low clay content limits moisture and nutrient retention.

Groundwater resources are currently being investigated but appear to be small to moderate. There are large areas of moderate quality sandy soils suitable for horticultural development with significant pockets of 'better quality' sands. The relatively flat land surface and large property sizes would favour the establishment of broader scale irrigation enterprises.

Opportunities:

- relatively high rainfall
- some areas of higher productivity sands
- some potential for groundwater abstraction
- property and parcel (lot) sizes allow for larger scale agricultural developments
- situated along transport corridor (Nangetty – Walkaway Road).

Constraints:

- groundwater resources unproven
- many of the sands have lower productivity
- careful management of irrigation and fertilisers is required to maintain productivity.

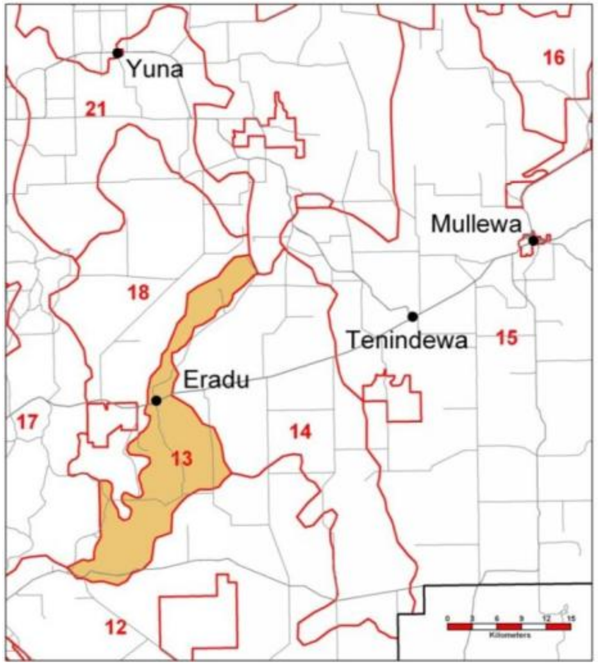
Casuarina sandplain ALA (86 400 ha)

Landform	Predominantly a combination of sandplain and gently undulating sandy slopes	**Gradients:** Mainly 1–3% slopes	**Remnant vegetation:** 7%
Soils	The most common soils are Gravelly pale deep sands (Casuarina series) with Pale deep sands (Allanooka series) and Yellow deep sands (Eurangoa and Eradu series) also being common. These are generally 'mid-range' sandplain soils with reasonable moisture-holding and fertility.		
Broadacre agriculture	**Growing season rainfall over past decade:**	Average: 311 mm	Geographical range: 270–335 mm
	Potential wheat production from all arable cleared land: 153 300 t	**Average potential yield:** 1.9 t/ha; ranging up to > 2 t/ha on better sandplain soils	**Value:** $40 million/year
	While rainfall is moderately high, the variable nature of the sandy soils results in lower yields than those on the 'better quality' sandplain to the east.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 21 mm/yr contributing to potential groundwater resource of around 17 830 ML/yr (spread across 84 850 ha).		
	Regional aquifer general licensing component:	4600 ML from 53% of the Yarragadee aquifer in the Casuarinas GWSA (covering 79 550 ha).	
	Though estimated recharge volumes would appear to suggest the presence of significantly larger water reserves than the general licensing component suggests, this ALA occurs within a GWSA with relatively small volumes of regional groundwater allocated. Salinity and aquifer thickness may limit usable supplies. **The conservative irrigation volumes and values below are therefore more likely to represent the maximum volumes and values**. Only a small portion of the general licensing component is currently allocated to existing licensed water entitlements.		
Irrigated agriculture	**Horticulture potential:** There are large areas of moderate quality sandy soils suitable for horticultural development with significant pockets of better quality sands. They are freely drained and easy to work but in many of the soils, the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these 'poorer' sands.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 22 430 ML/yr*	1710 ha* (2% of ALA)	$115 million/year*
	Conservative volume 5 670 ML/yr*	430 ha* (1% of ALA)	$30 million/year*
Property analysis	**Average property size:** 1339 ha	**Average parcel (lot) size:** 555 ha	
	No. of properties: 67	**No. of parcels (lots):** 157	**Average no. of parcels per property:** 3.2

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

* See note in red above.

4.3.13 Ellendale – Eradu Valley ALA



Location: The Ellendale – Eradu Valley ALA covers about 24 000 ha. It follows the Greenough River where it cuts a broad valley between the Eradu East and Eradu West Sandplain ALAs, stretching from the vicinity of Ellendale Pool in the south-west to the mouth of Kockatea Gully in the north-east.

Characteristics: This area is dominated by the sloping terrain of the Greenough River valley interspersed with depressions and gravel ridges above the river beds and narrow alluvial flats of the river. Soils are varied, dominantly sandy duplexes, shallow gravels and deep sands. Currently the area is mainly used for grain crops, particularly wheat. Grazing of sheep and cattle is also widespread. Property sizes are average for the district and parcel sizes are moderately small. About 22 per cent of the area is remnant vegetation, mainly on shallow soils, river flats and steeper slopes over 10 per cent.

Agricultural importance: The nature and productivity of these soils is very varied. While good to reasonable yields are achievable on some areas, much of the land is too steep or stony for cropping. The patchy, dissected nature of the landscape limits the potential for broad scale enterprises. Wheat yield potential ranges from > 2.5 t/ha on small areas of alluvial soils and better sandplain areas, to < 1.5 t/ha on poorer sandplain areas, shallow gravels and steeper side slopes of the river valley.

Groundwater resources are currently being investigated but appear to be small. Some of the soils are suitable for horticulture. Sloping land may limit the scale of operations. Flood risk is also a consideration on the valley flats.

Opportunities:

- moderate rainfall
- some potential for groundwater abstraction
- niche opportunities for horticulture in some areas
- reasonable proximity to Geraldton
- dissected by major road.

Constraints:

- groundwater resources unproven
- areas of steeper slopes and shallow soils
- flood risk along Greenough River may lead to crop losses and damage to infrastructure.

Ellendale – Eradu Valley ALA (24 000 ha)

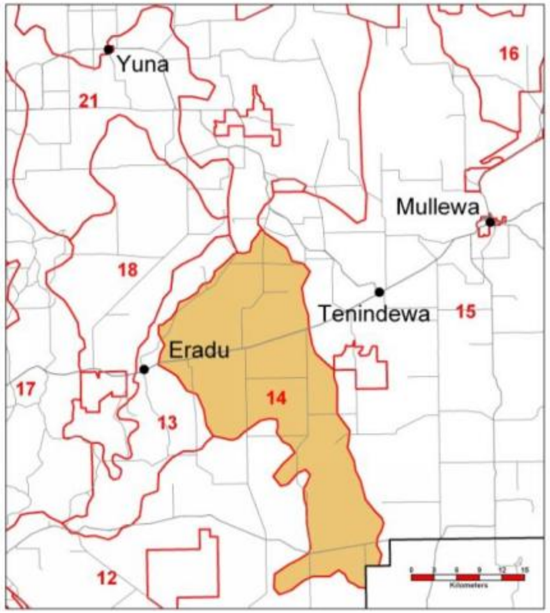
Landform	This area is dominated by valley slopes with depressions and gravel ridges above the river beds and narrow alluvial flats of the Greenough River	**Gradients:** Mainly 1–10%	**Remnant vegetation:** 22%
Soils	Soils are mainly a mixture of Grey deep sandy duplex (Heaton series), Shallow gravels (Bluewell series) and Pale deep sands (Allanooka and Balline series). Red sandy and loamy earths and duplexes are also common (Bootenal, Bowes, Kojarena and Mt Scratch series) with areas of Yellow deep sand (Eradu and Eurangoa series) and sandy gravels (Casuarina series).		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 296 mm	Geographical range: 250–340 mm	
	Potential wheat production from all arable cleared land: 30 000 t	**Average potential yield:** 1.6 t/ha	**Value:** $8 million/year
	The nature and productivity of these soils is very varied. Though there are areas of 'poorer' soils, the moderate rainfall maintains reasonable yields on the areas of arable land.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 19 mm/yr contributing to potential groundwater resource of around 4500 ML/yr (spread across 20 600 ha).		
	Regional aquifer general licensing component:	4600 ML from 5% of the Yarragadee aquifer in the Casuarinas GWSA (covering 7500 ha).	
	This ALA sits on the northern edge of a GWSA with relatively small volumes of regional groundwater allocated. **The conservative irrigation volumes and values below are more likely to represent the maximum volumes and values** as the ALA is sitting right on the edge of Yarragadee aquifer. Salinity levels may also be a problem.		
Irrigated agriculture	**Horticulture potential:** Some of the soils are suitable for horticulture. Sloping land may limit the scale of operations. Flood risk is also a consideration on the valley flats.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 9100 ML/yr*	700 ha* (3% of ALA)	$45 million/year*
	Conservative volume 1240 ML/yr*	95 ha* (< 1% of ALA)	$6 million/year*
Property analysis	**Average property size:** 1778 ha	**Average parcel (lot) size:** 144 ha	
	No. of properties: 11	**No. of parcels (lots):** 153	**Average no. of parcels per property:** 13.5

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

* See note in red above.

4.3.14 Eradu East Sandplain ALA

Location: The Eradu East Sandplain ALA covers about 60 000 ha and extends in a south-south-east direction from the Greenough River running between Eradu and Tenindewa.



Characteristics: This area is dominated by broad expanses of yellow sandplain with good water and nutrient-holding capacities. Currently it is mainly used for cropping, though the grazing of livestock (mostly sheep with a few cattle) is also significant. The main crops grown are wheat, lupins and canola. No significant irrigated agriculture exists. Properties and parcel sizes on the sandplain are typically large. Most of this area is currently cleared; only about 5 per cent is remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance: The combination of moderate growing season rainfall and 'good quality' sands places this amongst the highest yielding sandplain country in the Region. In seasons with below average rainfall, the better sands tend to outperform the heavier soils of the district but this advantage is not present in wetter years.

Groundwater resources are currently being investigated but appear to be relatively small. Salinity levels in the Yarragadee Aquifer are likely to be higher than they are under the adjoining Casuarina Sandplain ALA. The sandplain soils would be highly suitable for horticultural development, being freely drained and having reasonably good moisture and nutrient retention. The loose sandy topsoils are especially suited to root crops where tuber shape is important. The size of the properties and parcels would allow for large-scale agricultural development and the large and relative flat paddocks suggest there would be minimal ground preparation for setting up centre-pivots.

Opportunities:

- moderate rainfall
- highly productive sands
- yields relatively well in below average rainfall years
- some potential for groundwater abstraction
- flat landscape lends itself to centre-pivot irrigation
- property and parcel sizes allow for larger scale agricultural developments
- reasonable proximity to Geraldton
- bisected by two major roads.

Constraints:

- groundwater resources unproven
- non-major roads may require upgrading.

Eradu East Sandplain ALA (60 000 ha)

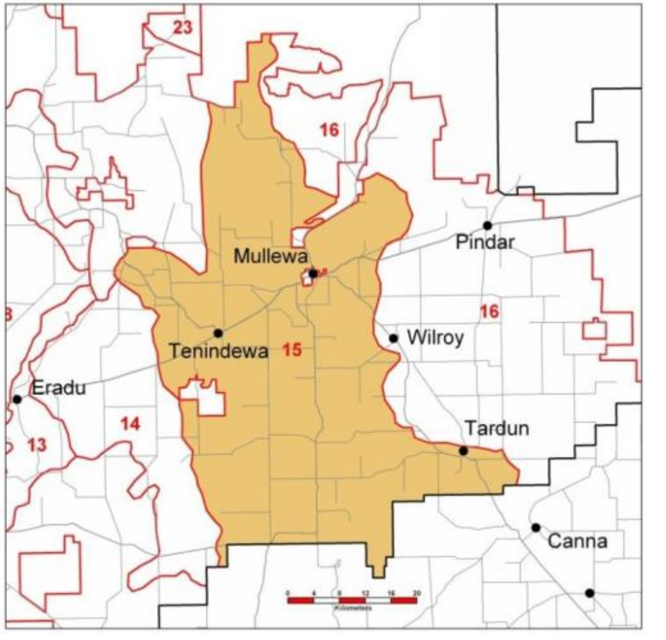
Landform	This area is dominated by broad expanses of yellow sandplain.	**Gradients:** Dominantly 1–3%	**Remnant vegetation:** 5%
Soils	Good quality Yellow deep sands, with some Yellow Sandy earths, (Eradu series) cover most of this area. The next most common soil type is Gravelly pale deep sand (Casuarina series).		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 262 mm	Geographical range: 235–300 mm	
	Potential wheat production from all arable cleared land: 130 000 t	**Average potential yield:** 2.3 t/ha	**Value:** $35 million/year
	The combination of moderate growing season rainfall and 'good quality' sands places this among the highest yielding sandplain country in the Region. In seasons with below average rainfall, the better sands tend to outperform the heavier soils. This advantage is not present in wetter years.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 11 mm/yr contributing to potential groundwater resource of around 6720 ML/yr (spread across 58 030 ha).		
	Regional aquifer general licensing component: 4600 ML from 28% of the Yarragadee aquifer in the Casuarinas GWSA (covering 42 250 ha). 500 ML from 87% of the Yarragadee aquifer in the Yuna/Eradu GWSA (covering 14 100 ha).		
	Though estimated recharge volumes would appear to suggest the presence of significantly larger water reserves than the general licensing component suggests, this ALA occurs within a GWSA with relatively small volumes of regional groundwater allocated. Salinity levels and aquifer thickness are likely to limit usable supplies. **The conservative irrigation volumes and values below are therefore more likely to represent the maximum volumes and values**. Only a small portion of the general licensing component is currently allocated to existing licensed water entitlements.		
Irrigated agriculture	**Horticulture potential:** These sandplain soils would be highly suitable for horticultural development, being freely drained and having reasonably good moisture and nutrient retention. The loose sandy topsoils are especially suited to root crops where tuber shape is important.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 11 820 ML/yr*	900 ha* (2% of ALA)	$60 million/year*
	Conservative volume 2540 ML/yr*	190 ha* (< 1% of ALA)	$13 million/year*
Property analysis	**Average property size:** 2962 ha	**Average parcel (lot) size:** 899 ha	
	No. of properties: 18	**No. of parcels (lots):** 66	**Average no. of parcels per property:** 4.7

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

* See note in red above.

4.3.15 Mullewa ALA

Location: The Mullewa ALA covers about 212 300 ha and forms a north-south running strip of land (about 10–35 km wide) that occupies the central portion of the former Shire of Mullewa. This ALA includes the localities of Mullewa, Coonawa, Tenindewa and Tardun.



Characteristics: This area is dominated by a mix of red soil flats and yellow sandplain, dissected by small areas of narrow valleys and undulating country with stony ridges and granite outcrops. Most of the land has very gentle to gentle slopes. Currently it is used mainly for cropping wheat, as well as lupins and canola. There is also some grazing of livestock (mostly sheep with some cattle). A sizeable area is listed as flora and fauna conservation. No significant irrigated agriculture currently exists.

Agricultural importance: Although some soils are suitable for horticulture, good quality groundwater supplies are very limited. Much of the groundwater in this area is saline, especially in the east. Any suitable supplies are likely to be small and scattered.

There are considerable areas of 'better quality' soils but lower levels of rainfall results in lower yields than experienced on similar soils to the south and west in most seasons. Lower land prices and low input systems contribute to sustaining profitable broadacre agriculture in this area.

Opportunities:

- profitability for broadacre agriculture is maintained by using low-input low-risk systems.
- low land prices

Constraints:

- low rainfall
- need to manage the risks associated with tight margins and changing circumstances

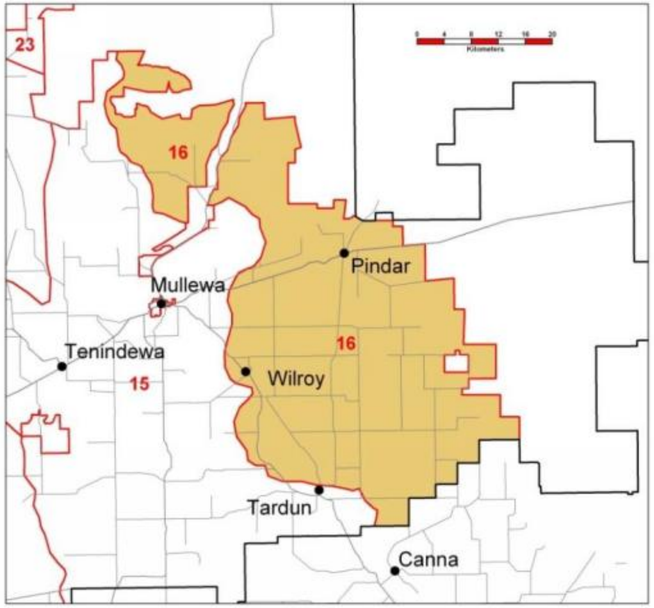
Mullewa ALA (212 300 ha)

<table>
<tr><td>Landform</td><td colspan="2">This area is dominated by a mix of red soil flats and yellow sandplain. Most of the land has very gentle to gentle slopes.</td><td>Gradients: Mainly 1–5% with significant areas of flatter land</td><td>Remnant vegetation: 17%</td></tr>
<tr><td>Soils</td><td colspan="4">Relict alluvial plains have Red-brown hardpan shallow loams and Red shallow loams (Mindage, Wilroy and Fegan series). Red loamy earths (Indar and Morawa series) and Red shallow sands (Grima series) are also found. The sandplains have Yellow deep sands and Yellow Sandy earths of variable quality (Indarra, Eradu and Eurangoa series).</td></tr>
<tr><td rowspan="3">Broadacre agriculture</td><td>Growing season rainfall over past decade:</td><td>Average: 229 mm</td><td colspan="2">Geographical range: 210–250 mm</td></tr>
<tr><td colspan="2">Potential wheat production from all arable cleared land: 240 000 t</td><td>Average potential yield: 1.4 t/ha; ranging up to 2 t/ha on better soils</td><td>Value: $65 million/year</td></tr>
<tr><td colspan="4">The nature and productivity of the soils is quite varied. Though there are considerable areas of ‘good quality’ soils, the relatively low rainfall limits yields in most seasons.</td></tr>
<tr><td rowspan="3">Groundwater resources</td><td colspan="4">Estimated recharge to fresh aquifers: 3 mm/yr contributing to potential groundwater resource of around 85 ML/yr (spread across 760 ha).</td></tr>
<tr><td>Regional aquifer general licensing component:</td><td colspan="3">No regional aquifer general licensing component for Mullewa/Byro GWSA or Yuna/Eradu GWSA.</td></tr>
<tr><td colspan="4">Much of the groundwater under this area is saline, especially in the east. Any suitable supplies are likely to be small and scattered.</td></tr>
<tr><td rowspan="4">Irrigated agriculture</td><td colspan="4">Horticulture potential: Although some soils are suitable for horticulture, good quality groundwater supplies are very limited</td></tr>
<tr><td colspan="2">Potential water for irrigated agriculture:</td><td>Area of mix of enterprises irrigated by potential water:</td><td>Potential value of irrigated crops:</td></tr>
<tr><td>Maximum volume</td><td>85 ML/yr</td><td>6 ha (< 1% of ALA)</td><td>$0.5 million/year</td></tr>
<tr><td>Conservative volume</td><td>20 ML/yr</td><td>2 ha (< 1% of ALA)</td><td>$0.1 million/year</td></tr>
<tr><td rowspan="2">Property analysis</td><td>Average property size: 2450 ha</td><td colspan="3">Average parcel (lot) size: 291 ha</td></tr>
<tr><td>No. of properties: 99</td><td colspan="2">No. of parcels (lots): 733</td><td>Average no. of parcels per property: 8.9</td></tr>
</table>

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.16 Pindar ALA

Location: The Pindar ALA covers about 169 000 ha occupying the eastern portion of the agricultural districts in the former Shire of Mullewa. It extends south-east from the Greenough River through Pindar to Sullivan and the Morawa Shire boundary. It is divided into two portions by the Urawa Nature Reserve. The small north-western area is 21 500 ha and the larger south-eastern portion is 147 400 ha.



Characteristics: This area is a mix of yellow sandplain and red soil flats on relict alluvial plains and undulating granitic country. Most of the land is flat to very gently sloping. Currently it is used mainly for cropping wheat in rotation with lupins or fallow, and grazing sheep and some cattle. Interest in oil mallee plantations has increased in recent times. No significant irrigated agriculture exists. The area features large properties and parcel sizes. About 17 per cent of this area remains uncleared, including part of the linear Urawa Nature Reserve.

Agricultural importance: The nature and productivity of the soils is quite varied. Though there are considerable areas of 'good quality' soils there are also significant areas of acid sands, shallow soils and saline soils. This combines with low rainfall to limit yields in most seasons. Lower land prices and low-input, low-risk systems contribute to sustaining profitable broadacre agriculture in this area.

Although some soils are suitable for horticulture, good quality groundwater supplies are very limited. Most of the groundwater in this area is saline. Any suitable supplies are likely to be small and scattered.

Opportunities:

- good quality soils
- large property sizes
- profitability for broadacre agriculture is maintained by using low-input, low-risk systems.
- lower land prices.

Constraints:

- limited groundwater resources
- low rainfall
- wildlife and vermin may reduce crop potential
- need to manage the risks associated with tight margins and changing circumstances.

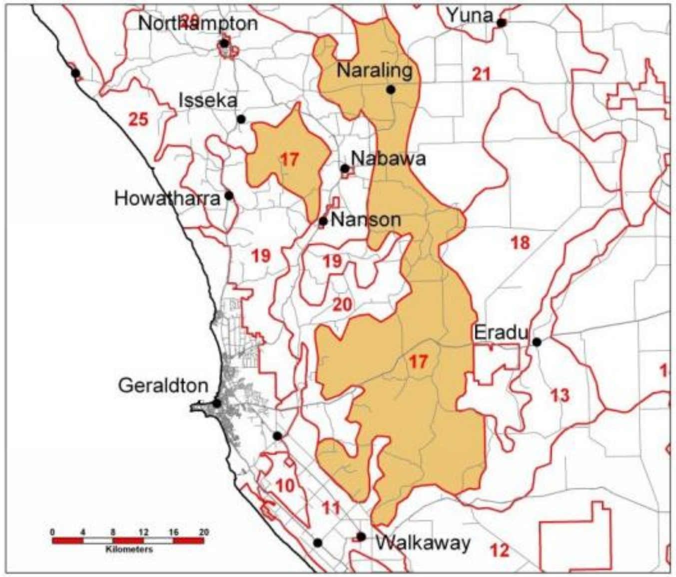
Pindar ALA (169 000 ha)

Landform	This area comprises a mix of yellow sandplain, red soil flats on relict alluvial plains and undulating granitic country. Most of the land is flat to very gently sloping.	**Gradients:** Mainly 0–3%	**Remnant vegetation:** 17%
Soils	The sandplains have Yellow Sandy earths and Yellow deep sands that are often acidic (Kelly and Pindar series). Relict alluvial plains have Red-brown hardpan shallow loams and Red shallow loams (Wilroy and Mindage series) with Red shallow loams (Fegan and Mindage series) and Red shallow sands (Grima series) found on sloping granitic terrain. Shallow gravels (Matteno series) and Stony soils are also present. Drainage lines often contain Saline wet soils.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 212 mm	Geographical range: 195–225 mm	
	Potential wheat production from all arable cleared land: 129 000 t	**Average potential yield:** 0.9 t/ha up to 1.5 t/ha on better soils	**Value:** $35 million/year
	Though there are considerable areas of ‘good quality’ soils there are also significant areas of acid sands, shallow soils and saline soils. This combines with low rainfall to limit yields in most seasons. Low-input systems contribute to sustaining profitable broadacre agriculture in this area.		
Groundwater resources	**Estimated recharge to fresh aquifers:** No significant recharge of fresh aquifers.		
	Regional aquifer general licensing component: Mullewa/Byro GWSA has no regional aquifers.		
	Most of the groundwater under this area is saline. Any suitable supplies are likely to be small and scattered.		
Irrigated agriculture	**Horticulture potential:** Although some soils are suitable for horticulture, good quality groundwater supplies are very limited.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 0 ML/yr	0 ha (0% of ALA)	$0
	Conservative volume 0 ML/yr	0 ha (0% of ALA)	$0
Property analysis	**Average property size:** 4540 ha	**Average parcel (lot) size:** 608 ha	
	No. of properties: 76	**No. of parcels (lots):** 294	**Average no. of parcels per property:** 4.2

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.17 Naraling Hills ALA

Location: The Naraling Hills ALA covers about 85 000 ha in two separate areas including a strip of land of about 76 000 ha extending from Naraling south to the Greenough River between Ellendale Pool and Walkaway. This strip includes Northern Gully, the Kojarena Range and Mount Pleasant. A smaller area of about 9000 ha between Nanson and Isseka has also been included in this ALA due to its similar characteristics.



Characteristics: This area is dominated by undulating hilly terrain, mostly on granite. Slopes are gentle to moderately steep in areas. Soils are dominantly red duplexes and earths. There are also some sizeable areas of gently undulating sandplain. Currently it is used mainly for cropping wheat, lupins and some canola. There is also grazing of livestock (mainly sheep with some cattle and a few horses, deer and pigs). Minor areas of irrigated agriculture occur here including table grapes, olives, vegetables and floriculture. Aquaculture is also present. Property sizes are typically large. About 17 per cent remains uncleared.

Agricultural importance: The nature and productivity of the soils is very varied. Though there are areas of 'poorer' soils, the relatively high rainfall maintains reasonable yields. While some of the soils are suitable for horticulture, limited groundwater resources make large-scale irrigation developments unlikely.

Opportunities:

- higher rainfall supports good production potential for broadacre agriculture
- niche opportunities for horticulture in some areas.

Constraints:

- limited groundwater resources
- areas of steeper slopes and rock outcrops
- risk of water erosion.

