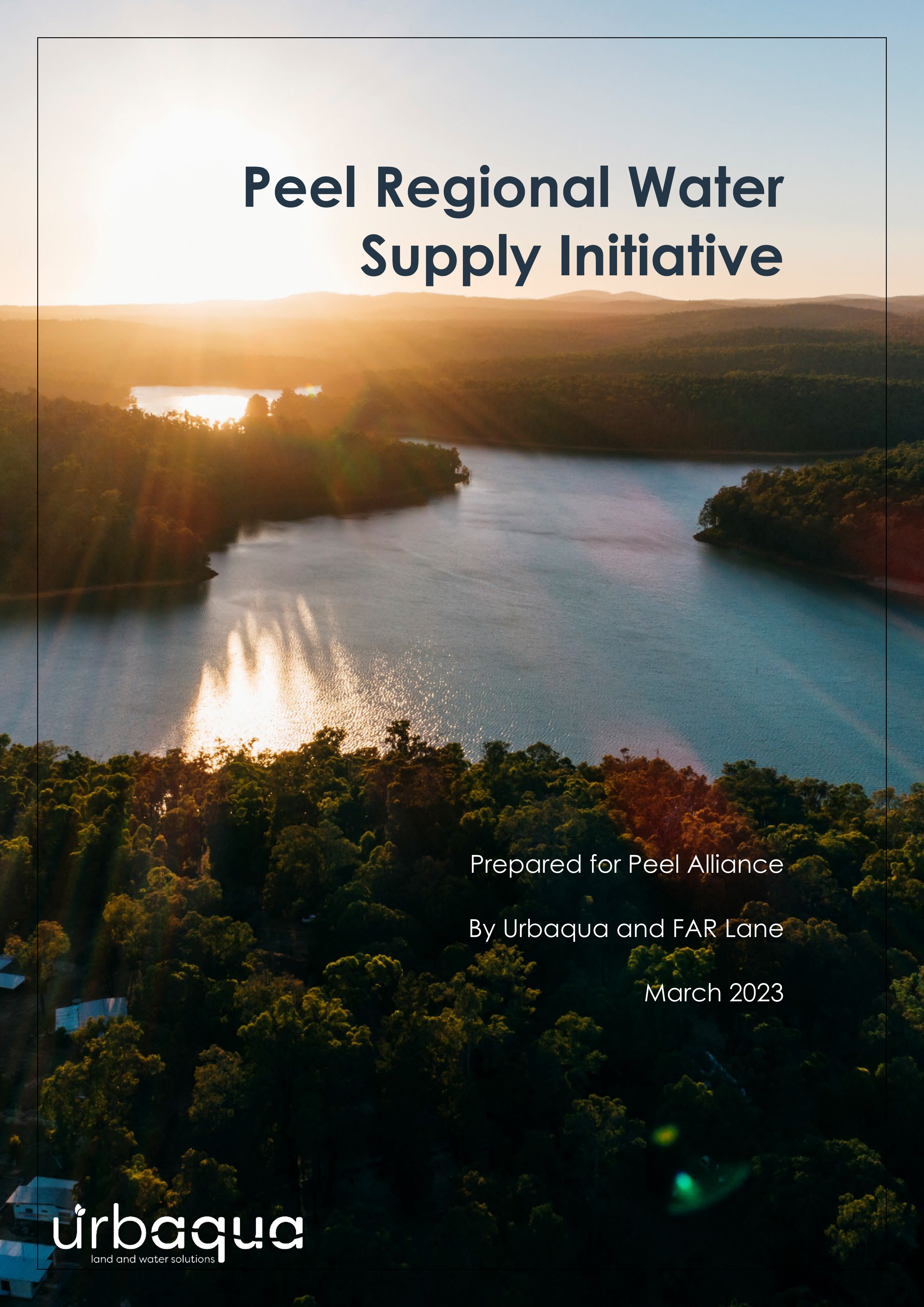

Peel Regional Water Supply Initiative

Prepared for Peel Alliance

By Urbaqua and FAR Lane

March 2023

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land and water solutions

Disclaimer and Limitation

Images: courtesy of Peel Alliance, DAFWA< PHCC and Urbaqua

From Peel Alliance

This project has been made possible by funding from Peel Alliance, Peel Development Commission, Department of Primary Industries and Regional Development, and Harvey Water.

We acknowledge and thank the representatives from the following organisations that worked with us collaboratively, providing their knowledge and expertise to develop a shared position on the outlook of the Peel Region's water demand and supply to 2050:

- Peel Development Commission (PDC)
- Department of Water and Environmental Regulation (DWER)
- Department of Primary Industries and Regional Development (DPIRD)
- Water Corporation
- Harvey Water
- Department of Planning, Lands and Heritage (DPLH)
- Department of Biodiversity, Conservation and Attractions (DBCA)
- Department of Local Government, Sport and Cultural Industries (DLGSC)

together with our Peel Alliance members:

- City of Mandurah
- Shire of Boddington
- Shire of Murray
- Shire of Serpentine Jarrahdale
- Shire of Waroona
- Peel-Harvey Catchment Council
- Regional Development Australia Peel
- Peel Community Development Group

Thank you Shelley Shepherd and Helen Brookes from Urbaqua, along with Jason MacFarlane and Giles Tuffin from FAR Lane Consulting, for undertaking this initiative on behalf of the Alliance.

Cr Mike Walmsley
Peel Alliance Chair

Funded by:

Department of Primary Industries and Regional Development, Government of Western Australia · Peel Development Commission · Peel Alliance · Harvey Water

Images: courtesy of Peel Alliance, DAFWA & PHCC and Urbaqua

Acknowledgement

Urbaqua would like to acknowledge the Bindjareb and Wilman Noongar people's continuing connection and custodianship of the Peel region's land and waters and pay our significant respect and thanks to the Bindjareb and Wilman people, past and present.

Executive summary

In October 2021, Peel Alliance members and stakeholders met to better articulate the water supply challenges facing the Peel region and develop a collective understanding of the problem. This included consideration of current and future residential and industry water demands, economic benefits, environmental and cultural water requirements, climate change impacts and total water cycle management and supply options. Workshop participants agreed to the following problem statement:

> *Currently accessible water is a finite resource that is being increasingly impacted by climate change. The Peel region has aspirations for its community, economy and environment that exceed currently accessible water resources with current business as usual practices.*
>
> *We need to understand how currently accessible water resources can be more sustainably and efficiently used, including redistribution if necessary; what the remaining gap is; what the options are to fill the gap; and what the associated costs are.*
>
> *We also recognise that there is unlikely to be a single solution due to the significant knowledge gaps and uncertainties associated with timing, changing community and environmental values and market considerations including net zero and willingness to pay. The continued commitment to collaborative delivery is therefore critical to achieve the desired outcome for the Peel region.*

This study was undertaken to provide a technical basis to support the collective understanding of the magnitude of the problem and assist in the identification of future strategies and actions that may be proposed to address the problem.

It provides an indication of the water needs of the community, industry, agriculture and the environment in 2021 and to 2051, having consideration of climate change, on the basis of agreed growth scenarios. It is a broad analysis only, providing a regional picture and is not intended to support planning or decision making at a local level. It has also been prepared with a number of assumptions which should be noted and have been outlined in various sections of the report.

Study area

The Peel Region is home to over 150,000 people, supports over 40,000 jobs and has an annual economic output of $23.325 billion (Remplan, 2022). It contains the five local governments of Boddington, Mandurah, Murray, Serpentine-Jarrahdale and Waroona, covering an area of approximately 5,500 square kilometres. Its key regional community centres include Mandurah, Pinjarra, Byford, Dwellingup, Falcon, Serpentine, Jarrahdale, Keysbrook, Dawesville, North Dandalup, Waroona, Boddington, Preston Beach and Lake Clifton.

The natural environment is a strong element of the Peel Region, with the Peel Inlet and Harvey Estuary and associated wetlands having environmental values of international importance. The natural environment is also a critical component of the regional economy, with recent work suggesting the total value of economic activity, social and health impact of the Peel Harvey waterways to be around $20.8 b with an annual economic benefit of $605.7m (Urbis, 2023).

A broadscale water balance of the region was developed to conceptually represent the flows of water into and out of the Peel Harvey system to assist in consideration of the effect of groundwater and surface water abstraction on flows to the estuary. This water balance indicates that streamflows from the waterways in the Peel Harvey system are a critical component of the flows into the estuary, with the Murray system providing the bulk of freshwater during the winter months. In the lower catchments, the flat, poorly drained landform creates large areas of surface storage of winter rainfall which makes its way into the shallow groundwater and eventually into the major waterways and the estuary. This contribution of groundwater to surface water from the broader catchment is considered critical to the health of the Peel Harvey Estuary. It is noted, however, that the major watercourses are showing a significant declining trend in stream flows in the upper catchments and there is a small declining trend in both surface water and groundwater storage within the lower catchments. Thus, even with no further changes of land use, vegetation cover or the climate in the catchments, continuing declines in groundwater levels and streamflows are expected.

Current water sources and demands of the Peel region

The water sources and supplies within the Peel region currently comprise groundwater, surface water, the Water Corporation's Integrated Water Supply Scheme (IWSS), Harvey Water, dams, rainwater tanks and treated wastewater.

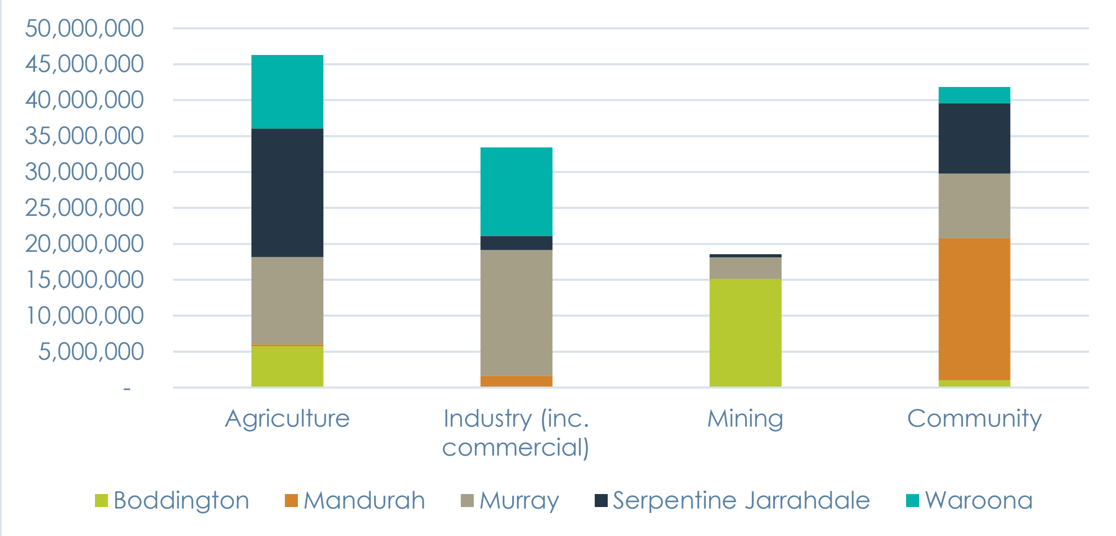
In 2021, the Peel Region had access to approximately 140 GL water from a range of sources to support the community, agriculture and industry. These are summarised in Summary Figure 1, Summary Figure 2, Summary Table 1 and Summary Table 2. This shows that currently, agriculture utilises 32%, the community 30%, industry including mineral processing and commercial uses comprises 24% and mining uses 14% of the total water demands, which are predominantly supplied by surface water (46%) and groundwater (42%) with scheme water comprising 11% and treated wastewater 1%.

Summary Table 1: Current water needs of the Peel Region

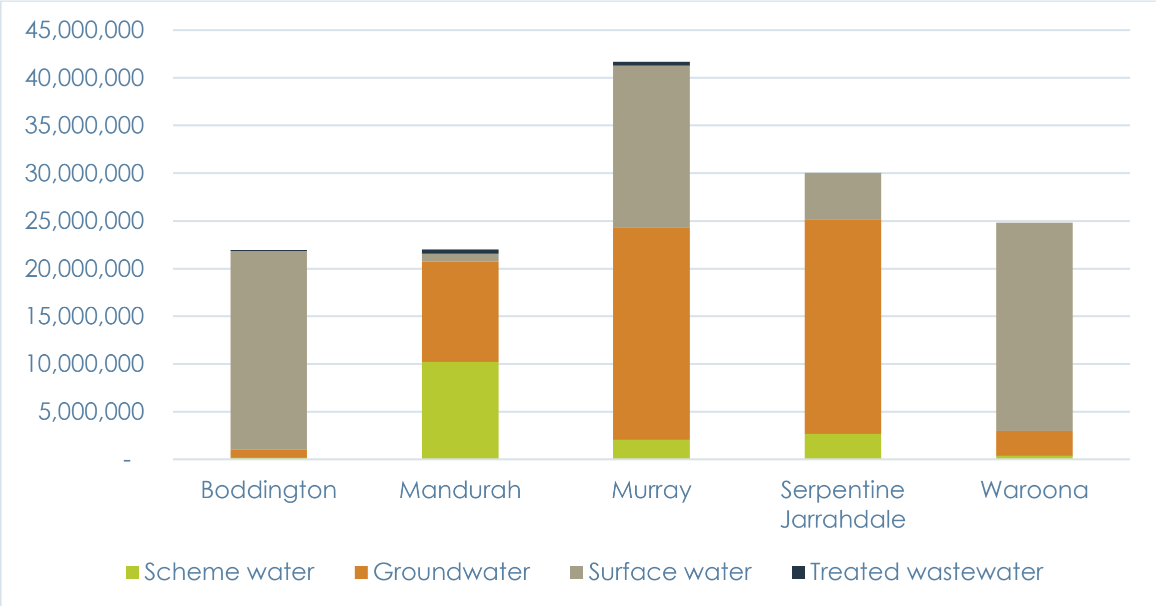
	Community	Agriculture	Industry (including commercial)	Mining	Totals
Boddington	1,031,537	5,757,804	43,164	15,132,900	**21,965,405**
Mandurah	19,755,215	242,585	1,567,673	12,500	**21,577,973**
Murray	8,995,888	12,176,144	17,541,403	2,962,597	**41,676,033**
Serpentine Jarrahdale	9,778,369	17,875,522	1,958,502	444,000	**30,056,393**
Waroona	2,284,365	10,242,571	12,301,416	0	**24,828,352**
Peel Region	**41,845,374**	**46,294,626**	**33,412,158**	**18,551,997**	**140,104,156**

Summary Table 2: Current water sources for the Peel Region

	IWSS	Groundwater	Surface water	Treated WW
Boddington	183,349	865,777	20,783,379	132,900
Mandurah	10,229,890	10,490,191	857,892	417,930
Murray	2,055,785	22,270,348	15,963,252	402,597
Serpentine Jarrahdale	2,638,630	22,516,467	4,163,076	0
Waroona	391,103	2,607,870	21,829,379	0
Peel Region	**15,498,757**	**58,750,653**	**63,596,978**	**953,427**



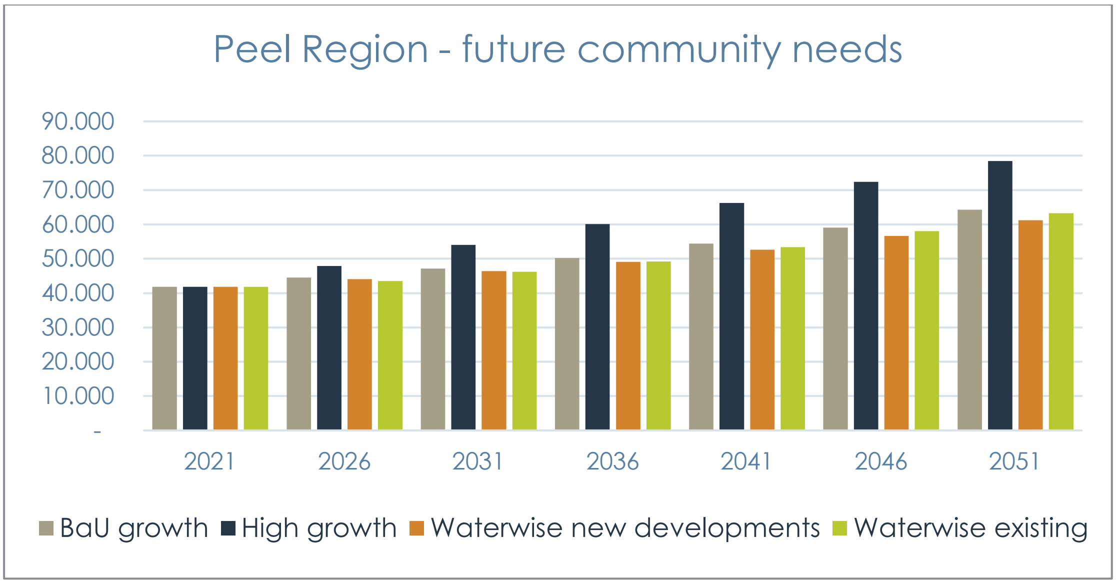
Summary Figure 1: Peel water needs summary by use and local government



Summary Figure 2: Current Peel water source summary

Future community, agricultural and industrial water needs

The key future water needs of the community include drinking water provided to new residential, commercial (including tourist) and industrial development through the IWSS, water for the irrigation of public open space and water for new peri-urban development. The estimation of demand was undertaken for agreed growth scenarios which represent business and usual (BAU) growth, high growth and future waterwise development. The results of the scenario analysis demonstrate that BAU growth will result in additional water demands of 22.5 GL by 2051 whereas the high growth scenario will need 36.6 GL. The water savings from 50% new residents having waterwise gardens is approximately 3.14 GL by 2051 and around 1.1GL from the waterwise retrofit of 30% existing gardens as shown in Summary Figure 3.

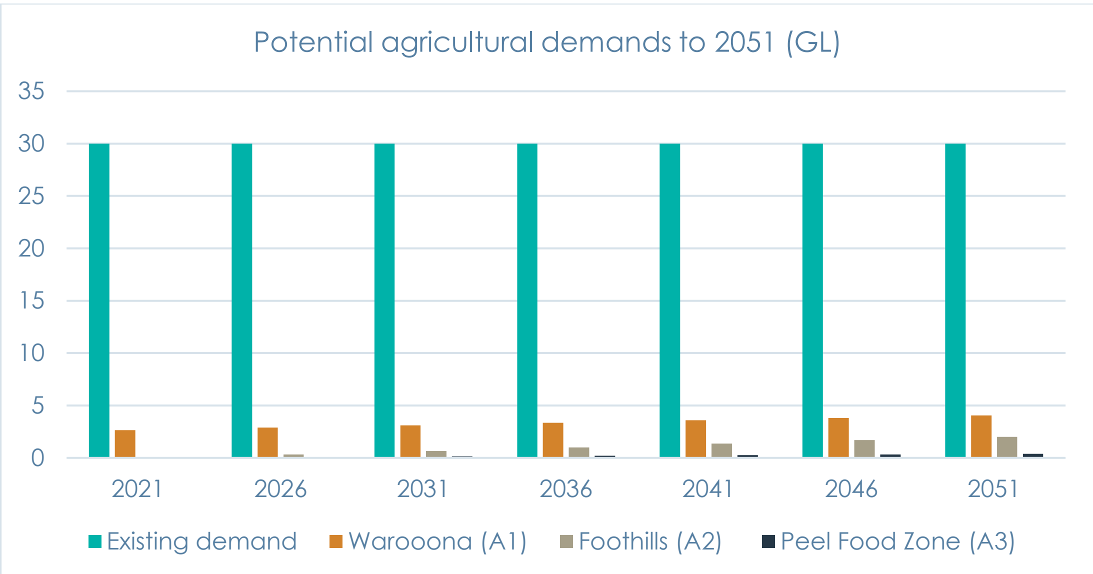


Summary Figure 3: Total community water demand for future scenarios (kL)

The future Peel agricultural water needs include the demands from existing irrigated agricultural areas and water captured by existing farm dams (currently approximately 30GL) plus the water required to support agricultural industry growth and the establishment of new areas of irrigated agriculture. The likely areas of growth were considered to be:

- Waroona Irrigation District - a change from irrigated pasture to perennial irrigated horticulture across 400 hectares by 2051 (scenario A1)
- North Dandalup to Serpentine foothills – development of 200 hectares of new intensive perennial irrigated agriculture by 2051 (Scenario A2)
- Peel Food Zone – 250 hectares of new closed-loop covered cropping by 2051 (Scenario A3)

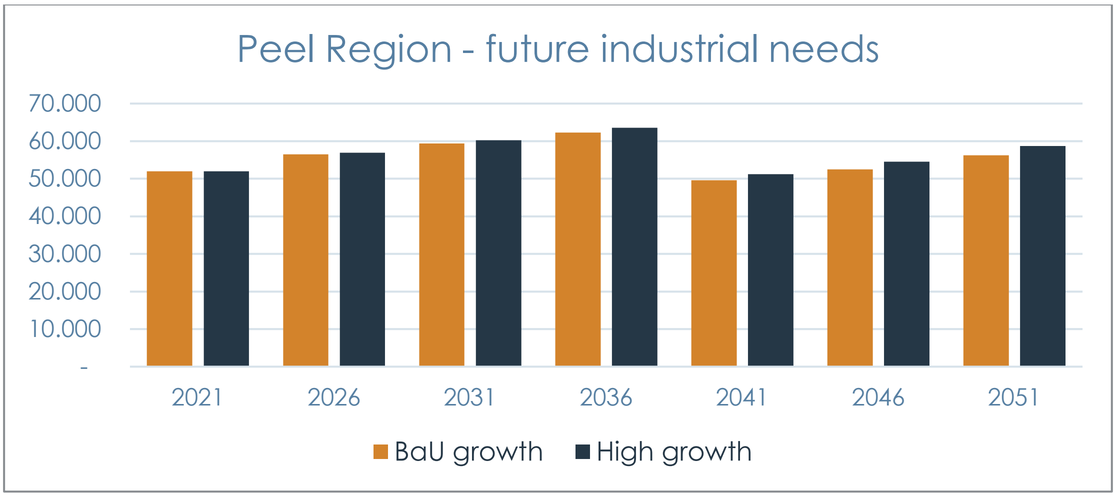
The demands for each scenario are shown in Summary Figure 4. The analysis indicates that, if all three scenarios were implemented, net water usage in the study area would increase by 6.46 GL in 2051.



Summary Figure 4: Potential agricultural demands to 2051 (GL)

Future industrial demands include growth in for population-driven industry in each local government area as well as growth in strategic industry and mining (as well as known mine closures), with the potential for emerging major water usage industries. The estimated growth in strategic industry considers the Industrial-zoned land available and the likely type of industry according to the location, however it is recognised that the water demands of industry are highly dependent on the nature of the future activity. Furthermore, there are some uncertainties associated with the future availability, particularly of surface water resources, so some broad assumptions were made to arrive at a future demand.

The scenario assessment suggested that future industrial needs of the Peel Region could increase to around 63 GL in 2036 then decline to between 57 and 59 GL in 2051. This is heavily influenced by the planned closure of the Newmont mine in Boddington in 2037.

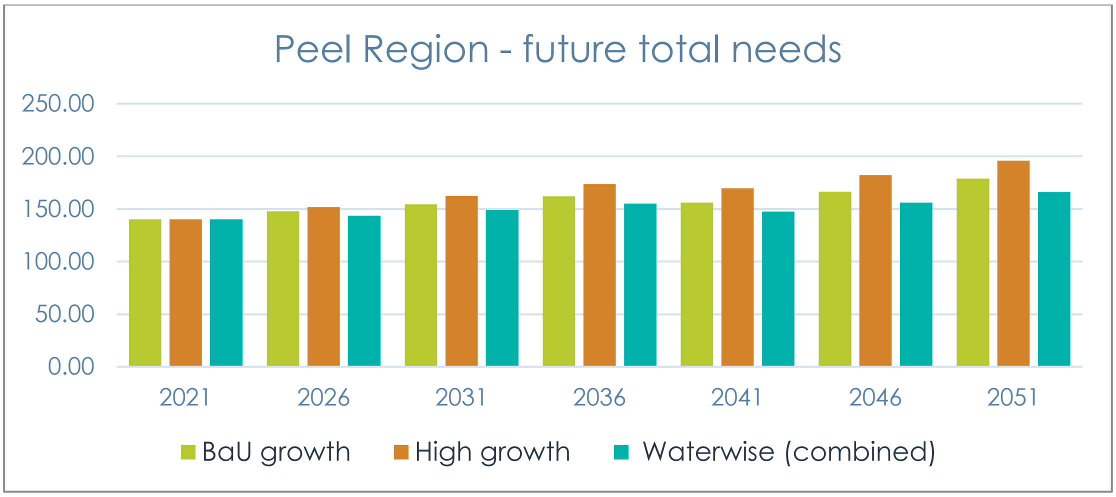


Summary Figure 5: Potential industrial demands to 2051 (GL)

The combined future water needs for the Peel Region are therefore estimated at:

- 179 GL for business-as-usual scenario
- 196 GL for the high growth scenario
- 166 GL for the waterwise scenario

noting the current baseline of 140GL.

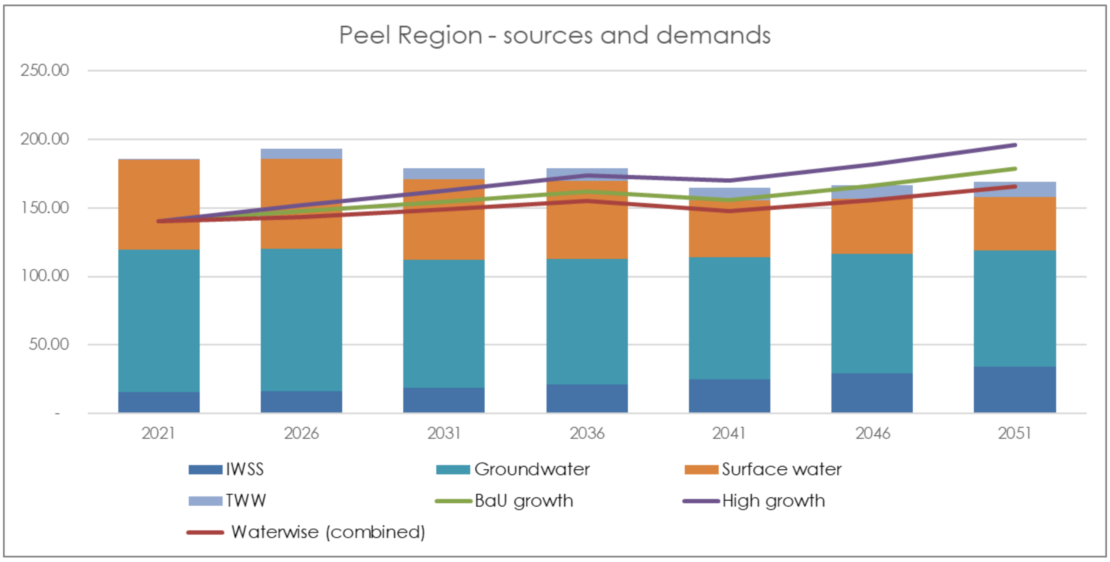


Summary Figure 6: Potential total demands to 2051 (GL)

Future environmental conditions and available water sources

This study reviewed the water source options currently available to meet the projected demand for the estimated growth in community, agricultural and industry needs. These include use of the IWSS to meet the future potable water needs of the community and population-driven industry; groundwater and surface water abstracted to available limits and the use of treated wastewater to the capacity of existing wastewater treatment plants.

Considering these sources at a regional level suggests that sufficient water is available (in 2021) to meet the future community, industrial and agricultural needs to 2051 under the waterwise scenario, to 2046 under BAU and to 2036 in the high growth scenario (Summary Figure 7).



Summary Figure 7: Future currently available water sources & demands of the Peel Region (GL)

This is not an accurate reflection of availability vs demand, however, as the location of the available sources **does not** align to the location of the demands, as indicated by the assessment at local government level which indicates that the Shire of Boddington will have insufficient readily available water supplies in 2026, followed by the Shire of Murray soon after 2031.

It is also recognised that there are significant existing constraints associated with obtaining access to some of these sources. The Department of Water and Environmental Regulation Water Register currently indicates that groundwater is available for allocation in some areas of Serpentine Jarrahdale, Murray and Waroona. However, the majority of this available water resource is in the Superficial Aquifer and significant yield limitations are likely for this resource in areas of clay soils. This means that it may not be possible to abstract groundwater up to the current allocation limit. Abstraction in the coastal superficial aquifer is also challenging as this area is prone to saline intrusion which is more likely as allocation limits are approached and sea level rise continues. In addition, 100% of wastewater generated/collected will not necessarily be available for reuse due to increasing competition for access to wastewater, infrastructure constraints and collection methodologies.

It is also noted that the water resources required to sustain the significant water-dependent environmental assets of the Peel Region will change in future, largely in response to changes to rainfall and evapotranspiration. This study has shown that the potential overall reduction in streamflows to the Peel Harvey Estuary by 2050 (~260 GL) due to climate change is significantly larger than the current level of surface water and groundwater abstraction combined

(~120 GL). This means that in a future climate, current freshwater flows into the Peel-Harvey system could not be maintained, even if all abstraction were to cease. This is likely to have significant implications for the health of the estuary over time.

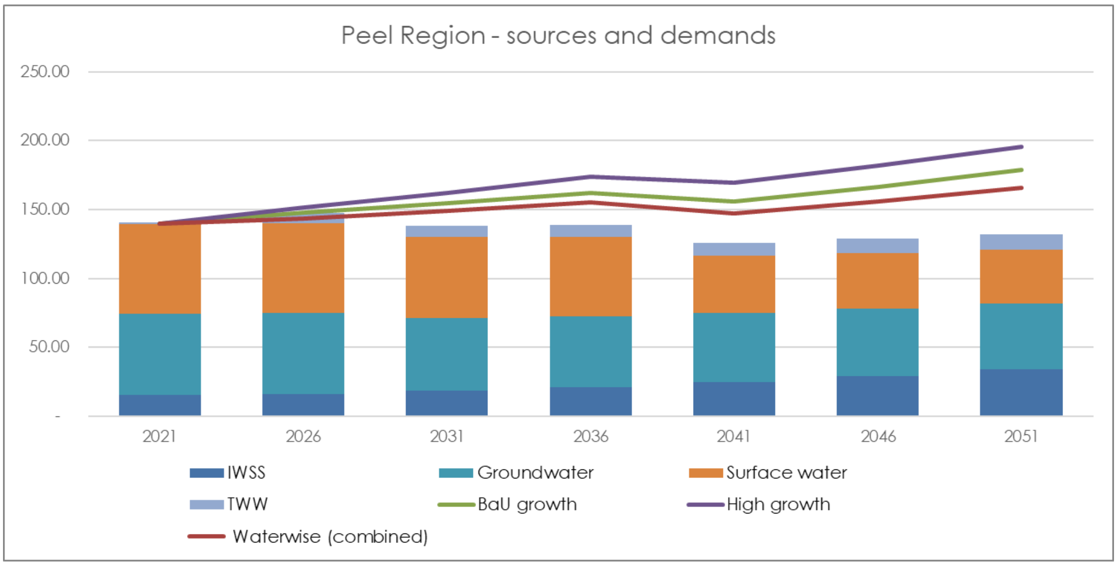
Therefore, impacts on estuary health may be exacerbated by any further abstraction from the superficial aquifer (even up to currently available limits) due to the nature of the connection between surface water and groundwater and the significant contribution of groundwater to streamflow in the Peel Harvey system.

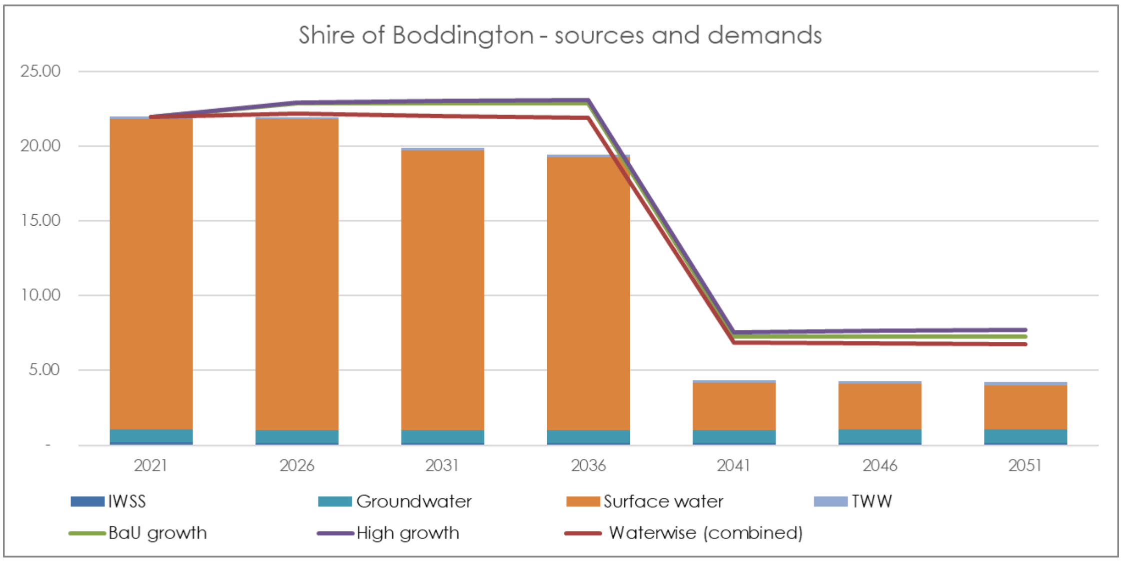
To account for the degree of impact of climate change on environmental flows, this study assessed a further scenario in which surface water abstraction is maintained at 2021 levels, groundwater allocation limits are maintained at 2021 levels to 2030, and then reduced by 10%, then reduced incrementally to reach a further 10% reduction by 2050. This scenario (labelled as Scenario E5 in the report) also addresses the recognised difficulty in accessing the currently available groundwater resources and acknowledges that it is unlikely that the currently remaining allocation can be accessed. It is also considered that this scenario most closely represents the current policy climate for management of groundwater and surface water resources, and while this scenario continues to see a declining trend in groundwater storage within the catchments and streamflow to the estuary (~290 GL by 2050), there is a small increase in surface water storage which reduces the potential for loss from waterways to the groundwater.

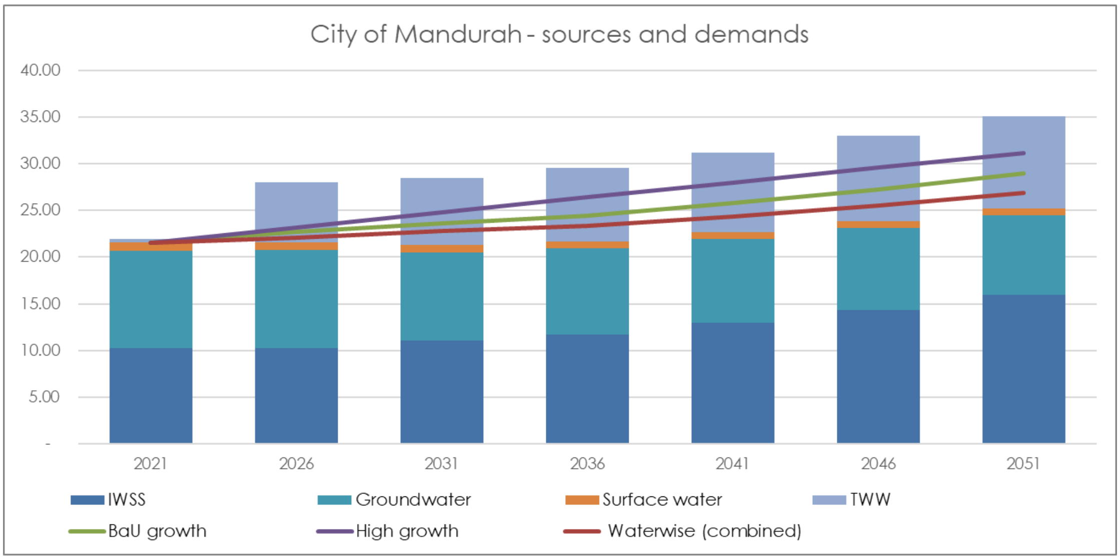
The analysis of this scenario suggests that the Peel Region will run out of currently available sources of water within the next few years and highlights the significant gaps in all local government areas except Mandurah (see Summary Table 3 and graphs below). A spatial representation of these supply gaps and currently utilised source options is provided in the report in Figure 54 and Figure 55.

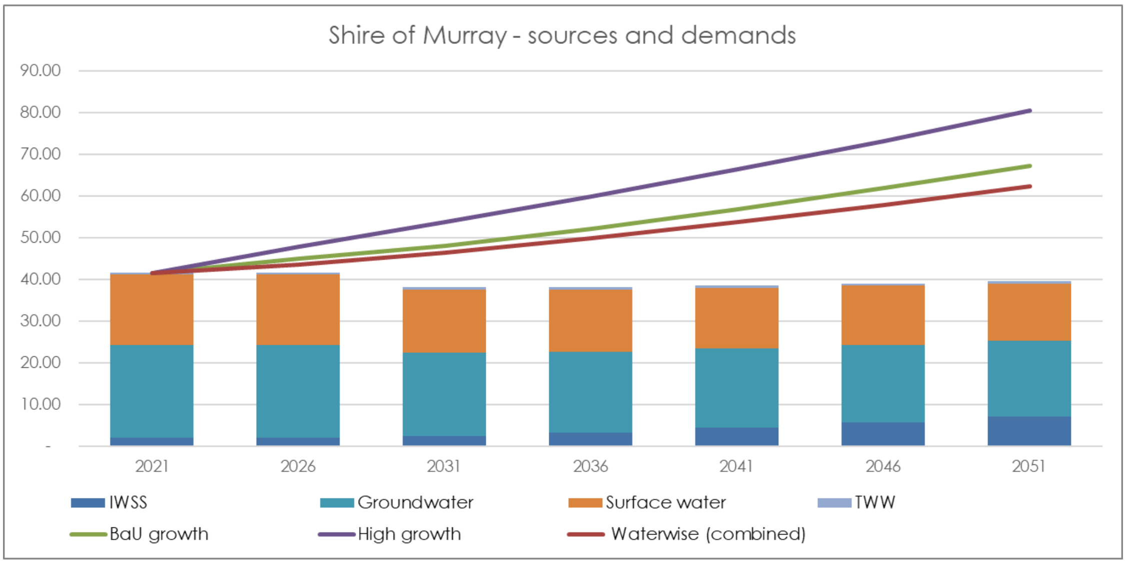
Summary Table 3: Available water sources for each growth scenario at 2051 under scenario E5

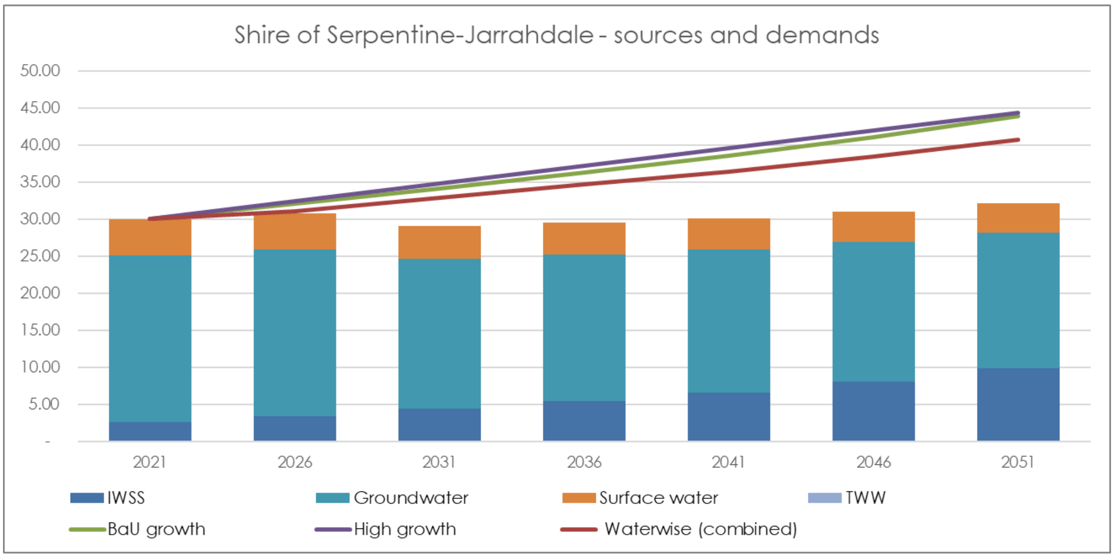
Local government	BaU	High growth	Waterwise
Boddington	-3.03	-3.49	-2.56
Mandurah	6.11	3.89	8.01
Murray	-27.69	-40.85	-23.28
Serpentine Jarrahdale	-11.67	-12.18	-8.80
Waroona	-10.26	-11.00	-8.21
Total (GL)	**-46.55**	**-63.63**	**-34.85**

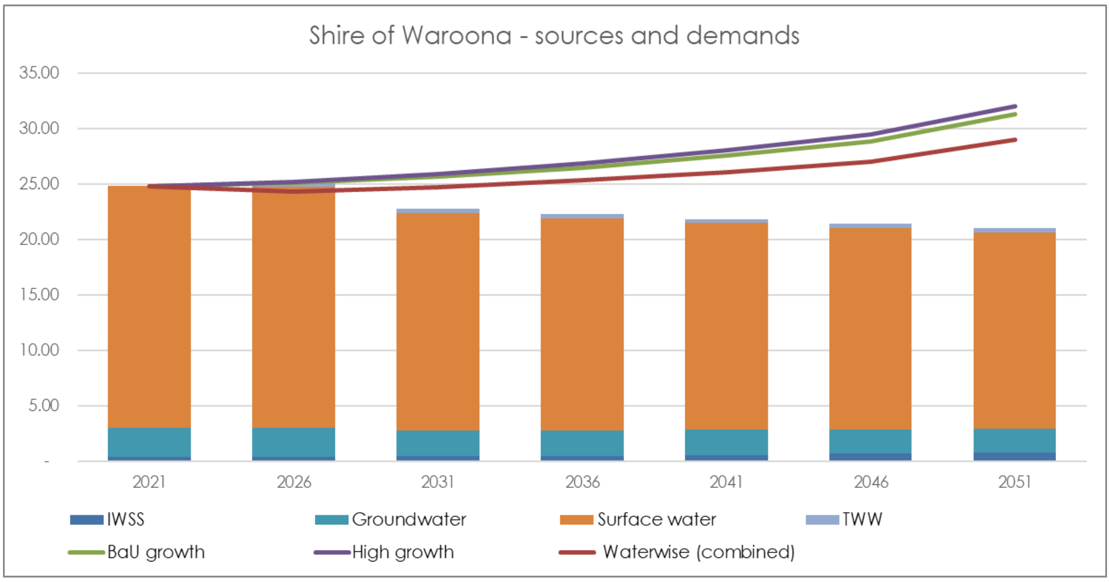

Peel Region - sources and demands
250.00
200.00
150.00
100.00
50.00
-
2021
2026
2031
2036
2041
2046
2051
IWSS
Groundwater
Surface water
TWW
BaU growth
High growth
Waterwise (combined)


Shire of Boddington - sources and demands
25.00
20.00
15.00
10.00
5.00
-
2021
2026
2031
2036
2041
2046
2051
IWSS
Groundwater
Surface water
TWW
BaU growth
High growth
Waterwise (combined)


City of Mandurah - sources and demands
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
2021
2026
2031
2036
2041
2046
2051
IWSS
Groundwater
Surface water
TWW
BaU growth
High growth
Waterwise (combined)


Shire of Murray - sources and demands
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
-
2021
2026
2031
2036
2041
2046
2051
IWSS
Groundwater
Surface water
TWW
BaU growth
High growth
Waterwise (combined)


Shire of Serpentine-Jarrahdale - sources and demands
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
2021
2026
2031
2036
2041
2046
2051
IWSS
Groundwater
Surface water
TWW
BaU growth
High growth
Waterwise (combined)


Shire of Waroona - sources and demands
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
2021
2026
2031
2036
2041
2046
2051
IWSS
Groundwater
Surface water
TWW
BaU growth
High growth
Waterwise (combined)

Towards a sustainable water future in the Peel Region

As stated previously, the availability of water sources into the future is heavily dependent on the likely impacts of climate change and water resource management regimes. Key considerations when planning for a sustainable water future include:

- The environmental values of the Peel region are significant, and the environment is already under stress. The level of environmental stress will only increase with the increasing impacts of climate change and is likely to become critical in response to any increased use of surface water or groundwater resources.
- There is some uncertainty associated with access to currently available groundwater resources within the superficial aquifer and further drawdown of this aquifer will reduce streamflows to the estuary.
- The viability of surface water resources will decline into the future and where possible, strategic releases of surface water to the environment may help to manage some of the impacts of climate change.
- Maximising use of recycled wastewater is an important opportunity that should be investigated as soon as possible.
- Alternative sources of water (including recycled water) are available, but these are generally complex and likely to cost more than current options. These solutions are more likely to succeed through collaborative partnerships that are flexible.

This report has identified the likelihood of significant water source shortfalls in the water requirements of the future community, agricultural and industrial growth and development within the Peel Region. It has considered the impact of climate change and the current water management regime on the environment, and particularly the internationally recognised Peel-Yalgorup Ramsar site. It is imperative that alternative sources of water are investigated by the Peel Alliance in partnership, so that any future solution considers the critical conditions together with the broad range of objectives and settings. This should include the consideration of any actions that can enhance environmental flows to and within the waterways of the Peel-Harvey Estuary (although our modelling has demonstrated the difficulty in achieving this objective).

It is therefore recommended that consideration is given to the following next steps:

- Consult with the Bindjareb and Wilman Noongar people to listen and share knowledge of the water resource needs, environmental conditions and likely impacts in order to improve management recommendations and outcomes.
- Each local government to continue optimising their current water source entitlements through identifying current sources, future needs, future water transfers (from developers), optimum supply network configuration and prioritisation of assets for irrigation.
- Continue to collaborate to develop collective and integrated solutions that can adapt to changing environmental conditions and development priorities.
- Seek further guidance on the viability of local and regional options including volumes, reliability, infrastructure and operational costs and arrangements, while meeting the principles to protect the Peel Harvey.
- Undertake detailed local, technical studies to prove sources.
- Develop a formal adaptive management framework to monitor environmental conditions, water supply sources and assess future demands which enables necessary responsive actions.

CONTENTS

Appendices

Figures

Tables

Section 1: Introduction

1 INTRODUCTION

In October 2021, Peel Alliance members and stakeholders met to better articulate the water supply challenges facing the Peel region and develop a collective understanding of the problem. This included consideration of current and future residential and industry water demands, economic benefits, environmental and cultural water requirements, climate change impacts and total water cycle management and supply options. Workshop participants agreed to the following problem statement:

> *Currently accessible water is a finite resource that is being increasingly impacted by climate change. The Peel region has aspirations for its community, economy and environment that exceed currently accessible water resources with current business as usual practices.*
>
> *We need to understand how currently accessible water resources can be more sustainably and efficiently used, including redistribution if necessary; what the remaining gap is; what the options are to fill the gap; and what the associated costs are.*
>
> *We also recognise that there is unlikely to be a single solution due to the significant knowledge gaps and uncertainties associated with timing, changing community and environmental values and market considerations including net zero and willingness to pay. The continued commitment to collaborative delivery is therefore critical to achieve the desired outcome for the Peel region.*

This study was undertaken to provide a technical basis to support the collective understanding of the magnitude of the problem and assist in the identification of future strategies and actions that may be proposed to address the problem.

1.1 Study area

The study area is the Peel Region, designated as the local governments of Boddington, Mandurah, Murray, Serpentine Jarrahdale and Waroona (Figure 1).

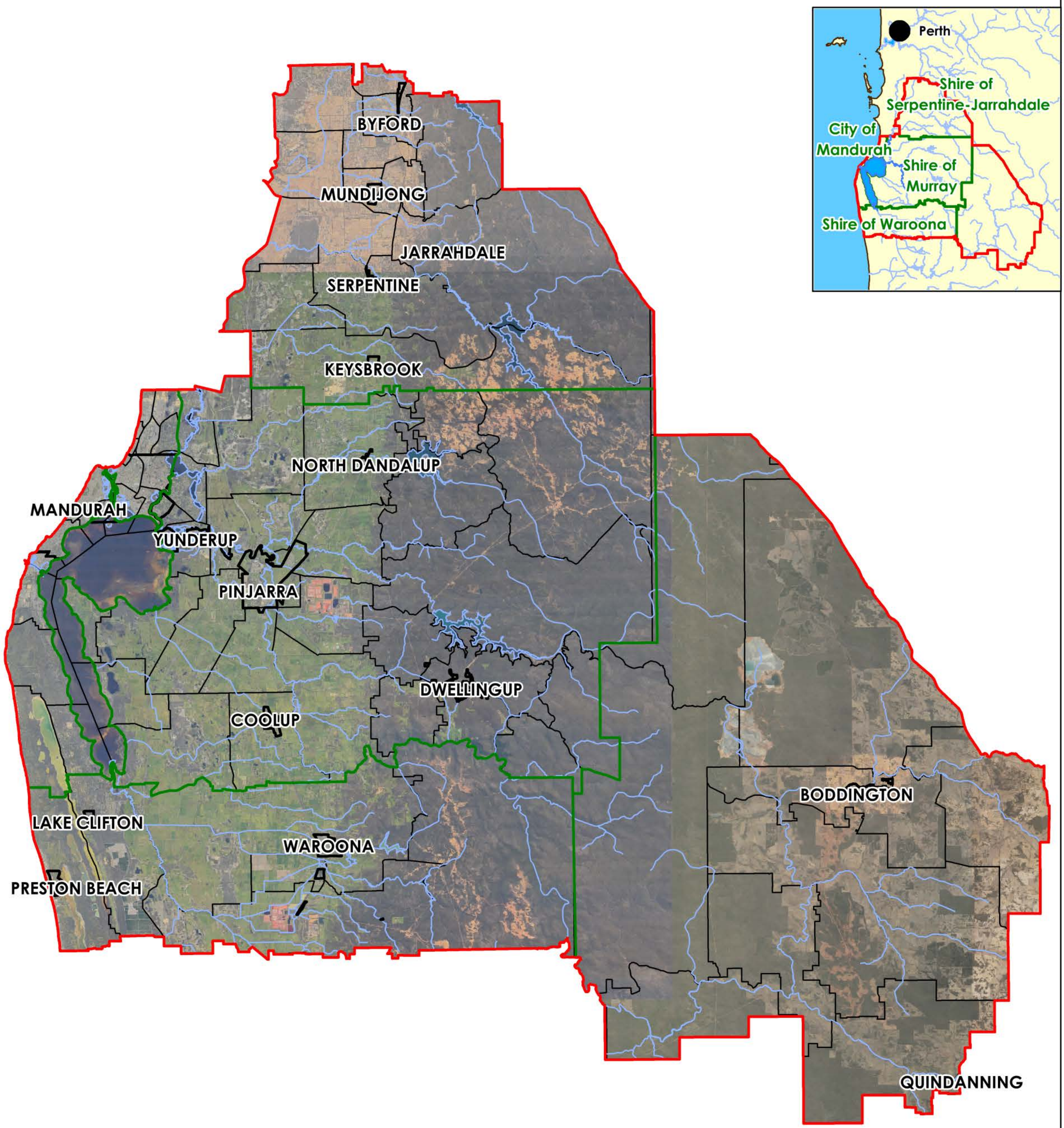
1.2 Preparation of the report

The information contained within this report has been sourced from publicly available sources or has been provided by key stakeholders. The information was accurate at the time of receipt but may need to be updated to reflect changes in use and allocation data in future. No effort has been made to validate the data provided by agencies.

The project team has consulted with each of the five local governments, the Water Corporation, Harvey Water, Department of Primary Industries and Regional Development (DPIRD), Department of Biodiversity, Conservation and Attractions, Department of Planning, Lands and Heritage, Department of Water and Environmental Regulation (DWER), the Peel Harvey Catchment Council and the Peel Development Commission during preparation of this report.

The scenarios assessed in this report were agreed by representatives of the stakeholder agencies at a workshop in October 2022.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 1 - Study area



LEGEND:
Study area
Local government boundaries
Townsites

0 20
kilometres
Scale 1:500,000 @ A4

Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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The report has also been prepared having consideration of the following statements provided by the Client:

- The desired outcome is the sustainable management of water for community, environmental and economic needs in the Peel Region to support the delivery of organisational goals.
- The planning horizon is to 2050, but staged consideration and planning will be critical, noting the considerable uncertainty associated with the possible future water needs and availability.
- Future estimation of water demands and availability will also need to consider the impacts of climate change and water's role in both causing and mitigating these impacts.
- While the project is focussed on the Peel Region, this should not preclude the consultant from considering solutions beyond the Peel Region (ie: Binningup/ Wellington).

1.3 Guiding policy, strategy and legislation

1.3.1 Legislation

Rights in Water and Irrigation Act 1914

The main state legislation that governs water resource management is the Rights in Water and Irrigation Act 1914 (RIWI Act) with DWER responsible for issuing licences and permits under the RIWI Act.

A licence issued by DWER is the main regulatory instrument governing the abstraction of surface and ground water. Each licence defines an annual right to take water (an individual annual entitlement or allocation) and sets conditions that apply to the allocation. DWER operates a first-in-first served approach to prioritising applications for water entitlements and it is recognised that this approach may not produce the best outcomes as a water resource approaches full allocation, as it does not direct water to the highest value use (DoW, 2011). Water is currently reserved for future public water supply, to meet the state's obligations under State Agreement Acts and to acknowledge unlicensed (legal) water use, but is not able to be reserved for specific future water uses through the water allocation planning process (DoW, 2011). Water entitlements are, however, able to be traded under the RIWI Act and potential trading partners are able to be identified from DWER's Water Register, consistent with the DWER *Policy: Water entitlement transactions for Western Australia* (DWER, 2020).

The RIWI Act also requires that water be set aside to sustain the environment. DWER prepares water allocation plans which state how much water can be taken for consumptive use, while leaving sufficient in the environment to meet in situ ecological and recreational or cultural needs. These plans, along with water source protection plans, prepared by DWER and the Water Corporation, include objectives and policies that the department takes into account when planning at strategic and operational levels.

Permits (related to the disturbance of beds and banks) and licences (for the taking and use of water) are required within proclaimed areas. The protection of water resources in the planning area is covered under the *Country Areas Water Supply Act 1947* and the *Metropolitan Water Supply Sewerage and Drainage Act 1909*. For information on water allocation plans see www.water.wa.gov.au/Managing+water/Allocation+planning/default.aspx.

Under the *Waterways Conservation Act 1976*, management areas may be set aside for the conservation of watercourses and associated lands. Five management areas have been established in WA, including the Peel/ Harvey Estuaries and associated rivers. Under this Act, the responsible minister can also use a licensing system to control the disposal of material into waterways.

The State Government is currently working on a program of Water Reform and is currently drafting the Water Reform Bill. While it is not expected that the Bill recommends major changes to the water allocation system, it may provide more flexibility to address climate change and changing requirements of the environment, industry and the community.

Environmental Protection Act 1986

The *Environmental Protection Act 1986* provides for:

- the identification of statutory environmental values and environmental quality criteria to be protected as part of Environmental Protection Policies (EPPs), with the most relevant policy being *the Environmental Protection (Peel Inlet - Harvey Estuary) Policy 1992* (see below); and
- the assessment of proposals which may have a significant impact on the environment and the setting of statutory conditions by the Minister for the Environment.

Other key relevant legislation includes:

- *Biosecurity and Agriculture Management Act 2007*
- *Planning and Development Act 2005*
- *Mining Act 1978*

1.3.2 Strategy

Perth and Peel @ 3.5million, principally the South Metropolitan Peel Sub-regional Planning Framework (WAPC, 2018)

The Perth and Peel @ 3.5million land use planning and infrastructure frameworks were released by the Western Australian Planning Commission in 2018. They aim to accommodate 3.5 million people in the Perth and Peel regions by 2050 by identifying areas for future development and intensification, key infrastructure upgrades and areas for environmental protection. The frameworks contain recommendations for increases in greenfield and infill dwellings for each local government in defined areas to accommodate the estimated population growth.

Bindjareb Djilba: A plan for the protection of the Peel-Harvey estuary

Bindjareb Djilba: A plan for the protection of the Peel-Harvey estuary (DWER, 2020) collates actions across the estuary and its catchment and asks for many groups to work together to protect the Peel-Harvey estuary for future generations. Actions are grouped into four work areas: Catchment; Estuary; Plans, Policy and Partnerships; and Measuring Progress.

Estuary actions (E) include the following actions aimed at developing a better understanding of the environmental water requirements of the estuary, as well as how to best respond to the risks posed by climate change:

- Action E7: Undertake an environmental water requirements study for the estuary to inform water licensing and abstraction decisions.

- Action E8: Assess estuary response to climate change and identify adaptation strategies.

Water quality improvement plan

The EPA's 2008 Peel-Harvey water quality improvement plan *(WQIP)* addresses catchment management measures and control actions for phosphorus. It was developed to meet the objectives of the *Environmental protection (Peel Inlet-Harvey Estuary) policy 1992* (Government of Western Australia 1992), with the following aim:

- improve water quality by reducing phosphorus discharges from the catchment through changes to agricultural and urban practices and land use planning

The WQIP establishes that the river flow objective for tidal reaches of Serpentine, Murray and Harvey Rivers to maintain current flow variability.

The WQIP also sets aspirational objectives within the catchment to protect wetlands and floodplains (to mimic natural inundation and drying patterns) and minimise the effect of damming on water quality (to mimic natural frequency, duration and seasonal flow).

The WQIP goes on to acknowledge the likely future climate change impacts to flows and notes that:

> *"The Environmental Protection Authority considers that returning flows to their original state is both impractical and unattainable. With the current drying climate further flow reductions are inevitable.*
>
> *The Environmental Protection Authority also considers that if studies show that a peak water flow event is needed for the health of the rivers then the Water Corporation should be required to release flows as permitted under their legislation.*
>
> *This is most likely to be triggered by an ecological need of the in-stream flora and fauna."*

1.3.3 Policy

Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992

Environmental Protection Policies (EPPs) are statutory policies developed under Part III of the *Environmental Protection Act 1986* (EP Act). They are whole-of-Government policies that are ratified by Parliament and have the force of law from the day they are published in the Western Australian Government Gazette.

Environmental Protection (Peel Inlet - Harvey Estuary) Policy (The Peel Harvey EPP) was gazetted in 1992 as a legislative framework to allow for catchment management initiatives in the policy area. The purpose of the Peel Harvey EPP is:

- to set out environmental quality objectives for the Estuary which if achieved will rehabilitate the Estuary and protect the Estuary from further degradation; and
- to outline the means by which the environmental quality objectives for the Estuary are to be achieved and maintained.

State Planning Policy 2.9: Planning for Water (draft, 2020)

Draft SPP 2.9 and Guidelines were prepared under Part Three of the *Planning and Development Act 2005* and apply to proposals prepared and assessed under the Act. Once gazetted, the new SPP 2.9 and Guidelines will supersede:

- SPP 2.1 Peel-Harvey Coastal Plain Catchment
- SPP 2.2 Gnangara Groundwater Protection
- SPP 2.3 Jandakot Groundwater Protection
- SPP 2.7 Public Drinking Water Source Policy
- SPP 2.9 Water Resources
- SPP 2.10 Swan-Canning River System
- the policy measures that address flooding within SPP 3.4 Natural Hazards and Disasters
- the Government Sewerage Policy
- Better Urban Water Management

In addition to general water resource management measures that apply statewide the policy contains specific area measures relating to development within the coastal plain catchment of the Peel-Harvey estuary. These measures include a requirement to have regard to the water quality objectives contained in *Environmental Protection (Peel Inlet – Harvey Estuary) Policy Approval Order 1992* for the Peel Harvey estuarine system.

Environmental Water Provisions Policy

Environmental Water Provisions Policy for Western Australia (WRC, 2000) describes the approach to be followed by DWER (formerly the Water and Rivers Commission) in determining how water will be provided to protect ecological values when allocating the rights to use water in Western Australia. The policy lists the guiding principles to be followed when making such decisions and outlines a water allocation planning framework in which these principles are to be applied.

The primary objective of this policy is:

- to provide for the protection of water dependent ecosystems while allowing for the management of water resources for their sustainable use and development to meet the needs of current and future users.

Environmental Water Provisions Policy for Western Australia (WRC, 2000) also provides the following definitions that are applied in this study:

> ***Ecological Water Requirements (EWRs)*** *are the water regimes needed to maintain ecological values of water dependent ecosystems at a low level of risk.*
>
> ***Environmental Water Provisions (EWPs)*** *are the water regimes that are provided as a result of the water allocation decision-making process taking into account ecological, social and economic impacts. They may meet in part or in full the ecological water requirements.*

Other key relevant policies include:

- State Planning Policy 2.4: Planning for Basic Raw Materials and the Planning for Basic Raw Material Guidelines (2021)
- State Planning Policy 2.5: Rural Planning and the Rural Planning Guidelines (2016)

1.3.4 Other key sources of information

Other key sources of information used in the preparation of this report include:

- Local Government documents including the Local Planning Strategy, Strategic Community Plan, Corporate Business Plan and Long-term investment plan
- Id forecasts for population and economic growth
- Water allocation and licensing data, dated July 2022
- Water Corporation CIP Planned assets database
- Transform Peel, Peel Integrated Water Initiative reports (various, DWER, 2021)
- Murray drainage and water management plan and accompanying reports, Department of Water, 2011
- Regional analysis of the potential for sustainable groundwater, water efficiency, water entitlement transactions and alternative water supplies to meet future non-potable water demand in Perth and Peel (Waterwise Perth Action Plan - Action 29, 2021 unpublished)
- Assessment of land, water and community wellbeing outcomes for public open space in Perth and Peel @ 3.5 million (Urbaqua for Department of Local Government, Sport and Cultural Industries, 2021, unpublished
- Balancing estuarine and societal health in a changing environment: Summary Report (Valesini et al, 2019)
- The changing hydrology of the Peel-Harvey Estuary: past, present and future. Balancing estuarine and societal health in a changing environment (Huang et al, 2019)
- Planning for the Peel Food Zone, Department of Primary Industries and Regional Development, Heather Percy,2020.
- High quality agricultural land in Western Australia – a new decision tool for planning, Dennis van Gool, Angela Stuart-Street and Peter Tille, Department of Agriculture and Food, Western Australia, 2014

1.4 Key assumptions

Readers of this report should note the findings and conclusions are made on the basis of a number of assumptions. While these are outlined in the body of the report as well as the appendices, some of the more critical are summarised below.

- As the timing for receipt of water resource allocation and servicing information was in 2021, this is the baseline for the analysis.
- Current populations are based on ABS Census figures for 2021
- Future population growth was estimated on the basis of available predictions. Where Forecast ID predictions were not available, data was taken from WA Tomorrow and Local Planning Strategies, as agreed with the individual local governments.
- Industry and agricultural growth is based on agreed scenarios
- The analysis used water allocation (licenced) volumes - not use volumes (which are not publicly available and are subject to change). Allocation volumes are, however, considered to be representative of use for the purposes of this broad study.

Other more specific assumptions are documented in relevant sections of the report.

1.5 Future condition scenarios

To predict future water needs of the community, agriculture, industry and the environment in the Peel region, the following scenarios were assessed. These scenarios were agreed by the project stakeholder agencies at a workshop in October 2022. Further detail regarding the methodology for assessment of these scenarios is contained in the relevant sections of the report and Appendices 3 and 4.

Community water needs

Scenario C1: Business as usual (BaU) growth including schools and public open space (incorporating a reduction in groundwater use of 10% by 2030)

Scenario C2: High growth scenario using the population projections in Perth and Peel @ 3.5 million (WAPC, 2018)

Scenario C3: Reduced water use by the community through waterwise gardens or medium density, assuming that after 2030, 50% new residents will reduce their water use to 70 kL/per person/year

Scenario C4: 30% of existing development incorporates a waterwise garden (water use at 70 kL/per person/year)

Agricultural water needs

Scenario A1: Waroona Irrigation District – a change from irrigated pasture to perennial irrigated horticulture across 400 hectares by 2051.

Scenario A2: North Dandalup to Serpentine foothills – development of 200 hectares of new intensive perennial irrigated agriculture by 2051.

Scenario A3: Peel Food Zone – 250 hectares of new closed-loop covered cropping by 2051.

Industrial and resources water needs

Scenario I1: Mining growth – increased water usage from planned expansions

Scenario I2: Strategic industry expansion – increased water usage from strategic industry expansion

Scenario I3: Emerging major water usage industries –increased water usage from the establishment of two new major water users: a hydrogen refinery, and a data processing centre.

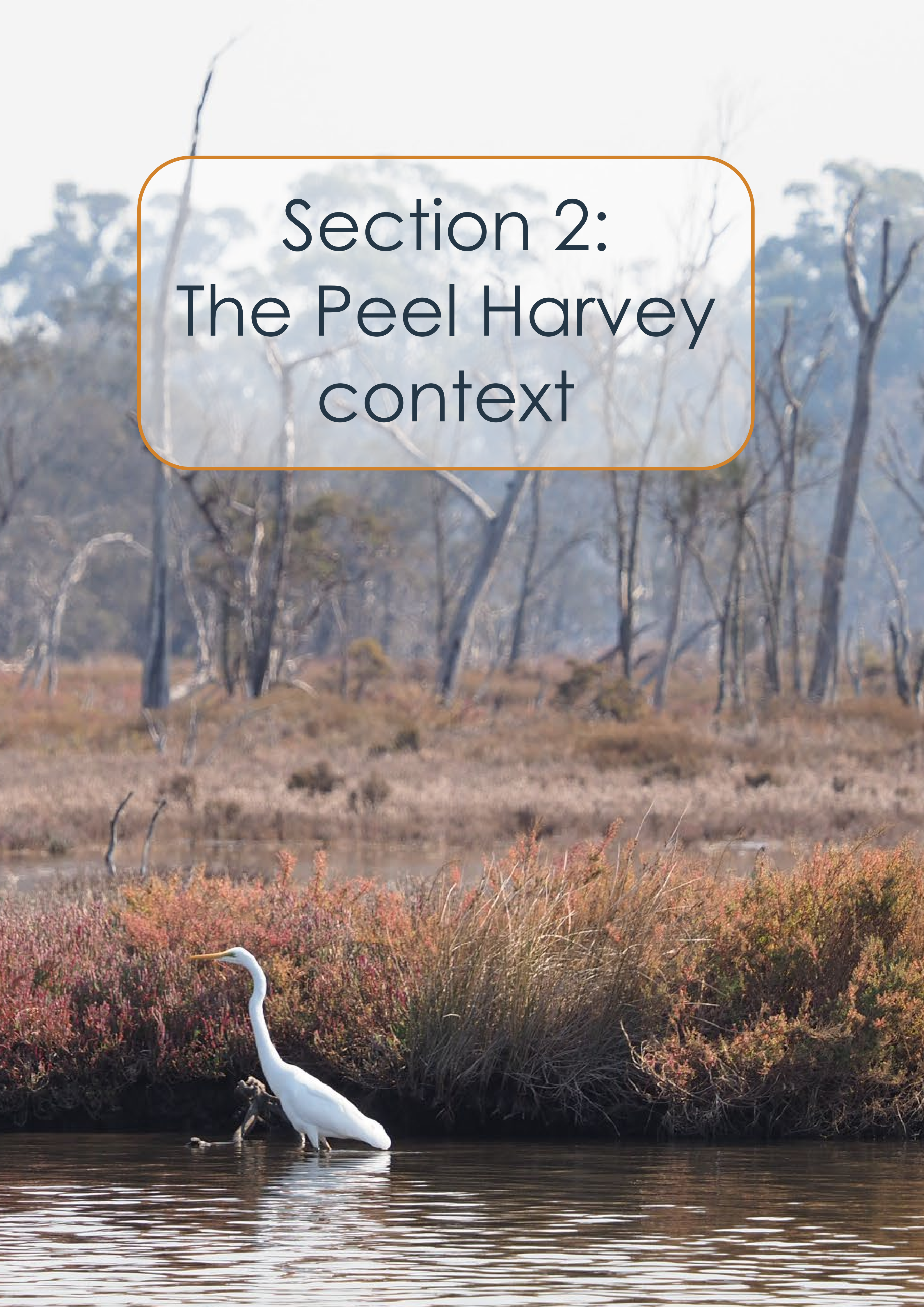
Environmental water

Scenario E1: Surface water and groundwater allocations capped at current levels resulting in net reduction of water for the environment

Scenario E2: Surface water and groundwater allocations are reduced to provide additional water for the environment sufficient to maintain current flows to the Peel-Harvey estuary.

Scenario E3: Surface water and groundwater allocations are reduced further to increase flows to the Peel-Harvey estuary consistent with Peel Harvey Ramsar Ecological Character Description requirements.

Section 2: The Peel Harvey context



2 THE PEEL HARVEY CONTEXT

The Peel Region is home to 151,517 people, supports 44,361 jobs and has an annual economic output of $23.325 billion (Remplan, 2022). It includes the five local governments of Boddington, Mandurah, Murray, Serpentine Jarrahdale and Waroona and is located 75 kilometres south of Perth and covers an area of approximately 5500 square kilometres.

The Peel region contains a diverse landscape which includes 50 kilometres of coastline, urban, agricultural and horticultural land predominantly on the coastal plan, and parts of the Darling Scarp. The region's economy, while dominated by mining activities, also includes stable manufacturing and construction service industries and agriculture (Remplan, 2022).