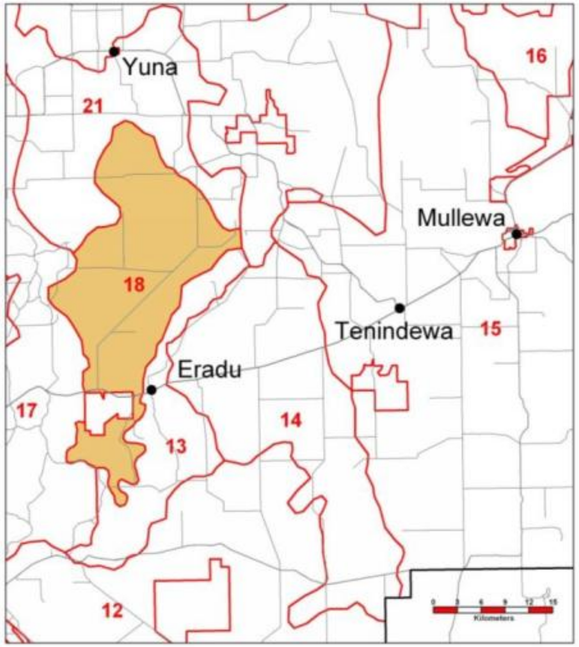
Naraling Hills ALA (85 000 ha)

Landform	This area is dominated by undulating hilly terrain, mostly on a granitic base.	**Gradients:** mainly up to10% but some steeper areas	**Remnant vegetation:** 17%
Soils	The most common soils are Red shallow sandy duplexes (Northern Gully series), Red loamy earths and Red shallow loamy duplexes (Kojarena and Mount Scratch series). There are also patches of Yellow deep sands (Eurangoa and Eradu series), Gravelly pale deep sands (Casuarina series), Pale deep sand (Allanooka and Balline series) and deep sandy duplexes (Moresby and Heaton series) on sandplains. Rocky outcrops are often present.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 327 mm	Geographical range: 290–355 mm	
	Potential wheat production from all arable cleared land: 121 000 t	**Average potential yield:**1.7 t/ha; ranging up to > 2.5 t/ha on better soils	**Value:** $30 million/year
	The nature and productivity of the soils here is very varied. Though there are areas of 'poorer' soils, the relatively high rainfall maintains reasonable yields.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 5 mm/yr contributing to potential groundwater resource of around 2820 ML/yr (spread across 19 780 ha).		
	Regional aquifer general licensing component: Northampton/Gelena GWSA has no regional aquifers.		
	Current knowledge suggests that groundwater supplies are small, scattered and often of questionable quality. They would mainly be restricted to local aquifers associated with the sandplains.		
Irrigated agriculture	**Horticulture potential:** Although some of the soils are suitable for horticulture, limited groundwater resources make large-scale irrigation developments unlikely. Sandplain areas may have suitable supplies for small developments in some locations.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 2820 ML/yr	220 ha (< 1% of ALA)	$15 million/year
	Conservative volume 710 ML/yr	55 ha (< 1% of ALA)	$4 million/year
Property analysis	**Average property size:** 630 ha	**Average parcel (lot) size:** 131 ha	
	No. of properties: 127	**No. of parcels (lots):** 635	**Average no. of parcels per property:** 6.3

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.18 Eradu West Sandplain ALA

Location: The Eradu West Sandplain ALA extends from just south of Yuna to the Ellendale – Eradu Valley ALA. It covers about 45 300 ha.



Characteristics: This area is dominated by broad expanses of gently undulating yellow sandplain with good water and nutrient-holding capacities. Currently this area is used mainly for cropping, though the grazing of livestock (mostly sheep with a few cattle) is also significant. Main crops are wheat, lupins and canola. No significant irrigated agriculture currently exists. Properties and parcel sizes on the sandplain are typically large. Most of this area is currently cleared; only about 7 per cent is remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance: The combination of moderate growing season rainfall and 'good quality' sands places this among the highest yielding sandplain country in the region. In seasons with below average rainfall, the better sands tend to outperform the heavier soils of the district but this advantage is not present in wetter years. Groundwater resources require further investigation. Small to moderate volumes may be present but water quality is likely to be an issue. These sandplain soils would be highly suitable for horticultural development, being freely drained and having reasonably good moisture and nutrient retention. The loose sandy topsoils are especially suited to root crops where tuber shape is important. The size of the properties and parcels would allow for large-scale agricultural development and the large and relative flat paddocks suggest there would be minimal ground preparation for setting up centre-pivots.

Opportunities:

- moderate rainfall
- highly productive sands
- yields relatively well in below average rainfall years
- flat landscape lends itself to centre-pivot irrigation
- property and parcel sizes allows for larger scale agricultural developments
- reasonable proximity to Geraldton
- dissected by major road.

Constraints:

- groundwater resources unproven
- non-major roads may require upgrading.

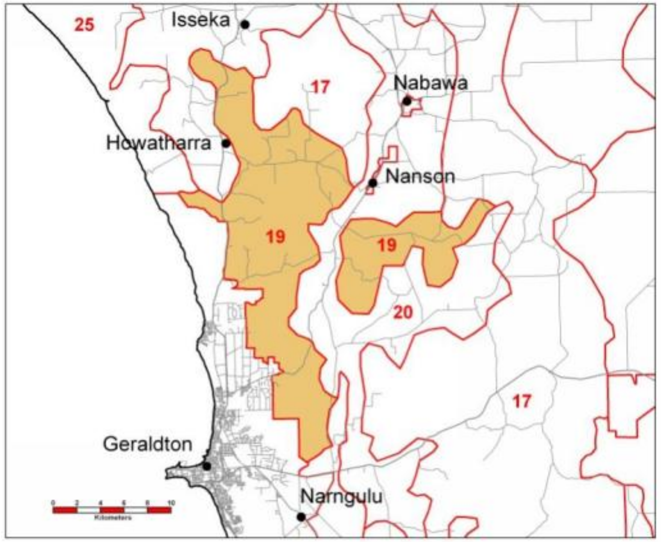
Eradu West Sandplain ALA (45 300 ha)

Landform	This area is dominated by broad expanses of gently undulating yellow sandplain.	**Gradients:** Mainly 1–5%	**Remnant vegetation:** 7%
Soils	Good quality Yellow deep sands, with some Yellow Sandy earths, (Eradu series) cover most of this area. The next most common soil type is Gravelly pale deep sand (Casuarina series).		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 284 mm	Geographical range: 250–340 mm	
	Potential wheat production from all arable cleared land: 101 000 t	**Average potential yield:** 2.4 t/ha	**Value:** $25 million/year
	The combination of moderate growing season rainfall and 'good quality' sands places this among the highest yielding sandplain country in the region. In seasons with below average rainfall, the better sands tend to outperform the heavier soils of the region but this advantage is not present in wetter years.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 12 mm/yr contributing to potential groundwater resource of about 5400 ML/yr (spread across 42 180 ha).		
	Regional aquifer general licensing component: General licensing components in Yuna/Eradu GWSA are not currently designated as regional.		
	Groundwater resources require further investigation. While the general licensing components of underlying aquifers (designated as local in this report) suggest the above recharge estimates may provide a reasonable indication of small to moderate volumes of groundwater, water quality is likely to be an issue. **The conservative irrigation volumes and values below are therefore more likely to represent the maximum amounts**.		
Irrigated agriculture	**Horticulture potential:** These sandplain soils would be highly suitable for horticultural development, being freely drained and having reasonably good moisture and nutrient retention. The loose sandy topsoils are especially suited to root crops where tuber shape is important.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 5400 ML/yr*	410 ha* (1% of ALA)	$30 million/year*
	Conservative volume 1350 ML/yr*	100 ha* (< 1% of ALA)	$7 million/year*
Property analysis	**Average property size:** 1440 ha	**Average parcel (lot) size:** 461 ha	
	No. of properties: 26	**No. of parcels (lots):** 91	**Average no. of parcels per property:** 6.8

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

* See note in red above.

4.3.19 Moresby Range ALA



Location: The Moresby Range ALA covers about 25 600 ha, comprising two discrete subareas (separated by the Chapman River) to the north-east of Geraldton. The main range lies to the west of the Chapman River and covers about 19 700 ha, extending around 30 km north from Mt Fairfax to Oakabella. On the opposite side of the Chapman River about 6000 ha of the range extends east from Yetna.

Characteristics: This area is dominated by undulating hilly terrain, typically appearing as flat-topped mesas and sandplain plateau remnants. Most of the land has gentle slopes but there are significant areas of moderate to steep slopes. The most common soils are sandy duplexes, and rock outcrops are frequent. Currently this area is used mainly for cropping wheat, as well as oats, barley, canola and lupins, and grazing sheep. There is also grazing of cattle and a few horses, pigs and goats. Currently there are sizeable olive and viticulture plantings and a number of other smaller areas of horticultural crops including table grapes, figs, citrus, floriculture and vegetables. There is also aquaculture. About 31 per cent of this area remains uncleared, including most of the steeper slopes. Property and parcel sizes are relatively small.

Agricultural importance: The nature and productivity of the soils is quite varied. While good to reasonable yields are achievable on the gentle foot slopes, much of the land is too steep or stony for cropping. The patchy, dissected nature of the landscape limits the potential for broad-scale enterprises.

Although many of the soils on the gentler slopes are suitable for horticulture, limited groundwater resources make large-scale irrigation developments unlikely. However, there may be suitable supplies for small developments in some locations.

Opportunities:

- niche opportunities for horticulture in some areas
- numerous small properties suitable for intensive agriculture development.

Constraints:

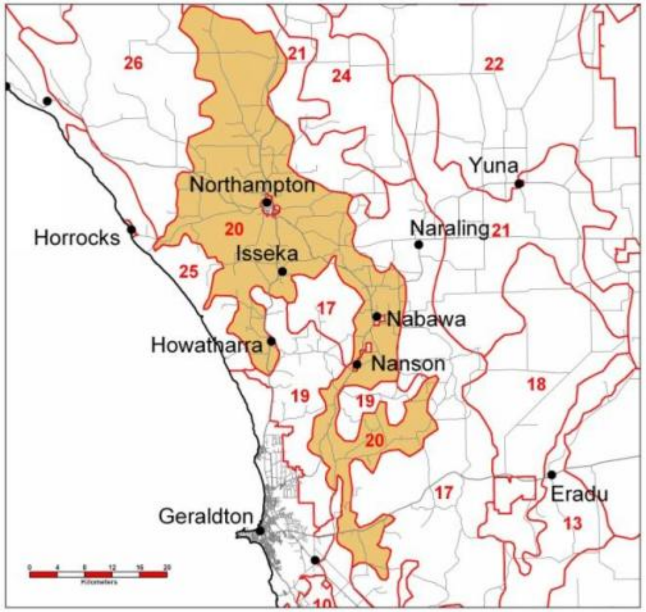
- steep side slopes
- limited groundwater resources
- potential for conflicts along urban interface and with ‘rural life-stylers’.

Moresby Range ALA (25 600 ha)

Landform	This area is dominated by undulating hilly terrain and flat-topped sandplain plateau remnants, mostly on a sedimentary base but with areas of granitic rocks. Most of the land has gentle slopes with significant areas of moderate to steep slopes associated mainly with mesas.	**Gradients:** Mainly 3–10% with many steeper areas > 10%	**Remnant vegetation:** 31%
Soils	The most common soils are Yellow/brown shallow and deep sandy duplexes (Moresby series). Yellow deep sands (Teakle series) are found on the low dunes over limestone. Red shallow and deep loamy duplexes (Northampton series) are found on granitic slopes. Other soils include Duplex sandy gravels, Shallow gravels (Bluewell series) and Yellow and Brown deep sands (Eurangoa series). Rock outcrops are common.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 344 mm	Geographical range: 325–360 mm	
	Potential wheat production from all arable cleared land: 32 400 t	**Average potential yield:** 1.8 t/ha	**Value:** $9 million/year
	The nature and productivity of the soils is quite varied. While good to reasonable yields are achievable on the gentle foot slopes, much of the land is too steep or stony for cropping. The patchy, dissected nature of the landscape limits the potential for broad-scale enterprises.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 7 mm/yr contributing to potential groundwater resource of around 1040 ML/yr (spread across 9210 ha).		
	Regional aquifer general licensing component: Northampton/Gelena GWSA has no regional aquifers.		
	Current knowledge suggest that groundwater supplies are small, scattered and often of questionable quality.		
Irrigated agriculture	**Horticulture potential:** Although many of the soils on the gentler slopes are suitable for horticulture, limited groundwater resources make large-scale irrigation developments unlikely. However, there may be suitable supplies for small developments in some locations.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 1040 ML/yr	80 ha (< 1% of ALA)	$5 million/year
	Conservative volume 260 ML/yr	20 ha (< 1% of ALA)	$1 million/year
Property analysis	**Average property size:** 207 ha	**Average parcel (lot) size:** 96 ha	
	No. of properties: 112	**No. of parcels (lots):** 259	**Average no. of parcels per property:** 2.7

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.20 Northampton–Chapman ALA



Location: The Northampton–Chapman ALA covers about 99 000 ha, extending south from the vicinity of west Ogilvie to near Moonyoonooka. It includes the settlements of Northampton, Isseka, Nabawa, Nanson and Howatharra.

Characteristics This area is dominated by undulating valleys and hills featuring loamy soil with good water and nutrient-holding capacities. Currently it is used mainly for cropping wheat, lupins and canola, and grazing sheep, with some cattle, horses, goats and ostriches.

Historically there has been some horticultural development in this area. Stone fruit orchards have long been established around Northampton and Isseka. Large areas of olives and table grapes also exist. In the past some of these could be irrigated from captured run-off but they are increasingly reliant on limited water supplies in fractured rock aquifers. Other crops currently irrigated include flowers, nuts, table grapes, citrus, mangoes, turf and sandalwood. There is an abattoir located here along with a cattle feedlot, a piggery, an egg farm, a tree nursery, and a small area of aquaculture. Properties and parcel sizes are mixed. Most of this area is currently cleared; about 13 per cent is remnant vegetation and much of this lies on the land least suited to agricultural production.

Agricultural importance The combination of relatively high growing season rainfall and 'rich' loamy soils places this among the highest yielding country in the district (especially in seasons with above average rainfall) but not all of the land is arable due the hilly terrain. There are significant pockets of steep slopes and shallow stony soils that are unsuitable for cropping but are used for grazing livestock.

The loamy soils with their good moisture and nutrient retention are also well suited to many horticultural crops. The sloping nature of the land is a limitation in some areas, especially for vegetable crops where the risk of soil erosion may be too great. Potential for future horticultural development beyond existing plantings is limited by groundwater resources, which are of varied reliability. Lead levels in the groundwater in isolated areas around Northampton are a further limitation.

Opportunities:

- relatively high rainfall
- highly productive soils, especially in good rainfall years
- reasonable proximity to labour supply and infrastructure in Geraldton
- well-established transport routes
- numerous small properties suitable for intensive agricultural development
- niche opportunities for horticulture in some areas.

Constraints:

- limited groundwater resources
- erosion risk and shallow soils limits suitability of some of the steeper slopes
- small parcels and dissected landscape limit the scale of operations
- high land prices
- traces of heavy metals may occur in the groundwater
- production efficiency of loams on hilly terrain reduced by rock outcrop.

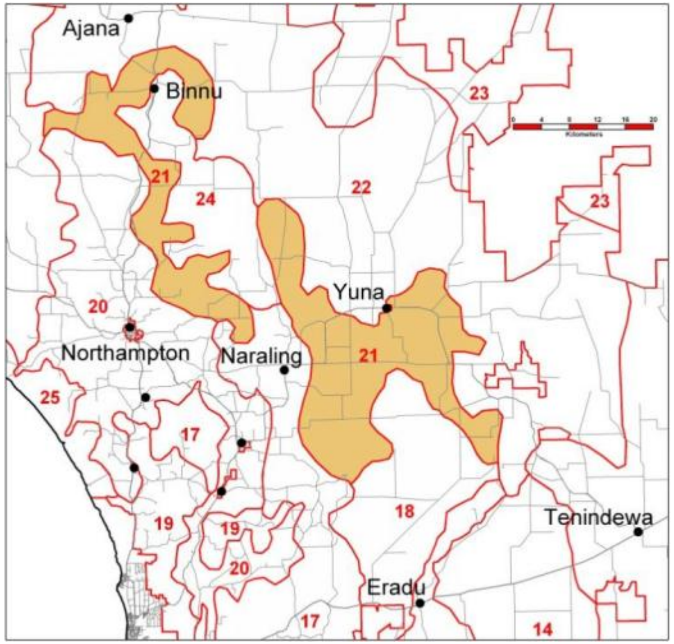
Northampton–Chapman ALA (99 000 ha)

Landform	This area is dominated by undulating terrain of valleys and hills with soils formed on crystalline rocks	**Gradients:** Mainly 1–5% with many steeper areas > 5%	**Remnant vegetation:** 13%
Soils	The dominant soils are Red shallow loamy duplexes (Northampton series) and Red loamy earths (Kojarena and Bowes series). Soils of lesser significance include Red sandy earths (Bootenal series) and Self-mulching cracking clays. Rock outcrops are fairly common.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 331 mm	Geographical range: 280–370 mm	
	Potential wheat production from all arable cleared land: 199 000 t	**Average potential yield:** 2.3 t/ha ranging up to > 2.5 t/ha on better soils	**Value:** $55 million/year
	While the combination of relatively high growing season rainfall and 'rich' loamy soils places this among the highest yielding country in the district (especially in seasons with above average rainfall), not all of the land is arable due to the hilly terrain. There are significant pockets of steep slopes and shallow stony soils unsuitable for cropping.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 3 mm/yr contributing to potential groundwater resource of around 1040 ML/yr (spread across 7710 ha).		
	Regional aquifer general licensing component:	Northampton/Gelena GWSA has no regional aquifers.	
	Groundwater resources are of varied reliability. Much of the water is in fractured rock aquifers from which yields are not particularly high, though probably higher than the recharge estimates above suggest. **The maximum irrigation volumes and values below are therefore more likely to represent the conservative irrigation volumes and values**. Current land use mapping shows over 100 ha of horticultural crops.		
Irrigated agriculture	**Horticulture potential:** Potential for future horticultural development is limited by groundwater resources. The loamy soils with their good moisture and nutrient retention are well suited to many horticultural crops. The sloping nature of the land is a limitation in some areas, especially for vegetable crops where the risk of soil erosion may be too great.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 1040 ML/yr*	80 ha* (< 1% of ALA)	$5 million/year*
	Conservative volume 260 ML/yr*	20 ha* (< 1% of ALA)	$1 million/year*
Property analysis	**Average property size:** 414 ha	**Average parcel (lot) size:** 67 ha	
	No. of properties: 240	**No. of parcels (lots):** 1380	**Average no. of parcels per property:** 6.7

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

* See note in red above.

4.3.21 Yuna – Binnu Sandplain ALA



Location: The Yuna – Binnu Sandplain ALA covers about 86 000 ha, comprising two discrete subareas—53 300 ha sitting mostly to the south and west of Yuna, and about 32 700 ha mainly to the south and west of Binnu. These two subareas have been combined due to similar rainfall and soils. They are separated by an area of land dominated by shallow gravelly soils (see Ogilvie Road South ALA – s 4.3.24). A further 100 000 ha of similar country extending south of the Yuna subarea have been mapped and described separately as it overlies some potential groundwater supplies (see Eradu West Sandplain ALA s 4.3.18).

Characteristics: These areas are dominated by broad expanses of undulating yellow sandplain with some areas of dune ridges. Currently they are used mainly for cropping (mostly wheat), though the grazing of livestock (mostly sheep with a few cattle) is also significant.

No significant irrigated agriculture exists. This area is typified by relatively large properties (mostly between 1000 and 5000 ha) comprised of relatively large parcels. Most of this area is cleared with only about 8 per cent of the remnant vegetation remaining. Much of this lies on the land least suited to agricultural production.

Agricultural importance: The combination of moderate growing season rainfall and 'good to fair quality' sands places this among the highest yielding sandplain country in the Region. In seasons with below average rainfall, the better sands tend to outperform the heavier soils of the Region but this advantage is not present in wetter years. Although the soils are highly suitable for horticulture, limited groundwater resources make sizeable irrigation developments unlikely.

Opportunities:

- moderate rainfall
- highly productive sands
- yields relatively well in below average rainfall years
- property and parcel sizes allow for larger scale agricultural developments.

Constraints:

- limited groundwater resources
- yields can be variable due to rainfall.

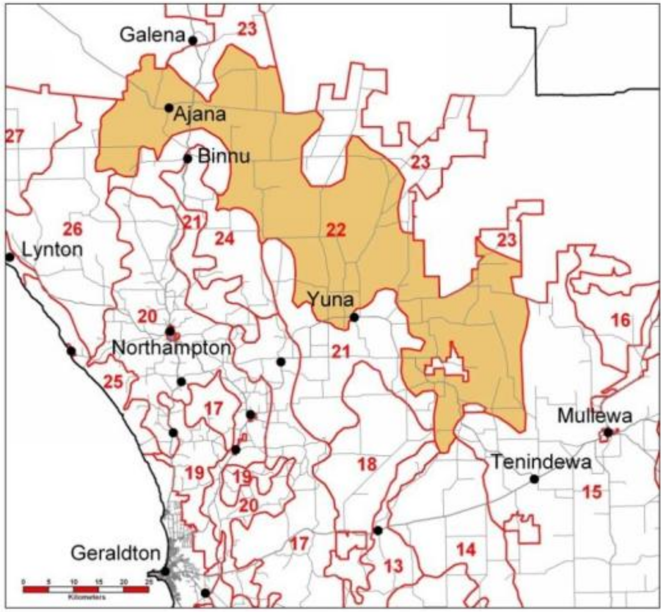
Yuna – Binnu Sandplain ALA (86 000 ha)

Landform	This area is dominated by broad expanses of yellow sandplain with areas of dune ridges	**Gradients:** Mainly 0–3%.	**Remnant vegetation:** 8%
Soils	Good quality Yellow deep sands, with some Yellow Sandy earths, (Eradu series) cover most of this area, along with fair quality Yellow deep sands (Eurangoa). Other soils include the poorer quality coarse yellow deep sands—generally on dunes (Indarra series); Grey deep sandy duplexes (Heaton series); and in the north, Red shallow loamy duplexes (Northampton series). Most of these soils are well drained.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 274 mm	Geographical range: 245–330 mm	
	Potential wheat production from all arable cleared land: 167 700 t	**Average potential yield:** 2.1 t/ha ranging up to > 2.5 t/ha on better soils	**Value:** $45 million/year
	The combination of moderate growing season rainfall and 'good to fair quality' sands places this among the highest yielding sandplain country in the Region. In seasons with below average rainfall, the better sands tend to outperform the heavier soils of the Region, but this advantage is not present in wetter years.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 6 mm/yr contributing to potential groundwater resource of around 125 ML/yr (spread across 980 ha).		
	Regional aquifer general licensing component: No Yuna/Eradu GWSA or Northampton/Gelena GWSA general licensing components relate to aquifers currently designated as being regional.		
	No significant groundwater has been identified beneath this ALA. Recharge estimates suggest groundwater resources are likely to be very limited.		
Irrigated agriculture	**Horticulture potential:** Although the soils are highly suitable for horticulture, limited groundwater resources make sizeable irrigation developments unlikely. Current knowledge suggest that groundwater supplies are small, scattered and often of questionable quality.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 125 ML/yr	10 ha (< 1% of ALA)	$0.6 million/year
	Conservative volume 30 ML/yr	3 ha (< 1% of ALA)	$0.2 million/year
Property analysis	**Average property size:** 2523 ha	**Average parcel (lot) size:** 318 ha	
	No. of properties: 38	**No. of parcels (lots):** 273	**Average no. of parcels per property:** 13.7

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.22 Ajana – East Yuna Sandplain ALA

Location: The Ajana – East Yuna Sandplain ALA covers about 208 000 ha extending in an arc from the west of Ajana to the vicinity of East Yuna.



Characteristics: This area is dominated by broad expanses of yellow sandplain with areas of dune ridges and red soil flats on relict alluvial plains. Currently it is mainly used for cropping wheat, as well as lupins and canola. There is also grazing of livestock (mostly sheep, some cattle and a few pigs). Integration of oil mallee plantations into the farming mix is also becoming more prominent. No significant irrigated agriculture exists. This area is typified by large properties with a variety of lot sizes. About 22 per cent of the area is uncleared.

Agricultural importance: Although this area is dominated by 'better quality' sandplain soils, the moderately low levels of rainfall results in lower yields than experienced on similar soils to the south and west in most seasons.

While the soils are highly suitable for horticulture in this area, limited groundwater resources make irrigation developments unlikely. Current knowledge suggests that groundwater supplies are small, scattered and often of questionable quality.

Opportunities:

- better quality soils
- property and parcel sizes allow for larger scale agricultural developments
- profitability for broadacre agriculture is maintained by using low input systems.

Constraints:

- limited groundwater resources
- traces of heavy metals may occur in the groundwater
- moderately low rainfall levels
- wildlife and vermin may reduce crop potential.