Key regional community centres include Mandurah, Pinjarra, Byford, Dwellingup, Falcon, Serpentine, Jarrahdale, Keysbrook, Dawesville, North Dandalup, Waroona, Boddington, Preston Beach and Lake Clifton.

2.1 Environmental water context

The Peel Region is rich in significant environmental values associated with its natural environment. The Ramsar-listed Peel-Yalgorup System of wetlands (Ramsar Site 482) which includes the Peel Inlet and Harvey Estuary, Yalgorup Lakes, Lake McLarty and Lake Mealup, and is recognised under the Ramsar convention as having environmental values of international importance.

The region includes many other waterways, wetlands and areas of vegetation that have regional and local environmental significance. All of these wetlands and waterways have some degree of dependency on both surface water and groundwater flows and levels and are therefore water-dependent.

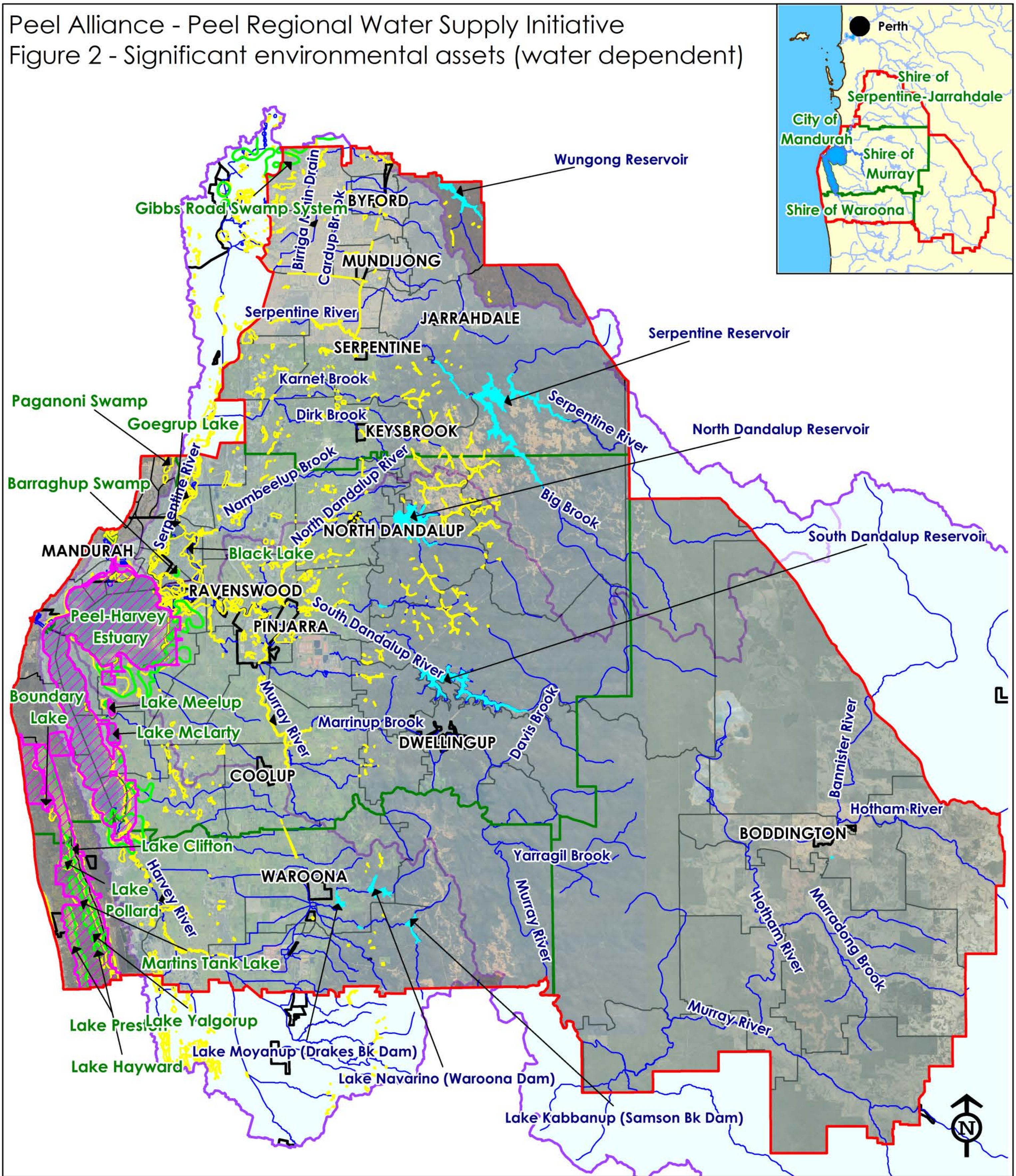
A study recently undertaken for the Peel Development Commission and Peel Harvey Catchment Council by Urbis noted that activation of the area, commercial and recreational activities, health and wellbeing of visitors and residents and the support for agriculture upstream all have significant and ongoing impacts on the WA economy. They estimated the total economic asset value at equivalent to $20.8 billion dollars (approximately 12 Optus Stadiums). Furthermore, the estimated annual economic contribution of the Peel Harvey waterways was approximated $605.7 million, which supports over 2,000 full-time equivalent jobs within the WA economy. It should also be noted that the region's water resources also support the effective delivery of the mining, agriculture, forestry and fishing industry activities which are together valued at around $5.9 billion (approximately 25% of the economy)[1].

2.1.1 Regionally significant water dependent environmental assets

The study area for this investigation contains most of the Ramsar-listed Peel-Yalgorup System of wetlands (Ramsar Site 482) as well as other important, and largely inter-connected wetlands and waterways including the major river systems of the Serpentine, Murray and Harvey Rivers. Figure 2 presents mapping of the significant water dependent environmental assets that can be found in the study area and which are described below.

[1] REMPLAN website, January 2023, https://app.remplan.com.au/peelregion/economy/tourism/output?state=w8dOlb!PGNYsRmydcXYg0Lt7Yr80HDFZHb1nFDv3v4cAGqGbs2H1ZuBHGh7aG3fzYj

Peel Alliance - Peel Regional Water Supply Initiative
Figure 2 - Significant environmental assets (water dependent)



LEGEND:

- Study area
- Local government boundaries
- Townsites
- Localities

Significant Environmental Assets (water dependent)

- Peel-Yalgorup RAMSAR site
- Important wetlands (Peel-Yalgorup)
- Important wetlands (other)
- Rivers
- Reservoirs and lakes
- Peel-Harvey catchments

0 — 20 kilometres
Scale 1:500,000 @ A4

Data source: Landgate. Created by: HB Projection: MGA: zone 50.

urbaqua
land and water solutions

Peel-Yalgorup System

Ramsar-listed Peel-Yalgorup System of wetlands (Ramsar Site 482) which includes the Peel Inlet and Harvey Estuary, Yalgorup Lakes, Lake McLarty and Lake Mealup, is of international importance.

The whole mapped Ramsar site extends over 26,377 hectares, while 23,466 hectares of the site lies within the Local Government boundaries that form this study area (City of Mandurah, Shire of Boddington, Shire of Murray, Shire of Serpentine Jarrahdale, and Shire of Waroona).

The key hydrological features and needs of the major component wetlands that form the Ramsar site 482 are described in summary below. This description largely relies on previous investigations and data collated by others and presented in key reference documents that include:

- *Ecological Character Description of the Peel-Yalgorup Ramsar Site* (Hale & Butcher, 2007)
- *Ecological Character Description for the Peel-Yalgorup Ramsar site: Addendum* (PHCC, 2019)
- Baseline Report Card Ramsar 482 Peel-Yalgorup System (PHCC, 2019)
- The changing hydrology of the Peel-Harvey Estuary: past, present and future. Balancing estuarine and societal health in a changing environment (Huang et al, 2019)
- *A river health assessment of the Serpentine River, Western Australia: Restoring the Serpentine River* (Beatty et al,2021)
- Serpentine River Action Plan 2020 (Urbaqua, 2020a)
- Bilya Maadjit – Murray River Action Plan (Urbaqua, 2022a)
- Lake McLarty flow augmentation feasibility study (Urbaqua, 2022b)
- Harvey River Restoration Conceptual Design – Harvey Dam to Lake Clifton Road (Urbaqua, 2019)
- Balancing estuarine and societal health in a changing environment: Summary Report (Valesini et al, 2019)

Peel Inlet-Harvey Estuary

The Peel-Harvey is the largest estuary in southern Western Australia (130 km2) and part of the Ramsar-listed Peel-Yalgorup wetland system (Hale and Butcher, 2007). The estuary has two large shallow basins that are both mostly less than 2m deep (Valesini et al, 2019, PHCC, 2019).

The estuary receives freshwater inflows from three major river systems, Serpentine, Murray, and Harvey, and is connected to the sea in two locations via permanently open channels. Other important sources of freshwater contributing to the hydrology of the system are direct rainfall and groundwater discharges from the Superficial Aquifer.

Hale and Butcher (2007) estimated that direct rainfall accounts for approximately 15% of total freshwater inflows to the system with the remaining 85% from riverine flows. Freshwater inputs are highest in winter with up to 80% of direct rainfall and 95% of river flows occurring between May and October (PHCC, 2019). Figure 3 shows average monthly flows from the lowest DWER gauging stations on the Murray, Serpentine, and Harvey Rivers (1995-2010) (PHCC, 2019).

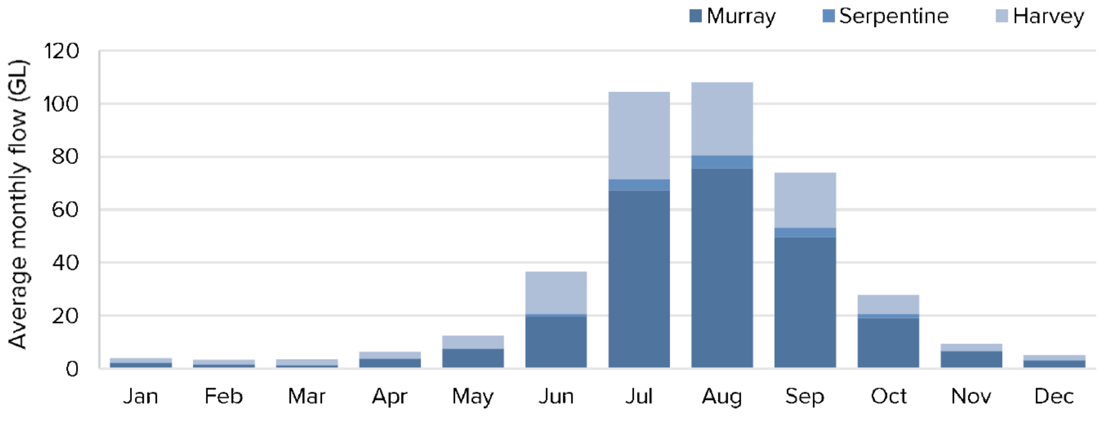


Figure 3: Average monthly flows from the lowest DWER gauging stations on the Murray, Serpentine, and Harvey Rivers (1995-2010) (PHCC, 2019)

Tidal exchange in the estuary occurs via both the natural Mandurah Channel and the artificial Dawesville Cut channel but is dominated by the latter. This channel was created in the mid-1990's to increase estuary flushing and help alleviate extreme nutrient enrichment and algal bloom issues that were causing significant environmental decline through the 1960's-1980's (Valesini et al, 2019).

Groundwater flows to the Peel-Harvey have been estimated to contribute approximately 2 gigalitres per year which is less than 0.5 % of the total inflows (Hale and Butcher, 2007).

Table 1 shows a summary of the water balance information presented by Hale and Butcher (2007) which was based on collated information from 1977 to1988 and Kelsey et al (2007) which was from SQUARE catchment modelling calibrated to gauged river flows from 1997 to 2007. Both of these water balances provide a similar estimate of flows into and out of the Peel Harvey estuary suggesting that the estuary maintained a relatively stable water balance prior to 2010.

Table 1: Summary Peel-Harvey estuary water balance comparison (Hale & Butcher, 2007 and Kelsey et al, 2011)

	Hale & Butcher (2007)			Kelsey et al (2011)		
In						
River flows	608	1977-1988	84.4%	683	1997-2007	86.3%
Serpentine	129			112		
Murray	254			360		
Harvey	225			211		
Groundwater	2	pre1981	0.3%		not given	0.0%
Direct rainfall	111		15.4%	108	1991-2017*	13.7%
	721			**791**		
Out						
Evaporation	184	1977-1979	25.5%	194	1991-2017*	24.5%
Net discharge	537		74.5%	598		75.5%
	721			**791**		

*Note: *evaporation and rainfall were not given in Kelsey et al (2011) data shown is based on BoM climate data for the coinciding period provided for comparison purposes only.*

Yalgorup Lakes

The Yalgorup Lakes are a group of interdunal wetlands found to the west of the Peel-Harvey estuary including Lake Clifton, Lake Preston, Martins Tank Lake, Lake Yalgorup, Lake Hayward, Lake Newnham, Lake Pollard, Boundary Lake, Duck Pond, and Swan Pond. All of these lakes are located within the local government boundaries of the City of Mandurah and Shire of Waroona although Lake Preston extends further to the south into the adjacent Shire of Murray which is outside the current study area.

There are no surface water inflows to the Yalgorup Lakes, and they are not connected to the ocean. Therefore, the hydrology of the lakes is dominated by direct rainfall and interaction with the underlying groundwater system. Each lake has a small local catchment consisting of the surrounding dunes, but the highly permeable sandy soils generate very little runoff and most rainfall is locally recharged into the groundwater system.

The lakes intercept westerly groundwater flows in the Superficial Aquifer which assists in maintaining relatively consistent water levels in the lakes through winter and into spring (PHCC, 2019). The dunes surrounding these lakes also contribute to maintaining water levels by holding locally recharged groundwater pockets which are slowly discharged, potentially flowing both easterly and westerly into the lakes. Figure 4 shows a conceptual cross section through the Yalgorup Lakes.

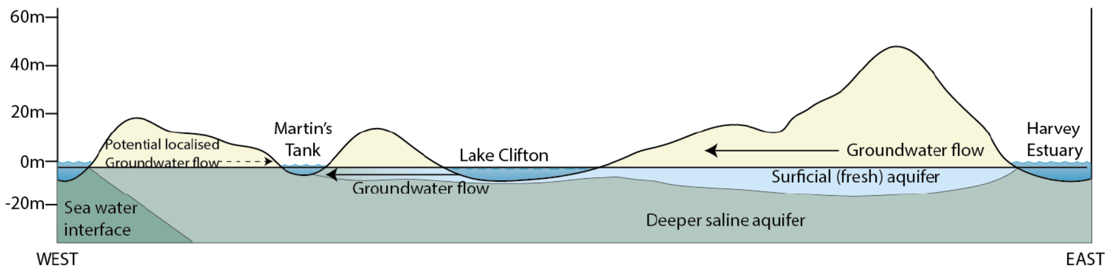


Figure 4: Conceptual cross section of the Yalgorup Lakes (PHCC, 2019)

Lake McLarty

Lake McLarty is a shallow (less than 1.5m deep) seasonally inundated wetland located to the east of the estuary, in the Shire of Murray. The lake's hydrology is dominated by direct rainfall, the local dunal catchment, and surface water inflows from the connected McLarty drainage catchment.

Conceptual water balance modelling undertaken by Urbaqua in 2022 estimated that direct rainfall contributes approximately 60% of surface water inflows to the lake with 13% and 24% contributed from the surrounding dunal catchment and McLarty drainage catchment respectively.

Lake McLarty has no outlet and evaporation from the lake surface accounts for virtually all losses from the lake. For much of the year, groundwater is below the lakebed level and surface inflows contribute to local groundwater recharge. When groundwater is higher during late winter and spring, there can be some small inflow from the surrounding groundwater system and this mechanism helps to extend the hydroperiod of the lake but does not substantially contribute to the water balance (Urbaqua, 2022).

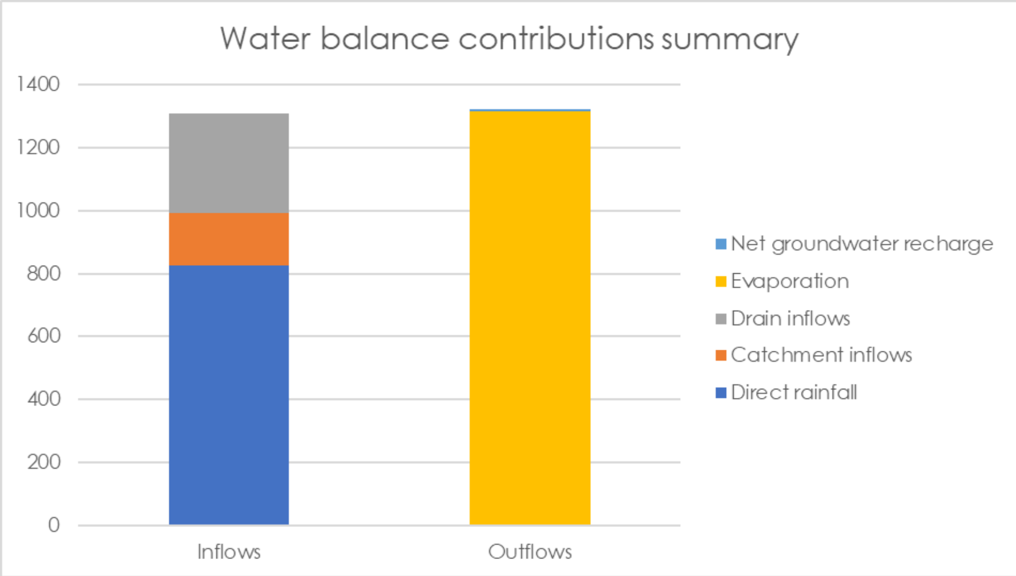


Figure 5: Conceptual water balance summary for Lake McLarty (Urbaqua, 2022)

To model the decline of lake water levels and consider the potential benefits of augmenting surface water flows into Lake McLarty, a range of hydrological criteria (environmental water provisions) were developed for the Lake based on an analysis of historic flows and rainfall together with consideration of the past health of the wetland. These were:

- The average hydroperiod (days dry) over ten years should lie in the range 0-83.1 days (2010-2020 average is 133 days)
- At least two to three years over ten years should include zero days dry (2010-2020 included 1 year)
- The preferred maximum peak annual water level over ten years is 1.59m (2010-2020 maximum is 1.29m)
- The preferred average peak annual water level over ten years is 1.06m (2010-2020 average is 0.69m)

Lake Mealup

Lake Mealup is a shallow (less than 1.5m deep) seasonally inundated wetland located to the east of the estuary, in the Shire of Murray. Prior to 2012, the lake's hydrology was dominated by direct rainfall and the local dunal catchment.

Historically the lake had been connected to the Mealup Main Drain providing additional surface water inflows from the connected drainage catchment. This drainage connection was closed in the early 1990's and this change, combined with declining rainfall patterns, resulted in drying of the lake which then became increasingly acidic. This pattern indicates that surface water inflows are the dominant hydrological component for Lake Mealup, similar to Lake McLarty, which lies approximately 1km to the south.

In 2012, a connection to the Mealup MD was re-established with an adjustable height weir installed to divert flows into the wetland and enable adaptive management of the wetland.

Figure 6: Mealup Main Drain and Lake Mealup diversion weir (Source H Bucktin, DBCA)

Other important waterways and wetlands

In addition to the wetlands of the Peel-Yalgorup Ramsar site, there are a number of other mapped important waterways and wetlands in the study area including the three main river systems: Serpentine, Murray and Harvey.

Hydrological and nutrient modelling of the Peel-Harvey catchment (Kelsey et al, 2011) presented modelling of the whole Peel-Harvey catchment. Modelled annual flows from the component subcatchments are presented in Table 2. The modelled subcatchments are shown in Figure 7.

Serpentine River system, including Nambeelup Brook and Goegerup and Black Lakes

The Serpentine River catchment (1,682 km2) extends from the Darling Scarp, where the river is dammed, to the estuary (Figure 2). The catchment upstream of the Serpentine Dam is largely state forest and reserves, including the Serpentine National Park and a special mining lease for Alcoa to extract bauxite from Crown land with requirements to protect environmental values (DoW, 2007).

Downstream of the Serpentine Dam towards the Lowlands Conservation Reserve, the river has been assessed as in a good condition, with higher values than other river systems on the Scarp, particularly where riparian vegetation is protected by fencing (DWER, 2017a).

Downstream of the Lowlands Conservation Reserve, the river meanders through the Swan Coastal Plain in a variety of forms; natural channel, artificial drains, modified channels and finally the estuarine system. These channels connect a series of pools and lakes along the river, including Lake Amarillo, Guananup Pool, Yalbanberup Pool, and Goegerup Lake. The river, lakes and pools are generally mapped as Conservation Category Wetlands.

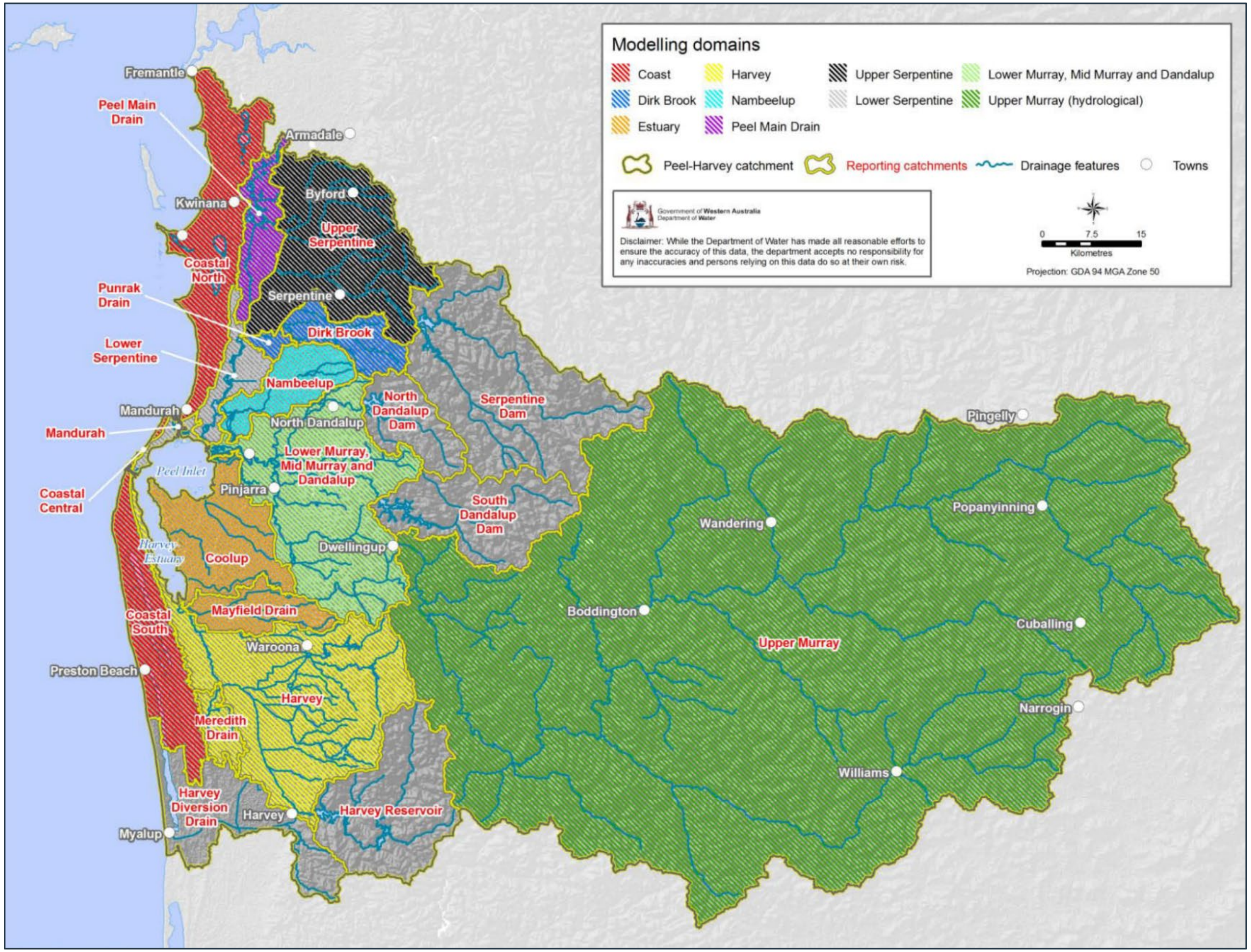


Figure 7: Modelled Peel-Harvey subcatchments (Source Kelsey et al, 2011)

Nambeelup Brook catchment drains a 14,300-hectare area between the Dandalup and Dirk Brook Catchments, discharging into the northern end of Black Lake which is in turn connected to Lake Goegerup.

Murray River system, including the North and South Dandalup Rivers

The Murray River catchment has an area of 7855 km2, of which 505 km2 (6%) has been dammed (North and South Dandalup and Conjurunup dams). Due to the large area of land cleared for agriculture in its upper catchment, the Murray River itself is too salty to be used as a water resource (Kelsey et al, 2011).

Harvey River system

In the Harvey Estuary catchment, 156 km2 (21%) of the 730 km2 area is dammed by Drakes, Samson and Logue brooks, and the Waroona, Harvey and Stirling dams (Kelsey et al, 2011).

Gibbs Road Swamp

Gibbs Road Swamp is an expansive wetland system surrounding and associated with Forrestdale Lake. The swamp is listed in the directory of important wetlands. However, only a very small portion of the mapped extent of the swamp is located in the study area and an even smaller portion of this area is recognised as a conservation category wetland.

Paganoni Swamp

Paganoni Swamp Reserve is located on Paganoni Road, Karnup. It is bounded by Paganoni Road to the north, Kwinana Freeway to the east, Southern Metro Rail to the west and the city boundaries of Rockingham and Mandurah to the south.

Paganoni Swamp Reserve is the most southern reserve of Rockingham Lakes Regional Park. This Conservation Category Wetland is the largest in the Stake Hill Wetlands chain.

Despite being located within the study area, Paganoni Swamp is not part of the Peel-Harvey catchment.

Table 2: Modelled annual flows from Peel-Harvey catchments (Kelsey et al, 2011)

Catchment	Area	Flow (GL)	Flows to
Serpentine Dam[1]	664		Upper serpentine
North Dandalup Dam[1]	152		Lower Murray, Mid Murray and Dandalup
South Dandalup Dam[1]	314		Lower Murray, Mid Murray and Dandalup
Harvey Reservoir, Stirling Dam[1]	379		Harvey and Harvey Diversion Drain
Coastal North	338	37.7	Ocean
Coastal Central	7	1	Ocean
Coastal South	247	13.9	Ocean
Peel Main Drain	120	11.2	Lower Serpentine
Upper Serpentine	502	55	Lower Serpentine
Dirk Brook	115	15.5	Punrak Drain

Catchment	Area	Flow (GL)	Flows to
Punrak Drain	19	2.7	Lower Serpentine
Nambeelup	143	18.6	Peel Inlet
Mandurah	24	3	Peel Inlet
Lower Serpentine	94	6.2	Peel Inlet
Upper Murray	6752	286.1	Lower Murray, Mid Murray and Dandalup
Lower Murray, Mid Murray and Dandalup	638	74.3	Peel Inlet
Coolup (Peel)	151	22.9	Peel Inlet
Coolup (Harvey)	113	15.9	Harvey Estuary
Mayfield Drain	119	19	Harvey Estuary
Harvey	710	142.1	Harvey Estuary
Meredith Drain	56	11.2	Harvey
Harvey Diversion Drain[2]	281		Ocean
Subtotal Peel Inlet	496		
Subtotal Harvey Estuary	188		
Subtotal Ocean	53		

Notes:

1. Dams assumed not to overflow. No flow estimations.
2. No flow estimations available for Harvey Diversion Drain flows.

2.2 Agriculture in the Peel region

Agriculture is a key industry for Peel, creating the following impacts for the region:

- Approximately 1,100 jobs.
- $485 million in annual output.
- $259 million in regional exports.
- $206 million in value add contributions.[2]

Primary agriculture outputs[3] from Peel include:

- Beef, poultry and pork production
- milk and eggs
- wool
- horticultural products such as avocados, rockmelons, and cucumbers.
- flowers and hay production.[4]

[2] REMPLAN Peel profile, based on Agriculture, Forestry & Fishing industry sector, https://app.remplan.com.au/peelregion/economy/industries/value-added?state=LONrlq!KnNrhw0bOI5aYgOhg8K7jHVFgH2wOIqXZXeSp0g08SQH4JfXHKh6hox4, last accessed November 2022.
[3] Please note water demand impacts for food processing, including meat production from abattoirs, is considered in the industry section.
[4] Peel Regional Investment Blueprint, 2015, p 32.

2.2.1 Peel's agricultural areas

Peel's major irrigated agricultural areas are listed in Table 3 and shown in Figure 8.

Table 3: Peel's major agricultural areas

Name	LGA
Oakford	Serpentine Jarrahdale
Oldbury	Serpentine Jarrahdale
Keysbrook	Serpentine Jarrahdale
Nambeelup	Murray
Coolup	Murray
Waroona	Waroona

The major water-using agricultural activities undertaken in each local government area are summarised in Table 4.

Table 4: Major agricultural water usage by local government area

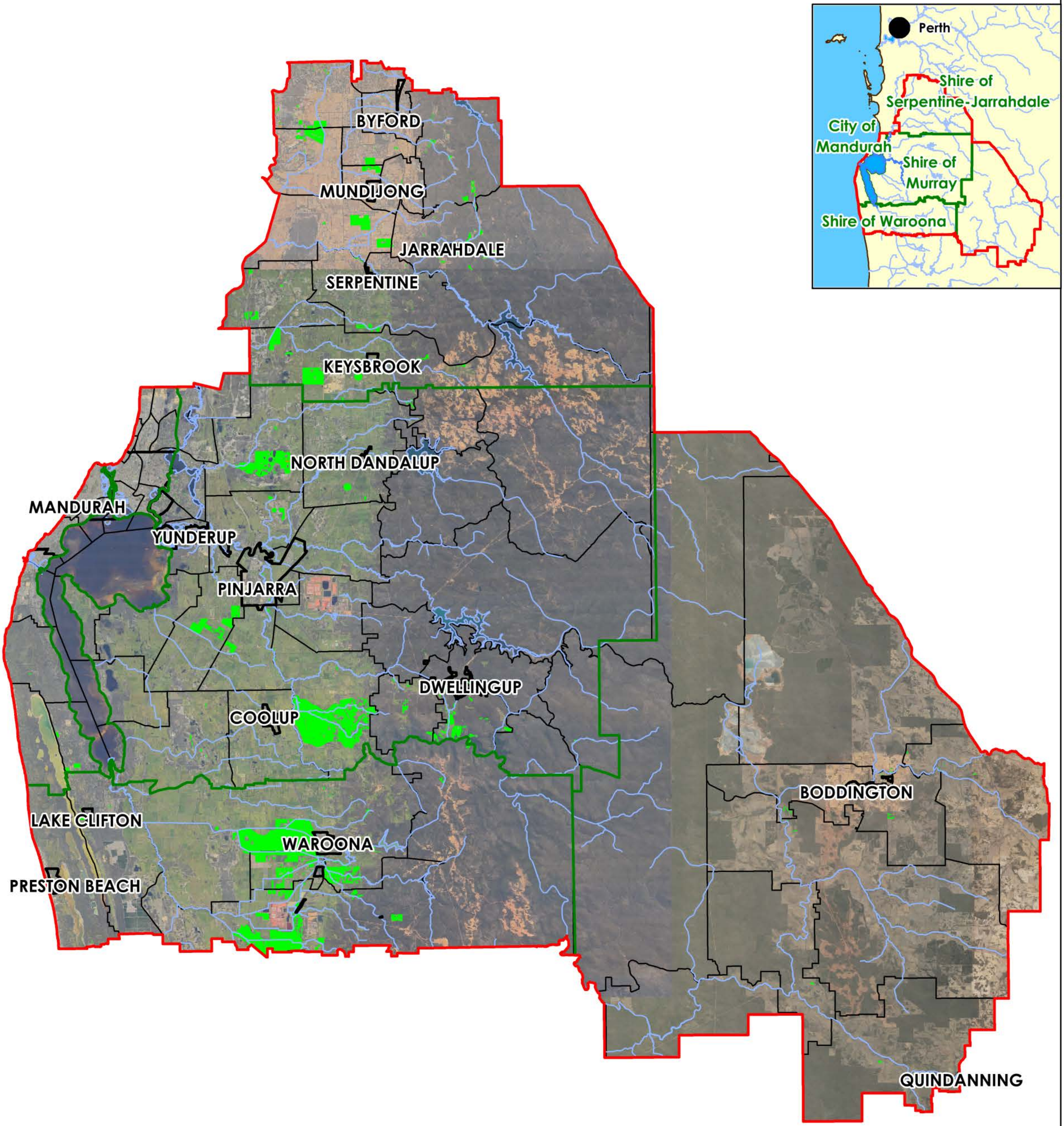
LGA	Major agricultural water uses/crops
Boddington	Pasture
Mandurah	Pasture, nurseries.
Murray	Pasture, turf farming, horticulture, orchards
Serpentine Jarrahdale	Pasture, turf farming, horticulture, vegetables
Waroona	Pasture, horticulture

Of the above uses in Table 4:

- Pasture is typically used grazing for beef and dairy cattle, and hobby.
- Horticulture includes:
  - Annual horticulture such as melons and seasonal vegetables.
  - Perennial horticulture including citrus, table grapes, vineyards and avocados.[5]

[5] Marsden Jacobs, Waroona/Murray/Harvey Water demand assessment, 2021, p 12.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 8 - Major agricultural areas in the Peel region



LEGEND:

- Study area
- Local government boundaries
- Townsites

Agricultural areas
- Irrigated agriculture
- Horticulture

0 20
kilometres
Scale 1:500,000 @ A4

Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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2.3 Industrial activities in the Peel region

This study broadly classifies industry into the following categories:

Population-driven industries – activity that primarily supports the residential Peel population and is therefore highly correlated to population growth or decline. As Peel's population grows, industries such as health, retail, and the services sector will also grow, and water demand for these industries will correspondingly increase.

Strategic industries - not directly linked to changes in population. These industries are export-orientated, providing goods and services to markets outside of Peel. They are therefore strategically important as they bring new money into a region, which supports further growth. Examples of strategic industries include manufacturing, tourism, food manufacturing and mining.

Mining is a critical strategic export industry and water user in Peel. While mining is categorised as a strategic industry, due to its importance this report will give separate consideration of mining, before including analysis in aggregate totals for strategic industries.

2.3.1 Industry and water in the Peel region

Peel supports a range of industries and employment types. Key economic impacts of industry in Peel include:

- Over 37,000 jobs supported
- Annual economic output of over $23 billion
- Approximately 62% of jobs in Peel are in population-driven industries, and approximately 38% of jobs in Peel are in strategic industries (mining, manufacturing, construction, tourism).[6]
- Approximately a quarter of all jobs are from the retail (12.8%) and health care (12.6%) industries

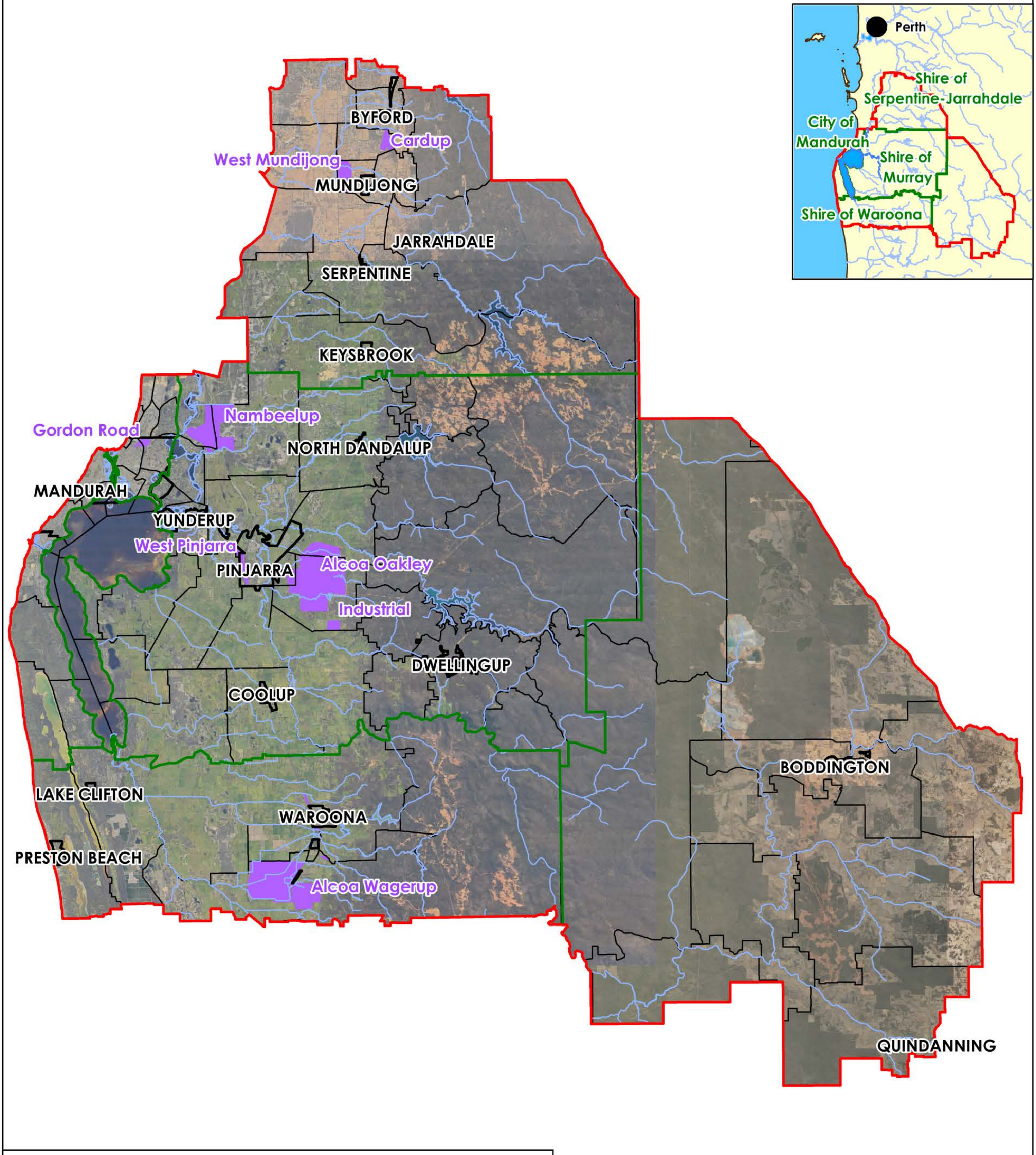
Water has a range of industrial uses in Peel. These include:

- Cleaning and hygiene requirements
- Providing ablutions.
- Cooling, including through evaporative mechanisms
- Manufacturing input
- Waste management
- Timber processing
- Compost production
- Vegetable washing
- Dust suppression for industrial purposes
- Mining purposes

Peel's major industrial areas by water usage are listed in Table 5 and shown in Figure 9.

[6] FAR Lane analysis based on REMPLAN Peel profile, https://app.remplan.com.au/peelregion/economy/industries/value-added?state=LONrlq!KnNrhw0bOl5aYgOhg8K7jHVFgH2wOIqXZXeSp0g08SQH4JfXHKh6hox4, last accessed November 2022.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 9 - Major industrial areas in the Peel region



LEGEND:

- Study area
- Local government boundaries
- Townsites
- Industrial areas

0 20
kilometres
Scale 1:500,000 @ A4

Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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Table 5: Peel's major industrial areas

Location	LGA	Industry type
Boddington town centre	Boddington	Population-driven industry
Boddington industrial area	Boddington	Strategic industry
Boddington gold mine (Newmont)	Boddington	Strategic industry
Worsley mine (South32)	Boddington	Strategic industry
Mandurah City Centre	Mandurah	Population-driven industry
Mandurah Forum	Mandurah	Population-driven industry
Mandurah Terrace	Mandurah	Population-driven industry
Halls Head town centre	Mandurah	Population-driven industry
Lakelands town centre	Mandurah	Population-driven industry
Falcon town centre	Mandurah	Population-driven industry
Gordon Road industrial area	Mandurah	Strategic industry
Pinjarra town centre	Murray	Population-driven industry
Dwellingup town centre	Murray	Population-driven industry
Huntly mine (Alcoa)	Murray	Strategic industry
Keysbrook mine (Doral)	Murray	Strategic industry
Pinjarra Industrial Area	Murray	Strategic industry
Pinjarra refinery (Alcoa)	Murray	Strategic industry
Byford town centre	Serpentine Jarrahdale	Population-driven industry
Serpentine town centre	Serpentine Jarrahdale	Population-driven industry
Jarrahdale town centre	Serpentine Jarrahdale	Population-driven industry
Waroona town centre	Waroona	Population-driven industry
Willowdale mine (Alcoa)	Waroona	Strategic industry
Wagerup Industrial Area (Alcoa)	Waroona	Strategic industry

2.3.2 Mining and water in the Peel Region

Mining is a critical industry in Peel, employing approximately 2800 direct workers, generating $5.8 billion in output and creating $1.8 billion in value added to the region's economy.[7]

Water is critical to the mining industry, both for the mining and refining stages of production. Key uses include:

- transport of waste and ore in suspension and slurries
- chemical processes to separate minerals

[7] REMPLAN, Peel Region, economy profile, https://app.remplan.com.au/peelregion/economy/industries/value-added?state=LONrlq!wrdAFp1A3svdPr2iy8jrQt9FxHJzlf0oKoPiPy4y7H2H8aTAHmheSg3N, last accessed October 2022.

- physical processes to separate minerals, such as in centrifugal separation
- cooling systems
- dust suppression
- washing of equipment.[8]

As a "rule of thumb", mining operations try to remove water as it impedes operations (with the exception of water used for dust suppression), while refineries require large quantities of water for processing.

Dewatering of mine sites is a critical issue. During the mining phase, mines are required to pump out water for sites that dig below the water table or when rainwater accumulates. The quantity of water required to be removed fluctuates with the seasons and corresponding rainfall. Removed water can contain by-products such as metals or toxins and must be safely treated and discharged.[9]

Refining processes use large quantities of water as it:

- Provides a low energy and low cost mechanism for transporting minerals between processes, and storing/disposing of waste materials.
- Allows ease of supplying chemical and other mixing materials to the refining process.
- Is an essential ingredient for some chemical refining processes.[10]

Major mining and refining linkages in Peel include:

- Alcoa mines bauxite at Huntly, which is refined at Pinjarra.
- Alcoa also mines bauxite at Willowdale, which is refined at Wagerup.
- South 32 mines bauxite at Boddington, which is refined in Collie in the South West.
- Newmont mines gold and copper at Boddington, and partially refines onsite
- Doral mines critical minerals at Keysbrook, which is refined in Picton in the South West.

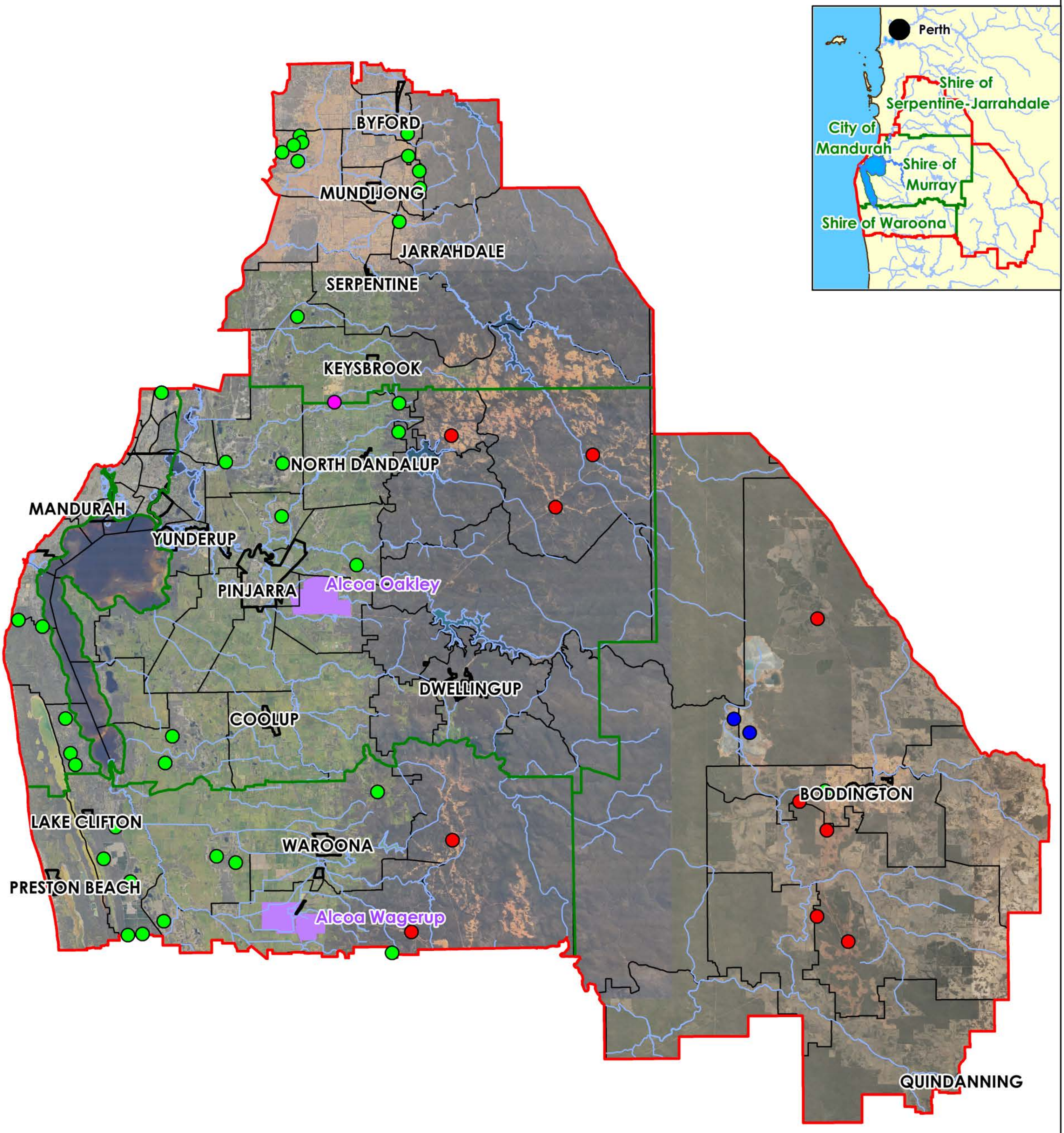
Figure 10 shows key mining operational sites in Peel. A summary of major mining operations in the Peel region is provided in Table 6.

Table 6: Summary of major mining operations in Peel.

Proponent	Location	Mining/operation	Operations to 2050
Alcoa	Huntly	Bauxite mining	Proposed expansion[11]
Alcoa	Willowdale	Bauxite mining	Ongoing
Alcoa	Pinjarra	Alumina refinery	Expanding [11]
Alcoa	Wagerup	Alumina refinery	Undergoing expansion
Doral	Keysbrook	Leucoxene mining	Ongoing
Newmont	Boddington	Gold / copper mining & refining	Ongoing
South 32 [Worsley]	Boddington	Bauxite mining	Proposed expansion[12]

[8] CSIRO, Water in Mining and Industry, in Water: Science and Solutions for Australia, 2011, p 138.
[9] CSIRO, Water in Mining and Industry, in Water: Science and Solutions for Australia, 2011, p 137.
[10] CSIRO, Water in Mining and Industry, in Water: Science and Solutions for Australia, 2011, p 138.
[11] Environmental Protection Authority website, Pinjarra Alumina Refinery Revised Proposal, https://www.epa.wa.gov.au/proposals/pinjarra-alumina-refinery-revised-proposal, last accessed November 2022.
[12] Environmental Protection Authority website, Worsley Mine Expansion – Revised Proposal, https://www.epa.wa.gov.au/proposals/worsley-mine-expansion-%E2%80%93-revised-proposal, last accessed November 2022.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 10 - Mining activity in the Peel region



LEGEND:

- Study area
- Local government boundaries
- Townsites

Resources

- Alumina
- Construction material
- Precious metal
- Speciality metal

- Mining infrastructure

0 20

kilometres

Scale 1:500,000 @ A4

Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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2.4 Conceptual water balance

As noted in section 2.1, significant water dependent environmental assets in the study area rely on underlying groundwater levels or surface water as runoff from local catchments or as streamflow. Most commonly in the study area, the environment is reliant on a combination of these processes with catchments and creeks or drains providing critical seasonal inflows and the underlying superficial groundwater system providing water to sustain deep rooted vegetation through long dry summers.

Conceptually, a simplified water balance can be utilised to estimate the water needs for the environment and consider the influences of various major hydrological processes and the ways that they will change in future.

The hydrological processes which need to be considered for a conceptual water balance are rainfall, evapotranspiration, surface water runoff, streamflow and infiltration, groundwater abstraction, lateral groundwater flow, leakage to and from deeper aquifers and infiltration of irrigation water (both returned groundwater and imported scheme water).

However, the study area is not hydrogeologically uniform and to develop a broad scale water balance for the study area it is necessary to break the area down into components that appropriately reflect that heterogeneity.

On the Swan Coastal Plain portion of the study area, there is substantial interaction between the superficial aquifer and shallow seasonal streams, rural drains, and wetlands. In this area the groundwater flux equation below (and represented graphically in Figure 11 should be satisfied.

$$RE - EVT - \Delta D - \Delta L + \Delta H - Ag + Irr = \Delta Vgw$$

Where:

- RE = gross recharge from rainfall
- EVT = evapotranspiration
- ΔD = net drainage from groundwater to surface water
- ΔL = net leakage to confined aquifers
- ΔH = net horizontal groundwater flow into the DSP area
- Ag = groundwater abstraction
- Irr = Re-infiltration of irrigation using groundwater and/or imported scheme water
- ΔV = change in superficial groundwater storage (net recharge)

In a stable system, where there is no observed change in superficial groundwater storage the equation above would approximately equal zero on an annual timestep.

In the study area, numerical water balances have been developed by the Department of Water and Environmental Regulation for two of the three principal catchments. The water balance for the lower Murray River catchment is presented in *Murray hydrological studies: Surface water, groundwater & environmental water, Model construction and calibration report* (Hall et al, 2010b) while *Lower Serpentine hydrological studies – Model construction and calibration report* (Marillier et al, 2012b) presents a similar water balance for the lower Serpentine River catchment.

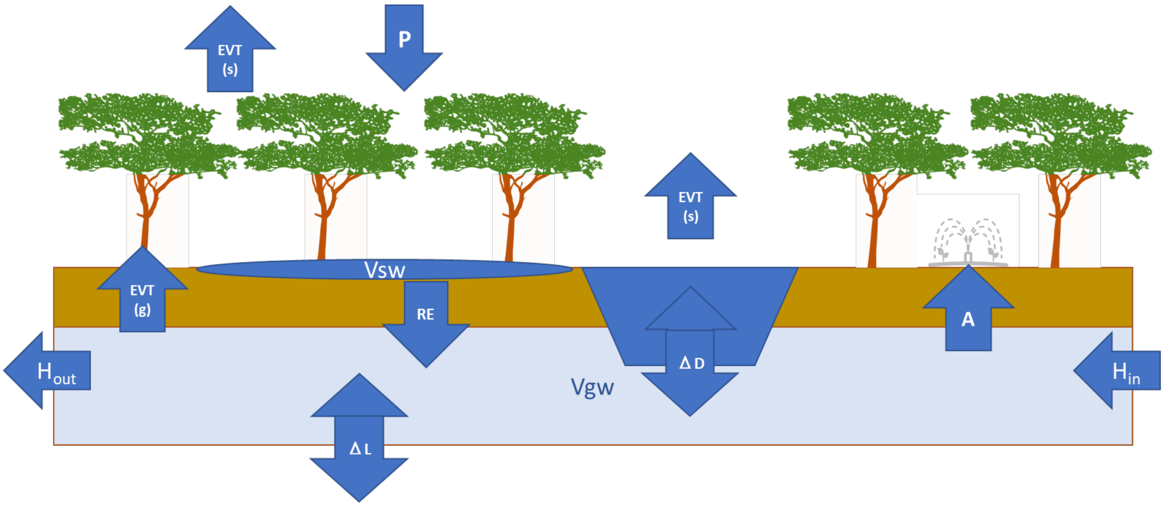


Figure 11: Conceptual water balance

For the upper catchments of the Peel-Harvey system, where there is no continuous superficial aquifer and streamflow dominates, the water balance can be adjusted to provide an estimate of streamflow

$$Q = P - EVT - \Delta D - As - \Delta Vsw$$

Where:

- Q = streamflow
- P = precipitation
- EVT = evapotranspiration
- ΔD = net drainage from surface water to groundwater
- As = surface water abstraction
- ΔV = change in catchment storage (dams and soil storage)

In the future, with a changing climate and increased development in the study area, several of the hydrological processes identified above may change significantly to affect streamflows and superficial groundwater levels. The key changes that need to be considered are:

- Changing precipitation rates and patterns resulting from climate change
- Changing evapotranspiration from climate change and clearing
- Changing abstraction rates and locations

2.4.1 Hydrological processes

As noted previously, the hydrological processes which need to be considered to develop a conceptual water balance are evapotranspiration, surface water runoff, streamflow and infiltration, groundwater abstraction, lateral groundwater flow, leakage to and from deeper aquifers and infiltration of irrigation water (both returned groundwater and imported scheme water). These processes are considered in more detail below, drawing on information available from previous studies and monitoring to develop a numerical assessment of the broadscale conceptual water balance.

Evapotranspiration

Evapotranspiration is applied as a collective term for several different processes which include:

- interception of rainfall by leaves;
- evaporation of rainfall from impervious and vegetated surfaces;
- evaporation from open surface water bodies;
- evaporation from soils;
- uptake and transpiration of water from unsaturated soils by shallow rooted vegetation;
- evaporation from shallow groundwater (incl. surface expressions of groundwater); and
- uptake and transpiration of groundwater by deep-rooted vegetation and trees.

In groundwater modelling, evaporation from shallow groundwater systems and uptake and transpiration of groundwater by deep-rooted vegetation and trees are typically grouped as groundwater evapotranspiration. Surface evapotranspiration processes, meanwhile, are usually accounted for through estimation of gross recharge rates for different surface types.

Hall et al (2010b) and Marillier et al (2012b) determined groundwater evapotranspiration rates of 244mm and 126mm for their Murray and Serpentine study areas respectively. These rates have been applied to the Swan Coastal Plain portions of the Murray and Serpentine catchment in broadscale water balance modelling for this study. The Murray groundwater evapotranspiration rate has also been applied to the Harvey catchment.

In the upper Serpentine and Murray catchments, groundwater evapotranspiration is expected to be mainly limited to areas of deep-rooted vegetation due to limited presence of shallow groundwater.

In areas with deep-rooted vegetation, evapotranspiration can be approximated as pan evaporation multiplied by a vegetation factor. Hall et al (2010) applied a vegetation factor of 1.1 for deep rooted vegetation reduced to 0.2 during the summer months (December to February) when plants are likely to transpire less. Marillier et al (2012) applied a vegetation factor of 1.0 reducing to 0.1 in the summer months and these rates have been applied in this study.

For this study, groundwater evapotranspiration for the upper Serpentine and Murray catchments has been estimated based on analysis of native vegetation coverage. The upper Murray catchment has approximately 43% coverage resulting in a groundwater evapotranspiration rate of 422mm/year while the upper Serpentine catchment has approximately 85% coverage resulting in a groundwater evapotranspiration rate of 768mm/year.

In the coastal catchment groundwater evapotranspiration has been similarly estimated. The catchment has approximately 57% vegetation coverage resulting in a groundwater evapotranspiration rate of 510mm/year.

The principal mechanisms that may be expected to result in changes to evapotranspiration rates are:

Clearing of deep-rooted vegetation

- climate change reducing precipitation
- clearing of vegetation causing reduced evapotranspiration
- climate change causing increased pan evaporation rates
- climate change causing vegetation to transpire at different rates and with different seasonal patterns

Recharge

Recharge, in broad terms, is the proportion of rainfall that infiltrates into the ground and reaches the water table. There are several different terms used to describe recharge, each of which either include or exclude various hydrogeological processes. The terms most frequently encountered are:

- **Potential recharge** (also sometimes referred to as deep drainage) is the amount of rainfall that infiltrates beyond the rootzones of most vegetation and therefore is equal to rainfall minus runoff and surface evapotranspiration processes.
- **Gross recharge** is the amount of rainfall that reaches the water table after interflow losses and therefore is equal to the potential recharge minus interflow lost horizontally through the unsaturated zone.
- **Net recharge** is the net amount of water that is contributed to the water table over the timestep considered and therefore is equal to gross recharge minus evapotranspiration and other losses including abstraction, vertical leakage and drainage from groundwater into surface water systems. In a steady state system, net recharge is expected to be close to zero on an annual timestep but will vary seasonally.

The principal mechanisms that may be expected to result in changes to net recharge are:

- climate change reducing precipitation
- construction of impervious surfaces increasing runoff
- clearing of vegetation causing reduced evapotranspiration
- changed abstraction resulting from changing land uses

Hall et al (2010b) and Marillier et al (2012b) determined gross annual recharge rates of 346mm and 264mm for their Murray and Serpentine study areas respectively. These rates have been applied to the Swan Coastal Plain portions of the Murray and Serpentine catchment in broadscale water balance modelling for this study. The Murray recharge rate has also been applied to the Harvey catchment.

Gross recharge rates have been derived for the upper Serpentine and Murray catchments, where a high proportion of rainfall is infiltrated into highly permeable soils. In most of the upper Serpentine catchment and a fair proportion of the upper Murray catchment, infiltrated rainfall may be subsequently expressed as springs via shallow 'interflow' above an underlying impervious layer (aquitard), contributing indirectly to streamflow from these catchments. Where true groundwater recharge occurs, the rate has been derived with consideration of groundwater trends presented in *Groundwater trend analysis for south-west Western Australia 2007–12* (Raper et al, 2014) which noted a declining trend in some areas including the upper Serpentine catchment and generally stable groundwater levels in other areas including the upper Murray catchment.

The derived annual recharge rates are 431mm and 810mm for the upper Murray and upper Serpentine catchments respectively.

Streamflow

Streamflow includes direct surface runoff from catchments, interflow from catchments where groundwater recharge by infiltrated rainwater is limited by an underlying impervious layer (aquitard) and drainage of groundwater where the groundwater level is sufficiently shallow.

Hall et al (2010b) and Marillier et al (2012b) determined groundwater drainage rates of 76mm and 81mm for their Murray and Serpentine study areas respectively as contributions to modelled streamflow. These rates have been applied to the Swan Coastal Plain portions of the Murray and Serpentine catchment in broadscale water balance modelling for this study. The Murray drainage rate has also been applied to the Harvey catchment.

Total streamflow for each catchment in this study has been adopted from modelling undertaken by DWER and presented in *Hydrological and nutrient modelling of the Peel-Harvey catchment* (Kelsey et al, 2012). For the dam catchments, which were excluded from streamflow modelling presented in Kelsey et al (2012), flows were calculated based on runoff coefficients described in *Rainfall–runoff relationships for Darling Range water supply catchments in 2007* (Raiter, 2012) which varied from 3.8% in the Serpentine Dam catchment to 7.9% in the North Dandalup catchment.

The principal mechanisms that may be expected to result in changes to streamflow are:

- climate change reducing precipitation
- construction of impervious surfaces increasing runoff
- clearing of vegetation causing reduced evapotranspiration
- changed abstraction resulting from changing land uses

Surface water and groundwater abstraction

Licensed surface water and groundwater abstraction volumes from the DWER water licensing database have been included in the broadscale water balance for this study.

The use of private unlicensed 'backyard' bores for garden irrigation on residential properties is widespread in Western Australia. It has been estimated that approximately 30% of households in Perth have a garden bore and prior to the winter sprinkler ban, the average bore pumped about 800 kL/yr (Davidson and Yu, 2006). More recent analysis by DWER suggests that groundwater use from garden bores (and stock and domestic purposes, which are exempt from licensing) varies according to block size as summarised in Table 7. For the dam catchments, abstraction rates have been adjusted to the estimated annual flows calculated based on runoff coefficients described by Raiter (2012).

Table 7: Indicative water usage rates for domestic groundwater bores and stock water use

Block size	Estimated annual usage
Urban block (<1,000 m^2)	300 to 430 kL / property
Rural block (<5,000 m^2)	970 - 1000 kL / property
Rural block (>5,000 m^2)	1,500 - 3040 kL / property

Groundwater leakage to and from confined aquifers

The vertical transfer of groundwater between aquifers was modelled for the Murray and Serpentine catchments by Hall et al (2010b) and Marillier et al (2012b). For this study, similar rates have been applied to the Harvey catchment and leakage has been excluded from the water balance for upper catchments due to the absence of continuous layered aquifers.

Horizontal groundwater flow

The horizontal flow of superficial groundwater was modelled for the Murray and Serpentine catchments by Hall et al (2010b) and Marillier et al (2012b). For this study, similar rates have been applied to the Harvey catchment horizontal flow has been excluded from the water balance for upper catchments due to the absence of a continuous superficial aquifer.

2.4.2 Summary of the broadscale conceptual water balance

A broadscale conceptual water balance for the groundwater and surface water components of the whole Peel-Harvey system is presented in Table 8 and Table 9. There are small deficits shown in both tables, indicating a small declining trend in both surface water and groundwater storage within the catchments. Thus, even with no further changes of land use, vegetation cover or the climate in the catchments, continuing declines in groundwater levels and streamflows may be expected.

In future, with declining rainfall and potentially increasing demands for both surface water and groundwater abstraction, more significant declines in groundwater levels and streamflows are likely to be experienced.

It must be noted that this water balance is broadscale and conceptual in nature. It has been developed at a very high level to assist with consideration of the environmental implications of future water demands from the community, industry and agriculture. The numbers expressed in this water balance should not be relied upon for any other purpose.

Table 8: Broadscale conceptual water balance (Superficial groundwater)

Superficial groundwater		
Inputs	***mm***	***GL***
Gross recharge from rainfall	444	5,130
	444	5,130
Outputs		
Evapotranspiration from groundwater	405	4,676
Net drainage from groundwater to surface water	30	343
Abstraction from superficial groundwater	6	65
Vertical leakage	2	28
Net horizontal flow	3	33
	446	5,144
Water balance deficit (storage change)	-1	-15

Table 9: Broadscale conceptual water balance (Surface water)

Surface water		
Inputs	***mm***	***GL***
Baseflow from groundwater	30	343
Rainfall runoff	40	459
	69	801
Outputs		
River discharges	62	718
Abstraction from rivers and dams	7	85
	70	803
Water balance deficit (storage change)	-0.1	-2

Figure 12 and Figure 13 present a breakdown of the water balance by catchment so that differences between the water balance components in each catchment can be observed.

The groundwater balance in all catchments is dominated by recharge and evapotranspiration with net drainage from groundwater to surface water providing the next largest contribution.

As expected, the contribution from groundwater to surface water is largest in the Harvey River catchments and the lower catchments of the Serpentine and Murray Rivers. The Serpentine River catchment also has larger contributions from vertical leakage between aquifers and larger abstraction rates.

The surface water balance varies similarly between catchments with a dominant proportion of surface water flows coming from groundwater in the Harvey River and lower catchments of the Serpentine and Murray Rivers and surface runoff dominant in the upper Murray and Coastal catchments. In the upper Serpentine River catchment, the contributions from runoff and groundwater are almost equal. Abstraction is obviously most significant in the dammed upper catchments with the Upper Serpentine most notably affected.

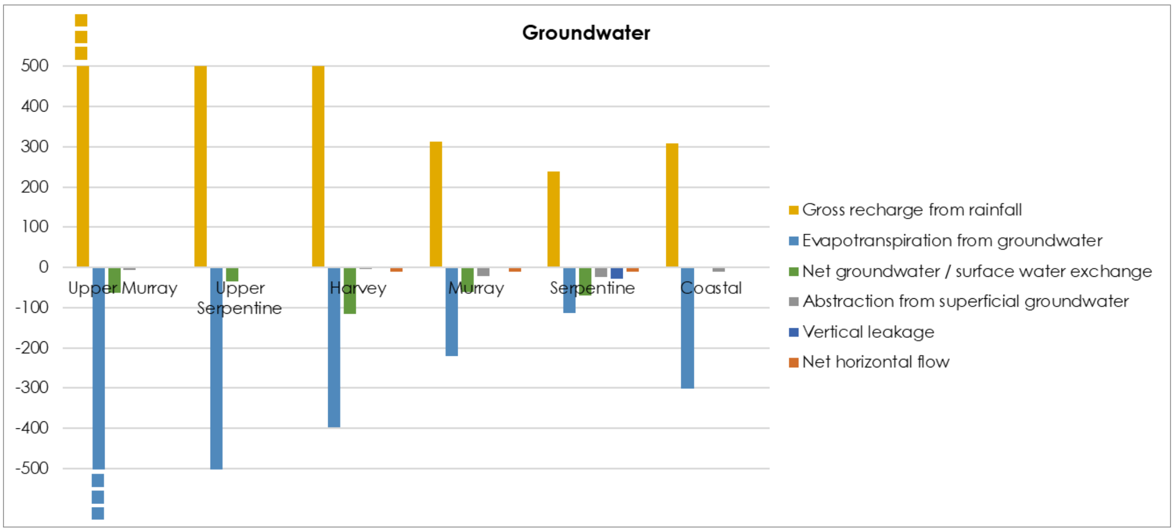


Figure 12: Broadscale conceptual water balance summary (superficial groundwater)

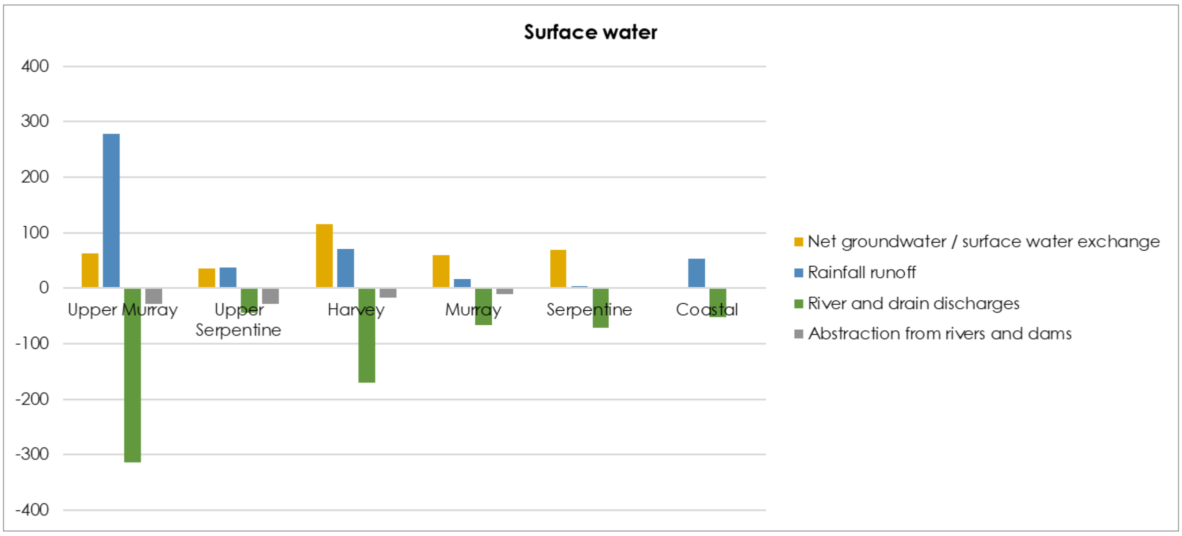


Figure 13: Broadscale conceptual water balance summary (surface water)

Section 3: Current water sources and supplies

3 CURRENT WATER SOURCES AND SUPPLIES

The water sources and supplies within the Peel region currently comprise:

- Groundwater
- Surface water
- Water Corporation's Integrated Water Supply Scheme
- Harvey Water
- Dams
- Wastewater

These sources and supplies are discussed further below.

3.1 Groundwater

The abstraction of groundwater is controlled by the RIWI Act, which identifies proclaimed groundwater areas that require a licence to abstract groundwater. All proclaimed groundwater areas in the study area are located between the coast and the Darling escarpment.

The abstraction and licensing of groundwater resources are managed within groundwater management areas, which are further divided into subareas for each aquifer (Figure 14). Groundwater allocation limits are set for subareas in proclaimed areas through allocation plans. Groundwater availability for the relevant subareas are aquifers has been summarised in Appendix 5 and is shown on Figure 15.

The most recent allocation plan is the *Murray groundwater area allocation statement* which was released by DWER in late 2022 which was based on a review of allocation limits set in 2012. The review found that it is no longer sustainable to take groundwater up to the 2012 allocation limits, given groundwater levels are declining and climate change continues to reduce rainfall and groundwater recharge (DWER, 2022) and includes a reduction in allocatable resources in many areas such that the Superficial aquifer in the Pinjarra subarea and groundwater resources in the Nambeelup subarea are fully allocated. Groundwater remains locally available in the Superficial aquifer in the Coolup and Waroona subareas; however, it is recognised that accessing this groundwater may be difficult (due to poor water quality and bore yield). It is also noted that the deeper aquifers were not reviewed.

The review did note that the review of the allocation limits in the Murray groundwater area was a step towards achieving the target of 10 per cent less groundwater use across the Perth-Peel region by 2030 set in *the Kep Katitjin - Gabi Kaadadjan Waterwise Perth Action Plan 2* (Government of Western Australia 2022).