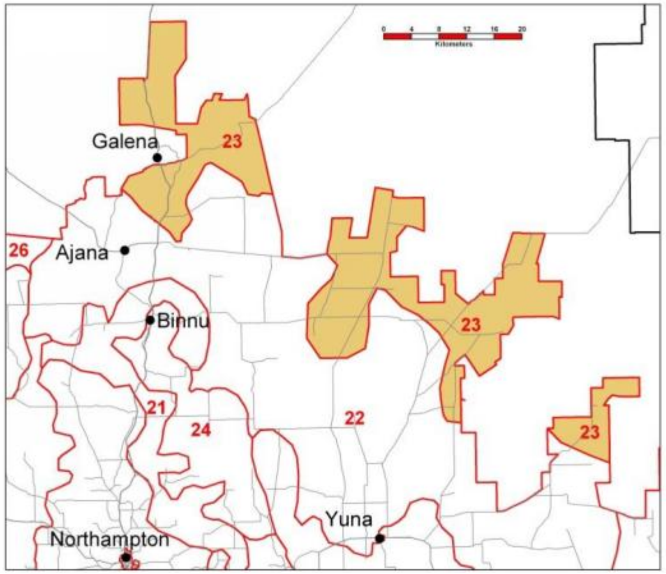
Ajana – Yuna East Sandplain ALA (208 000 ha)

Landform	This area is dominated by broad expanses of yellow sandplain with areas of dune ridges and red soil flats on relict alluvial plains	**Gradients:** Mainly 1–5%	**Remnant vegetation:** 22%
Soils	Good quality Yellow deep sands with some Yellow Sandy earths (Eradu series) cover much of this area, along with fair quality Yellow deep sands (Eurangoa) and Pale deep sands (Allanooka series). There are significant areas of the poorer quality coarse yellow deep sands (Indarra series). Depressions in the sandplain contain Red-brown hardpan shallow loams (Mindage and Wilroy series). Most of these soils are well drained.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 244 mm	Geographical range: 220–280 mm	
	Potential wheat production from all arable cleared land: 275 300 t	**Average potential yield:** 1.7 t/ha	**Value:** $75 million/year
	Although this area is dominated by 'better quality' sandplain soils, lower rainfall results in lower yields than experienced on similar soils to the south and west in most seasons.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 5 mm/yr contributing to potential groundwater resource of around 200 ML/yr (spread across 1150 ha).		
	Regional aquifer general licensing component:	No Yuna/Eradu GWSA or Northampton/Gelena GWSA general licensing components relate to aquifers currently designated as being regional.	
	Current knowledge and recharge estimates suggest that groundwater supplies are small, scattered and often of questionable quality.		
Irrigated agriculture	**Horticulture potential:** Although the soils are highly suitable for horticulture, limited groundwater resources make sizeable irrigation developments unlikely. Current knowledge suggest that groundwater supplies are small, scattered and often of questionable quality.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 200 ML/yr	15 ha (< 1% of ALA)	$1 million/year
	Conservative volume 50 ML/yr	4 ha (< 1% of ALA)	$0.3 million/year
Property analysis	**Average property size:** 2121 ha	**Average parcel (lot) size:** 366 ha	
	No. of properties: 88	**No. of parcels (lots):** 523	**Average no. of parcels per property:** 7.1

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.23 Galena–Wandana ALA

Location: The Galena–Wandana ALA covers about 76 700 ha, comprising three small areas sitting on the northern fringe of the agricultural districts. The north-western area is about 28 000 ha, straddling the Murchison River to the east of the Kalbarri National Park; the central area is about 42 000 ha, sitting to the north-west of the Wandana Nature Reserve. The smaller, south-eastern portion is about 6000 ha and is bordered by the Wandana Nature Reserve on three sides.



Characteristics: This area comprises a mix of yellow sandplain and dune ridges, red soil flats on relict alluvial plains and undulating granitic country. Most of the land has flat to gentle slopes. Currently it is used for grazing sheep (and a few cattle) and cropping wheat, as well as lupins, canola and very limited areas of chickpeas where soil types are suitable. Perennial pastures are increasingly important in grazing systems. Integration of oil mallee plantations into the farming mix on poorer performing soils is also becoming more prominent.

No significant irrigated agriculture exists. Twenty–two per cent of this area remains uncleared and a sizeable area is listed as flora conservation. Property and parcel sizes are typically very large.

Agricultural importance: The nature and productivity of the soils is varied. Though there are considerable areas of 'good quality' soils, the relatively low rainfall limits yields in most seasons.

While some soils are highly suitable for horticulture, limited groundwater resources make irrigation developments unlikely. Current knowledge suggests that groundwater supplies are small, scattered and often of questionable quality.

Opportunities:

- good quality soils
- large property sizes
- profitability for broadacre agriculture is maintained by using low-input, low-risk systems.

Constraints:

- limited groundwater resources
- low rainfall
- traces of heavy metals may occur in the groundwater
- wildlife and vermin may reduce crop potential.

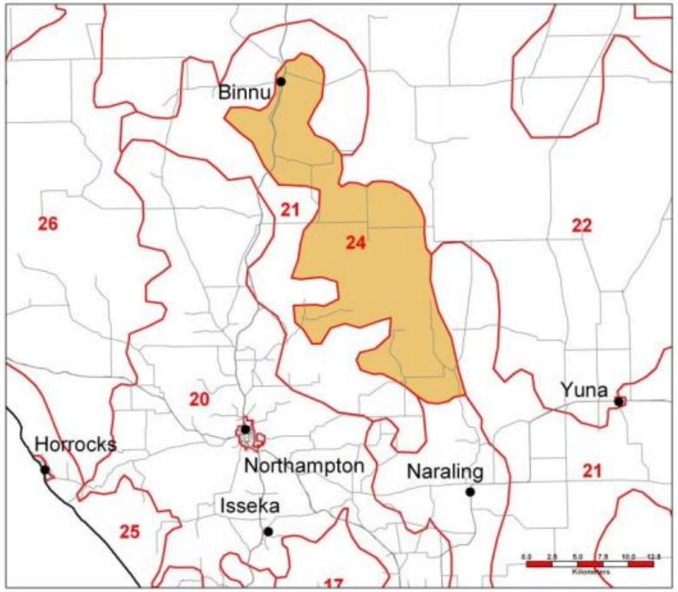
Galena–Wandana ALA (76 700 ha)

Landform	This area is a mix of yellow sandplain, red soil flats on relict alluvial plains and undulating granitic country. Most of the land has flat to gentle slopes	**Gradients:** Dominantly 1–3%	**Remnant vegetation:** 22%
Soils	The sandplains have Yellow deep sands and Yellow Sandy earths of variable quality (Eradu, Indarra, Eurangoa and Ajana series). Relict alluvial plains have Red-brown hardpan shallow loams and Red shallow loams (Mindage and Wilroy series) with Red shallow loamy duplexes (Northampton series) also found on sloping granitic terrain.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 222 mm	Geographical range: 185–250 mm	
	Potential wheat production from all arable cleared land: 81 800 t	**Average potential yield:** 1.4 t/ha; yields range from < 1 t/ha on poorer soils up to 2 t/ha on better sandplain areas.	**Value:** $20 million/year
	The nature and productivity of the soils is varied. Though there are considerable areas of 'good quality' soils, the relatively low rainfall limits yields in most seasons.		
Groundwater resources	**Estimated recharge to fresh aquifers:** No significant recharge of fresh aquifers.		
	Regional aquifer general licensing component:	No Yuna/Eradu GWSA or Northampton/Gelena GWSA general licensing components relate to aquifers currently designated as being regional.	
	Current knowledge and recharge estimates suggest that groundwater supplies are small, scattered and often of questionable quality.		
Irrigated agriculture	**Horticulture potential:** Although some soils are highly suitable for horticulture, limited groundwater resources make irrigation developments unlikely.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 0 ML/yr	0 ha (0% of ALA)	$0
	Conservative volume 0 ML/yr	0 ha (0% of ALA)	$0
Property analysis	**Average property size:** 6913 ha	**Average parcel (lot) size:** 620 ha	
	No. of properties: 25	**No. of parcels (lots):** 208	**Average no. of parcels per property:** 10.8

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.24 Ogilvie Road South ALA

Location: The Ogilvie Road South ALA covers about 29 300 ha and forms a strip of land about 35 km long and 10 km wide, extending south-east from Binnu to the north of Naraling.



Characteristics: This area is dominated by sandplain dissected by numerous drainage lines. Most of the land appears flat to very gently sloping with low gravel ridges. Gravels and stony soils are dominant with areas of deep yellow sands. Currently it is used mainly for cropping wheat (and some lupins) and grazing sheep (and some cattle). No significant irrigated agriculture exists. This area has large properties with varying parcel sizes. About 13 per cent of the area remains uncleared.

Agricultural importance: The patches of ‘good quality’ sandplain (almost one-third of the area) have the potential to yield more than 2 t/ha. The predominance of shallow and stony soils results in considerably lower overall yields than are achieved from the surrounding areas.

The dominance of shallow, stony soils and limited groundwater resources make irrigation developments unlikely. There are some patches of ‘good quality’ sandplain that could be used for small-scale developments if suitable local groundwater supplies were identified.

Opportunities:

- some patches of good quality sandplain.

Constraints:

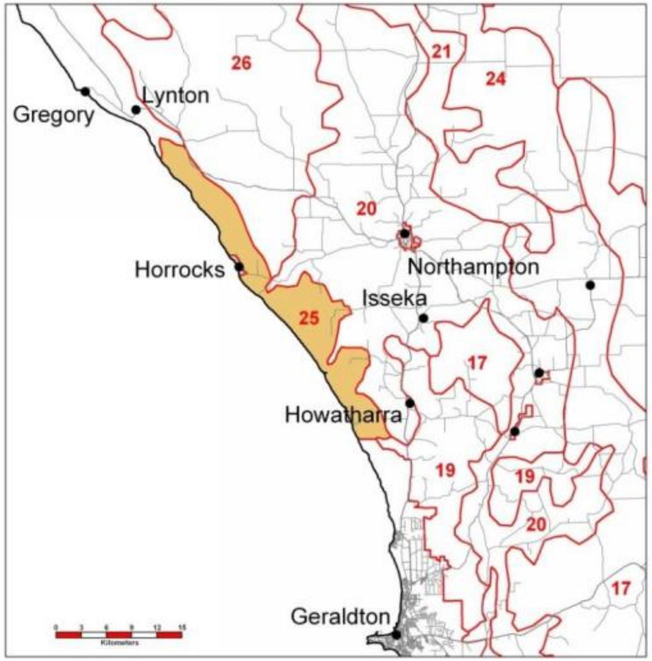
- shallow and stony soils are yield constraints
- salinity along drainage lines
- limited groundwater supplies.

Ogilvie Road South ALA (29 300 ha)

Landform	This area is dominated by dissected sandplain. Most of the land is flat to very gently inclined with areas of gentle slopes.	**Gradients:** Mainly 1–3% with areas of gentle slopes 3–5%	**Remnant vegetation:** 13%
Soils	Shallow gravels (Rennie and Bluewell series) dominate but there are also significant patches of Yellow deep sands of varying quality (Eradu, Indarra and Eurangoa series) and deep and shallow sandy duplex soils (Moresby series). The valley floors have Saline wet soils.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 270 mm	Geographical range: 255–305 mm	
	Potential wheat production from all arable cleared land: 35 900 t	**Average potential yield:** 1.4 t/ha. Yield ranges from > 2 t/ha on yellow sandplain soils to < 0.5 t/ha on shallow gravels and salt-affected land.	**Value:** $10 million/year
	The predominance of shallow and stony soils results in considerably lower than average potential yields than are achieved from the surrounding areas.		
Groundwater resources	**Estimated recharge to fresh aquifers:** No significant recharge of fresh aquifers due to groundwater salinity.		
	Regional aquifer general licensing component: Northampton/Gelena GWSA has no regional aquifers.		
	Current knowledge suggests that local groundwater supplies are small, scattered and often of poor quality.		
Irrigated agriculture	**Horticulture potential:** Shallow and stony soils and limited groundwater resources make large-scale irrigation developments unlikely. There are some patches of 'good quality' sandplain that could be used for small scale developments if suitable local groundwater supplies were identified.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 0 ML/yr	0 ha (0% of ALA)	$0
	Conservative volume 0 ML/yr	0 ha (0% of ALA)	$0
Property analysis	**Average property size:** 1655 ha	**Average parcel (lot) size:** 218 ha	
	No. of properties: 15	**No. of parcels (lots):** 121	**Average no. of parcels per property:** 8.7

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.25 Horrocks Coast ALA



Location: The Horrocks Coast ALA covers about 16 300 ha running in a strip along the coast between Lynton to Oakajee.

Characteristics: Deep and shallow sands dominate here, covering a mixture of sandplain, broad dunes and hills with small areas of low breakaways and eroded slopes. Currently this area is used mainly for cropping. The grazing of livestock (mostly sheep and some cattle) is also significant, with smaller areas of pasture for hay production. No significant irrigated agriculture exists. Property and parcel sizes are moderately small. More than one-third of the area (37%) is remnant vegetation, mainly on the steeper slopes and other areas unsuited for agriculture.

Agricultural importance: The nature and productivity of the soils is quite varied. Though there are considerable areas of ‘poorer’ soils, the relatively high rainfall maintains reasonable yields.

Large-scale irrigation developments are unlikely due to limited groundwater resources. There is some potential that supplies in the Carnarvon Basin sediments may be better than current knowledge suggests, but further investigations are required.

Opportunities:

- water supplies may be better than current knowledge suggests—further research is required
- high rainfall.

Constraints:

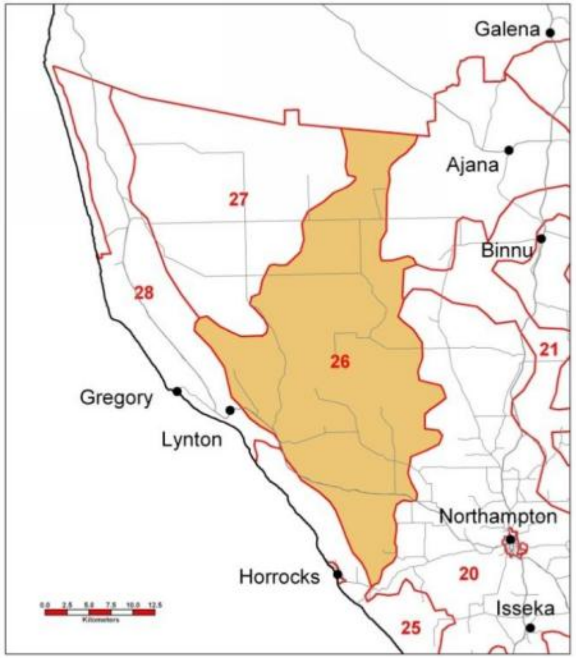
- groundwater resources are unproven but unlikely to be significant
- poorer soils—careful management of irrigation and fertilisers would be required to maintain production.

Horrocks Coast ALA (16 300 ha)

Landform	This area has a mix of sandplain, hills and broad dunes	**Gradients:** Mainly 1–10% with some steeper slopes > 10%	**Remnant vegetation:** 37%
Soils	Yellow deep sand is widespread with smaller areas of shallow yellow sands (Teakle series). Coastal dunes are dominated by Calcareous deep and shallow sands (Bookara, Quindalup and Southgate series) with areas of limestone outcrop. Shallow gravels (Rennie and Bluewell series) and sandy duplex soils (Heaton series) are also found on breakaways and hill slopes away from the coast.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 341 mm	Geographical range: 320–365 mm	
	Potential wheat production from all arable cleared land: 18 100 t	**Average potential yield:** 1.8 t/ha	**Value:** $5 million/year
	The nature and productivity of the soils is quite varied. Though there are considerable areas of ‘poorer’ soils, the relatively high rainfall maintains reasonable yields.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 8 mm/yr contributing to potential groundwater resource of around 820 ML/yr (spread across 5260 ha).		
	Regional aquifer general licensing component:	No Kalbarri/Eurardy GWSA or Northampton/Gelena GWSA general licensing components relate to aquifers currently designated as being regional.	
	Current knowledge and recharge estimates suggest that groundwater supplies are small, scattered and often of questionable quality. Further investigation of Carnarvon Basin aquifers in the north and local Tamala aquifers in the south may reveal some suitable groundwater supplies.		
Irrigated agriculture	**Horticulture potential:** Further investigations are required. There are areas of better quality sandy soils that would be suitable for horticultural development if groundwater resources are identified.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 830 ML/yr	60 ha (<1% of ALA)	$4 million/year
	Conservative volume 210 ML/yr	15 ha (<1% of ALA)	$1 million/year
Property analysis	**Average property size:** 1312 ha	**Average parcel (lot) size:** 301 ha	
	No. of properties: 15	**No. of parcels (lots):** 49	**Average no. of parcels per property:** 10.3

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.26 Hutt River ALA



Location: The Hutt River ALA covers about 65 200 ha. It lies inland from the dunes of Horrocks Coast and Gregory ALAs and stretches northward to the Kalbarri National Park, between the Ajana and Christmas Hill ALAs.

Characteristics: This area is dominated by a level to gently undulating sandplain dissected by the drainage channels of the Hutt River and its tributaries. These are combined with areas of low hills, gravel ridges and breakaways. Soils are varied but dominated by deep sands. Currently the main activity is cropping wheat in rotation with lupins and canola. Small areas of floriculture also exist. Grazing of sheep and cattle is common and perennial pastures are increasingly important in grazing systems to improve productivity on poorer performing sands. Interest in the integration of oil mallee plantations into the farming mix on poorer soils is also becoming more prominent. Moderate property sizes are dominant with moderately small parcels. About 22 per cent of this area remains uncleared, including steeper slopes, drainage lines and other areas unsuitable for agriculture.

Agricultural importance: While rainfall is moderately high, the variable nature of the sandy soils results in yields that are generally lower than those achieved from ‘better quality’ sandplain to the east.

Groundwater resources of the underlying Carnarvon Basin aquifers warrant further investigation. There is some potential of small to moderate water supplies. While many soils are of poorer quality, there are significant areas of ‘fair quality’ yellow deep sands suitable for horticultural crops.

Opportunities:

- moderately high rainfall
- niche opportunities for horticulture in some areas
- water supplies may be better than current knowledge suggests—further investigation is warranted.

Constraints:

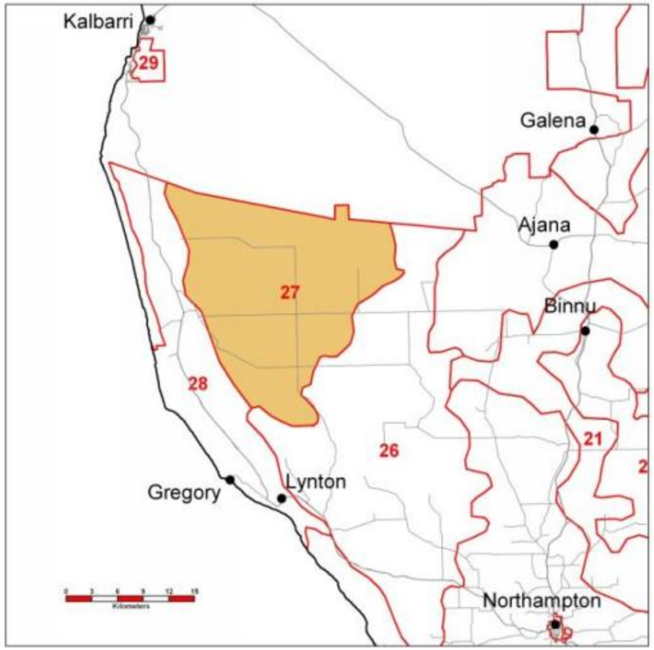
- groundwater resources unproven
- areas of poorer soil quality—careful management of irrigation and fertilisers would be required to maintain production
- wind erosion risk.

Hutt River ALA (65 200 ha)

Landform	This area is dominated by a level to gently undulating sandplain, dissected by the drainage of the Hutt River and its tributaries.	**Gradients:** Mostly 1–3% with some steeper land at 3–10%	**Remnant vegetation:** 21%
Soils	The most common soils are ‘fair to poor’ quality Pale deep sands (Allanooka and Balline series) with significant areas of ‘fair quality’ Yellow deep sands (Eurangoa and Teakle series) and poorer yellow sands on some sand dunes (Indarra series). Many of these have both poor water-holding capacity and fertility. Shallow loamy gravels (Rennie series) and deep and shallow sandy gravels (Nabbeja series) are also common, with smaller areas of poorly drained red shallow sandy duplex soils.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 312 mm	Geographical range: 270–345 mm	
	Potential wheat production from all arable cleared land: 85 800 t	**Average potential yield:** 1.7 t/ha ranges from < 1.5 t/ha on poorer sands to > 2 t/ha on better soils	**Value:** $25 million/year
	While rainfall is moderately high, the variable nature of the sandy soils results in lower yields than achieved from ‘better quality’ sandplain to the east.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 20 mm/yr contributing to potential groundwater resource of around 12 800 ML/yr (spread across 55 160 ha).		
	Regional aquifer general licensing component:	No Kalbarri/Eurardy GWSA general licensing components relate to aquifers currently designated as being regional.	
	Groundwater resources require further investigation. The general licensing components of underlying aquifers (designated as local in this report) suggest the above recharge estimate may provide a reasonable indication of small to moderate volumes of groundwater.		
Irrigated agriculture	**Horticulture potential:** There are sizeable areas of the better sandy soils that would be suitable for horticultural development but further investigations are required to confirm groundwater. Soils are freely drained and easy to work but in many of the soils the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these sands.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 12 800 ML/yr	970 ha (2% of ALA)	$65 million/year
	Conservative volume 3200 ML/yr	250 ha (<1% of ALA)	$17 million/year
Property analysis	**Average property size:** 1646 ha	**Average parcel (lot) size:** 289 ha	
	No. of properties: 39	**No. of parcels (lots):** 221	**Average no. of parcels per property:** 6.9

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.27 Christmas Hill ALA



Location: The Christmas Hill ALA covers about 43 700 ha and forms a block extending south from the edge of Kalbarri National Park.

Characteristics: This area is dominated by broad expanses of flat to gently sloping sandplain mainly with pale and yellow deep sands of fair to poor quality. The sandplain is interrupted in areas by low rises and stony ridges dominated by stony sands and rock fragments. Currently the dominant use is for cropping wheat in rotation with lupins and canola. Grazing of sheep and cattle is common and perennial pastures are becoming increasingly important in grazing systems to improve productivity on poorer performing sands. Interest in the integration of oil mallee plantations into the farming mix on poorer soils is also becoming more prominent. Property sizes are average for the district, with very large parcel sizes dominant. About 56 per cent of this area remains uncleared, often in large areas of poor sandy, leached soils.

Agricultural importance: While rainfall is moderately high, the poorer nature of the sandy soils results in yields that are lower than those achieved from 'better quality' sandplain to the east.

Groundwater resources of the underlying Carnarvon Basin aquifers warrant further investigation. There is some potential of small to moderate water supplies. While the soils are dominantly poor quality, there are some pockets of 'fair quality' yellow deep sands suitable for horticultural crops.

Opportunities:

- large property sizes
- moderately high rainfall
- niche opportunities for horticulture in some areas
- water supplies here may be better than current knowledge suggests—further investigation is warranted.

Constraints:

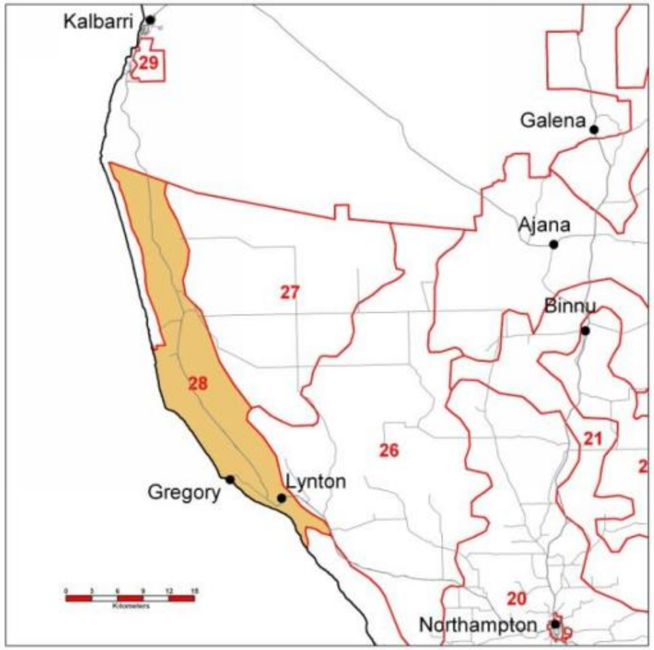
- groundwater resources unproven
- areas of poorer soil quality—careful management of irrigation and fertilisers would be required to maintain production
- wind erosion risk
- native fauna control and vermin may be problematic.

Christmas Hill ALA (43 700 ha)

Landform	This area is dominated by broad expanses of sandplain. Most of the land is flat to gently inclined but there are significant areas of slightly steeper land.	**Gradients:** Mostly 1–5% with some steeper land at 5–10%	**Remnant vegetation:** 56%
Soils	The dominant soils are 'poor' quality Pale deep sands (mainly Balline series) with some associated Gravelly pale deep and shallow sands (Bluewell series). Many of these have poor water-holding capacity and fertility. There are significant pockets of 'fair quality' Yellow deep sands (Eurangoa series). Shallow gravels and Stony soils are also common.		
Broadacre agriculture	**Growing season rainfall over past decade:** Average: 301 mm	Geographical range: 280–320 mm	
	Potential wheat production from all arable cleared land: 22 500 t	**Average potential yield:** 1.2 t/ha	**Value:** $6 million/year
	While rainfall is moderately high, the poorer sandy soils results in yields that are lower than those achieved from 'better quality' sandplain to the east.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 13 mm/yr contributing to potential groundwater resource of about 5410 ML/yr (spread across 20 600 ha).		
	Regional aquifer general licensing component:	No Kalbarri/Eurardy GWSA general licensing components relate to aquifers currently designated as being regional.	
	Groundwater resources require further investigation. The general licensing components of underlying aquifers (designated as local in this report) suggest the above recharge estimate may provide a reasonable indication of small to moderate volumes of groundwater.		
Irrigated agriculture	**Horticulture potential:** There are pockets 'fair quality' sandy soils that would be suitable for horticultural development but further investigations are required to confirm groundwater. Soils are freely drained and easy to work but in many of the soils, the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these sands.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 5410 ML/yr	410 ha (1% of ALA)	$30 million/year
	Conservative volume 1350 ML/yr	100 ha (< 1% of ALA)	$7 million/year
Property analysis	**Average property size:** 1846 ha	**Average parcel (lot) size:** 964 ha	
	No. of properties: 18	**No. of parcels (lots):** 41	**Average no. of parcels per property:** 1.6

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.28 Gregory ALA



Location: Gregory ALA covers about 25 800 ha, forming a strip of land along the coast extending south from the edge of Kalbarri National Park to Port Gregory and Lynton.