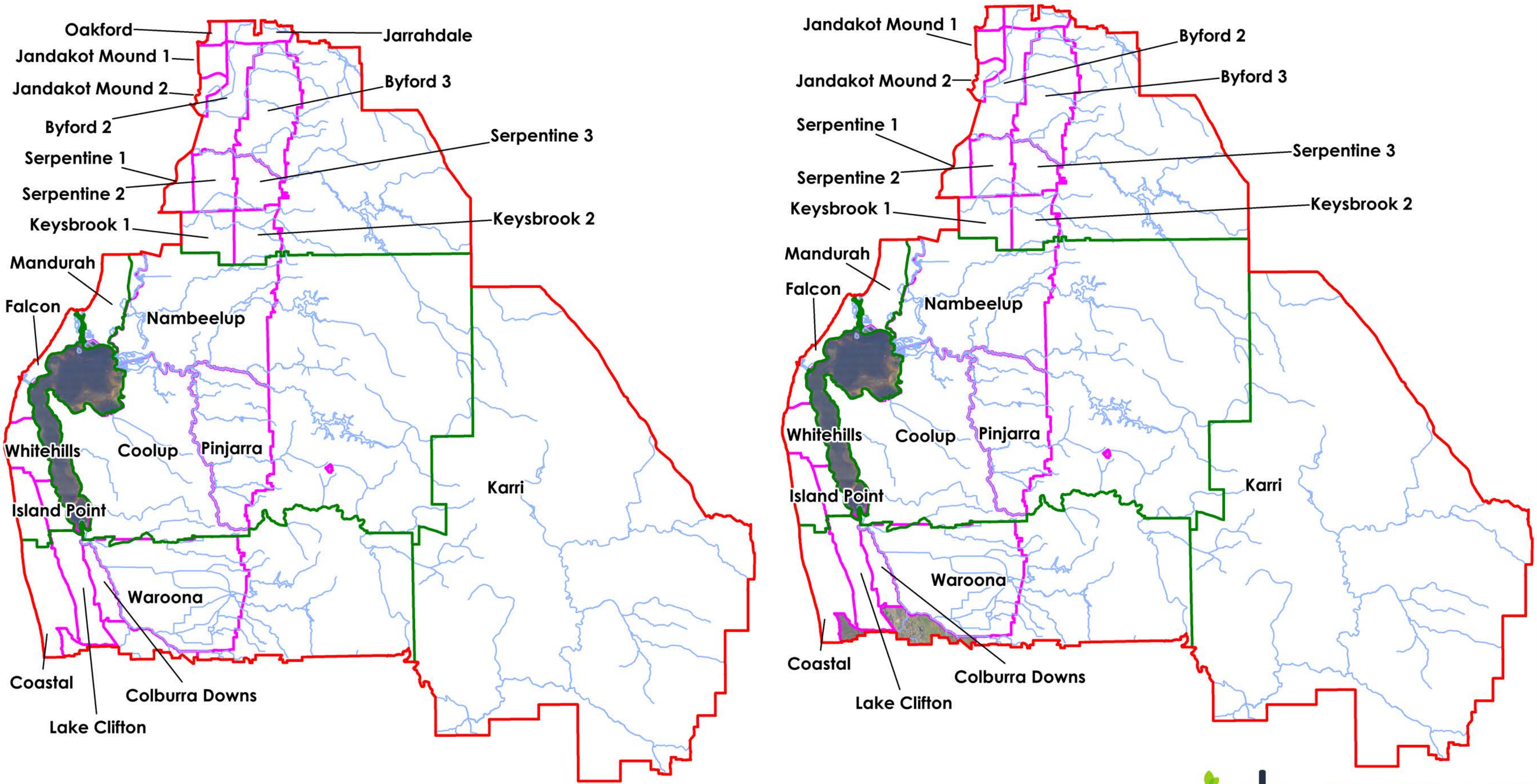
The only other groundwater allocation plan is for the Peel Coastal area around Mandurah (DoW, 2015a) which is completely allocated (both superficial and Leederville aquifers).

Groundwater licencing in unproclaimed areas

Water can be taken from groundwater in an unproclaimed area without a licence where the groundwater source is non-artesian. Accordingly, no licence is required to take water within the Karri groundwater management area, however this aquifer is characterised as fractured rock and supplies are usually low volume, short-term and un-reliable. Any plan to take water from a fractured rock aquifer should also consider the potential to impact nearby bores.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 14 - Groundwater management subareas

Unconfined Aquifers **Confined Aquifers**



Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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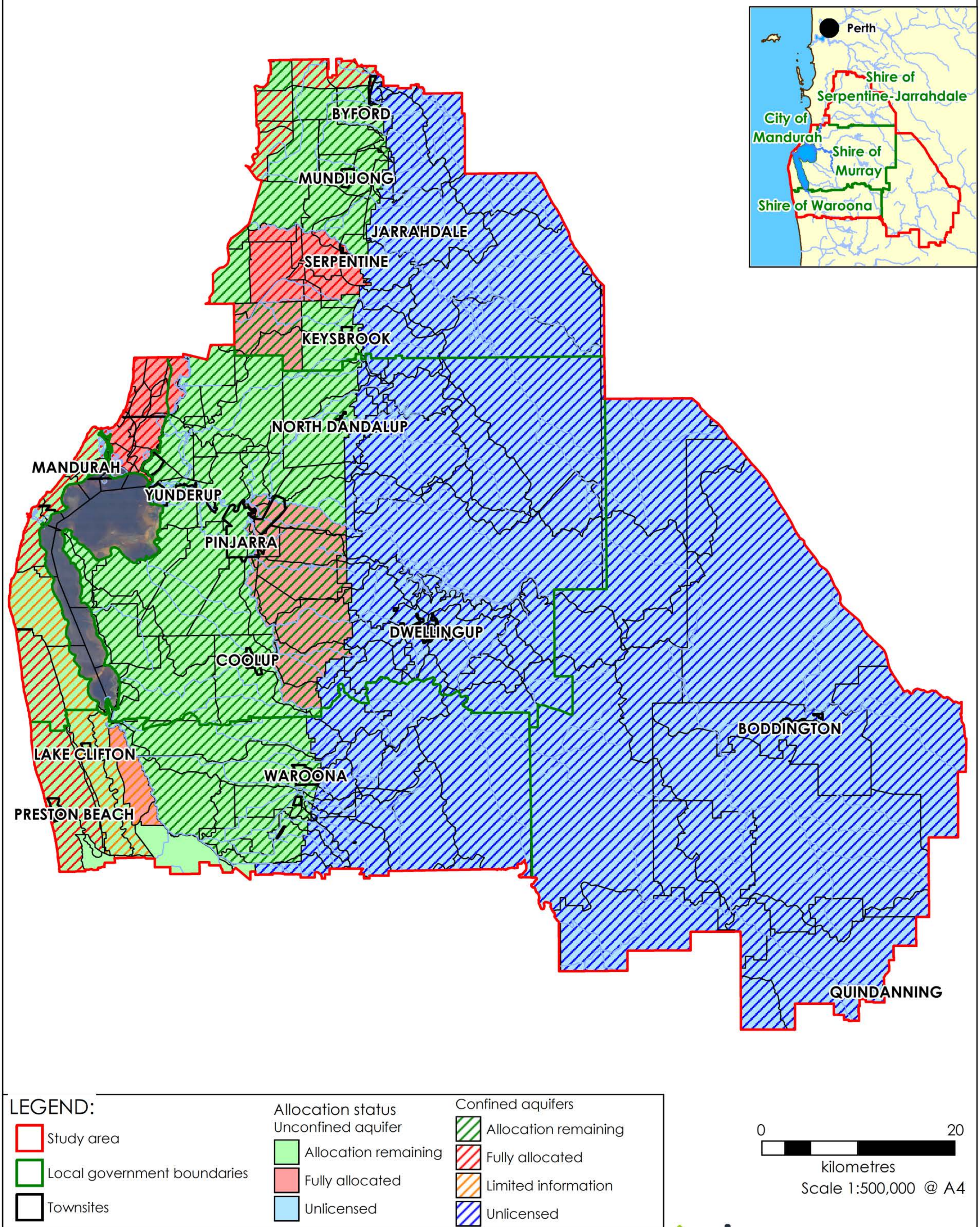
Peel Alliance - Peel Regional Water Supply Initiative
Figure 15 - Groundwater allocation availability (2021)



Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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3.2 Surface water

Key surface water features in the study area are the Murray River Basin and Harvey River catchment, and associated dams.

3.2.1 Murray River Basin

The Murray River Basin extends across approximately 10,150 km^2, with the northern edge bordering Fremantle, the southern edge bordering the Harvey River catchment, and the Indian Ocean to the west. The Murray River Basin includes the Murray, Serpentine, Dandalup, Hotham and Williams, Bannister Rivers, the Peel Main Drain and smaller tributaries.

Larger dams that are still operating within this catchment include the Serpentine Dam and the North and South Dandalup Dams (and associated Pipehead Dams), which are used for drinking water supply. Smaller dams located within this catchment include the Conjurunup Pipehead Dam, Wandering Dams (1 & 2), Bottle Creek Dam, and the Dwellingup Soak. Dam supplies are discussed further in Section 3.5.

3.2.2 Harvey River catchment

The Harvey River catchment is 1,921 km^2 and is located approximately 100 km south of Perth. The northern boundary borders the Murray River Catchment, and the southern boundary borders the Collie River catchment, with the Indian Ocean to the west.

The main rivers within this catchment include the Harvey River and its tributaries including Drakes, Samson and Logue Brooks and the Harvey Main Drain. Many of the waterways within this catchment have been modified, and these portions re-named as drains. Flows in this catchment are heavily regulated, with a series of large dams managed for different purposes:

- Harvey Dam, Logue Brook Dam, Waroona Dam, Drakes Brook Dam, and Wokalup Dam: used to supply the Harvey and Waroona Irrigation Districts, managed by Harvey Water.
- Stirling Dam and Samson Dams: used to supply the Integrated Water Supply Scheme (IWSS) potable water supply.

3.2.3 Surface water allocation

Water resources are assigned to surface water management areas, with allocation limits to control the take of water from these resources under the *Rights in Water and Irrigation Act 1914* (the RIWI Act). The RIWI Act identifies proclaimed areas and irrigation districts, as shown on Figure 16.

- Proclaimed areas – Areas where there is a need for management of water use to protect social and ecological value of a water body.
- Irrigation districts – areas where water service providers can supply water to landowners for irrigation purposes.

In unproclaimed surface water areas, landowners can take water without a licence provided they do not significantly diminish the flow of water in the watercourse.

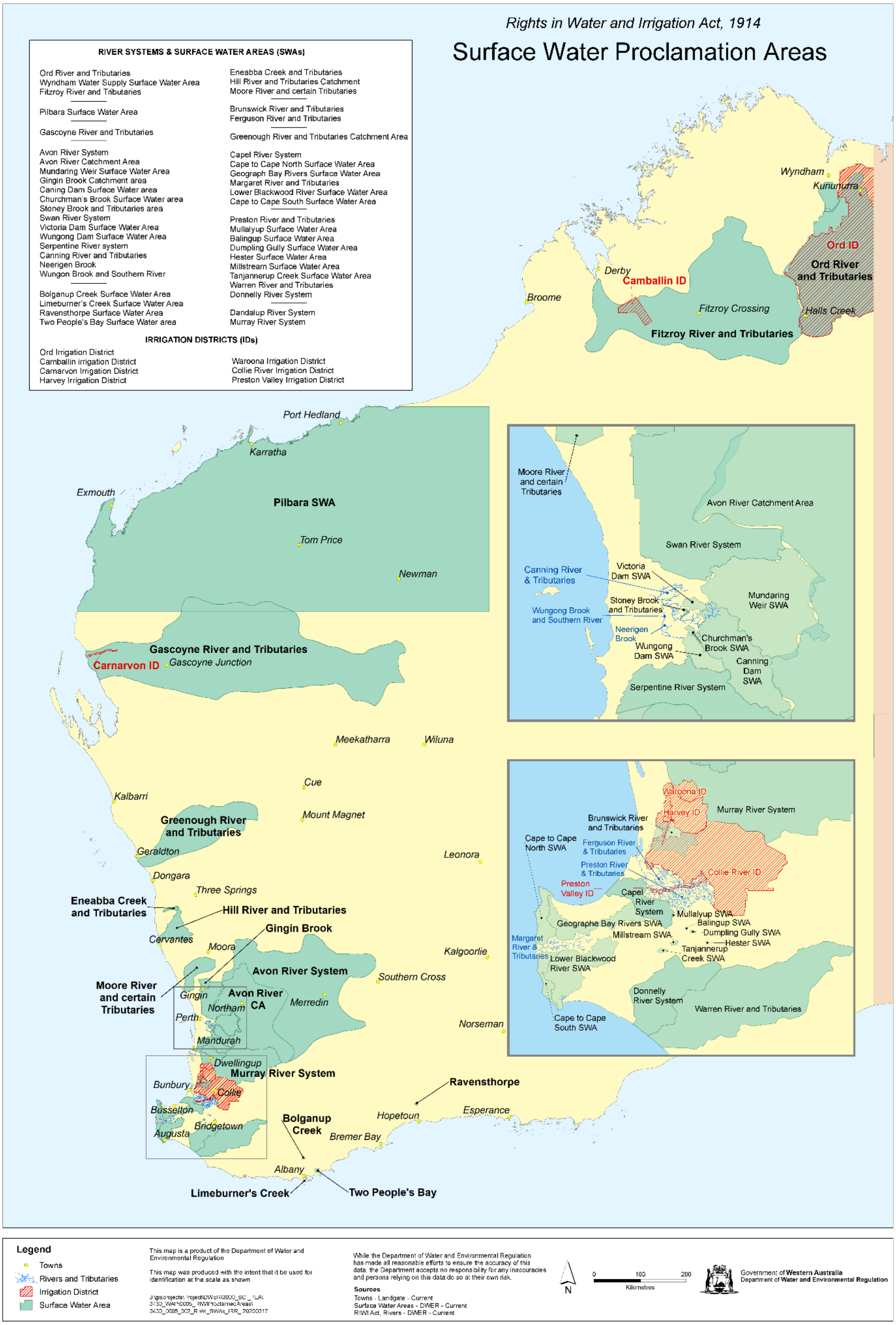


Figure 16: Surface water proclamation areas (Source: DWER)

There are 5 surface water areas within the Peel Region that are proclaimed for licencing purposes under the RIWI Act. These are (Figure 16):

- Canning Dam SWA
- Serpentine River system
- Dandalup River System
- Murray River System
- Harvey Irrigation District

Surface water is managed through surface water allocation plans, which set out allocation limits for surface water resources in management areas. With the exception of the Canning Dam SWA which comprises only a small proportion of the region and flows north into the Swan Canning system, there are currently no allocation limits set for proclaimed surface water resources in the region. Proposals to take surface water are therefore assessed by DWER on a case-by-case basis, having consideration of downstream users and sustainable diversion limits of the surface water resource which are used to determine suitable allocation volumes to take. Further guidance is provided in the following references

- SKM, 2009, Estimation of sustainable diversion limits for South West Western Australian catchments: regionalisation of sustainable diversion limits for catchments.
- SKM, 2008, Approach for determining sustainable diversion limits for South West Western Australia.

3.2.4 Drainage

Water within drainage networks is considered to be surface water under the RIWI Act 1914. Accordingly, a licence is required to take water from drainage systems in proclaimed areas.

In 2019, Dr Don McFarlane investigated drainage water as a potential source of recycling in the Perth-Peel region (McFarlane, 2019a). This work categorised four main types of drainage water in the Perth-Peel region; main drains, street drains, subsurface drains and agricultural drains.

Within the Peel Region, the coastal plan portion is dominated by urban and rural main drains which were installed to lower the groundwater level to permit agriculture and/or development. Where these are gazetted, permission is also required from the Water Corporation to access the water within these drains so as not to impact their management responsibilities. While main drains and agricultural drains may provide an alternative (local) source of water, issues associated with seasonality (likely requiring storage) and water quality would need to be addressed. Consideration would also need to be given to the potential impact of reducing flows on receiving environments.

It is unlikely that drainage water from street drainage could be considered for anything other than passive irrigation of street trees and rain gardens. This is because most street (and roof) drainage is already diverted to the Superficial Aquifer in the Perth-Peel region (McFarlane, 2019a) either through leaky side entry pits or suburban sumps, or, more recently, the application of water sensitive urban design practices which seek to maintain post development levels of runoff at predevelopment levels (where possible). This practice contributes to groundwater recharge and is accounted for in the Department of Water and Environmental Regulation's allocation models.

More recently, some sub-surface drainage networks have been installed in areas with a high water table to facilitate development, largely in Serpentine Jarrahdale. Currently the volumes are small, and the water may be hard to collect and divert to aquifers with the capacity to accept the water (McFarlane, 2019a).

3.3 Water Corporation Integrated Water Supply Scheme

The potable water supply network within the study area is owned and managed by the Water Corporation. Potable water supply is currently taken from groundwater, surface water and desalinated water sources, and stored in dams (with a small amount of treated wastewater also stored in MAR schemes) before distribution to end users. Dams are now predominantly used to store potable water supplies, as stream flows into dam catchments have significantly lowered in recent years, as shown in Figure 17.

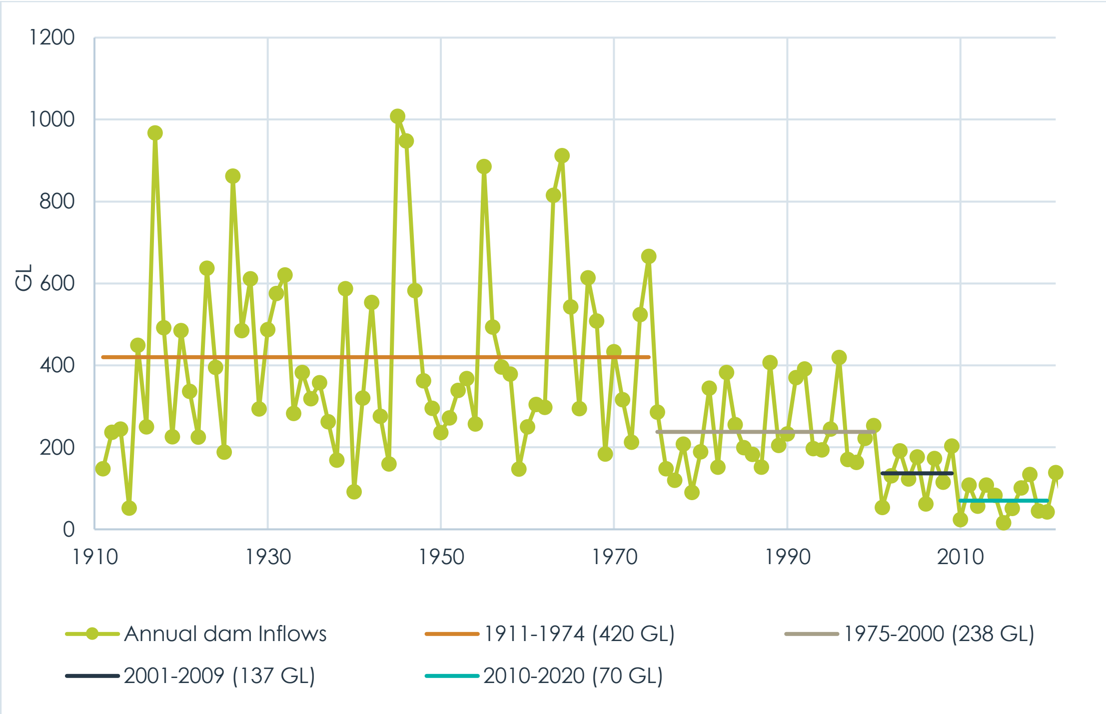


Figure 17: Stream flows into IWSS dams (Source: (Water Corporation, 2022)

The potable supply network is shown on Figure 18, displaying the current dams, larger pipelines, water sources (desalination and groundwater), and smaller water treatment plants within the study area. Due to reduced inflows, some dams are now predominantly used for storage of desalinated seawater or treated groundwater. Dam supplies only comprised 11% of the total IWSS potable supply during 2020-2021, whereas groundwater supplied 40% and desalination comprised 45% (the remaining portion is supply from groundwater replenishment schemes). Dams are discussed further in section 3.5 below.

Two potable supply desalination plants are located within the study area. The Perth Seawater Desalination Plant (Kwinana) (50GL/annum capacity) and the Southern Seawater Desalination Plant (Binningup) (100GL/annum capacity) currently supply treated seawater to users within the study area as part of the IWSS, and are both operated and managed by the Water Corporation. Options are being considered for a third desalination plant which include a second Perth Seawater Desalination Plant (PSDP 2) at Kwinana (50GL/annum) or a new desalination plant at Alkimos (100GL/annum).

While it is noted that water contained within the IWSS is sourced from many locations to supply the Peel region (and other areas), the Water Corporation has a substantial allocation of groundwater and surface water for public water supply within the region (Table 10).

Table 10: Surface and groundwater allocated for public water supply in the region (kL)

Local government area	Allocated groundwater	Allocated surface water	Total
Boddington		140,000	140,000
Mandurah	20,000		20,000
Murray	1,166,000	55,100,000	56,266,000
Serpentine Jarrahdale	6,720	53,800,000	53,806,720
Waroona		16,300,000	16,300,000
Total	**1,192,720**	**125,340,000**	**126,532,720**

3.4 Harvey Water

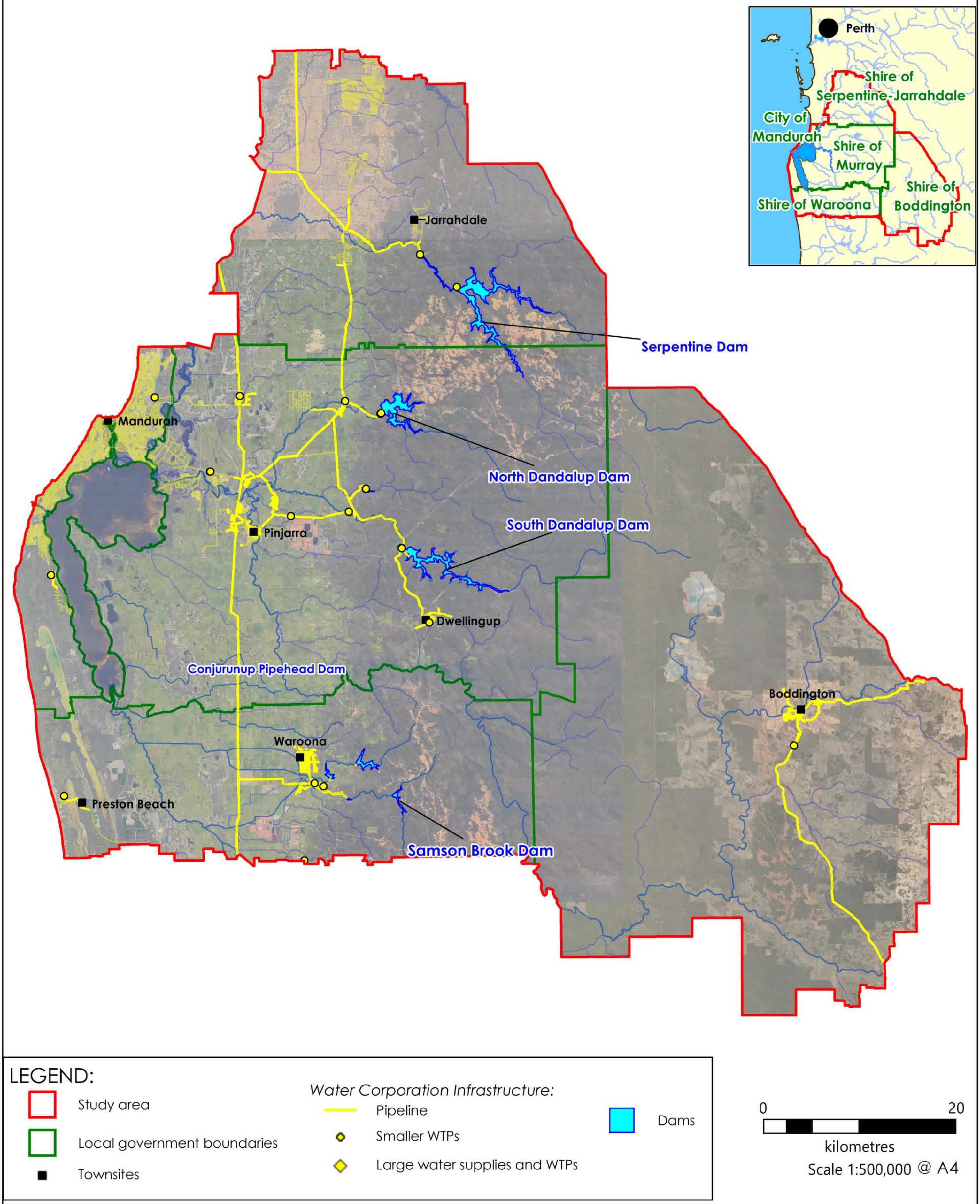
Harvey Water is a cooperative that delivers non-potable water to three irrigation districts located in the south west)(Figure 19):

- Waroona Irrigation District – supplied by the Waroona and Drakesbrook Dams (previously included Samson brook but has been transferred to potable supply).
- Harvey Irrigation District – supplied by the Harvey Dam (downstream of Stirling Dam), Wokalup Pipehead Dam and Logue Brook Dam.
- Collie River Irrigation District – supplied by the Wellington Dam (via Burekup Weir)

Although Harvey Water predominantly provides water outside the Peel region (only Waroona is located within the Peel Region), it is a notable water provider for the area. Harvey Water currently has 722 irrigator members and 433 non-member customers that include industrial users, hobby farmers and community uses. It is licenced to supply 133.7 GL/year (Harvey Water, 2022). Most of the 133 GL/year is supplied by the Wellington and Harvey Dams.

Irrigation water is supplied to irrigation districts with allocations that are determined based on how much water is received by non-potable supply dams. The allocations (or "shares") allow users to extract a proportion of the total water supplied by Harvey Water, meaning the share of water changes each year depending on climatic factors.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 18 - Water Corporation IWSS network within the Peel Region



Data source: Landgate, Water Corporation Created by: RM Projection: MGA: zone 50.

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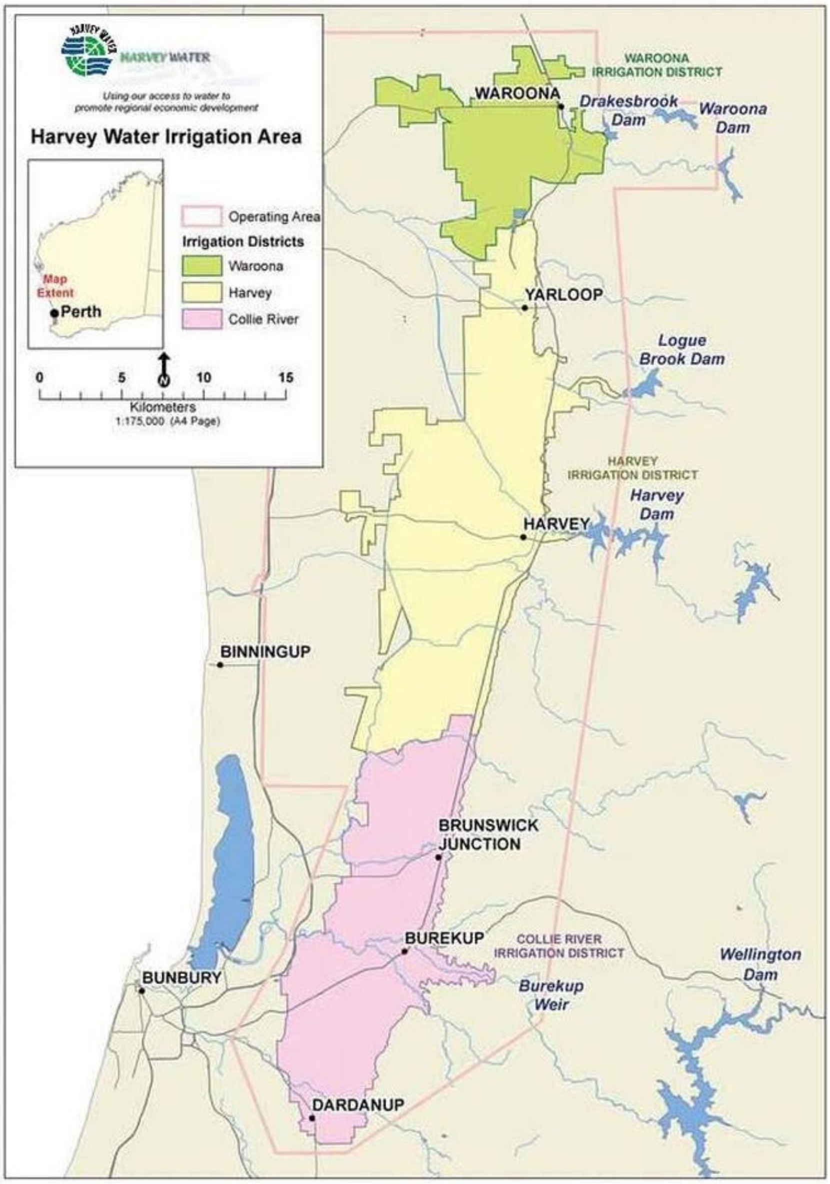


Figure 19: Harvey Water irrigation area (Source: Harvey Water, 2022).

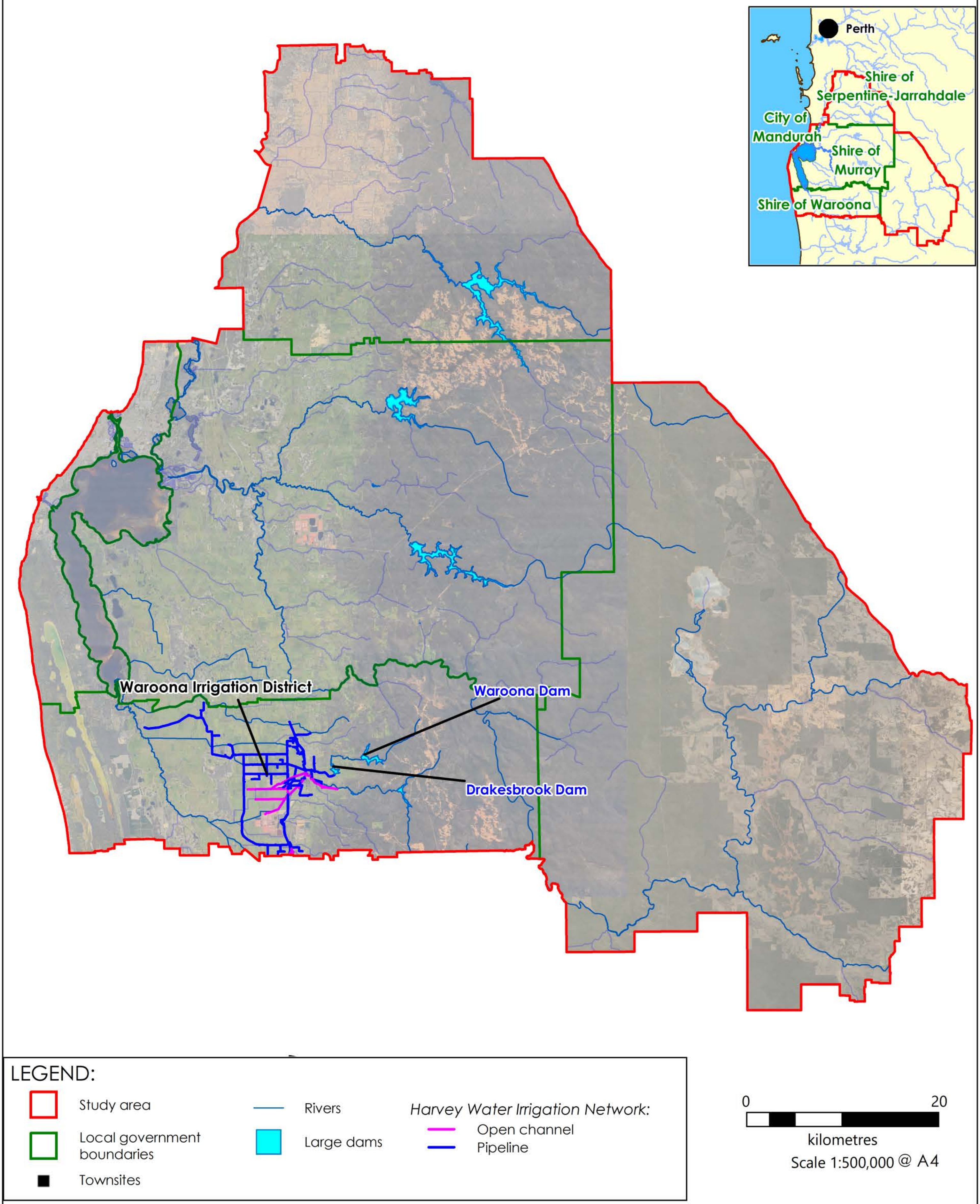
For example, while allocation for water year (October 1st to September 30th) 2020-21 was 38%, allocation for 2022-23 is 65%.[13]. It is also noted that in 2021-2022, users could extract the full allocation within the Collie River Irrigation District but only 60% of allocations in the Harvey and Waroona Districts.

All Harvey Water non-potable supply dams within the study area have been summarised in Table 12. The irrigation districts and Harvey Water supply network is shown on Figure 20.

Harvey Water are currently progressing a Market-Led Proposal through the State Government to develop significant further water infrastructure in the area called Collie to Coast. However, this proposal is commercial-in-confidence and cannot be detailed here.

[13] Harvey Water, https://www.harveywater.com.au/about.html, last accessed November 2022.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 20 - Harvey Water open channels and pipelines



Data source: Landgate, Harvey Water, DWER Created by: RM Projection: MGA: zone 50.

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3.5 Dams

Dams are used extensively across the south west and include both public and private dams. While the water contained in the region's public dams is accounted for in surface water and groundwater calculation, it is useful to understand the current uses and capacities of the potable and non-potable dams. These are summarised in Table 12. Farm dams are discussed further below.

3.5.1 Farm dams

Farm dams are used extensively in the Peel region as a primary water source for agriculture, supplying water for irrigation and stock watering. The Department of Primary Industries and Regional Development have spatially mapped farm dams throughout the region (DPIRD-083). There are currently 4,345 farm dams mapped within the study area with a total area of over 2,300 hectares. Table 11 below provides a summary of the number and area of mapped farm dams in each local government, as well as the amount of rainfall captured by farm dams.

Table 11: Farm dams in the Peel region

Local Government	No of mapped dams	Area of mapped dams (Ha)	Rainfall (m/yr)	Rainfall captured (kL)
Boddington	1,544	1,072.5	0.5363	5,751,992
Mandurah	28	11.1	0.8276	91,685
Murray	1,557	660.5	0.8436	5,571,840
Serpentine Jarrahdale	859	350.6	0.8210	2,878,591
Waroona	357	226.7	1.1191	2,536,731
Totals	**4,345**	**2,321.4**		**16.83 GL**

For this study farm dam use has been estimated from the direct rainfall captured by the area of farm dams in current DPIRD mapping for each local government. It is noted that this method of calculation is a high-level estimate only as some dams will capture more water than the direct rainfall amount, and many will overtop, releasing some water back into the environment. Additionally, it should be noted that the 'use' of water from farm dams includes evaporative losses from the open water.

3.6 Wastewater

There are several Water Corporation wastewater treatment plants (WWTPs) located throughout the study area connected to the public reticulated wastewater network (receiving residential sewerage for treatment). Most of the larger Water Corporation systems are located close to the coast in areas of existing urban development, and smaller regional WWTPs are located further inland (Figure 21).

While industrial wastewater is accepted by the Water Corporation's wastewater treatment plants where licenced, this can only occur where there is access to a wastewater network. Accordingly, some private wastewater treatment plants are assumed to be located in key industrial areas (including mining) within the study area where there is no network.

Table 12: Potable and non-potable supply dams

Name	Potable / Non-potable supply	Capacity (GL)	Allocation and Supply Notes
Drakes Brook Dam	Non-potable	2.2	• Levels maintained by Waroona Dam releases. • 9.1 GL/y allocated to Harvey Water (industrial and irrigation supply)
North Dandalup Dam	Potable	73.8	• Receives water from the North Dandalup River catchment, other dams and desalinated water from Binningup. Dam is narrow and deep, so optimal for storage of treated water. • Water released over summer to maintain flows, and not released in winter. Summer release arrangements are based on proceeding winter inflows. • Water Corporation allocation is 22.2 GL/yr. (DWER, 2017c)
Samson Brook Dam	Potable and non-potable	8	• 16.3 GL/year allocated to Water Corporation for public water supply (includes allocation from Samson Brook Pipehead Dam) • Supplies IWSS and the Waroona and Hamel water supply schemes. (DWER, 2019)
Serpentine Dam (and Serpentine Pipehead Dam)	Potable	194.5	• Supplies 39 GL/year to the IWSS (through the Serpentine pipehead dam), including 2 GL/year supplementation from the pipehead dam.
South Dandalup (and South Dandalup Pipehead Dam)	Potable	208	• Supplies drinking water as part of the IWSS, • 26.9 GL/yr allocated to the Water Corporation from the South Dandalup River (via this dam) • 6 GL/yr allocated to the Water Corporation from the pipehead dam.
Waroona Dam	Non-potable	14.8	• Harvey Water manages releases from the Waroona Dam, to maintain levels in Drakesbrook Dam (then to Waroona Irrigation District).
Outside the region			•
Harris Dam	Potable	71	• Created as a response to saline Wellington Dam water for potable supply. • Releases managed by Water Corp. to maintain Stirling Dam levels and potable supplies. • 17.5 GL/yr allocated for water supply, with 2 GL/yr reserved for growth and 0.5 GL/yr reserved for environmental releases. (Collie-Wellington Basin Water Source Options Steering Committee, 2007)

Name	Potable / Non-potable supply	Capacity (GL)	Allocation and Supply Notes
Harvey Dam	Non-potable	55.6	• Supplies Harvey Irrigation District and Harvey Town non-potable water supply • Harvey Water has rights to most of this dam allocation (35.5 GL/yr) – small amount retained for environmental flows.
Logue Brook Dam	Non-potable	24.2	• Used to supply the Harvey Irrigation District, managed by Harvey Water • Rarely provides its licenced allocation – small catchment and infrequency of spilling • Harvey Water has allocation of 11 GL/year from Logue Brook.
Mungalup Reservoir	Potable	0.692	• Supplies drinking water to south Collie and Mungalup townsites. • Water Corporation has a licence for 0.5 GL/year
Stirling Dam	Potable, but also maintains Harvey Dam levels for irrigation	55.6	• 56.3 GL/yr allocated to Water Corp. for public water supply • Harvey water has rights to ~20% of inflows, and Water Corp has remaining ~80% (excludes Harris Dam inflow). • Harvey Water licence is 9.5 GL/year, sent to maintain Harvey Dam levels. Water corp. licence is 56.31 GL/year.
Wellington Dam	Non-potable	186.0	• 68 GL/yr – reduced in 2017 (from 85.1 GL/yr) as a result of 40% reduction of flows). • Rights to water owned entirely by Harvey Water, but Water Corporation has a licence for 0 kL/year, which may be a temporary hold if water quality improves for drinking water supply. (DWER, 2017b) • 4GL/yr can be transferred to the Harvey-Waroona integrated system via a dedicated pipeline
Wokalup Dam	Non-potable	NA	• Releases pumped to Harvey Dam for irrigation • Harvey Water has allocation of 9.5 GL/year

Treated wastewater for the Water Corporation's WWTPs may be supplied to industry via a commercial agreement. The quality of the supplied water is an important consideration of the cost.

The current capacity of the Water Corporation WWTPs are shown Table 13 below which also includes an indication of the sources currently being reused in the region. It is considered possible that 100% of the wastewater produced (collected) is available for reuse although this is dependent on collection strategies and infrastructure constraints.

Table 13: Current capacity of Water Corporation WWTPs

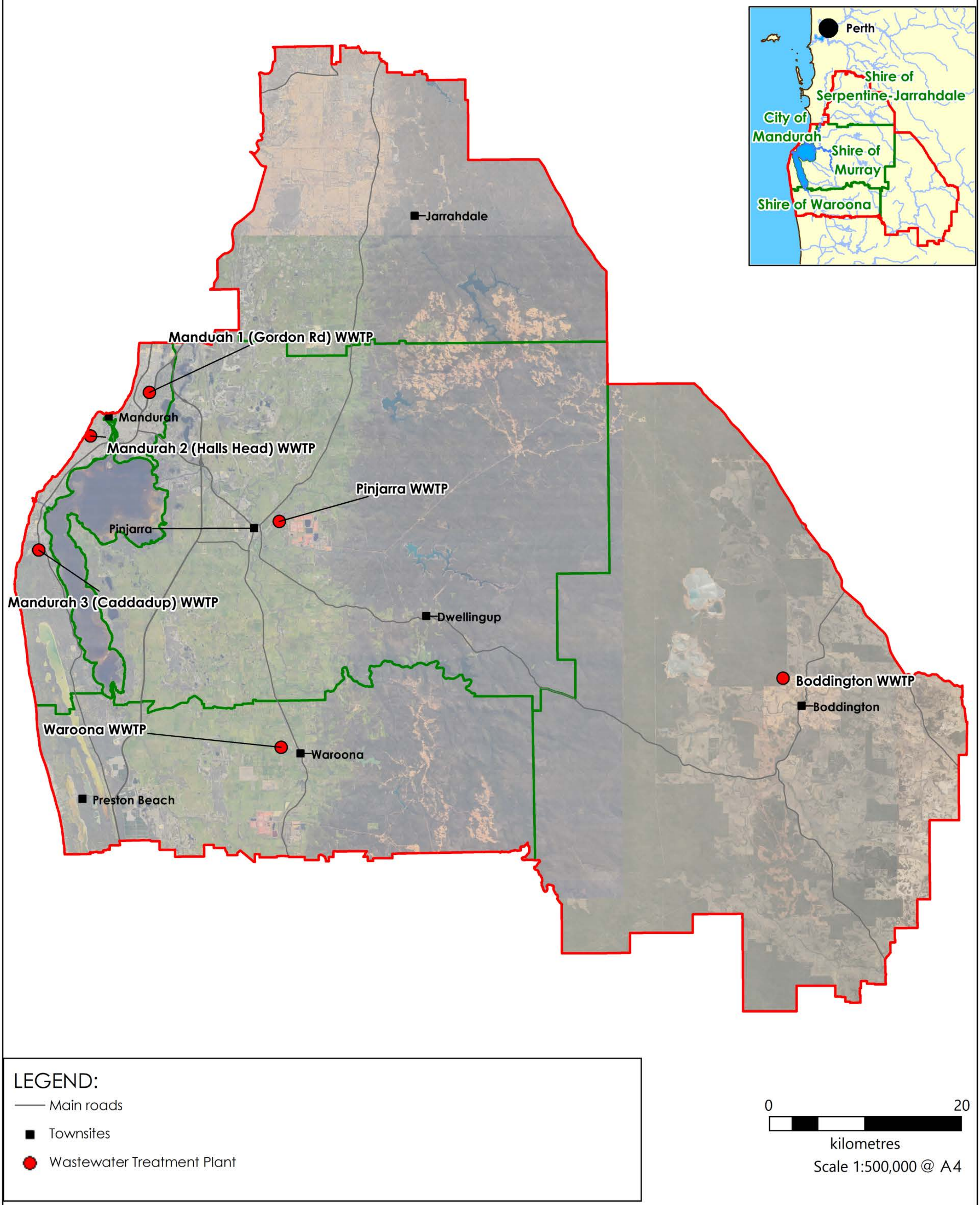
Wastewater treatment plant	Capacity	Current use
Gordon Road	12 ML/day	City of Mandurah
Halls Head	5.8 ML/day	City of Mandurah
Pinjarra	1.84 ML/day	Alcoa
Caddadup	3 ML/day	City of Mandurah
Waroona	0.24 ML/day	None
Boddington	0.122 ML/day	Newmont
Outside study area		
Woodman Point	180 ML/day	Kwinana Wastewater Recycling Plant
Kwinana	12 ML/day	Maintenance of wetland levels for The Spectacles
East Rockingham	20ML/day (will expand)	None (planned)
Point Peron	20 ML/day	None (will go to East Rockingham)

The City of Mandurah has successfully established three recycled water schemes with the Water Corporation to reuse treated wastewater and is currently undertaking the planning to recycle increased volumes of treated wastewater from all three WWTPs (Gordon Road, Halls Head and Caddadup). The Water Corporation currently treats wastewater to a secondary standard at the Caddadup and Halls Head WWTPs. Treated wastewater effluent is disposed via infiltration basins. Effluent infiltration is reclaimed from bores, through Managed Aquifer Recharge (see below), and supplied via a commercial arrangement between the Water Corporation and City of Mandurah.

The current licenced entitlements are:

- 120,000kL/annum for the Caddadup recycled water sceheme which irrigates the public open space at Ocean Road Primary School and St Damien's Catholic Primary School.
- 145,000 kL/annum for the Halls Head Reclaimed Water Supply Scheme which used for irrigation of public open spaces and verges at the adjacent Seascapes Development and the Merlin Street Sporting Ovals. In addition, the Mandurah Country Club operates four production bores along the perimeter of the WWTP which abstract infiltrated wastewater. The Mandurah Country Club currently has a groundwater allocation for 250,000 kL/year.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 21 - Water Corporation wastewater infrastructure



Data source: Landgate, Water Corporation Created by: RM Projection: MGA: zone 50.

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- 300,000kL/annum from the Gordon Road Reclaimed Water Supply Scheme which is planned to be increased to 2GL/annum to ensure sustainable public open space irrigation and ongoing shallow aquifer recharge

It is noted that the licenced allocations are less than 10% of the annual wastewater infiltration at each site.

3.7 Managed aquifer recharge

While not a water source per se, managed aquifer recharge (MAR) can provide an opportunity to store other water sources for use at the desired time.

Managed Aquifer Recharge (MAR) is the infiltration or injection of water into aquifers for storage, transport and recovery when needed. The recharged water can be sourced from various sources (if acceptable treatment is provided) such as treated wastewater, desalinated water, or treated stormwater. MAR provides a water storage option (as an alternative to traditional tanks or dams) for any of the above water source options, particularly where seasonal storages are needed.

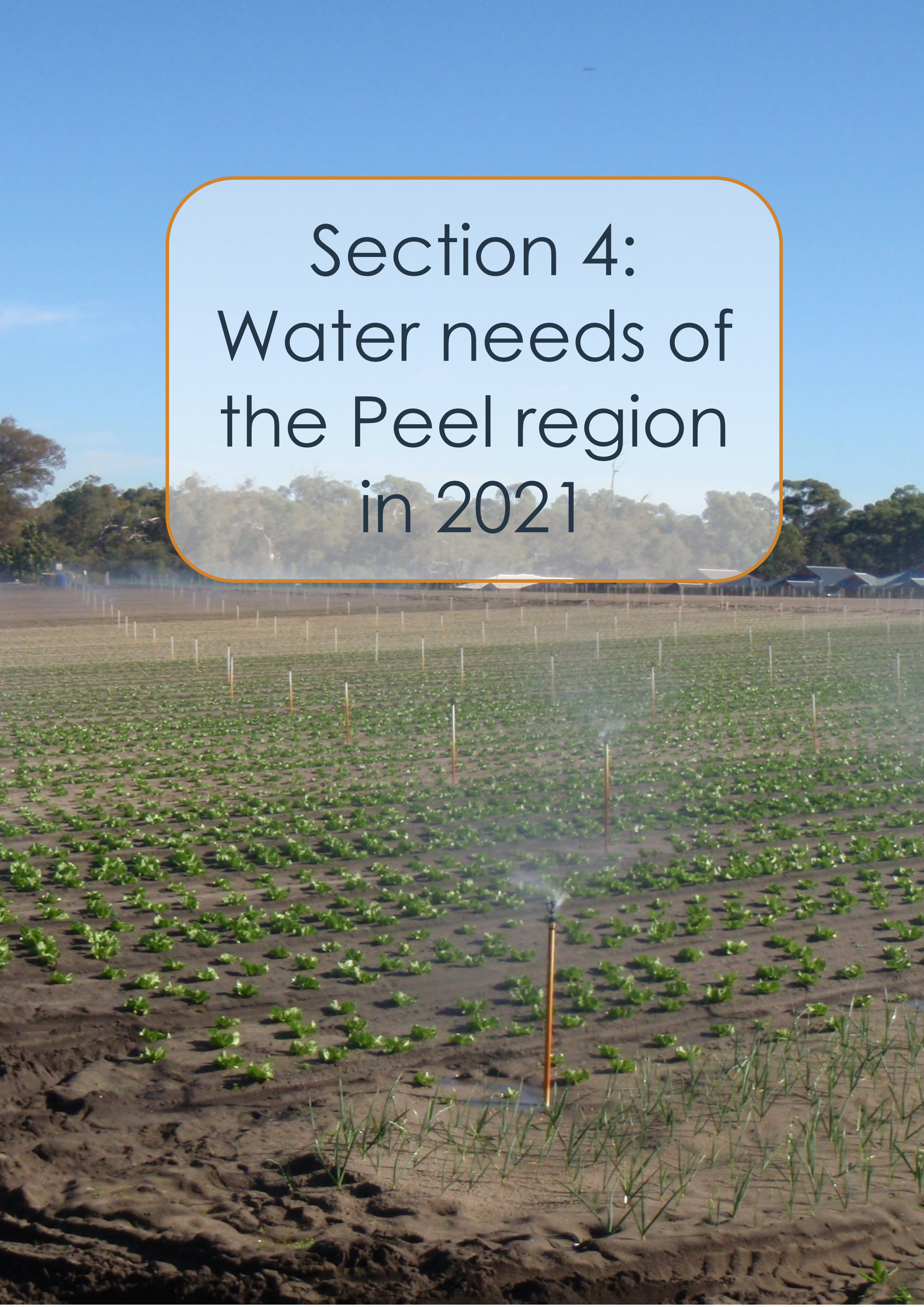
MAR is beneficial where water requirements or supplies are seasonally variable and require a certain amount of storage for use in drier months. Injection of water into aquifers for later reuse also results in some water savings, as it reduces evaporative losses. MAR can also be used to support groundwater abstraction.

For MAR to be feasible the correct hydrogeological conditions must be met, which includes access to permeable aquifers capable of receiving certain volumes of suitably treated water at certain injection rates. Areas with fractured rock aquifers, shallow clays (for infiltration projects) or shallow groundwater levels will usually not be suitable for MAR schemes, unless a deeper, more suitable aquifer can be accessed.

The location of the injection sites is also a consideration, particularly those that are close to environmentally sensitive areas such as wetlands, groundwater dependent vegetation or public drinking water source areas (PDWSAs). MAR schemes within PDWSAs or reservoir/wellhead protection zones are usually only allowed in deeper aquifers.

Assessing the suitability of MAR as a storage option will requires extensive, local studies. Investigations should be undertaken in accordance with the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risk – Managed Aquifer Recharge* which provide a framework for assessing the risks involved in MAR and how those risks can be mitigated to ensure that schemes are sustainable. It is noted, however, that the Department of Water and Environmental Regulation have done a considerable amount of work to determine the suitability of the aquifers within the Peel Integrated Water Initiative area for MAR.

Section 4: Water needs of the Peel region in 2021



4 WATER NEEDS FOR THE PEEL REGION IN 2021

The current water needs for the community, agriculture, industry / mining, and the environment in the Peel Region are summarised below.

4.1 Community water needs

Community water needs are currently supplied by the following sources:

- **Groundwater and surface water** – is generally used by local governments to irrigate landscapes and public open space, as well as for domestic purposes mostly in peri-urban areas. The use of water from surface water and groundwater sources must be in accordance with the *Rights in Water and Irrigation Act 1914* (the RIWI Act), which generally requires a licence to take water within areas that are proclaimed. No licence is required to take water in unproclaimed areas or for domestic purposes less than 1500kL/year.
- **Integrated Water Supply Scheme** (IWSS/Scheme water) – the Water Corporations IWSS supplies potable water to the region for use by the community and industry. It is recognised that a very large volume of water from the Peel Region is currently allocated to public water supply (126 GL). This volume has not been included in this analysis as it is better represented by scheme water use volumes.
- **Treated wastewater** – is provided by the Water Corporation from a number of local wastewater treatment plants (WWTP) for community use such as irrigation of playing fields. It should be noted that the volumes provided are accounted by DWER as "allocated groundwater" rather than treated wastewater as the volumes of abstraction are controlled via a groundwater allocation licence and are reviewed annually as recharge zones within the aquifer/s grow or change.
- **Rainwater tanks** – are used largely in peri-urban areas to provide a potable water source when connection to the IWSS is not possible. The number of households serviced in this way has been estimated based on the number of connections reported by the Water Corporation in each local government area and the current number of dwellings. Current rainwater tank use has then been estimated by applying DPLH rainwater tank sizing requirements (106 kL/person/year) to all dwellings not currently connected to the IWSS. It is unlikely that more areas will be developed with this servicing approach in future. It is also expected that if future rainfall decline makes continued reliance on rainwater tanks unviable, existing properties will alternatively self-supply by trucking-in water or potentially in future by on-site wastewater recycling, but that they may ultimately be abandoned. Therefore, any growth in this water source has been excluded from our analysis.

The total water needs of the community for residential, commercial, peri-urban and public open space is just over 46 GL, comprising water from the IWSS, allocated groundwater and surface water as well as unlicenced water use from unproclaimed areas and treated wastewater (Table 14 and Figure 22). It should be noted that this includes the water needs of commercial areas, which are also accounted for in the industry sector (population-driven industry).

Table 14: Total community water allocation by source (kL)

Water source	Total community allocation (kL)
IWSS	15,338,645
Licenced groundwater	5,466,459
Licenced surface water	481,800
Unlicenced groundwater	12,843,520
Unlicensed rainwater tanks	2,448,434
Treated wastewater	0[14]
Total	**46,189,142**

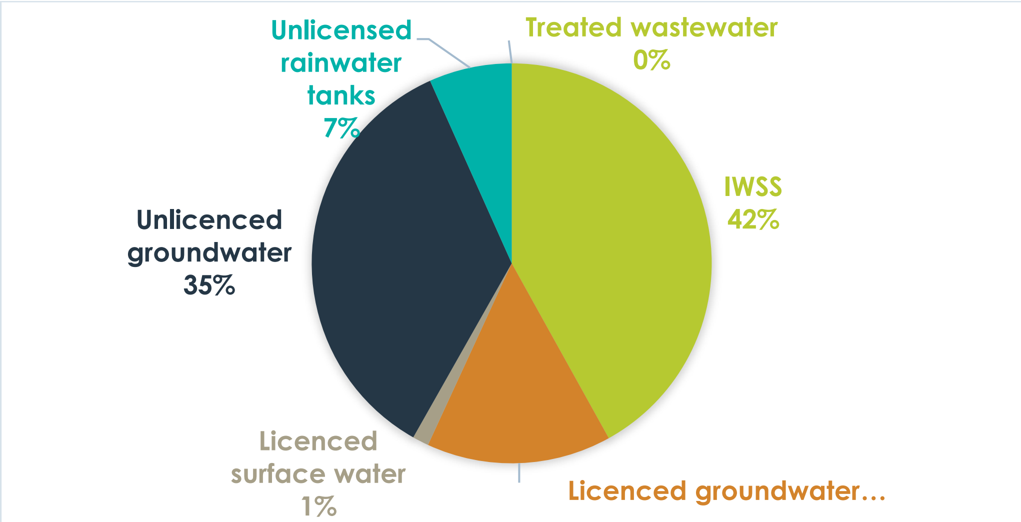


Figure 22: Current community water needs

While it is acknowledged that the water demand of the community is driven by population, it is interesting to consider the areas of each local government that contribute to water use. These are shown in Table 15.

Table 15: Area of land uses allocated to community water demand by local government

Local Planning Scheme Use	Boddington	Mandurah	Murray	Serpentine Jarrahdale	Waroona
Commercial/ town centre	8.76	450.95	46.89	4.74	20.73
Tourism	3.06	7.37	24.08		
Urban/residential	140.21	3617.35	2308.69	3498.62	374.73
Rural residential	2172.51	2042.95	5185.12	4634.31	1656.65

14 Treated wastewater from the three WWTPs in Mandurah is accounted for in the groundwater allocation data. Treated wastewater from Pinjarra and Boddington is supplied to the mining industry and water from Waroona WWTP is discharged to the environment.

Local Planning Scheme Use	Boddington	Mandurah	Murray	Serpentine Jarrahdale	Waroona
POS/recreation	8.00	378.04	205.36	456.00	94.60
Total (ha)	**2332.54**	**6496.66**	**7770.14**	**8593.67**	**2146.71**
Community water use (all sources) (kL)	1,072,912	21,177,396	10,291,555	11,272,229	2,375,050
Water use per ha	460	3,260	1,325	1,312	1,106
Water use per person (all community uses)	610	223	561	310	545

4.1.1 Scheme water

The Water Corporation currently supplies the Peel Region with over 15GL of scheme water. Of this, the majority (approximately 90%) is for residential use (Table 16 and Figure 23). This equates to an average residential use per person of 96 kL, which is higher than the metropolitan average of 84 kL/year.

Table 16: Scheme water use by sector and local government (kL)(Source: Water Corporation)

	Residential	Non-residential	Agriculture	Population 2021	Scheme water use per person
Boddington	134,373	43,164	5,812	1759	100
Mandurah	9,203,343	1,026,487	60	94917	107
Murray	1,769,677	277,659	8,449	18336	111
Serpentine Jarrahdale	2,433,112	201,778	3,740	36403	72
Waroona	314,187	76,916	-	4357	89
	13,854,692	**1,626,004**	**18,061**	**155,772**	**96**

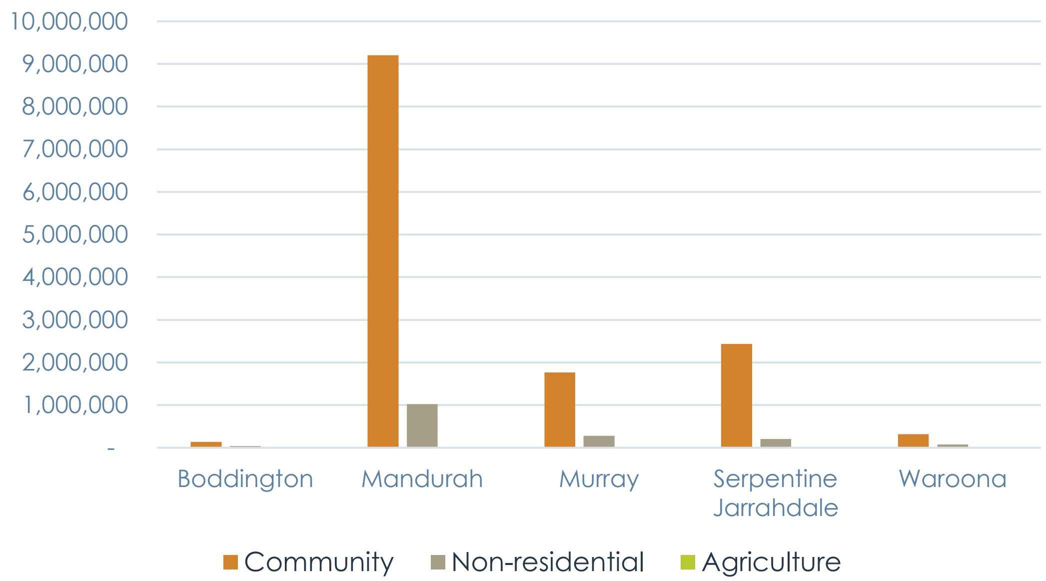


Figure 23: Scheme water use by sector and local government

4.1.2 Surface and groundwater

Groundwater and surface water resources also provide a significant source of water to the region. While the allocation for public water supply comes from the Region, it is accounted for in the scheme water use considered above. Excluding this water from the calculations results in approximately 28 GL of groundwater and surface water being used within the region for community water needs (Figure 24).

Table 17: Surface water and groundwater allocated for community purposes

Surface water and groundwater	Boddington	Mandurah	Murray	Serpentine Jarrahdale	Waroona	Totals
Allocated - Commercial	0	500,386	1,032,794	1,308,735	17,900	**2,859,815**
Allocated - Firefighting and evaporation losses	0	0	44,242	16,847	0	**61,089**
Allocated - Parks, gardens and recreation	652,897*	4,343,521	1,789,309	2,752,068	11,400	**8,896,298**
Allocated - Stock and domestic	0	309,544	969,723	1,776,647	32,530	**3,088,444**
Unallocated – Stock & domestic	212,880	5,132,600	4,060,000	1,642,440	1,795,600	**12,843,520**
Unallocated – Rainwater tanks	*31,387*	*766,207*	*362,937*	*1,157,255*	*130,648*	***2,448,434***
Allocated - Public water supply	*140,000*	*20,000*	*56,266,000*	*53,806,720*	*16,300,000*	***126,532,720***
Totals	**352,880**	**10,307,113**	**64,162,068**	**61,303,457**	**18,157,430**	**154,282,948**

Note: *Boddington aquifers are unproclaimed therefore POS use is unlicensed

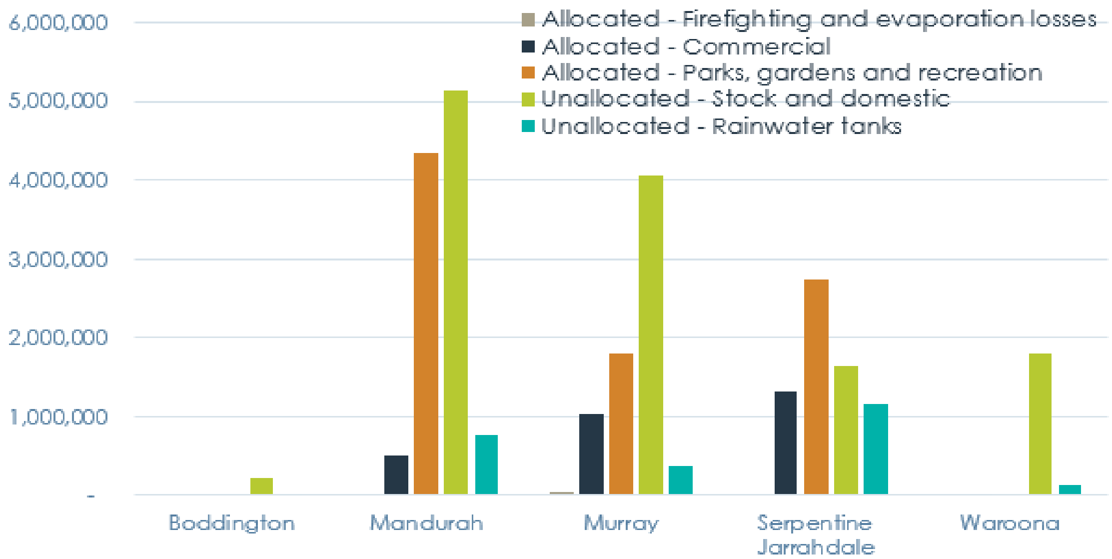


Figure 24: Surface water and groundwater use by sector and local government

The largest component of allocated use of groundwater is for irrigation of public open space and schools, accounting for nearly 65% of the allocated resource. Work undertaken for the Department of Local Government, Sport and Cultural Industries (Urbaqua, 2021, unpublished) through the *Assessment of land, water and community wellbeing outcomes for public open space in Perth and Peel @ 3.5 million* found that all the local governments in the Peel Region had more sport and recreational (irrigated) public open space than required to meet agreed benchmarks, although it is noted that the area of recreational public open space is less than the suggested required 10% benchmark.

Table 18: Public open space benchmarks as measured in the Assessment of land, water and community wellbeing outcomes for public open space in Perth and Peel @ 3.5 million

Local government	Total Area: POS (ha)	Area (ha) POS (excl ROS) per 1,000 population (Benchmark = 3.36)	Area POS (excl ROS) as % urban area (Benchmark = 10 per cent)	Area Sport + Rec POS as % urban area (Benchmark = 8 per cent)	Average distance (m) to closest POS (excl ROS)
Boddington (S)[15]	7,338	13.12	5.30		-
Mandurah (C)	6,120	6.29	9.05	7.80	286
Murray (S)	8,678	128.10	85.85	3.98	723
Serpentine Jarrahdale (S)	9,252	22.14	22.52	5.33	1,083
Waroona (S)	19,339	34.69	18.36	1.44	483

An individual analysis at the local government level is provided in Appendix 1.

4.2 Agricultural water needs

Agricultural water needs are currently supplied from groundwater and surface water, the IWSS and Harvey Water, although the main source of water for agriculture is self-supplied groundwater, followed by surface water from farm dams, as shown at Table 19. Farm dam use has been estimated from the direct rainfall captured by the area of farm dams in current DPIRD mapping for each local government. It is noted that this method of calculation is a high-level estimate only as some dams will capture more water than the direct rainfall amount, and many will overtop, releasing some water back into the environment. Additionally, it should be noted that the 'use' of water from farm dams includes evaporative losses from the open water.

The analysis indicates that Serpentine Jarrahdale accounts for the majority of total agricultural water usage in the Peel region, with it predominantly sourced from groundwater. For all local governments other than Boddington and Waroona, groundwater is the major water source for agriculture.

[15] Boddington was not included in this study and accordingly not all calculations are available.

Table 19: Water source for agricultural use (kL)

	Allocated groundwater (self supply)	Allocated groundwater (Irrigation scheme)	Unallocated surface water (farm dams)	Allocated surface water (self-supply)	Allocated surface water (Irrigation scheme)	Scheme water	Total
Boddington	-	-	5,751,992	-	-	5,812	**5,757,804**
Mandurah	150,840	-	91,685	-	-	60	**242,585**
Murray	5,611,805	-	5,571,840	984,050	-	8,449	**12,176,144**
Serpentine Jarrahdale	13,836,671	418,300	2,878,591	738,220	-	3,740	**17,875,522**
Waroona	53,840	-	2,536,731	-	7,652,000	-	**10,242,571**
Total (GL)	**19.65**	**0.42**	**16.83**	**1.72**	**7.65**	**0.02**	**46.29**

Agricultural products grown with groundwater and surface water allocations in Peel are summarised in Table 20 and shown in Figure 25. The categories in Figure 25 reflect the information in DWER licence data and may not reflect actual uses.

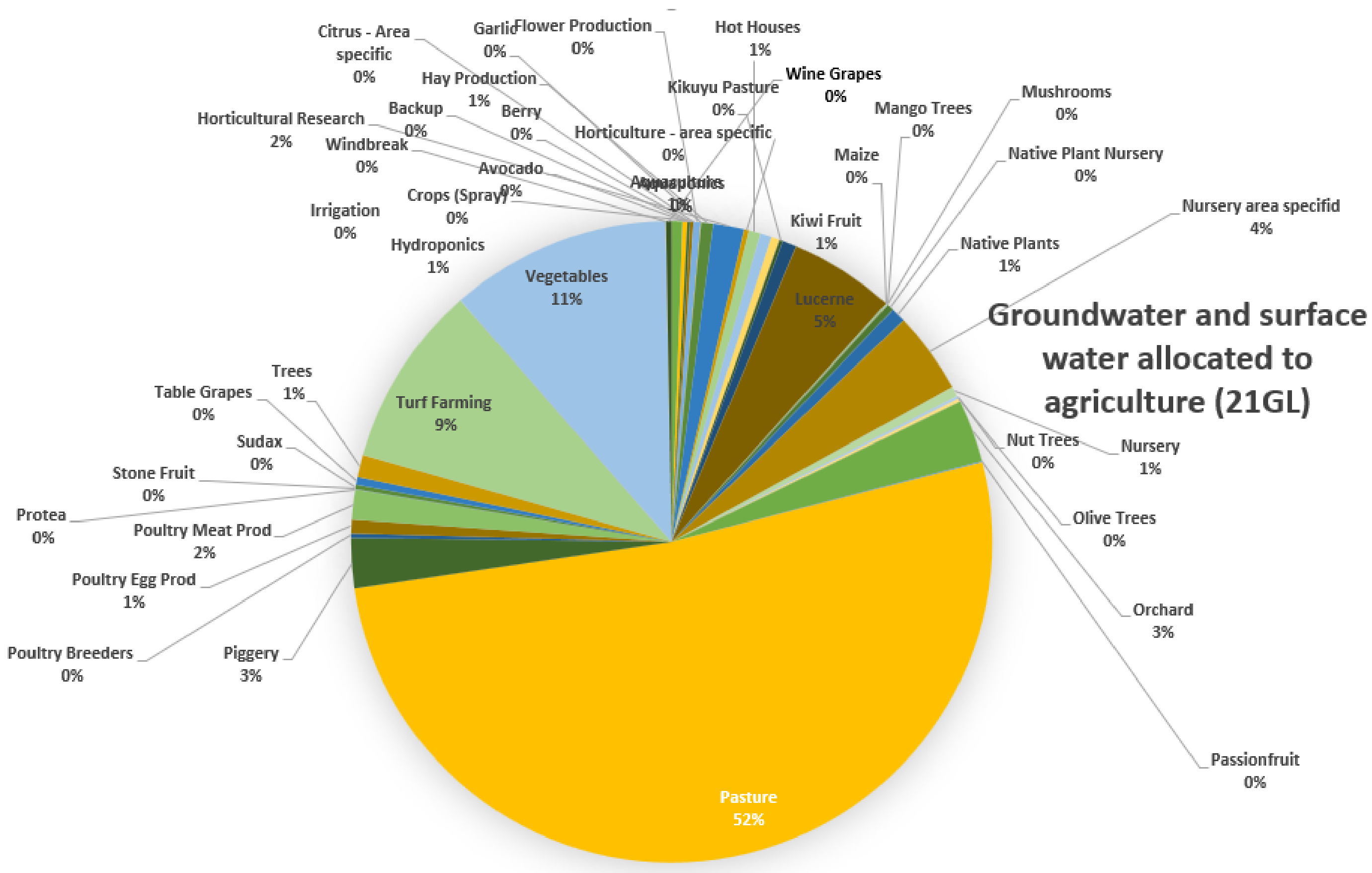


Figure 25: Agricultural uses indicated by water allocation licence data

Table 20: Agricultural products grown with groundwater and surface water

Groundwater/surface water agriculture use	Quantity (GL)	Percent
Pasture	11.041	52%
Vegetables	2.381	11%
Lucerne	1.133	5%
Horticulture & 'Other'	6.7	32%
Total	**21.38**	**100%**

The analysis indicates that pasture, vegetables, lucerne and horticulture/other are the predominant types of agriculture crop produced with ground and surface water. The "Other" category includes a wide variety of agricultural products, such as turf farming.