Characteristics: This area is dominated by rises and low hills of relict coastal dunes and some limestone outcrop. These combine with areas of more recent coastal dunes and a narrow alluvial plain behind the dunes that are breached by the Hutt River at Port Gregory. A feature of the area is Hutt Lagoon.

Grazing of sheep is common, along with areas of broadacre cropping dominated by wheat. Perennial pastures are increasingly important in grazing systems to improve productivity on poorer performing sands. The area also features egg production and a large aquaculture development (beta carotene harvesting at Hutt Lagoon). About 37 per cent of this area remains uncleared, including large areas of the ‘poorer quality’ coastal sands, steeper slopes and other areas unsuitable for agriculture.

Agricultural importance: While rainfall is relatively high, the ‘poorer quality’ sandy soils result in wheat yields that are generally considerably lower than those achieved from adjoining areas of loamy and clayey soils, and more comparable with yields from lower rainfall areas inland.

Groundwater resources of the underlying Carnarvon Basin aquifers warrant further investigation. There is some potential of small to moderate water supplies. While the soils are dominantly poor quality there are significant pockets of ‘fair quality’ yellow deep sands suitable for horticultural crops. Niche opportunities such as egg production and aquaculture are currently significant.

Opportunities:

- large property sizes
- moderately high rainfall
- may be niche opportunities for horticulture in some areas
- water supplies here may be better than current knowledge suggests—further investigation is warranted.

Constraints:

- dominated by poor quality sands
- wind erosion risk
- over one-third remains uncleared
- groundwater resources unproven.

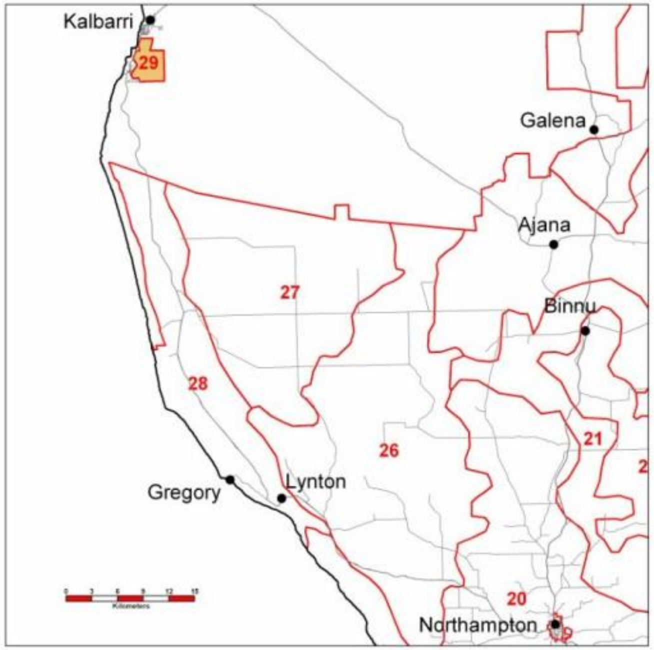
Gregory ALA (25 800 ha)

Landform	Mainly rises and low hills with relict coastal dunes and some limestone outcrop. Also areas of more recent coastal dunes and minor areas of river beds and a narrow alluvial plain.	**Gradients:** Mainly < 10%	**Remnant vegetation:** 37%
Soils	The dominant soils here are the Calcareous deep and shallow sands of the coastal dunes (Bookara, Quindalup and Southgate series). Extensive areas of Yellow deep and shallow sands are also found (Teakle series). The Salt lake soil of Hutt Lagoon is a prominent feature.		
Broadacre agriculture	**Growing season rainfall over past decade:**	Average: 307 mm	Geographical range: 290–320 mm
	Potential wheat production from all arable cleared land: 17 000 t	**Average potential yield:** 1.0 t/ha	**Value:** $5 million/year
	While rainfall is relatively high, the 'poorer quality' sandy soils result in wheat yields that are considerably lower than those achieved from adjoining areas.		
Groundwater resources	**Estimated recharge to fresh aquifers:** 10 mm/yr contributing to potential groundwater resource of about 2480 ML/yr (spread across 14 510 ha).		
	Regional aquifer general licensing component:	No Kalbarri/Eurardy GWSA general licensing components relate to aquifers currently designated as being regional.	
	Groundwater resources require further investigation. The general licensing components of underlying aquifers (designated as local in this report) suggest the above recharge estimate may provide a reasonable indication of small volumes of groundwater.		
Irrigated agriculture	**Horticulture potential:** There are some areas of 'fair quality' sandy soils that would be suitable for horticultural development but further investigations are required to confirm groundwater. Soils are freely drained and easy to work but in many of the soils the low clay content limits moisture and nutrient retention. Careful management of irrigation and fertilisers would be required to maintain production on these sands.		
	Potential water for irrigated agriculture:	**Area of mix of enterprises irrigated by potential water:**	**Potential value of irrigated crops:**
	Maximum volume 2480 ML/yr	190 ha (1% of ALA)	$13 million/year
	Conservative volume 620 ML/yr	45 ha (< 1% of ALA)	$3 million/year
Property analysis	**Average property size:** 1714 ha	**Average parcel (lot) size:** 216 ha	
	No. of properties: 15	**No. of parcels (lots):** 81	**Average no. of parcels per property:** 10.9

Note: The data presented in this table are indicative only and should not be used without first reading the text in s 4.3. The regional aquifer general licensing components will not necessarily be available for licensing to agricultural users. Nor are they exclusively for the use of licensees located within the ALA. Recharge estimates do not translate directly into water availability. Crop yields do not represent actual production. Dollar values do not include the full contribution of agriculture activities to the economy. Yields and dollar values should not be used as a guide for enterprise budgeting.

4.3.29 Kalbarri ALA

Location: Kalbarri ALA covers about 1400 ha in a single block south of Kalbarri town site and surrounded by national park.



Characteristics: This area is dominated by level to gently undulating sandplain and sandplain remnants dissected by the steep and rocky slopes surrounding Wittecarra Gully. The sandplain areas mainly feature deep and shallow pale sands with sandy gravel and yellow deep sands. Steeper slopes of the gully generally feature shallow and rocky soils and rock outcropping. The land is dominantly vegetated with just 13 per cent cleared.

Agricultural importance: Lower rainfall levels and the shallow and poor quality sandy soils tend to result in very low yields. Most of this area is unused and no significant agricultural activity exists. Adjacent land is subdivided and developed for rural residential living.

Opportunities:

- short distance to labour supply, infrastructure and transport.

Constraints:

- limited groundwater resources
- unlikely to be developed for broadacre agriculture
- wind erosion hazard
- many of the soils are low-yielding or non-arable
- may be environmental considerations
- native fauna control and vermin may be problematic
- steep slopes in some areas
- potential for conflicts with ‘rural life-stylers’.

5. HQAL in the Geraldton planning region

5.1 Grouping ALAs

The final step in the process of identifying the high quality agricultural land was to place the ALAs into groups according to their relative agricultural importance (Table 5.1, Figure 5.1).

Each ALA was firstly ranked separately for its potential value for broadacre and irrigated agriculture. Table 5.3 presents these rankings along with supporting data showing the potential value of agriculture. While Table 5.3 allows for a quick comparison between ALAs, it is important to remember that the dollar values are estimates only. Table 5.4 provides similar data for the two areas of UCL. The broadacre ranking and potential value have been excluded from this table as these UCLs are unlikely to be released for this use.

In grouping the ALAs, the existing value of broadacre agriculture was weighed up against the potential value of production if their groundwater resources were to be used for irrigated agriculture. Areas with the greatest versatility are those that combine high yielding soils and good rainfall (that is, conditions highly ranked for broadacre agriculture) with sizeable groundwater resources.

Those areas with access to the large groundwater resources have the potential to generate the most significant agricultural income. However, as discussed previously, access to groundwater is far from guaranteed. Barring a continued decline in rainfall, the value of broadacre production is likely to continue regardless of access to groundwater. The groups developed were:

- **Group A** – greatest versatility (largest water resource; high rainfall and yields)
- **Group B** – high versatility (large to moderate water resource; high rainfall; moderate to high yields)
- **Groups C** – moderate versatility (high crop yields; some areas with horticulture potential)
- **Group D** – moderate versatility (moderate or potential water resources; good rainfall; moderate to low yields)
- **Group E** – lower versatility (potential to insignificant water resources; variable rainfall; moderate to low yields)
- **Group F** – low versatility (limited to insignificant water resources; low rainfall and yields)
- **Group G** – limited agricultural potential.
- **UCL** – Unallocated Crown Land

Table 5.1 shows the placement of the ALAs into one of the groups above on the basis of their combined rankings for irrigated and broadacre agriculture. The two areas of UCL with access to groundwater are also included. Figure 5.1 shows the distribution of these ALA/UCL groupings across the Region. The colour-coding in Tables 5.1 and 5.2 matches that in Figure 5.1.

Table 5.1 **Grouping of ALAs**

	Irrigated agriculture ranking				
Broadacre agriculture ranking	**1. Largest water resource for irrigation**	**2. Moderate water resource for irrigation**	**3. Potential water resource for irrigation**	**4. Limited water resource for irrigation**	**5. Insignificant water resource for irrigation**
1. Highest yielding land for broadacre agriculture	**Group A:** Irwin Valley, Greenough Flats	**Group A**	**Group C**: Eradu East Sandplain	**Group C**: Eradu West Sandplain, Northampton-Chapman	**Group C**: Yuna – Binnu Sandplain
2. Higher yields	**Group A**	**Group B**: Casuarina Sandplain	**Group C**	**Group C**	**Group E**
3. Moderately high yields	**Group B**: Lefroy	**Group B**: Mt Horner	**Group D**: Hutt River	**Group E**: Naraling Hills, Moresby Range	**Group E**: Allanooka, Ajana – Yuna East Sandplain
4. Moderately low yields	**Group B**: Drummonds Crossing	**Group D**	**Group D**: Ellendale – Eradu Valley	**Group E**	**Group E**: Mullewa, Galena–Wandana, Horrocks Coast
5. Lower yields	**Group D**	**Group D**: Geraldton–Dongara	**Group E**: South Dongara	**Group F**: Christmas Hill	**Group F**: Pindar, Ogilvie Road South
6. Lowest yielding land for broadacre agriculture	**Group D**	**Group D**	**Group E**	**Group F**: Gregory	**Group G**: Knobby Head, Kalbarri
Unallocated Crown Land	**UCL**: Arrowsmith River, Tompkins Road				

Table 5.2 **List of ALAs colour-coded to match grouping in Table 5.1 and Figure 5.1**

No.	Name	No.	Name	No.	Name
1	Knobby Head	**13**	Ellendale – Eradu Valley	**23**	Galena–Wandana
3	Drummonds Crossing	**14**	Eradu East Sandplain	**24**	Ogilvie Road South
5	Lefroy	**15**	Mullewa	**25**	Horrocks Coast
6	South Dongara	**16**	Pindar	**26**	Hutt River
7	Irwin Valley	**17**	Naraling Hills	**27**	Christmas Hill
8	Mt Horner	**18**	Eradu West Sandplain	**28**	Gregory
9	Allanooka	**19**	Moresby Range	**29**	Kalbarri
10	Geraldton–Dongara	**20**	Northampton–Chapman	**2**	Arrowsmith River
11	Greenough Flats	**21**	Yuna – Binnu Sandplain	**4**	Tompkins Road
12	Casuarina Sandplain	**22**	Ajana – East Yuna Sandplain		

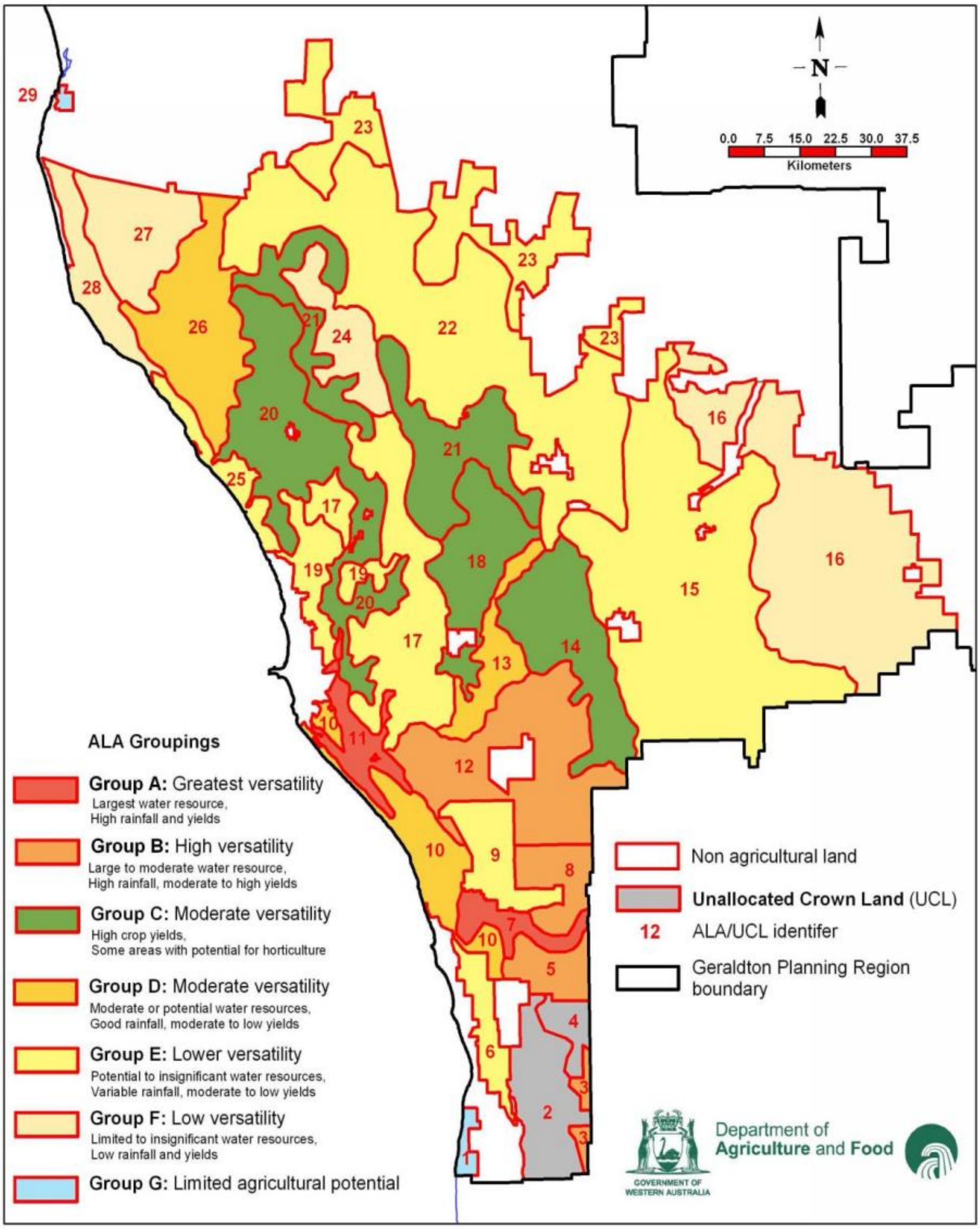


Figure 5.1 **Grouping of ALAs in the Geraldton planning region**

The ALAs in Group A have the greatest versatility, combining high yielding soils and good rainfall with sizeable groundwater resources. Not only is production higher in these areas, but also degradation risks tend to be lower. Environmental impacts associated with farming land of higher capability tend to be easier to manage than in areas with less favourable soil, landscape and climatic conditions.

ALAs with moderate to large water supplies that produce more moderate broadacre yields still have high versatility and were placed into Group B. While the soil types most suited to broadacre agriculture also tend to be the most productive under irrigation, soil productivity is less significant to irrigation enterprises. Horticultural crops tend to have a significantly higher value per hectare than broadacre crops making inputs, such as fertiliser, more cost-effective.

ALAs with high broadacre yields but smaller or unproven water supplies are considered to have moderate versatility and were placed into Group C. While the opportunities for irrigation developments on these areas are more limited, broadacre production is likely to remain significant contributors to the agricultural economy.

Also considered to have moderate versatility are ALAs that produce relatively low broadacre yields, but are underlain by groundwater resources that provide some potential for irrigated developments. These areas have been placed into Group D. They contain significant areas of poorer soils, such as pale deep sands, on which it can be difficult to achieve maximum production even with increased inputs. The development of irrigated agriculture on these soils of lower capability involves greater environmental risks, higher levels of management and greater costs.

The ALAs placed into Group E have relatively low versatility. Broadacre yields are lower due to rainfall or soil types while water supplies are unproven or limited. Most of these ALAs still make a significant contribution to the agricultural economy of the Region due to their size. In fact, they represent about 40 per cent of the potential broadacre production.

The ALAs placed into Group F are considered to have lowest versatility. They predominantly produce low broadacre yields (due to rainfall or soils) and the water resources for irrigation are limited.

The two ALAs placed into Group G remain largely uncleared and there is limited potential for agricultural development as groundwater resources are restricted and the soils are generally low yielding.

Most of the data relating to broadacre agriculture in Table 5.3 is as presented for the individual ALAs in s 4.3.1 to s 4.3.29.[80] The data relating to the value of irrigated agriculture in Tables 5.3 and 5.4 is a modification of that presented in s 4.3.1 to 4.3.29. See Appendix H for further explanation.

[80] Values above $15 million have been rounded to the nearest $5 million in Table 5.3.

Table 5.3 **Summary of ALA rankings, groupings and potential value of agriculture**

ALA			Agriculture type ranking		ALA area	Potential value of agriculture (combined)			Potential value of irrigated agriculture		Potential value of broadacre agriculture		Average		
No.	**Name**	**Group**	**Irrig-ated**	**Broad-acre**	**Total ha**	**Cleared %**	**$m**	**$'000/ha**	**$m**	**$'000/ha**	**$m**	**$'000/ha**	**Relative wheat yield t/ha**	**Growing season rain mm**	**Soil product-ivity***
7	Irwin Valley	A	1	1	15 000	90	215	14.3	207	13.8	8	0.51	2.1	339	Mod. high
11	Greenough Flats		1	1	19 700	94	71	3.6	59	3.0	12	0.60	2.4	334	High
5	Lefroy	B	1	3	16 900	90	189	11.2	182	10.8	7	0.43	1.8	324	Mod.
3	Drummonds Crossing		1	4	5 200	75	171	32.6	170	32.3	2	0.34	1.7	322	Mod. low
12	Casuarina Sandplain		2	2	86 400	93	70	0.8	30	0.3	41	0.47	1.9	311	Mod.
8	Mt Horner		2	3	20 700	91	53	2.6	44	2.1	9	0.44	1.8	331	Mod.
14	Eradu East Sandplain	C	3	1	60 000	95	48	0.8	13	0.2	34	0.57	2.3	262	High
20	Northampton–Chapman		4	1	99 000	87	59	0.6	7	< 0.1	53	0.53	2.3	331	High
18	Eradu West Sandplain		4	1	45 300	93	31	0.7	4	0.1	27	0.59	2.4	284	High
21	Yuna – Binnu Sandplain		5	1	86 000	92	45	0.5	< 1	< 0.1	43	0.52	2.1	274	High
10	Geraldton–Dongara	D	2	5	38 700	62	47	1.2	38	1.0	9	0.23	1.4	338	Mod. low
26	Hutt River		3	3	65 200	79	64	1.0	42	0.6	23	0.35	1.7	312	Mod.
13	Ellendale – Eradu Valley		3	4	24 000	78	18	0.7	10	0.4	8	0.33	1.6	296	Mod.
6	South Dongara	E	3	5	17 000	35	9	0.5	7	0.4	2	0.12	1.3	333	Low
17	Naraling Hills		4	3	85 000	83	41	0.5	9	0.1	32	0.38	1.7	327	Mod. high
19	Moresby Range		4	3	25 600	69	12	0.5	3	0.1	9	0.34	1.8	344	Mod. high
22	Ajana – Yuna East Sandplain		5	3	208 000	78	74	0.4	< 1	< 0.1	73	0.35	1.7	244	Mod. high
9	Allanooka		5	3	26 300	93	12	0.4	< 1	< 0.1	12	0.44	1.8	332	Mod.
15	Mullewa		5	4	212 300	83	64	0.3	< 1	< 0.1	64	0.30	1.4	229	Mod. high
23	Galena–Wandana		5	4	76 700	78	24	0.3	< 1	< 0.1	22	0.28	1.4	222	Mod. high
25	Horrocks Coast		5	4	16 300	63	7	0.5	3	0.2	5	0.29	1.8	341	Mod.

(continued)

Table 5.3 continued

ALA			Agriculture type ranking		ALA area	Potential value of agriculture (combined)			Potential value of irrigated agriculture		Potential value of broadacre agriculture		Average		
No.	Name	Group	Irrig-ated	Broad-acre	Total ha	Cleared %	$m	$'000/ha	$m	$'000/ha	$m	$'000/ha	Relative wheat yield t/ha	Growing season rain mm	Soil product-ivity*
27	Christmas Hill	F	4	5	43 700	44	24	0.5	18	0.4	6	0.14	1.2	301	Mod. low
28	Gregory		4	6	25 800	63	13	0.5	8	0.3	5	0.18	1.0	307	Low
16	Pindar		5	5	169 000	83	34	0.2	< 1	< 0.1	34	0.20	0.9	212	Mod.
24	Ogilvie Road South		5	5	29 300	87	9	0.3	< 1	< 0.1	9	0.32	1.4	270	Mod. low
1	Knobby Head	G	5	6	4 360	6	< 1	0.2	< 1	0.1	< 1	0.01	0.8	335	Low
29	Kalbarri		5	6	1 400	13	< 1	0.2	< 1	< 0.5	< 1	0.05	1.4	269	Mod. low

* See Appendix H for an explanation of how the soil productivity categories were determined.

Table 5.4 **Summary of UCL ranking and potential value of agriculture**

Unallocated Crown Land (UCL) area			Agriculture type ranking		UCL		Potential value of agriculture (combined)		Potential value of irrigated agriculture		Average	
No.	Name	Group	Irrigated	Broadacre	Total ha	Cleared %	$m	$'000/ha	$m	$'000/ha	Growing season rain mm	Soil productivity
4	Tompkins Road	UCL	1	Non-agric	10 200	0	167	16.4	167	16.4	316	Mod.
2	Arrowsmith River		1	Non-agric	38 400	1	62	1.6	62	1.6	326	Mod. low

6. Broad guidelines for ALAs

Broad development guidelines are provided for all these groups. The productive capacity of the land and water resources identified in the more highly ranked areas requires a higher level of protection.

The overarching guidelines for the consideration of any proposed development on rural land should be to improve the sustainability and long-term agricultural viability of farming operations, and to protect and enhance the productive capacity of agricultural land.

6.1.1 Guideline 1: Groups A, B and C

It is recommended that non-agricultural development should be directed away from Groups A, B and C because of their productive capacity. These areas need to be protected from incompatible uses.

Group A: Greatest versatility—largest water resource for irrigation, high rainfall, high yielding soils		
Large groundwater resources		
7	Irwin Valley	• mix of property and parcel sizes suitable for smaller intensive or larger scale irrigated agricultural development
Potential access to alternative water supplies for high value horticulture		
11	Greenough Flats	• currently limited groundwater resources; may have potential for alternative irrigation supplies; highest productivity for broadacre agriculture

Group B: Relatively high versatility—large to moderate water resource for irrigation, good rainfall, moderate to high yielding soils		
Large water resources, moderate to moderately low yielding sandplain		
5	Lefroy	• moderately high yields for broadacre agriculture • larger properties suitable for larger scale agricultural developments
3	Drummonds Crossing	• moderately low yields for broadacre agriculture • mix of property and parcel sizes suitable for smaller intensive or larger scale irrigated agricultural development
Moderate water resources, moderately high to high yielding sandplain		
12	Casuarina Sandplain	• high yields for broadacre agriculture • property and parcel sizes allow for larger scale agricultural developments
8	Mt Horner	• moderately high yields for broadacre agriculture • property and parcel sizes allow for larger scale agricultural developments

Group C: Moderate versatility—highest yielding soils, good to high rainfall, some potential for irrigation*		
Potential water resources, highest yielding sandplain soils		
14	Eradu East Sandplain	• best sandplain soils for broadacre cropping • water supplies unproven • may be niche opportunities for horticulture in some areas
Limited water resources		
20	Northampton–Chapman	• niche opportunities for horticulture in some areas • productive loamy soils for broadacre cropping • numerous small to moderate properties suitable for intensive agricultural development
18	Eradu West Sandplain	• best sandplain soils for broadacre cropping • currently limited groundwater resources; some areas may have potential for alternative irrigation supplies • mix of property and parcel sizes suitable for smaller intensive or larger scale irrigated agricultural development
Insignificant water resources, highest yielding sandplain soils		
21	Yuna – Binnu Sandplain	• moderate rainfall • among best sandplain soils for broadacre cropping
* The four ALAs in Group C represent about 30 per cent of the total potential value of broadacre agriculture for the Region.		

6.1.2 Guideline 2: Groups D, E and F

> It is recommended that within Groups D, E & F, non-agricultural development be directed away from areas of productive soils onto less productive areas. The productive capacity of these areas needs protection to maintain profitability while allowing for suitably located developments which will not compromise agricultural activities.