Recent water use on farms in the Peel-Harvey region is at Table 21. While the Peel-Harvey region is broader than the study area for this report, it provides an indication of water usage on farms that are either in the study area, or highly similar to those being studied.

Table 21: Recent water use on farms in the Peel-Harvey region (ML)

Description	2016-17	2017-18	2018-19	2019-20
Number of agricultural businesses irrigating	116	124	171	177
Total volume of water from all sources (ML)	25,877	32,024	49,906	37,936
Water taken from irrigation channels or irrigation pipelines (ML)	10,578	16,677	28,167	20,290
Water taken from on-farm dams or tanks (ML)	6,972	7,787	9,082	5,192
Water taken from rivers, creeks, lakes, etc (ML)	1,239	422	2,286	1,436
Where a volumetric or usage charge occurs (ML)	-810	-62	-40	-704
Where no charge occurs (ML)	-428	-360	-2246	-732
Groundwater (ML)	6,768	6,808	9,932	10,397
Recycled/re-used water from off-farm sources (ML)	195	196	324	6
Town or reticulated mains supply (ML)	124	135	114	610
Percentage of water taken from irrigation channels and pipelines	0.41	0.52	0.56	0.53
Average water use (ML) per business	**223**	**259**	**291**	**214**

Source: Marsden Jacobs, 2021.

The analysis indicates that while 2019-20 showed a decline in total water usage, a trend of increasing demand is demonstrated for on-farm water usage, including irrigation channels and pipelines, groundwater and scheme water.

4.2.1 Water requirements for irrigated agriculture

Marsden Jacobs, in work undertaken for DPIRD, has developed the following table of average water requirements for irrigated crops and pastures within Waroona and Murray that provides an indication of water usage by crop type and planting season for the study area (Table 22)[16]. However, it is important to note that irrigation requirements vary depending on the crop being grown, soil type, planting month, and shade.

Table 22: Average water requirements for irrigated crops and pastures (ML/hectare)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Avocado	1.9	1.86	1.55	0.68	0.06	0	0	0	0.16	0.88	1.33	1.69	10.11
Citrus	1.9025	1.6225	1.36	0.675	0.11	0	0	0	0.1625	0.7675	1.1675	1.69	9.46
Table Grapes	1.3575	1.275	0.7775	0.2425	0.015	0	0	0	0.01825	0.11	0.5025	0.965	5.26
Rockmelon/ Honeydew	2.23	1.9	1.21	0.34	0.07	0	0	0	0.04	0.36	0.89	1.8	8.83
January planting	2.5675	2.5325	2.4275	0.805	0	0	0	0	0	0	0	0	8.33
February planting	0	2.165	2.1125	1.205	0.3925	0	0	0	0	0	0	0	5.88
September planting	1.095	0	0	0	0	0	0	0	0.22	1.155	2.05	3.0175	7.54
October planting	3.4	0.9325	0	0	0	0	0	0	0	1.0125	1.75	2.9675	10.06
November planting	3.4	2.8975	0.47	0	0	0	0	0	0	0	1.535	2.5325	10.84
December planting	2.9225	2.8975	2.27	0	0	0	0	0	0	0	0	2.2525	10.34
Low pasture	1.36	1.16	0.97	0.48	0.05	0	0	0	0.03	0.55	0.84	1.21	6.63

Source: Marsden Jacobs, 2021.

4.3 Industrial and mining water needs

The water sources for industrial use in the Peel region include groundwater and surface water, the IWSS and treated wastewater.

4.3.1 Population driven industry

Major population-driven industry users of water by Local Government are shown in Table 23. Industries are listed by industry classification.

[16] Marsden Jacobs, Waroona/Murray/Harvey Water demand assessment, 2021.

Table 23: Population-driven industry users of water by Local Government

Local Government	Predominant population-driven industry
Boddington	Education, culture/recreation, hospitality, health and community services, finance/insurance/property/business, wholesale and retail trade
Mandurah	Education, culture/recreation, hospitality, health and community services, finance/insurance/property/business, wholesale and retail trade, communication services
Murray	Education, culture/recreation, hospitality, health and community services, finance/insurance/property/business, wholesale and retail trade, communication services, government and defence
Serpentine Jarrahdale	Education, culture/recreation, hospitality, health and community services, finance/insurance/property/business, wholesale and retail trade, communication services, government and defence
Waroona	Education, culture/recreation, hospitality, health and community services, finance/insurance/property/business, wholesale and retail trade, communication services

Current water usage for population-driven industry is at Table 24.

Table 24: Current water usage for population-driven industry

Local Government	Allocated groundwater and surface water	Scheme water	Water usage (kL)
Boddington	-	41,375	41,375
Mandurah	500,386	921,795	1,422,181
Murray	1,032,794	262,873	1,295,667
Serpentine Jarrahdale	1,308,735	185,125	1,493,860
Waroona	17,900	72,785	90,685
Total (GL)	**2.86**	**1.48**	**4.34**

4.3.2 Strategic industry

Groundwater and surface water allocated to strategic industry (not mining) in Peel is approximately 29GL. Major strategic industry users of water (excluding mining but including mineral processing) in the Peel region are summarised in Table 25 and shown in Figure 26. However, it is important to note that the information represents allocated volumes, not use, and it is likely that the volume is an overestimation of actual use, particularly from surface water sources. In addition, limitations of the supplied DWER data regarding surface and groundwater licenses mean detailed breakdowns of water uses are not available.

Table 25: Strategic industry users of water (excluding mining)

Predominant strategic industries	Total Water Usage (kL)
Industrial	29,458,896
Extraction industry and dust suppression	238,920
Food processing (Dairy and vegetable washing)	206,973
Compost production	104,500
Abattoirs	92,300

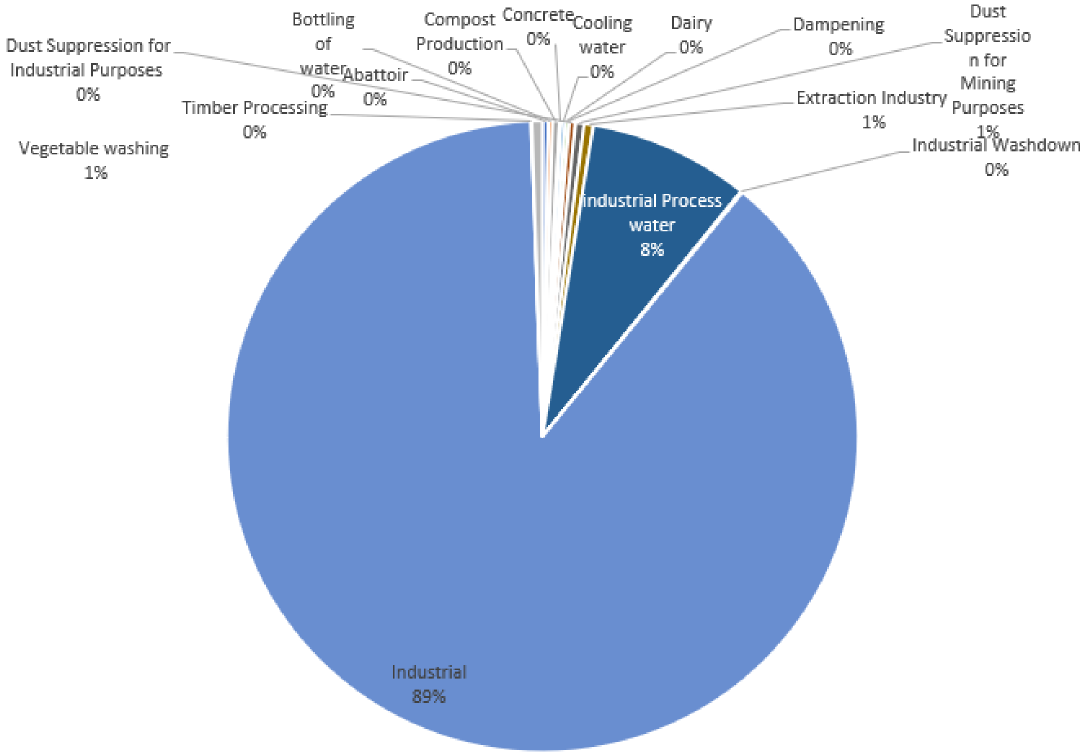


Figure 26: Groundwater and surface water allocated to industrial uses in Peel

Approximate water usage for strategic industry (excluding mining but including mineral processing) is at Table 26.

Table 26: Approximate water usage for strategic industry (excluding mining)

Local Government	Groundwater (kL)	Surface water (kL)	Scheme water (kL)	Total (kL)
Boddington	-	-	1,789	1,789
Mandurah	40,800	-	104,692	145,492
Murray	7,130,950	9,100,000	14,786	16,245,736
Serpentine Jarrahdale	421,339	26,650	16,653	464,642
Waroona	696,600	11,510,000	4,131	12,210,731
Total (GL)	**8.29**	**20.64**	**0.14**	**29.07**

4.3.3 Current mining water usage in Peel

Table 27 shows water license allocations for mining in Peel, noting that allocations do not necessarily reflect actual water usage.

Table 27: Water license allocations for mining in Peel

	Area Mining[17] (ha)	Groundwater (kL)	Surface water (kL)	Total (kL)
Boddington	1,508	-	15,000,000	**15,000,000**
Mandurah	29	12,500	-	**12,500**
Murray	2,715	2,060,000	500,000	**2,560,000**
Serpentine Jarrahdale	535	444,000	-	**444,000**
Waroona	284*	-	-	-
Total (GL)	**5,072**	**2.52**	**15.50**	**18.02**

*Note: *Waroona mining area is mineral processing, water use for this area is included in strategic industry*

The analysis indicates that Boddington has the largest water allocation for mining, noting that this is predominantly surface water. When only groundwater is considered, Murray has the largest allocation.

4.4 Current water needs of the Peel Region

In 2021, the Peel Region had access to approximately 140 GL water from a range of sources to support the community, agriculture and industry. These are summarised in Table 28, Table 29, Figure 27 and Figure 28. This shows that currently, agriculture utilises 32%, the community 30%, industry including mineral processing and commercial uses comprises 24% and mining uses 14% of the total water demands, which are predominantly supplied by surface water (46%) and groundwater (42%) with scheme water comprising 11% and 1% treated wastewater.

Table 28: Current water needs of the Peel Region

	Agriculture	Industry (including commercial)	Mining	Community	Totals
Boddington	5,757,804	43,164	15,132,900	1,031,537	**21,965,405**
Mandurah	242,585	1,567,673	12,500	19,755,215	**21,577,973**
Murray	12,176,144	17,541,403	2,962,597	8,995,888	**41,676,033**
Serpentine Jarrahdale	17,875,522	1,958,502	444,000	9,778,369	**30,056,393**
Waroona	10,242,571	12,301,416	0	2,284,365	**24,828,352**
Peel Region	**46,294,626**	**33,412,158**	**18,551,997**	**41,845,374**	**140,104,156**

[17] DPIRD Catchment scale land use mapping (DPIRD-067)

Table 29: Current water sources for the Peel Region

	IWSS	Groundwater	Surface water	Treated WW
Boddington	183,349	865,777	20,783,379	132,900
Mandurah	10,229,890	10,490,191	857,892	417,930
Murray	2,055,785	22,270,348	15,963,252	402,597
Serpentine Jarrahdale	2,638,630	22,516,467	4,163,076	0
Waroona	391,103	2,607,870	21,829,379	0
Peel Region	**15,498,757**	**58,750,653**	**63,596,978**	**953,427**

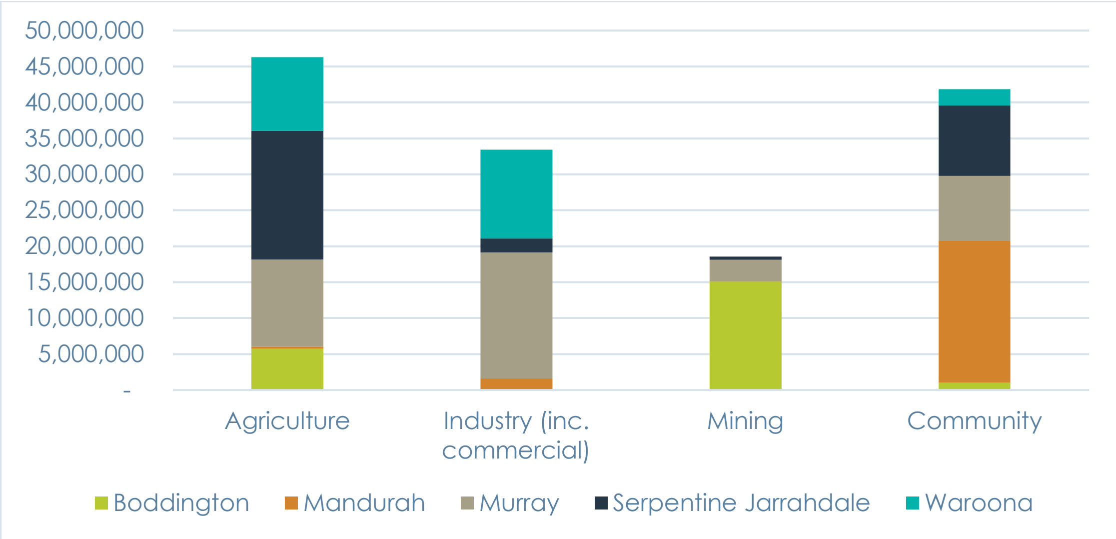


Figure 27: Peel water needs summary by use and local government

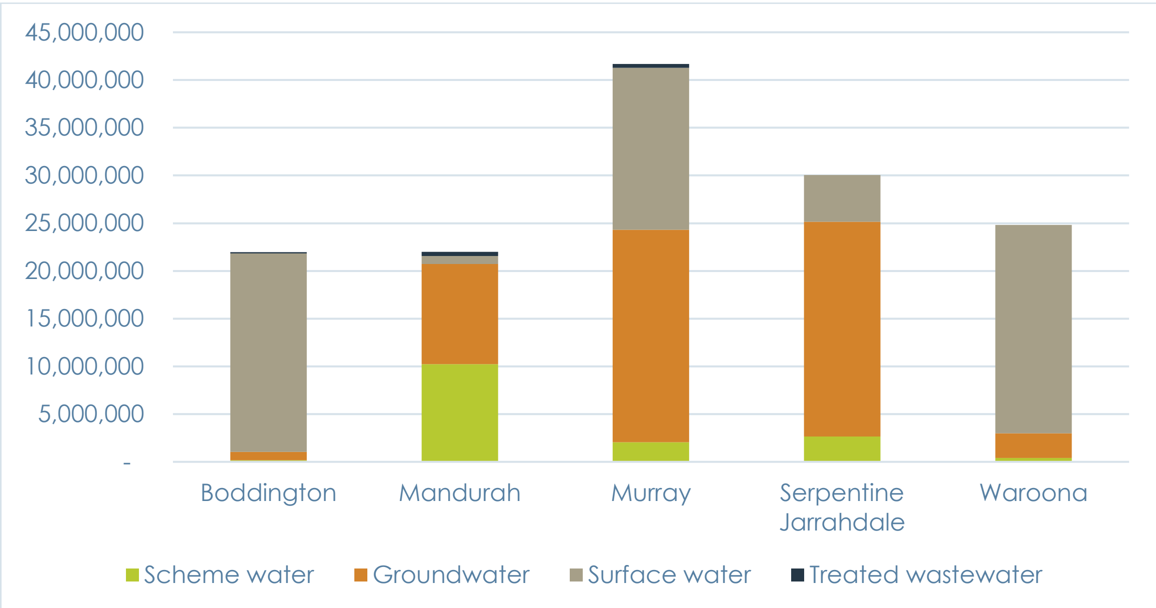


Figure 28: Current Peel water source summary

Section 5: Innovation and opportunities to reduce water demand in Peel

5 INNOVATION AND OPPORTUNITIES TO REDUCE WATER DEMAND IN PEEL

There are a number of opportunities to improve water use efficiency for community, industrial and agricultural needs as documented below. In most instances, these have been considered by the scenarios presented in section 6.

5.1 Community water use efficiency

The Water Corporation has been actively advocating for community water use efficiency for a number of decades through its Waterwise messaging and education programs which include Waterwise councils (together with DWER), Waterwise businesses and Waterwise developments. The Water Corporation website also contains a significant amount of information on Waterwise plants, products and offers, and contains a list of endorsed Waterwise specialists.

These programs have had an impact on water use as, over the last decade, average household water use in the Perth region has decreased from 277kL/year/household to 219kL/year/household, a reduction of around 20 per cent. Indoor water use reduced 10% in the last decade, because of higher uptake of water efficient devices, washing machines and other appliances. Outdoor water use reduced by 35% in the last decade, largely due to changes in Perth's built form. Higher density infill development, more apartments and reduced block sizes in greenfield development areas have resulted in smaller gardens requiring less irrigation (Water Corporation H2ome study, unpublished). The Water Corporation also notes that the most effective demand-management approaches have been widely adopted; hence targeted approaches are now required to achieve further reductions in demand (Government of WA, 2022).

In response to declining groundwater availability and the Perth-Peel target to use 10% less groundwater across the region (Kep Katijin - Gabi Kaadadjan, Government of WA, 2022), many local governments are also working to improve the efficiency of open space irrigation or reduce demands. Opportunities include:

- regular recording of metered water use at park level;
- upgrade to best practice irrigation systems and hydrozoning;
- use of web based irrigation operation and monitoring;
- upgrades of playing surfaces (improved turf species/ turf management to reduce water demand);
- increased tree planting to provide shade and reduce irrigation needs:
- use of soil moisture sensors, tissue analysis and/or real-time weather information to optimise irrigation regimes;
- re-scheduling of sports away from grounds with limited access to water to reduce wear on the surface (and resultant irrigation needs);
- re-allocation of irrigation from verges and other uses to POS; however, this is not recommended in areas with high urban heat and vulnerable populations;
- obtaining access to additional groundwater licences through trading; and/or
- municipal-wide planning for POS irrigation needs on the basis of function, including consideration of where alternative water sources may be viable.

5.2 Agricultural practices

Traditional farming techniques are under considerable pressure. Climate change is reducing water availability and decreasing the amount of arable land available for crop growing, while human activity is increasing pollution. Combined with a rapidly increasing global population, farming is being challenged to produce more food with less resources - particularly water. Consequently, a range of innovations are taking place in farming to reduce water usage.

5.2.1 Precision farming technology and irrigation

Precision farming technology includes farming management innovations used to make timely decisions based on accurate information that increase the efficiency and productivity of farmland. A wide range of technologies and processes exist that enable growers to observe and understand the variability in their production systems by tailoring inputs to their desired outputs. These include:

- Variable Rate Technology.
- Soil sensors.
- Yield monitors.
- Mass spectral analysis of foliage and weed growth.

Precision irrigation and precision spraying is a subset of precision farming technology that allows highly specific quantities of water to be provided to crops that optimise growth, thereby reducing water usage and costs. Approaches include:

- Mini-sprinkle and trickle - more precise versions of traditional irrigation that provides water to plants at the surface.
- Drip and subsurface irrigation - provides water directly to the crop's root system where it is absorbed by the plant. This is considerably more efficient than surface irrigation, as it reduces the amount of water not being absorbed by the crop and avoids evaporation.[18]

5.2.2 Greenhouses and protective cropping

Greenhouses are a well established farming approach used globally. Depending on their level of technological sophistication, greenhouses can help address issues such as poor soil, reduced access to water, and unsuitable climates for a given crop. Technologies range from simple plastic coverings, to climate and lighting controls, and automation.[19] Greenhouses typically have high productivity for water usage.[20]

Protected cropping is defined as "the production of horticultural crops within, under or sheltered by artificial structures and/or materials to provide and/or enable modified growing conditions and/or protection from pests and adverse weather".[21] Protected cropping covers a variety of terms including greenhouse horticulture, low cost protected cropping and controlled environment horticulture.[22]

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[18] Far Lane, Carabooda Nowergup Agri-Precinct: Implementation Plan, 2018, p 31.
[19] Arris, Peel Food Zone greenhouse prefeasibility report: A 10ha greenhouse base unit analysis, 2019, p 38.
[20] Arris, Peel Food Zone greenhouse prefeasibility report: A 10ha greenhouse base unit analysis, 2019, p 15.
[21] Arris, Peel Food Zone greenhouse prefeasibility report: A 10ha greenhouse base unit analysis, 2019, p 38.
[22] Arris, Peel Food Zone greenhouse prefeasibility report: A 10ha greenhouse base unit analysis, 2019, p 38.

Greenhouses and protected cropping can significantly increase productivity for some crops due to their ability to grow crops year round and more productively. For example, Table 30 compares tomato production in an open field to in a greenhouse.

Table 30: Water requirements under field and greenhouse conditions

Criteria for comparison	Field	Greenhouse	Increase
Size	1 ha	1 ha	0
Plant density (average/m^{2})	1.1	2.2	1
Total plants	11,000	22,000	1
Annual production (kg)	69,231	585,000	8.45
1st grade	80+%	95+%	0.12
Effective production, 1st grade (kg)	58,846	555,750	9.44
Effective production (kg per m^{2})	5.9	55.6	9.44
Effective production (kg per plant)	5.3	25.3	4.72
Water use (ML)	8	14.5	1.82
Conversion rate (grams fruit per litre water)	7.4	38.2	5.19
Production per ML/t	8.7	40.2	4.65
Market returns (gross)	$82,385 ($1.40/kg)	$1,667,250 ($3/kg)	20.24
Crop length (months)	± 7	11.5	1.64
Equivalent field production (ha)	1	9.4	9.44

Source: DWER, 2021.

The analysis indicates that growing tomatoes in greenhouses creates greater market returns, with an equivalent field production of 1 to 9.4 in favour of greenhouse cropping.

Greenhouses are likely to be of considerable importance to new agricultural development in Peel. A detailed table of key greenhouse features by technology is therefore included here (Table 31). Note that all four greenhouse options are suitable for hydroponics.

Table 31: key greenhouse features by technology

	Low tech	Medium tech	High tech – poly	High tech – glass
Cost guide (est.)	$30 – 50 /m2	$70 – 90 / m2	$150 – 250 / m2	$200 – 350 / m2
Potential crop productivity	40 – 60%	60 – 80%	100%	100%
Crop suitability *suitability in low to medium tech systems highly dependent on external climate	Salad crops Fresh herbs Greenlife Short-term floriculture	Salad crops / Asian veg Fresh herbs Greenlife Floriculture Berries Eggplant Cucurbits	Fully versatile	Fully versatile

	Low tech	Medium tech	High tech – poly	High tech – glass
Features	• Basic hoop structure polyethylene • cladding • No vents • 3.5m peak height • Single span • Closed hydroponics	• House structure • Polyethylene cladding • Wall vents +/or • roof vents <30% floor area • 5m peak height • Single or Gutter connected spans • Heating system • Cooling system • Closed hydroponics • Computer controllers	• House structure • Fully engineered & insurable polyethylene • cladding or polycarbonate • Roof vents >30% floor area +/or active cooling Min 5m peak height • Spans gutter connected • Heating system • Cooling system • Closed hydroponics • System integration & automation	• House structure • Fully engineered & insurable • Glass cladding Roof vents >30% floor area +/or active cooling • Min 5m peak height • Spans gutter connected • Heating system • Cooling system • Closed hydroponics • System integration & automation
Height		✓✓	✓✓✓	✓✓✓
Air volume		✓✓	✓✓✓	✓✓✓
Ventilation		✓✓	✓✓✓	✓✓✓
Temperature control		✓	✓✓✓	✓✓✓
Humidity control		✓✓	✓✓✓	✓✓✓
Light transmission	✓	✓✓	✓✓	✓✓✓
Shape	✓✓	✓✓✓	✓✓✓	✓✓✓
Suitability for internal screens		✓✓$	✓✓✓	✓✓✓
Suitability for automation	✓	✓✓$	✓✓✓	✓✓✓
Suitability for mechanisation		✓✓$	✓✓✓	✓✓✓
Suitability for biocontrol		✓✓	✓✓✓	✓✓✓
Suitability for hydroponics	✓✓✓	✓✓✓	✓✓✓	✓✓✓

	Low tech	Medium tech	High tech – poly	High tech – glass
Labour efficiency (ergonomics, WHS, logistics)		✓✓	✓✓✓	✓✓✓
Input efficiency	✓	✓✓	✓✓✓	✓✓✓

Source: Arris, 2019.

The analysis indicts that a variety of options and outputs can be utilised for greenhouse cropping.

DPIRD commissioned Arris to develop a detailed pre-feasibility report investigating the opportunity, requirements and potential benefits of intensive greenhouse horticulture enterprise in the Peel Food Zone in East Keralup. The report is comprehensive and contains useful further reading on greenhouses and protected cropping, and its suitability for Peel.[23]

It is important to note that greenhouses are not closed-loop systems. While greenhouses typically have lower water usage than traditional farming (as noted above), issues exist regarding wastewater treatment and nutrient runoff. For example, current industry practice for perennial tree crops is to irrigate nutrient-rich wastewater which may have led to considerable nutrient runoff. Further research is required to clarify how best to manage this issue, its potential impacts, and determination of best practice.[24] Furthermore, reusing water from greenhouses can be challenging due to salinity issues.[25]

5.2.3 Vertical farming

Vertical farming is an agricultural innovation that is likely to be crucial to withstanding climate change and increasing production, as it offers best practice irrigation techniques and clear opportunities for improved outcomes.

Vertical farming is an indoor factory for growing vegetables. Typically constructed as multilevel warehouses, the growing occurs in a controlled climate entirely shielded from the elements with a closed loop for water and air, and heating and light provided by LEDs. Temperature, moisture, humidity and other factors can be varied to emulate ideal growing conditions and optimise crop yields. Data, robotics and AI are employed to increase productivity. Crops are mostly grown in soil but are also grown in liquids or even wool.[26]

[23] Arris, Peel Food Zone greenhouse prefeasibility report: A 10ha greenhouse base unit analysis, 2019.
[24] Department of Water and Environmental Regulation, Transform Peel – Peel Integrated Water Initiative report, 2021, p 102.
[25] Phone conversation with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.
[26] Benke and Tomkins, Future food-production systems: vertical farming and controlled-environment agriculture, in Sustainability: Science, Practice and Policy, volume 13, 2017. link

Plate 1: Vertical farming system (Source: The Grocer, 2021. link)

A typical vertical farm closed loop system is at Figure 29.

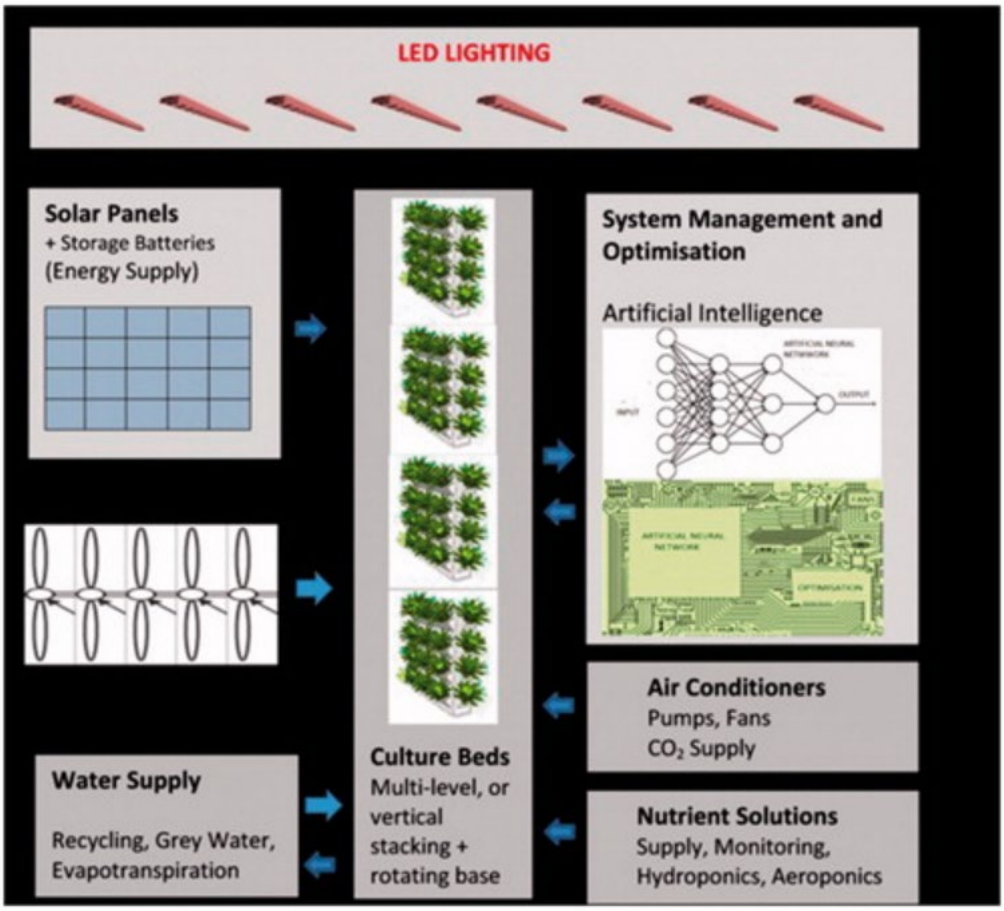

Figure 29: Vertical farming closed loop system (Source: Benke and Tomkins, 2017. link)

Benefits of vertical farms

Key benefits of vertical farms compared to traditional farming include:

- Climate proof – not reliant on rainfall, and can avoid droughts, floods, and pests.
- Higher yields – substantially higher yields by area, depending on the crop.
- Closed-loop system – significantly reduces the need for, and costs of, water, pesticides, and nutrients.
- Urbanisation – can grow food close to major population centres, providing more fresh food and reducing shipping costs and carbon emissions.
- Year-round crop production – not reliant on seasons to grow crops.
- Ongoing productivity gains – from new research, data and knowhow.
- Low environmental impact – no nutrient runoff, reduction of pathogens, fossil fuels (no tractors or farm machinery) and no pesticides.[27]

A comparison of benefits of conventional farming and vertical farming is at Table 32.

Table 32: Benefits of conventional farming and vertical farming

	Conventional farming	Vertical farming
Water consumption	250 kg per kg produce	3 - 8 kg per kg produce
Food production loss	20%	0%
Fertiliser use	5.9 g/m2	1.8 g/m2
Land area	256 m2 to grow one ton	0.4 – 29 m2 to grow one ton
Yield per area	4 kg per m2 per year	34 – 447 kg per m2 per year
Electricity consumption	0 kWh per key produce	17.5kWh per kg produce

Source: Association for Vertical Farming, 2021.

Vertical farming challenges

Key challenges of vertical farms compared to traditional farming include:

- High start-up costs – significant capital is required to acquire well placed land and construct and fit out warehouses, particularly given the tech-intensive nature of the equipment.
- Fewer crops – meat cannot be grown, and not all vegetables have yet been cultivated in vertical farms. Grains and potatoes have not yet been grown at scale.
- Lack of knowhow – there are currently no vertical farms in Western Australia, although one is currently being established in Peel (see Eden Towers case study below).[28]

Vertical farming is an emerging industry. Consequently the above challenges are likely to become less prevalent over time as the industry becomes better established.

[27] Benke and Tomkins, Future food-production systems: vertical farming and controlled-environment agriculture, in Sustainability: Science, Practice and Policy, volume 13, 2017. link

[28] Benke and Tomkins, Future food-production systems: vertical farming and controlled-environment agriculture, in Sustainability: Science, Practice and Policy, volume 13, 2017.

Case study – Aerofarms, USA

Aerofarms is an American vertical farming business that is operating on an industrial scale, including from a 14,164 square meter facility in Newark, New Jersey. Predominantly growing green leafy vegetables for the American east coast market, Aerofarms uses AI and machine vision (which allows computers to "see" the crops) to collect and refine data and help optimise yields. Over 550 different types of plants are grown, and their farms are entirely digital and can be operated remotely from across the globe. Aerofarms are also moving into producing natural products for the pharmaceutical industry.

Aerofarms claims its operations have the following benefits compared to field farming:

- 95% less water
- 45% less fertiliser
- 390 times productivity gains.[29]

Case study – Eden Towers, Shire of Murray Western Australian Food Innovation Precinct (WAFIP)

Eden Towers is a vertical farm currently under development in the Peel Business Park. The farm will consist of a four-tower industrial scale, solar powered indoor complex that will generate 120 tonnes of produce per annum once fully operational, including lettuce, spinach, kale, microgreens, edible flowers and herbs. The farm's development is being supported by a $200,000 grant from WAFIP.[30]

Eden Towers note that the farm will have high productivity by acreage, with a 40 sqm growth tower producing an equivalent yield to a 6000 sqm traditional paddock, and using 98% less water than traditional farming.[31]

Going forward, Eden Towers has strong potential to act as a useful exemplar for further developing vertical farming in Peel and Western Australia more broadly.

5.3 Mining and industry

Water is an integral part of mining, used in exploration, mining operations, mineral processing, care-and-maintenance and rehabilitation after a mine's closure. After mining or processing activities, water is either reused, returned to the environment, supplied to other users or lost through evaporation. Managing this water safely and to meet regulatory requirements is a significant challenge and high priority for the industry.[32]

Water saving and reuse technologies are readily available within the mining industry. This includes efficient dispersal systems to control dust from extraction operations, as well as numerous chemical, process and biological methods of wastewater treatment to enable reuse in fit-for-purpose opportunities. While the drive for the resources industry is generally operational efficiency and cost-effectiveness, these technologies will also reduce environmental impact. Key opportunities are reuse of tailings water and treatment of saline discharges.

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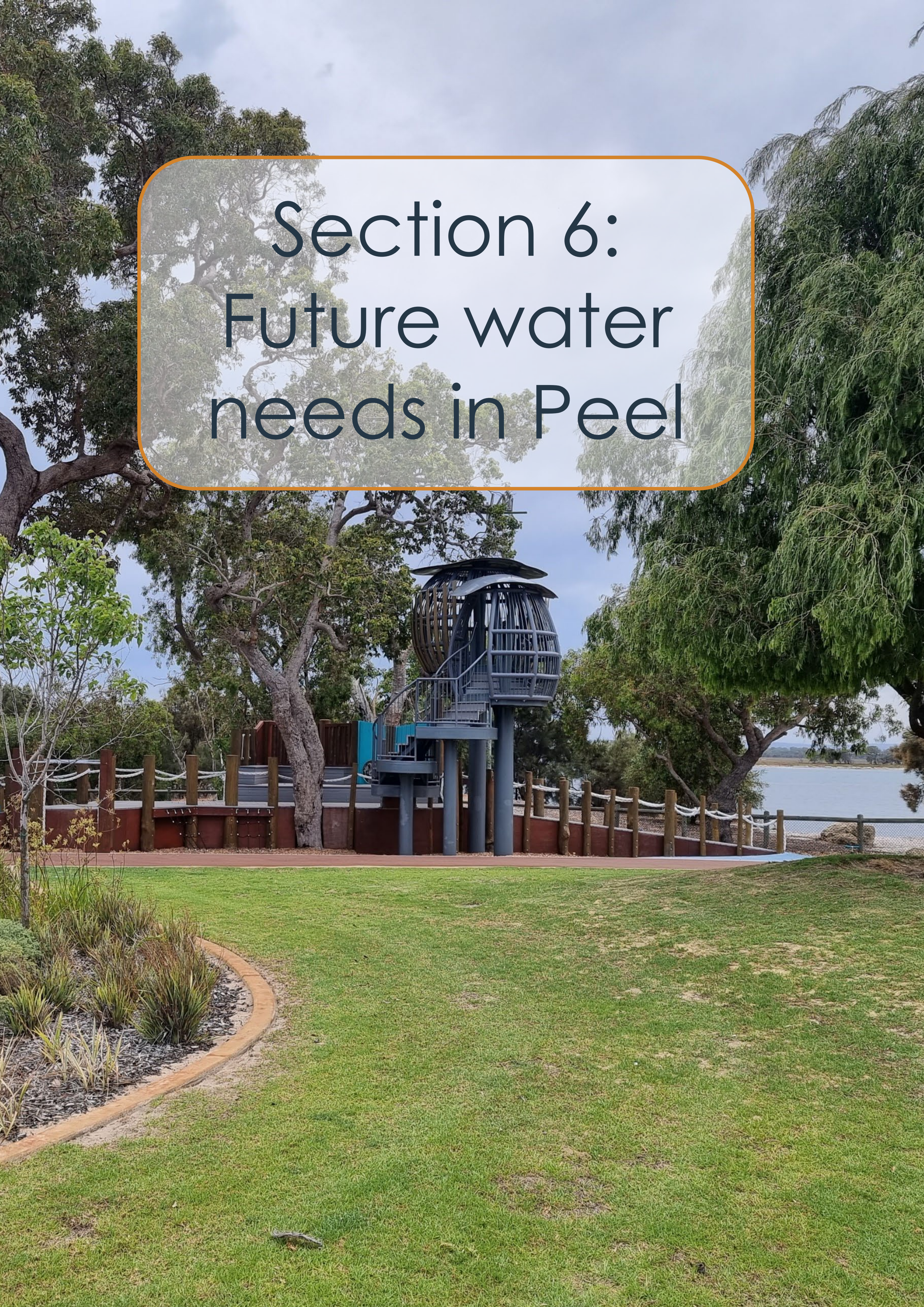
[29] Business Insider, "The world's largest vertical farm will produce 2 million pounds of lettuce every year", August 2016.
[30] Peel Development Commission, media release, "Skies the Limit for WA Vertical Farm Company", January 2022.
[31] Eden Towers website, https://www.edentowers.life/pages/about-us, last accessed November 2022.
[32] CSIRO, 2022, https://www.csiro.au/en/work-with-us/industries/mining-resources/social-and-enviromental-performance/mine-wastewater-treatment

For example, Newmont's *Global Water Strategy* seeks to "manage water as a precious resource and work collaboratively to create value and improve lives through sound water stewardship." The Boddington Gold operation extracts ore from mine pits which is trucked to crushing circuits where milled product is processed through a dry processing plant and wet processing plant before the tailings are disposed of in partially lined tailings storage facilities. Newmont also incorporates multiple sewage facilities, an onsite inert landfill and water desalination for potable water supply. Newmont has Ministerial approval for the disposal of up to 9,600 ML of excess mine water per year however, the current and future estimated water balance is such that all mine water is currently stored in water supply reservoirs for reuse in processing and general mining operations. Newmont also accepts treated sewage wastewater from the Water Corporation's Boddington Wastewater Treatment Plant that is discharged to one of the tailings storage facility.

In addition to water-saving technologies and improved re-use opportunities, changes to the water source and supply balance in the Peel Region may occur if the industry moves towards utilisation of more climate-independent sources. This report has noted the significant reliance of some mining industry activities on surface water which is now recognised as being increasingly unreliable. Furthermore, the State Government commitment to reduce groundwater use by 10% in the Perth and Peel region (Government of WA, 2022) means that efforts may be made to reduce annual licensed water entitlements in resources that are overallocated. . This commitment, together with the increasing impacts of climate change, also foreshadow the potential for further reductions in groundwater allocations in the future. As water is critical to mining operations and processing, it is considered likely that the mining companies will seek to identify or create climate-independent sources of water to replace surface and groundwater sources, thereby freeing up this water for other uses or for environmental benefit. However, as mine sites and processing plants are generally located away from areas of development, these sources are unlikely to assist with community uses, but they may provide a source for other industry or agriculture.

Section 6: Future water needs in Peel



6 FUTURE WATER NEEDS

The future water needs for community, agriculture and industrial (including mining) uses in the Peel Region to 2051 are discussed below.

6.1 Future community water needs

The key future water needs of the community include drinking water provided to new residential, commercial (including tourist) and industrial development through the IWSS; water for the irrigation of public open space and water for new peri-urban development as discussed below.

6.1.1 Public open space

The future water needs of the community (including supporting community landuses) are dependent on population growth with the exception of public open space which is provided on an area basis. For the purposes of this study, the recently updated *Perth and Peel @3.5million planning investigation areas* (WAPC, 2022) have been included in the calculation of public open space. Future water needs for public open space and schools in 2051 are provided in Table 33.

Table 33: Water needs of future public open space and schools

	Existing POS area (Ha)	Existing POS irrigation demand (kL)	Future POS area (Ha)	Future POS Irrigation demand (kL)	Existing Schools area (Ha)	Existing Schools irrigation demand (kL)	Future Schools area (Ha)	Future Schools irrigation demand (kL)
Boddington	7,338	543,057	-	-	22	49,500	-	-
Mandurah	6,118	4,343,521	568	-	150	353,300	74	149,850
Murray	8,677	1,771,309	2,116	479,266	50	61,450	144	291,600
Serpentine Jarrahdale	9,252	2,752,068	282	755,246	64	104,975	208	421,200
Waroona	19,337	11,400	1,425	140,738	14	31,500	32	64,800
	50,722	**9,421,355**	**4,391**	**1,375,250**	**300**	**600,725**	**458**	**927,450**

Notes:
Exiting POS from allocations except Boddington which is irrigated at 7500 kL/Ha (except nature)
Existing school demand from allocations except for Boddington/Waroona where 30% of existing school area is irrigated at 7500 kL/Ha
New government high schools (10 ha each) are provided at rate of 1 per 6600 dwellings
New government primary schools (4 ha each) are provided at rate of 1 per 1650 dwellings
New private high schools (10 ha each) are provided at rate of 1 per 13200 dwellings
New private primary schools (4 ha each) are provided at rate of 1 per 4950 dwellings
30% of future school area is irrigated at 6750 kL/Ha
Future POS is irrigated at 6750 kL/Ha
DWER has allocated groundwater from the Lower Leederville aquifer in the Nambeelup subarea for future irrigation of Ravenswood's regional scale playing fields.

6.1.2 Other "community use" water needs

As stated earlier, community water needs include water for commercial and tourist areas (supplied from scheme water, groundwater and surface water): water for firefighting; and licenced and unlicenced groundwater and surface water for domestic and small stock purposes in peri-urban areas.

This study accounts for future growth in commercial areas in the Industry sector, represented as "population-driven industry". It should also noted that all future population driven industry is assumed to use scheme water, therefore no increase in groundwater or surface water use for future commercial land uses is proposed.

Consideration was also given to the likely increase in water allocated for firefighting and for new Rural Residential areas (in either licenced or unlicenced areas for stock and domestic use). It was assumed that as new urban development is likely to occur in some of the current rural residential areas, this loss in demand could account for any future increase. It is also noted that there is limited allocation remaining in most areas.

6.1.3 Population growth and development scenarios

To predict future residential scheme water needs of the community in the Peel region, the following scenarios were assessed on the basis of future population projections agreed with each local government. These scenarios were agreed by the project stakeholder agencies at a workshop in October 2022.

Scenario C1: Business as usual (BaU) growth including schools and public open space (incorporating a reduction in groundwater use of 10% by 2030)

Scenario C2: High growth scenario using the population projections in Perth and Peel @ 3.5 million (WAPC, 2018)

Scenario C3: Reduced water use by the community through waterwise gardens or medium density, assuming that after 2030, 50% new residents will reduce their water use to 70 kL/per person/year

Scenario C4: 30% of existing development incorporates a waterwise garden (water use at 70 kL/per person/year)

The results of the scenario analysis demonstrate that business as usual growth (scenario C1) will result in additional water demands of 22.5 GL by 2051 whereas the high growth scenario (C2) will need 36.6 GL. The water savings from 50% new residents having waterwise gardens (C3) is approximately 3.14 GL by 2051 and around 1.1GL from the waterwise retrofit of 30% existing gardens (C4) (Table 34 and Figure 30).

Table 34: Additional community water demand for future scenarios

Peel Region	C1 - BaU	C2 - High growth	C3 – Waterwise (new developments)	C4 - Waterwise (existing)
2021	-	-	-	-
2026	2.64	6.06	2.26	1.70
2031	5.32	12.17	4.59	4.3
2036	8.349	18.29	7.21	7.38
2041	12.52	24.40	10.79	11.52
2046	17.24	30.52	14.84	16.20
2051	22.48	36.63	19.34	21.41

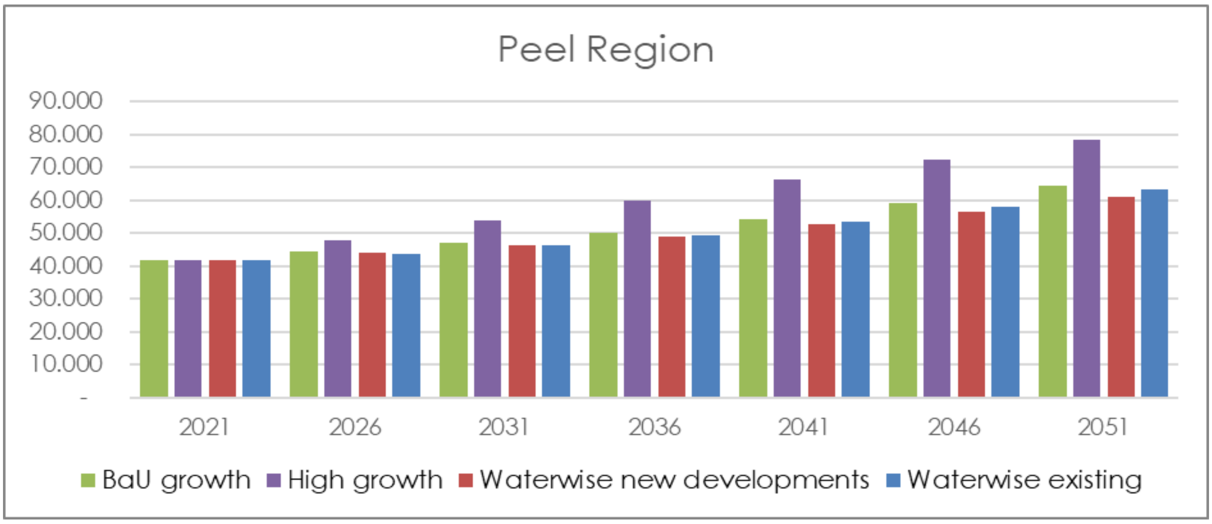


Figure 30: Total residential water demand (including rainwater tanks) for future scenarios

6.2 Future agricultural water needs

The future Peel agricultural water needs include the demands from existing irrigated agricultural areas plus the water required to support industry growth and the establishment of new areas of irrigated agriculture.

6.2.1 Existing agricultural areas

As previously indicated in Section 4.2, approximately 30 GL of water is currently allocated for agricultural production in the Peel region. This study assumes that the current levels of water allocated to agricultural production in the Peel will continue to support agricultural production in 2050 (i.e. it is unlikely that these allocations will be returned to the Department of Water and Environmental Regulation or traded for other purposes). The current allocated volumes are provided in Table 35. Also indicated in Section 4.2.1, approximately 17 GL of water is estimated to be used (including evaporative losses) via farm dams in the Peel region. Similarly, this study assumes that current dams are maintained, and no new dams are constructed.

Table 35: Current groundwater and surface water licenced allocations for agricultural uses

Local Government	Intensive agricultural land area (ha)[33]	Groundwater		Surface water	
		General agriculture	Irrigation scheme	General agriculture	Irrigation scheme
Boddington	84	-	-	-	-
Mandurah	355	150,840	-	-	-
Murray	6,523	5,611,805	-	984,050	-
Serpentine Jarrahdale	19,473	13,836,671	418,300	738,220	-
Waroona	4,552	53,840	-	-	7,652,000
Total Peel (GL)	**30,988**	**19,653,156**	**418,300**	**1,722,270**	**7,652,000**

33 DPIRD Catchment scale land use mapping (DPIRD-067). Includes “Rural residential with agriculture”

While the impact of rising temperatures in the region leading to increased water demands of plants due to higher evapotranspiration is acknowledged, this study assumes that new technologies or improved irrigation efficiencies will occur to maintain the desired level of agricultural production at current levels of water allocation by 2050. This is addressed further below.

6.2.2 New agricultural areas

While Peel has well established agricultural areas, urbanisation pressures are slowly reducing the amount of agricultural land available.[34] However, as emerging technologies and approaches become available, new agricultural areas may open up or transition to new types of production.

Considerable work has been undertaken to identify suitable agricultural land for development and preservation. Critical issues include:

- Water supply - ensuring access to availability of water in the required quantities and locations.
- Water disposal – ability to appropriately dispose of wastewater, including consideration of environmental consequences and recycling opportunities.
- Soil type – identifying and avoiding high phosphorus-fixing soils (i.e. soils that absorb phosphorus, a crucial fertiliser, thereby making it unavailable to plants) that make crop growth more challenging.
- Nutrient runoff – ensuring that nutrients from applied fertilisers do not affect the Peel-Harvey catchment.

Underlying these issues is how agricultural in the region will change and adapt to a drying climate, including increasing competition for water as it becomes scarcer.

Moving towards 2050, high value, low nutrient horticulture is likely to be most viable option for expansion, as the impact from water and nutrient usage is better managed and nutrient runoff into the Peel-Harvey catchment can be avoided.[35]

Peel Food Zone

The Peel Food Zone project is currently investigating an area of 42,000 hectares for agricultural opportunities in the Shire of Murray and Shire of Serpentine Jarrahdale. The zone is adjacent to the Peel Business Park and WAFIP. A map of the Peel Food Zone is at Figure 31.

Key goals of the Peel Food Zone project include:

- Understanding opportunities for new high quality, year-round produce.
- Attracting investment.
- Supporting the development of new food technologies through WAFIP and the Peel Business Park.
- Creating exports for global markets.

[34] Department of Planning, Lands, and Heritage, South Metropolitan Peel Sub-regional Planning Framework, 2018.
[35] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.

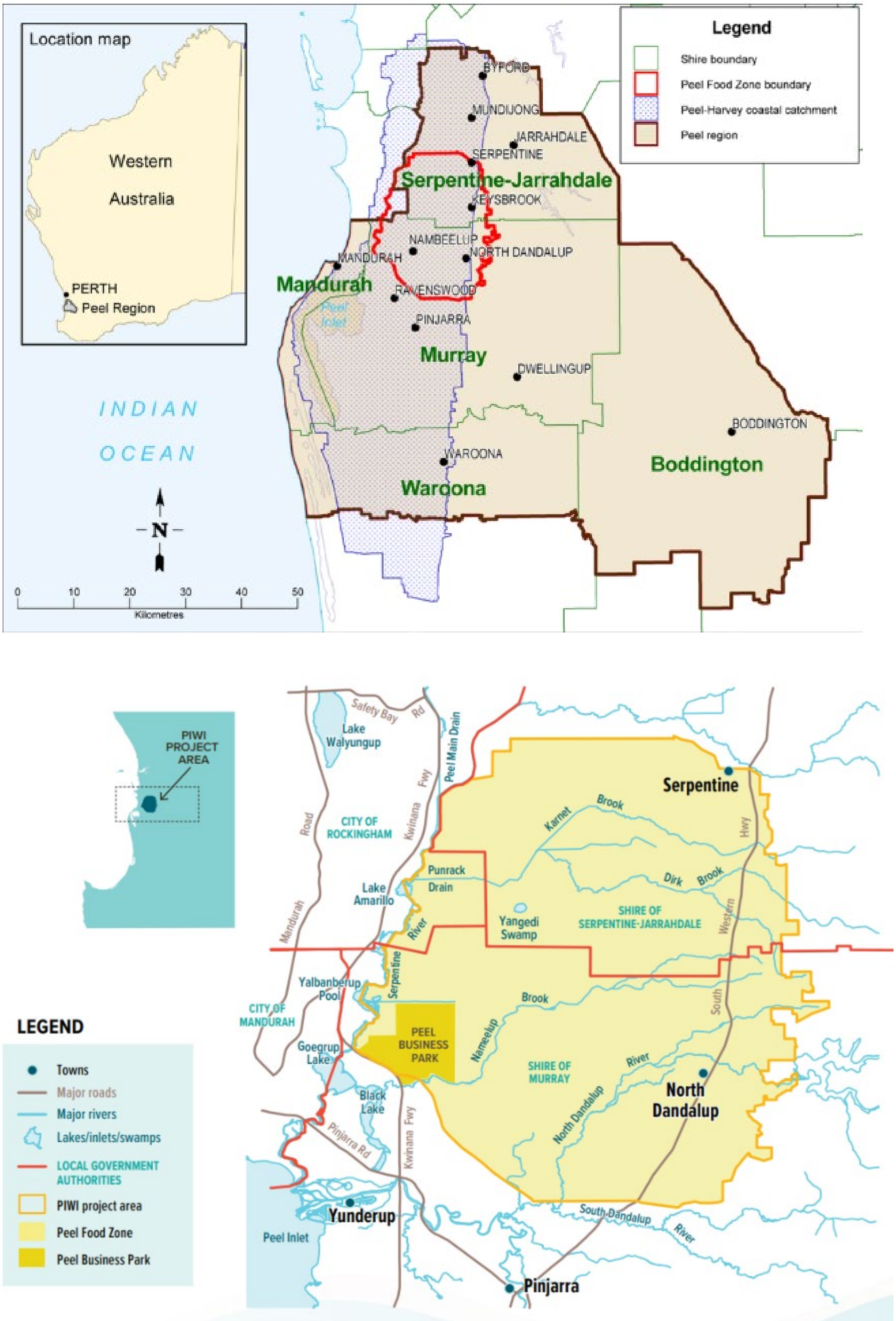


Figure 31: Peel Food Zone (Source: DWER and DPIRD).

https://library.dpird.wa.gov.au/cgi/viewcontent.cgi?article=1060&context=pubns

Considerations of the project include investigating soil types, nutrients, water availability, land zoning, environmental factors, and the effects of climate change.

The project is being led by DPIRD, which commissioned GHD to undertake a detailed report on the zone's potential. Key findings include:

- The eastern zone is suitable for growing a variety of crops and pastures, including vegetables and fruit trees. However, water supplies will need to be closely monitored to ensure there is sufficient supply.
- The western side is suitable to closed-loop systems of agriculture such as hydroponics, vertical farms and greenhouses.
- Some areas of the zone are highly constrained and not suitable for development.
- New methods of farming that limit water usage and fertiliser are required to protect wetlands in the Peel-Harvey region.[36]

The Peel Food Zone falls within the Transform Peel Program, which also includes the Peel Business Park and Peel Integrated Water Initiative (PIWI). DWER have produced a detailed PIWI report assessing water opportunities and constraints that may affect the Transform Peel Program.

The PIWI report investigated water requirements for developing the Peel Business Park at 1000 hectares, and the Peel Food Zone hosting up to 3000 hectares of irrigated horticulture. The PIWI report's focus areas include:

- Water catchment analysis.
- Available water sources, including opportunities to diversify supply.
- Strategies for nutrient reduction entering the estuary system.
- Testing innovative water source and storage options.

The PIWI report concluded that:

- Poor soil, limited water supplies, and environmental considerations (particularly relating to the Peel-Harvey estuary) are significant constraints to agricultural development.
- Large scale, in-ground (i.e. crops planted directly into the soil) intensive horticulture is unrealistic and undesirable for the Peel Food Zone.
- Intensive horticulture using greenhouse systems are the most appropriate form of agricultural development, due to low water requirements and mechanisms for capturing and manage wastewater.[37]

The PIWI report concluded that "The feasibility of establishing a greenhouse development with closed-loop waste streams, supplied by existing water from conventional sources, is worthy of further investigation as it presents the most suitable option for large-scale horticultural development in the Peel study area".[38]

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[36] DPIRD website, https://www.agric.wa.gov.au/peelfoodzone, last accessed November 2022.
[37] Department of Water and Environmental Regulation, Transform Peel – Peel Integrated Water Initiative report, 2021, p 9.
[38] Department of Water and Environmental Regulation, Transform Peel – Peel Integrated Water Initiative report, 2021, p 15.

While a defined development pathway for greenhouse development in the Peel Food Zone has not been developed, this mode of agriculture is likely to become more common after 2030.[39]

Other new agricultural developments

Aside from the Peel Food Zone, there is limited further identified land for new agriculture development in Peel, as agriculture in the region is already well established. Noting the above determinants of water supply, water disposal, soil types, and nutrient runoff, the only potential new area that has been identified is the foothills from north Dandalup to Serpentine, noting any development is likely to be small scale irrigated agriculture.[40] Consideration of this possibility is included in the scenarios.

6.2.3 *Scenario assessment*

Following the scenario workshop in October 2022, further consultation with DPIRD shaped the following scenarios for analysis.[41] These scenarios are based on plausible agricultural changes between now and 2051[42] that:

- would lead to non-BAU agricultural water usage
- control nutrient runoff
- utilise higher value, lower nutrient horticultural approaches.

The selected scenarios are:

Scenario A1: Waroona Irrigation District – a change from irrigated pasture to perennial irrigated horticulture across 400 hectares by 2051.

Scenario A2: North Dandalup to Serpentine foothills – development of 200 hectares of new intensive perennial irrigated agriculture by 2051.

Scenario A3: Peel Food Zone – 250 hectares of new closed-loop covered cropping by 2051.

Key findings from the scenario analysis are presented below. Note that:

- Full methodology is at Appendix 3.
- Constant growth rates between 2021 and 2051 are used.
- All scenarios use the assumption that suitable water is available until 2051, noting that potential water supply sources will be identified in the next phase of the project and discussed in the final report.

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[39] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.
[40] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.
[41] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.
[42] 2051, rather than 2050, is used as this aligns with forthcoming Census dates that have been used for other modelling in this project.

Scenario A1 - Waroona Irrigation District – a change from irrigated pasture to perennial irrigated horticulture across 400 hectares by 2051.

The Waroona Irrigation District is suitable for transitioning some of its current pasture growing to high value irrigated agriculture by 2051. This scenario therefore models 400 hectares being transitioned at a constant rate of growth from present to 2051 (Table 36).

Table 36: Water demands from scenario A1 to 2051 (GL)

	2021	2026	2031	2036	2041	2046	2051
Total Usage (GL)	2.65	2.88	3.12	3.35	3.58	3.81	4.04
Change since 2021 (GL, %)	0	+0.23 9%	+0.46 17%	+0.70 26%	+0.93 35%	+1.16 44%	+1.39 52%

The analysis indicates that transitioning irrigated pasture to perennial irrigated horticulture across 400 hectares in the Waroona irrigated agricultural district by 2051 would lead to an annual net increase of 1.39 GL by 2051, or a 52% increase on current water usage rates.

Scenario A2 – North Dandalup to Serpentine foothills – development of 200 hectares of new intensive irrigated agriculture by 2051

The North Dandalup to Serpentine foothills are potentially suitable for developing into new perennial horticultural cropping such as table grapes, fruit trees, and avocados. This scenario therefore models 200 hectares of new perennial horticulture being developed, at a constant rate of growth from present to 2051 (Table 37).

Table 37: Water demands from Scenario A2 to 2051

	2021	2026	2031	2036	2041	2046	2051
Total Usage (GL)	0	0.34	0.67	1.01	1.35	1.69	2.02

The analysis indicates that 200 hectares of new perennial horticulture cropping in the foothills by 2051 would lead to an annual net increase of 2.02 GL by 2051 (noting there are no current water usage rates for this scenario, as it reflects a new agricultural zone).

Scenario A3 - Peel Food Zone – 250 hectares of new closed-loop covered cropping by 2051

The Peel Food Zone is highly suitable for the development of new closed-loop covered cropping systems such as vertical farms (noting that most greenhouses are not closed-loop).[43] This scenario therefore models an area of 250 hectares of closed-loop cropping at a constant rate of growth from present to 2051 (Table 38).

[43] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.

A low water use crop (lettuce) and high water use crop (carrots) that are both plausible for closed-loop farming at scale in the Peel Food Zone by 2051 have been modelled. Assumptions include:

- Lettuce requires 4.6 ML/ha of water.[44]
- Carrots require 7.88 ML/ha of water.[45]

Closed-loop farming requires 20% of the water required to grow the same crop via open field irrigation.[46]

Table 38: Water demands from scenario A3 to 2051

	2021	2026	2031	2036	2041	2046	2051
Lettuce (GL)	0	0.04	0.08	0.12	0.15	0.19	0.23
Carrots (GL)	0	0.07	0.13	0.20	0.26	0.33	0.39
Difference	0	0.03	0.06	0.08	0.11	0.14	0.16

The analysis indicates that 250 hectares of new closed-loop covered cropping in the Peel Food Zone would lead to between 0.23 GL and 0.39 GL of increased water usage by 2051.

It is noted that PIWI report estimates that 250 ha of greenhouses will require 3.75 GL of water for irrigation per annum. This study has investigated the water demands for closed-loop cropping systems, which accounts for the reduced demand calculated above.

Scenarios – conclusion

A summary of potential water usage for each scenario until 2051 is at Table 39.

Table 39: Summary of potential additional demands to 2051

	2021	2026	2031	2036	2041	2046	2051
Scenario A1 (GL)	2.65	2.88	3.12	3.35	3.58	3.81	4.04
Scenario A2 (GL)	0	0.34	0.67	1.01	1.35	1.69	2.02
Scenario A3 – High water usage crop (carrots) (GL)	0	0.07	0.13	0.2	0.26	0.33	0.39
Total (GL)	**2.65**	**3.29**	**3.92**	**4.56**	**5.19**	**5.83**	**6.45**

The analysis indicates that, if all three scenarios were implemented, net water usage in the study area would increase by 6.45 GL in 2051.

[44] FAR Lane analysis based on the DPIRD irrigation calculator, 2022.
[45] FAR Lane analysis based on the DPIRD irrigation calculator, 2022.
[46] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.

6.3 Future industrial water needs

Approximately 49.8 GL of surface water and groundwater is currently allocated for industry and resources use in the Peel region, including population driven (commercial) industries. With the exception of 15 GL of surface water allocated to the mining industry in Boddington which will likely be returned to the environment in 2036 on the closure of the Newmont mine, this study assumes that the current levels of water allocated to mining and industry will continue to support the sector in 2050. This is to address the uncertainty associated with the future of groundwater and surface water licences, as it is not possible to predict if they will be traded or returned to the environment in future. The current allocated volumes are provided in Table 40.

Table 40: Current groundwater and surface water licenced allocations and scheme use for mining and industry

Local Government	Industrial land area (ha)	Groundwater		Surface water		Scheme water	
		Industry	Mining	Industry	Mining	Industry	Mining
Boddington	1,496	-	-	-	15,000,000	43,164	-
Mandurah	554	541,186	12,500	-	-	1,026,487	-
Murray	3,090	8,163,744	2,060,000	9,100,000	-	277,659	-
Serpentine Jarrahdale	475	1,679,474	444,000	77,250	500,000	201,778	-
Waroona	1,576	714,500	-	1,510,000	-	76,916	-
Total Peel	**7,191**	**11,098,904**	**2,516,500**	**20,687,250**	**15,500,000**	**1,626,004**	**0**

6.3.1 New population-driven industry

Potential future water demand for population-driven industry in each local government in Peel is described in Table 41. Forecasting is based on increasing population (as for community needs) and corresponding demand for population-driven industries and associated water usage. Full methodology is at Appendix 4.

Table 41: Potential future water demand for population-driven industry (GL)

	2021	2026	2031	2036	2041	2046	2051
Boddington	0.04	0.04	0.04	0.04	0.05	0.05	0.05
Mandurah	0.92	1.00	1.09	1.17	1.25	1.34	1.42
Murray	0.26	0.31	0.35	0.40	0.44	0.49	0.53
Serpentine Jarrahdale	0.19	0.23	0.27	0.31	0.36	0.40	0.44
Waroona	0.07	0.08	0.09	0.11	0.12	0.13	0.14
Total (GL)	**1.48**	**1.67**	**1.85**	**2.03**	**2.21**	**2.40**	**2.58**

The analysis indicates that water usage by population-driven industry will increase significantly from 1.48 GL to 2.58 GL by 2051.

Industrial Precincts by local government

Peel contains several major industrial areas hosting a variety of industries, both population-driven and strategic. A map of key industrial precincts in the Peel region is at Figure 32. Please note that:

- Mine sites are not included as they are addressed separately.
- Commercial activity centres (such as shopping centres) are not individually considered, as increased water demand for these centres is captured through analysis of population-driven industry demand in Table 41 above.

An overview of notable industrial precincts in Peel is at Table 42.

Table 42: Industrial precincts in the Peel Region

Location	Existing operations	Significant growth potential?
Boddington		
Boddington industrial area	Light industry.	No. Nearing capacity.[47]
Gold Mine Road	Under development.	Unclear. Land has been zoned for expansion[48]. Unclear if demand exists for growth.
Mandurah		
Gordon Road industrial area	Light industry, water treatment.	No. At capacity, no expansion potential.[49]
Murray		
East Keralup	Under development into agribusiness precinct.	Yes, up to 1,600 hectares.[50]
Pinjarra Industrial Area	Supporting industry for the nearby Alcoa refinery.	Yes. Stage 3 lots currently for sale from DWA.[51]
Nambeelup Industrial Area / Peel Business Park	New industrial area under development as an agriprecinct.	Yes. All stage 1 lots sold, stage 2 currently on the market from DWA.[52]

[47] Shire of Boddington Local Planning Strategy, 2018, p 14.
[48] Shire of Boddington Local Planning Strategy, 2018, p 14.
[49] DevelopmentWA, 10-Year Industrial Lands Strategy, 2021, p 48.
[50] Email correspondence with Adrian Parker, Director Regional Development, Peel Development Commission, November 2022.
[51] DevelopmentWA, Pinjarra Industrial Estate website, https://developmentwa.com.au/projects/industrial-and-commercial/pinjarra-industrial-estate/overview, last accessed November 2022.
[52] DevelopmentWA, Peel Business Park website, https://developmentwa.com.au/projects/industrial-and-commercial/peel-business-park/overview, last accessed November 2022.

Location	Existing operations	Significant growth potential?
Serpentine Jarrahdale		
Cardup Business Park	Industrial investigation area.	Yes. Possibility for expansion as Byford's population continues to grow. [53]
West Mundijong	Industrial investigation area.	Yes. Potential for activation as a dry port and supporting industry.[54] Phase 1: Dry-lot subdivision has commenced
Waroona		
Wagerup Industrial Area	Alumina refinery (Alcoa) and supporting industry.	Yes. Alcoa are currently proposing to expand its refinery and Frontier Energy are seeking to build a hydrogen refinery

The analysis suggests that some industrial areas in Peel are at, or are nearing, capacity. However, for the purposes of this analysis, the following industrial areas were considered likely for significant expansion and corresponding increase in water usage:

- Cardup
- East Keralup
- Nambeelup - Peel Business Park
- Pinjarra
- West Mundijong
- Wagerup

Further analysis of these industrial areas is provided below.

Future industrial development areas in Peel

As noted above, the following industrial areas are considered likely for significant expansion and corresponding increase in water usage. Analysis of each site is provided below.

Cardup – Shire of Serpentine Jarrahdale

Cardup is under investigation by the State Government as potential industrial land to support Byford's growing population. If developed, the land is likely to be used to support population-driven retail-based light industry ("big box" retail).[55] Corresponding increases in water demand is picked up in population-driven industry analysis calculations above and will not be further considered in this section.

East Keralup – Shire of Murray

East Keralup is a 1,600 hectare site 10km north east of Mandurah. The site is being developed by the Peel Development Commission and is likely to host agribusinesses, including a major composting business (C-Wise) and closed loop horticulture and aquaculture.[56]

[53] Department of Planning, Lands and Heritage, South Metropolitan Peel sub-regional Framework, 2018, p 37.
[54] DevelopmentWA, 10-Year Industrial Lands Strategy, 2021, p 46.
[55] Department of Planning, Lands and Heritage, South Metropolitan Peel sub-regional Framework, 2018, p 37.
[56] Email correspondence with Adrian Parker, Director Regional Development, Peel Development Commission, November 2022.