Group D: Moderate versatility—moderate or potential water resources for irrigation, good rainfall, moderate to low yielding soils		
Potential water resource, moderate yields		
26	Hutt River	• varied soils—water supplies uncertain
13	Ellendale – Eradu Valley	• moderately low yields on varied soils for broadacre agriculture • some potential for groundwater abstraction • niche opportunities for horticulture in some areas
Moderate water resource, lower yielding sandy soils		
10	Geraldton–Dongara	• potential water, good land for irrigation, moderate potential for broadacre • some areas already have numerous small properties suitable for intensive agricultural development—no need for further subdivisions

Group E: Relatively low versatility—moderate or potential water resources for irrigation, moderate to low yields, variable rainfall and soils		
Limited water resources, good rainfall, moderately yielding soils		
17	Naraling Hills	• varied soils with moderate yields, yields enhanced by better rainfall • niche opportunities for intensive agriculture • manage non-agricultural uses to minimise conflict with surrounding agricultural activities
19	Moresby Range	
Insignificant water resources, moderate to high yielding soils, lower rainfall*		
22	Ajana – East Yuna Sandplain	• high yielding sandplain soils
15	Mullewa	• moderate productivity, limited mainly by rainfall • low rainfall limits broadacre crop yields in most years—productive soils produce good yields in higher rainfall years • lower land prices and low-input systems improve profitability
23	Galena–Wandana	
***** These three ALAs represent almost 30 per cent of total potential value of broadacre agriculture for the Region.		
Insignificant water resources, moderate to low yielding soils, good rainfall		
9	Allanooka	• good water supplies but restrictions apply for intensive development due to its Public Drinking Water Source Area status
25	Horrocks Coast	• moderate productivity, limited mainly by soils
Potential water resources, high rainfall, generally low yielding soils		
6	South Dongara	• less productive soils but relatively high rainfall maintains moderate broadacre crop yields • some potential for irrigation but water quality may be an issue especially in the west • manage non-agricultural uses to minimise conflict with surrounding agricultural activities

Group F: Low versatility—moderate or potential water resources for irrigation, moderate to low yields, variable rainfall and soils		
Generally low yielding soils, limited water resources, good rainfall		
27	Christmas Hill	• large areas under remnant vegetation • soils are generally poor with some better areas
28	Gregory	
Lowest rainfall, soil yields variable, insignificant water resources		
16	Pindar	• low rainfall limits broadacre crop yields in most years—productive soils produce good yields in higher rainfall years • lower land prices and low-input systems improve profitability
Soils or rainfall limit productivity, insignificant water resources		
24	Ogilvie Road South	• reasonable rainfall but many shallow soils • contains pockets of more productive land • valley floors are saline

6.1.3 Guideline 3: Group G

These areas are unlikely to be developed for any significant agricultural activity due to their productivity constraints. These areas may be more suitable for other developments.

Group G: Limited agricultural potential—low yielding soils, insignificant water supplies		
Low yielding coastal soils, insignificant water supplies		
1	Knobby Head	• largely under remnant vegetation • landholders should maintain and manage land to prevent degradation
29	Kalbarri	

6.1.4 Unallocated Crown Land (UCL)

The final group comprises areas of Unallocated Crown Land. This land remains under natural vegetation and was previously considered unsuitable for release for broadacre agriculture (Ted Griffin, DAFWA, pers. comm.). Most of these areas have limited agricultural potential but they have relatively good groundwater resources and some soils that may be suitable for horticultural crops. There may be a future opportunity for developing a small horticultural precinct within these UCLs. Issues that would need to be addressed before the release and clearing of any portion of these UCLs include native title status, biodiversity/environmental values, existing mining tenements, and obtaining of water entitlements.

Unallocated Crown Land		
UCL: Unallocated Crown Land		
2	Arrowsmith River	• areas of UCL with good water supplies for potential development of small horticultural precincts
4	Tompkins Road	

7. How to use this information

To identify the agricultural importance of a parcel of land, follow these steps:

1. Locate area of interest in the ALA map (Figure 4.6)
2. Go to s 4.3 to locate the relevant information sheet/s to understand the characteristics of the ALA/s and its relative importance to the agricultural industry.
3. Go to s 5 to see how the ALA/s has been grouped across the Region.
4. Go to s 6 to consider the recommended guidelines for the ALA/s.
5. Go to the detailed irrigated and broadacre agricultural potential maps (Figures 3.7, 3.8 and 3.22), to understand the level of variation of land quality in the area of interest. These maps show more of the complexity of the area and are intended to provide a clearer idea of the characteristics of a specific location. These maps will assist in identifying areas of higher and lower agricultural quality within an ALA and may indicate which land may be more appropriate for development.

LAST

It is important to remember that the boundaries of the ALAs are not intended for direct use as planning or zoning boundaries. Rather, they provide one layer of information that assists the process of identifying planning boundaries, with the accompanying information sheet and the broad guidelines helping to provide a rationale for planning policies.[81] This approach will help to balance the preservation of HQAL with population and other development pressures particular to each shire.

[81] Many other factors (such as industry, urban growth, environmental considerations, transport corridors and existing cadastral boundaries) need to be considered when drawing up planning boundaries.

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Appendixes

Appendix A Shortened forms and glossary

Table A.1 **List of shortened forms**

Term	Definition
ABS	Australian Bureau of Statistics
ALA	Agricultural land area
BoM	Bureau of Meteorology
CRIS	DAFWAs Client Resource Information System
DAFWA	Department of Agriculture and Food, Western Australia
DEC	Department of Environment and Conservation
DoP	Department of Planning
DoW	Department of Water
UCL	Unallocated Crown Land

Table A.2 **Glossary**

Term	Definition
Allocation limit	Annual volume of water set aside for licensed and unlicensed use from a water resource.
Aquifer	A geological formation or group of formations comprising of layers of rock, unconsolidated deposits or regolith that is able to receive, store and transmit significant quantities of water. The term is usually applied to saturated materials that currently contain water.
Aquitard	A saturated but poorly permeable geological formation that transmits water at a very slow rate compared to an aquifer, acting as a confining layer (see Confined aquifers).
Broadacre	A term used to describe farming or cropping enterprises that cover large areas of land and is generally reliant on rainfall. The term 'broadacre cropping' is used to differentiate the growing of crops such as wheat, lupins and canola, from the intensive cropping practised in horticulture.
Confined aquifer	An aquifer lying below an aquitard or confining layer (such as clay, coal or rock) that restricts the upward movement of water. In a confined aquifer, there is no watertable because the aquitard prevents water from rising. It contains the water under pressure.
Groundwater	Water found under the land surface that saturates the soil and is at greater than atmospheric pressure and will therefore flow freely into a bore or a well. This term is commonly applied to permanent bodies of water found under the ground surface.
General licensing component (GLC)	Annual volume of water set aside for general licensing from a water resource. This is a component of the allocation limit. The general licensing component includes existing licensed entitlements of general licensees (both agricultural and non-agricultural users) as well as water currently available for licensing. It does not include public water supply reserves, current allocations to the Water Corporation, or the exempt unlicensed component (that is, water that is not required to be licensed under the *Rights in Water and Irrigation Act 1914,* such as domestic and stock water).
Groundwater area (GWA)	Area proclaimed under the *Rights in Water and Irrigation Act 1914* for the purposes of licensing and managing water use.
Groundwater subarea (GWSA)	Groundwater areas (GWAs) are further subdivided into groundwater subareas. The subareas are not proclaimed, but are administrative boundaries used to manage the abstraction and licensing of groundwater resources.
General licensing component (GLC)	Annual volume of water set aside for general licensing from a water resource. This is a component of the allocation limit. The GLC includes existing licensed entitlements of general licensees (both agricultural and non-agricultural users) as well as water currently available for licensing. It does not include public water supply reserves, current allocations to the Water Corporation, or the exempt unlicensed component (that is, water that is not required to be licensed under the *Rights in Water and Irrigation Act 1914,* such as domestic and stock water).
Lot	see Parcel

(continued)

Table A.2 continued

Term	Definition
Parcel	A legally defined area of land defined by Landgate's cadastral database. These are often referred to as lots. Parcel data supplied by Landgate is updated twice a year.
Property	A land management unit defined as one or many contiguous parcels. Property boundary and ownership information are updated on a daily basis by DAFWA in the CRIS client property database.
Recharge	Water that moves into a groundwater body and therefore replenishes or increases sub-surface storage. Recharge typically enters an aquifer by rainfall infiltrating the soil surface and then percolating through the soil.
Region	Geraldton planning region
Regolith	All unconsolidated earth materials occurring above solid bedrock. Regolith includes soil, unconsolidated sediments and weathered bedrock.
Superficial (Surficial)	These are unconsolidated formations occurring in alluvial sediments and aeolian deposits. They are easily exploited and are the major sources of freshwater groundwater when associated with larger river systems. See 'Unconfined aquifer'
Unconfined aquifer	The aquifer nearest the surface, having no overlying confining layer. The upper surface of the groundwater within this aquifer is called the watertable (also referred to as 'superficial' or 'surficial' aquifer).
Zone land unit (ZLU)	These are a combination of landform and Soil Groups of WA and have been allocated to map units from all major surveys in the South West of Western Australia, linking the map units to soil property, land quality and land capability data. For more information, see Schoknecht et al. (2004).

Appendix B Land quality value codes used in ratings tables

Land quality ***(and units of measure)***	**Value codes**
Ease of excavation	**H** (high), **M** (moderate), **L** (low), **VL** (very low)
Inherent fertility	**VH** (very high), **H** (high), **M** (moderate), **L** (low), **VL** (very low)
Flood hazard	**N** (nil), **L** (low), **M** (moderate), **H** (high)
Land instability	**N** (nil), **VL** (very low), **L** (low), **M** (moderate), **H** (high)
Permeability	**R** (rapid), **W** (well), **MW** (moderately well), **M** (moderate), **P** (poor), **VP** (very poor)
pH 0–10 cm, pH 15–25 cm & pH 50–80 cm *(ph in $CaCl_2$)*	**Vsac** (very strongly acid: < 4.2), **Sac** (strongly acid: 4.2–4.5), **Mac** (moderately acid: 4.5–5.0), **Slac** (slightly acid: 5.0–5.5), **N** (neutral: 5.5–7.0), **Malk** (moderately alkaline: 7.0–8.0), **Salk** (strongly alkaline: > 8.0)
Phosphorus export risk	**L** (low), **M** (moderate), **H** (high), **VH** (very high) **E** (extreme)
Rooting depth *(cm)*	**VS** (< 15), **S** (15–30), **MS** (30–50), **M** (50–80), **D** (> 80), **VD** (> 150)
Salinity hazard	**NR** (none), **PR** (partial or low), **MR** (moderate), **HR** (high), **PS** (saline land)
Salt spray exposure	**S** (susceptible), **N** (not susceptible)
Site drainage potential	**R** (rapid), **W** (well), **MW** (moderately well), **M** (moderate), **P** (poor), **VP** (very poor)
Soil water storage 0–50 cm *(mm of available water)*	**EL** (extremely low: < 15), **VL** (very low: 15–25), **L** (low: 25–35), **ML** (moderately low: 35–50), **M** (moderate: 50–65), **H** (high: > 65)
Soil water storage 0–100 cm *(mm of available water)*	**EL** (extremely low: < 30), **VL** (very low: 30–50), **L** (low: 50–70), **ML** (moderately low: 70–100), **M** (moderate: 100–130), **H** (high: > 130)
Soil workability	**G** (good), **F** (fair), **P** (poor), **VP** (very poor)
Subsurface acidification susceptibility	**L** (low), **M** (moderate), **H** (high), **P** (presently acid)
Subsurface compaction susceptibility	**L** (low), **M** (moderate), **H** (high)
Surface salinity	**N** (nil), **S**, (slight), **M** (moderate), **H** (high), **E** (extreme)
Surface soil structure decline susceptibility	**L** (low), **M** (moderate), **H** (high)
Surface gravels / stones	**N** (none)**, VF** (very few)**, F** (few)**, C** (common)**, M** (many)**, A** (abundant)
Trafficability	**G** (good), **F** (fair), **P** (poor), **VP** (very poor)
Water erosion hazard	**VL** (very low), **L** (low), **M** (moderate), **H** (high), **VH** (very high), **E**(extreme)
Water repellence susceptibility	**N** (nil), **L** (low), **M** (moderate), **H** (high)
Waterlogging / inundation risk	**N** (nil), **VL** (very low), **L** (low), **M** (moderate), **H** (high), **VH** (very high)
Wind erosion hazard	**L** (low), **M** (moderate), **H** (high), **VH** (very high), **E** (extreme)

Appendix C Inherent fertility calculations in the SoilCalc Database

The methodology for assessing the land quality 'inherent fertility' concentrates on the nutrient retention capacity of the topsoil. It uses the following soil layer properties: clay percentage; organic carbon percentage; phosphorus retention index; and coarse fragments. These are assigned to each soil layer of each zone modal soil profile in the SoilCalc Database.

The methodology described here is a first approximation and is likely to be refined in the future as more soil layer properties (for example, cation exchange capacity) are added to the SoilCalc Database.

In the database, a fertility score is calculated for each soil layer in the following manner:

1. The organic carbon percentage multiplied by 5 (for example, 20 per cent organic carbon scores 100; 0.4 per cent organic carbon scores 2)
2. The phosphorus retention index divided by 2 (for example, a PRI of 200 or more scores 100; a PRI of 4 scores 2)
3. The clay percentage multiplied by 2 (for example, 50 per cent clay scores 100; 1 per cent clay scores 2).
4. The average of these three values is calculated and then multiplied by the proportion of the soil layer that is fine earth fraction (that is, the proportion that is not coarse fragments. If the soil layer has no coarse fragments, the average score is multiplied by 1; if the soil layer has 10 per cent coarse fragments, the average score is multiplied by 0.9; if the soil layer has 25 per cent fragments, the average score is multiplied by 0.75).

The result is a fertility score for each layer, nominally out of 100.[82] The existing criteria for these fertility scores are somewhat arbitrary and will require future review.

The profile fertility score (also nominally out of 100) is then calculated by multiplying the layer scores at six depths down the profile by a weighting factor. The weighting factors add up to 100 per cent and give the greatest weighting to the topsoil, as this is where the plants derive most of their nutrition. The top few centimetres have a slightly lower weighting as they are the first to dry out after rainfall and nutrient uptake is reduced in these dry conditions. The depths and weighting factors are shown in Table C.1.

Table C.1 **Weighting factor for fertility score at various depths in the soil profile**

Profile depth cm	Weighting factor %
2.5	25
7.0	35
12.0	15
27.0	10
52.0	10
82.0	5

For example, a fertility score of 20 at the depth of 2.5 cm is multiplied by a weighting factor of 25 per cent to become a weighted score of 5, while the fertility score of 20 at the depth of 52 cm is multiplied by 10 per cent to become a weighted score of 2.

[82] The score can exceed 100 in cases where there is a very high clay or organic carbon content but this will be a rare occurrence.

These weighted scores are then added together to determine the profile fertility score. A value for the land quality ‘inherent fertility’ is then assigned using the criteria in Table C.2.

Table C.2 **Criteria for conversion of profile fertility score into inherent fertility value**

Inherent fertility value	Profile fertility score
Very low (VL)	< 3.5
Low (L)	3.5–7.0
Moderate (M)	7–25
High (H)	25–50
Very high (VH)	> 50

Appendix D Example of map unit mean yield constant calculation

Table D.1 provides an example showing how the mean yield constant was calculated for the soil-landscape map unit Northampton 1 (255No_1) as discussed in s 3.3.1.

As shown in Figure 3.2 and Table 3.1, this map unit incorporates a number of unmapped Zone Land Units (ZLUs) that occupy varying proportions of the map unit. The proportion of the map unit that the ZLU occupies is expressed as an area percentage in column A of Table D.1.

Column B contains the capability rating for wheat (production only) for each ZLU as determined using Table 3.3. The capability ratings were then converted into yield constants (column C) as shown in Table 3.5.

Proportional yield constants for wheat (column D) for each ZLU were calculated by multiplying the yield constants (column C) by the map unit proportion (column A). These ZLU proportional yield constants were then summed to produce the mean yield constant (production only) for the map unit. For map unit 225No_1, this mean constant is 139.0

Column E contains the capability rating for wheat (degradation hazards and management only) for each ZLU, as determined using Table 3.4. Where this rating is Class 1, 2 or 3, the adjusted yield constant for wheat (column F) and the adjusted proportional yield constant for wheat (column G) were the same as the wheat only yield constant (column C) and proportional yield constant (Column D) respectively.

Where the rating in column E is Class 4 or 5, it was assumed that the land will not be cropped due to the unacceptable degradation risk or major management constraints. In these cases, the yield constant for wheat (column F) and the proportional yield constant for wheat (column G) were adjusted to 0.

The two ZLUs discussed in s 3.3.1 are included in Table D.1. These high yielding Kojarena and Northampton soils occur on erosion prone slopes (gradients of 10–15 per cent), so the yield constant has been adjusted to 0.

The proportional yield constants in column G are then summed to produce the final mean yield constant for wheat. In the case of map unit 225No_1, the final mean yield constant of 114.6 is considerably lower than the production only mean yield constant of 139.0

Table D.1 **Calculation of the mean yield constant for map unit 225No_1 (Northampton 1)**

Zone land unit (ZLU)			Column A	Column B	Column C	Column D	Column E	Column F	Column G
				Wheat (production only)			Wheat (degradation and management)		
Landform component %	WA Soil Group component	Soil Group qualifier component	Map unit proportion %	Capability rating Class	Yield constant	Prop. yield constant*	Capability rating Class	Adjusted yield constant	Prop. yield constant*
Crests & slopes (gradients < 3%)	Bare rock	—	2	Class 5	40	0.8	Class 5	0	0.0
Crests & slopes (gradients < 3%)	Red loamy earth	rock substrate	2	Class 2	140	2.8	Class 2	140	2.8
Crests & slopes (gradients < 3%)	Red shallow loamy duplex	rock substrate	5	Class 2	140	7.0	Class 3	140	7.0
Gentle slopes (3–5%)	Red loamy earth	rock substrate	3	Class 2	140	4.2	Class 2	140	4.2
Gentle slopes (3–5%)	Red shallow loamy duplex	neutral subsoil	8	Class 2	140	11.2	Class 2	140	11.2
Gentle slopes (3–5%)	Red shallow loamy duplex	rock substrate	10	Class 2	140	14.0	Class 3	140	14.0
Gentle slopes (3–5%)	Self-mulching cracking clay	neutral subsoil	5	Class 1	180	9.0	Class 2	180	9.0
Gentle slopes (5–10%)	Bare rock	—	2	Class 5	40	0.8	Class 5	0	0.0
Gentle slopes (5–10)	Red loamy earth	rock substrate	5	Class 2	140	7.0	Class 3	140	7.0
Gentle slopes (5–10%)	Red shallow loamy duplex	neutral subsoil	9	Class 2	140	12.6	Class 3	140	12.6
Gentle slopes (5–10%)	Red shallow loamy duplex	rock substrate	20	Class 2	140	28.0	Class 3	140	28.0
Gentle slopes (5–10%)	Self-mulching cracking clay	neutral subsoil	5	Class 1	180	9.0	Class 3	180	9.0
Moderate slopes (10–15%)	Red loamy earth (Kojarena soil series)	rock substrate	5	Class 2	140	7.0	Class 4	0	0.0
Moderate slopes (10–5%)	Red shallow loamy duplex (Northampton soil series)	rock substrate	6	Class 2	140	8.4	Class 4	0	0.0
Moderate slopes (15–30%)	Bare rock	—	1	Class 5	40	0.4	Class 5	0	0.0
Moderate slopes (15–30%)	Red shallow loamy duplex	rock substrate	5	Class 2	140	7.0	Class 5	0	0.0
Very gentle slopes (1–3%)	Red shallow loamy duplex	neutral subsoil	5	Class 2	140	7.0	Class 2	140	7.0
Well drained drainage depression	Red shallow loamy duplex	rock substrate	2	Class 2	140	2.8	Class 3	140	2.8
			Mean yield constant (production only)			**139.0**	**Final mean yield constant**		**114.6**

* Prop. = proportional

Appendix E Irrigated agriculture land use ratings tables

Table E.1 **Capability ratings table for root crops**

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L	M		H
Inherent fertility	VH, H, M	L	VL		
Land instability hazard	N, VL, L		M	H	
pH at 0–10 cm	Slac, N	Mac	Vsac, Sac, Malk, Salk		
pH at 15–25 cm	Slac, N	Sac, Mac	Vsac, Malk	Salk	
pH at 50–80 cm	Slac, N	Sac, Mac	Vsac, Malk	Salk	
Phosphorus export risk	L, M	H	VH	E	
Rooting depth	VD, D	M	MS	S	VS
Salinity hazard	NR	PR		MR, HR	PS
Salt spray exposure	N			S	
Site drainage potential	R, W, MW	M	P		VP
Soil water storage	H, M, ML	L, VL	EL		
Soil water storage 0–50 cm	H, M, ML	L	VL	EL	
Soil workability	G	F		P	VP
Subsurface compaction	L, M	H			
Surface gravels	N	VF, F	C	M	A
Surface salinity	N		S	M	H, E
Surface soil structure decline	L	M	H		
Surface stones	N	VF, F	C	M	A
Trafficability	G	F		P	VP
Water erosion hazard	VL	L	M	H, VH	E
Water repellence susceptibility	N, L, M	H			
Waterlogging / inundation risk	N, VL	L	M	H	VH
Wind erosion risk	L, M	H	VH		E

Table E.2 **Capability ratings table for citrus**

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L		M	H
Inherent fertility	VH, H, M	L	VL		
Land instability hazard	N, VL, L		M		H
pH at 0–10 cm	Slac, N	Mac	Vsac, Sac, Malk, Salk		
pH at 50–80 cm	Slac, N	Mac	Malk, Salk	Vsac, Sac	
Phosphorus export risk	L	M, H	VH		E
Rooting depth	VD, D		M	MS	S, VS
Salinity hazard	NR		PR	MR	HR, PS
Salt spray exposure	N			S	
Site drainage potential	R, W	MW	M	P	VP
Soil water storage	H, M, ML	L	VL	EL	
Soil water storage 0–50 cm	H, M, ML, L, VL, EL				
Soil workability	G	F	P	VP	
Subsurface compaction	L, M	H			
Surface salinity	N		S	M	H, E
Trafficability	G	F		P	VP
Water erosion hazard	VL, L	M, H		VH	E
Water repellence susceptibility	N, L, M	H			
Waterlogging / inundation risk	N, VL		L	M	H, VH
Wind erosion risk	L	M, H	VH		E

Table E.3 **Capability ratings table for avocados**

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L		M	H
Land instability hazard	N, VL, L		M		H
pH at 0–10 cm	Slac, N	Mac	Vsac, Sac, Malk, Salk		
pH at 50–80 cm	Slac, N	Mac, Malk	Salk	Vsac, Sac	
Phosphorus export risk	L	M, H	VH		E
Rooting depth	VD, D		M	MS	S, VS
Salinity hazard	NR		PR	MR	HR, PS
Salt spray exposure	N			S	
Site drainage potential	R, W	MW	M	P	VP
Soil water storage	H, M, ML	L	VL	EL	
Soil water storage 0–50 cm	H, M, ML, L, VL, EL				
Soil workability	G	F	P	VP	
Subsurface compaction	L, M	H			
Surface salinity	N		S	M	H, E
Trafficability	G	F		P	VP
Water erosion hazard	VL, L	M, H, VH		E	
Water repellence susceptibility	N, L, M	H			
Waterlogging / inundation risk	N, VL		L	M	H, VH
Wind erosion risk	L	M, H	VH		E

Table E.4 **Capability ratings table for grape vines**

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L		M	H
Inherent fertility	VH, H, M	L	VL		
Land instability hazard	N, VL, L		M		H
pH at 0–10 cm	Slac, N	Mac	Vsac, Sac, Malk, Salk		
pH at 50–80 cm	Slac, N	Mac, Malk	Vsac, Sac, Salk		
Phosphorus export risk	L, M	H	VH	E	
Rooting depth	VD, D	M		MS	S, VS
Salinity hazard	NR		PR	MR	HR, PS
Salt spray exposure	N			S	
Site drainage potential	R, W	MW	M	P	VP
Soil water storage (m)	H, M, ML	L, VL	EL		
Soil water storage 0–50 cm	H, M, ML, L, VL, EL				
Soil workability	G	F	P	VP	
Subsurface compaction	L, M	H			
Surface salinity	N		S	M	H, E
Trafficability	G	F		P	VP
Water erosion hazard	VL, L	M, H		VH, E	
Water repellence susceptibility	N, L, M	H			
Waterlogging / inundation risk	N, VL	L	M	H	VH
Wind erosion risk	L, M	H, VH	E		

Table E.5 **Capability ratings table for mangoes**

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N, L		M		H
Inherent fertility	VH, H, M	L	VL		
Land instability hazard	N, VL, L		M		H
pH at 0–10 cm	Slac, N	Mac, Malk	Vsac, Sac, Salk		
pH at 50–80 cm	Slac, N	Mac, Malk	Sac, Salk	Vsac	
Phosphorus export risk	L, M	H	VH	E	
Rooting depth	VD	D		M	MS, S, VS
Salinity hazard	NR			PR, MR	HR, PS
Salt spray exposure	N			S	
Site drainage potential	R, W	MW	M	P	VP
Soil water storage	H, M, ML	L	VL	EL	
Soil water storage 0–50 cm	H, M, ML, L, VL, EL				
Soil workability	G	F	P	VP	
Subsurface compaction	L, M	H			
Surface salinity	N		S		M, H, E
Trafficability	G	F		P	VP
Water erosion hazard	VL, L	M, H		VH	E
Water repellence susceptibility	N, L, M	H			
Waterlogging / inundation risk	N, VL	L	M	H	VH
Wind erosion risk	L, M	H, VH		E	

Table E.6 **Capability ratings table for olives**

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L		M	H
Permeability (zn)	R, MR, M	VR	S, MS		VS
pH at 0–10 cm (zf)	N, Slac	Mac	Sac, Vsac, Malk, Salk		
pH at 50–80 cm (zg)	N, Slac	Mac, Sac, Malk	Vsac, Salk		
Phosphorus export risk (n)	L, M	H	VH	E	
Rooting depth (r)	VD, D	M	MS		S, VS
Salinity hazard (y)	NR		PR	MR	HR, PS
Salt spray exposure (zi)	N			S	
Soil water storage (m)	M, H	ML, L, VL	EL		
Soil workability (k)	G	F	P	VP	
Subsurface compaction susceptibility (zc)	L, M	H			
Surface salinity (ze)	N		S	M	H, E
Water erosion hazard (e)	VL, L	M	H	VH	E
Water repellence susceptibility (za)	N, L, M	H			
Waterlogging / inundation risk (i)	N, VL		L	M, H	VH
Wind erosion risk (w)	L, M	H	VH	E	

Table E.7 **Capability ratings table for irrigated pastures (using centre-pivots)**

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N, L	M	H		
Inherent fertility	VH, H, M	L	VL		
Land instability hazard	N, VL, L		M	H	
pH at 0–10 cm	Slac, N	Vsac, Sac, Mac, Malk	Salk		
pH at 15–25 cm	Slac, N	Sac, Mac, Malk	Vsac, Salk		
pH at 50–80 cm	Slac, N	Sac, Mac, Malk, Salk	Vsac		
Phosphorus export risk	L	M	H, VH	E	
Rooting depth	VD, D, M	MS	S	VS	
Salinity hazard	NR	PR		MR, HR	PS
Salt spray exposure	N		S		
Soil water storage	H, M, ML	L	VL, EL		
Soil water storage 0–50 cm	H, M, ML, L, VL, EL				
Soil workability	G, F	P	VP		
Subsurface acidification susceptibility	L, M	H, P			
Subsurface compaction susceptibility	L, M	H			
Surface salinity	N	S	M	H	E
Surface soil structure decline	L, M	H			
Trafficability	G, F		P	VP	
Water erosion hazard	VL, L, M		H	VH	E
Water repellence susceptibility	N, L	M	H		
Waterlogging / inundation risk	N, VL, L	M	H	VH	
Wind erosion risk	L, M	H	VH	E	

Appendix F Map unit adjustments for salinity

The estimated proportion of saline watertables (shown in Figure 3.19) was used in the calculation of estimated recharge to fresh aquifers. The salinity proportion of each soil-landscape mapping unit was obtained primarily from the Map Unit Database, based on the salinity risk of the component ZLUs.

For some map units, this value was increased manually to include areas known to be underlain by saline watertables but in which this salinity is unlikely to develop a surface expression. This adjustment was based on data presented in Bairstow et al. (2006).[83]

Table F.1 shows the salinity adjustments applied to each of the soil-landscape systems occurring within the Region. These adjustments relate to soil-landscapes at the system level in the mapping unit hierarchy, however, they were applied to all the component subsystems and phases of the system (Schoknecht et al. 2004). The exception was where the proportion of the map unit shown as having a salinity risk in the Map Unit Database exceeded the adjustments in Table F.1.

Table F.1 **Soil-landscape system adjustments for salinity**

Salinity adjustment %	Soil-landscape zone	Soil-landscape system
100	221	221Ea
80	221	22In
	258	258Bb, 258Cw, 258Ih, 258Wa, 258Wh
	270	270Ga, 270Pd, 270Vi
	271	271Ba, 271Ch, 271Co, 271Cw, 271De, 271Dg, 271Eu, 271Fe, 271In, 271Jo, 271Ka, 271Ml, 271Mn, 271Mu, 271Na, 271Ne, 271Ng, 271Pd, 271Pe, 271Pi, 271Pk, 271Sd, 271Ta, 271Th, 271Ti, 271Wa, 271Wh, 271Wt, 271Yo, 271Yw
	273	273Ch, 273Er, 273Ka, 273Ne, 273Nr, 273Ny, 273Ti, 273Yw
	275	275By, 275Ho, 275Mo, 275Ro
70	221	221Ga, 221Qu
	223	223Bn, 223Dn, 223Eu, 223Hi
	225	225Og
	226	226Dd, 226Mb, 226Mg, 226Ms, 226Ne, 226Nt, 226Wh, 226Yn
	227	227Be, 227Bo, 227Cs, 227Da, 227En, 227Eu, 227Gu, 227Jo, 227Ne
	234	234Bi, 234Bo, 234Bu, 234Cl, 234Eu, 234Hi, 234Na, 234Ne, 234Pi, 234Sl, 234St, 234Yd, 234Yo
50	220	220Er
	225	225Bi, 225Ta
40	221	221Ta
	231	231Ta
35	220	220Ca, 220Ge, 220Mh
30	221	221En
0	221	221Cy
	222	222Ag, 222Co, 222La, 222Mr
	224	224Bh, 224Ge, 224Ir, 224Ma, 224Mh, 224Ms, 224Mt, 224Ny, 224Ot, 224Ye
	225	225Aj, 225Cw, 225Dw, 225Ge, 225Mo, 225Mt, 225No, 225Qu, 225Su, 225Ya
	231	231Gy, 231Qu, 231Ri, 231Tu, 231Zu
	232	232Ba, 232Bw, 232Ch, 232Kb, 232Mr, 232Pi, 232Tu, 232Ur, 232Wi, 232Ya

[83] These adjustments are listed in Appendix F.

Appendix G ALA data tables

The following tables contain the ALA and UCL data used in the information sheets in s 4 and the summary tables in s 5. Additional information about the data in the tables is contained in the notes following each table.

Table G.1 presents data relating to the potential for broadacre agriculture in each ALA. It also characterises each ALA in terms of the number and size of properties and parcels.

Table G.2 summarises the general licensing component (GLC) of the regional aquifer allocation limits for each ALA by aquifer and GWSA. It also shows the proportion of each GWSA aquifer falling within the ALA as an indication of potential access to that aquifer from outside the ALA.

Table G.3 summarises the estimates of recharge to fresh aquifers within each ALA and provides some of the data upon which these estimates were based.

Table G.4 combines data from Table G.2 and Table G.3 to provide an overall summary of potential irrigation resources. The general licensing components (GLC) and recharge estimates are added to indicate total volumes of water potentially available for licensing in each ALA. Adjustments have also been made to the maximum volumes to provide a more conservative estimate of the water that may be actually available for irrigation.

Table G.5 shows the area (in hectares) of a mix of horticultural crops (Table G.6) that could be irrigated with the volumes of water presented in Table G.4. The potential value of these crops is also given.

Table G.1 **Summary of broadacre agriculture potential of agricultural land areas**

ALA No.	ALA Name	1a Total area ha	1b Average growing season rain mm	1c Average relative yield t/ha	1d Total tonnes for all land in area	1e Crop value* $m	1f Remnant vegetation %	1g No. of properties	1h No. of parcels	1i Average property size ha	1j Average parcel size ha	1k Average parcel per property[†]
1	Knobby Head	4 360	335	0.8	180	< 1	94	1	4	3 917	979	4.0
3	Drummonds Crossing	5 200	322	1.7	6 800	2	25	5	6	2 399	1 735	2.2
5	Lefroy	16 900	324	1.8	27 200	7	10	10	38	2 613	561	10.5
6	South Dongara	17 000	333	1.3	7 700	2	62	17	61	951	254	5.4
7	Irwin Valley	15 000	339	2.1	29 000	8	10	31	264	200	50	4.0
8	Mt Horner	20 700	331	1.8	34 300	9	9	9	29	3 053	777	11.8
9	Allanooka	26 300	332	1.8	43 700	12	7	26	48	1 089	439	5.2
10	Geraldton–Dongara	38 700	338	1.4	33 400	9	38	190	392	193	92	2.7
11	Greenough Flats	19 700	334	2.4	44 900	12	6	162	455	105	36	3.4
12	Casuarina Sandplain	86 400	311	1.9	153 300	40	7	67	157	1 339	555	3.2
13	Ellendale – Eradu Valley	24 000	296	1.6	30 000	8	22	11	153	1 778	144	13.5
14	Eradu East Sandplain	60 000	262	2.3	130 000	35	5	18	66	2 962	899	4.7
15	Mullewa	212 300	229	1.4	240 000	65	17	99	733	2 450	291	8.9
16	Pindar	169 000	212	0.9	129 000	35	17	76	294	4 540	608	4.2
17	Naraling Hills	85 000	327	1.7	121 000	30	17	127	635	630	131	6.3
18	Eradu West Sandplain	45 300	284	2.4	101 000	25	7	26	91	1 440	461	6.8

(continued)

Table G.1 continued

ALA No.	ALA Name	Column 1a: Total area ha	1b: Average growing season rain mm	1c: Average relative yield t/ha	1d: Total tonnes for all land in area	1e: Crop value* $m	1f: Remnant vegetation %	1g: No. of properties	1h: No. of parcels	1i: Average property size ha	1j: Average parcel size ha	1k: Average parcel per property†
19	Moresby Range	25 600	344	1.8	32 400	9	31	112	259	207	96	2.7
20	Northampton–Chapman	99 000	331	2.3	199 000	55	13	240	1 380	414	67	6.7
21	Yuna – Binnu Sandplain	86 000	274	2.1	167 700	45	8	38	273	2 523	318	13.7
22	Ajana – East Yuna Sandplain	208 000	244	1.7	275 300	75	22	88	523	2 121	366	7.1
23	Galena–Wandana	76 700	222	1.4	81 800	20	22	25	208	6 913	620	10.8
24	Ogilvie Road South	29 300	270	1.4	35 900	10	13	15	121	1 655	218	8.7
25	Horrocks Coast	16 300	341	1.8	18 100	5	37	15	49	1 312	301	9.7
26	Hutt River	65 200	312	1.7	85 800	25	21	39	221	1 646	289	6.9
27	Christmas Hill	43 700	301	1.2	22 500	6	56	18	41	1 846	964	1.6
28	Gregory	25 800	307	1.0	17 000	5	37	15	81	1 714	216	10.9
29	Kalbarri	1 400	269	1.4	250	< 1	87	n.a.	n.a.	n.a.	n.a.	n.a.
Unallocated Crown Land (UCL)												
2	Arrowsmith River	38 400	326	n.a.	n.a.	n.a.	99	1	1	409	409	1.0
4	Tompkins Road	10 200	316	n.a.	n.a.	n.a.	100	n.a.	n.a.	n.a.	n.a.	n.a.

* Where the crop value exceeds $15 million it has been rounded to the nearest $5 million to avoid giving a false impression of accuracy.

† The values for average parcels per property (column 1k) were not calculated by dividing data from the number of parcels (column 1h) by data from the number of properties (column 1g). See under the heading property and parcel statistics in s 3.3 for an explanation of how these values were calculated.

Notes on Table G.1

Some of the values in this table have been rounded to prevent giving a false impression of accuracy. The total area (column 1a) has been rounded to the nearest hundred hectares to reflect the 'fuzzy' nature of the ALA boundaries. Wheat tonnage (column 1d) has been rounded to the nearest hundred tonnes and crop value (column 1e) has been rounded to the nearest million dollars.

Wheat yield potential (column 1c) is the average of the estimated relative wheat yields based on growing season rainfall over the period 2000–09. It represents the average yield for all arable land within the ALA, excluding land under remnant vegetation.

The potential yields presented in Table G.1 may not always reflect the actual wheat yields achieved across the ALA. With good crop management, the best land in the ALA would be expected to yield significantly higher than the figure presented in the table, especially in a good season. On the poorest land, or in a poor season, the yield potential may not be achievable. As it is common for the most productive land to be cropped selectively, actual average yields for some ALAs could be higher than the suggested potential yields.[84] It would be a mistake to use the average potential yield for the ALA to assess the productive potential of individual properties occurring within the ALA. Nor are these yields intended to be used as an aid to farm budgeting.

The total tonnes for all land in the area (column 1d) and crop value (column 1e) provide further interpretations of the wheat yield potential (column 1c). Some larger ALAs may have low yields but may produce significantly greater tonnage than the smaller, higher yielding ALAs. These values are intended to provide an indication of productive potential for a range of broadacre land uses rather than a realistic assessment of actual wheat production.

It is unfeasible that all arable cleared land within the ALA would be planted to wheat each year as the tonnages and values in Table G.1 suggest. Not only are some areas always going to be planted to other crops (such as lupin or canola) or used for pasture to raise livestock, but also some land will be left fallow in any given year. A certain proportion of cleared land is also put to uses other than agricultural production.

Summing the ALA wheat tonnage values in column 1d provides a total tonnage amount for the Region of just over 2 million tonnes with a value of $540 million. This is more than three times the amount of wheat recorded by the ABS as being produced in the Region over the decade. The ABS reports an average of 0.62 million tonnes of wheat each year of the decade, valued at $155 million, with about one-third of the cleared land being cropped (Tables 4.1 and 4.2). In fact, the total value of the potential wheat crop calculated here for the ALAs ($540 million) is around twice the ABS's average annual value of broadacre production ($268 million). This partly reflects the higher value of wheat per hectare than some of the other agricultural activities. It also suggests that not all land is used to its maximum productive potential.

The data on properties and their component parcels presented in columns 1g to 1k provide a rough assessment of the scale of agricultural operations within each ALA. They also provide some indication of the potential availability of land for future agricultural development. As explained in s 3.3, some parcels were allocated to a different ALA than their parent property as some properties were spread across a number of ALAs. As a result, some values in average parcels per property (column 1k) differ from those that would be calculated by dividing the number of parcels (column 1h) by the number of properties (column 1g).

[84] For example, the Greenough Flats ALA comprises a mix of highly productive loamy and clayey alluvial soils on the flats with sands of lower productive potential on the limestone ridge separating the front and back flats. These sandy soils reduce the average potential yield (column 1c), even though most of the actual cropping occurs on the flats.

Table G.2 **Summary of agricultural land area regional aquifer groundwater**

		2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k
ALAla			Groundwater subarea (GWSA)		Regional aquifer (within GWSA)				GSWA aquifer within ALA			Water available for licensing# in May 2012
No	Name	Total area ha	Name	Total area ha	Name	GLC* ML/yr	Total area ha	GLC† ML/ha/yr	Area‡ ha	Prop. of ALA§ %	Prop. of aquifer‖ %	ML/yr
1	Knobby Head	4 360	Dongara	171 699	Cattamarra	200	63 681	0.003	4 292	98	7	195
2	Arrowsmith River UCL	38 400	Eneabba	151 073	Yarragadee	20 440	113 603	0.180	38 039	99	33	2 117
3	Drummonds Crossing	5 200	Eneabba	151 073	Yarragadee	20 440	113 603	0.180	4 098	78	4	2 117
			Twin Hills	231 252	Yarragadee	42 830	215 954	0.198	1 159	22	1	22 079
					ALA total	63 270	329 557	0.192	5 257	100	2*	24 196
4	Tompkins Road UCL	10 200	Eneabba	151 073	Yarragadee	20 440	113 603	0.180	4 439	44	4	2 117
			Twin Hills	231 252	Yarragadee	42 830	215 954	0.198	5 733	56	3	22 079
					ALA total	63 270	329 557	0.192	10 172	100	3*	24 196
5	Lefroy	16 900	Eneabba	151 073	Yarragadee	20 440	113 603	0.180	1 300	8	1	2 117
			Twin Hills	231 252	Yarragadee	42 830	215 954	0.198	15 613	92	7	22 079
					ALA total	63 270	329 557	0.192	16 913	100	5*	24 196
6	South Dongara	17 000	Dongara	171 699	Yarragadee	3 750	51 221	0.073	16 859	99	33	3 253
7	Irwin Valley	15 000	Allanooka	54 100	Yarragadee	8 500	53 882	0.158	3 337	22	6	8 434
			Dongara	171 699	Yarragadee	3 750	51 221	0.073	1 141	8	2	3 253
			Eneabba	151 073	Yarragadee	20 440	113 603	0.180	6 909	46	6	2 117
			Twin Hills	231 252	Yarragadee	42 830	215 954	0.198	3 695	24	2	22 079
					ALA total	75 520	434 660	0.174	15 082	100	3*	35 823
8	Mt Horner	20 700	Allanooka	54 100	Yarragadee	8 500	53 882	0.158	20 678	100	38	8 434
9	Allanooka	26 300	Allanooka	54 100	Yarragadee	8 500	53 882	0.158	22 787	87	42	8 434
			Eneabba	151 073	Yarragadee	20 440	113 603	0.180	3 367	13	3	2 117
					ALA total	28 940	167 485	0.173	26 154	99	15*	10 551

(continued)

Table G.2 continued

ALA		2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k
			Groundwater subarea (GWSA)		Regional aquifer (within GWSA)				GSWA aquifer within ALA			Water available for licensing[#] in May 2012
No	Name	Total area ha	Name	Total area ha	Name	GLC* ML/yr	Total area ha	GLC[†] ML/ha/yr	Area[‡] ha	Prop. of ALA[§] %	Prop. of aquifer[‖] %	ML/yr
10	Geraldton–Dongara	38 700	Dongara	171 699	Yarragadee	3 750	51 221	0.073	17 371	45	34	3 253
			Dongara	171 699	Cattamarra	200	63 681	0.003	10 310	27	16	195
			Eneabba	151 073	Yarragadee	20 440	113 603	0.180	8 170	21	7	2 117
					ALA total	24 390	228 505	0.107	30 742	91	11*	5 565
11	Greenough Flats	19 700	Dongara	171 699	Cattamarra	200	63 681	0.003	12 486	63	20	195
12	Casuarina Sandplain	86 400	Casuarinas	175 113	Yarragadee	4 600	151 265	0.030	79 532	92	53	4 007
13	Ellendale – Eradu Valley	24 000	Casuarinas	175 113	Yarragadee	4 600	151 265	0.030	7 521	31	5	4 007
14	Eradu East Sandplain	60 000	Casuarinas	175 113	Yarragadee	4 600	151 265	0.030	42 252	70	28	4 007
			Yuna / Eradu	1 034 351	Yarragadee	500	16 212	0.031	14 118	24	87	500
					ALA total	5 100	167 477	0.030	56 371	94	34*	4 507
15	Mullewa	212 300	Yuna / Eradu & Mullewa / Byro		No current regional aquifer GLC							
16	Pindar	169 000	Mullewa / Byro		No current regional aquifer GLC							
17	Naraling Hills	85 000	Northampton / Gelena		No current regional aquifer GLC							
18	Eradu West Sandplain	45 300	Casuarinas & Yuna / Eradu		No current regional aquifer GLC							
19	Moresby Range	25 600	Northampton / Gelena		No current regional aquifer GLC							
20	Northampton–Chapman	99 000	Northampton / Gelena		No current regional aquifer GLC							
21	Yuna – Binnu Sandplain	86 000	Yuna / Eradu & Northampton / Gelena		No current regional aquifer GLC							

(continued)

Table G.2 continued

		2a	2b	2c	2d	2e	2f	2g	2h	2i	2j	2k
ALA			Groundwater subarea (GWSA)		Regional aquifer (within GWSA)				GSWA aquifer within ALA			Water available for licensing# in May 2012
No	Name	Total area ha	Name	Total area ha	Name	GLC* ML/yr	Total area ha	GLC† ML/ha/yr	Area‡ ha	Prop. of ALA§ %	Prop. of aquifer‖ %	ML/yr
22	Ajana – East Yuna Sandplain	208 000	Yuna / Eradu & Northampton / Gelena		No current regional aquifer GLC							
23	Galena–Wandana	76 700	Yuna / Eradu & Northampton / Gelena		No current regional aquifer GLC							
24	Ogilvie Road South	29 300	Northampton / Gelena		No current regional aquifer GLC							
25	Horrocks coast	16 300	Northampton / Gelena & Kalbarri / Eurardy		No current regional aquifer GLC							
26	Hutt River	65 200	Kalbarri / Eurardy		No current regional aquifer GLC							
27	Christmas Hill	43 700	Kalbarri / Eurardy		No current regional aquifer GLC							
28	Gregory	25 800	Kalbarri / Eurardy		No current regional aquifer GLC							

* General licensing components (GLCs) of the total allocation limits (data based on Tables 3.15 and 3.16). Where there is more than one GLC per ALA, the individual GLCs have been summed to calculate the ALA total GLC.

† GLC (ML/ha/yr) is calculated by dividing regional aquifer GLC in ML/yr (column 2e) by aquifer area (column 2f).

‡ The area of the GWSA–regional aquifer combination occurring within the boundaries of the ALA.

§ GWSA aquifer within ALA as a proportion of ALA (column 2i) is calculated by dividing the area of the aquifer in the ALA (column 2h) by the area of ALA (column 2a).

‖ GWSA aquifer within ALA as a proportion of the regional aquifer (column 2j) is calculated by dividing the area of the aquifer in the ALA (column 2h) by the area of aquifer (column 2f). Where an ALA has multiple regional aquifer GLCs in column 2e, the ALA total percentage in column 2j was calculated by adding the individual aquifer percentage after they had been subjected to a weighting. This weighting consisted a multiplying the individual aquifer percentages in column 2j by the proportional GLC for that aquifer (that is, the individual aquifer GLC in column 2e divided by the total ALA GLC also in column 2e) and summing the results. These total percentages based on weighted individual percentages are denoted by an asterisk in column 2j.

The volumes of water available for licensing (column 2k) were current in May 2012 and are likely to have altered subsequently.

Note: The data shaded blue or grey relates to the entire ALA. Unshaded data relates to regional aquifer components that are summed to derive the ALA total.

Notes on Table G.2

It needs to be stressed that some of the general licensing components (GLC) are shown against multiple ALAs in Column 2e. For example, the Yarragadee aquifer GLC of 42 830 ML/yr for the Twin Hills GWSA is recorded against four ALAs. This remains a single GLC and does not imply that 42 830 ML/yr can be abstracted from each ALA simultaneously. The water can only be licensed to one user at a time. Any portion of a GLC licensed for abstraction from one ALA (or to users outside the Region) cannot be available to users in other ALAs.[85,86]

In Table G.2 the GLCs are expressed both in terms of megalitres per year (column 2e) and megalitres per hectare per year (column 2g). Column 2e shows the volumes of water set aside for general licensing for abstraction in each GWSA, including any existing licensed water entitlements. Column 2g is calculated by dividing these GLC volumes (column 2e) by the area of the aquifer within the GWSA from which they may be potentially abstracted (column 2f).

The data in column 2g provides a rough indication of the likelihood of being able to abstract that water from any given point above the aquifer. Higher megalitres per hectare values tend to suggest a greater chance of abstracting significant volumes of water. This is both in terms of potential aquifer yields and the likelihood of competition for the water resource from other users.

The proportion of the aquifer occurring within the ALA (column 2i) indicates from how much of the ALA it is physically possible to access the aquifer's water. For example, where the proportion is 30 per cent, it is not possible to directly abstract that water from 70 per cent of the land in the ALA. To irrigate this 70 per cent of the ALA, it would be necessary to abstract water from the 30 per cent of the ALA overlying the aquifer (or from another source) and to find a means of transporting the water to the area to be irrigated.

The percentage of the GWSA – regional aquifer combination occurring within the ALA (column 2j) provides an indication of likely competition for the water resource from users outside the ALA. If this value is 100 per cent, then the resource is available exclusively for abstraction from within the ALA. Very small percentages suggest a high likelihood of the water being abstracted elsewhere and therefore unlikely to be available for licensing within the ALA. This is only an indication and does not rule out the possibility of accessing the water from within the ALA.

For example, the Irwin Valley ALA overlies the Yarragadee aquifer but is also situated on the junction of four groundwater subareas—the Allanooka, Eneabba Plains, Dongara and Twin Hills GWSAs (Figure G.1). As can be seen in Table G.2, each of these GWSAs has a separate GLC for the Yarragadee aquifer

Each of these GLCs (which total 75 520 ML) is potentially accessible from within the boundaries of the Irwin Valley ALA. If the full volume of this water were actually abstracted in the Irwin Valley ALA, none would then be available for abstraction from the remainder of the four GWSAs. Consequently, none of the Yarragadee GLC would be available for licensing from the Allanooka, Mt Horner, Lefroy, Geraldton–Dongara, Dongara South, Arrowsmith River, Tompkins Road and Drummonds Crossing ALAs.

The Yarragadee aquifer covers 434 660 ha within the four GWSAs (Figure G.2), while the Irwin Valley ALA occupies only about 3 per cent of this area (15 082 ha). It would therefore

[85] Eighty-five per cent of the Yarragadee aquifer within the Twin Hills GWSA is located outside the Region.

[86] The exceptions will be if the licence is terminated, or expires and therefore becomes available to users in all ALAs. Similarly a licence could be transferred from one ALA to another.

be realistic to expect that a significant proportion of these Yarragadee GLCs would be licensed for abstraction for areas located outside the Irwin Valley ALA, which is the current situation.