Nambeelup – Peel Business Park – Shire of Murray

Developing Nambeelup is a major part of the Transform Peel program which aims to diversify Peel's industrial and employment base. Developing agribusiness is a key goal, and the precinct includes the Shire of Murray's Food Innovation Precinct WA (FIPWA). Once completed, FIPWA will include research and development facilities, logistics, packaging, value-add processing, and dry storage and warehousing.[57]

Pinjarra Industrial Estate – Shire of Murray

Pinjarra Industrial Estate is a well established industrial precinct that houses a variety of businesses including agriculture, mining, transport, manufacturing and construction, including some that support Alcoa's nearby refinery east of Pinjarra. Key current occupants include Western Power, Murray Engineering and Huckleberry Tanks. DevelopmentWA is currently selling third stage lots in the precinct, most of which are sold or under offer.[58]

West Mundijong Industrial Area – Shire of Serpentine Jarrahdale

West Mundijong Industrial Area is a 440 hectare industrial precinct in Serpentine Jarrahdale. The site has the potential to cater for a variety of strategic industries including agriculture and transport.[59] Arguably the most important potential use of the site is as an intermodal freight terminal that connects to the forthcoming Westport, making it a strategically important site for Peel with significant growth potential. An intermodal terminal would require realignment of the Kwinana–South West freight rail line that runs along the eastern boundary, allowing freight to be transported to and from harbour via rail and then onto trucks for movement to further destinations. Further consideration will be given during the upcoming stages of Westport's development and will be subject to environmental considerations.[60]

Wagerup – Shire of Waroona

Wagerup industrial area is currently dominated by Alcoa's refinery. However, Frontier Energy is progressing Bristol Springs, a major new hydrogen facility. This project is anticipated to be a substantial consumer of water, with an in-principle deal with Water Corporation recently brokered to access scheme water through the nearby Stirling Trunk Main pipeline, although it is possible the facility could use recycled wastewater from Bunbury. The deal is expected to be finalised in the short term. Frontier Energy anticipate using 1,250 KLS per day (0.456 GL per annum) once the site is fully operational.[61]

The Waterous Road abattoir is also located nearby. Despite previously operating and having recently been refurbished by Prime Meat Co, the site is note currently operating and the site is currently for sale.[62] However, it is arguable the facility will reopen within the study period i.e. before 2050. The abattoir would potentially use between 0.1 and 0.31 GL.[63]

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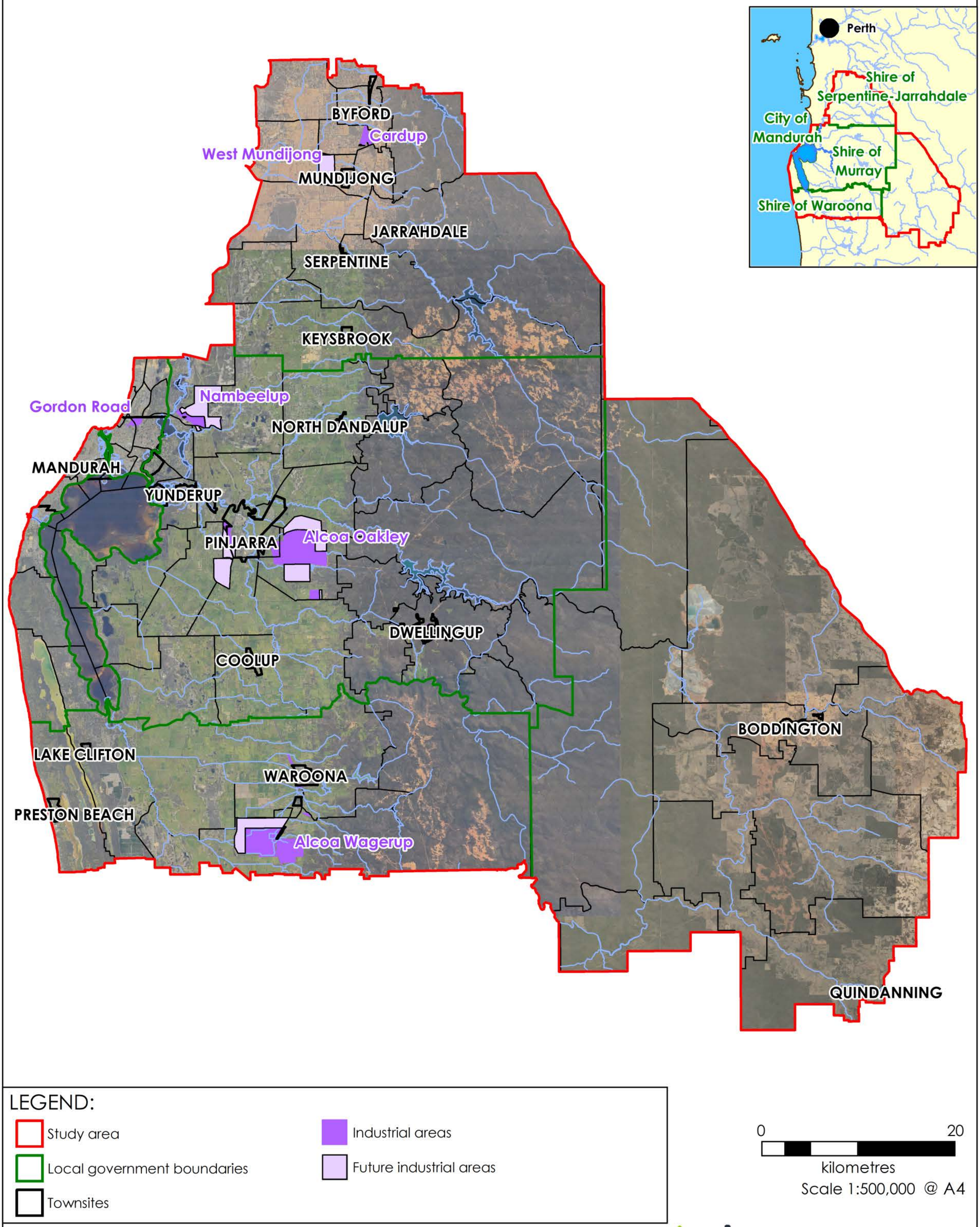
[57] Food Innovation Precinct WA website, https://fipwa.com.au/theprecinct/, last accessed November 2022.
[58] DevelopmentWA, Pinjarra Industrial Estate website, https://developmentwa.com.au/projects/industrial-and-commercial/pinjarra-industrial-estate/overview, last accessed November 2022.
[59] DevelopmentWA, 10-Year Industrial Lands Strategy, 2021, p 46.
[60] DevelopmentWA, 10-Year Industrial Lands Strategy, 2021, p 23.
[61] ASX Announcement – Frontier Energy, Major Milestone as Water Access Confirmed for Green Hydrogen Production, 14 September 2022, available at https://cdn-api.markitdigital.com/apiman-gateway/ASX/asx-research/1.0/file/2924-02567719-6A1109480?access_token=83ff96335c2d45a094df02a206a39ff4.
[62] ABC, Prime Meat Co, Harvey Cheese forced to repay Regional Economic Development grants, https://www.abc.net.au/news/2022-11-22/wa-businesses-forced-to-pay-back-regional-government-grants/101680142, last accessed November 2022.
[63] FAR Lane analysis based on Strategen-JBS&G data, 2022. Full methodology at Appendix A.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 32 - Future industrial areas in the Peel region



Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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6.3.2 Future water demand for strategic industry (excluding mining)

Future strategic industry expansion in Peel is likely to occur in designated industrial areas outlined above. Future water demand for these areas is modelled as per the methodology in Table 43.

Table 43: Method for estimating demand in strategic industry area

Industrial area	Development type	Method	Growth
East Keralup	Agribusiness	Usage by area for a combination of composting and closed-loop agribusinesses	Linear to 2051
Nambeelup - Peel Business Park	Agribusiness	Usage by area for a combination of closed-loop agribusinesses, an abattoir, and light industrial	Linear to 2051
Pinjarra industrial estate	Light industrial	Usage by area for light industrial reflecting current businesses	Linear to 2051
West Mundijong	Light industrial	Usage by area for light industrial	Linear to 2051
Wagerup (excepting Alcoa)	Hydrogen and abattoir	Modelling of water usage for a hydrogen refinery and abattoir	Hydrogen from 2026, abattoir from 2031

Potential increases to future water demand by strategic industry expansion areas is at Table 44. Full methodology is at Appendix 4.

Table 44: Increases in future water demand by strategic industry

Industrial area	Increased water usage	Potential development size
East Keralup	0.65 GL	1,000 hectares
Nambeelup - Peel Business Park	10.15 GL	1,000 hectares
Pinjarra industrial estate	0.52 GL	50 hectares
West Mundijong	4.92 GL	474 hectares
Wagerup (except Alcoa)	0.87 GL	n/a
Total	**17.11 GL**	

The analysis indicates:

- Peel Business Park has the largest potential water demand, due to its large size (1,000 hectares) and the nature of industries anticipated.
- Water usage for other industrial areas varies greatly depending on the size and industries for potential development.
- A total increase in potential water demand for strategic industry in Peel at 2051 is 17.11 GL.

Future cumulative water demand for strategic industry (excluding mining) by local government is at Table 45.

Table 45: Cumulative water demand for existing and new strategic industry (excluding mining)

	2021	2026	2031	2036	2041	2046	2051
Boddington	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Mandurah	1.57	1.65	1.74	1.84	1.95	2.06	2.19
Murray	17.54	19.47	21.41	23.36	25.32	27.29	29.27
Serpentine Jarrahdale	1.96	2.82	3.69	4.58	5.48	6.39	7.33
Waroona	12.30	12.31	12.32	12.34	12.36	12.38	13.27
Total (GL)	**33.41**	**36.30**	**39.22**	**42.16**	**45.14**	**48.17**	**52.11**

The analysis indicates that for (non-mining) strategic industry in Peel:

- Water demand for strategic industry may potentially grow from 33.41 GL to 52.11 GL by 2051.
- Murray is anticipated to have the highest water usage at 29.27 GL by 2051.
- Limited change to water demand in Boddington is anticipated due to no major industrial precincts being forecast for development.

6.3.3 Potential mining expansion in Peel

It is anticipated that all current mining operations in Peel will be ongoing or expanding. Known proposed mining expansion are detailed below.

Alcoa proposed expansion – Pinjarra

Alcoa is seeking to:

- Expand its current operations from the Huntly mine to nearby Myara North and Holyoake.
- Correspondingly increase production at its Pinjarra refinery by 5 per cent from 5.0 million tonnes per annum 5.25 million tonnes per annum.

The proposal is currently at stage 2 (of 5) of its assessment by the EPA.[64]

Alcoa's increased water requirements for expanding mining to Myara North and Holyoake are assumed to have no net increase on water demand, as water usage will transfer from current mining operations to the new operations. However, analysis indicates expansion of its Pinjarra refinery will potentially increase its water usage from 15.5 GL to 16.28 GL, an increase of 0.775 GL.[65]

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[64] EPA website, Pinjarra Alumina Refinery - Revised Proposal, https://www.epa.wa.gov.au/proposals/pinjarra-alumina-refinery-revised-proposal, last accessed November 2022.

[65] FAR Lane analysis based on Alcoa's Long Term Residue Management Strategy for Pinjarra, 2016. Full methodology is at Appendix A.

It is also noted that a number of Alcoa's surface water licences (for 9GL) were due to expire in 2022 and a further allowance of 2.5 GL/year from the Cattamarra Aquifer under a Drought Provision Licence, is due to expire in 2026. It is understood that a renewal of the licences is currently being considered by the Department of Water and Environmental Regulation.

South 32 proposed expansion - Boddington

South 32 is seeking to expand the size of its bauxite mine site at its current Boddington operations, noting that its proposed mining rate will remain unchanged at 1.8 million tonnes per annum.[66] The proposal is currently at stage 3 (of 5) of its assessment by the EPA.[67]

South32's proposal notes that average water usage for its bauxite mining operations in Boddington will expand from 0.5 GL per annum to 0.9 GL, for a total expansion of 0.4 GL.[68] Refining will continue to take place outside the study area and is therefore not considered in this report.

Newmont Boddington Gold proposed expansion and closure

Newmont are proposing an expansion to Boddington's north and south pits, however there is limited publicly available information on the size of the proposed expansion or the corresponding increase in water requirement to 2036, which is the life of the mine. A nominal amount of 0.5GL has been included in this study to account for the increased demand.

After the mine closes, it is not anticipated that the water used by Newmont will be available for use elsewhere. Due to the need to increase flows into waterways, it is anticipated that the surface water allocation (surface water abstracted from the Hotham River with an allocation limit of 15GL) would be returned to the environment. No additional groundwater would be available as the location of the operations is within an unlicenced area and any water collected or reused as part of the mine operations will not be available after mining operations cease. The only potential source of water would be from the Boddington wastewater treatment plant. This source is dependent on the population of the town but is likely to be in the order of 100ML (0.1GL).

Rio Tinto proposed exploration license

Rio Tinto has also applied for a large exploration license which is currently pending (E 70/6053), a map of which is at Figure 33. This area overlaps Alcoa's and South 32's current mining tenements, and it is unclear when if ever this license will be granted, when any mining operations would potentially commence, and the effects it will have on water usage in Peel. It is therefore not considered in this report.

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[66] South32, Worsley Mine Expansion Referral Supporting Document, May 2019, p 18.
[67] EPA website, Worsley Mine Expansion – Revised Proposal, https://www.epa.wa.gov.au/proposals/worsley-mine-expansion-%E2%80%93-revised-proposal, last accessed November 2022.
[68] South32, Worsley Mine Expansion Referral Supporting Document, May 2019, p 18.

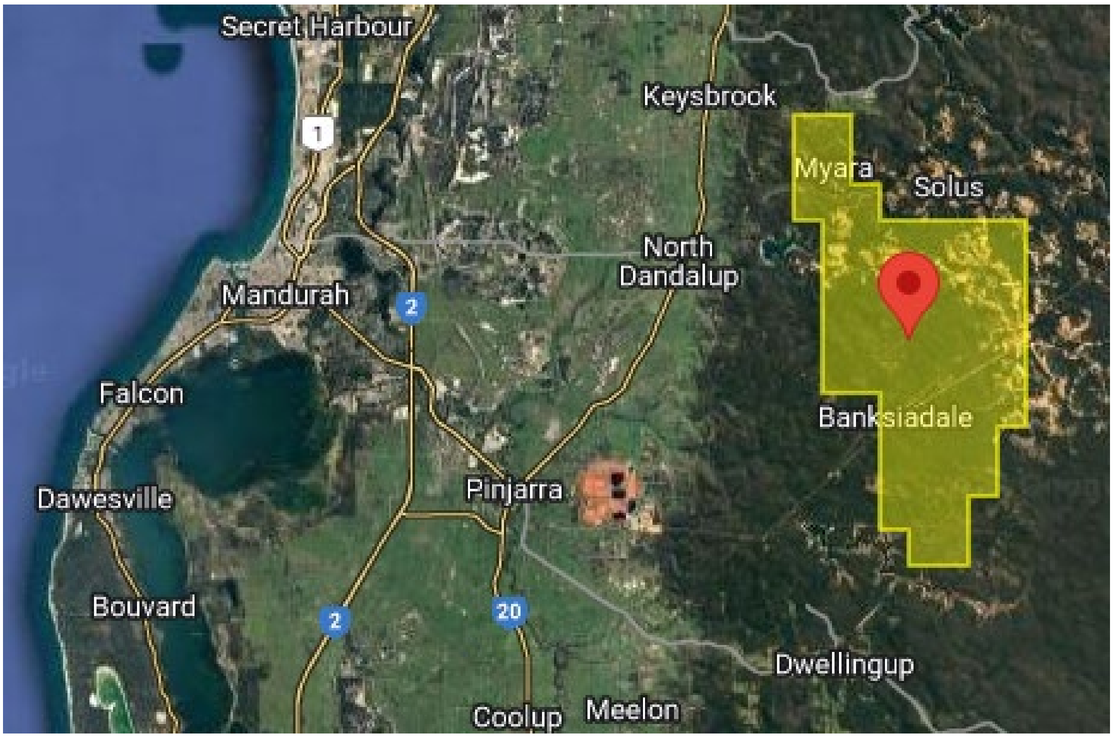


Figure 33: Rio Tinto's pending exploration license in Peel (Source: DMIRS, 2022).

Table 46 summarises future known increases in mining water requirements in Peel.

Table 46: Known increases in mining water requirements in Peel

Proponent	Proposal	Increased water requirements
Alcoa	Myara North and Holyoake mine expansion	-
Alcoa	Increased processing at Pinjarra refinery	0.775 GL then an additional 2.5GL likely in 2026
South32	Expansion of bauxite mining operations at existing Boddington mine	0.4 GL
Newmont	Expansion of production at Boddington Gold mine	0.5 GL to 2037 (when the mine is scheduled to close)

The analysis indicates that known increases in mining water requirements will potentially increase by 2.5GL in 2026, then 4.175 GL to 2036, then by 3.675 GL to 2051. Noting that the expansions are yet to be approved by the EPA and some uncertainty in the continuing availability of surface and groundwater allocations.

Future water demand – all industries

A summary table indicating potential water demand for all industries (population-driven, strategic, mining) is provided in Table 47.

Table 47: Future water demand for all industries (GL)

	2021	2026	2031	2036	2041	2046	2051
Boddington	15.18	16.08	16.08	16.08	0.45	0.45	0.45
Mandurah	1.58	1.66	1.75	1.83	1.91	1.99	2.08
Murray	20.50	23.21	25.14	27.07	29.00	30.94	32.87
Serpentine Jarrahdale	2.40	3.26	4.13	4.99	5.85	6.71	7.58
Waroona	12.30	12.31	12.32	12.33	12.35	12.36	13.24
Total	**51.96**	**56.53**	**59.42**	**62.31**	**49.56**	**52.45**	**56.21**

Note: Assumes Newmont 15GL allocation licence is retuned to DWER on closure of the mine in 2036.

6.3.4 Scenario assessment

The scenarios assessed in this report were developed in response to information gathered by this study, consultation with stakeholders and agreed by representative of the stakeholder agencies at a workshop in October 2022. The scenarios are based on plausible changes to industry in Peel between now and 2051.[69]

Scenario I1 - Mining growth – increased water usage from planned mining expansions

Scenario I2 - Strategic industry expansion – increased water usage from strategic industry expansion

Scenario I3 - Emerging major water usage industries – increased water usage from the establishment of two new major water users: a hydrogen refinery, and a data processing centre.

Scenario I1 - Mining growth – increased water usage from mining planned expansions

As previously discussed in section 6.3.3, Table 48 summarises future known increases in mining water requirements in Peel. This is replicated again below for ease of reference.

Table 48: Future known increases in mining water requirements in Peel

Proponent	Proposal	Increased water requirements
Alcoa	Myara North and Holyoake mine expansion	-
Alcoa	Increased processing at Pinjarra refinery	0.775 GL then an additional 2.5GL likely in 2026
South32	Expansion of bauxite mining operations at existing Boddington mine	0.4 GL
Newmont	Expansion of production at Boddington Gold mine until closure in 2037.	0.5 GL to 2036

[69] 2051, rather than 2050, is used as this aligns with forthcoming Census dates that have been used for other modelling in this project.

Scenario I2 - Strategic industry expansion – increased water usage from strategic industry expansion.

As previously discussed in Section 6.3.2, increases in strategic industry are likely to occur in East Keralup, Nambeelup (Peel Business Park), Pinjarra industrial estate, West Mundijong and Wagerup (except Alcoa) as these industrial areas become fully developed as a result of population growth. While water demands for industrial areas varies greatly depending on the type and size of specific industries, increases in demands are estimated to be in the order of 52.11 GL.

Scenario I3 - Emerging major water usage industries – increased water usage from the establishment of two new major water users in Peel: a hydrogen refinery, and a data processing centre.

Hydrogen refinery

Hydrogen manufacturing requires significant quantities of potable water, as it is as major input in the manufacturing process.

As noted in section 4.5, Frontier Energy is progressing Bristol Springs, a major new 500 MW hydrogen facility slated for Waroona. Noting its location in Peel and contemporary estimates, Bristol Springs is a suitable benchmark.

Frontier Energy anticipate using 1,250 kL per day once the site is fully operational. [70] Using this benchmark, a hydrogen refinery in Peel would potentially use 0.46 GL per annum. The date Bristol Springs will become operational is unclear but is likely to occur by 2026.

Data centre

Data centres can be major consumers of water which is used for evaporative cooling to counter the significant heat generated by the centre's equipment. A 100 MW data centre is estimated to use 1.1 million gallons (4164 KL) of water per day.[71] Using this benchmark, a 100 MW data centre in Peel would potentially use 1.52 GL per annum. There are no known plans for a data centre to become established in Peel.

6.4 Peel Region needs to 2050

Three scenarios are presented for the total Peel Region needs to 2050 – business as usual (BAU), high growth and waterwise, as explained below:

1. BaU, comprising:
    - Population-based use (Community and Population-based industry) at BaU population growth rates and current consumption rates (scenario C1).
    - Mining (scenario I1) fully realised (incremental growth).
    - Strategic industry (scenario I2) fully realised (incremental growth).
    - Strategic industry (scenario I3) commencing in 2051.
    - Agriculture (scenarios A1 & A2) fully realised (incremental growth)

[70] ASX Announcement – Frontier Energy, Major Milestone as Water Access Confirmed for Green Hydrogen Production, 14 September 2022, available at https://cdn-api.markitdigital.com/apiman-gateway/ASX/asx-research/1.0/file/2924-02567719-6A1109480?access_token=83ff96335c2d45a094df02a206a39ff4.
[71] Data Centre Dynamics, An industry in transition 1: data center water use, November 2021.

2. High growth comprising:
    - Population-based use (Community and Population-based industry) at High population growth rates and current consumption rates (scenario C2).
    - Mining (scenario I1) fully realised (incremental growth).
    - Strategic industry (scenario I2) fully realised (incremental growth).
    - Strategic industry (scenario I3) commencing in 2051.
    - Agriculture (scenarios A1, 2 & 3) fully realised (incremental growth)
3. Waterwise, comprising:
    - Residential use at BaU population growth rates with 30% existing residences and 50% future residences achieving waterwise consumption rates (C3 & C4).
    - Other population-based uses (Community and Population-based industry) at BaU population growth rates.
    - Mining (scenario I1) fully realised (incremental growth).
    - Strategic industry (scenario I2) fully realised (incremental growth).
    - Strategic industry (scenario I3) commencing in 2051.
    - Agriculture (scenarios A1 & A2) fully realised (incremental growth)

Analysis of the three scenarios suggests the future water needs (by 2051) of the Peel region are:

- 178.78 GL for business-as-usual scenario
- 195.85 GL for the high growth scenario
- 165.90 GL for the waterwise scenario

This is an increase from the current (2021) baseline of 138.38 GL. The water needs for each scenario by local government from now to 2015 are presented in Tables 48 to 50 and Figure 34.

Table 49: Business as usual scenario – water needs growth to 2051 (GL)

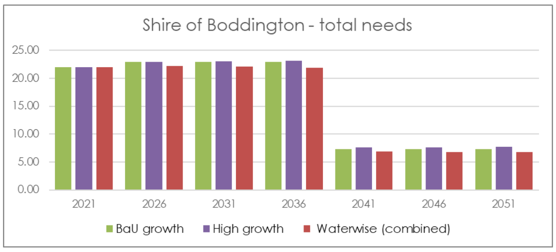
	Boddington	Mandurah	Murray	Serpentine Jarrahdale	Waroona	Peel region total
2021	21.97	21.58	41.68	30.06	24.83	140.10
2026	22.87	22.74	45.05	32.11	25.11	147.88
2031	22.88	23.65	48.18	34.19	25.68	154.58
2036	22.88	24.43	52.14	36.25	26.50	162.21
2041	7.25	25.77	56.81	38.52	27.56	155.91
2046	7.26	27.27	61.92	41.05	28.86	166.36
2051	7.27	28.98	67.36	43.89	31.28	178.78

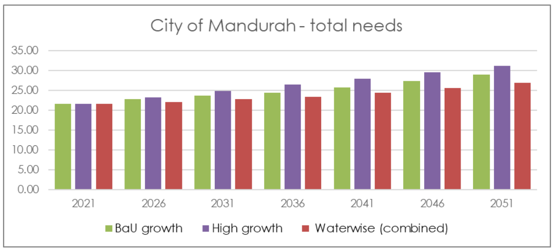
Table 50: High growth scenario – water needs growth to 2051

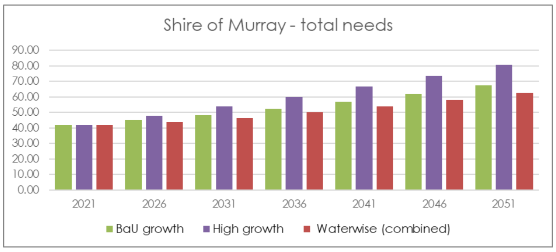
	Boddington	Mandurah	Murray	Serpentine Jarrahdale	Waroona	Peel region total
2021	21.97	21.58	41.68	30.06	24.83	140.10
2026	22.95	23.20	47.95	32.46	25.23	151.79
2031	23.03	24.80	53.79	34.85	25.95	162.41
2036	23.11	26.40	59.96	37.24	26.90	173.61
2041	7.56	28.00	66.48	39.62	28.09	169.74
2046	7.64	29.60	73.33	42.01	29.50	182.08
2051	7.72	31.20	80.51	44.40	32.02	195.85

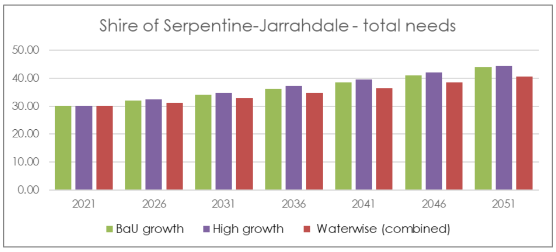
Table 51: Waterwise scenario – water needs growth to 2051

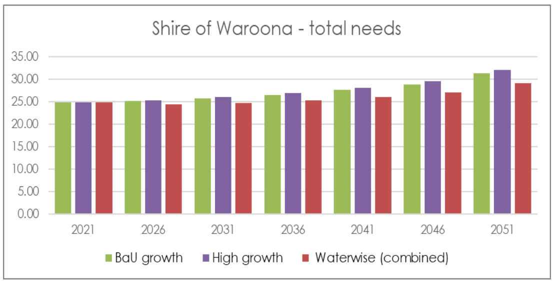
	Boddington	Mandurah	Murray	Serpentine Jarrahdale	Waroona	Peel region total
2021	21.97	21.58	41.68	30.06	24.83	140.10
2026	22.18	22.05	43.69	31.14	24.35	143.40
2031	22.04	22.79	46.42	32.94	24.74	148.93
2036	21.88	23.36	49.86	34.66	25.34	155.10
2041	6.86	24.38	53.76	36.45	26.08	147.54
2046	6.80	25.55	58.01	38.46	27.04	155.86
2051	6.74	26.89	62.51	40.73	29.03	165.90

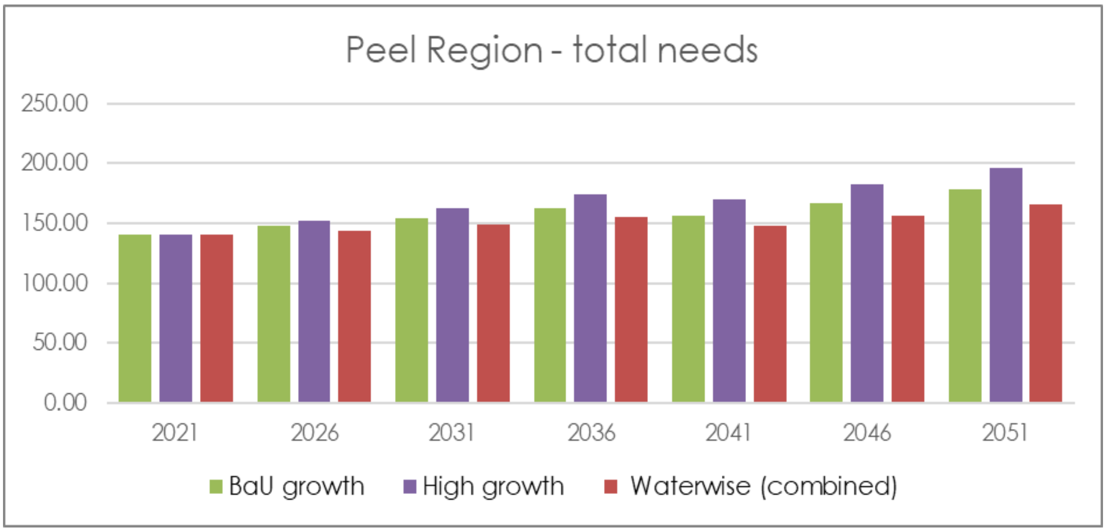




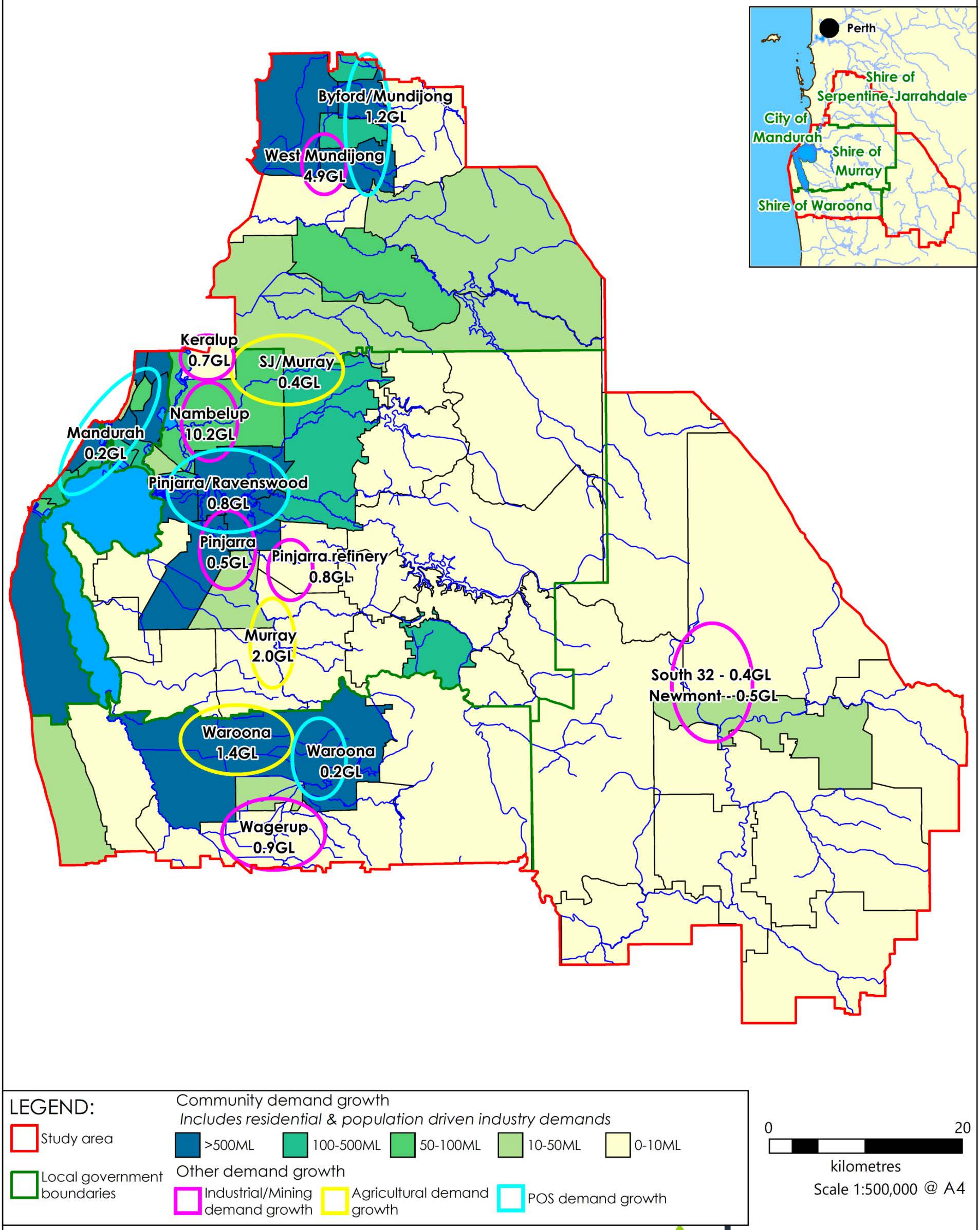








Peel Alliance - Peel Regional Water Supply Initiative
Figure 34 - Water needs growth to 2051



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Section 7: Future water sources in Peel

7 FUTURE WATER SOURCES

This study has considered the options that are currently available to meet the estimated future water demands for the predicted growth in community, agriculture and industry needs. These include the cumulative currently utilised options of:

- Use of the IWSS to meet the future potable water needs of the community and population-driven industry
- Groundwater and surface water abstracted to available limits
- Use of treated wastewater to the capacity of existing wastewater treatment plants.

It is recognised, however, that there are some existing constraints to access of these sources (as well as being insufficient to 2051) and alternative options will be required to meet the demands in future. The considerations for both currently utilised and alternative source approaches are presented below.

7.1 Currently utilised water sources

The existing water source options available to meet the water demands of the Peel region in the future include:

- Groundwater from licenced groundwater areas
- New surface water allocations
- Treated wastewater

The other source included in the assessment is the use of the IWSS to meet the future needs of the community and population-driven industry growth. This study assumes that the Water Corporation will undertake appropriate source planning to meet this need in future (as it is consistent with Perth and Peel @ 3.5 million) and so it is not discussed further. The other sources are discussed in more detail below.

7.1.1 Groundwater from licenced groundwater areas where allocation is available

As shown in Appendix 5 and Figure 15, some licenced allocation remains in a number of groundwater management sub areas. The allocatable volumes have been lumped together in Table 52 via local government and aquifer to broadly represent the magnitude of source availability. It should be noted, however, that the available allocation may not be located in proximity to the demand when considered at the level of the groundwater management subarea.

Furthermore, although availability remains in the superficial aquifer, significant yield limitations are likely in areas of clay soils, and it may not be possible to abstract groundwater up to the allocated limit. Abstraction in the coastal superficial aquifer is also challenging as this area is prone to saline intrusion which is more likely as allocation limits are approached.

Where further water entitlements are sought from the superficial aquifer, it is recommended that investigations are undertaken to determine likely yields and identify any water quality issues to establish if more innovative methods of abstraction are required. These include harvesting of subsoil drainage water, utilising a system of horizontal bores, or summer extraction of groundwater to create storage in the Superficial or deeper aquifers to make room for excess water during winter and spring (superficial source enhancement).

Table 52: Sum of available allocation volume per local government via aquifer

Available volume (kL)/ aquifer	Mandurah	Mandurah /Murray	Murray	Serpentine Jarrahdale	Waroona
Superficial	54,472	52,050	7,585,662	20,116,132	8,379,800
Leederville	0	0	5,797,340	134,287	3,682,850
Yarragadee			0	0	-
Cattamarra Coal Measures	0		0	0	100,000
Fractured Rock			50,000	0	20,000
Totals	***54,472***	***52,050***	***13,433,002***	***20,250,419***	***12,182,650***
Grand Total					**45,972,593**

It should also be noted; however, that due to the nature of the connection between surface water and groundwater and the significant contribution of groundwater to streamflow in the Peel Harvey system, any further abstraction from the superficial aquifer has the potential to impact on the internationally recognised ecological values of the Ramsar-listed estuary (see sections 2.1, 2.4 and 7.2.1).

Allocation also remains in some parts of the deeper aquifers – the Leederville and Cattamarra Coal Measures aquifers. The connectivity between these aquifers and the Superficial is complex and abstraction from one resource may have the potential to impact on the recharge in the other aquifers (DWER, 2021). The quality is also variable. Kretschmer et.al. (2011) indicates that electrical conductivity is variable throughout the Cattamarra aquifer but generally increases from east to west, with a range of 344 µS/cm (205 mg/L) to 6,001 µS/cm (3,600 mg/L). The pH is variable (5.6 to 9) and average hardness is 108 mg/L, generally ranging between moderately-soft to slightly-hard water. Nutrients are low with an average NOx-N of 0.16 mg/L and average TP of 0.02 mg/L. These values were generally within the ANZECC (2000) short-term irrigation guidelines, while crop irrigation suitability ranged between 'sensitive' to 'very tolerant' crops in terms of salinity (DWER, 2011).

Applications for water entitlements from the deeper aquifers will need to be supported by appropriate investigations to characterise any vertical connectivity between the aquifers and ensure abstraction does not impact on overlaying aquifers.

Source suitability: Fair

7.1.2 New surface water allocations

Within proclaimed areas, any request for surface water entitlement must demonstrate no detrimental impact on downstream environmental conditions or users. As the retention of surface water flows for environmental health of waterways and the Peel Harvey System is being increasingly recognised, it is considered unlikely for any substantial new surface water allocation to be granted.

In unproclaimed surface water areas, landowners can take water without a licence provided they do not significantly diminish the flow of water in the watercourse. However, the decline in annual rainfall has resulted in a significant reduction in surface runoff to streams in the Peel

Region such that surface water resources are becoming an increasingly unreliable water source.

Source suitability: Poor

7.1.3 Treated wastewater

Treated wastewater is a climate independent water source. It may be sourced directly from a WWTP either prior to treatment or afterwards or "mined" from a reticulated sewage network at pump stations (see sewer mining below). Treated wastewater provided directly from a Water Corporation WWTP is supplied with no cost per volume of water "for community benefit".

Treated wastewater is largely underutilised in WA, with only a few examples of reuse in the City of Mandurah (indirect MAR reuse) and reuse by industry in Kwinana (from the Sepia Depression Ocean Outfall Line or Kwinana Water Recycling Plant), Pinjarra (Alcoa) and Boddington (Newmont).

The main factor influencing wastewater generation is population growth which is focussed in urban centres. The volume of wastewater generation is largely stable seasonally, which increases year-round reliability and reduces the need for large storages.

A major customer agreement would need to be made with the Water Corporation to use their treated wastewater (after defining requirements, agreeing to commercial terms and engineering investigations). The value of this water may increase in the future as the perception of treated wastewater shifts from "waste" to "resource".

WWTP expansions and changes to outputs

While wastewater treatment plants inflows are expected to expand with population growth and urban expansion, Water Corporation has advised that further expansions beyond current capacities are unlikely. Research by Dr Don McFarlane into wastewater as a possible source of recycling in the Perth-Peel region noted that there were more than 140 GL/y of inflows to 14 WWTPs in the Perth-Peel region in 2017, an increase of over 40 GL/y or 40% since 2000. These inflows are expected to increase to 170 GL/y by 2030, and to 243 GL/y by 2060 if water use efficiencies of 115 kL/person/year are achieved by 2030. Volumes will be about 4% greater if these efficiencies are not attained (McFarlane, 2019b).

This shows that 92% of the growth is expected to occur at the five largest WWTPs across Perth that are all connected to ocean outfalls. Although the Woodman Point plant is located the furthest away from the region, this plant is shown to have the greatest growth out of all WWTPs across Perth and Peel, and the largest volume of water that could potentially be available for reuse. Of the smaller plants, the Gordon Road WWTP shows the greatest opportunity for growth nearby. Table 53 provides the future output projection assumptions for each plant, where information was available.

Recently, Stage 2 of the Water Corporation's groundwater replenishment scheme in Beenyup was commissioned (Water Corporation, 2022). Although this is far north of the study area, this shows that the Water Corporation is looking to treated wastewater as a resource to replenish groundwater resources for greater climate independence and may affect the future availability of both treated wastewater and improve groundwater supplies in the future (McFarlane D. D., 2019a).

Table 53: Wastewater treatment plant summary

WWTP Name	Licenced Capacity (kL/day)	Production Volume (kL/day) (year)	Output Quality	Current Disposal Method	Future Projection (McFarlane D. D., 2019b)
Boddington	122 (2021)	124 (2019-20) 132 (2020-21)	Secondary	• Nemwont gold mine reuse, direct pipeline. Uses all of the output volume.	• Will be based on population and land use changes, however output likely to be too small to be useful.
Pinjarra	1,840	1,088 (2020-21)	Secondary	• All treated WW reused at Alcoa Pinjarra Refinery.	• Inflows expected to increase from 0.3 GL/yr to 1.6 GL/yr by 2060. Slight increase to 2030 (~0.2 GL/yr).
Mandurah 1 (Gordon Rd)	12,000	10,439 (2021-22)	Secondary	• Infiltrated via onsite ponds as part of MAR scheme to the superficial aquifer. • WW abstracted for irrigation of City of Mandurah (CoM) public open space (POS) (120 ML in 2018/2019) from down-gradient bores via a 10-year agreement.	• Inflows expected to increase from 4.0 GL/yr to 5.5 GL/yr by 2030, and almost 12 GL/yr by 2060. • **As all output is currently reused by CoM, this could mean only an additional 1.5 GL/year is available for reuse to 2030 (38% increase on current output), and 9 GL to 2060.** • Current MAR and reuse may mean this is not available for future supply if CoM expand their supply.
Mandurah 2 (Halls Head)	5800	3497.33 (2021-22)	Tertiary	• Onsite ponds for infiltration to the superficial aquifer. • Abstraction of this and subsequent irrigation of CoM POS (Seascapes development).	• Inflows expected to stay at 1 GL/year, with little to no change in output volume.
Mandurah 3 (Caddadup)	3000	2131 (2021-22), 1326 (average flow 2012/2013)	Secondary	• Onsite ponds infiltrate to the superficial aquifer. • Nearby golf course abstraction likely utilises most of this water.	• Inflows expected to increase from approx. 0.8 GL/year to 1 GL/year. • This equates to a 25% increase, or 0.39 GL/year.
Waroona	240 (possibly expand to 880)	306 (2021-22)	Secondary	• Previously a planted tree lot, now discharged via swale leading to agricultural drain, Drakesbrook Drain.	• Will be based on population and land use changes, however output likely to be too small to be useful.

WWTP Name	Licenced Capacity (kL/day)	Production Volume (kL/day) (year)	Output Quality	Current Disposal Method	Future Projection (McFarlane D. D., 2019b)
Outside study area					
Brunswick	580	219 (2021-22)	NA	• Agricultural drain?	• Will be based on population and land use changes, however output likely to be too small to be useful.
Collie	2200 (11,000 people)	1496 (2021-22)	Tertiary	• Filtered and disinfected treated wastewater is pumped 4 kilometres to a 1.25 km effluent infiltration channel situated in natural bushland at the headwaters of Lyalls Brook.	• Will be based on population and land use changes, however output likely to be too small to be useful. • Population projected to decline by 0.4% to 2030, meaning less treated wastewater will be available to reuse.
East Rockingham	20,000	3,560 (2020-21) 3,976 (2021-22)	Secondary	• Treated wastewater sent to the SDOOL.	• Inflows expected to increase from ~2.5 GL/yr to ~8 GL/yr by 2030 (also receives some of Kwinana inflows in 2027), and to ~18 GL/yr by 2060. • Approximately half of inflows to Point Peron WWTP will also transfer to East Rockingham in 2032. • **Approximately 4.67 GL/yr of treated wastewater could be available by 2030, calculated as 2.2 times the current production volumes. This is predicted to increase to 10.51 GL/yr by 2060.** • With Woodman Pt and Kwinana, this makes a total of 60.6 GL/yr treated wastewater to be sent to the SDOOL by 2030. • Third pipe network connecting this WWTP to the East Rockingham Industrial Park will compete for recycle wastewater from this source (Water Corporation, 2009).
Kwinana	12,000	5803.67 (2019-20)	Secondary	• 4.7 ML/day is allowed to infiltrate locally to the superficial aquifer (restricted), with the remainder sent to the SDOOL. • Some outflow is also redirected to the Kwinana Wastewater	• Inflows expected to increase by 57% from 2.8 GL/yr to 4.1 GL/yr by 2030, and ~3.9 GL/yr by 2060. • **Approximately 1.73 GL/year of treated wastewater could be available by 2030, based on current production volumes and taking into account the 4.7 ML/day infiltrated locally.**

WWTP Name	Licenced Capacity (kL/day)	Production Volume (kL/day) (year)	Output Quality	Current Disposal Method	Future Projection (McFarlane D. D., 2019b)
				Recycling Plant (KWRP) for reuse.	• Inflows will decline after 2030 as these will be transferred to East Rockingham (around 2027). • With Woodman Pt and East Rockingham, this makes a total of 60.6 GL/yr treated wastewater to be sent to the SDOOL by 2030.
Harvey (Wokalup)	1100	771 (2021-22)	Secondary	• Treated water sent to the Harvey Diversion Drain (HDD), or to infiltrate on a woodlot and wetland with overflow to the HDD.	• Will be based on population and land use changes, however output likely to be too small to be useful.
Kemerton	3,600	2,029 (2021-22)	NA	• Woodlot irrigation in Binningup.	• Treats wastewater from the Eaton and Bunbury residential areas. • Separate network from the KSIA, which treats industrial wastewater and reuses onsite.
Roelands	• Limited information				
Woodman Point	180,000	146,526 (2020-21) 146,318 (2021-22)	Secondary	• Sepia Depression Ocean Outfall Line (SDOOL). • Future – possibly advanced water recycling plant (AWRP) for groundwater replenishment.	• Inflows expected to increase by 10% from 58 GL/yr to 62 GL/yr by 2030, and to 92 GL/yr by 2060 • **Approximately 59 GL/year of treated wastewater could be available by 2030 based on current production volumes.** This doesn't take into account proposed reuse at the AWRP. • With Kwinana and East Rockingham, this makes a total of 60.6 GL/yr treated wastewater to be sent to the SDOOL by 2030.

Note: Bold points are calculated based off projected increase in production rates per year, applied to actual rounded production volumes. Calculations have only been made for larger WWTPs as smaller WWTPs are unlikely to have sufficient outputs based on current capacities.

It should also be noted that the current prospects for potential industrial reuse in the Kwinana area exceed the amount of water available. In addition to this, both plants are under consideration for future potable reuse. This will likely limit the resource available for other uses.

Ocean outfalls

There are two ocean outfalls close to the study area, being the Sepia Depression Ocean Outfall Line (SDOOL) at Point Peron, and the Bunbury outfall. These are shown on Figure 21.

The SDOOL receives outflow from the Woodman Point, East Rockingham and Point Peron WWTPs (to be decommissioned in the future), excess flows from the Kwinana WWTP and saline discharge from the Kwinana Water Recycling Plant. The outflow from this location equated to 55.7 GL/year in 2017 and is a significant volume of unused water. There may be opportunity for reuse of this outflow, however connection and distribution would be expensive. A small volume is diverted from the SDOOL to the Kwinana Wastewater Recycling Plant (KWRP) (designed for reuse of 5 GL/year) for treatment and reuse of treated wastewater from the SDOOL by heavy industry. From projected outflow calculations, the total volume could be as large as 60.6 GL/year sent to the SDOOL.

The Bunbury Ocean Outfall receives treated wastewater from the Bunbury WWTP and has capacity to dispose of up to 6 GL/year (forecasted to the year 2040).

Source suitability: Good

7.2 Currently utilised water source and supply shortfalls

Consideration of the growth scenarios against currently available groundwater (as at 2021), surface water, treated wastewater and IWSS (for potable and community needs only) suggests that these sources could sustain the Peel region as a whole for all scenarios to 2036 and for the waterwise scenario to 2051 (Figure 35 and Table 54). This is not an accurate reflection of availability vs demand, however, as the location of the available sources **does not** align to the location of the demands, as indicated by the assessment at local government level which indicates that the Shires of Murray and Boddington will have insufficient readily available water supplies in 2026 (Figures 36 to 40).

In addition, the current allocation limits in Serpentine Jarrahdale (and possibly Murray and Waroona) are likely to be unachievable from traditional groundwater bores in the Superficial (where almost all the remaining availability is in Serpentine Jarrahdale) due to yield issues (as stated previously in section 7.1.1). It is possible that abstraction to these levels from the superficial aquifer in Palus Plain areas could be achieved through the innovative approaches mentioned earlier i.e. seasonal over-abstraction in some places and subsoil drainage harvesting /horizontal bores in other places.

Note: Current source predictions to 2050 are based on the following assumptions:

- IWSS
  - IWSS is assumed to grow sufficiently to supply all new residential needs and continue servicing all existing accounts.
- Self-supply
  - Surface water and groundwater availability is capped at current allocation limits to 2031 when a 10% reduction is applied. Thereafter incremental reductions are applied to reach a further 10% reduction by 2051.
  - Surface water currently allocated to Newmont is returned after 2036 and is not re-allocated.
- Treated wastewater
  - Future availability from WC to 2033 extended to 2051 assuming continued stable growth rates.

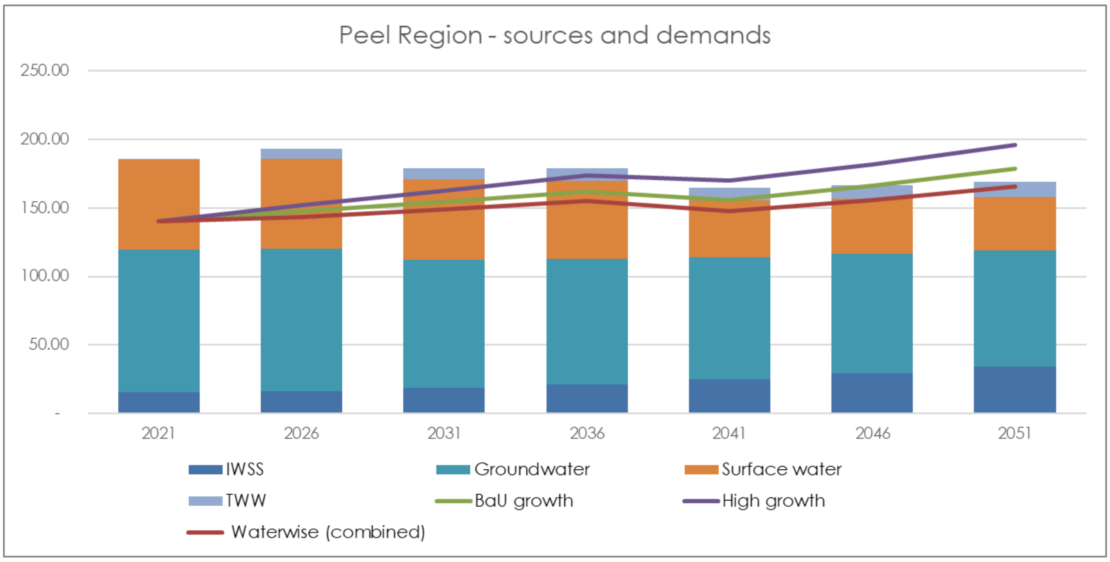


Figure 35: Future water sources and demands at current availability for the Peel Region to 2051

Table 54: Available water from currently utilised sources at current availability for the growth scenarios at 2051

Local government	BaU	High growth	Waterwise
Boddington	-3.03	-3.49	-2.56
Mandurah	6.38	4.16	8.28
Murray	-18.67	-31.83	-14.26
Serpentine Jarrahdale	5.57	5.07	8.45
Waroona	0.17	-0.57	2.22
Total (GL)	**-9.57**	**-26.65**	**2.12**

Note: "-" indicates a gap in source availability

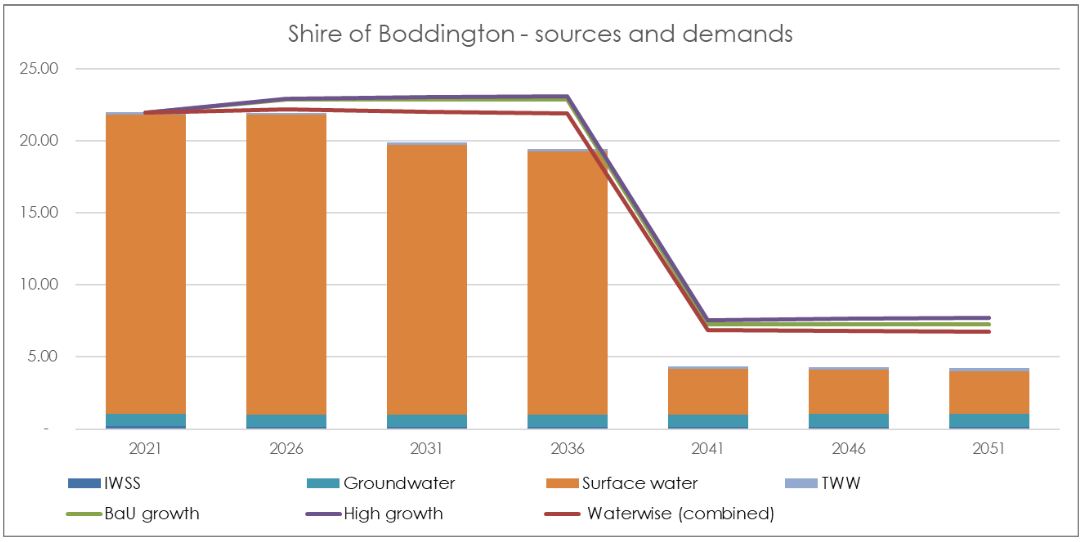


Figure 36: Future water sources & demands at current availability for Shire of Boddington to 2051

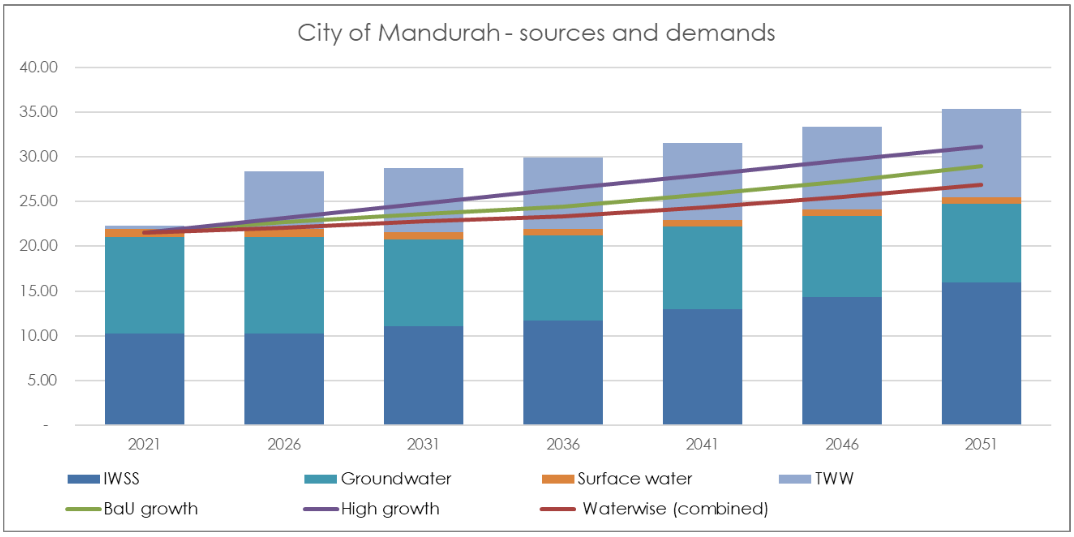


Figure 37: Future water sources & demands at current availability for City of Mandurah to 2051

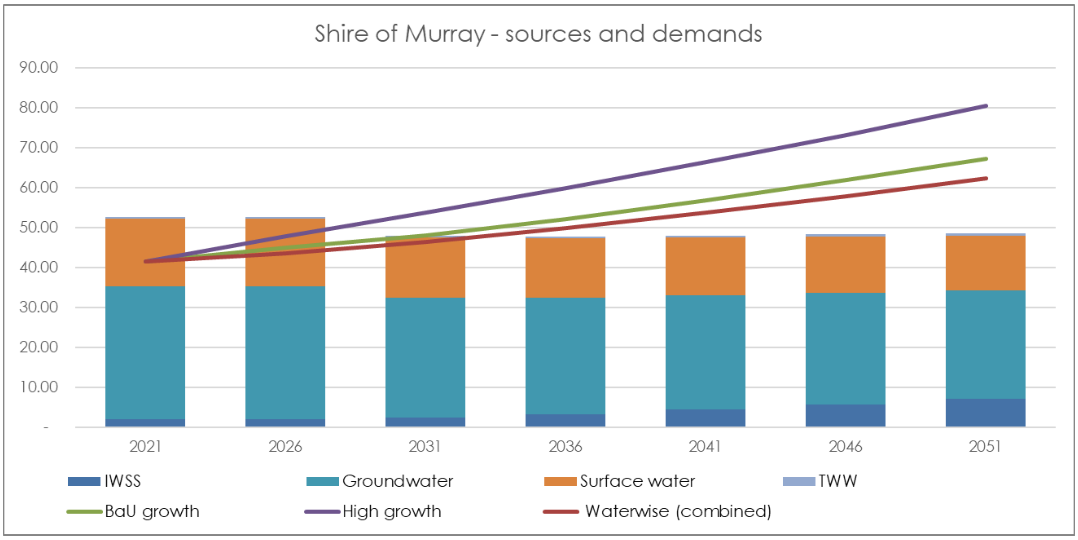


Figure 38: Future water sources & demands at current availability for Shire of Murray to 2051

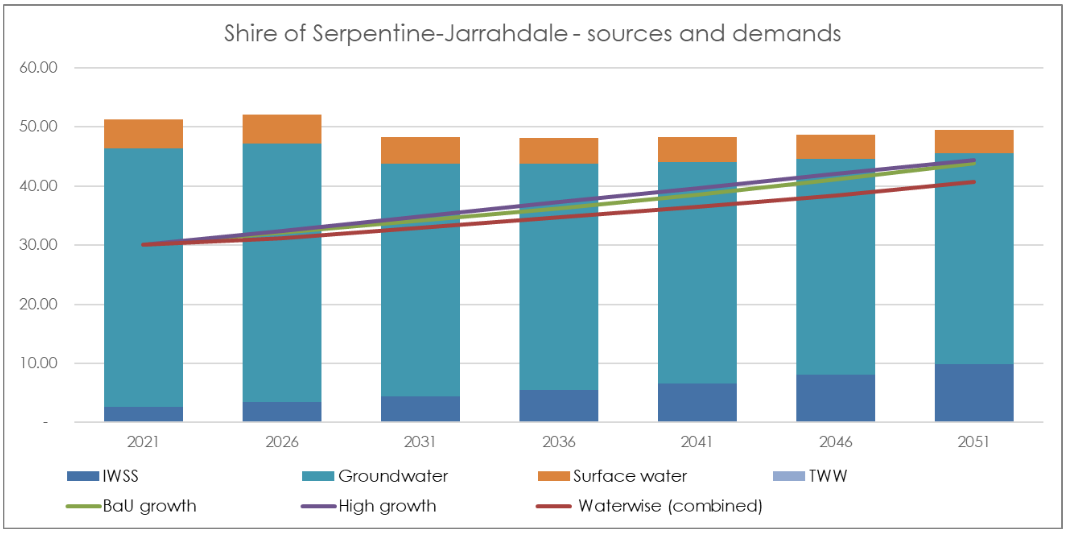


Figure 39: Future water sources & demands at current availability for Shire of Serpentine Jarrahdale to 2051

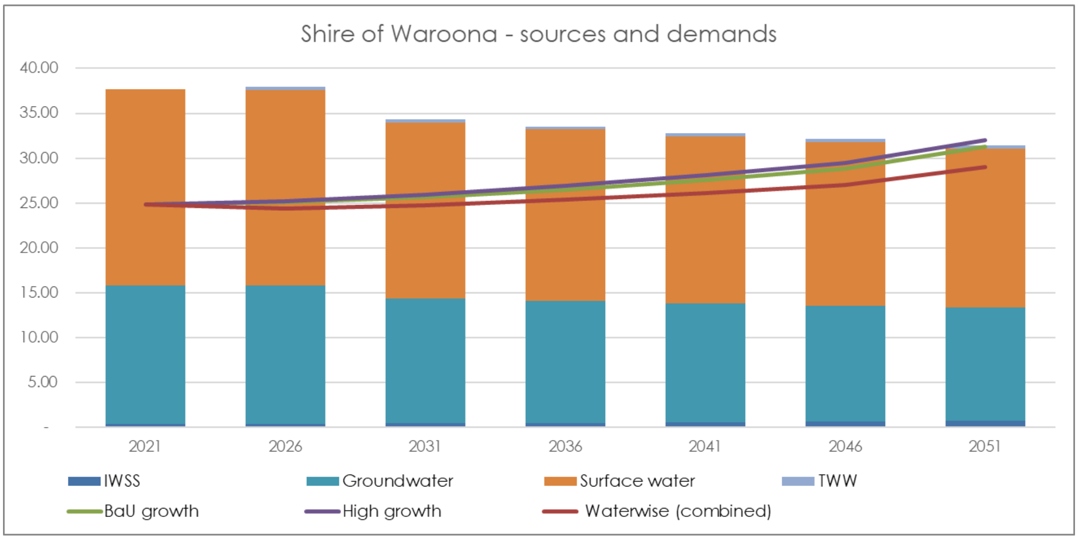


Figure 40: Future water sources & demands at current availability for Shire of Waroona to 2051

7.2.1 Assessment of reduced groundwater accessibility

Having consideration of the above, a further assessment of source/supply shortfalls was undertaken to address the known current constraints with accessing groundwater predominantly in the Shires of Serpentine Jarrahdale and Waroona. This scenario equates to capping groundwater levels at current levels with further reductions for climate change and is Scenario E5 which will be described in more detail in the next section.

The assessment, including current source predictions to 2050, is based on the following assumptions:

- IWSS
  - IWSS is assumed to grow sufficiently to supply all new residential needs and continue servicing all existing accounts.
- Self-supply
  - Surface water and groundwater availability is capped at current use (licensed and unlicensed) to 2031 when a 10% reduction is applied. Thereafter incremental reductions are applied to reach a further 10% reduction by 2051.
  - Surface water currently allocated to Newmont is returned after 2036 and is not re-allocated.
- Treated wastewater
  - Future availability from WC to 2033 extended to 2051 assuming continued stable growth rates.

The sources and demands for the Peel Region for the three growth scenarios are shown in Figure 41, demonstrating a shortfall of 46.55, 63.63 and 34.85 GL by 2051 (Table 55).

This scenario suggests that the Peel Region will run out of currently available sources of water within the next few years and highlights the significant gaps in all local government areas except Mandurah.

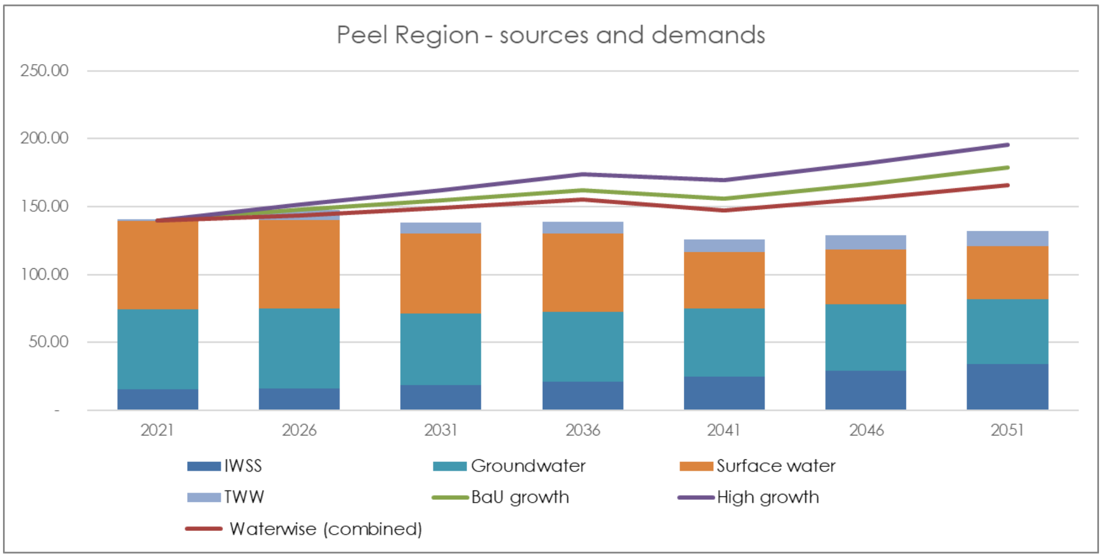


Figure 41: Future water sources and demands for the Peel Region to 2051 – scenario E5

Table 55: Available water sources for the growth scenarios at 2051 – scenario E5

Local government	BaU	High growth	Waterwise
Boddington	-3.03	-3.49	-2.56
Mandurah	6.11	3.89	8.01
Murray	-27.69	-40.85	-23.28
Serpentine Jarrahdale	-11.67	-12.18	-8.80
Waroona	-10.26	-11.00	-8.21
Total (GL)	**-46.55**	**-63.63**	**-34.85**

It is noted that a deficit exists at 2051 in most local government areas with the exception of Mandurah. The results for each local government area are shown in Figures 42 to 46.

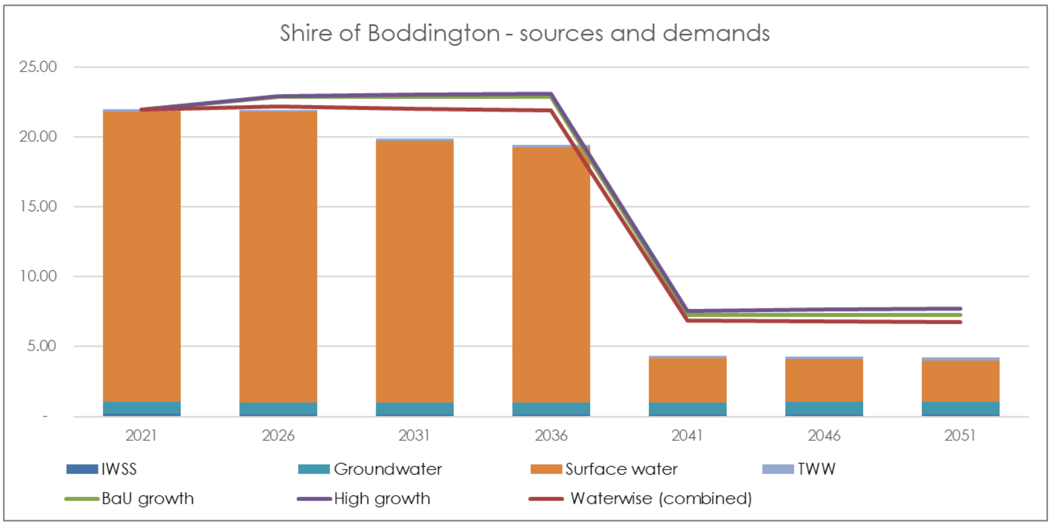


Figure 42: Future water sources and demands for the Shire of Boddington to 2051 – scenario E5

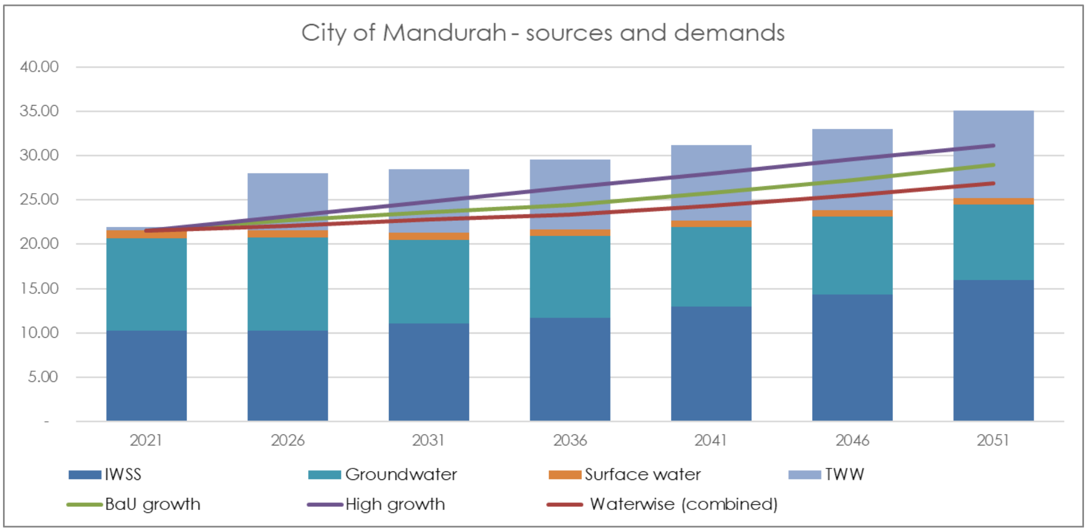


Figure 43: Future water sources and demands for the City of Mandurah to 2051 – scenario E5

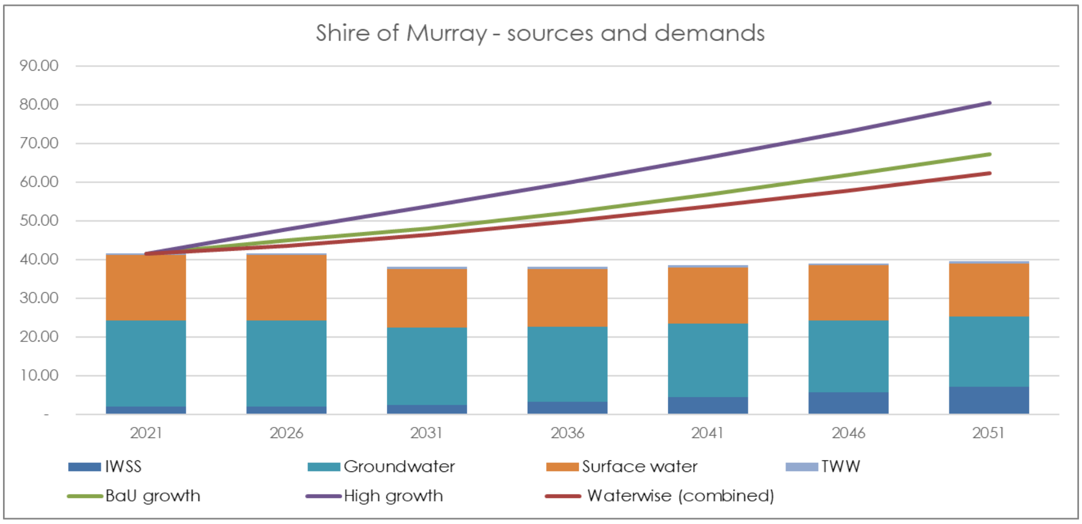


Figure 44: Future water sources and demands for the Shire of Murray to 2051 – scenario E5

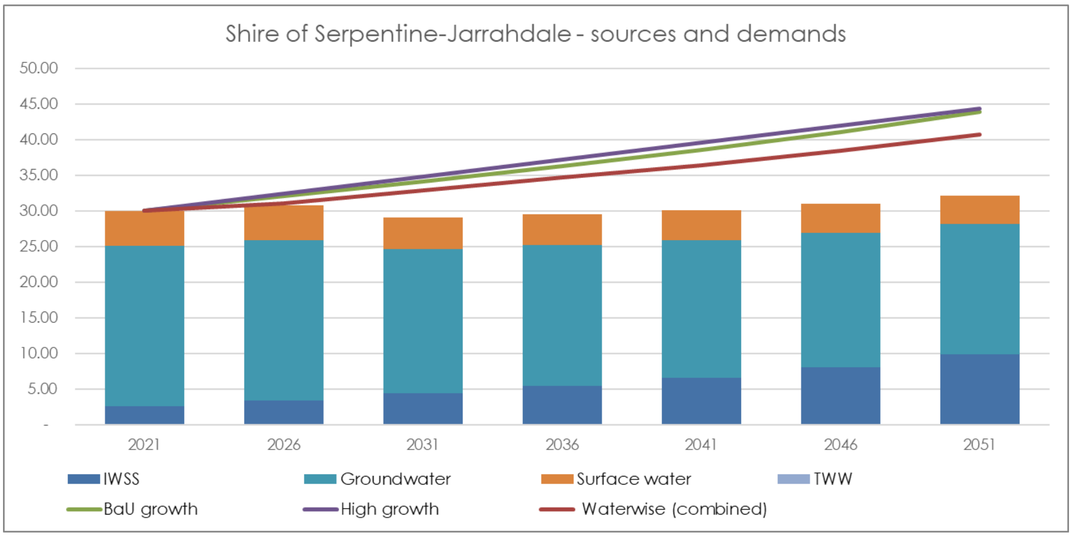


Figure 45: Future water sources and demands for the Shire of Serpentine Jarrahdale to 2051 – scenario E5

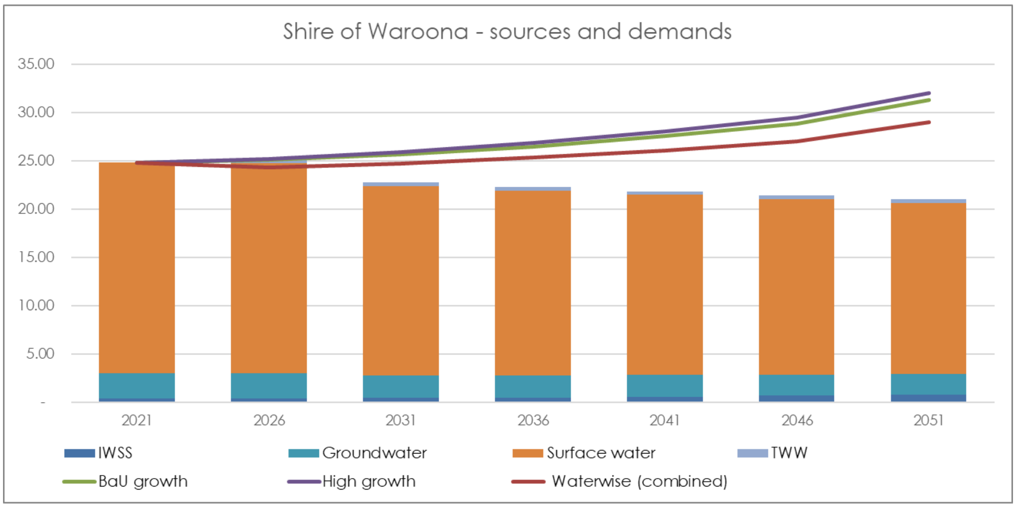


Figure 46: Future water sources and demands for the Shire of Waroona to 2051 – scenario E5

7.3 Future environmental conditions

The water that is needed to sustain the significant environmental assets currently present in the study area will change in future in response to the changing climate. The key climate change elements that will affect the environment are changes to rainfall and evapotranspiration.

Water Resource Assessment in the Peel Region: historical and under projected future climate (Barron et al, 2020) provides a summary of the projected future climate that is relevant to this study. Two approaches from DWER and Climate Change in Australia (CCIA) were used for future climate projections. The approaches have different historical baselines; however, their projected rainfall changes were broadly consistent. The key findings for the two approaches at 2050 were:

- Mean annual rainfall changes of:
  - Dry: -25.4% and -26.3%
  - Median: -16.2% and -18.3%
  - Wet: -5.4% and -0.1%

- Annual potential evapotranspiration changes of:
  - Dry: 5.4% and 4.8%
  - Median: 2.9% and 5.3%
  - Wet: 4.9% and 3.8%

To provide a high level assessment of the changing needs of the environment in the study area, the broadscale conceptual water balance model presented in Section 2.4 has been used to assess future development scenarios. This assessment incorporates an annual reduction in rainfall in all catchments by 17.25% (average or median scenario changes) and potential evapotranspiration increased in all catchments by 4.5% (average of all scenario changes)(consistent with the PIWI report findings as referred to above). The future water balance scenarios are discussed further below)

7.3.1 Future water balance scenarios

A baseline future (2050) water balance, considering the effects of declining rainfall and increasing potential evapotranspiration discussed above would represent a continuation of current land uses, water management and licensed water use and is therefore likely to be unrealistic.

In reality, the environment's increased need for water in the future will be in direct competition with other projected future demands. This means that the way we choose to respond to the increased environmental need has important implications for the availability of surface water and groundwater resources for other purposes in future.

To enable consideration of future development scenarios, three different management options were agreed by workshop participants for further consideration. These were:

- E1 Surface water and groundwater allocations remain capped at current levels resulting in net reduction of water for the environment.
- E2 Surface water and groundwater allocations are reduced to provide additional water for the environment sufficient to maintain current flows to the Peel-Harvey estuary.
- E3 Surface water and groundwater allocations are reduced further to increase flows to the Peel-Harvey estuary consistent with Peel Harvey Ramsar Ecological Character Description requirements.

This study assessed the implications of the first option above and found that potential overall reduction in streamflows by 2050 (~260 GL) was significantly larger than the current surface water and groundwater abstraction rates combined (~120 GL). This means that in a future climate, current flows into the Peel-Harvey estuary could not be maintained, even if all abstraction were to cease. Accordingly, scenarios 2 and 3 above are not feasible for consideration. Amended scenarios are therefore presented below:

- E4 All surface water and groundwater abstraction ceases by 2050.
- E5 Surface water abstraction is maintained at 2021 levels. Groundwater allocation limits are maintained at 2021 levels to 2030, then reduced by 10%, then reduced incrementally to reach a further 10% reduction by 2050.

The results of the application of the broadscale water balance for the three revised strategies is presented below.

Summary of the broadscale conceptual water balance at 2050 – baseline scenario (E1)

A broadscale conceptual water balance for the groundwater and surface water components of the whole Peel-Harvey system at 2050 is presented in Table 56 and Table 57. The small deficits previously noted have increased substantially in both tables, indicating a more significant future declining trend in both surface water and groundwater storage within the catchments.

It must be noted that this water balance is broadscale and conceptual in nature. It has been developed at a very high level to assist with consideration of the environmental implications of future water demands from the community, industry and agriculture. The numbers expressed in this water balance should not be relied upon for any other purpose.

Table 56: Broadscale conceptual water balance (E1) (Superficial groundwater)

Superficial groundwater		
Inputs	***mm***	***GL***
Gross recharge from rainfall	366	4,226
	366	4,226
Outputs		
Evapotranspiration from groundwater	350	4,044
Net drainage from groundwater to surface water	14	163
Abstraction from superficial groundwater	5	53
Vertical leakage	2	28
Net horizontal flow	3	33
	374	4,320
Water balance deficit (storage change)	-8.1	-94

Table 57: Broadscale conceptual water balance (E1) (Surface water)

Surface water		
Inputs	***mm***	***GL***
Baseflow from groundwater	14	163
Rainfall runoff	27	307
	41	470
Outputs		
River discharges	39	456
Abstraction from rivers and dams	6	70
	45	525
Water balance deficit (storage change)	-4.8	-56

Figure 47 and Figure 48 present a breakdown of the 2050 water balance by catchment so that differences between the water balance components in each catchment can be observed.

The 2050 groundwater balance in all catchments continues to be dominated by recharge and evapotranspiration with net drainage from groundwater to surface water providing the next largest contribution. Notably in the upper Murray catchment this element has reversed and there is now a net transfer from surface water to groundwater. In other catchments, the net exchange remains as a transfer from groundwater to surface water, albeit greatly reduced in all catchments. Abstraction from groundwater remains unchanged in this scenario.

The 2050 surface water balance remains relatively similar to the current water balance with the dominant proportion of surface water flows still coming from groundwater in the Harvey River and lower catchments of the Serpentine and Murray Rivers and surface runoff dominant in the upper Murray and Coastal catchments. It is noted that rainfall/runoff has declined to almost zero in the lower Murray and Serpentine catchments. In this scenario, abstraction rates have been reduced where necessary due to lack of availability but otherwise remain unchanged.

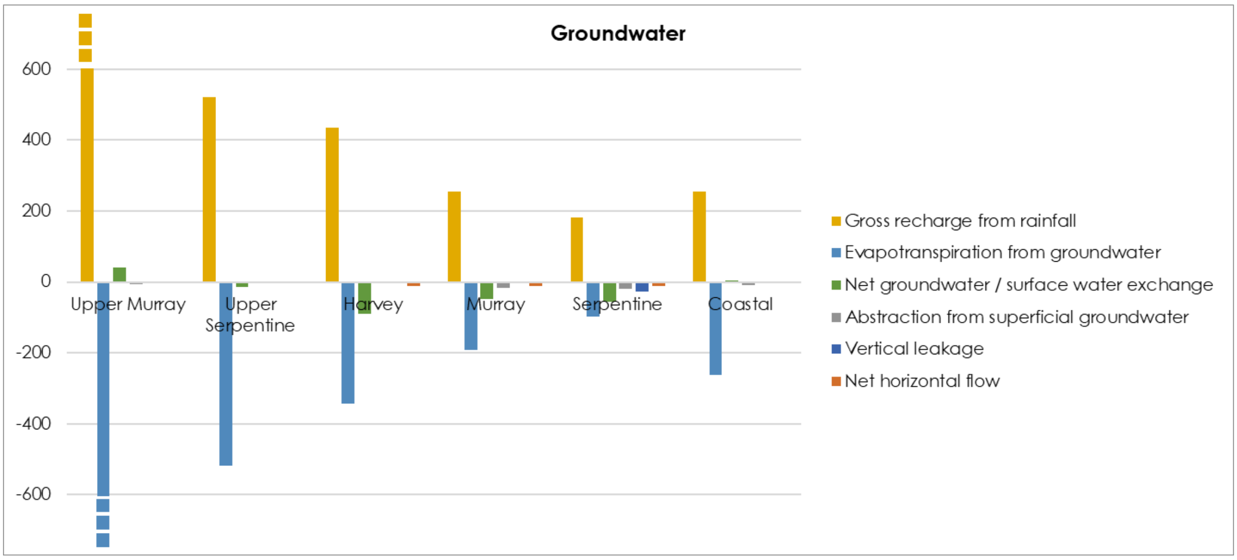


Figure 47: Broadscale conceptual water balance (E1) summary at 2050 (superficial groundwater)

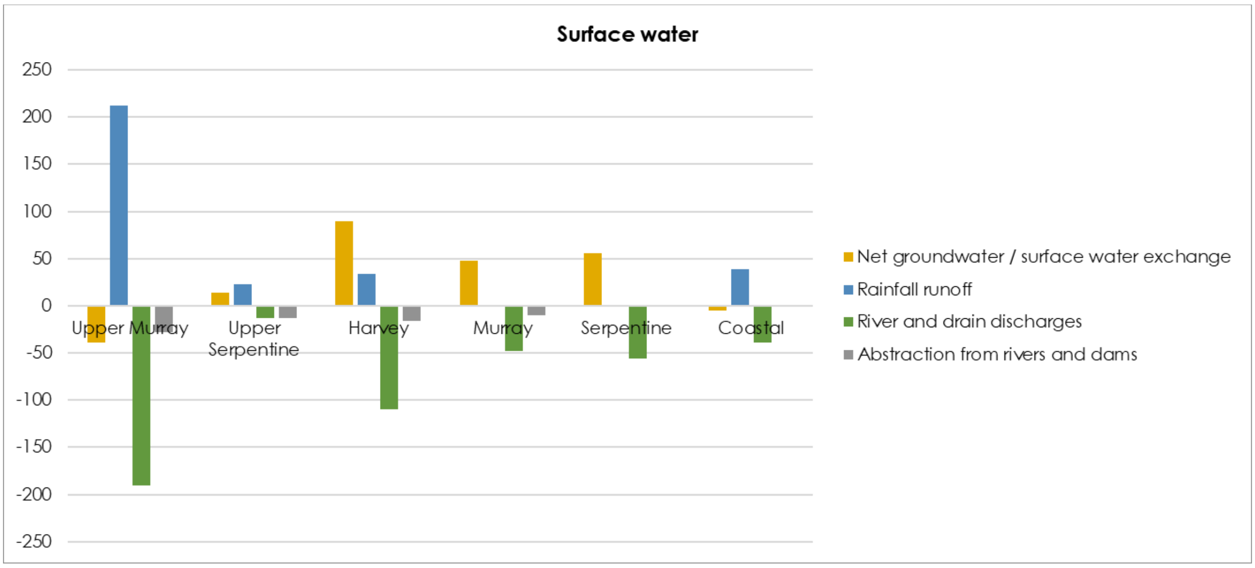


Figure 48: Broadscale conceptual water balance (E1) summary at 2050 (surface water)

Summary of the broadscale conceptual water balance at 2050 – zero abstraction scenario (E4)

A broadscale conceptual water balance for the groundwater and surface water components of the whole Peel-Harvey system at 2050, assuming zero abstraction from surface water or superficial groundwater, is presented in Table 58 and Table 59. The small deficit previously noted has increased substantially in the groundwater balance table, indicating a more significant future declining trend in groundwater storage within the catchments. However, there is now a small increase in surface water storage. This is principally related to the cessation of abstraction from the dam catchments and could be considered as an opportunity for additional releases to assist with sustaining downstream environments. In addition to these storage changes, the previously noted declines in river discharges and the net drainage of groundwater to surface water have been reduced.

It must be noted that this water balance is broadscale and conceptual in nature. It has been developed at a very high level to assist with consideration of the environmental implications of future water demands from the community, industry, and agriculture. The numbers expressed in this water balance should not be relied upon for any other purpose.

Table 58: Broadscale conceptual water balance (E4) (Superficial groundwater)

Superficial groundwater		
Inputs	***mm***	***GL***
Gross recharge from rainfall	366	4,226
	366	4,226
Outputs		
Evapotranspiration from groundwater	350	4,044
Net drainage from groundwater to surface water	13	152
Abstraction from superficial groundwater	0	0
Vertical leakage	2	28
Net horizontal flow	3	33
	374	4,312
Water balance deficit (storage change)	-7.4	-86

Table 59: Broadscale conceptual water balance (E4) (Surface water)

Surface water		
Inputs	***mm***	***GL***
Baseflow from groundwater	18	208
Rainfall runoff	27	307
	28	561
Outputs		
River discharges	43	496
Abstraction from rivers and dams	0	0
	43	496
Water balance deficit (storage change)	1.7	19

Figure 49 and Figure 50 present a breakdown of the 2050 water balance by catchment for scenario E4 so that differences between the water balance components in each catchment can be observed.

The 2050 (E4: zero abstraction) is relatively unchanged from the baseline scenario with the abstraction volume principally restoring some of the decline in net groundwater to surface water, particularly in the lower Serpentine and Murray catchments.

The 2050 (E4: zero abstraction) surface water is also largely consistent with the baseline scenario although increased streamflows are noted in both the lower Serpentine and Murray catchments.

Importantly, this water balance scenario demonstrates that the potential overall reduction in streamflows by 2050 (~270 GL) remains significant even with zero abstraction. However, this could be further improved by making use of the opportunity presented by cessation of abstraction from the dams to release an additional ~19GL into the downstream environment.

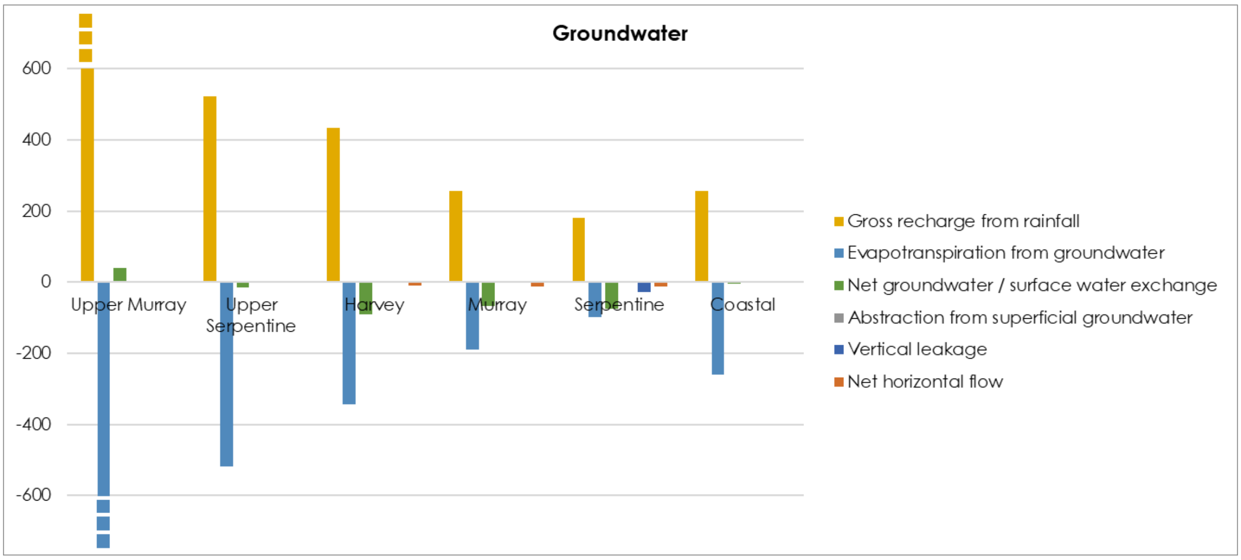


Figure 49: Broadscale conceptual water balance summary at 2050 with no abstraction (E4) (superficial groundwater)

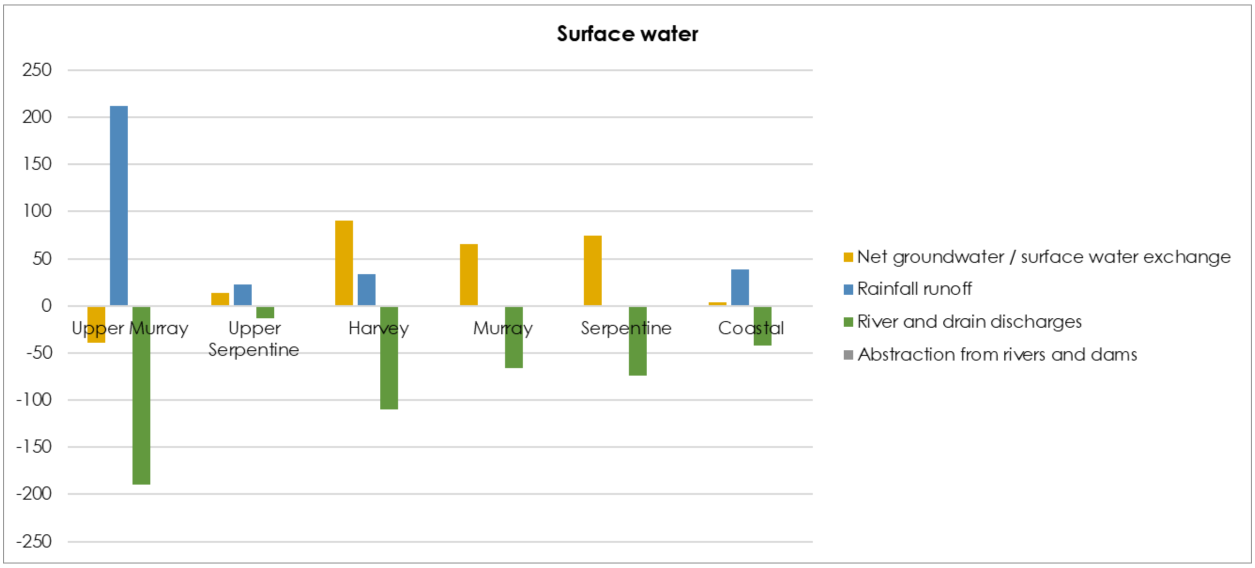


Figure 50: Broadscale conceptual water balance summary at 2050 with no abstraction (E4) (surface water)

Summary of the broadscale conceptual water balance at 2050 – modified groundwater abstraction scenario (E5)

A broadscale conceptual water balance for the groundwater and surface water components of the whole Peel-Harvey system at 2050, assuming ongoing abstraction from surface water at current rates but modified superficial groundwater abstraction rates, is presented in Table 60 and Table 61. This scenario accepts that some increases in groundwater use are supported by current groundwater allocations but accounts for future reductions in line with current policy indications.

The small deficit previously noted has increased substantially in the groundwater balance table, indicating a more significant future declining trend in groundwater storage within the catchments. However, there is now a small increase in surface water storage. This is principally related to the cessation of abstraction from the dam catchments and could be considered as an opportunity for additional releases to assist with sustaining downstream environments. In addition to these storage changes, the previously noted declines in river discharges and the net drainage of groundwater to surface water have been reduced.

It must be noted that this water balance is broadscale and conceptual in nature. It has been developed at a very high level to assist with consideration of the environmental implications of future water demands from the community, industry, and agriculture. The numbers expressed in this water balance should not be relied upon for any other purpose.

Table 60: Broadscale conceptual water balance (E5) (Superficial groundwater)

Superficial groundwater		
Inputs	***mm***	***GL***
Gross recharge from rainfall	366	4,226
	366	4,226
Outputs		
Evapotranspiration from groundwater	350	4,044
Net drainage from groundwater to surface water	13	136
Abstraction from superficial groundwater	8	90
Vertical leakage	2	28
Net horizontal flow	3	33
	375	4,330
Water balance deficit (storage change)	-9.0	-104

Table 61: Broadscale conceptual water balance (E5) (Surface water)

Surface water		
Inputs	***mm***	***GL***
Baseflow from groundwater	12	136
Rainfall runoff	27	307
	38	443
Outputs		
River discharges	37	430
Abstraction from rivers and dams	6	70
	43	499
Water balance deficit (storage change)	-4.8	-56

Figure 51 and Figure 52 present a breakdown of the 2050 water balance by catchment for scenario E5 so that differences between the water balance components in each catchment can be observed.

The 2050 (E5: modified groundwater abstraction) groundwater shows that the increased groundwater abstraction volume increases the likelihood of groundwater level decline and results in less net groundwater to surface water, particularly in the lower Serpentine and Murray catchments.

The 2050 (E5: modified groundwater abstraction) surface water shows reduced streamflows in both the lower Serpentine and Murray catchments resulting in reduced river discharges into the Peel-Harvey estuary.

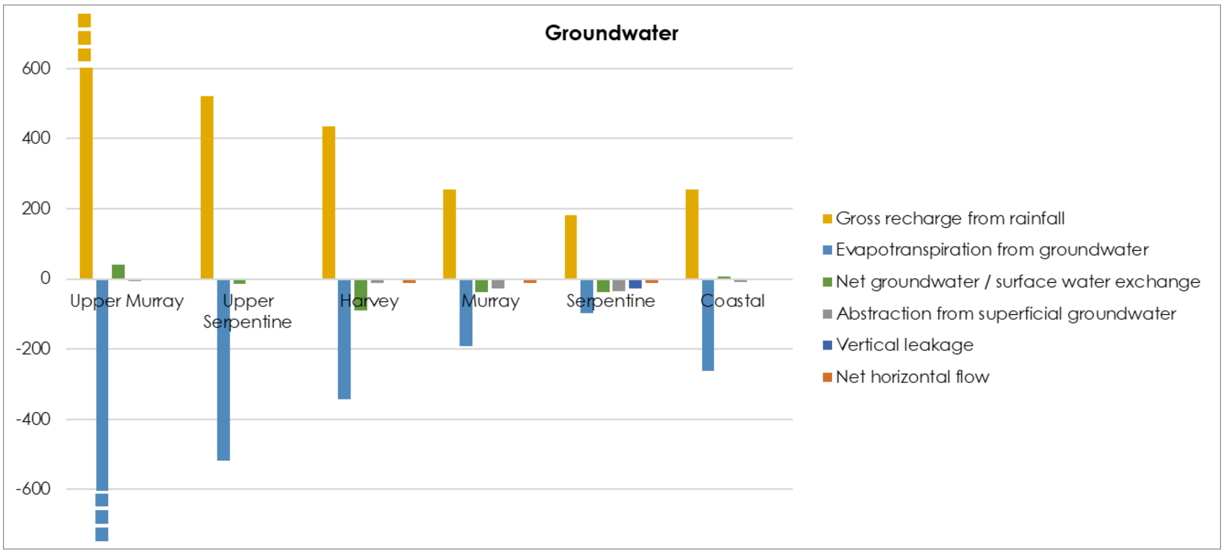


Figure 51: Broadscale conceptual water balance summary at 2050 with no abstraction (E5) (superficial groundwater)

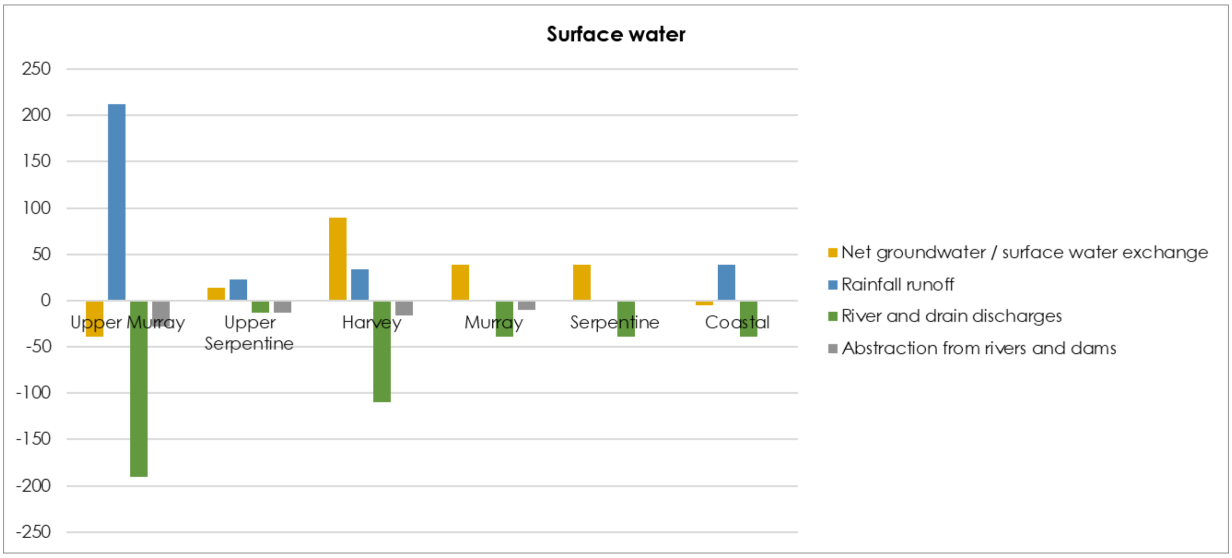


Figure 52: Broadscale conceptual water balance summary at 2050 with no abstraction (E5) (surface water)

This water balance scenario demonstrates that the most likely groundwater abstraction regime, based on current policy indications, may result in a potential overall reduction of ~290 GL in streamflows by 2050.

7.3.2 Implications and opportunities for the environment

The broadscale water balance at 2050 (as depicted in Figure 53) shows that the potential magnitude of rainfall decline and potential evapotranspiration increases are significant in all catchments, even with zero abstraction. This means that there is likely to be less rejected recharge expressed as surface inundation, less streamflow, declining groundwater levels and overall, less water in the environment.

The environmental implications of this change may include:

- transition of waterways from perennial to intermittent and ephemeral flow patterns
- drying and terrestrialisation of lakes and seasonally inundated wetlands (sumplands)
- loss of seasonally waterlogged wetlands (damplands)
- loss of wetland and dryland vegetation
- increasing sedimentation of wetlands and waterways
- increasing salinity of wetlands and waterways

It is noted that some of the predicted decline in streamflows and groundwater levels can be prevented by ceasing to abstract surface water and superficial groundwater. In addition, by ceasing abstraction from surface water dams, additional releases into the downstream environment would be possible and these could be scheduled to support the environment in key periods of stress.

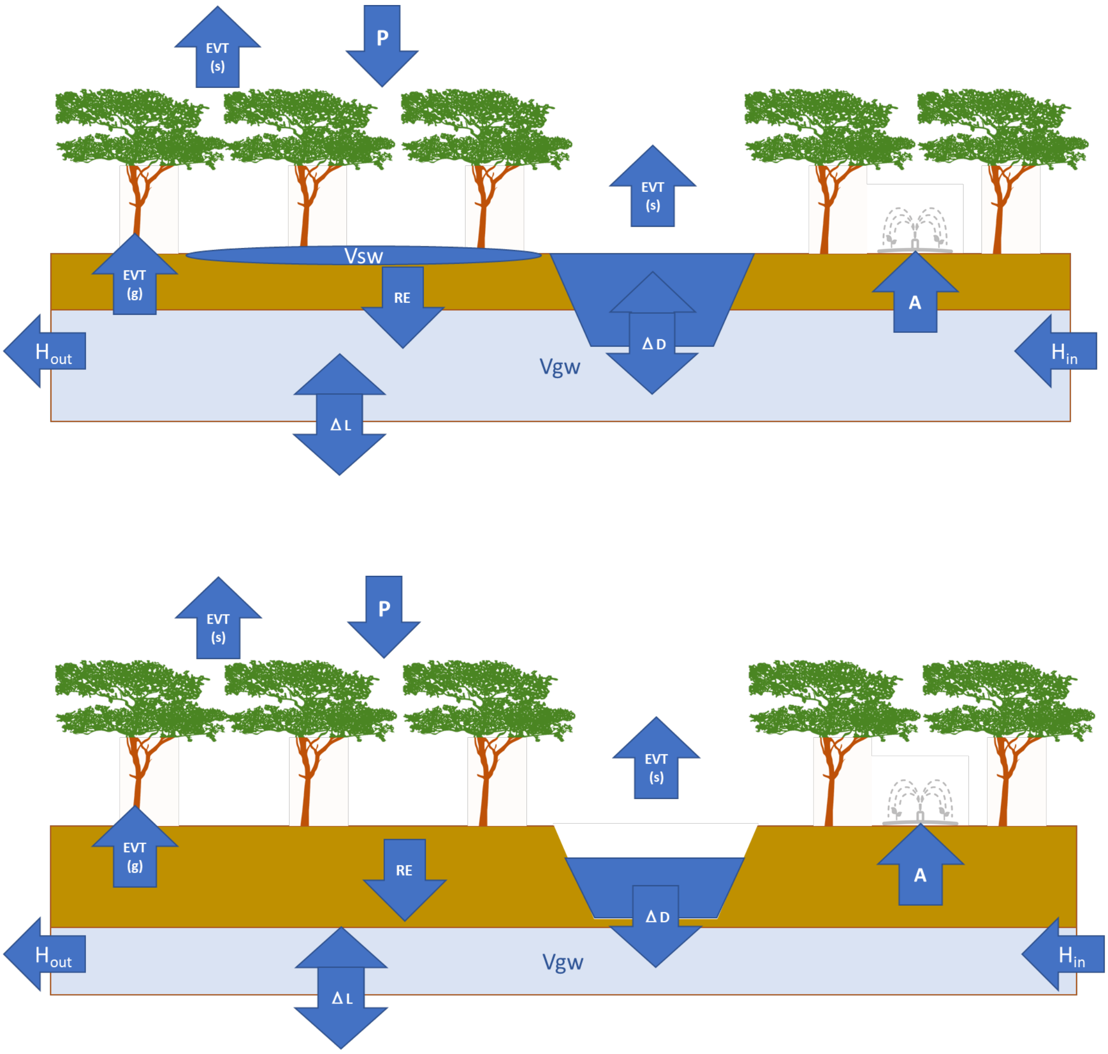


Figure 53: Change in conceptual water balance from 2021 to 2050

Section 8: Towards a sustainable water future in Peel

8 TOWARDS A SUSTAINABLE WATER FUTURE IN THE PEEL

The previous sections of the report have identified the likelihood of significant water source shortfalls in the water requirements of the future community, agricultural and industrial growth and development within the Peel Region. It has also considered the impact of climate change and the current water management regime on the environment, and particularly the internationally recognised Peel-Yalgorup Ramsar site. It is imperative that alternative sources of water are investigated by the Peel Alliance in partnership, so that any future solution considers the critical conditions together with the broad range of objectives and conditions.

These aspects are briefly discussed below to assist with preliminary discussions moving forwards.

8.1 Critical conditions

The importance of the Peel-Harvey Estuary and associated waterways and wetlands to the people and economy of the Peel Region is well recognised. The health of the estuary is, however, under threat from environmental changes resulting from climate change, changes in land use and intensification of development, agriculture and mining activities, as well as water resource use and management.

This study has demonstrated the importance of shallow groundwater across the region to the health of the Peel Harvey system – particularly in terms of streamflows. It will be critical to consider this hydrological function as part of any decisions on water source and supply options for the future. Actions should seek to maintain environmental flows to and within the waterways of the Peel-Harvey Estuary (although our modelling has demonstrated the difficulty in achieving this objective).

Consideration could also be given to opportunities to enhance stream flows. It is commonly accepted that our potable water system no longer relies on inflows to dams to provide a water source and that they serve a storage and supply function. The limited amount of streamflow entering them could therefore be considered available for environmental release (estimated at approximately 19GL).

Recent studies have detected declining groundwater levels in areas of the Superficial, Leederville and Cattamarra resources, which are caused by a combination of abstraction and reduced rainfall as a result of climate change (DWER, 2022). These reductions in groundwater levels, particularly in the superficial aquifer, pose a significant risk to the health of the region's wetlands, river systems and riparian vegetation (DWER, 2021). Accordingly, there is a critical need to ensure the sustainable management of our groundwater resources so they can sustain the important social, economic and environmental functions for future generations. It is therefore likely that reductions in groundwater abstraction from licenced areas will be required in future to account for reduced rainfall and recharge based on technical assessments by the Department of Water and Environmental Regulation.

8.2 Likely shortfalls

At the regional level, the scenario analysis has identified the potential for shortfalls in current water source availability across the Region of 9.75 GL for BAU and 26.65 GL for the high growth scenario by 2051, although sufficient water may be available if the waterwise development solution is adopted. However, it is noted that the available sources are not located in proximity to the demands, and it is likely that additional sources of water would be required within the Shire of Murray by 2036 (Figure 54). In addition, this scenario assumes that prospective users are able to access all the remaining groundwater and surface water allocations and wastewater generated, which may not be possible. A spatial representation of the identified supply gaps and currently utilised source options is provided in Figure 54 and Figure 55.

As highlighted above, this report has noted the difficulty in accessing the currently available groundwater resources included in the above assessment. Issues with groundwater quality particularly in coastal areas as well as low yields from bores in areas with clayey soils have been reported across the region. This study, therefore, sought to assess the demand and supply balance at current allocation levels with future reductions to account for climate change impacts. This is consistent with the approach recently taken by the Department of Water and Environmental Regulation in the *Murray groundwater area allocation statement* (2022), which also notes the continuing program of review of allocation limits across Perth and Peel.

The findings of this alternative assessment suggest that there may be a shortfall of between 35 GL and 64 GL at 2051. This demonstrates the need to consider alternative source options.

8.3 Alternative water source options

There are a number of alternative water source options that could also be used to address the shortfall in available water in the Peel Region in future. These include:

- Groundwater from unlicenced groundwater areas
- Groundwater trading
- Surface water trading
- Water Corporation IWSS
- Harvey Water irrigation scheme
- Sewer mining
- Inland desalination
- Ocean desalination
- Rainwater harvesting
- Greywater reuse
- Stormwater harvesting
- Superficial Source Enhancement

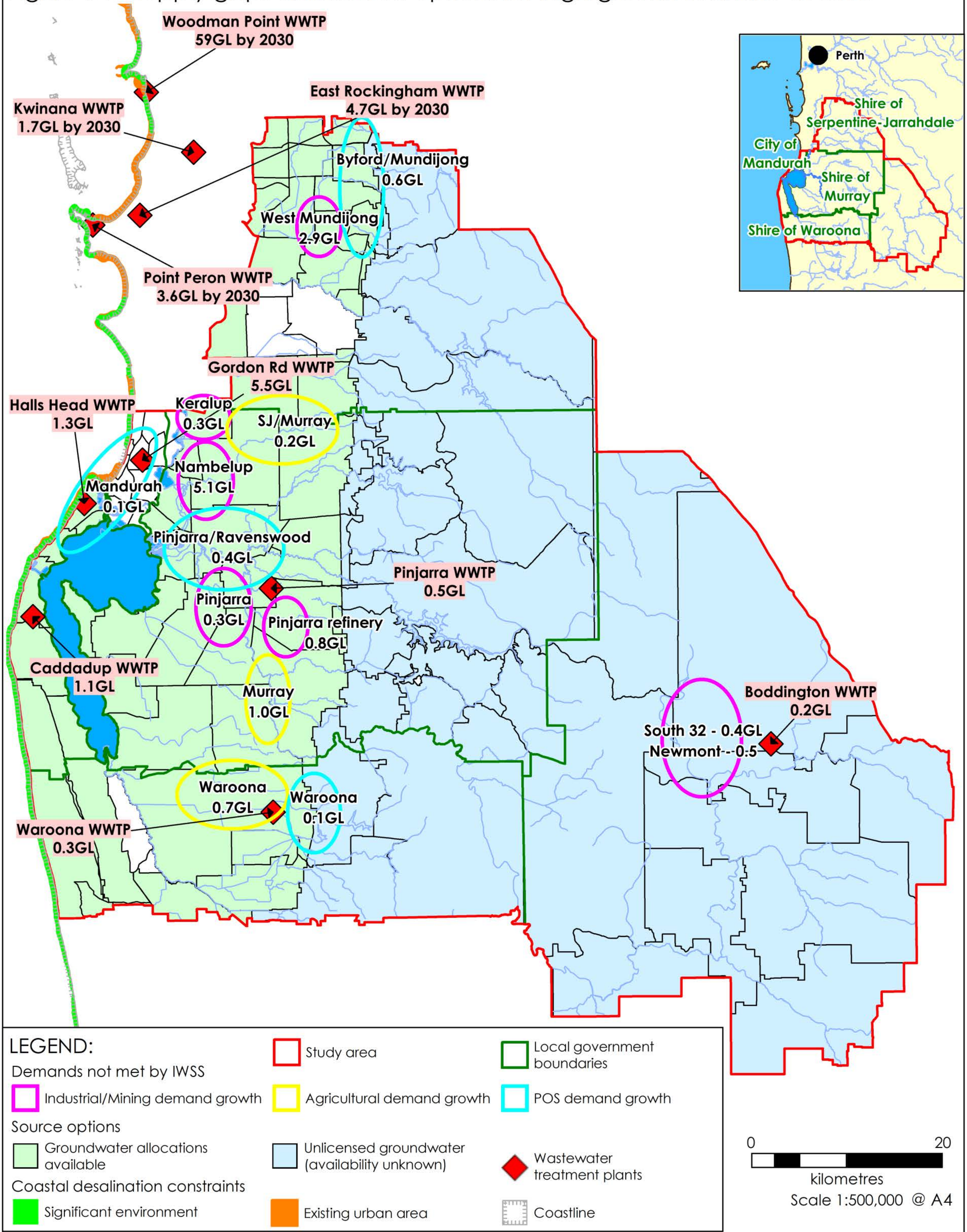
It is noted that some of these options are not new or "alternative" i.e. using groundwater from unlicenced areas or water trading. They have been included here as they are unable to be accounted for in the calculations and so are considered to provide an additional opportunity that could be explored. These options are described in more detail below, together with an indication of source suitability to address the shortfalls identified above.

8.3.1 Groundwater from Karri management area (fractured rock aquifer)

While no licence is required to take groundwater from the Karri groundwater management area, this aquifer is fractured rock and so the yield is likely to be low in volume and unreliable. Where low volumes are required for non-essential needs, this source may provide an opportunity, however.

Source suitability: Marginal

Peel Alliance - Peel Regional Water Supply Initiative, Agricultural needs report
Figure 54 - Supply gaps and source options for high growth scenario at 2036



Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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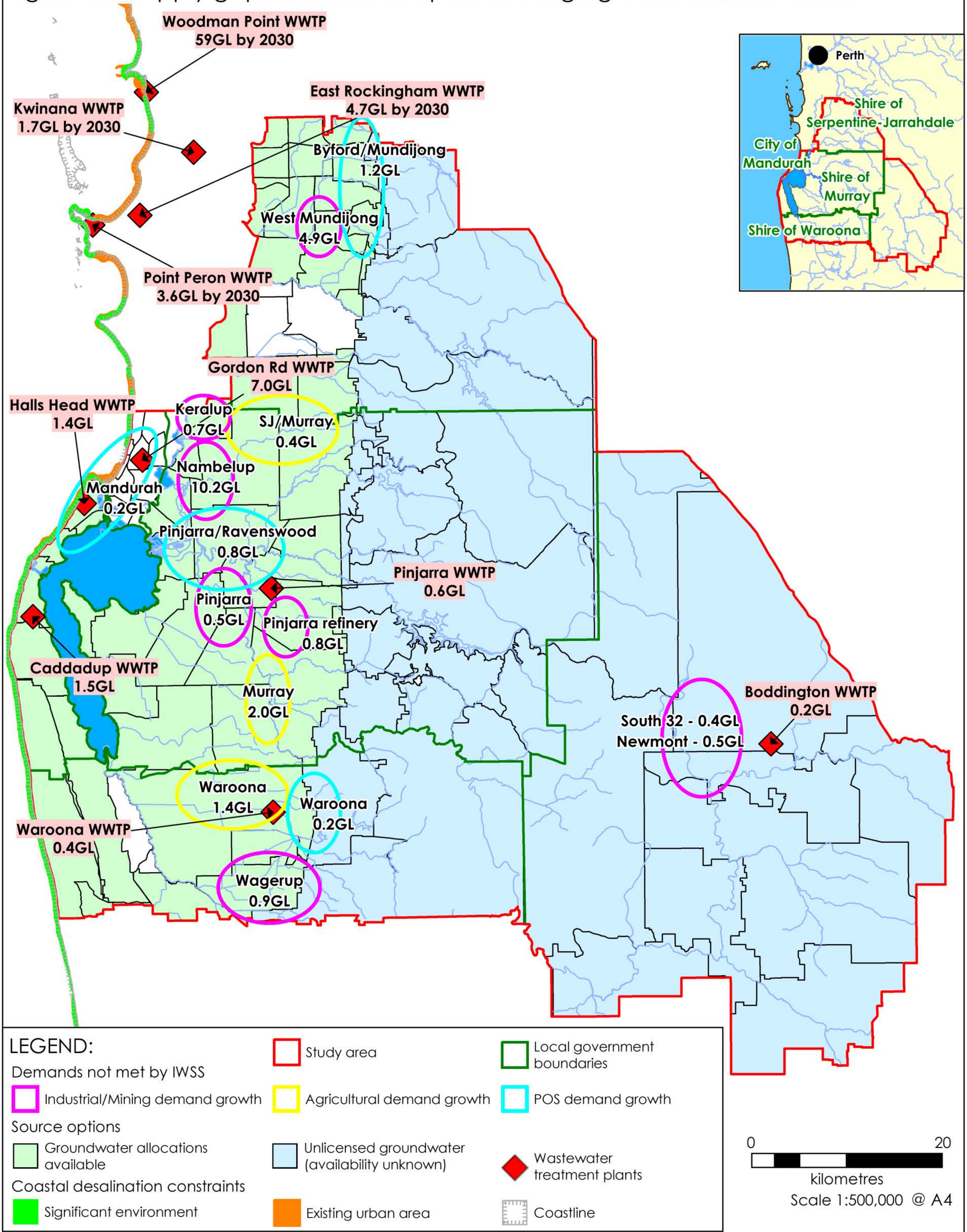
Peel Alliance - Peel Regional Water Supply Initiative, Agricultural needs report
Figure 55 - Supply gaps and source options for high growth scenario at 2051



Data source: Landgate. Created by: HB Projection: MGA: zone 50.

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8.3.2 Groundwater trading

Trading of water entitlements is an effective process for moving water to higher-value uses as it provides an opportunity for new water users to access the limited resources where an existing licence holder no longer requires access to the water source. Information on current water licences to facilitate trade discussions is publicly available on the Department of Water and Environmental Regulation's Water Register (https://maps.water.wa.gov.au/#/webmap/register).

Trading is most common when a water resource becomes fully allocated. Current licenses may increase efficiency or be used for low-value production. This water may be available to be traded to support development (DWER, 2021), however, it should also be noted that the Department may seek a portion of the traded licence to be returned for environmental reasons or to address the impacts of climate change.

Source suitability: Marginal

8.3.3 Surface water trading

Similarly to new surface water allocations, it is considered unlikely that existing surface water resources would be able to be traded without a substantial reduction in yield to account for the diminished streamflows due to climate change. In addition, the specific "take off" points stipulated in licence conditions provide limited flexibility regarding the location of the available source.

Source suitability: Poor

8.3.4 Licenced schemes

This option proposes entering into an agreement with a local water provider (the Water Corporation or Harvey Water) to supply either potable or non-potable water.

Water Corporation

The Water Corporation supply network has been summarised in Section 3.3. Supplies could be sourced directly from dams or water treatment plants, with higher costs associated with higher quality water supply (i.e., drinking water quality water is likely to be priced higher than saline Wellington Dam water supply). Supplies for commercial users are usually provided subject to a Major Customer Agreement with the Water Corporation, which requires assessment.

Even though infrastructure already exists, Water Corporation has advised that even if a volume of water is available to supply a large industrial or agricultural user, often the distribution network required to supply that water is the limiting factor. Usually, a major consumer will need to construct a dedicated main back to a trunk main or reservoir, which can be expensive.

Source suitability: Good

Harvey Water

Access to the Harvey Water Irrigation Scheme is via a "share" of the total water supply available, which equates to a volume that changes each year depending on rainfall and evaporation factors.

Harvey Water has existing infrastructure spread throughout Waroona and extending into Murray (see section 3). The main considerations are the variable nature of the supply and the ongoing cost of water, which could increase in future to facilitate improved supply networks and improve water security.

Harvey Water currently have all rights to water allocation from the Wellington Dam, to supply the Collie, Harvey and Waroona Irrigation Districts and industrial activity in the area. Although the dam supply is not climate independent, the future Collie to Coast project is expected to expand current water availabilities and provide a volume available for use into the future.

Harvey Water have also recently expanded water supply options to provide groundwater for potable supply to the Kemerton Strategic Industrial Area, which shows that if the need is there, Harvey Water are likely to expand and diversify current supplies or possibly partner to provide supply for several users.

Source suitability: Good/Fair

8.3.5 Sewer mining

Sewer mining is a form of wastewater reuse in which wastewater is extracted from a sewer network prior to entering a wastewater treatment system (meaning raw wastewater is received instead of treated effluent). This can help to alleviate pressures on current sewer networks, which are already requiring expansion especially closer to Perth. The Water Corporation considers that sewer mining may be viable within 500m of a pump station with a flow greater than 150 kL/day.

Currently, there are no sewer mining schemes being implemented in WA and as such it may be difficult to deliver this option from a governance and risk (public health) perspective. It has been suggested that sewer mining volumes around the 10 GL/year mark could be available by 2030, as predicted by the (then) Department of Water for the Perth region (DoW, 2009c).

Sewer mining also has the risk that extracting wastewater from the sewer network will lower the volumes of treated wastewater produced by WWTPs (and available for reuse), and as such, any schemes using treated wastewater from the WWTPs may be affected by a sewer mining proposal.

8.3.6 Desalination

Saline water can be used as a fit-for -purpose water source with minimal treatment, or it can be further treated for higher quality applications (such as drinking water) by removing increasing concentrations of dissolved solids.

Inland desalination

Options for inland desalination within the Peel Region are limited as the brackish surface water systems are generally controlled by the network of dams across the Scarp. Desalination of water taken from the Cattamarra Coal Measures aquifer could provide a source of high quality water is required.

Desalination of Wellington Dam (south of the study area) is not considered as Harvey Water has all rights to the water in this source.

Source suitability: Poor

Seawater desalination

The removal of salts from seawater through desalination provides an opportunity to create water suitable for a range of uses. The existing seawater desalination plants in Western Australia treat water to drinking water quality, however it is also feasible to treat water to a lower quality (higher salinity) to provide a fit-for-purpose use for agriculture or industry. It is also available at a range of scales (from 1LG/annum plants to 100GL/annum).

While seawater desalination provides a climate independent source of water, it requires large amounts of energy and produces a concentrated saline discharge which needs to be managed. It also requires a location on the coast and the ability to create a distribution network that does not impact on the environmental values of the region i.e. would need to be located outside the Peel Yalgorup Ramsar site.

Source suitability: Good

8.3.7 Small scale water reuse

The options for small-scale water reuse include rainwater harvesting, greywater reuse, stormwater harvesting and Superficial Source Enhancement. These options are considered to be small scale or local in nature, as the source is generally low yield and/or only available at certain times of the year. These options are described in further detail below.

Rainwater harvesting

Tanks may be used to collect and store rainwater runoff from roofs. Where there is no access to scheme water, this may provide a source of drinking water (where the system is appropriately maintained), but can also be used for non-drinking water purposes such as toilet flushing, irrigation or industrial uses. While rainwater harvesting can provide multiple benefits, eg. reduced demand on the IWSS and the need for source supplementation, it is limited by rainfall, roof size and tank size, and is generally unable for applications beyond a single lot.

Source suitability: Poor

Greywater reuse

Greywater is a domestic stream of wastewater from all sources other than the toilet (usually called blackwater). It is still classified as "sewage" under the *Health Act 1911* and so approvals are required from the Department of Health to install and operate greywater systems (with the exception of a domestic greywater system that reuses greywater via greywater diversion device (GDD) for watering garden via sub-surface irrigation – this needs Local Government approval).

The viability of greywater is dependent on the volume and timing of greywater generated, which is generally small in nature. While commercial greywater reuse schemes from multiple dwellings (such as an apartment building) are possible, the regulatory requirements to support the operation of such a scheme are complex.

Source suitability: Poor

Stormwater harvesting

Stormwater may be harvested from catchments via agricultural drains or from impermeable surfaces through road drainage networks or sub-surface drainage. Dr Don McFarlane found that the volumes from sub-surface drains are very small when compared with main drains and street drain volumes, because they occupy a very small area. The water is also mainly available in areas with extensive high watertables making it difficult to identify storage sites, unless these are created by heavy pumping over summer or unless the drainage water is recharged to a deeper aquifer (McFarlane, 2019a). Dr McFarlane considered that agricultural drains in the Peel area could provide a potential source of recharge for both the environment and for irrigated agriculture, however, while reducing nutrient loads entering estuaries (McFarlane, 2019a).

Further investigation of the viability of stormwater harvesting was undertaken for the Peel Integrated Water Initiative (PIWI), which found that the capture, treatment and storage of winter flows in the existing drainage network for fit-for-purpose use in the PIWI investigation area is technically viable and provided a conservative estimate of up to 2 GL/yr (taking five per cent of mean annual surface flows) abstraction with an annual reliability of 80 per cent from Punrak, Dirk Brook, Nambeelup, Dandalup and other catchments combined. The report also noted that the potential volume of surface water available for allocation was estimated to reduce to about 1 GL per year by 2050 as a result of a drier projected climate (DWER, 2021).

As stated above, while the volume may be technically able to be abstracted, utilisation of the total volume is unlikely due to the location of abstraction sites in proximity to its use and the need to address water quality risks consistent with the Peel Harvey EPP.

A further qualifier in the report is that the estimates are subject to change in response to “the environmental water requirements of the Peel Harvey Estuary as these are not yet known”. Consideration should therefore be given to the water balance findings from this study, as discussed below.

Source suitability: Fair

Superficial Source Enhancement (SSE)

Superficial Source Enhancement (SSE) (as described in Transform Peel, DWER, 2021) aims to increase groundwater replenishment in an unconfined aquifer by lowering the watertable in waterlogged areas to capture future rainfall. The report notes:

> *On average, 5.6 GL could have been potentially available for SSE with reliability of 80 per cent of this period. Under future climate scenarios, rainfall above the 350–400 mm threshold was projected to reduce to 50 per cent, and under some scenarios to zero per cent, limiting the available source water for SSE.*
>
> *Based on this analysis it was determined that current rainfall, causing seasonal inundation/waterlogging, is likely to substantially decline under a future drying climate. This means that this component of the regional water balance is not reliable into the future, and as such this source for SSE was determined to be unviable and no further assessment was warranted. However, if alternative water sources become available (e.g. desalinated water, treated wastewater), SSE may become technically a viable option for the water resource enhancement, pending further assessment.*

Source suitability: Poor

8.4 Considerations for future water source options

As shown in section 8.3, there are a number of potential water sources that could be considered to address the larger shortfalls in water availability in the Peel Region at 2050. This does not preclude consideration of other smaller volume sources that may address local needs. The larger sources include:

- Groundwater from the superficial aquifer
- Groundwater from the Leederville
- Water Corporation IWSS
- Harvey Water irrigation scheme
- Treated wastewater
- Seawater desalination
- Stormwater harvesting from agricultural drains

A high level discussion of issues that may affect the feasibility of these sources is provided below.

8.4.1 Groundwater from the superficial aquifer

The low cost of groundwater as a source of water for irrigation is well recognised in Western Australia. While a few, simple applications may be required to obtain the water entitlement, currently no fees are payable for either application to construct a bore (26D licence) or take groundwater (5C licence); however, a recent $200 fee has been introduced for applications for temporary licences or to transfer a licence. The key costs are associated with construction of the bore, which can range from $2,000 if it is shallow, to $200,000 for very deep bores, and the operational cost of the bore which is estimated at around 30c per kL.

The use of groundwater is also not considered to be a complex solution as there is limited infrastructure and the apparatus and operational requirements are well known. However, within the Peel region, this option has the potential to negatively impact on the environmental, social and cultural values of the Peel-Yalgorup system, particularly in proximity to waterways and wetlands. The water balance assessment estimated that abstraction from the superficial aquifer to the allocatable volume limits would result in reduced streamflows of approximately 290GL as compared to ~260GL for the baseline scenario which caps limits at existing allocations (E1).

8.4.2 Groundwater from the Leederville

The Department of Water and Environmental Regulation's water register records as at August 2021 suggests that over 9.6GL is available for allocation from the Leederville aquifer within the Peel Region. This volume includes 225,000 kL which is reserved for public open space use in Murray and likely relates to the water required to irrigate the planned Regional Open Space near Ravenswood, as referred to in the *Murray groundwater allocation statement* (DWER, 2022).

The remaining allocatable volume is part of the "General component" and can be allocated on a first-in-first-served basis for any legitimate use. It should also be recognised that the Department of Water and Environmental Regulation has plans to review allocation limits in the Leederville and Cattamarra resources in the Coolup, Pinjarra and Waroona subareas soon (DWER, 2022), which may reduce the available volumes.

Similarly to the option above, applications will be required to construct a bore and take the water and the Department of Water and Environmental Regulation is likely to require a hydrological assessment to determine vertical connectivity between the aquifers. Applicants may also be required to develop an operating strategy and monitoring program[72]. This increases the complexity and cost of this solution.

8.4.3 Water Corporation IWSS

Industry's capacity to pay for water will vary greatly depending on the nature of the industry and the volumes of water required. It can be estimated based on the price it pays for water in other locations. Across Western Australia there is substantial variation in the cost of water for industry, depending on whether it is obtained through a self-supply source (such as groundwater) or is drawn from scheme water (RPS, 2020).

The Water Corporation currently charges businesses in the Perth metropolitan area $2.712 per kL (2022-23 price)[73]. Outside the metropolitan area, scheme water use charges are based on the cost of providing water to each town. The Water Corporation classifies towns into one of 15 "steps" – each with a different charge per kL of water used. Table 62 sets out the current pricing for each of the 15 steps and identifies some example towns in eth Peel Region. This shows the significant variability in the prices that are charged – from $3.048 per kL for Pinjarra

Table 62: Regional non-residential water use steps 2022-23

Steps	Regional locations	Dollars/kL
1		$2.797
2	Pinjarra	$3.048
3		$3.315
4		$3.612
5		$3.934
6		$4.282
7	Furnissdale, Madora Bay, Mandurah, Yunderup	$4.665
8		$5.079
9		$5.531
10	Harvey	$6.023
11	Hamel, Waroona	$6.557
12	North Dandalup	$7.141
13		$7.777
14		$8.470
15	Dwellingup, Preston Beach	$9.220

[72] https://water.wa.gov.au/licensing/water-licensing/the-water-licensing-process/assessing-an-application

[73] https://www.watercorporation.com.au/Help-and-advice/Business-customers/Business-bill-and-account/Bill-and-charges-for-business

Other considerations for accessing the Water Corporation's IWSS include the quality of water required and whether an opportunity exists to take water from one of the Water Corporation's dams prior to treatment (which would be provided at a reduced cost). The supply network including distance from the existing reticulated network and the need for a dedicated trunk main should also be investigated.

As the sources of the IWSS include groundwater, dams, desalination and wastewater, this source is considered to rate well for "climate independence" and poorly for "low environmental impact". This is due to the significant land footprint and energy cost of these supplies.

8.4.4 Harvey Water irrigation scheme

Harvey Water is a cooperative that delivers non-potable water largely from Wellington Dam to industrial users, hobby farmers and for community uses. Although Harvey Water largely provides water outside of the Peel region, it a notable water provider for the study area.

The cooperative model used by Harvey Water sees water sold as "shares", with the quantity of water per share differing each year depending on rainfall and weather conditions. Seasonal allocations vary markedly depending on rainfall. For example, while allocation for water year (October 1st to September 30th) 2020-21 was 38%, allocation for 2022-23 is 65%, which is markedly higher.[74]

The Cooperative model does not require complex approvals or agreements and is not considered to be a complex solution provided that the location of the demand is in proximity to the Harvey Water irrigation network.

Although the dam supply is not climate independent, the future Collie to Coast project is expected to expand current water availabilities and provide an additional volume available for use into the future. This opportunity is considered to enhance economic development within the region.

8.4.5 Treated wastewater

There are a number of options for the application of treated wastewater. This includes projects with a single irrigation customer, multiple industrial customers or a precinct scale third pipe scheme servicing a residential development. In most instances, the water will be sourced from the WWTP after treatment and the quality of the water will depend on the type of treatment process operated by the WWTP.

Wastewater can be treated to be suitable for different non-potable end uses. Generally, the higher the level of exposure for customers, the higher the level of treatment required. This is also associated with higher energy and capital costs.

One of the main barriers associated with treated wastewater reuse is the cost of infrastructure, including the distribution network and pumping stations from the WWTP to site. This may be especially difficult in regions with undulating topography, as multiple pumping stations will be required to pump treated wastewater to the demand location across multiple slopes.

The Water Services Association of Australia suggests that the levelised cost of the treated wastewater and reuse ranges from $0.40 to $15 per kilolitre. The cost of recycled water for non-

[74] Harvey Water, 2022.

drinking is relatively high cost, because while this option includes lower cost projects that use recycled water for agriculture and industrial processes, it also includes higher cost projects including where pipework is duplicated to provide recycled water to households. The median levelised cost was $4.35 per kilolitre (WSAA, 2020).

Other considerations include the often substantial technical investigations and management and monitoring plans required to support application and approval processes. Ongoing monitoring and reporting of performance against standards and criteria will also be required.

Benefits of using recycled wastewater include reduced demand on drinking water systems and the avoidance of wastewater discharges to the environment. It is also a relatively reliable, climate-independent water supply option, and provides increased water security at all times of the year. This means that where demand is seasonal, an additional disposal option may be required when irrigation/ use is not required. If the seasonal demand exceeds the summer flows from the wastewater treatment plant, winter storage may be required.

8.4.6 Seawater desalination

Seawater desalination provides a rainfall-independent source of water. The size of a desalination plant can range from a small unit the size of a shipping container to large plants such as the Southern Seawater Desalination Plant in Binningup (100GL/yr). It requires a location for a plant on the coast, together with the potential for connecting infrastructure to the location of the water demand.

Seawater desalination is an energy-intensive and expensive treatment process which produces a reliable and consistent quality and volume of water as well as waste brine sent to ocean outfalls. The environmental impact of seawater desalination plants can be reduced through utilisation of energy generated from renewable sources.

The design and approval process, as well as the operational requirements and responsibilities are likely to be complex and time consuming, although the technology is well understood and well operated by the Water Corporation throughout Western Australia. The Water Corporation has estimated the capital cost of a 100GL/yr plant at $1.4bn, and a 450ML/year plant at around $10m which produces water at $3.70/kL (GHD for the Water Corporation, unpublished).

8.4.7 Stormwater harvesting from agricultural drains

As highlighted in section 8.3.7, harvesting water from rural stormwater drains may provide sufficient volumes of water to be a viable source. Important considerations for feasibility include proximity to groundwater dependent environments, proximity to demand location (source need), seasonality of source need and requirement for storages and water quality.

A feasibility assessment of the use of direct subsoil drainage harvesting to provide a non-potable water supply scheme at the 1,000 ha Nambeelup Industrial Area was undertaken by RPS for the PIWI (RPS, 2020). This assessment found that the option (Option 2 in the report) was economically viable compared to the cost of scheme water based on 2020 engineering cost estimates, demand and other input assumptions. Economic feasibility would be impacted, however, if the demand was not constant year-round and/or the end use was for other than irrigation (RPS, 2020).

The above notwithstanding, in the Peel-Harvey estuary catchment, due to sensitivity of the environment to changes in the water balance, it is considered too high risk to take more water from unconfined aquifers or surface waters. This solution is also affected by climate change impacts and is likely to be complex in design and operation as it will require further assessment of ecological water requirements and is relatively untested in the Peel-Harvey.

8.4.8 Summary of other considerations

While the volume of the available source is the defining variable, consideration should also be given to a number of other aspects including:

- Climate independence and solution resilience
- Environmental impact (including landscape footprint, impact on environmental values, greenhouse gas emissions)
- Business continuity (sustainability/timing of demand/supply is right)
- Complexity of solution (right scale, design, and operation)
- Approvals and agreements (governance and partnerships)
- Financial metrics (capital cost, pricing /operational cost)
- Social and cultural values (impacts and benefits)
- Economic development (support of local industries)

An indication of the magnitude of each consideration is provided in Table 63. This indication is highly qualitative in nature and the degree of consideration will vary according to agency priorities.

Table 63: Future water source considerations

	Groundwater - superficial	Groundwater - Leederville	IWSS	Harvey Water	Treated wastewater	Seawater desalination	Stormwater harvesting
Climate independence	✓	✓	✓✓	✓✓	✓✓✓	✓✓✓	✓
Low environmental impact	✓✓	✓✓	✓	✓✓	✓✓✓	✓	✓✓
Business continuity	✓	✓	✓✓✓	✓	✓✓	✓✓✓	✓
Low complexity of solution	✓✓✓	✓✓	✓✓✓	✓✓	✓	✓✓	✓
Approvals and agreements	✓✓✓	✓✓	✓✓	✓✓	✓	✓✓	✓
Low financial metrics	✓✓✓	✓✓	✓	✓	✓	✓	✓✓
Social and cultural benefits	✓✓	✓✓	✓	✓	✓✓	✓	✓✓
Economic development	✓	✓	✓	✓✓	✓✓	✓✓	✓✓

8.5 Moving forwards

This study aimed to assess the level of currently accessible water within the Peel Region against likely future growth in community, agricultural and mining water needs to 2050, having consideration of climate change and the potential to impact the environmental values of the area. The assessment was undertaken at the local government level but has also been presented at a regional level to simplify understanding of quantities. It must be noted, however, that the regional-level information is an over-simplification of the problem, which has a strong spatial basis. Accordingly, the conclusions of this report should be used to underpin preliminary discussions only, with discussion of option viability supported by further technical studies.

Key findings of this study include:

- The environmental values of the Peel region are significant but the environment is already under stress. The level of environmental stress will only increase with the increasing impacts of climate change.
- There is some uncertainty associated with access to currently available groundwater resources within the superficial aquifer and further drawdown of this aquifer has the potential to reduce streamflows to the Estuary.
- The viability of surface water resources will decline into the future.
- Maximising use of recycled wastewater is an important opportunity that should be investigated as soon as possible.
- Alternative sources of water (including recycled water) are available but these are generally complex and likely to cost more than current options. These solutions are more likely to succeed through collaborative partnerships that are able to be flexible.

It is therefore recommended that consideration is given to the following next steps:

- Consult with the Bindjareb and Wilman Noongar people to listen and share knowledge of the water resource needs, environmental conditions and likely impacts in order to improve management recommendations and outcomes.
- Each local government to continue optimising their current water source entitlements through identifying current sources, future needs, future water transfers (from developers), optimum supply network configuration and prioritisation of assets for irrigation.
- Continue to collaborate to develop collective and integrated solutions that can adapt to changing environmental conditions and development priorities.
- Seek further guidance on the viability of local and regional options including volumes, reliability, infrastructure and operational costs and arrangements, while meeting the principles to protect the Peel Harvey.
- Undertake detailed local, technical studies to prove sources
- Develop a formal adaptive management framework to monitor environmental conditions, water supply sources and assess future demands which enables necessary responsive actions.

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APPENDIX 1: WATER NEEDS OF PEEL LOCAL GOVERNMENTS

Shire of Boddington

The Shire of Boddington covers around 1891 square kilometres and is located approximately 123 kilometres southeast of Perth and 92 kilometres east of Mandurah.

A1.1.1 Population

According to census data, the current population (in 2021) of Boddington is 1,646 residents, located in 661 households. The Shire of Boddington Local Planning Strategy (2018) notes that approximately 50 per cent of the Shire of Boddington's population live within the Boddington and Ranford townsites. A further 2000 people are housed at Newmont Mining's mining camp, located northwest of the Boddington townsite. Residents of the mining camp are not permanent residents of Boddington and generally drive in/out of Boddington on a weekly basis (Shire of Boddington, 2018).

A review of census data suggests that the population of Boddington is in decline (Table 64). This is consistent with projections in *Western Australia Tomorrow* (WAPC, 2015, which sets out the State Government's official population forecasts for the years 2014 to 2026, which suggests that household sizes in the Shire are likely to decrease - slightly - from approximately 2.51 to 2.61 people per dwelling, to approximately 2.43 to 2.5 people per dwelling in 2026.

Table 64: Shire of Boddington population

Suburb	Population 2011	Population 2016	Population 2021	Population growth rate 2011 - 2021	Household size 2021	# of households 2021	% increase over 5 years - actuals
Boddington	1,908	1,198	1,178	-38.3%	2.5	471	-19.1%
Crossman	n/a	203	153	-24.6%	2.6	59	-24.6%
Lower Hotham	n/a	26	13	-50.0%	1.8	7	-50.0%
Marradong	128	48	58	-54.7%	2.7	21	-27.3%
Quindanning	n/a	55	43	-21.8%	2.3	19	-21.8%
Ranford	184	180	201	9.2%	2.4	84	4.6%
Total	**2,220**	**1,710**	**1,646**	**-25.9%**		**661**	

Population growth

The Shire's Local Planning Strategy estimates that approximately 1,000 additional dwellings will need to be built within the Shire of Boddington in the period ending 2030. This is based on:

- (a) a projected population increase of 1816 residents;
- (b) an average household size of 2.43 people; and
- (c) a dwelling occupancy rate of 76.6 per cent.

Boddington isn't included in *Perth and Peel @ 3.5 million*, *however WA Tomorrow Population Repot No 11* (DPLH, 2019) suggests that the population of Boddington in 2031 will be 2,050.

After discussion with the Shire of Boddington, the ultimate population figure of 2,071 was agreed as being representative of both the ABS data and WA tomorrow. The growth rates used for the study are shown in

Table 65: Population growth rate for Shire of Boddington used in the study

Local Government	2021	2026	2031	2036	2041	2046	2051	Average Annual Growth Rate
Boddington	1,759	1,807	1,857	1,908	1,961	2,015	2,071	0.6%

A1.1.2 Land use

Residential development

The key residential areas in the Shire of Boddington are Boddington and Ranford (Figure 56).

The Shire's Local Planning Strategy estimates that approximately 1,000 additional dwellings will need to be built within the Shire of Boddington in the period ending 2030. This is based on:

- (a) a projected population increase of 1816 residents;
- (b) an average household size of 2.43 people; and
- (c) a dwelling occupancy rate of 76.6 per cent.

The development outlook indicates that the majority of growth is expected to occur in Boddington, and to a lesser extent, Ranford, as essential services such as scheme water and wastewater become readily available.

There are opportunities for urban consolidation (that is, increased residential density) in residential areas and development of 'greenfield' sites where land suitability and servicing requirements have been addressed.

Commercial development

Small areas are identified to expand the Boddington Town centre although the Local Planning Strategy does not comment on this. Scheme water currently used in the Shire's commercial centres is around 37,000 kL.