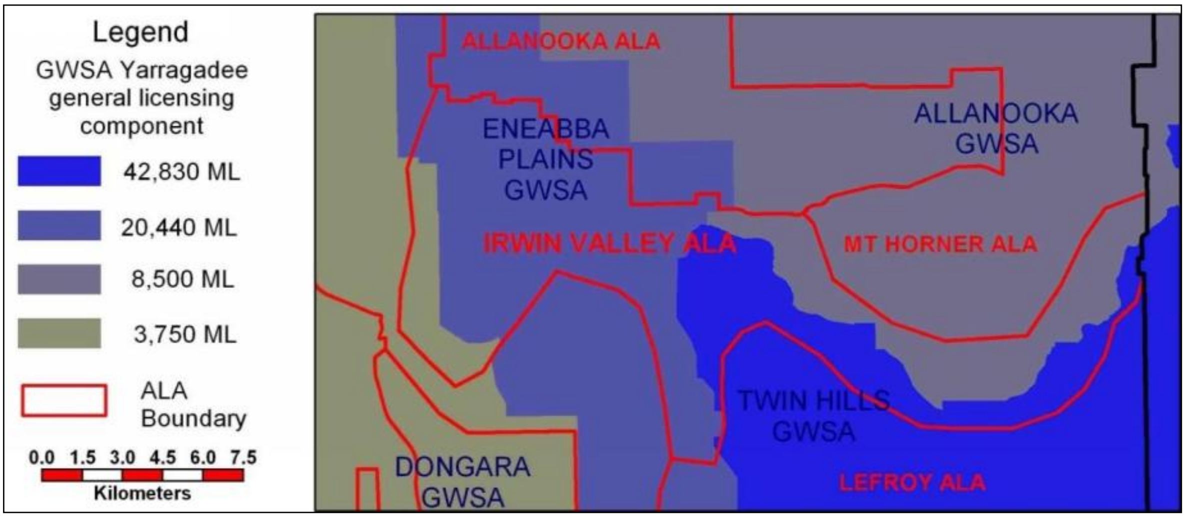

Figure G.1 **GWSA general licensing components for Yarragadee aquifer in the Irwin Valley ALA**

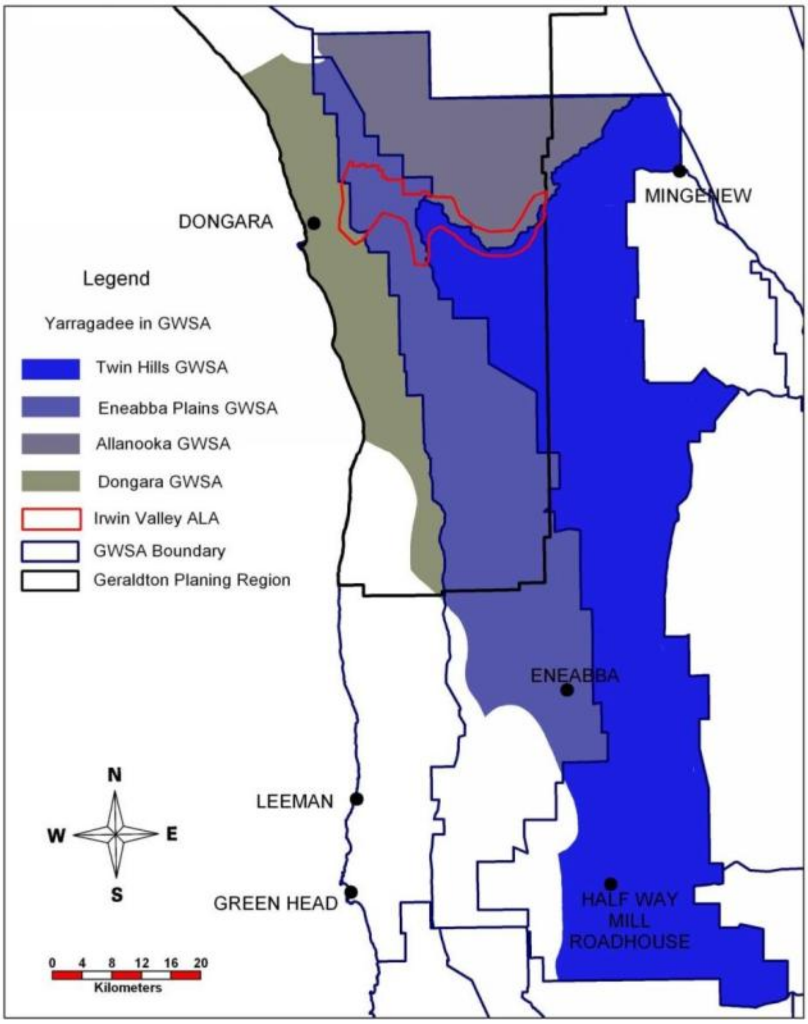

Figure G.2 **Irwin Valley ALA in relation to the Yarragadee aquifer in four groundwater subareas**

Water available for licensing (column 2k) contains data obtained from Department of Water on 15 May 2012. This is the GLC with all existing water entitlements (as well as future commitments and current request) subtracted. This was the balance of water available for future licensing at that time.

The volume of water available for licensing provides an indication of existing demands on the water resource. These figures are subject to change at any time. It will be necessary to contact the Department of Water to ascertain the current situation. In most cases, some of the current water entitlement will be licensed to both agricultural and non-agricultural users.

Table G.3 **Summary of estimated recharge to fresh aquifers**

ALA		Column											
		3a	3b	3c	3d	3e	3f	3g	3h	3i	3j	3k	3l
				Average estimated recharge to fresh aquifers			Average recharge in excess of 10 mm/yr			Average for ALA			
No.	Name	Total area ha	Average rainfall 1975–2005 mm/yr	mm/yr	ML/ha/yr*	ML/yr†	Area receiving recharge‡ ha	ML/ha/yr	ML/yr§	Remnant vegetation %	Saline water-tables %	Infiltration index %	Local aquifer storage factor %
1	Knobby Head	4 360	438	2.0	0.02	86	176	0.18	32	94	42	85	100
3	Drummonds Crossing	5 200	444	24.1	0.24	1 265	4 359	0.29	1 249	25	1	90	90
5	Lefroy	16 900	437	24.3	0.24	4 105	15 407	0.27	4 084	10	8	89	92
6	South Dongara	17 000	438	7.7	0.08	1 324	6 334	0.18	1 137	65	44	85	100
7	Irwin Valley	15 000	451	18.2	0.18	2 746	10 388	0.24	2 461	10	31	82	93
8	Mt Horner	20 700	431	26.2	0.26	5 418	20 356	0.27	5 412	9	4	89	90
9	Allanooka	26 300	449	27.6	0.28	7 244	25 442	0.28	7 210	7	3	89	91
10	Geraldton–Dongara	38 700	453	14.0	0.14	5 423	27 440	0.19	5 193	38	44	85	99
11	Greenough Flats	19 700	445	8.8	0.09	1 788	3 629	0.17	627	6	58	77	84
12	Casuarina Sandplain	86 400	412	20.7	0.21	17 853	84 852	0.21	17 828	7	22	90	90
13	Ellendale – Eradu Valley	24 000	386	18.9	0.19	4 543	20 584	0.22	4 501	22	8	84	89
14	Eradu East Sandplain	60 000	332	11.3	0.11	6 763	58 026	0.12	6 721	5	49	91	95
15	Mullewa	212 300	308	3.1	0.03	6 679	758	0.11	84	17	75	80	59
16	Pindar	169 000	297	0.3	0.00	583	0	0.00	0	17	81	80	12
17	Naraling Hills	85 000	431	4.8	0.05	4 106	19 779	0.14	2 820	17	4	73	22
18	Eradu West Sandplain	45 300	354	12.2	0.12	5 535	42 183	0.13	5 401	7	47	90	94
19	Moresby Range	25 600	439	7.2	0.07	1 848	9 207	0.11	1 039	31	4	77	34

(continued)

Table G.3 continued

ALA		Column 3a	3b	3c	3d	3e	3f	3g	3h	3i	3j	3k	3l
				Average estimated recharge to fresh aquifers			Average recharge in excess of 10 mm/yr			Average for ALA			
No.	Name	Total area ha	Average rainfall 1975–2005 mm/yr	mm/yr	ML/ha/yr*	ML/yr†	Area receiving recharge‡ ha	ML/ha/yr	ML/yr§	Remnant vegetation %	Saline water-tables %	Infiltration index %	Local aquifer storage factor %
20	Northampton–Chapman	99 000	426	2.0	0.02	1 999	7 709	0.13	1 040	13	2	76	8
21	Yuna – Binnu Sandplain	86 000	350	6.0	0.06	5 189	985	0.13	124	8	59	88	73
22	Ajana – East Yuna Sandplain	208 000	308	4.8	0.05	9 990	1 152	0.17	199	22	63	88	82
23	Galena–Wandana	76 700	289	3.9	0.04	2 972	0	0.00	0	22	55	84	72
24	Ogilvie Road South	29 300	357	3.7	0.04	1 076	0	0.00	0	13	66	79	48
25	Horrocks Coast	16 300	419	8.0	0.08	1 291	5 259	0.16	826	37	34	86	66
26	Hutt River	65 200	393	19.8	0.20	12 944	55 161	0.23	12 803	21	3	85	87
27	Christmas Hill	43 700	395	13.3	0.13	5 812	20 600	0.26	5 412	56	0	92	93
28	Gregory	25 800	385	10.2	0.10	2 612	14 505	0.17	2 479	37	41	88	99
29	Kalbarri	1 400	363	4.3	0.04	62	182	0.25	46	87	1	87	84
Unallocated Crown Land (UCL)													
2	Arrowsmith River	38 400	443	1.8	0.02	683	375	0.27	100	99	17	89	94
4	Tompkins Road	10 200	438	1.8	0.02	188	33	0.28	9	100	0	90	90

* Recharge in megalitres per hectare per year (column 3d) equals recharge in millimetres per year (column 3c) divided by 100.

† Recharge in ML/yr (column 3e) equals recharge in ML/ha/yr (column 3d) multiplied by total area (column 3a).

‡ Total area of land within the ALA receiving more than 10 mm of estimated recharge to fresh aquifer per year (areas shaded in colours other than yellow in Figure 3.20).

§ Average recharge in excess of 10 mm/yr (column 3h) calculated by multiplying the area receiving recharge (column 3f) by the recharge in ML/ha/yr (column 3g).

Notes on Table G.3

This table contains the estimates of average recharge to fresh aquifers for each of the ALAs. Recharge in mm/yr (column 3c) is derived from the data shown in Figure 3.20. This recharge is also expressed as megalitres per hectare per year (column 3d). From this value and the total area of the ALA (column 3c), the volume of recharge has been calculated in megalitres per year (column 3d).

Table G.3 also presents summaries of the data on which the recharge estimates are based—the average annual rainfall from 1975 to 2005 (column 3c); the proportion of the ALA covered by remnant vegetation (column 3i); the estimated proportion of saline watertables (column 3j); the average infiltration index (column 3k); and the average local aquifer storage factor of assigned to the aquifers (column 3l). These values give an indication of the factors determining the recharge estimates.

For example, despite the relatively high rainfall (426 mm/yr), recharge in the Northampton–Chapman ALA is low (2 mm/yr) due to the low local aquifer storage factor (8 per cent). This is because the regolith is very shallow and overlies a crystalline basement over much of this ALA.

The adjoining Drummonds Crossing ALA and Tompkins Road UCL share many characteristics, including similar rainfall (444 and 438 mm/yr respectively). However, estimated recharge is 10 times higher for Drummonds Crossing (24 mm/yr) than Tompkins Road (2 mm/yr), reflecting the fact that Drummonds Crossing has only 25 per cent cover of remnant vegetation while Tompkins Road has 100 per cent.

The relatively low recharge of fresh aquifer estimate for Galena–Wandana ALA (4 mm/yr) reflects not only the lower rainfall (289 mm/yr) but also that 55 per cent of the ALA is estimated to be underlain by saline watertables.

The recharge estimates presented in column 3d and column 3e have been adjusted in columns 3g and 3h to exclude all land on which the estimated recharge to fresh aquifers was less than 10 mm per year (< 0.1 ML/ha/yr). This adjustment was made because in areas receiving less recharge than 10 mm/yr, the volume of recharge would likely be too small (or too thinly spread) to produce a groundwater resource of any significance. This exclusion significantly reduces the volume of the recharge estimates for some ALAs.

For example, the Mullewa ALA has an average estimated recharge of only 3.1 mm, spread across more than 212 280 ha to total 6679 ML/yr. This amount would appear to be a significant volume of water. Using the assumptions from Table 3.24[87], this volume would be sufficient to irrigate over 500 ha of crops. However, to irrigate these crops it would be necessary to abstract this water from a large number of far-flung points across the ALA and to somehow transport it to the relatively small area to be irrigated. This would not be economical or even practical. Using the process described above, the volume of water has been adjusted down to 84 ML/yr, restricted to the 758 ha of land on the western margins of the Mullewa ALA that receive an average of 11 mm/yr of recharge. This adjustment appears to be a more realistic indication of groundwater availability around Mullewa.

The Knobby Head ALA provides another example. It receives an average recharge of 2 mm/yr across 4360 ha, totalling 86 ML/yr. About one-third of this volume (32 ML/yr) occurs on the small proportion of cleared land in the ALA (176 ha) with an average recharge rate of 18 mm/yr.

[87] That 1 ML of water per year would be enough to irrigate 0.0764 ha of the mix of enterprises shown in Table 3.24.

Table G.4 **Summary of ALA groundwater resources**

ALA		Column												
		4a	4b	4c	4d	4e	4f	4g	4h	4i	4j	4k	4l	4m
				Average estimated recharge to fresh aquifers: Total		Average estimated recharge to fresh aquifers: Greater than 10 mm/yr			Regional aquifer general licensing component				Total potential water for irrigated agriculture	
No.	Name	Total area ha	Average rainfall 1975–2005 mm/yr	mm/yr	ML/yr	Area receiving recharge ha	Max. local aquifer volume* ML/yr	25% adjust.† ML/yr	Max. regional aquifer volume‡ ML/yr	Aquifer area ha	Prop. adjust.§ ML/yr	Further 50% adjust.‖ ML/yr	Max. volume# ML/yr	Cons. volume** ML/yr
1	Knobby Head	4 360	438	2	86	176	32	8	200	4 292	13	7	232	15
3	Drummonds Crossing	5 200	444	24	1 265	4 359	1 249	312	63 270	5 257	967	484	64 519	796
5	Lefroy	16 900	437	24	4 105	15 407	4 084	1 021	63 270	16 912	3 330	1665	67 354	2 686
6	South Dongara	17 000	438	8	1 324	6 334	1 137	284	3 750	16 859	1 234	617	4 887	901
7	Irwin Valley	15 000	451	18	2 746	10 388	2 461	615	75 520	15 082	2 586	1 293	77 981	1 908
8	Mt Horner	20 700	431	26	5 418	20 356	5 412	1 353	8 500	20 678	3 262	1 631	13 912	2 984
9	Allanooka	26 300	449	28	7 244	25 442	7 210	1 802	28 940	26 154	4 201	2 100	36 150	3 903
10	Geraldton–Dongara	38 700	453	14	5 423	27 440	5 193	1 298	24 390	35 850	2 774	1 387	29 583	2 685
11	Greenough Flats	19 700	445	9	1 788	3 629	627	157	200	12 486	39	20	827	176
12	Casuarina Sandplain	86 400	412	21	17 853	84 852	17 828	4 457	4 600	79 532	2 419	1 209	22 428	5 666
13	Ellendale – Eradu Valley	24 000	386	19	4 543	20 584	4 501	1 125	4 600	7 521	229	114	9 101	1 240
14	Eradu East Sandplain	60 000	332	11	6 763	58 026	6 721	1 680	5 100	56 371	1 720	860	11 821	2 540
15	Mullewa	212 300	308	3	6 679	758	84	21	< 1	< 1	< 1	< 1	84	21
16	Pindar	169 000	297	< 1	583	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
17	Naraling Hills	85 000	431	5	4 106	19 779	2 820	705	< 1	< 1	< 1	< 1	2 822	705
18	Eradu West Sandplain	45 300	354	12	5 535	42 183	5 401	1 350	< 1	< 1	< 1	< 1	5 401	1 350
19	Moresby Range	25 600	439	7	1 848	9 207	1 039	260	< 1	< 1	< 1	< 1	1 039	260
20	Northampton–Chapman	99 000	426	2	2 781	7 709	1 040	260	< 1	< 1	< 1	< 1	1 040	260
21	Yuna – Binnu Sandplain	86 000	350	6	5 235	985	124	31	< 1	< 1	< 1	< 1	124	31

(continued)

Table G.4 continued

ALA		Column 4a	4b	4c	4d	4e	4f	4g	4h	4i	4j	4k	4l	4m
				Average estimated recharge to fresh aquifers					Regional aquifer general licensing component				Total potential water for irrigated agriculture	
				Total		Greater than 10 mm/yr								
No.	Name	Total area ha	Average rainfall 1975–2005 mm/yr	mm/yr	ML/yr	Area receiving recharge ha	Max. local aquifer volume* ML/yr	25% adjust.† ML/yr	Max. regional aquifer volume‡ ML/yr	Aquifer area ha	Prop. adjust.§ ML/yr	Further 50% adjust.‖ ML/yr	Max. volume# ML/yr	Cons. volume** ML/yr
22	Ajana – East Yuna Sandplain	208 000	308	5	9 990	1 152	199	50	< 1	< 1	< 1	< 1	199	50
23	Galena–Wandana	76 700	289	4	2 972	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
24	Ogilvie Road South	29 300	357	4	1 076	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
25	Horrocks Coast	16 300	419	8	1 290	5 259	826	207	< 1	< 1	< 1	< 1	826	207
26	Hutt River	65 200	393	20	12 944	55 161	12 803	3 201	< 1	< 1	< 1	< 1	12 803	3 201
27	Christmas Hill	43 700	395	13	5 812	20 600	5 412	1 353	< 1	< 1	< 1	< 1	5 412	1 353
28	Gregory	25 800	385	10	2 612	14 505	2 479	620	< 1	< 1	< 1	< 1	2 479	620
Unallocated Crown Land (UCL)														
2	Arrowsmith River	38 400	443	2	683	375	100	25	20 440	38 039	6 844	3 422	20 540	3 447
4	Tompkins Road	10 200	438	2	188	33	9	2	63 270	10 172	1 936	968	63 279	970

* Maximum local aquifer volume (column 4f) is the average recharge in excess of 10 mm/yr (column 3h in Table G.3).

† The 25 per cent adjustment (column 4g) is the maximum local aquifer volume (column 4f) divided by four. This adjustment considers the likelihood of allocations to non-agricultural users, the environment and regional aquifer recharge, as well as possible technical difficulties in abstracting some groundwater for irrigation.

‡ Maximum regional aquifer volume (column 4h) is the general licensing component (column 2e in Table G.2). Where multiple aquifers are shown in column 2e, the ALA total volume has been used.

§ The proportional adjustment (column 4j) is maximum regional aquifer volume (column 4h) multiplied by the proportion of the aquifer occurring within the ALA (column 2j from Table G.2). It is based on the assumption that the groundwater resource is distributed evenly within the GWSA–aquifer combination.

‖ The further 50 per cent adjustment (column 4k) is the proportional adjustment (column 4j) divided in half. It is based on the assumption that half of the groundwater allocations will be licensed to non-agricultural users.

Maximum volume of total potential water for irrigated agriculture (column 4l) is the sum of maximum local aquifer volume (column 4f) and maximum regional aquifer volume (column 4h).

** Conservative volume of total potential water for irrigated agriculture (column 4m) is the sum of 25 per cent adjustment (column 4g) and further 50 per cent adjustment (column 4k).

Notes on Table G.4

This table combines data from Tables G.2 and G.3 to provide a summary of total potential groundwater resources. The summary includes the volumes taken directly from Table G.2 and Table G.3 as well as some adjustments of these volumes to provide a more realistic assessment of groundwater availability.

It is difficult to predict just how much groundwater will be available for allocation to irrigated agriculture in the Region at any given time. Allocations to irrigated agriculture—and the proportion of the total volume of groundwater resources these represent—will fluctuate over time and vary from area to area.

The estimates of annual recharge to fresh aquifers were used to assess potential supplies in local aquifers. The fresh aquifer recharge greater than 10 mm/yr (column 3h in Table G.3) was designated as the maximum local aquifer groundwater volume (column 4f). The total GLC for regional aquifers in each ALA (column 2e from Table G.2) was designated as the maximum region aquifer groundwater volume (column 4h).

Both of these maximum volumes present a somewhat unrealistic picture of the groundwater resources that are likely to ever be available for irrigated agriculture. As stated in the Notes on Table G.2, the full volume of single 'regional aquifer GLC' is often assigned to multiple ALAs and therefore contributes to a number of the maximum regional aquifer groundwater volume (column 4h). As a result, the sum of these individual ALA maximum regional aquifer groundwater volumes is much is greater than the total GLC for the entire Arrowsmith GWA.[88] Water abstracted in one ALA cannot be simultaneously abstracted in another area.

Consideration also needs to be given to the fact that groundwater resources are unlikely to be licensed to agricultural users exclusively. A portion of these maximum volumes will be abstracted for industrial, mining or recreational uses. For these reasons, the maximum volumes have been adjusted to provide a conservative volume of groundwater potentially available for irrigated agriculture.

An adjusted local aquifer groundwater volume presented in column 4g is one-quarter of the maximum local aquifer volume (column 4f). While this 25 per cent adjustment is nominal, it was considered to provide a more realistic assessment of the water likely to be available for licensing from local aquifers for irrigated agriculture. This represents a significant reduction but considers that:

- A proportion of the recharge may be physically difficult to abstract.
- Some recharge will be required for environmental purposes (for example, wetlands and stream flow).
- Some recharge will be contributing to supplies in regional aquifers.
- Non-agricultural users may be licensed to abstract local groundwater.

Two adjusted volumes are presented for water from regional aquifers. First, the proportional adjustment (column 4j) was calculated by dividing maximum regional aquifer volume (column 4h) by the total proportional area of the aquifers (that these allocations apply to) occurring within the ALA (column 2j from Table G.2). The assumption behind this adjustment is that the distribution of groundwater resources within a GWSA–aquifer combination will be evenly distributed. This does not reflect the Department of Water's policy and there is no

[88] The total general licensing component for the entire Arrowsmith GWA includes total general licensing components for subareas not occurring within the Region, as well as the total general licensing components for local aquifers not included in the regional aquifer general licensing components in Table G.4.

intention to suggest that such a policy be adopted in the future. Rather, this adjustment presents a more realistic estimate of the volumes of regional aquifer groundwater that are likely to be available for licensing within the Region and within each ALA. Adopting this assumption prevents the same GLC volume being assigned to multiple ALAs.

A further adjustment was made to the regional aquifer volumes in column 4k. Here, the proportionally adjusted volume (column 4j) is halved, based on the assumption that 50 per cent of the groundwater will be licensed to non-agricultural users. This assumption is not unrealistic given the continued growth of the mining industry in the Mid West (and the potential for associated industrial development).

The total potential water for irrigated agriculture is a combination of the regional and local volumes:

- For the maximum total potential volume (column 4l), the maximum regional aquifer volume (column 4h) and the maximum local aquifer volume (column 4f) were summed.
- For the conservative total potential volume (column 4m), the regional aquifer further 50 per cent adjustment (column 4k) and the local aquifer 25 per cent adjusted volume (column 4g) were summed.

While the maximum total potential volume (column 4l) may theoretically be available for irrigated agriculture, in reality this availability is highly unlikely for most ALAs. This figure is presented to provide the upper limit of currently known groundwater resources within current allocation boundaries. It also provides an indication of the opportunity cost of allocating these groundwater resources to other areas or to non-agricultural users. In some cases, this volume may increase in the future following more detailed groundwater investigations. Conversely, declining rainfall or a better understanding of aquifers could result in a decrease in the maximum volume of groundwater available for licensing.

The conservative total potential volume (column 4m) does not represent the lower limit of water for agriculture. This will be zero if all the water is licensed to non-agricultural users or is licensed for abstraction from other ALAs or from outside the Region. The conservative volume is intended as a more realistic estimate. The volume of groundwater actually used for agriculture in the future may be somewhere between the conservative and maximum volumes for some ALAs and less than the conservative volume for other ALAs.

Table G.5 **Potential value of production from irrigated agriculture by ALA**

ALA		Column									
		5a	**5b**	**5c**	**5d**	**5e**	**5f**	**5g**	**5h**	**5i**	**5j**
			Potential water for irrigated agriculture*		**Mix of enterprises irrigated by potential water**					**Potential value of irrigated crops‖ per annum**	
					Area†		**Proportion of ALA‡**				
No.	**Name**	**Total area ha**	**Max. volume ML/yr**	**Conservative volume ML/yr**	**Max. ha**	**Conser-vative ha**	**Max. %**	**Conser-vative %**	**Land suitable for irrigation§ ha**	**Max. $m/yr**	**Conser-vative $m/yr**
1	Knobby Head	4 360	232	15	18	1	< 1	< 1	3 574	1	< 1
3	Drummonds Crossing	5 200	64 519	796	4 930	61	94	1	3 001	355	4
5	Lefroy	16 900	67 354	2 686	5 146	205	30	1	16 371	350	14
6	South Dongara	17 000	4 887	901	373	69	2	< 1	13 271	25	5
7	Irwin Valley	15 000	77 981	1 908	5 958	146	40	1	14 945	405	10
8	Mt Horner	20 700	13 912	2 984	1 063	228	5	1	20 634	72	15
9	Allanooka	26 300	36 150	3 903	2 762	298	11	1	23 505	188	20
10	Geraldton–Dongara	38 700	29 583	2 685	2 260	205	6	1	29 285	154	14
11	Greenough Flats	19 700	827	176	63	13	< 1	< 1	19 986	4	1
12	Casuarina Sandplain	86 400	22 428	5 666	1 714	433	2	1	86 349	116	29
13	Ellendale – Eradu Valley	24 000	9 101	1 240	695	95	3	< 1	24 067	47	6
14	Eradu East Sandplain	60 000	11 821	2 540	903	194	2	< 1	59 768	61	13
15	Mullewa	212 300	84	21	6	2	< 1	< 1	186 750	< 1	< 1
16	Pindar	169 000	< 1	< 1	< 1	< 1	< 1	< 1	131 814	< 1	< 1
17	Naraling Hills	85 000	2 820	705	215	54	< 1	< 1	81 884	15	4
18	Eradu West Sandplain	45 300	5 401	1 350	413	103	1	< 1	45 269	28	7
19	Moresby Range	25 600	1 039	260	79	20	< 1	< 1	18 447	5	1
20	Northampton–Chapman	99 000	1 040	260	79	20	< 1	< 1	98 485	5	1

(continued)

Table G.5 continued

ALA		Column									
		5a	5b	5c	5d	5e	5f	5g	5h	5i	5j
			Potential water for irrigated agriculture*		Mix of enterprises irrigated by potential water					Potential value of irrigated crops‖ per annum	
					Area†		Proportion of ALA‡				
		Total area	Max. volume	Conservative volume	Max.	Conser-vative	Max.	Conser-vative	Land suitable for irrigation§	Max.	Conser-vative
No.	Name	ha	ML/yr	ML/yr	ha	ha	%	%	ha	$m/yr	$m/yr
21	Yuna – Binnu Sandplain	86 000	124	31	10	3	< 1	< 1	84 481	< 1	< 1
22	Ajana – East Yuna Sandplain	208 000	199	50	17	4	< 1	< 1	199 335	1	< 1
23	Galena–Wandana	76 700	< 1	< 1	< 1	< 1	< 1	< 1	74 661	< 1	< 1
24	Ogilvie Road South	29 300	< 1	< 1	< 1	< 1	< 1	< 1	25 990	< 1	< 1
25	Horrocks Coast	16 300	826	207	63	16	< 1	< 1	13 121	4	1
26	Hutt River	65 200	12 803	3 201	978	245	2	< 1	57 666	66	17
27	Christmas Hill	43 700	5 412	1 353	414	103	1	< 1	1 806	28	7
28	Gregory	25 800	2 479	620	189	47	1	< 1	8 440	13	3
Unallocated Crown Land (UCL)											
2	Arrowsmith River	38 400	20 540	3 447	1 569	263	4	1	20 882	107	18
4	Tompkins Road	10 200	63 279	970	4 835	74	48	1	10 172	329	5

* These volumes are taken from columns 4l and 4m in Table G.4.