Public open space and recreation

The Boddington townsite is well provided for in terms of sport and recreation facilities and there is a range of recreation/formal public open space. This includes approximately 8ha of public open space that provides a recreational function for the urban community.

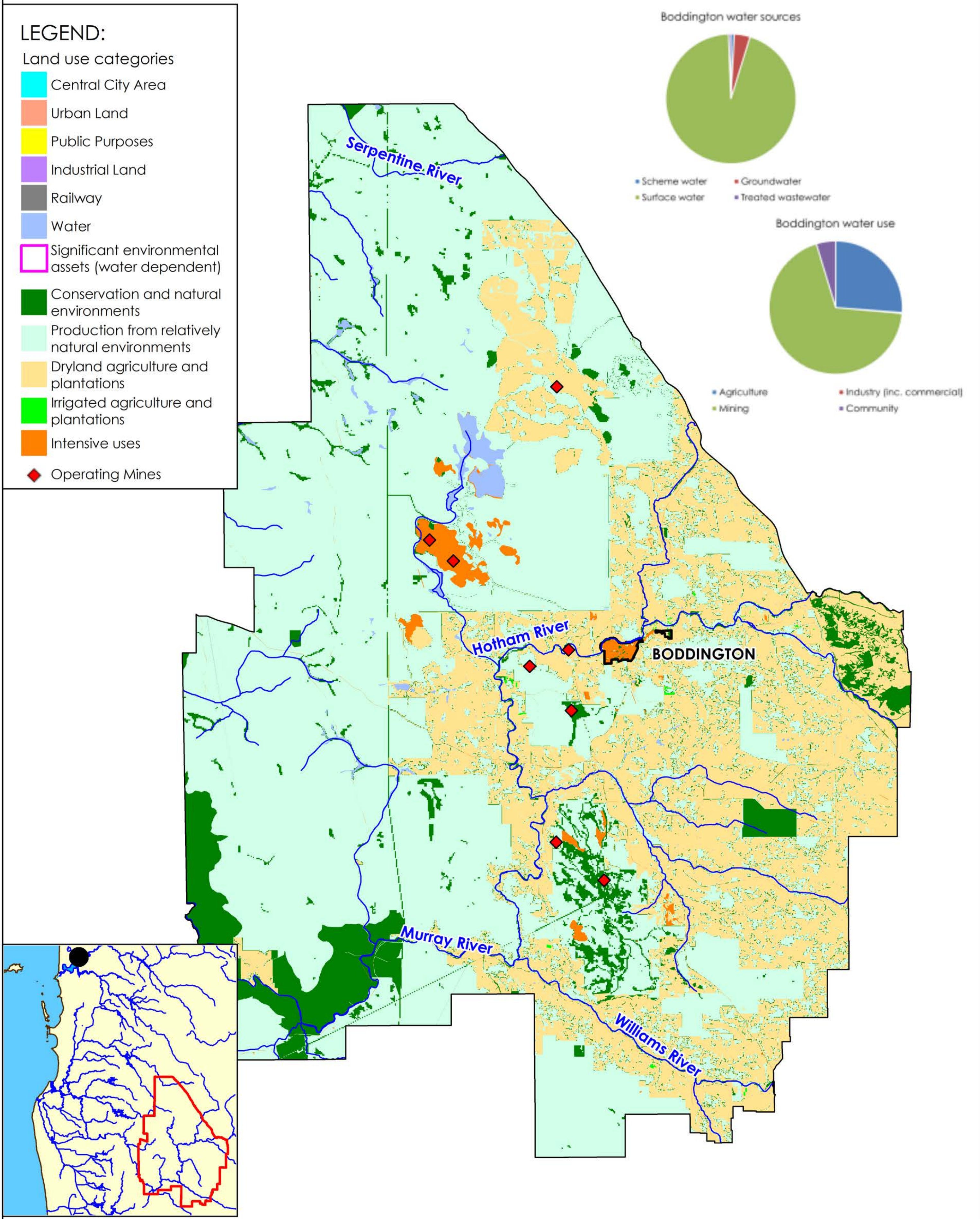
Almost 44 per cent of the Shire of Boddington is state forest.

Industrial development

Shire of Boddington contains a light industrial estate, an undeveloped industrial estate and some industrial development in rural areas.

Peel Alliance - Peel Regional Water Supply Initiative

Figure 56 - Shire of Boddington land use and water allocation



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land and water solutions

Rural living

Rural living development includes 'rural residential' and 'rural smallholding' zones, and comprises over 750ha of land in Boddington. This equates to just over half of all residential development. Generally, rural residential lots are between 1and 4 hectares in size and Rural smallholding lots are between four and 40 hectares in size.

Water supply

Harris Dam, which supplies potable water to the Boddington and Ranford townsites, is located north of the Collie townsite in the Shires of Collie and Harvey.

The catchments of the South Dandalup Dam (the largest dam supplying drinking water to the Perth metropolitan region) and the Serpentine Dam do extend into the Shire of Boddington

Wastewater

The Boddington wastewater treatment plant, located northwest of town, was upgraded in 2010 and is capable of supporting a population of (approximately) 2500 people. However, most of the development within the Shire of Boddington utilises some form of onsite wastewater disposal, such as an alternative treatment unit.

100 per cent of the wastewater treated at the Boddington Wastewater Treatment Plant is recycled and used at the Boddington gold mine (Table 66).

Table 66: Capacity of the Boddington WWTP

WWTP Name	Licenced Capacity (kL/day)	Production Volume (kL/day) (year)	Output Quality	Current Disposal Method	Future Projection (McFarlane D. D., 2019b)
Boddington	122 (2021)	124 (2020-21) 122 (2021-21)	Secondary	Newmont gold mine reuse, direct pipeline. Uses all of the output volume.	Will be based on population and land use changes, however output likely to be too small to be useful

A1.1.3 Environmental water resources

There are numerous waterways within the Shire of Boddington, including the Hotham, Bannister and Williams rivers, and many of these feed into the Murray River. Almost all of the Shire of Boddington is located within the Murray River's catchment, with smaller areas in the catchments of the South Dandalup and Serpentine rivers.

The groundwater management areas are not proclaimed and therefore no licence is required to take groundwater. Due to the fractured rock characteristics of the aquifers on the Darling Plateau, access to groundwater is generally limited and where it does occur, its quality varies considerably. Bore yields are generally low, reflecting the lack of good aquifers, and are generally only suitable for stock watering.

A1.1.4 Agriculture

Within the Shire of Boddington, approximately 96,374 hectares of land (or approximately 51 per cent of the Shire of Boddington) has been zoned for rural/rural-smallholdings use; however, the Shire does not contain any of the Region's strategic agricultural areas.

A1.1.5 Industry and resources

The Shire of Boddington's economy is focussed on mining, construction, manufacturing and agriculture, forestry and fishing. The Shire of Boddington contains significant resources of gold, copper and alumina. Newmont's Boddington mine is located approximately 16 kilometres from the Boddington townsite and South32's Worsley alumina mine. The Shire of Boddington also contains basic raw material deposits such as gravel and sand.

Shire of Boddington contains a light industrial estate, an undeveloped industrial estate and some industrial development in rural areas.

Current water needs

The current community water needs in the Shire of Boddington are under 400,000kL as summarised in Table 67 and shown in Figure 57. The large volume of unlicenced water for stock and domestic is representative of the nature of the aquifer and exemption from licencing and reporting.

Table 67: Total community water demands in the Shire of Boddington

Water demands	Volume (kL)	
Scheme water (IWSS)		
Residential scheme water use	134,373	
Non-residential scheme water	41,375	
Sub total		*175,748*
Surface water/ groundwater resources		
Allocated – Commercial	0	
Allocated – Firefighting and evaporation losses	0	
Allocated – Parks, gardens and recreation	0	
Unallocated – Parks, gardens and recreation	652,897	
Allocated – Stock and domestic	0	
Unallocated – Stock & domestic	212,880	
Unallocated – Residential rainwater tanks	31,387	
Sub total		*897,164*
Totals		**1,072,912**

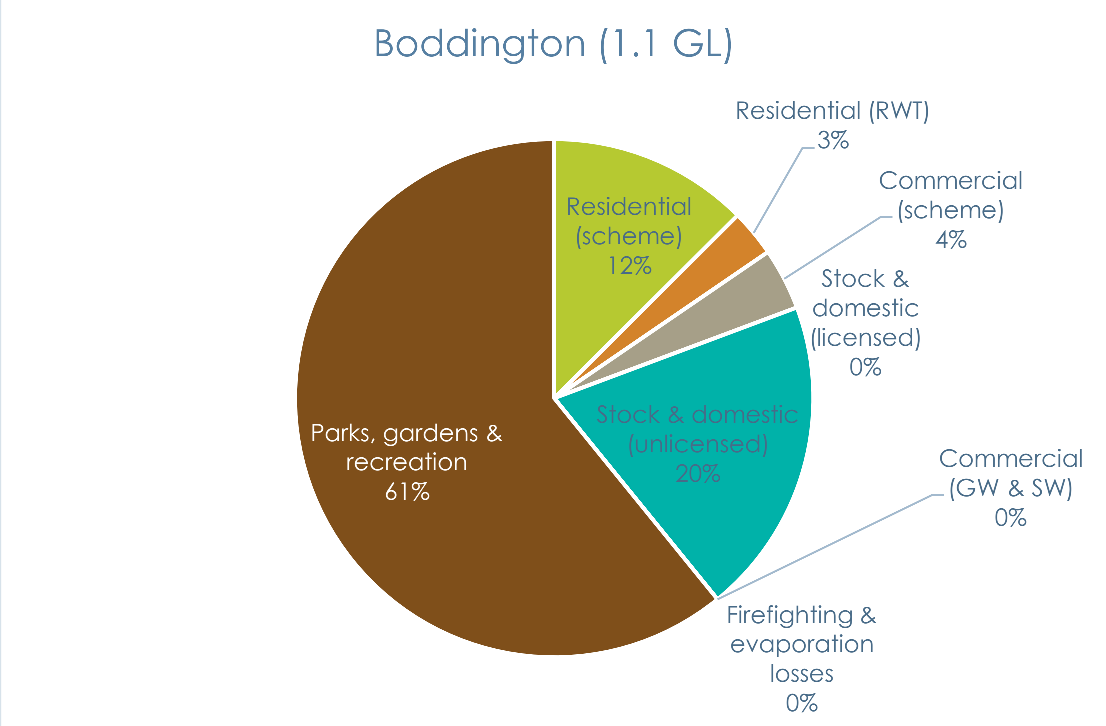


Figure 57: Total community water demands in the Shire of Boddington

Future water needs

These future water needs of the Boddington community focus on the growth of scheme water for residential needs and public open space. As noted previously, commercial growth is addressed in the Industry report and no increase in water for firefighting or rural residential activities was considered necessary (see section 2.3). The future needs are shown below.

Table 68: Growth in suburban scheme water use in Boddington to 2051

Suburb	Water Use per House (kL)	2021 Water Usage (kL)	2026 Water Usage	2031 Water Usage	2036 Water Usage	2041 Water Usage	2046 Water Usage	2051 Water Usage
Boddington	221.6	106,356	109,431	112,590	115,837	119,173	122,601	126,124
Crossman	180.8	2,351	2,664	2,986	3,317	3,657	4,007	4,366
Lower Hotham	-	-	-	-	-	-	-	-
Marradong	258.2	1,291	1,454	1,622	1,795	1,972	2,154	2,341
Quindanning	224.0	896	1,019	1,146	1,276	1,410	1,548	1,689
Ranford	273.0	23,479	24,152	24,844	25,555	26,286	27,037	27,808
TOTAL (KL)		**134,373**	**138,721**	**143,190**	**147,781**	**152,499**	**157,347**	**162,328**

Table 69: Rainwater tank use in Boddington to 2051

Rainwater Tank Use per House (kL)[1]	No. Unserviced Households (2021)[2]	2021 Water Usage[3]
253	119	31,387

Notes:

1. Rainwater tanks are assumed to supply all unserviced dwellings at rate of 106kL/person/yr.
2. Number of IWSS accounts is used to approximate the number of serviced dwellings.
3. Rainwater tank use is assumed to continue at current rates (i.e. all new development is connected to IWSS).

Table 70: Water needs of future public open space and schools in Boddington

	Existing POS area (Ha)	Existing POS irrigation demand (kL)	Future POS area (Ha)	Future POS Irrigation demand (kL)	Existing Schools area (Ha)	Existing Schools irrigation demand (kL)	Future Schools area (Ha)	Future Schools irrigation demand (kL)
Boddington	7,338	603,397	-	-	22	49,500	-	-

As previously stated in section1.5, four community growth scenarios (excluding commercial growth which has been separately assessed with other industry uses) were assessed by the study. The results of the analysis for Boddington are tabulated below.

Scenario 1: Business as usual growth including schools and public open space (incorporating a reduction in groundwater use of 10% by 2030)

Scenario 2: High growth scenario using the population projections in Perth and Peel @ 3.5 million (WAPC, 2018)

Scenario 3: Reduced water use by the community through waterwise gardens or medium density, assuming that after 2030, 50% new residents will reduce their water use to 70 kL/per person/year

Scenario 4: 30% of existing development incorporates a waterwise garden (water use at 70 kL/per person/year)

The results of the scenario assessment are shown below.

Table 71: Results of community scenario assessment for Boddington

Shire of Boddington	S1 - BaU	S2 - High growth	S3 - Waterwise (new developments)	S4 - Waterwise (existing)
2021	1.032	1.032	1.032	1.032
2026	1.035	1.094	1.034	1.025
2031	1.040	1.159	1.038	1.029
2036	1.044	1.223	1.042	1.034
2041	1.049	1.288	1.046	1.039
2046	1.054	1.352	1.050	1.043

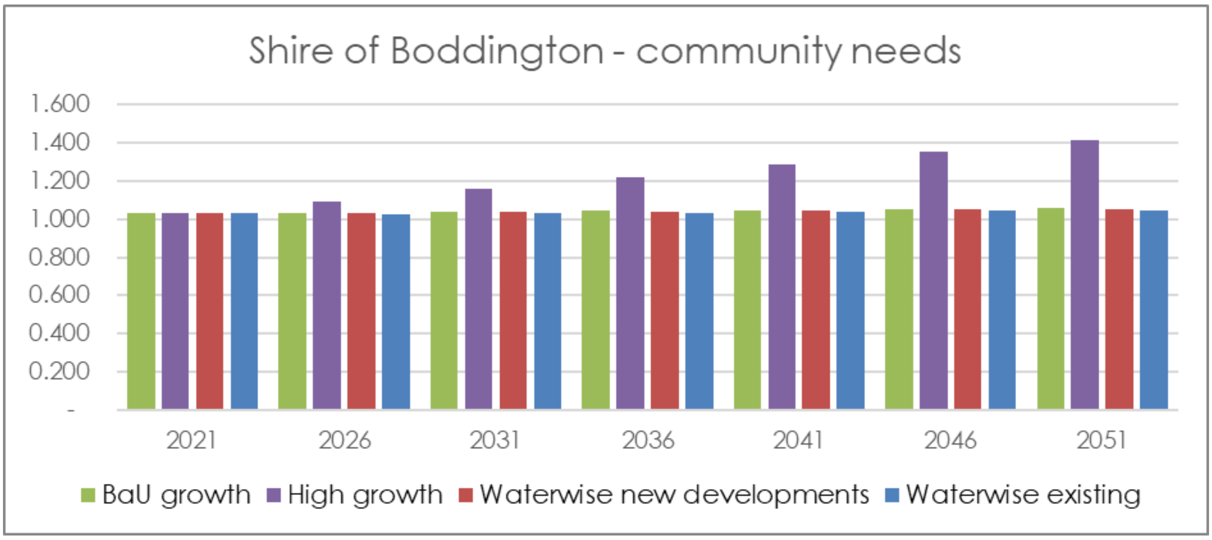


Figure 58: Results of community scenario assessment for Boddington

City of Mandurah

The City of Mandurah is located on the coast within the Peel Region, south of the City of Rockingham and north of the Shire of Waroona. It is approximately 173.5 square kilometres, and extends from Madora Bay and Lakelands in the north to Herron and Lake Clifton in the south. The City of Mandurah is approximately 50km long, yet only 8km wide at its widest point.

A1.1.6 Population

According to census data, the current population (in 2021) of the City of Mandurah is 89,861 residents, located in over 38,000 households (Table 72).

Table 72: City of Mandurah population (Source: ABS)

Suburb	Population 2011	Population 2016	Population 2021	Population growth rate 2011 - 2021	Household size 2021	# of households 2021	% increase over 5 years - actuals
Bouvard	821	826	910	10.8%	2.2	414	5.4%
Coodanup	3,526	3,932	4,366	23.8%	2.2	1,985	11.9%
Dawesville	4,299	5,824	7,143	66.2%	2.6	2,747	33.1%
Dudley Park	5,751	6,240	6,957	21.0%	2.2	3,162	10.5%
Erskine	4,100	4,665	5,429	32.4%	2.0	2,715	16.2%
Falcon	4,666	5,164	5,531	18.5%	2.2	2,514	9.3%
Greenfields	9,939	9,855	9,869	-0.7%	2.3	4,291	-0.4%
Halls Head	13,044	13,870	14,474	11.0%	2.5	5,790	5.5%
Lakelands	2,923	4,830	6,171	111.1%	2.8	2,204	55.6%

Suburb	Population 2011	Population 2016	Population 2021	Population growth rate 2011 - 2021	Household size 2021	# of households 2021	% increase over 5 years - actuals
Madora Bay	1,721	2,728	3,830	122.5%	2.9	1,321	61.3%
Mandurah	7,327	7,837	8,804	20.2%	1.9	4,634	10.1%
Meadow Springs	5,920	8,195	9,160	54.7%	2.7	3,393	27.4%
Parklands	539	581	603	11.9%	3.0	201	5.9%
San Remo	884	964	1,022	15.6%	2.6	393	7.8%
Silver Sands	1,241	1,258	1,450	16.8%	2.4	604	8.4%
Wannanup	2,769	3,621	4,142	49.6%	2.5	1,657	24.8%
Total	**69,470**	**80,390**	**89,861**	**29.4%**		**38,023**	

Population growth

The *City of Mandurah Local Planning Strategy* (2021) notes that "Mandurah's historical 5-year average growth rate has been above the Western Australian average. Mandurah's population is forecast to continue growing steadily, to reach approximately 120,000 sometime in the next 20 years. This means that Mandurah will become home to almost 50,000 new residents over the next two decades. This equates to approximately 20,000 additional dwellings being required to be built within Mandurah."

The WAPC's *South Metropolitan Peel Sub-regional Planning Framework* (WAPC, 2018) suggests that at 2050, the City of Mandurah will contain over 148,000 people, while *WA Tomorrow* predicts between 116,900 and 126,200 at 2031 (WAPC, 2019) and Forecast ID predicts a population of 119,887 by 2036 (https://forecast.id.com.au/mandurah).

The population forecast used by the study has been agreed with the City of Mandurah as an annual growth rate of 1.8%, and is based on the Forecast ID projections with an annual growth rate equal to the average growth rate since 2016 after 2036. The forecast population figures used in the study are shown in Table 73

Table 73: Population growth rate for City of Mandurah used in the study

Local Government	2021	2026	2031	2036	2041	2046	2051	Average Annual Growth Rate
Mandurah	94,917	105,160	113,061	119,877	132,036	145,994	162,079	1.8%

A1.1.7 Land use

Residential development

The majority of the City of Mandurah is developed for residential uses (Figure 59). This includes the areas of Coodanup, Dawesville, Dudley Park, Erskine, Falcon, Greenfields, Halls Head, Lakelands, Madora Bay, Mandurah, Meadow Springs, San Remo, Silver Sands and Wannanup.

Land zoned for future urban includes Madora Bay North and East; Lakelands North (Ocean Hill), East and North East; Florida; Bailey Boulevard; Panorama; and Dawesville South.

All residential areas are connected to the Water Corporation's Integrated Water Supply Scheme and reticulated sewerage network.

Commercial development

The City of Mandurah has a number of strategic, district and neighbourhood centres that provide commercial functions for the community. These are located within the Mandurah City Centre/Ocean Marina, Mandurah Forum, Mandurah TOD, Mandurah Terrace, Inner Mandurah, Lakelands Town Centre, Halls Head Town Centre, Falcon Town Centre, Meadow Springs, Greenfields Shopping Centre, Erskine and Dawesville (Florida) (proposed).

The City also contains a number of local centres and mixed use/business areas as discussed below.

Tourism precincts

Tourism within the City of Mandurah is strongly supported by the region's water resources. Tourism precincts identified within the Mandurah Local Tourism Strategy include:

- Madora Bay North
- Mandurah Terrace, Mandurah Ocean Marina, Mandurah City Centre Precincts
- Mandurah Quay Precinct
- Falcon Village Precinct

While the use of water within tourism precincts is accounted for in commercial users, the critical water resource management aspect is the protection and maintenance of the health of water systems that support tourism. This include the Peel-Harvey Estuary and coastal areas.

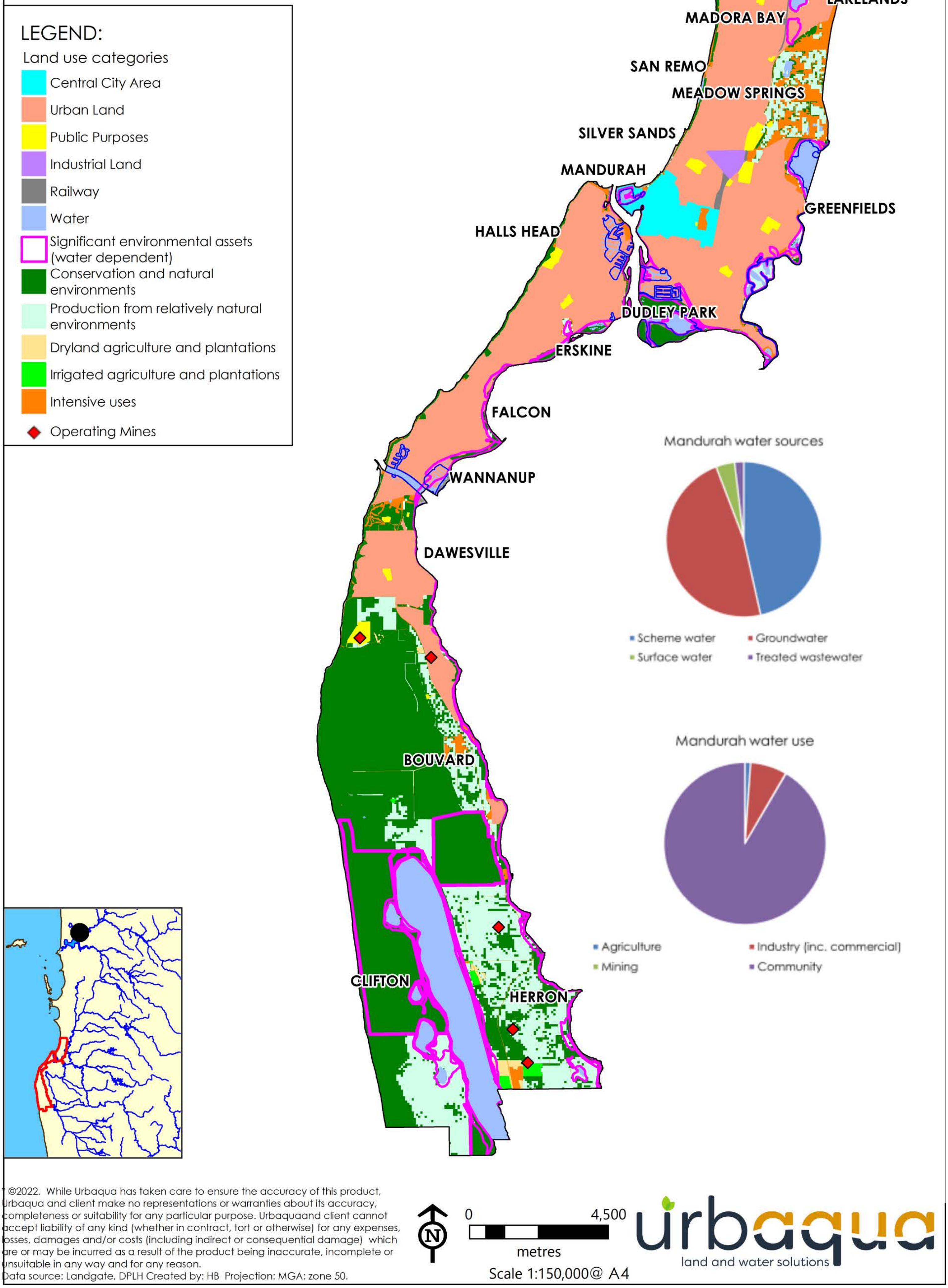
Mixed business/Industrial development

Light, service and general industries, showroom and bulky goods developments are accommodated within the Industry and Service Commercial zones and as identified within relevant precinct plans with precincts including Pinjarra Road, Gordon Road, Mandurah Ocean Marina, Lakelands South (proposed), Mandurah East (under development) and Galbraith Loop.

Other centres

The Peel Health Campus and Peel Education and Training Campus are reserved 'Public Purposes' in the Peel Region Scheme. These areas provide an important function for the community, as well as providing a green link and access to natural areas.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 59 - City of Mandurah land use and water allocations



Data source: Landgate, DPLH Created by: HB Projection: MGA: zone 50.

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Rural living

The remaining Rural areas of the City of Mandurah are highly constrained for future development as many contain environmental values that warrant protection, are affected by flood risk or contain areas of basic raw materials. This includes areas south of Dawesville as well as the location of Parklands which is east of Meadow Springs. Lot sizes in these areas are restricted to no greater than 5ha (Rural Residential) and 10ha (Rural Smallholdings) and are often associated with limited access to scheme water or reticulated sewerage. Water supplies in these areas (with no connection to Scheme) will be via rainwater tanks or groundwater bores, which are usually unlicenced.

Public open space

The City of Mandurah currently contains 5,400 ha of public open space. This includes 4,965 ha reserved under the Peel Region Scheme and 435 ha reserved under the Local Planning Scheme. The majority of open space in Mandurah (97%) has a nature function (Table 74).

Table 74: Public open space by function in the City of Mandurah

POS function	Area (Ha)
Nature	5234
Recreation	70
Sport	95
Grand Total	**5,400**

The City's local planning strategy notes that the distribution of public open space across the municipality is not even across the urban landscape, although the residential population have the closest average distance to travel to a park in the Peel region of 286m (Table 75).

Table 75: Public open space benchmarks in the City of Mandurah

Local government	Mandurah (C)
Total Area: POS (ha)	6,120
Area (ha) POS (excl ROS) per 1,000 population (Benchmark = 3.36)	6.29
Area POS (excl ROS) as % urban area (Benchmark = 10 per cent)	9.05
Area Sport + Rec POS as % urban area (Benchmark = 8 per cent)	7.80
Average distance (m) to closest POS (excl ROS)	286

The current water needs of public open space and schools is shown below.

Existing POS area (Ha)	6,118
Existing POS irrigation demand (kL)	4,343,521
Existing Schools area (Ha)	150
Existing Schools irrigation demand (kL)	353,300

Wastewater

There are three wastewater treatment plants within the City of Mandurah (Table 76). The City has been working with the Water Corporation and the Department of Water and Environmental Regulation to develop successful wastewater reuse projects to irrigate public open space.

Table 76: WWTPs in the City of Mandurah

WWTP Name	Mandurah 1 (Gordon Rd)	Mandurah 2 (Halls Head)	Mandurah 3 (Caddadup)
Licenced Capacity (kL/day)	12,000	5800	3000
Production Volume (kL/day) (year)	10,439 (2021-22)	3497.33 (2021-22)	3131 (2021-22), 1326 (average flow 2012/2013
Output Quality	Secondary	Tertiary	Secondary
Current Disposal Method	Infiltrated via onsite ponds as part of MAR scheme to the superficial aquifer. WW abstracted for irrigation of CoM POS (120 ML in 2018/2019) from down-gradient bores via a 10-year agreement.	Onsite ponds for infiltration to the superficial aquifer Abstraction of this and subsequent irrigation of CoM POS (Seascapes development).	Onsite ponds infiltrate to the superficial aquifer Nearby golf course abstraction likely utilises most of this water.
Future Projection (McFarlane D. D., 2019b)	Inflows expected to increase from 4.0 GL/yr to 5.5 GL/yr by 2030, and almost 12 GL/yr by 2060. As all output is currently reused by CoM, this could mean only an additional 1.5 GL/year is available for reuse to 2030 (38% increase on current output), or 8 GL to 2060. Current MAR and reuse may mean this is expected for any future supplies.	Inflows expected to stay at 1 GL/year, with little to no change in output volume.	Inflows expected to increase from approx. 0.8 GL/year to 1 GL/year. This equates to a 25% increase, or 0.39 GL/year.

The City worked with Ocean Road Primary School and St Damien's Catholic Primary School to reclaim treated waste water from the Water Corporation's Caddadup Waste Water Treatment Plant via a Managed Aquifer Recharge bore field and associated water storage and irrigation infrastructure. The bore field extracts infiltrated treated wastewater from the recharged Superficial aquifer and conveys it to site through the commissioning of a 1.3 kilometre recycled water mainline. Water for irrigation is acknowledged as low risk and the project is subject to continuous water quality monitoring and irrigation of the active ovals at night time. This is the fourth water re-use scheme within the City of Mandurah.

A1.1.8 Environmental features

Key water dependent environmental features in the City of Mandurah are the Peel-Yalgorup System (Peel Inlet and Harvey Estuary), Lower Serpentine River, Murray River, Lake Clifton, Lake Goergrup, the Creery Wetlands and other wetlands at Hexam Close and Samphire Cove. The

The water requirements of these important environmental features are discussed in the body of the report.

A1.1.9 Agriculture

While there are no strategic agricultural areas located within the City of Mandurah, 1,660ha of the City of zoned for Rural activities and 2,043 ha of peri-urban land. Accordingly, there is limited agricultural water demand. Peri-urban demands include 309,544 kL of groundwater and surface water allocated for stock and domestic purposes and an estimated 5,132, 600 kL of unallocated groundwater.

A1.1.10 Industry and resources

The City of Mandurah contains a number of areas zoned for commercial development that provide a community function and are not considered to be heavy industry. These include:

- Mandurah City Centre
- Mandurah Forum
- Mandurah Terrace
- Halls Head town centre
- Lakelands town centre
- Falcon town centre

The Water Corporation data suggests that 1,041,822 kL of scheme water is provided for non-residential purposes. This is assumed to include the water provided for the above centres.

There are are number of existing extractive industries located within Mandurah which extract basic raw materials, sand and limestone. There are no mining licenses/tenements in the City.

Current water needs

The current water demands of the City of Mandurah are approximately 20.6 GL, of which 50% is from the IWSS and 50% is from surface and groundwater sources, as shown in Table 77 and Figure 60. This includes water recovered from the three wastewater treatment plants, which is accounted for via licenced abstraction.

Table 77: Total community water demands in the City of Mandurah

Water demands	Volume (kL)	
Scheme water (IWSS)		
Residential scheme water use	9,203,343	
Non-residential scheme water	921,795	
Sub total		*10,125,138*

Surface water/ groundwater resources		
Allocated – Commercial	500,386	
Allocated - Firefighting and evaporation losses	0	
Allocated - Parks, gardens and recreation	4,343,521	
Allocated - Stock and domestic	309,544	
Unallocated – Stock & domestic	5,132,600	
Unallocated – Residential rainwater tanks	766,207	
	Sub total	*11,052,258*
	Totals	**21,177,396**

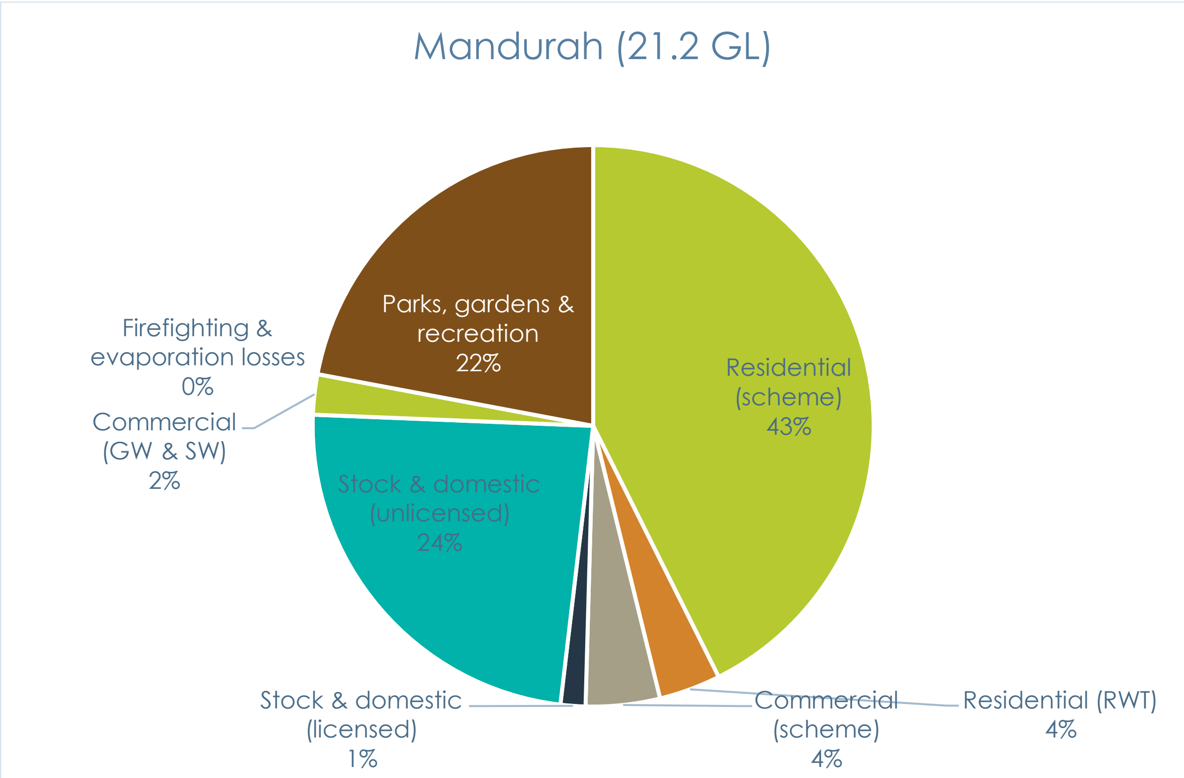


Figure 60: Total community water demands in the City of Mandurah

Future water needs

These future water needs of the Mandurah community focus on the growth of scheme water for residential needs and public open space. As noted previously, commercial growth is addressed in the Industry section and no increase in water for firefighting or rural residential activities was considered necessary (see section 2.3). The future needs are shown below.

Table 78: Growth in suburban scheme water use in Mandurah to 2051

Suburb	Water Use per House (kL)	2021 Water Usage (kL)	2026 Water Usage	2031 Water Usage	2036 Water Usage	2041 Water Usage	2046 Water Usage	2051 Water Usage
Coodanup	220.2	440,619	524,999	608,530	645,507	722,875	808,345	902,767
Dawesville - Bouvard - Herron - Clifton	230.2	922,582	1,111,672	1,269,841	1,369,725	1,611,519	1,891,860	2,216,892
Dudley Park	220.5	708,983	736,547	770,157	809,812	857,966	908,928	962,862
Erskine	207.4	553,334	647,365	678,244	688,538	749,065	813,769	882,936
Falcon	282.2	734,292	754,320	770,116	789,834	816,627	844,530	873,589
Greenfields - Parklands	183.5	894,917	977,755	1,053,758	1,127,109	1,208,497	1,294,698	1,385,998
Halls Head	288.5	1,747,588	1,811,789	1,890,104	1,967,623	2,056,073	2,148,547	2,245,228
Lakelands	209.4	564,621	814,667	893,751	874,004	1,074,743	1,315,402	1,603,917
Madora Bay	285.4	347,336	417,541	519,281	669,283	822,448	1,015,198	1,257,763
Mandurah	158.2	767,690	896,417	1,061,589	1,253,054	1,451,004	1,676,515	1,933,426
Meadow Springs	225.7	776,020	800,838	785,947	773,304	792,475	812,070	832,098
Silver Sands - San Remo	259.6	242,474	245,183	250,137	257,723	262,572	267,540	272,632
Wannanup	280.6	502,887	518,589	512,860	509,783	533,986	559,403	586,096
TOTAL (KL)		**9,203,343**	**10,257,682**	**11,064,316**	**11,735,299**	**12,959,849**	**14,356,805**	**15,956,204**

Table 79: Rainwater tank use in Mandurah to 2051

Rainwater Tank Use per House (kL)[1]	No. Unserviced Households (2021)[2]	2021 Water Usage[3]
254	2,997	766,207

Notes:

1. Rainwater tanks are assumed to supply all unserviced dwellings at rate of 106kL/person/yr.
2. Number of IWSS accounts is used to approximate the number of serviced dwellings.
3. Rainwater tank use is assumed to continue at current rates (i.e. all new development is connected to IWSS).

Table 80: Water needs of future public open space and schools in Mandurah

	Existing POS area (Ha)	Existing POS irrigation demand (kL)	Future POS area (Ha)	Future POS Irrigation demand (kL)	Existing Schools area (Ha)	Existing Schools irrigation demand (kL)	Future Schools area (Ha)	Future Schools irrigation demand (kL)
Mandurah	6,118	4,343,521	568	-	150	353,300	74	149,850

As previously stated in section 1.4, four community growth scenarios (excluding commercial growth which has been separately assessed with other industry uses) were assessed by the study. The results of the analysis for Mandurah are tabulated below.

Scenario 1: Business as usual growth including schools and public open space (incorporating a reduction in groundwater use of 10% by 2030)

Scenario 2: High growth scenario using the population projections in Perth and Peel @ 3.5 million (WAPC, 2018)

Scenario 3: Reduced water use by the community through waterwise gardens or medium density, assuming that after 2030, 50% new residents will reduce their water use to 70 kL/per person/year

Scenario 4: 30% of existing development incorporates a waterwise garden (water use at 70 kL/per person/year)

The results of the scenario assessment are shown below.

Table 81: Results of community scenario assessment for Mandurah

City of Mandurah	C1 - BaU	C2 - High growth	C3 - Waterwise (new developments)	C4 - Waterwise (existing)
2021	19.755	19.755	19.755	19.755
2026	20.835	21.246	20.666	20.239
2031	21.666	22.713	21.371	21.071
2036	22.362	24.180	21.970	21.767
2041	23.612	25.646	23.033	23.016
2046	25.034	27.113	24.244	24.438
2051	26.658	28.580	25.632	26.063

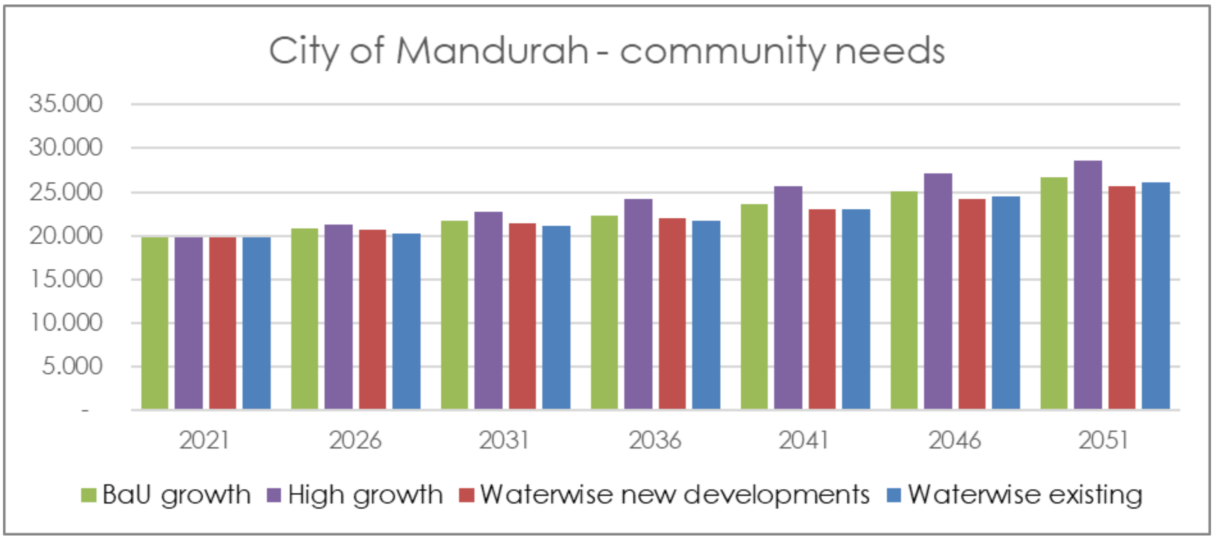


Figure 61: Results of community scenario assessment for Mandurah

Shire of Murray

The Shire of Murray is 1,821km2 in area and situated approximately 20kms east of Mandurah. It is bounded by the Shire of Serpentine Jarrahdale and City of Rockingham to the north, Shire of Boddington to the east, Shire of Waroona to the south and City of Mandurah to the west. The Shire contains a large proportion of Swan Coastal Plain and extends onto the Darling Scarp, including around 77,000 hectares of State forest.

A1.1.11 Population

According to census data, the current population (in 2021) of the Shire of Murray is 18,248 residents, located in over 7,400 households (Table 82).

Table 82: Shire of Murray population (Source: ABS)

Suburb	Population 2011	Population 2016	Population 2021	Population growth rate 2011 - 2021	Household size 2021	# of households 2021	% increase over 5 years - actuals
BARRAGUP	806	928	940	16.6%	3	313	8.3%
Banksiadale	0	0	0	0.0%		0	0.0%
Birchmont	0	73	86	17.8%	2.6	33	8.9%
Blythewood	0	64	85	32.8%	2.1	40	16.4%
COOLUP	362	386	420	16.0%	3.1	135	8.0%
DWELLINGUP	700	557	524	-25.1%	2.4	218	-12.6%
Etmilyn	0	0	0	0.0%		0	0.0%
FAIRBRIDGE	n/a	48	55	14.6%	3	18	14.6%
FURNISSDALE	1,027	1,029	1,061	3.3%	2	531	1.7%
Holyoake	0	19	22	15.8%	1.6	14	7.9%

Suburb	Population 2011	Population 2016	Population 2021	Population growth rate 2011 - 2021	Household size 2021	# of households 2021	% increase over 5 years - actuals
Inglehope	n/a	38	18	-52.6%	2.8	6	-52.6%
Keralup	0	0	0	0.0%		0	0.0%
Keysbrook	502	626	265	-47.2%	2.4	110	-23.6%
Marrinup	0	0	0	0.0%			0.0%
Meelon	224	201	174	-22.3%	2.4	73	-11.2%
Myara	0	0	0	0.0%		0	0.0%
NAMBEELUP	512	318	361	-29.5%	2.9	124	-14.7%
Nirimba	n/a	71	80	12.7%	2.7	30	12.7%
NORTH DANDALUP	572	712	863	50.9%	3	288	25.4%
NORTH YUNDERUP	849	849	840	-1.1%	2.2	382	-0.5%
PINJARRA	4,254	4,910	4,914	15.5%	2.4	2,048	7.8%
RAVENSWOOD	1,659	2,176	2,483	49.7%	2.4	1,035	24.8%
Solus	0	0	0	0.0%		0	0.0%
SOUTH YUNDERUP	2235	3114	3860	72.7%	2.4	1,608	36.4%
STAKE HILL	494	485	469	-5.1%	3.1	151	-2.5%
Teesdale	n/a	103	89	-13.6%	2.5	36	-13.6%
West Coolup	n/a	155	182	17.4%	2.6	70	17.4%
WEST PINJARRA	397	410	448	12.8%	3.2	140	6.4%
Whittaker	n/a	10	9	-10.0%	3	3	-10.0%
Total	**14,593**	**17,282**	**18,248**	**25.0%**			

Population growth

The Shire's website estimates that by 2051, the Shire's population will have grown to 70,913. This is significantly lower than the projected population at 2050 contained within Perth and Peel @ 3.5 million of 164,250 (WAPC, 2018). By comparison the WA Tomorrow estimates (WAPC, 2019) suggest that there will be between 19 630 and 23 650 people in the Shire by 2031.

The future population projections used by the study have been agreed with the Shire in line with that proposed by Forecast ID (https://forecast.id.com.au/murray-shire). These are shown in Table 83.

Table 83: Population growth rate used in the study

Local Government	2021	2026	2031	2036	2041	2046	2051	Average Annual Growth Rate
Murray	18,336	20,042	23,734	32,352	44,639	57,801	70,913	3.4%

A1.1.12 Land use

The key land uses in the Shire of Murray are agriculture, industry, mining, residential and rural residential (Figure 62).

Residential

The majority of the population of the Shire resides in the urban centres of Pinjarra, Ravenswood, Yunderup, Barragup and Furnissdale as well as in the smaller towns of Dwellingup and North Dandalup (Figure 62).

Future urban development is proposed to occur in proximity to existing urban areas as greenfield urban development to ensure the orderly provision of services. Only a small proportion of infill is proposed.

The area identified in *South Metropolitan Peel Sub-regional Planning Framework* (WAPC, 2018) for future urban development (urban deferred, urban expansion and urban investigation) is approximately 2,335ha.

Table 84: Future development areas in Murray

Future development		Murray (S)
Future industrial		4,113
Industrial Expansion	2,901	
Industrial Investigation	1,212	
Future urban		289
Urban deferred	126	
Urban Expansion	133	
Urban Investigation	31	
ROS		56
Regional open space	56	
Planning Investigation		2,046
Future urban	2,046	
Grand Total		6,504

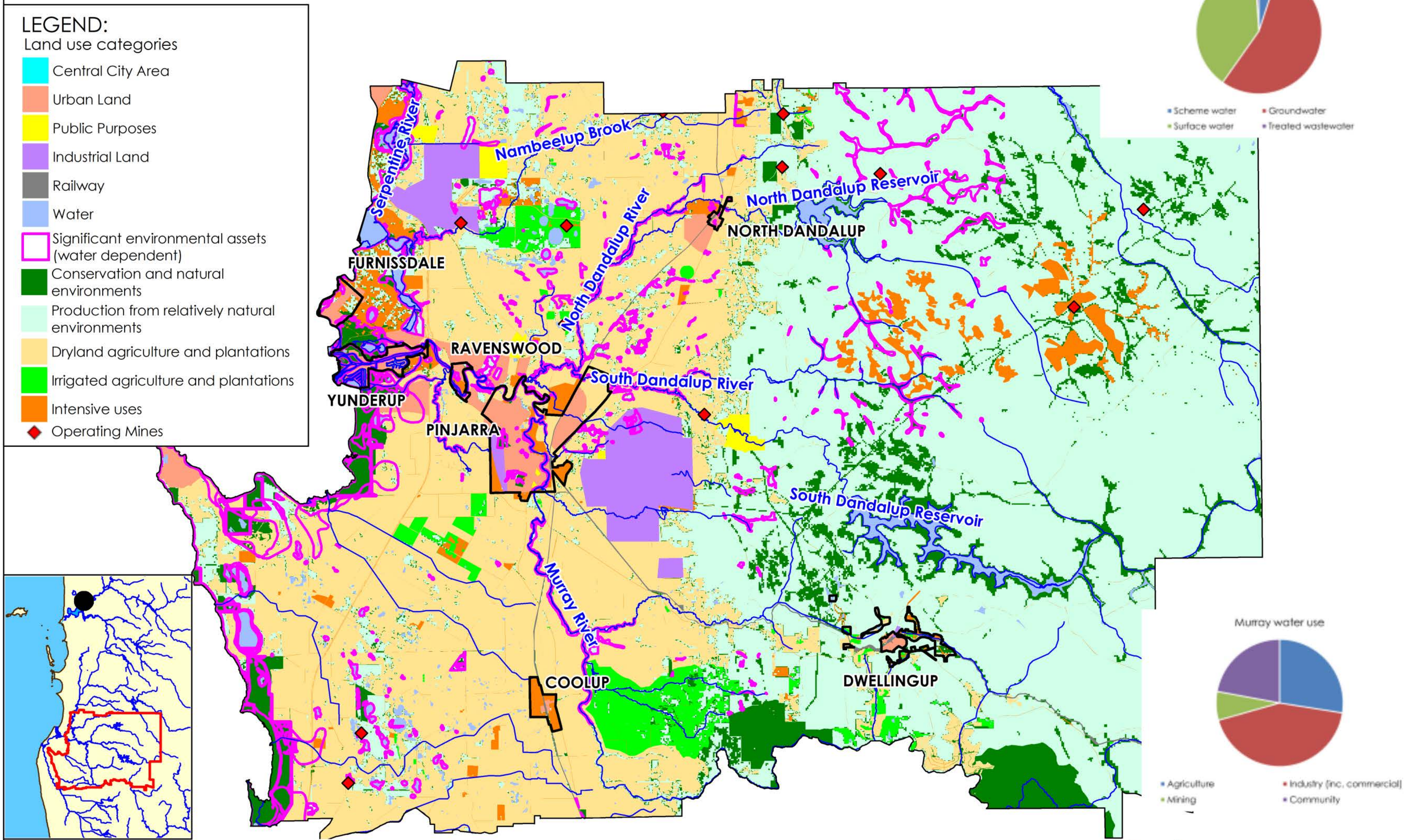
Public open space

The Shire of Murray contains over 6,038 ha of public open space. This includes 5,871 ha of regional open space and 167 ha of open space reserved in the local planning scheme. Over 97% of the Shire's open space is reserved for nature (Table 85).

Table 85: Public open space by function in the Shire of Murray

POS function	Gross Area (Ha)
Nature	5878
Recreation	123
Sport	37
Grand Total	**6038**

Peel Alliance - Peel Regional Water Supply Initiative
Figure 62 - Shire of Murray land use and water allocation



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Data source: Landgate, DPLH Created by: HB Projection: MGA: zone 50.

N

0 10,000
metres
Scale 1:250,000 @ A4

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The current water needs of public open space and schools is shown below.

Existing POS area (Ha)	8,677
Existing POS irrigation demand (kL)	1,771,309
Existing Schools area (Ha)	50
Existing Schools irrigation demand (kL)	61,450

An analysis of open space benchmarks for the Shire of Murray suggests that there is insufficient sport and recreation space (Table 86). As this form and function of public open space is generally associated with an irrigation demand, the consideration of available water sources for irrigation of additional grassed areas is a key consideration.

Table 86: Public open space benchmarks in the Shire of Murray

Local government	Murray (S)
Total Area: POS (ha)	8,678
Area (ha) POS (excl ROS) per 1,000 population (Benchmark = 3.36)	128.1
Area POS (excl ROS) as % urban area (Benchmark = 10 per cent)	85.85
Area Sport + Rec POS as % urban area (Benchmark = 8 per cent)	3.98
Average distance (m) to closest POS (excl ROS)	723

Peri-urban

Large areas (over 5,000ha) of the Shire are designated for peri-urban living (Special Residential, Special Rural, Farmlet and Hills Landscape Protection zones), however, the majority of these areas are connected to the IWSS but not the reticulated sewerage network. This includes the localities of Furnissdale, Barragup and Lansdown. Coolup is not connected to the IWSS or sewerage and so will require rainwater tanks and/or shallow groundwater bores for water supply.

Commercial development

The key commercial centres are in Pinjarra, Furnissdale, North Dandalup and Dwellingup with smaller commercial areas, often just one or two lots, in South Yunderup, Ravenswood, Coolup and Carcoola. Water supplied to businesses in these areas is usually designated as non-residential use.

Industrial development

There are a number of areas in the Shire of Murray that are zoned for Industrial Use. This includes an area within the Pinjarra and Dwellingup town centres, the Pinjarra Industrial Area and Peel Business Park as well as the heavy industry sites associated with the Huntly mine (Alcoa), Keysbrook mine (Doral) and Pinjarra refinery (Alcoa).

Scheme water use associated with activities within the Pinjarra and Dwellingup town centres, Peel Business Park and Pinjarra Industrial Area is likely to be recorded as a non-residential use, while scheme water used by Alcoa and Doral will be recorded as Industrial use. Additional water is also sourced for these activities from surface and groundwater resources.

Wastewater

The Shire of Murray currently contains one wastewater treatment plant in Pinjarra, however, the Water Corporation is undertaking planning for a future plant in Nambeelup. The Pinjarra wastewater treatment plant currently supplies treated wastewater to the Alcoa Pinjarra Refinery.

Table 87: WWTPs in the Shire of Murray

WWTP Name	Licenced Capacity (kL/day)	Production Volume (kL/day) (year)	Output Quality	Current Disposal Method	Future Projection (McFarlane D. D., 2019b)
Pinjarra	1,840	1,088 (2020-21)	Secondary	All treated WW reused at Alcoa Pinjarra Refinery	Inflows expected to increase from 0.3 GL/yr to 1.6 GL/yr by 2060. Slight increase to 2030 (~0.2 GL/yr),

A1.1.13 Environmental features

The Shire of Murray contains a number of water resources with significant environmental values. This includes the Ramsar listed Peel Harvey Estuary, Lake McLarty and Lake Mealup, Goegrup Lakes, Stakehill Swamp, Serpentine River, North and South Dandalup rivers, Murray River, public drinking water source areas and a number of nature reserves. These environmental values and the water they require is discussed in more detail in the body of the report.

A1.1.14 Agriculture

The strategic agricultural areas of Nambeelup and Coolup are contained within the Shire of Murray. DPIRD land use data suggests that approximately 6523 ha is developed for irrigated agriculture.

An analysis of water allocation data reveals that the current water demands for agricultural activities is around 6.5 GL which includes 5,611,805 kL of groundwater, 984,050kL of surface water, 8,449 kL of scheme water.

Additional agricultural activities are being explored within the Peel Food Zone which is located within the Shire of Serpentine Jarrahdale as well as the Shire of Murray. Water for future agricultural needs is discussed further in the body of the Report.

A1.1.15 Industry and resources

As noted above, the Shire of Murray contains a number of large industrial areas including operational mine sites and refineries. While these are discussed in more detail in the Industrial report, the other industrial areas within the Shire are considered to provide a community function and are considered here. This includes the small industrial areas within the Pinjarra and Dwellingup town centres, the Pinjarra Industrial Area and Peel Business Park. These areas currently occupy over 1500ha.

Data from the Water Corporation suggests that 264,523 kL of scheme water is being used within the Shire of Murray for industrial purposes at the moment.

Current water needs

Currently, nearly 10GL of water is being used within the Shire of Murray for community purposes (Table 88). This includes nearly 8GL of surface and groundwater and nearly 2 GL of scheme water (Figure 63). The available treated wastewater is currently being used for industrial activities.

Table 88: Total community water demands in the Shire of Murray

Water demands		Volume (kL)	
Scheme water (IWSS)			
Residential scheme water use		1,769,677	
Non-residential scheme water		262,873	
	Sub total		*2,032,550*
Surface water/ groundwater resources			
Allocated – Commercial		1,032,794	
Allocated - Firefighting and evaporation losses		44,242	
Allocated - Parks, gardens and recreation		1,789,309	
Allocated - Stock and domestic		969,723	
Unallocated – Stock & domestic		4,060,000	
Unallocated – Rainwater tanks		362,937	
	Sub total		*8,259,005*
	Totals		**10,291,555**

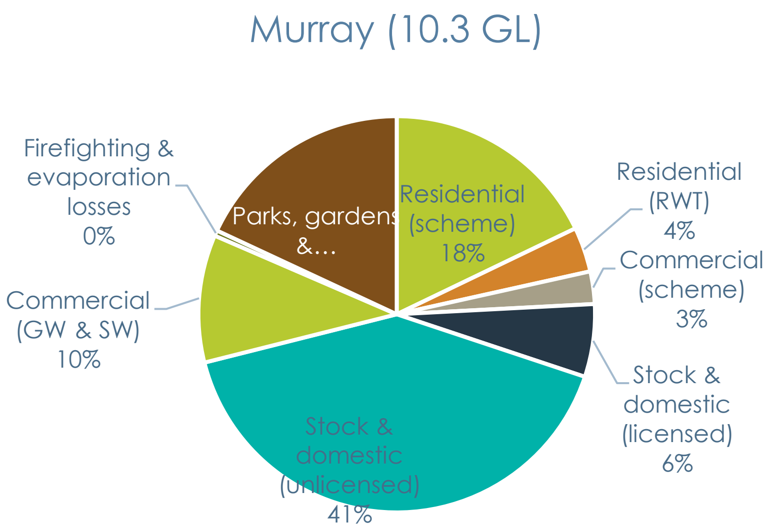


Figure 63: Total community water demands in the Shire of Murray

Future water needs

These future water needs of the Murray community focus on the growth of scheme water for residential needs and public open space. As noted previously, commercial growth is addressed in the Industry report and no increase in water for firefighting or rural residential activities was considered necessary (see section 2.3). The future needs are shown below.

Table 89: Growth in suburban scheme water use in Murray to 2051

Suburb	Water Use per House (kL)	2021 Water Usage (kL)	2026 Water Usage	2031 Water Usage	2036 Water Usage	2041 Water Usage	2046 Water Usage	2051 Water Usage
Furnissdale	335.0	113,237	127,308	133,673	138,699	143,724	148,582	153,439
North Dandalup - Rural North	229.1	62,547	75,072	92,331	109,133	125,705	142,048	158,468
North Yunderup	275.2	130,982	130,607	147,367	163,502	190,769	211,658	232,671
Pinjarra	293.3	549,671	618,600	761,346	926,091	1,089,614	1,259,736	1,432,180
Point Grey	-	-	-	-	-	-	-	-
Ravenswood	327.8	276,630	333,715	387,795	439,281	490,494	541,297	591,963
Ravenswood North	254.3	-	1,696	11,021	253,488	780,600	1,340,564	1,894,699
Rural South	174.4	43,072	43,435	47,141	51,428	55,787	59,856	63,925
South Yunderup	265.2	501,665	535,472	598,224	823,602	1,078,478	1,398,206	1,725,556
Stake Hill - Barragup - Nambeelup	303.3	75,221	86,342	94,228	102,013	110,304	118,190	126,278
West Pinjarra	260.2	16,652	19,986	94,302	236,673	415,145	594,024	766,642
TOTAL (KL)		**1,769,677**	**1,972,232**	**2,367,430**	**3,243,911**	**4,480,621**	**5,814,160**	**7,145,822**

Table 90: Rainwater tank use in Murray to 2051

Rainwater Tank Use per House (kL)[1]	No. Unserviced Households (2021)[2]	2021 Water Usage[3]
264	1,223	362,937

Notes:

1. Rainwater tanks are assumed to supply all unserviced dwellings at rate of 106kL/person/yr.
2. Number of IWSS accounts is used to approximate the number of serviced dwellings.
3. Rainwater tank use is assumed to continue at current rates (i.e. all new development is connected to IWSS).

Table 91: Water needs of future public open space and schools in Murray

	Existing POS area (Ha)	Existing POS irrigation demand (kL)	Future POS area (Ha)	Future POS Irrigation demand (kL)	Existing Schools area (Ha)	Existing Schools irrigation demand (kL)	Future Schools area (Ha)	Future Schools irrigation demand (kL)
Murray	8,677	1,771,309	2,116	479,266	50	61,450	144	291,600

As previously stated in section 1.4, four community growth scenarios (excluding commercial growth which has been separately assessed with other industry uses) were assessed by the study. The results of the analysis for Murray are tabulated below.

Scenario 1: Business as usual growth including schools and public open space (incorporating a reduction in groundwater use of 10% by 2030)

Scenario 2: High growth scenario using the population projections in Perth and Peel @ 3.5 million (WAPC, 2018)

Scenario 3: Reduced water use by the community through waterwise gardens or medium density, assuming that after 2030, 50% new residents will reduce their water use to 70 kL/per person/year

Scenario 4: 30% of existing development incorporates a waterwise garden (water use at 70 kL/per person/year)

The results of the scenario assessment are shown below.

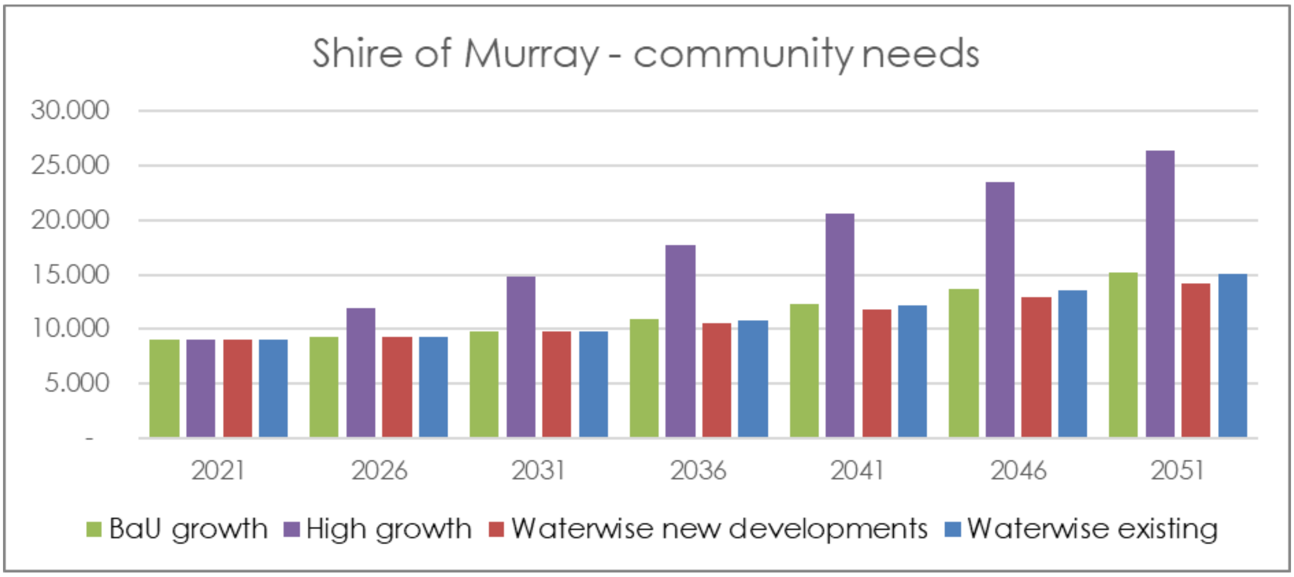


Figure 64: Results of community scenario assessment for Murray

Table 92: Results of community scenario assessment for Murray

Shire of Murray	C1 - BaU	C2 - High growth	C3 - Waterwise (new developments)	C4 - Waterwise (existing)
2021	8.996	8.996	8.996	8.996
2026	9.327	11.888	9.285	9.228
2031	9.852	14.785	9.739	9.752
2036	10.873	17.683	10.597	10.757
2041	12.264	20.580	11.757	12.122
2046	13.751	23.477	12.996	13.584
2051	15.236	26.374	14.233	15.044

Shire of Serpentine Jarrahdale

The Shire of Serpentine Jarrahdale is 905 square kilometres in area and comprises a large area of the Swan Coastal Plan and the Darling Scarp. The Shire is situated between the local governments of Armadale, Kwinana, Rockingham, Murray, and Wandering.

A1.1.16 Population

According to census data, the current population (in 2021) of the Shire of Serpentine Jarrahdale is 32,074 residents, located in nearly 11,000 households (Table 93).

Table 93: Shire of Serpentine Jarrahdale population (Source: ABS)

Suburb	Population 2011	Population 2016	Population 2021	Population growth rate 2011 - 2021	Household size 2021	# of households 2021	% increase over 5 years - actuals
Byford	7034	14,908	18,878	26.6%	3	6,293	13.3%
Cardup	970	1,110	1,163	4.8%	3.1	375	2.4%
Darling downs	1129	1,200	1,591	32.6%	3	530	16.3%
Hopeland	349	336	313	-6.8%	3	104	-3.4%
Jarrahdale	1084	1,192	1,205	1.1%	2.6	463	0.5%
Keysbrook	502	626	265	-57.7%	2.4	110	-28.8%
Mardella	301	480	446	-7.1%	3	149	-3.5%
Mundijong	3009	1,232	1,246	1.1%	2.8	445	0.6%
Oakford	2408	2,632	2,803	6.5%	3.2	876	3.2%
Oldbury	320	338	296	-12.4%	2.6	114	-6.2%
Serpentine	2026	2,317	2,863	23.6%	2.7	1,060	11.8%
Whitby	n/a	319	1,005	215.0%	3	335	215.0%
Total	**19,132**	**26,690**	**32,074**	**67.6%**		**10,855**	

Population growth

The WAPC's *South Metropolitan Peel Sub-regional Planning Framework* (WAPC, 2018) suggests that at 2050, the Shire of Serpentine Jarrahdale will contain over 113,000 people, while *WA Tomorrow* predicts between 59,220 and 66,100 at 2031 (WAPC, 2019) and Forecast ID predicts a population of 61,898 by 2036 (https://forecast.id.com.au/ Serpentine Jarrahdale).

The study team worked with the Shire to agree the business as usual population projections contained in Table 94 which represent the Forecast ID projections to 2036, followed by an annual growth rate equal to the average annual growth rate since 2016.

Table 94: Population growth rate used in the study

Local Government	2021	2026	2031	2036	2041	2046	2051	Average Annual Growth Rate
Serpentine Jarrahdale	36,403	46,995	57,785	68,335	81,186	96,789	115,744	4.6%

A1.1.17 Land use

Land use on the Swan Coastal plain portion is described in the Shire of Serpentine Jarrahdale Local Planning Strategy as predominantly Rural and including equestrian, intensive agricultural and food bowl industries, as well as industrial areas which support urban core functions surrounded by medium density residential development (Figure 65). The key settlements are Byford, Mundijong and Serpentine, with an additional settlement in Jarrahdale on the Darling scarp.

Residential development

There are four main areas of residential development within the Shire – Byford (5,530ha), Mundijong (5,461ha), Serpentine (7,270ha) and Jarrahdale (45,032ha) in various stages of development. The Shire's Local Planning Strategy suggests that at full development, these centres will house 107,000 people.

Further residential development may be possible in areas designated for Planning Investigation. The State Government recently provided their support for investigations into the feasibility of further residential development at 1,808ha, however it is recognised that this will not increase the projected population figures – it just provides additional space for the development to occur.

Table 95: Future development areas in Serpentine Jarrahdale

Future development		
Future industrial		603
Industrial Expansion	497	
Industrial Investigation	106	
Future urban		619
Urban deferred	241	
Urban Expansion	378	
Urban Investigation	0	
ROS		80
Regional open space	80	

Future development		
Planning Investigation		2,195
Future urban	1,808	
Remaining rural residential	387	
Grand Total		3496

Commercial development

The key activity centres within the Shire are shown in Figure 65. It is assumed that these centres will be provided with scheme water and require future access.

Table 96: Commercial centres in the Shire of Serpentine Jarrahdale

Commercial activity centre	Indicative net lettable area
Byford Town Centre,	15,500m2
Whitby District Centre	22,500m2
Mundijong Townsite	5,000m2
The Glades Village Centre	5,000m2
Thomas Road	5,000m2
Orton Road	5,000m2
Mundijong Whitby East	5,000m2
Mundijong Whitby West	5,000m2
Serpentine	5,000m2
Jarrahdale	5,000m2
Oakford	500m2
Keysbrook	500m2
	79,000m2

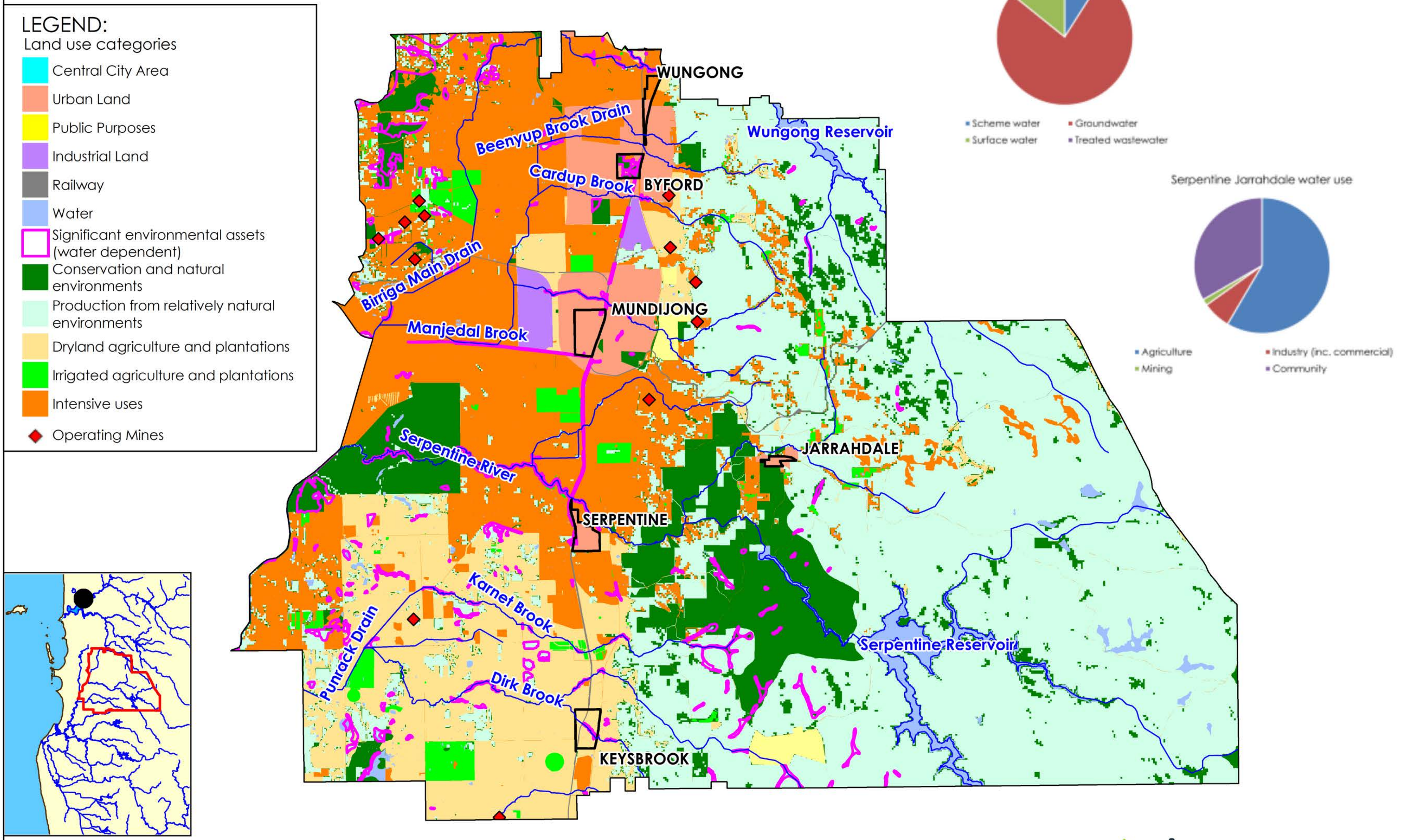
Public open space

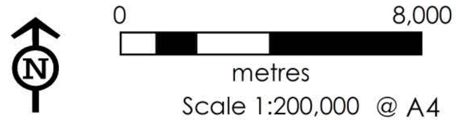
The Shire of Serpentine Jarrahdale contains over 9,000 ha of open space (not counting State Forest). This includes 8204ha reserved under the Metropolitan Region Scheme and 868ha reserved under the local planning scheme. Over 985 of the area of open space provide a nature function (Table 97).

Table 97: Public open space in the Shire of Serpentine Jarrahdale by function

POS function	Gross Area (Ha)
Nature	8929
Recreation	96
Sport	51
Grand Total	**9076**

Peel Alliance - Peel Regional Water Supply Initiative
Figure 65 - Shire of Serpentine-Jarrahdale land use and water allocation





Data source: Landgate, DPLH Created by: HB Projection: MGA: zone 50.

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The current water needs of public open space and schools is shown below.

Existing POS area (Ha)	9,252
Existing POS irrigation demand (kL)	2,752,068
Existing Schools area (Ha)	64
Existing Schools irrigation demand (kL)	104,975

It is also noted that as of 2020, the DLGGSCI found that the area of active recreation (POS with a sport or recreation function) within the Shire was less than the recommended benchmark (Table 98). Should the Shire wish to create additional areas of public open space for sport or recreation, consideration will need to be given to available sources of water for irrigation.

Table 98: Public open space benchmarks in the Shire of Serpentine Jarrahdale

Local government	Serpentine Jarrahdale (S)
Total Area: POS (ha)	9, 252
Area (ha) POS (excl ROS) per 1,000 population (Benchmark = 3.36)	22.14
Area POS (excl ROS) as % urban area (Benchmark = 10 per cent)	22.52
Area Sport + Rec POS as % urban area (Benchmark = 8 per cent)	5.33
Average distance (m) to closest POS (excl ROS)	1,083

Rural living

The Shire also contains large areas for rural activities including peri-urban living in areas designated as Rural Residential, Rural Smallholdings and Special Residential. A special control areas has also been established for "Residential and Stables Area". In these areas, there is limited access to reticulated water (IWSS) and no access to reticulated sewerage.

Industrial development

The West Mundijong Industrial Area and Cardup Business Park provide for a variety of industries and businesses ranging from low intensity service industries to intensive general industries which may have offsite impacts. This Cardup Business Park is considered to support community development and is categorised as a population-driven industry, while the West Mundijong Industrial Area is categorised as strategic industry (see Industrial section for more information).

Data from the Water Corporation suggests that 575,444 kL of scheme water is being used within the Shire of Serpentine Jarrahdale for industrial purposes at the moment.

Wastewater

There are no wastewater treatment plants within the Shire of Serpentine Jarrahdale.

A1.1.18 Environmental features

The key water dependent environmental features are discussed in the Environment report but include the Serpentine River, Serpentine Dams, Karnet and Dirk Brook, Cardup Brook and Berriga Main Drain. The majority of the Shire lies within the Peel Estuary – Serpentine River catchment. This catchment drains into the Ramsar listed Peel-Yalgorup System. The Serpentine catchment provides around 15% of the annual surface inflow to the Peel-Harvey system.

The western portion of the Shire, coinciding with the Swan Coastal Plain is largely categorised as Multiple Use Wetland. This is largely attributed to the geological system of the Guildford Formation, typically sand over clay, which is seasonally waterlogged flat land. The Shire also contains a number of conservation category wetlands, Bush Forever areas and areas of bushland of local significance.

A1.1.19 Agriculture

The Shire of Serpentine Jarrahdale includes a number of strategic agricultural areas at Oakford, Oldbury and Keysbrook. The Shire's Local Planning Scheme also recognises the importance of protecting significant agricultural areas through Agri-Food Special Control Area. Water for agricultural production is discussed further in the body of the report.

A1.1.20 Industry and resources

The Shire is rich in resources primarily basic raw materials. It contains a large mineral sands extractive industry which is a large user of water. This is discussed further in the body of the Report.

Current water needs

The total community water needs for the Shire of Serpentine -Jarrahdale exceed 11 GL (Table 99). This includes just over 2.5GL of scheme water and nearly 7.5GL of surface and groundwater (Figure 66).

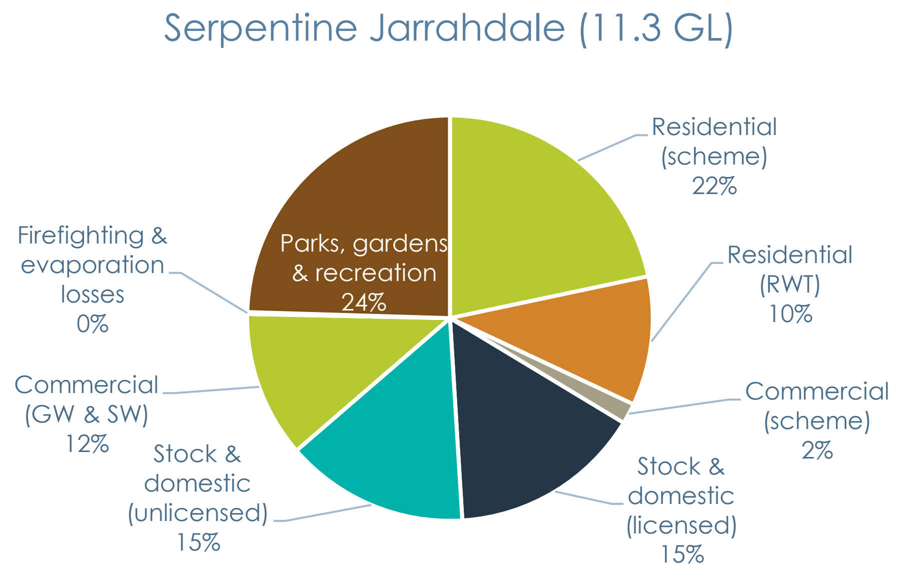


Figure 66: Total community water demands in the Shire of Serpentine Jarrahdale

Table 99: Total community water demands in the Shire of Serpentine Jarrahdale

Water demands	Volume (kL)	
Scheme water (IWSS)		
Residential scheme water use	2,433,112	
Non-residential scheme water	185,125	
Sub total		*2,618,237*
Surface water/ groundwater resources		
Allocated – Commercial	1,308,735	
Allocated - Firefighting and evaporation losses	16,847	
Allocated - Parks, gardens and recreation	2,752,068	
Allocated - Stock and domestic	1,776,647	
Unallocated – Stock & domestic	1,642,440	
Unallocated – Rainwater tanks	1,157,255	
Sub total		*8,653,992*
Totals		**11,272,229**

Future water needs

These future water needs of the Serpentine Jarrahdale community focus on the growth of scheme water for residential needs and public open space. As noted previously, commercial growth is addressed in the Industry sector and no increase in water for firefighting or rural residential activities was considered necessary. The future needs are shown below.

Table 100: Growth in suburban scheme water use in Serpentine Jarrahdale to 2051

Suburb	Water Use per House (kL)	2021 Water Usage (kL)	2026 Water Usage	2031 Water Usage	2036 Water Usage	2041 Water Usage	2046 Water Usage	2051 Water Usage
Byford area	278.0	1,842,695	2,540,968	2,959,690	3,128,792	3,827,082	4,674,034	5,701,296
Cardup area	242.5	485	485	485	485	485	1,183	3,907
Darling Downs area	327.4	95,260	123,849	140,435	135,197	162,158	190,909	221,569
Hopeland - Keysbrook area	212.0	1,272	3,785	6,140	8,339	10,963	13,725	16,632
Jarrahdale area	244.1	86,402	85,276	87,247	91,096	93,102	95,126	97,167
Mundijong area (post 2036 growth slows)	266.9	177,222	436,306	1,006,520	1,824,475	2,286,733	2,855,937	3,556,829

Suburb	Water Use per House (kL)	2021 Water Usage (kL)	2026 Water Usage	2031 Water Usage	2036 Water Usage	2041 Water Usage	2046 Water Usage	2051 Water Usage
Oakford - Oldbury area	427.8	40,213	44,892	49,571	54,651	59,277	64,096	69,116
Serpentine area	315.4	189,563	195,871	203,815	214,796	225,972	237,617	249,749
TOTAL (KL)		**2,433,112**	**3,428,928**	**4,449,992**	**5,453,216**	**6,663,792**	**8,132,626**	**9,916,264**

Table 101: Rainwater tank use in Serpentine Jarrahdale to 2051

Rainwater Tank Use per House (kL)[1]	No. Unserviced Households (2021)[2]	2021 Water Usage[3]
306	3,768	1,157,255

Notes:

1. Rainwater tanks are assumed to supply all unserviced dwellings at rate of 106kL/person/yr.
2. Number of IWSS accounts is used to approximate the number of serviced dwellings.
3. Rainwater tank use is assumed to continue at current rates (i.e. all new development is connected to IWSS).

Table 102: Water needs of future public open space and schools in Serpentine Jarrahdale

	Existing POS area (Ha)	Existing POS irrigation demand (kL)	Future POS area (Ha)	Future POS Irrigation demand (kL)	Existing Schools area (Ha)	Existing Schools irrigation demand (kL)	Future Schools area (Ha)	Future Schools irrigation demand (kL)
Serpentine Jarrahdale	9,252	2,752,068	282	755,246	64	104,975	208	421,200

As previously stated in section 1.4, four community growth scenarios (excluding commercial growth which has been separately assessed with other industry uses) were assessed by the study. The results of the analysis for Serpentine Jarrahdale are tabulated below.

Scenario 1: Business as usual growth including schools and public open space (incorporating a reduction in groundwater use of 10% by 2030)

Scenario 2: High growth scenario using the population projections in Perth and Peel @ 3.5 million (WAPC, 2018)

Scenario 3: Reduced water use by the community through waterwise gardens or medium density, assuming that after 2030, 50% new residents will reduce their water use to 70 kL/per person/year

Scenario 4: 30% of existing development incorporates a waterwise garden (water use at 70 kL/per person/year)

The results of the scenario assessment for Serpentine Jarrahdale are shown below.

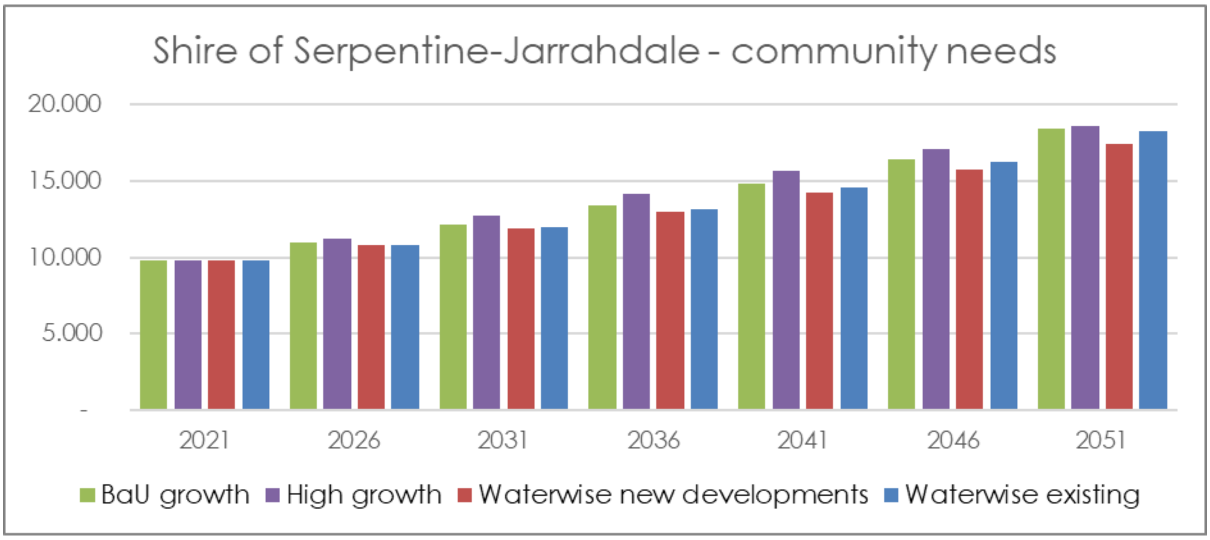


Figure 67: Results of community scenario assessment for Serpentine Jarrahdale

Table 103: Results of community scenario assessment for Serpentine Jarrahdale

Shire of Serpentine Jarrahdale	C1 - BaU	C2 - High growth	C3 - Waterwise (new developments)	C4 - Waterwise (existing)
2021	9.778	9.778	9.778	9.778
2026	10.970	11.263	10.843	10.776
2031	12.187	12.731	11.927	11.993
2036	13.387	14.198	12.994	13.192
2041	14.793	15.666	14.245	14.599
2046	16.458	17.134	15.722	16.264
2051	18.438	18.601	17.473	18.243

Shire of Waroona

The Shire of Waroona is the southern-most local government area in the Peel Region. It is 835 square kilometres in area and extends from the Darling Plateau in the east to the Indian Ocean in the west. The Shire of Murry is on the northern boundary, with the Shire of Boddington to the east and the Shire of Harvey to the south.

A1.1.21 Population

According to census data, the current population (in 2021) of the Shire of Waroona is 4,233 residents, located in nearly 1,750 households (Table 104).

Table 104: Shire of Waroona population (Source: ABS)

Suburb	Population 2011	Population 2016	Population 2021	Population growth rate 2011 - 2021	Household size 2021	# of households 2021	% increase over 5 years - actuals
Hamel	223	265	286	28.3%	2.6	110	14.1%
Lake Clifton	406	683	759	86.9%	2.8	271	43.5%
Preston Beach	218	227	268	22.9%	1.8	149	11.5%
Wagerup	n/a	31	52	67.7%	2.3	23	67.7%
Waroona	2736	2934	2868	4.8%	2.4	1,195	2.4%
Total	**3,583**	**4,140**	**4,233**	**2.2%**		**1,748**	

Population growth

The *Shire of Waroona Local Planning Strategy* (2009) estimated the potential population at 2021 of 6,480 people, based on an annual average growth rate of 3.7%. This rate of growth is higher than the rate of 2.2% that was actually achieved over this time.

It is noted that the WAPC's *South Metropolitan Peel Sub-regional Planning Framework* (WAPC, 2018) suggests that at 2050, the Shire of Waroona will contain 18,230 people, while *WA Tomorrow* predicts between 3 790 and 5 670 at 2031 (WAPC, 2019). These figures were considered by the study team in consultation with the Shire of Waroona and a figure of 3% growth was agreed to be used for the study (Table 105).

Table 105: Population growth rate used in the study

Local Government	2021	2026	2031	2036	2041	2046	2051	Average Annual Growth Rate
Waroona	4,357	5,013	5,768	6,636	7,635	8,784	10,106	3.0%

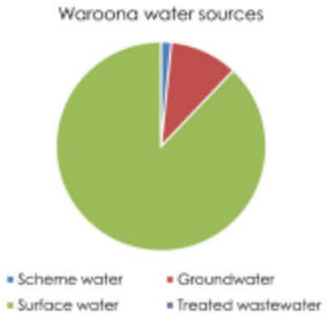
A1.1.22 Land use

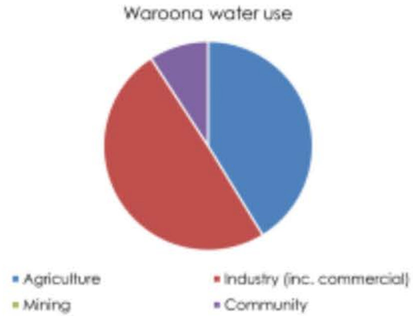
Residential development

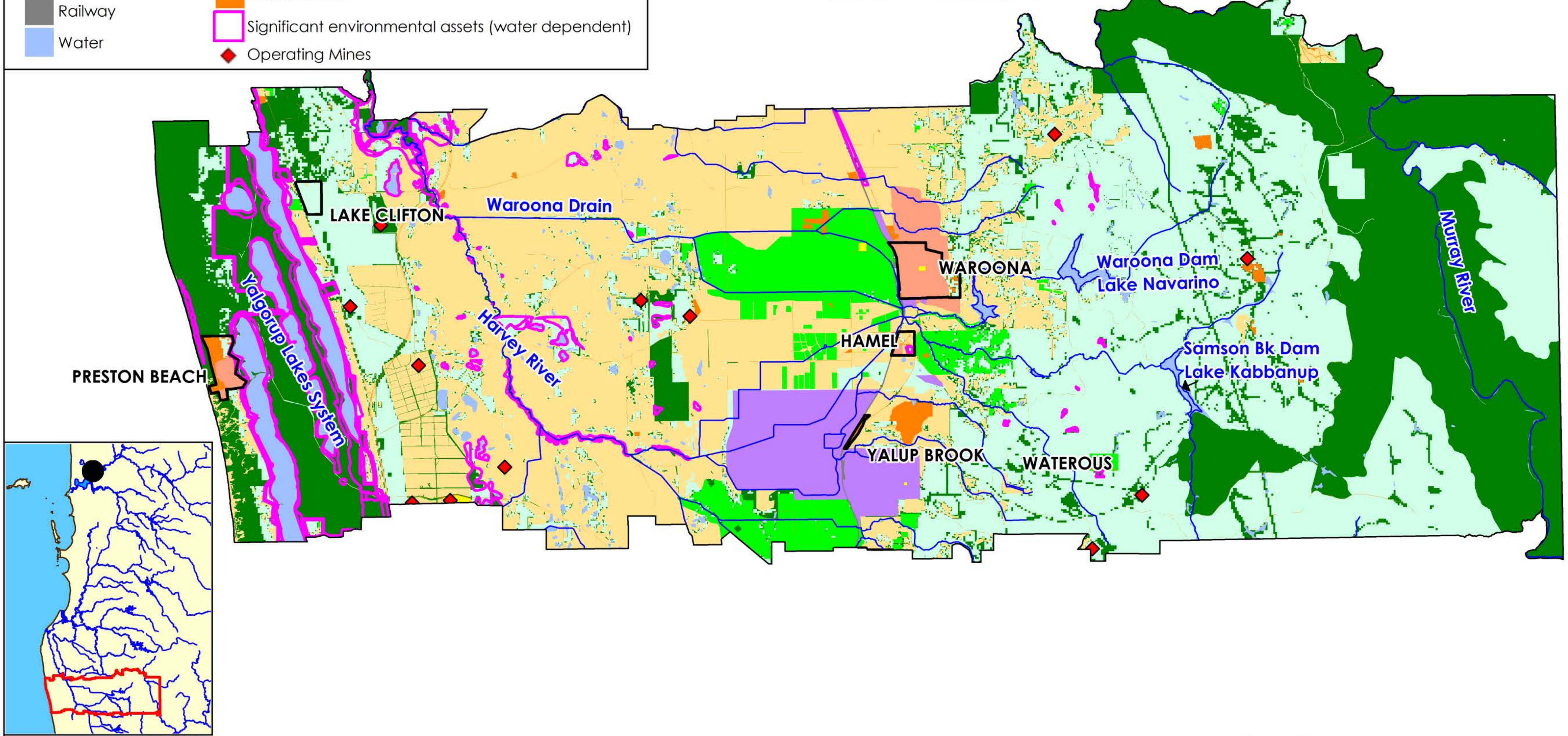
The Waroona townsite provides the majority of the residential development area within the Shire. Other settlement areas include Hamel, Preston Beach and Lake Clifton (Rural Residential) (Figure 68). The projected growth in population is likely to occur in either Waroona or Preston Beach, as these areas have access to scheme water.

The area identified in *South Metropolitan Peel Sub-regional Planning Framework* (WAPC, 2018) for future urban development (urban expansion) is approximately 338ha.

Peel Alliance - Peel Regional Water Supply Initiative
Figure 68 - Shire of Waroona land use and water allocations







Data source: Landgate, DPLH Created by: HB Projection: MGA: zone 50.

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Table 106: Future development areas in the Shire of Waroona

Future development		
Future industrial		1,576
Industrial Expansion	788	
Industrial Investigation	788	
Future urban		338
Urban deferred	0	
Urban Expansion	338	
Urban Investigation	0	
Total		1,914

Public open space

The Shire of Waroona contains over 24,500 ha of open space (not counting State Forest). This includes approximately 24,400ha reserved under the Peel Region Scheme and 94ha reserved under the local planning scheme. Over 989% of the area of open space provides a nature function (Table 97).

Table 107: Public open space in the Shire of Waroona by function

POS function	Gross Area (Ha)
Nature	24,542
Recreation	3
Sport	8
Grand Total	**24,553**

The current water needs of public open space and schools is shown below.

Existing POS area (Ha)	19,337
Existing POS irrigation demand (kL)	11,400
Existing Schools area (Ha)	14
Existing Schools irrigation demand (kL)	31,500

It is also noted that as of 2020, the DLGGSCI found that the area of active recreation (POS with a sport or recreation function) within the Shire was less than the recommended benchmark (Table 108). Should the Shire wish to create additional areas of public open space for sport or recreation, consideration will need to be given to available sources of water for irrigation.

Table 108: Public open space benchmarks in the Shire of Waroona

Local government	Waroona (S)
Total Area: POS (ha)	19,339
Area (ha) POS (excl ROS) per 1,000 population (Benchmark = 3.36)	34.69
Area POS (excl ROS) as % urban area (Benchmark = 10 per cent)	18.36

Local government	Waroona (S)
Area Sport + Rec POS as % urban area (Benchmark = 8 per cent)	1.44
Average distance (m) to closest POS (excl ROS)	483

Commercial and industrial development

The Waroona townsite contains an area of "community and civic" use and "service commercial" (37ha and 7ha respectively). These areas are considered to provide services to the community and it is likely that their water requirements are recorded by the Water Corporation as non-residential uses. The growth in water needs of this area is considered to be a factor of population growth.

The local planning scheme also contains a large area zoned for Industry that covers the Wagerup Alumina Refinery. This strategic industry activity is discussed further in the body of the report.

Rural

Large areas of the Shire are Rural and provide for farming and a range of agricultural activities categorised as General Farming, Coastal, Coastal Highway, Hills Face, Darling Range, Rural Residential, Rural Small Holdings and Hills Landscape Protection. The Shire also contains a significant area zoned for irrigated agriculture (4,312ha) to the west of the Waroona Townsite.

The peri urban areas of the Shire do not have access to reticulated water or sewer.

Wastewater

The Shire of Waroona has access to reticulated sewerage within the Waroona townsite only. Treated wastewater from the Waroona Waste Water Treatment Plant is discharged via a swale into the Drakesbrook Drain (Table 109).

Table 109: WWTPs in the Shire of Waroona

WWTP Name	Licenced Capacity (kL/day)	Production Volume (kL/day) (year)	Output Quality	Current Disposal Method	Future Projection (McFarlane D. D., 2019b)
Waroona	240 (possibly expand to 880)	306 (2021-22)	Secondary	Previously a planted tree lot, now discharged via swale leading to agricultural drain, Drakesbrook Drain	Will be based on population and land use changes, however output likely to be too small to be useful

A1.1.23 Environmental features

The key water dependent environmental features in the Shire of Waroona are the Yalgorup Lake System in particular Lake Clifton and Lake Preston, the Harvey River and many conservation category wetlands. These features are sustained by rainfall, surface water and groundwater and are discussed in more detail in the body of the report.

A1.1.24 Agriculture

The Shire of Waroona includes the Waroona Irrigation District. The Shire's Local Planning Strategy (2009) notes that "about 1,000 hectares are irrigated with good quality water from the Waroona, Drakesbrook and Samson Brook dams. In 2003 the irrigation channels were replaced with pipes, increasing the efficiency and flexibility of water delivery. Piping has also allowed for the expansion of the irrigation area to the west and north of Waroona."

Additional areas of irrigated agriculture are located east of Hamel and south of Wagerup. The water needs of these areas is discussed further in the body of the report.

A1.1.25 Industry and resources

The key mining activity is the Wagerup Refinery. Mining and resources sector water needs are discussed further in the body of the Report.

Current water needs

The current total community water demands for the Shire of Waroona are around 2.2GL (Table 110). This includes 2GL of groundwater and surface water use, largely from unlicenced sources, as well as around 320,000kL of scheme water (Figure 69).

Table 110: Total community water demands in the Shire of Waroona

Water demands	Volume (kL)	
Scheme water (IWSS)		
Residential scheme water use	314,187	
Non-residential scheme water	17,900	
Sub total		*386,972*
Surface water/ groundwater resources		
Allocated – Commercial	17,900	
Allocated - Firefighting and evaporation losses	0	
Allocated - Parks, gardens and recreation	11,400	
Allocated - Stock and domestic	32,530	
Unallocated – Stock & domestic	1,795,600	
Unallocated – Rainwater tanks	130,648	
Sub total		*1,988,078*
Totals		**2,375,050**

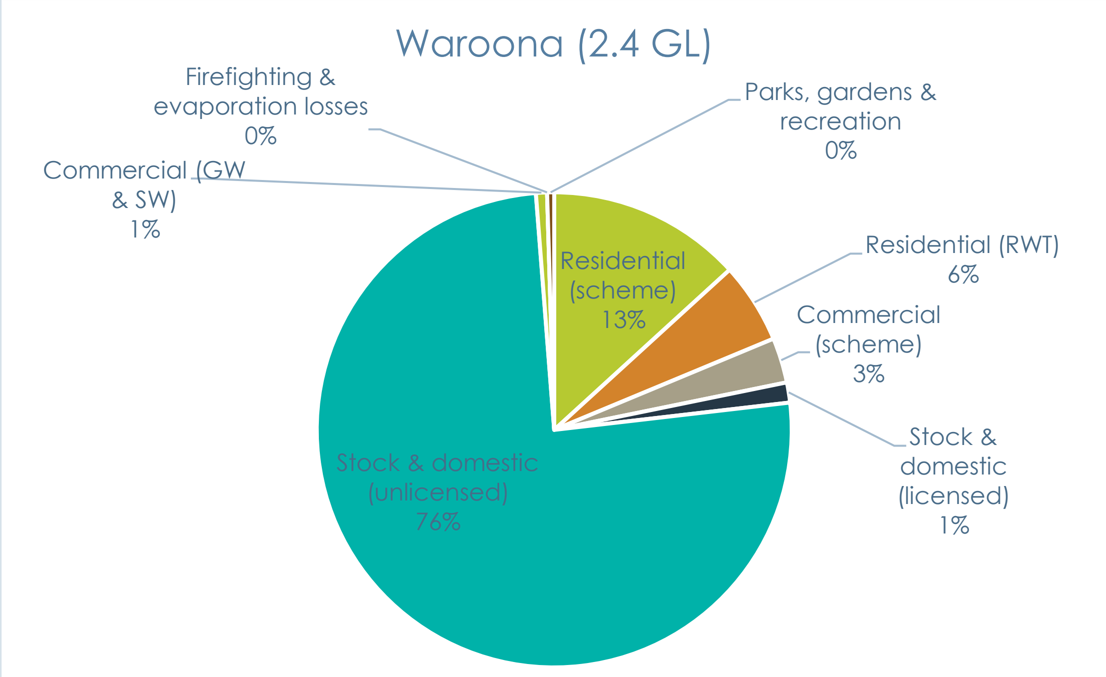


Figure 69: Total community water demands in the Shire of Waroona

Future water needs

These future water needs of the Waroona community focus on the growth of scheme water for residential needs and public open space. As noted previously, commercial growth is addressed in the Industry section and no increase in water for firefighting or rural residential activities was considered necessary (see section 2.3). The future needs are shown below.

Table 111: Growth in suburban scheme water use in Waroona to 2051

Suburb	Water Use per House (kL)	2021 Water Usage (kL)	2026 Water Usage	2031 Water Usage	2036 Water Usage	2041 Water Usage	2046 Water Usage	2051 Water Usage
HAMEL	236.6	8,753	12,785	17,424	22,762	28,903	35,968	44,097
Lake Clifton	-	-	-	-	-	-	-	-
PRESTON BEACH	116.1	40,039	42,716	45,797	49,341	53,419	58,110	63,508
WAGERUP	-	-	-	-	-	-	-	-
WAROONA	245.3	265,395	310,812	363,067	423,188	492,359	571,943	663,508
TOTAL (KL)		**314,187**	**12,785**	**17,424**	**22,762**	**28,903**	**35,968**	**44,097**

Table 112: Rainwater tank use in Waroona to 2051

Rainwater Tank Use per House (kL)[1]	No. Unserviced Households (2021)[2]	2021 Water Usage[3]
252	334	130,648

Notes:

1. Rainwater tanks are assumed to supply all unserviced dwellings at rate of 106kL/person/yr.
2. Number of IWSS accounts is used to approximate the number of serviced dwellings.
3. Rainwater tank use is assumed to continue at current rates (i.e. all new development is connected to IWSS).

Table 113: Water needs of future public open space and schools in Waroona

	Existing POS area (Ha)	Existing POS irrigation demand (kL)	Future POS area (Ha)	Future POS Irrigation demand (kL)	Existing Schools area (Ha)	Existing Schools irrigation demand (kL)	Future Schools area (Ha)	Future Schools irrigation demand (kL)
Waroona	19,337	11,400	1,425	140,738	14	31,500	32	64,800

As previously stated in section 1.4, four community growth scenarios (excluding commercial growth which has been separately assessed with other industry uses) were assessed by the study. The results of the analysis for Waroona are tabulated below.

Scenario 1: Business as usual growth including schools and public open space (incorporating a reduction in groundwater use of 10% by 2030)

Scenario 2: High growth scenario using the population projections in Perth and Peel @ 3.5 million (WAPC, 2018)

Scenario 3: Reduced water use by the community through waterwise gardens or medium density, assuming that after 2030, 50% new residents will reduce their water use to 70 kL/per person/year

Scenario 4: 30% of existing development incorporates a waterwise garden (water use at 70 kL/per person/year)

The results of the scenario assessment for the Shire of Waroona are shown below.

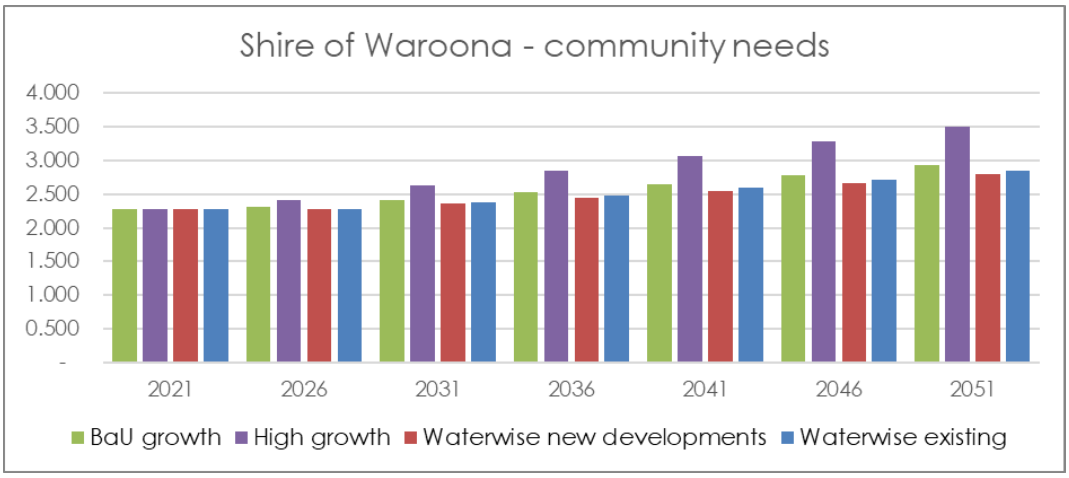


Figure 70: Results of community scenario assessment for Waroona

Table 114: Results of community scenario assessment for Waroona

Shire of Waroona	C1 - BaU	C2 - High growth	C3 - Waterwise (new developments)	C4 - Waterwise (existing)
2021	2.284	2.284	2.284	2.284
2026	2.319	2.414	2.275	2.279
2031	2.419	2.632	2.360	2.373
2036	2.529	2.850	2.454	2.477
2041	2.650	3.068	2.556	2.590
2046	2.784	3.286	2.668	2.716
2051	0.7	1.3	0.7	0.7

APPENDIX 2: Key assumptions and approximations

Integrated Water Supply Scheme (IWSS)

- Usage in 2021 is used as the baseline.
- Number of accounts is used to approximate the number of serviced dwellings.

Licensed self-supply

- Surface water and groundwater licenced amounts by industry sector from DWER. Includes:
  - POS/recreation (incl. schools)
  - Industry
  - Mining
  - Commercial
  - Stock and domestic
  - Fire-fighting
- Water allocated to irrigation schemes applied as agricultural use
- Water allocated to MAR schemes considered in both groundwater and treated wastewater use analysis but applied only as treated wastewater use in summary charts and tables.
- Water allocated to public water supply not included in groundwater use, considered through IWSS use.
- Groundwater use for POS (except nature areas) and schools (30% area) in Boddington estimated as 7,500 kL/Ha.

Unlicensed self-supply

Farm dams

- The area of mapped farm dams from DPIRD (*Farm dams of Western Australia, DPIRD-083, 2022*) in each local government area multiplied by average annual rainfall has been applied as an estimate of farm dam usage.
- Annual average rainfall for each local government area was obtained from a single representative BoM site for Boddington, Mandurah and Waroona. For Murray and Serpentine Jarrahdale, annual average rainfalls reported in *Murray hydrological studies: Surface water, groundwater & environmental water, Model construction and calibration report* (Hall et al, 2010b) while *Lower Serpentine hydrological studies – Model construction and calibration report* (Marillier et al, 2012b) were applied for consistency with water balance modelling.

Local government	BoM site reference	BoM site location	Average annual rainfall (mm)	Length of record
Boddington	10917	Wandering	536.3	1998 to 2020
Mandurah	9572	Halls Head	827.6	1991 to 2017
Murray	9596	Pinjarra/SILO	843.6	1985-2009
Serpentine Jarrahdale	9039	Serpentine/SILO	821.0	1970-2010
Waroona	9538	Dwellingup	1119.1	1991 to 2020

Local Government	Existing farm dams	Area of dams (m^2)	Rainfall (m/yr)	Rainfall captured (kL)
Boddington	1,544	10,725,326	0.5363	5,751,992
Mandurah	28	110,784	0.8276	91,685
Murray	1,557	6,604,837	0.8436	5,571,840
Serpentine Jarrahdale	859	3,506,201	0.8210	2,878,591
Waroona	357	2,266,760	1.1191	2,536,731

Rainwater tanks

- Number of IWSS accounts is used to approximate the number of serviced dwellings.
- Rainwater tanks are assumed to supply all unserviced dwellings at rate of 106kL/person/yr.

Groundwater (backyard bores)

Where available (Mandurah, Murray, Serpentine Jarrahdale, and Waroona) the DWER exempt use provision for each groundwater license subarea has been applied as an estimate of unlicensed groundwater use. In Boddington, where all groundwater use is unlicensed, a provision of 800kL/yr/dwelling has been applied to 30% of dwellings.

Local Government	Existing dwellings	Exempt provision (kL/yr)	Estimated exempt use (kL/yr)
Boddington	887	n/a	212,880
Mandurah	35,400	5,132,600	n/a
Murray	6,750	4,060,000	n/a
Serpentine Jarrahdale	6,440	1,642,440	n/a
Waroona	1,880	1,795,600	n/a

Groundwater (public open space/schools – Boddington only))

- Groundwater use for POS (except nature areas) and schools (30% area) in Boddington estimated as 7,500 kL/Ha.

Growth scenarios

Population based growth

- BaU population growth from 2021 applies annual growth rates from Forecast ID where available (Mandurah, Murray, Serpentine Jarrahdale).
- BaU population growth from 2021 applies annual growth rates from WA Tomorrow for Boddington.
- BaU population growth from 2021 applies annual growth rates from Local Planning Strategy for Waroona.
- High-growth populations are based on highest predicted 2051 population for each local government from all sources (WA Tomorrow, Forecast ID, Perth & Peel @ 3.5M, Local Planning Strategies).

Agriculture scenarios

- BaU growth includes scenarios 1 and 2 fully realised (incremental growth) by 2051.
- High-growth adds scenario 3 fully realised (incremental growth) by 2051.

Industry scenarios

- BaU growth includes proportional growth of commercial uses based on population growth rates, mining and strategic industry scenarios 1 and 2 fully realised (incremental growth) by 2051 and strategic industry scenario 3 commencing in 2051.
- High-growth increases commercial uses based on high-growth population rates.

Residential drinking water (IWSS) scenarios

- BaU growth includes proportional growth of water use based on population growth rates.
- High-growth increases proportional growth of water use based on high-growth population rates.
- Two waterwise scenarios are considered:
    - 50% new development achieves waterwise IWSS use rate of 70kL/person
    - 30% existing households achieve waterwise IWSS use rate of 70kL/person
- A single combined waterwise scenario is presented in summary source & demand charts.

Residential non-drinking water scenarios

- New government high schools (10 ha each) are provided at rate of 1 per 6,600 dwellings.
- New government primary schools (4 ha each) are provided at rate of 1 per 1,650 dwellings.
- New private high schools (10 ha each) are provided at rate of 1 per 13,200 dwellings.
- New private primary schools (4 ha each) are provided at rate of 1 per 4,950 dwellings.
- 30% of future school area is irrigated at 6,750 kL/Ha.
- Future POS is irrigated at 6,750 kL/Ha.
- Rainwater tank and domestic (licensed and unlicensed) surface water and groundwater use is assumed to continue at current rates (i.e. all new development is connected to IWSS).
- Domestic Fire-fighting use is assumed to continue at current rates.

Source predictions

IWSS

- IWSS is assumed to grow sufficiently to supply all new residential needs and continue servicing all existing accounts.

Self-supply

- Surface water and groundwater availability is capped at current use (licensed and unlicensed) to 2031 when a 10% reduction is applied. Thereafter incremental reductions are applied to reach a further 10% reduction by 2051.
- Surface water currently allocated to Newmont is returned after 2036 and is not re-allocated.

Treated wastewater

- Future availability from WC to 2033 extended to 2051 assuming continued stable growth rates.

APPENDIX 3: AGRICULTURAL SCENARIO WATER ASSESSMENT METHODOLOGY

Scenario A1 - Waroona Irrigation District – a change from irrigated pasture, to perennial irrigated horticulture, across 400 hectares by 2051.

This scenario models the Waroona Irrigation District transitioning 400 hectares of its current pasture growing to high value irrigated agriculture by 2051 (Table 115). Assumptions include:

- Irrigated pasture requires 6.63 ML/ha of water.[75]
- Avocados are selected to represent a potential intensive agriculture crop due to its high water requirements of 10.11 ML/ha of water.[76]
- A constant rate of transition is used from present to 2051.

Table 115: Scenario A1 results

	2021	2026	2031	2036	2041	2046	2051
Low Pasture water usage (ML)	2652	2210	1768	1326	884	442	0
Intensive Agriculture water usage (ML)	0	674	1348	2022	2696	3370	4044
Total water usage (ML)	2652	2884	3116	3348	3580	3812	4044
Change (ML)	0	232	464	696	928	1160	1392
% Change		9%	17%	26%	35%	44%	52%

The analysis indicates that transitioning irrigated pasture to perennial irrigated horticulture across 400 hectares in the Waroona irrigated agricultural district by 2051 would lead to an annual net increase of 1.39 GL by 2051, or a 52% increase on current water usage rates.

Scenario A2 – North Dandalup to Serpentine foothills – development of 200 hectares of new intensive irrigated agriculture by 2051

The North Dandalup to Serpentine foothills are potentially suitable for developing into new perennial horticultural cropping such as table grapes, fruit trees, and avocados. This scenario therefore models 200 hectares of new perennial horticulture being developed (Table 116).

Assumptions include:

- Avocados are selected to represent a potential intensive agriculture crop due its high water requirement of 10.11 ML/ha of water.[77]
- A constant rate of transition is used from present to 2051.

[75] FAR Lane analysis based on the DPIRD irrigation calculator, 2022.
[76] FAR Lane analysis based on the DPIRD irrigation calculator, 2022.
[77] FAR Lane analysis based on the DPIRD irrigation calculator, 2022.

Table 116: Scenario A2 results

	2021	2026	2031	2036	2041	2046	2051
Total Usage (ML)	0	337	674	1011	1348	1685	2022

The analysis indicates that 200 hectares of new perennial horticulture cropping in the foothills by 2051 would lead to an annual net increase of 2.02 GL by 2051 (noting there are no current water usage rates for this scenario, as it reflects a new agricultural zone).

Scenario A3 - Peel Food Zone – 250 hectares of new closed-loop covered cropping by 2051

The Peel Food Zone is highly suitable for the development of new covered cropping systems with closed-loop or highly managed control of nutrients (noting that most greenhouses are not closed-loop).[78] This scenario therefore models a transition to an area of 250 hectares of closed-loop cropping by 2051 (Table 117).

A low water use crop (lettuce) and high water use crop (carrots) that are both plausible for closed-loop farming at scale in the Peel Food Zone by 2051 have been modelled. While it is unlikely that carrots will be economically feasible for high intensity covered cropping, they are modelled here to indicate a maximum possible water usage range.

Assumptions include:

- Lettuce requires 4.6 ML/ha of water.[79]
- Carrots require 7.88 ML/ha of water.[80]
- Closed-loop farming requires 20% of the water required to grow the same crop via open field irrigation.[81]

Table 117: Scenario A3 results

	2021	2026	2031	2036	2041	2046	2051
Lettuce (GL)	0	38.33	76.67	115.00	153.33	191.67	230.00
Carrots (GL)	0	65.67	131.33	197.00	262.67	328.33	394.00
Difference	0	27.33	54.67	82.00	109.33	136.67	164.00

The analysis indicates that 250 hectares of new closed-loop covered cropping in the Peel Food Zone would lead to between 0.23 GL and 0.39 GL of increased water usage by 2051.

[78] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.
[79] FAR Lane analysis based on the DPIRD irrigation calculator, 2022.
[80] FAR Lane analysis based on the DPIRD irrigation calculator, 2022.
[81] Email correspondence with Neil Guise, Manager Land and Water Development Branch, DPIRD, November 2022.

APPENDIX 4: INDUSTRIAL AND RESOURCES WATER ASSESSMENT METHODOLOGY

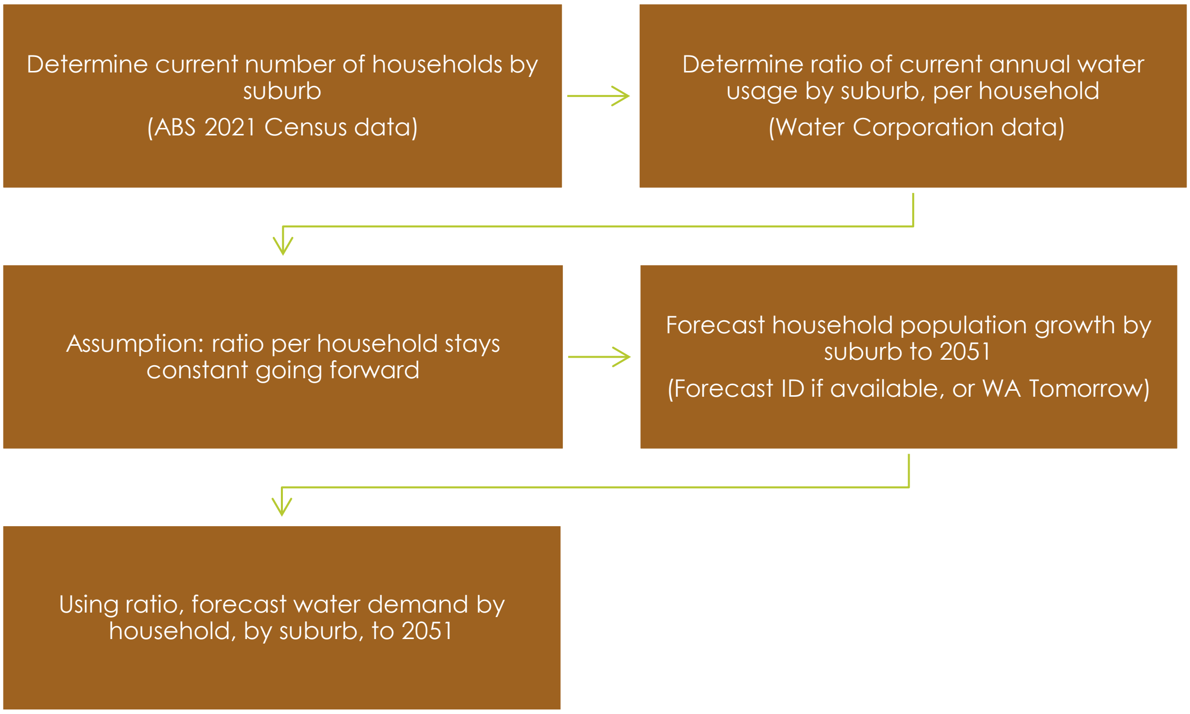
Population-driven industries

Population-driven industries change in direct response to population growth or decline. As Peel's population grows, industries such as health, retail, and the services sector will also grow, and water demand for these industries will correspondingly increase.

A population forecasting model was developed that:

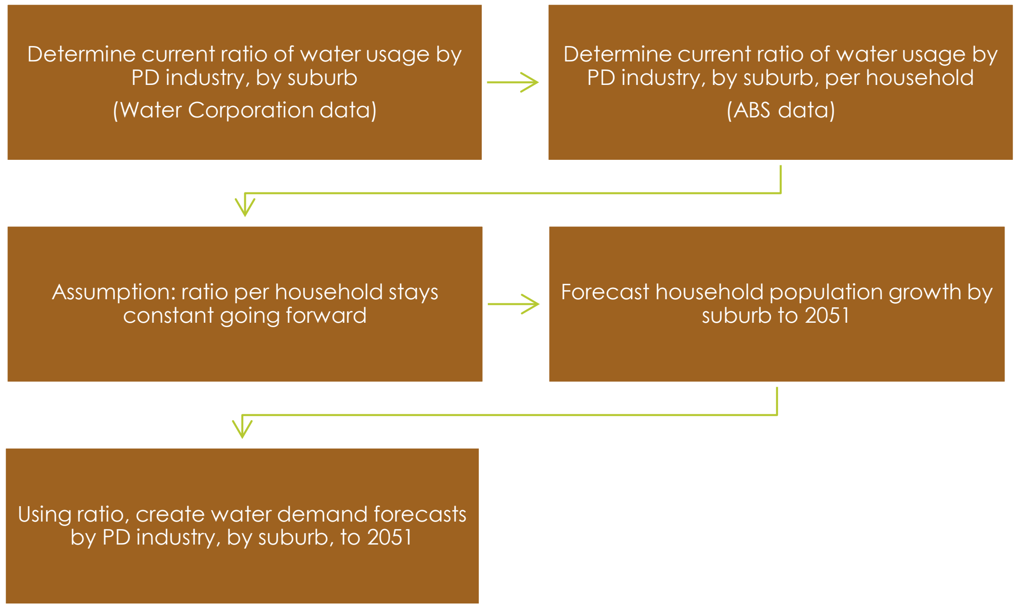
- Created forecasts in five-yearly increments that aligned with Census dates.
- Showed breakdowns by suburb and LGA.
- Allowed for inflection points in be modelled to forecast major changes in a given suburb/LGA and allow for non-linear growth.

The flow chart below displays the methodology for developing population forecasting model and corresponding water usage.



A model forecasting water demand caused by changes in population-driven industries was then created, as per the methodology at figure XX. All industries were included in analysis as population-driven industries except for the following (which were determined to be strategic industries):

- Accommodation and food services (tourism).
- Agriculture, forestry and fishing.
- Manufacturing and construction.
- Mining.



Strategic industries

Development of strategic industries are not directly linked to changes in population, and are also important as they are export-orientated and therefore bring new money into a region which supports growth. Examples of strategic industries include agriculture, mining, manufacturing, and tourism.

Future water demand for strategic industry excluding mining

Future strategic industry expansion in Peel is likely to occur in designated industrial areas outlined in Table 5. Future water demand for these areas is modelled as per the methodology in Table 118 below.

Table 118: Future water demand modelling methodology

Industrial area	Development type	Method	Growth
East Keralup	Agribusiness	Usage by area for a combination of composting and closed-loop agribusinesses	Linear to 2051
Nambeelup - Peel Business Park	Agribusiness	Usage by area for a combination of closed-loop agribusinesses, an abattoir, and light industrial	Linear to 2051
Pinjarra industrial estate	Light industrial	Usage by area for light industrial reflecting current businesses	Linear to 2051
West Mundijong	Light industrial	Usage by area for light industrial	Linear to 2051
Wagerup (excepting Alcoa)	Hydrogen and abattoir	Modelling of water usage for a hydrogen refinery and abattoir	Hydrogen from 2026, abattoir from 2031

Individual detailed methodology for each industrial area is below.

East Keralup

Potential/probable land parcel development parcels at East Keralup are at Table 119.

Table 119: Potential/probable land parcel development parcels at East Keralup

Potential use	Lot size
Compost (C-Wise)	270 hectares
Closed-loop horticulture	150 hectares
Closed-loop aquaculture	150 hectares
Total potential East Keralup development size	1,600 (not including constraints)
Remaining potential development size	1,030 hectares (not including constraints)

The analysis indicates that approximately 1000 hectares remain in East Keralup for development after accounting for current proponents that are likely to become established on the site. This estimate does not account for site constraints, however, using this figure will ensure a conservatively high value is used for water demand analysis.

Of the agribusiness that will potentially become established in East Keralup:

- C-Wise composting is negotiating with DWER to transfer its existing 350,000 KL groundwater license allocation from Nambeelup, which will have no net changes to water demand in Peel.
- The potential horticulture and aquaculture operations will have negligible water demand because they are closed-loop systems.[82]

This analysis therefore only considers potential water demand from lots where there is currently no clearly identified proponent or business. Assumptions are:

- Half of development will be closed-loop systems with negligible water requirements.
- A composting business will be modelled as a suitable agribusiness to expand/become established in the area.

Methodology is at Table 120.

Table 120: East Keralup modelling methodology

Methodology	Measurement
Potential lot development size	1000 hectares
Potential development size for a composting business (50% of land area)	500 hectares
Benchmark for compost water usage for 270 hectares (C-Wise)	350,000 KL

[82] Email correspondence with Adrian Parker, Director Regional Development, Peel Development Commission, November 2022.

Methodology	Measurement
Water required per hectare	1296.3 KL
Compost water usage for 500 hectares	648,148 KL

The analysis indicates that if East Keralup was developed to full capacity with a mix of closed-loop and composting businesses, it would increase water demand in Peel by approximately 0.65 GL at 2051.

Pinjarra industrial estate

Pinjarra Industrial Estate is a well established industrial precinct that houses a variety of businesses including mining engineering, transport, manufacturing and construction, including some that support Alcoa's nearby refinery east of Pinjarra. Future potential water demand is calculated using current water usage as a benchmark, and modelling by potential full size of the estate. Methodology is at Table 121.

Table 121: Pinjarra industrial estate modelling methodology

Methodology	Measurement
Current precinct size	39.1 hectares[83]
Scheme water usage	2,686 kL[84]
Ground water allocation	400,000 kL
Total current water usage per hectare	0.01 GL/hectare
Total potential precinct expansion size	50 hectares[85]
Total potential water usage at 2051	0.52 GL

The analysis indicates that Pinjarra industrial estate's potential water use at 2051 if developed for light industry is 0.52 GL.

Nambeelup – Peel Business Park

Estimating water usage in Nambeelup is challenging, as it is unclear exactly what types of businesses will become established in the precinct and what their water requirements will be. DevelopmentWA has noted that, due to the precinct's connection to scheme water supplies, food processing, logistics and closed-loop agriculture are likely potential industries.[86] A variety of industries reflecting this were selected to model water demand at Peel Business Park. Table 122 outlines these types of industries and corresponding assumed land sizes used for modelling.

[83] FAR Lane analysis based on Google Maps, November 2022.
[84] FAR Lane analysis based on Water Corp data, November 2022.
[85] Department of Planning, Lands and Heritage, South Metropolitan Peel sub-regional Framework, 2018, p 35.
[86] Department of Water and Environmental Regulation, Transform Peel – Peel Integrated Water Initiative report, 2021, p 58.

Table 122: Peel Business Park modelling methodology

Methodology	Size assumption
Total area of Peel Business Park (not including constraints)	1000 hectares
Variety of closed loop agribusinesses (noting this also represents a scenario for the Agriculture report (#A2))	250 hectares
One meat processing facility (abattoir)	100 hectares
Remainder – light industry	650 hectares

Methodology for each land use type is below.

- Closed-loop agribusinesses' potential water use is calculated as per scenario #3 from the Agriculture report (#2) (i.e. 250 hectares), giving a potential increase in water demand of 1.15 GL at 2051.
- The abattoir's potential water use is based on the potential abattoir to be established in Wagerup (see below) at 100 hectares, giving a forecast increase in water demand of 1.98 GL at 2051.
- The light industries' potential water use is based on the water usage per hectare ratio calculated for light industry in Pinjarra (see above) at 650 hectares, giving a potential increase in water demand of 6.7 GL at 2051.

This analysis suggests that Peel Business Park's increased potential water use at 2051, if developed for the industry types and sizes detailed above, is approximately 9.81 GL.

West Mundijong

Future potential water demand for West Mundijong is modelled based on water usage per hectare ratio for light industry (as determined above for modelling for Pinjarra), and potential maximum land size.

Table 123: West Mundijong modelling methodology

Methodology	Input
Water usage per hectare ratio for light industry	0.01GL per hectare
Potential maximum land size	474.34 hectares[87]
Total potential water usage at 2051	4.89 GL

The analysis indicates that West Mundijong industrial area's increased potential water use at 2051, if developed for light industry (including an intermodal precinct), is 4.89 GL.

[87] West Mundijong Industrial Area Local Structure Plan, Shire of Serpentine Jarrahdale, 2021, p 5.

Wagerup

Future water demand for Wagerup is modelled based on:

- A new hydrogen processing facility commencing operations at an assumed date of 2026.
- A new abattoir commencing operations at an assumed date of 2031.

Increased water demand from hydrogen processing is estimated at 0.46 GL per annum, as calculated at scenario I3.

Anticipated water usage for the abattoir is at Table 125.

Table 124: Wagerup modelling methodology

Input	Water use per head	Production rate per day	Annual water usage (GL)
Cattle	1,700 litres	700	0.309
Sheep	100 litres	4000	0.104
Total			0.413 GL

Source: FAR Lane analysis based on Strategen-JBS&G data, 2022.

It should be noted that, while the most recent proposal for the abattoir's processing listed its water source as Harvey Water,[88] it cannot be determined what water source would be used in the longer term should operations commence.

Total potential increase in water demand for Wagerup industrial area at 2051 is at Table 125.

Table 125: Water demands at Wagerup

Input	Potential water demand at 2051
Hydrogen refinery	0.46 GL
Abattoir	0.413 GL
Total	0.87 GL

The analysis indicates that Wagerup industrial estate's increased potential water use at 2051, if a hydrogen refinery and abattoir are developed, is 0.87 GL.

[88] Strategen-JBS&G, Prime Meat Co Pty Ltd Waroona Abattoir Works Approval Application Supporting Attachments, November 2020, page 4.

Summary of potential increased water usage from strategic industry expansion

The above analysis for potential future water demand by strategic industry expansion areas is summarised at Table 126.

Table 126: Potential future water demand by strategic industry expansion areas

Industrial area	Potential water demand at 2051
East Keralup	0.65 GL
Nambeelup - Peel Business Park	9.82 GL
Pinjarra industrial estate	0.52 GL
West Mundijong	4.89 GL
Wagerup (except Alcoa)	0.87 GL
Total	17.11 GL

Alcoa potential expansion – Pinjarra

Alcoa is seeking to expand its current operations from the Huntly mine to nearby Myara North and Holyoake, increasing bauxite exports from 5 to 5.25 megatons per annum. This will increase production at its Pinjarra refinery by 5 per cent from 5.0 million tonnes per annum 5.25 million tonnes per annum.[89] Alcoa have previously indicated that it uses 3.1KL of water to refine one ton of alumina.[90] The below analysis (Table 127) uses this benchmark to determine potential increased water needs from Alcoa's expansion of its Pinjarra refinery.

Table 127: Potential increased water needs from Alcoa's Pinjarra refinery expansion

Methodology	Measurement
Water used to refine one ton of alumina	3.1 KL
Current alumina production	5,000,000 tons pa
Total current annual water use	15,500,000 KL
Projected increased alumina production	250,000 tons pa
Water required for projected increase	775,000 KL
Total water required including projected increase	16,275,000 KL

The analysis indicates expansion Alcoa's planned expansion of its Pinjarra refinery will potentially increase its water usage from 15.5 GL to 16.28 GL, an increase of 0.775 GL.

[89] EPA website, Pinjarra Alumina Refinery - Revised Proposal, https://www.epa.wa.gov.au/proposals/pinjarra-alumina-refinery-revised-proposal, last accessed November 2022.
[90] Alcoa, Long Term Residue Management Strategy Pinjarra, 2016.

APPENDIX 5: Groundwater availability as at August 2021

Management Area	Management Sub Area	Local Government	Resource	Allocation status (2021)	Allocation plan
Dwellingup	Dwellingup	Murray	Dwellingup, Dwellingup, Combined - Fractured Rock West - Fractured Rock	limited information	
Jandakot	Forrestdale	Armadale	Jandakot, Forrestdale, Perth - Superficial Swan	fully allocated	
Jandakot	Jandakot Confined	Cockburn	Jandakot, Jandakot Confined, Perth - Yarragadee North.	limited information	
Jandakot	Mandogalup	Rockingham	Jandakot, Mandogalup, Perth - Superficial Swan	fully allocated	
Jandakot	Oakford	Serpentine Jarrahdale	Jandakot, Oakford, Perth - Superficial Swan	allocation remaining	
Jandakot	Wright	Armadale	Jandakot, Wright, Perth - Superficial Swan	allocation remaining	
Kwinana Peel Coastal	Kwinana Peel Coastal	Rockingham	Kwinana Peel Coastal	limited information	
Murray	Coolup	Murray	Murray, Coolup, Combined - Fractured Rock West - Fractured Rock	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Coolup	Murray	Murray, Coolup, Perth - Cattamarra Coal Measures.	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Coolup	Murray	Murray, Coolup, Perth - Lower Leederville.	fully allocated	Murray groundwater allocation plan (2022)
Murray	Coolup	Murray	Murray, Coolup, Perth - Superficial Swan	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Coolup	Murray	Murray, Coolup, Perth - Upper Leederville.	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Nambeelup	Murray	Murray, Nambeelup, Combined - Fractured Rock West - Fractured Rock	allocation remaining	Murray groundwater allocation plan (2022)

Management Area	Management Sub Area	Local Government	Resource	Allocation status (2021)	Allocation plan
Murray	Nambeelup	Murray	Murray, Nambeelup, Perth - Cattamarra Coal Measures.	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Nambeelup	Murray	Murray, Nambeelup, Perth - Lower Leederville.	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Nambeelup	Murray	Murray, Nambeelup, Perth - Superficial Swan	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Nambeelup	Murray	Murray, Nambeelup, Perth - Upper Leederville.	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Nambeelup	Murray	Murray, Nambeelup, Perth - Yarragadee North.	limited information	Murray groundwater allocation plan (2022)
Murray	Pinjarra	Murray	Murray, Pinjarra, Combined - Fractured Rock West - Fractured Rock	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Pinjarra	Murray	Murray, Pinjarra, Perth - Cattamarra Coal Measures.	fully allocated	Murray groundwater allocation plan (2022)
Murray	Pinjarra	Murray	Murray, Pinjarra, Perth - Lower Leederville.	allocation remaining	Murray groundwater allocation plan (2022)
Murray	Pinjarra	Murray	Murray, Pinjarra, Perth - Superficial Swan	fully allocated	Murray groundwater allocation plan (2022)
Murray	Waroona	Waroona	Murray, Waroona, Combined - Fractured Rock West - Fractured Rock	allocation remaining	
Murray	Waroona	Waroona	Murray, Waroona, Perth - Cattamarra Coal Measures.	allocation remaining	
Murray	Waroona	Waroona	Murray, Waroona, Perth - Lower Leederville.	allocation remaining	
Murray	Waroona	Waroona	Murray, Waroona, Perth - Superficial Swan	allocation remaining	
Murray	Waroona	Waroona	Murray, Waroona, Perth - Upper Leederville.	allocation remaining	
Serpentine	Byford 2	Serpentine Jarrahdale	Serpentine, Byford 2, Perth - Cattamarra Coal Measures.	limited information	

Management Area	Management Sub Area	Local Government	Resource	Allocation status (2021)	Allocation plan
Serpentine	Byford 2	Serpentine Jarrahdale	Serpentine, Byford 2, Perth - Leederville.	allocation remaining	
Serpentine	Byford 2	Serpentine Jarrahdale	Serpentine, Byford 2, Perth - Superficial Swan	allocation remaining	
Serpentine	Byford 2	Serpentine Jarrahdale	Serpentine, Byford 2, Perth - Yarragadee North.	limited information	
Serpentine	Byford 3	Serpentine Jarrahdale	Serpentine, Byford 3, Combined - Fractured Rock West - Fractured Rock	limited information	
Serpentine	Byford 3	Serpentine Jarrahdale	Serpentine, Byford 3, Perth - Cattamarra Coal Measures.	fully allocated	
Serpentine	Byford 3	Serpentine Jarrahdale	Serpentine, Byford 3, Perth - Leederville.	allocation remaining	
Serpentine	Byford 3	Serpentine Jarrahdale	Serpentine, Byford 3, Perth - Superficial Swan	allocation remaining	
Serpentine	Byford 3	Serpentine Jarrahdale	Serpentine, Byford 3, Perth - Yarragadee North.	limited information	
Serpentine	Jandakot Mound 1	Serpentine Jarrahdale	Serpentine, Jandakot Mound 1, Perth - Leederville.	limited information	
Serpentine	Jandakot Mound 1	Serpentine Jarrahdale	Serpentine, Jandakot Mound 1, Perth - Superficial Swan	allocation remaining	
Serpentine	Jandakot Mound 1	Serpentine Jarrahdale	Serpentine, Jandakot Mound 1, Perth - Yarragadee North.	limited information	
Serpentine	Jandakot Mound 2	Serpentine Jarrahdale	Serpentine, Jandakot Mound 2, Perth - Leederville.	limited information	
Serpentine	Jandakot Mound 2	Serpentine Jarrahdale	Serpentine, Jandakot Mound 2, Perth - Superficial Swan	allocation remaining	
Serpentine	Jandakot Mound 2	Serpentine Jarrahdale	Serpentine, Jandakot Mound 2, Perth - Yarragadee North.	limited information	
Serpentine	Keysbrook 1	Serpentine Jarrahdale	Serpentine, Keysbrook 1, Perth - Leederville.	allocation remaining	

Management Area	Management Sub Area	Local Government	Resource	Allocation status (2021)	Allocation plan
Serpentine	Keysbrook 1	Serpentine Jarrahdale	Serpentine, Keysbrook 1, Perth - Superficial Swan	fully allocated	
Serpentine	Keysbrook 1	Serpentine Jarrahdale	Serpentine, Keysbrook 1, Perth - Yarragadee North.	limited information	
Serpentine	Keysbrook 2	Serpentine Jarrahdale	Serpentine, Keysbrook 2, Combined - Fractured Rock West - Fractured Rock	limited information	
Serpentine	Keysbrook 2	Serpentine Jarrahdale	Serpentine, Keysbrook 2, Perth - Cattamarra Coal Measures.	fully allocated	
Serpentine	Keysbrook 2	Serpentine Jarrahdale	Serpentine, Keysbrook 2, Perth - Leederville.	allocation remaining	
Serpentine	Keysbrook 2	Serpentine Jarrahdale	Serpentine, Keysbrook 2, Perth - Superficial Swan	allocation remaining	
Serpentine	Keysbrook 2	Serpentine Jarrahdale	Serpentine, Keysbrook 2, Perth - Yarragadee North.	limited information	
Serpentine	Serpentine 1	Serpentine Jarrahdale	Serpentine, Serpentine 1, Perth - Cattamarra Coal Measures.	limited information	
Serpentine	Serpentine 1	Serpentine Jarrahdale	Serpentine, Serpentine 1, Perth - Leederville.	allocation remaining	
Serpentine	Serpentine 1	Serpentine Jarrahdale	Serpentine, Serpentine 1, Perth - Superficial Swan	allocation remaining	
Serpentine	Serpentine 1	Serpentine Jarrahdale	Serpentine, Serpentine 1, Perth - Yarragadee North.	limited information	
Serpentine	Serpentine 2	Serpentine Jarrahdale	Serpentine, Serpentine 2, Perth - Leederville.	fully allocated	
Serpentine	Serpentine 2	Serpentine Jarrahdale	Serpentine, Serpentine 2, Perth - Superficial Swan	fully allocated	
Serpentine	Serpentine 2	Serpentine Jarrahdale	Serpentine, Serpentine 2, Perth - Yarragadee North.	limited information	
Serpentine	Serpentine 3	Serpentine Jarrahdale	Serpentine, Serpentine 3, Combined - Fractured Rock West - Fractured Rock	limited information	

Management Area	Management Sub Area	Local Government	Resource	Allocation status (2021)	Allocation plan
Serpentine	Serpentine 3	Serpentine Jarrahdale	Serpentine, Serpentine 3, Perth - Cattamarra Coal Measures.	fully allocated	
Serpentine	Serpentine 3	Serpentine Jarrahdale	Serpentine, Serpentine 3, Perth - Leederville.	fully allocated	
Serpentine	Serpentine 3	Serpentine Jarrahdale	Serpentine, Serpentine 3, Perth - Superficial Swan	allocation remaining	
Serpentine	Serpentine 3	Serpentine Jarrahdale	Serpentine, Serpentine 3, Perth - Yarragadee North.	limited information	
South West Coastal	Coastal	Mandurah/Murray	South West Coastal, Coastal, Perth - Leederville.	fully allocated	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Coastal	Mandurah/Murray	South West Coastal, Coastal, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Colburra Downs	Murray	South West Coastal, Colburra Downs, Perth - Leederville.	limited information	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Colburra Downs	Murray	South West Coastal, Colburra Downs, Perth - Superficial Swan	limited information	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Falcon	Mandurah	South West Coastal, Falcon, Perth - Cattamarra Coal Measures.	limited information	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Falcon	Mandurah	South West Coastal, Falcon, Perth - Leederville.	fully allocated	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Falcon	Mandurah	South West Coastal, Falcon, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Harvey	Harvey	South West Coastal, Harvey, Perth - Leederville.	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Harvey North	Waroona	South West Coastal, Harvey North, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Harvey South	Harvey	South West Coastal, Harvey South, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Island Point	Mandurah	South West Coastal, Island Point, Perth - Leederville.	limited information	Peel Coastal groundwater allocation plan (2015)

Management Area	Management Sub Area	Local Government	Resource	Allocation status (2021)	Allocation plan
South West Coastal	Island Point	Mandurah	South West Coastal, Island Point, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Lake Clifton	Waroona	South West Coastal, Lake Clifton, Perth - Leederville.	limited information	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Lake Clifton	Waroona	South West Coastal, Lake Clifton, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Lake Preston	Harvey	South West Coastal, Lake Preston, Perth - Leederville.	fully allocated	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Lake Preston North	Harvey	South West Coastal, Lake Preston North, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Lake Preston South	Harvey	South West Coastal, Lake Preston South, Perth - Superficial Swan	fully allocated	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Mandurah	Mandurah	South West Coastal, Mandurah, Perth - Cattamarra Coal Measures.	limited information	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Mandurah	Mandurah	South West Coastal, Mandurah, Perth - Leederville.	fully allocated	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Mandurah	Mandurah	South West Coastal, Mandurah, Perth - Superficial Swan	fully allocated	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Myalup	Harvey	South West Coastal, Myalup, Perth - Superficial Swan	fully allocated	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Wellesley	Harvey	South West Coastal, Wellesley, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Whitehills	Mandurah	South West Coastal, Whitehills, Perth - Leederville.	limited information	Peel Coastal groundwater allocation plan (2015)
South West Coastal	Whitehills	Mandurah	South West Coastal, Whitehills, Perth - Superficial Swan	allocation remaining	Peel Coastal groundwater allocation plan (2015)

Client: Peel Alliance

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