† The maximum area irrigated (column 5d) is calculated by multiplying the maximum volume (column 5b) by the area of 0.0764 ha irrigated by one ML of water per year for the mix of enterprises in Table G.6. The conservative area irrigated (column 5e) is calculated by multiplying the conservative volume (column 5b) by the same figure.

‡ The proportion of the ALA (columns 5f and 5g) are calculated by dividing the maximum and conservative area irrigated (columns 5d and 5e) by the total area (column 5a).

§ The land suitable for irrigation (column 5h) is based on the land category data displayed in Figure 4.4.

‖ The potential value of irrigated crops (columns 5i and 5j) was calculated by multiplying the maximum and conservative volumes (columns 5b and 5c) by the crop/rotation value of $5192/ML for the mix of enterprises in Table G.6. The exception is the case in which the land suitable for irrigation (column 5h) is a smaller area than the maximum area irrigated (column 5d). In these cases, the land suitable for irrigation in hectares (column 5h) is multiplied by $67 956/ha ($5192/ML multiplied by 0.0764 ha/ML, from Table G.6) to determine the maximum potential value of irrigated crops (column 5i). Where the irrigated crop value exceeds $15 million it has been rounded to the nearest $5 million to avoid giving a false impression of accuracy.

Notes on Table G.5

This table uses the potential water for irrigated agriculture volumes shown in Table G.4 and the crop data in Table G.6 to estimate a potential value of irrigated agriculture in each ALA.

Table G.6 provides water requirement and production value data for the crops and rotations selected to make up an enterprise mix representative of the potential for irrigated agriculture in the Region (s 3.3.2).

Table G.6 **Water requirement and value for selected mix of enterprises (adapted from Table 3.24)**

		Column						
		6a	6b	6c	6d	6e	6f	6g
			Crop/ rotation value†			For 1 ML of water		
Crop type	**Crop/rotation (enterprise)**	**Area irrigated* ha/ML/yr**	**$/ML/yr**	**$/ha/yr**	**Enterprise weighting score‡ %**	**Irrigation volume§ ML/yr**	**Area irrigated‖ ha**	**Value# $/yr**
Perennial tree and vine crops	Avocado	0.04	1 603	40 500	5	0.05	0.0020	80
	Citrus (oranges)	0.09	4 940	56 000	10	0.10	0.0088	494
	Mangoes	0.05	2 518	50 000	10	0.10	0.0050	252
	Olives	0.21	1 042	5 000	5	0.05	0.0104	52
	Peaches (early)	0.13	9 111	71 250	10	0.10	0.0128	911
	Table grapes	0.13	5 732	45 000	10	0.10	0.0127	573
Annual crop rotations	Carrot/Onion	0.04	3 860	106 224	12.5	0.125	0.0045	483
	Potato/Corn	0.07	6 883	98 002	12.5	0.125	0.0088	860
	Cucumber/Melon	0.05	5 019	108 210	12.5	0.125	0.0058	627
	Tomato/Melon	0.04	6 878	156 070	12.5	0.125	0.0055	860
Total					**100.0**	**1.00**	**0.0764**	**5 192**

* Area irrigated (column 6a) is taken from Table 3.22.

† Crop rotation values (columns 6b and 6c) are taken from Table 3.23.

‡ The crop weighting score (column 6d) represents the perceived importance of the crop (see Table 3.11 and associated text).

§ Irrigation volume (column 6e) equals 1 ML multiplied by the crop weighting score (column 6d).

‖ Area of enterprise mix irrigated by 1 ML (column 6f) equals the area of crop/rotation irrigated by 1 ML (column 6a) multiplied by the crop weighting score (column 6d).

Value of enterprise mix irrigated by 1 ML (column 6g) equals the crop/rotation value (column 6b) multiplied by the crop weighting score (column 6d).

It is not suggested that any single figure could represent the potential value of irrigated agriculture for each of the ALAs. As stated previously, due to a variety of factors the crucial issue of the volume of water likely to be available for agriculture cannot be determined precisely.

Furthermore, it is difficult to predict the value of production without knowing what crops are being irrigated. There is a broad range of crops to which that irrigation water may be applied, with significant variations in crop water requirements, crop yields, market niches, and prices paid for the produce. Even for a single crop, there can be considerable variations in these factors, depending on the design and management of plantings.

There is also potential for value-adding to the economic returns derived from some produce. For example, some olive growers in the Region are not just producing raw olives but bottling and selling their own olive oil and other olive-based products. Their value of production would be considerably higher than the $5000 per hectare per year shown in column 6c of Table G.6. There are other high value (non-horticultural) intensive agricultural activities reliant on groundwater supplies that could also be considered. Current activities in the Region include aquaculture, egg farms and abattoirs.

For the above reason, a range of potential values for irrigated agriculture are provided for each for ALA. This range consists of two values—the first assumes that the entire maximum volume (column 5b) of water is used for production of irrigated crops; the second assumes that only the conservative volume (column 5c) is used.

Rather than assess potential values for a range of individual land uses, the mix of enterprises in Table G.6 was used as the basis of the calculations. Two assumptions generated from this table were applied to both the maximum and conservative volumes. These assumptions are that the:

- area irrigated by one megalitre of water is 0.0764 ha, and
- value of production per megalitre is $5192.

The volumes of groundwater in columns 5b and 5c were multiplied by 0.0764 ha/ML to calculate the maximum and conservative areas that could be irrigated by the potential water supplies (columns 5d and 5e). The volumes in columns 5b and 5c were multiplied by $5192/ML to calculate the maximum and conservative potential value of irrigated agriculture (columns 5i and 5j).

The maximum and conservative values for the area irrigated (columns 5d and 5e) and value of production (columns 5i and 5j) do not necessarily represent the upper and lower limits of the range of these values. Apart from the availability of water, much will depend on what crops are actually grown and the prevailing market conditions.

If low water use crops (such as olives) were planted exclusively in an ALA (instead of the enterprise mix in Table G.6), there is a possibility of irrigating a larger area than suggested in column 5d.[89] But if olives dominated the plantings, the value of production may be lower than the conservative value (column 5j) suggests.

In an ALA dominated by high water use crops (such as some of the vegetable rotations), it may not be possible to irrigate all of the conservative area (column 5e) even if more than the conservative volume (column 5c) was used.

The proportion of each ALA that can be irrigated by the volumes of water (columns 5f and 5g) were calculated by dividing the maximum and conservative areas irrigated (columns 5d and 5e) by the total area of the ALA (column 5a). In most cases, this proportion is very small, suggesting that the development of irrigated agriculture is unlikely to cause any major displacement of existing broadacre agriculture.[90]

Land suitable for irrigation (column 5h) is based on the combined very high, high and moderate, irrigated land categories in Figure 4.4. This data provides an indication of the likelihood of finding sufficient land for using the potential groundwater supplies.

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89 Assuming that the maximum volume of water was available.

90 There may be some issues with the compatibility of broadacre and irrigated crops (such as spray drift) that could affect existing land use.

In most cases, there is more than sufficient land to accommodate the use of the potential groundwater supplies for irrigation. In two ALAs (Drummonds Crossing and Christmas Hill), however, the area of suitable land is smaller than the area that could be irrigated by the maximum volume of water. In these cases, the maximum potential of irrigated agriculture has been adjusted accordingly.[91]

The maximum and conservative potential values of irrigated agriculture (columns 5i and 5j) are based on nominal 'farm gate' values of harvest produce only. The real value of irrigated agriculture to the local economy is likely to be much greater. The values in columns 5i and 5j do not consider the output multiplier impact of production on the local economy. The production of irrigated crops economically involves the suppliers of rural merchandise, fertilisers, transportation services, machinery maintenance and seasonal labour, among other factors. All of these individuals and companies make a further contribution to the economy.

The values in columns 5i and 5j do not include the potential for value-adding of produce either. Processing grapes into wine, stone fruit into jam, or olives into oil, greatly increase their value. Some of this value-adding may occur on a small scale on-farm but if a sufficient area of crop is grown there is potential for downstream processing on a larger scale, such as a factory to process potatoes into crisps or frozen chip production.

Notes on Table G.6

It needs to be stressed that the data in Table G.6 is not suitable for planning or budgeting individual enterprises. This data was compiled solely as means of estimating the potential value of irrigated agriculture for the ALAs and is based on some broad assumptions. Decisions for an individual enterprise should be based on data that are more specific.

Those seeking information on crop water requirements need to treat the data in columns 6a and 6f with caution. They should make their own calculation using the Irrigation Calculator website (DAFWA 2010) or contact an irrigation consultant. Care needs to be taken when calculating crop water requirements to ensure that evaporation rate and soil types used are appropriate for the property in question. The irrigation proportion and efficiency also need to match the proposed crop layout and irrigation system.

The data showing crops and rotation values (columns 6a, 6b and 6c) are not appropriate for farm budgeting. They are based on broad assumptions about water use requirements (see preceding paragraphs), crop yields and market prices. The yield estimates are largely unproven in local conditions while market prices fluctuate greatly. The values presented in Table G.6 do not provide any guide to profitability of the different crops. They are based only on 'farm gate' prices and do not consider the cost of production in any way. A crop may have a large produce value but a low profit margin due to the high cost of inputs such as labour.

Further investigation of potential yields, costs and prices (or seeking professional advice) is advised to those considering establishing a horticultural enterprise in the Region.

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[91] In these cases, the maximum potential value of irrigated crops (column 5i) is calculated by multiplying the land suitable for irrigation in hectares (column 5h) by $67 956/ha. This value per hectare was derived from the data in Table 3.24 (i.e. $5192/ML multiplied by 0.0764 ha/ML).

Appendix H Determining ALA ranking and grouping

The ranking and grouping of the individual ALA and UCLs was undertaken using the data in Tables H.1 and H.5. The data were derived from Tables G.1, G.4 and G.5 in Appendix G. Some of this data was modified in accordance with observations made about each ALA in s 4.3.1 to s 4.3.29.

A subset of this data is presented in Tables 5.3 and 5.4 to provide a summary and comparison of each ALA and UCL.

Broadacre agriculture ranking

Table H.1 shows the data used to characterise the ALAs for broadacre agriculture and determine their potential value and ranking. The two UCLs have not been included as they are unlikely to be released for broadacre agriculture.

The ALA total area (column a), growing season rainfall (column c) and relative wheat yield (column e) and are taken directly from Table G.1. The percentage area of the ALA that is cleared (column b) is equal to 100 minus the percentage area of remnant vegetation (column 1f in Table G.1).

The potential value of broadacre agriculture in millions of dollars (column f) is the same as the crop value (column 1e in Table G.1).

The potential value of broadacre agriculture in thousands of dollars per hectare (column g) was calculated by multiplying the value in millions of dollars (column f) by 1000 and dividing the resultant value by the total area of the ALA (column a). As the total area incorporates both cleared land and remnant vegetation, this value is not always directly proportional to the relative wheat yield (column e) which was only calculated for cleared land.

The soil productivity category (column d) was based on the mean yield constants assigned to the soil landscape mapping units (s 3.3.1).[92] This was averaged across the cleared land within the ALA on an area basis as shown in Table H.2.

Though based on wheat production, soil productivity also provides a good guide to the suitability of the soil for irrigated crops.

[92] These yield constants are used in combination with the growing season rainfall to calculate the relative wheat yields. They are based on the capability rating wheat (production only).

Table H.1 **Data used for ALA/UCL potential broadacre agriculture values and rankings**

No.	Name	Total ha	Clear-ed %	Growing season rain mm	Soil prod-uct-ivity	Relative wheat yield t/ha	Broadacre agriculture: Potential value $m	Broadacre agriculture: Potential value $'000 /ha	Broadacre agriculture: Ranking
		a	b	c	d	e	f	g	h
1	Knobby Head	4 360	6	335	Low	0.76	0	0.01	6
3	Drummond's Crossing	5 200	75	322	Mod. low	1.73	2	0.34	4
5	Lefroy	16 900	90	324	Mod.	1.79	7	0.43	3
6	South Dongara	17 000	35	333	Low	1.29	2	0.12	5
7	Irwin Valley	15 000	90	339	Mod. high	2.14	8	0.51	1
8	Mt. Horner	20 700	91	331	Mod.	1.82	9	0.44	3
9	Allanooka	26 300	93	332	Mod.	1.79	12	0.44	3
10	Geraldton–Dongara	38 700	62	338	Mod. low	1.39	9	0.23	5
11	Greenough Flats	19 700	94	334	High	2.43	12	0.60	1
12	Casuarina Sandplain	86 400	93	311	Mod.	1.92	41	0.47	2
13	Ellendale–Eradu Valley	24 000	78	296	Mod.	1.58	8	0.33	4
14	Eradu East Sandplain	60 000	95	262	High	2.28	34	0.57	1
15	Mullewa	212 300	83	229	Mod. high	1.36	64	0.30	4
16	Pindar	169 000	83	212	Mod.	0.92	34	0.20	5
17	Naraling Hills	85 000	83	327	Mod. high	1.71	32	0.38	3
18	Eradu West Sandplain	45 300	93	284	High	2.41	27	0.59	1
19	Moresby Range	25 600	69	344	Mod. high	1.84	9	0.34	3
20	Northampton-Chapman	99 000	87	331	High	2.31	53	0.53	1
21	Yuna-Binnu Sandplain	86 000	92	274	High	2.13	44	0.52	1
22	Ajana-Yuna East Sandplain	208 000	78	244	Mod. high	1.69	73	0.35	3
23	Galena-Wandana	76 700	78	222	Mod. high	1.38	22	0.28	4
24	Ogilvie Road South	29 300	87	270	Mod. low	1.40	9	0.32	5
25	Horrocks coast	16 300	63	341	Mod.	1.77	5	0.29	4
26	Hutt River	65 200	79	312	Mod.	1.67	23	0.35	3
27	Christmas Hill	43 700	44	301	Mod. low	1.17	6	0.14	5
28	Gregory	25 800	63	307	Low	1.05	5	0.18	6
29	Kalbarri	1 400	13	269	Mod. low	1.37	0	0.05	6

Table H.2 **Soil productivity criteria**

Average yield constant	Soil productivity
> 1.20	High
1.99 – 1.20	Moderately high
0.90 – 1.00	Moderate
0.75 – 0.89	Moderately low
< 0.75	Low

The ranking for broadacre agriculture (column h) was based primarily on the relative wheat yield (column e) with an adjustment for the total value of potential production (column f). This adjustment takes into account the larger ALAs that make a significant contribution to production in the region despite their relatively low average yields.

First, a broadacre score was calculated using the following equation:

Broadacre score = relative wheat yield (t/ha) x 2.5 + total potential production adjustment

The total potential production adjustment was determined according to Table H.3.

Table H.3 **Total potential production adjustment**

Total value of potential production*	Total potential production adjustment
< $1 million	– 1.0
$1–5 million	– 0.5
$5–10 million	– 0.3
$10–20 million	0.0
$20–50 million	+ 0.3
> $50 million	+ 0.5

* Column f in Table H.1.

The ranking for broadacre agriculture was then determined from the broadacre score (Table H.4). Where the score exceeded 5.0, the ranking differentiated between ALAs with average relative wheat yields above and below 2.0 t/ha. This was to ensure that only the best performing land fell into the top ranking.

Table H.4 **Broadacre agriculture ranking criteria**

Ranking	Broadacre score* (from above equation)	Relative wheat yield† t/ha
1	> 5.0	> 2.0
2	> 5.0	< 2.0
3	4.0–5.0	Any
4	3.5–4.0	Any
5	2.5–3.5	Any
6	< 2.5	Any

* From equation above.

† Column e in Table H.1.

Irrigated agriculture ranking

Table H.5 shows the data used to characterise the ALAs for irrigated agriculture and determine their potential value and ranking.

Maximum potential value of irrigated agriculture (column b) and conservative potential value (column g) are taken from Table G.5 (column 5i and Colum 5j respectively).

Maximum potential value of agriculture irrigated from regional aquifer GLCs (column c) was obtained by multiplying the maximum regional aquifer volume (column 4h in Table G.4) by $5192[93] and dividing the resultant value by one million.

Maximum potential value of agriculture irrigated from local aquifer GLCs (column e) was obtained by multiplying the maximum local aquifer volume (column 4f in Table G.4) by $5192[94] and dividing the resultant value by one million.

Conservative potential value of agriculture irrigated from regional aquifer GLCs (column h) was obtained by multiplying the further 50% regional aquifer adjustment (column 4k in Table G.4) by $5192 and dividing the resultant value by one million.

Conservative potential value of agriculture irrigated from local aquifer GLCs (column j) was obtained by multiplying the 25% local aquifer adjustment (column 4g in Table G.4) by $5192 and dividing the resultant value by one million.

Where it was noted in the ALA information sheets that either the maximum or conservative regional or local aquifer values were likely to be over/underestimates, these relevant values were adjusted. Table H.6 shows the ALAs for which adjustments were required and the rationale for the adjustments.

Where the value of agriculture irrigated from regional aquifer GLCs required adjustment, both the maximum (column c) and conservative (column h) values were multiplied by the regional aquifer adjustment factor in Table H.6. This resulted in the adjusted maximum regional aquifer value (column d) and the adjusted conservative regional aquifer value (column i).

Where the value of agriculture irrigated from local aquifer GLCs required adjustment, both the maximum (column e) and conservative (column j) values were multiplied by the local aquifer adjustment factor in Table H.6. This resulted in the adjusted maximum local aquifer value (column f) and the adjusted conservative local aquifer value (column k).

The adjusted maximum value of irrigated agriculture (column l) was calculated by summing the maximum local and regional values (columns d and f). The adjusted conservative value of irrigated agriculture (column m) was calculated by summing the conservative local and regional values (columns i and k).

A single potential irrigated agriculture value in millions of dollars (column n) was calculated averaging of the adjusted maximum (column l) and conservative (column m) values.

The potential value of irrigated agriculture in thousands of dollars per hectare (column o) was calculated by multiplying the value in millions of dollars (column n) by 1000 and dividing the resultant value by the total area of the ALA (column b).

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[93] This is the estimated value of the selected enterprise mix irrigated by 1 ML of water per year (Table G.6).

[94] This is the estimated value of the selected enterprise mix irrigated by 1 ML of water per year (Table G.6).

Table H.5 **Data used for ALA/UCL potential irrigated agriculture values, rankings and grouping**

ALA/UCL			Maximum irrigated agriculture value					Conservative irrigated agriculture value					Value of irrigated agriculture				
				Regional aquifers only		Local aquifers only			Regional aquifers only		Local aquifers only				Average		
No.	Name	Area ha	Total $m	$m	Adj. $m	$m	Adj. $m	Total $m	$m	Adj. $m	$m	Adj. $m	Max. adj. $m	Cons adj. $m	$m	$'000/ha	Rank-ing
		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
1	Knobby Head	4 360	1	1	1	0	0	0	0	0	0	0	1	0	1	0.1	5
2	Arrowsmith River	38 400	107	106	106	1	1	18	18	18	0	0	107	18	62	1.6	1
3	Drummond's Crossing	5 200	335	329	329	6	6	4	3	3	2	2	335	4	170	32.3	1
4	Tompkins Road	10 200	329	329	329	0	0	5	5	5	0	0	329	5	167	16.4	1
5	Lefroy	16 900	350	329	329	21	21	14	9	9	5	5	350	14	182	10.8	1
6	South Dongara	17 000	25	19	10	6	1	5	3	2	1	0	11	2	7	0.4	3
7	Irwin Valley	15 000	405	392	392	13	13	10	7	7	3	3	405	10	207	13.8	1
8	Mt. Horner	20 700	72	44	44	28	28	15	8	8	7	7	72	15	44	2.1	2
9	Allanooka	26 300	188	150	0	37	0	20	11	0	9	0	0	0	0	0.0	5
10	Geraldton-Dongara	38 700	154	127	63	27	7	14	7	4	7	2	70	5	38	1.0	2
11	Greenough Flats	19 700	4	1	104	3	3	1	0	10	1	1	107	11	59	3.0	1
12	Casuarina Sandplain	86 400	116	24	24	93	23	29	6	6	23	6	47	12	30	0.3	2
13	Ellendale-Eradu Valley	24 000	47	24	12	23	6	6	1	0	6	1	18	2	10	0.4	3
14	Eradu East Sandplain	60 000	61	26	13	35	9	13	4	2	9	2	22	4	13	0.2	3
15	Mullewa	212 300	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	5

(continued)

Table H.5 continued

ALA/UCL			Maximum irrigated agriculture value					Conservative irrigated agriculture value					Value of irrigated agriculture				
				Regional aquifers only		Local aquifers only			Regional aquifers only		Local aquifers only				Average		
No.	Name	Area ha	Total $m	$m	Adj. $m	$m	Adj. $m	Total $m	$m	Adj. $m	$m	Adj. $m	Max. adj. $m	Cons adj. $m	$m	$'000/ha	Rank-ing
		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
16	Pindar	169 000	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	5
17	Naraling Hills	85 000	15	0	0	15	15	4	0	0	4	4	15	4	9	0.1	4
18	Eradu West Sandplain	45 300	28	0	0	28	7	7	0	0	7	2	7	2	4	0.1	4
19	Moresby Range	25 600	5	0	0	5	5	1	0	0	1	1	5	1	3	0.1	4
20	Northampton-Chapman	99 000	5	0	0	5	11	1	0	0	1	3	11	3	7	0.1	4
21	Yuna-Binnu Sandplain	86 000	1	0	0	1	1	0	0	0	0	0	1	0	0	0.0	5
22	Ajana-Yuna East Sandplain	208 000	1	0	0	1	1	0	0	0	0	0	1	0	1	0.0	5
23	Galena-Wandana	76 700	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	5
24	Ogilvie Road South	29 300	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	5
25	Horrocks coast	16 300	4	0	0	4	4	1	0	0	1	1	4	1	3	0.2	5
26	Hutt River	65 200	66	0	0	66	66	17	0	0	17	17	66	17	42	0.6	3
27	Christmas Hill	43 700	28	0	0	28	28	7	0	0	7	7	28	7	18	0.4	4
28	Gregory	25 800	13	0	0	13	13	3	0	0	3	3	13	3	8	0.3	4
29	Kalbarri	1 400	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	5

Table H.6 **Aquifer value adjustment factors**

ALA		Adjustment factor		
		Regional aquifer GLC	Local aquifer recharge estimate	
No.	Name	%	%	Rationale
6	South Dongara	50	25	Salinity issues reduce suitability of groundwater, especially in the west
9	Allanooka	0	0	Public Drinking Water Source Area unlikely to be developed for intensive agriculture due to land use restrictions
10	Geraldton–Dongara	50	25	Salinity issues reduce suitability of groundwater, especially in the west
11	Greenough Flats	10 000	—	Potential for irrigation from the Allanooka pipeline[95]
12	Casuarina Sandplain	—	25	Aquifer thickness and salinity may reduce suitable groundwater
13	Ellendale – Eradu Valley	50	25	ALA sitting on edge of aquifer, full GLC may not be accessible
14	Eradu East Sandplain	50	25	Aquifer thickness and salinity may reduce suitable groundwater
18	Eradu West Sandplain	—	25	Salinity issues reduce suitability of groundwater
20	Northampton–Chapman	—	200	Recharge to fractured rock aquifers appears to be underestimated

The irrigated agriculture ranking (column p) was then determined according to the criteria in Table H.7.

Table H.7 **Irrigated agriculture ranking criteria**

Irrigated agriculture ranking	Adjusted maximum potential value of irrigated agriculture from regional aquifers (column d in Table H.5)	Average potential value of irrigated agriculture (column n in Table H.5)
1	> $80 million	Any
2	$20–80 million	Any
3	$10–20 million	Any
3	< $10 million	> $30 million
4	< $10 million	$3–30 million
5	< $10 million	< $3 million

95 This adjustment of the one million dollar value shown in column k is based on the estimation by McGhie and Meaton (1999) that up to 1000 ha of the Greenough Flats could be irrigated with water piped from the Allanooka bore field. The value of production for this area would be around $68 million based on the data for the horticultural enterprise mix shown in Table 3.24. The likelihood of intense shade house production on the Greenough Flats means that the value of production could be significantly higher than the $67 956/ha calculated for the enterprise mix.

ALA grouping

Finally, the ALA grouping shown in Table 5.2 was determined using the irrigated agriculture ranking (column p from Table H.5) and broadacre agriculture ranking (column h in Table H.1) as shown in Table H.8.

Table H.8 **Grouping of ALAs**

Broadacre ranking (Column h from Table H.1)	**Irrigated ranking (Column p from Table H.5)**				
	1. Largest water resource for irrigation	**2. Moderate water resource for irrigation**	**3. Potential water resource for irrigation**	**4. Limited water resource for irrigation**	**5. Insignificant water resource for irrigation**
1. Highest yielding land for broadacre agriculture	Group A	Group A	Group C	Group C	Group C
2. Higher yields	Group A	Group B	Group C	Group C	Group E
3. Moderately high yields	Group B	Group B	Group D	Group E	Group E
4. Moderately low yields	Group B	Group D	Group D	Group E	Group E
5. Lower yields	Group D	Group D	Group E	Group F	Group F
6. Lowest yielding land for broadacre agriculture	Group D	Group D	Group E	Group F	Group G