Northern Adelaide Plains Water Stocktake
The Goyder Institute for Water Research

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Acronyms

ADP – Adelaide Desalination Plant

ASR – Aquifer Storage and Recovery

BIL – Barossa Infrastructure Limited

BOOT – Build Own Operate Transfer

CWMS - Community Wastewater Management Schemes

DAFF – Dissolved Air Flotation and Filtration

DEWNR – Department of Environment, Water and Natural Resources

EOI – Expression of Interest

ET – Evapotranspiration

GL - Gigalitre

MAR – Managed Aquifer Recharge

ML – Megalitre

NAIS – Northern Adelaide Irrigation Scheme

NAP – Northern Adelaide Plains

NCEDA – National Centre of Excellence in Desalination Australia

PIRSA – Primary Industries and Regions SA

PWA – Prescribed Wells Area

PWRA – Prescribed Water Resources Area

SRFP – Selective Request for Proposal

SWMZ – Surface Water Management Zone

VPS – Virginia Pipeline Scheme

WAP – Water Allocation Plan

WILMA – Water Information and License Management Systems

WNA – Waterproofing Northern Adelaide

WWTP – Wastewater Treatment Plant

Executive summary

The Northern Adelaide Plains is a major producer of fresh food in South Australia. Growing global demand for food presents a large economic opportunity but requires greater certainty about water availability. Improved understanding of current and future water quantity and quality will support further investment in the region.

It is expected that approximately 26 GL of additional water could be made available for economic development in the region in the short-term, with water quality suitable for most forms of agriculture. This consists of:

- 2.5 GL of winter water from the Virginia Pipeline Scheme that is not being utilised
- 20 GL through the current SA Water Expression of Interest process in relation to upgrades to the Bolivar Dissolved Air Flotation and Filtration plant; and
- approximately 3 GL of water-use efficiency gains in the horticulture sector.

The results of sustainable yields modelling suggest that there could be some increase in groundwater extraction by current licensees (or by transfer of allocation from current licensees), although any such increases would only be possible in the zones beyond the major better water quality extraction zones. Potentially between 2 to 4 GL could be available in these zones for increased extraction, although this is subject to the finalisation of the Adelaide Plains Water Allocation Plan and subsequent decisions by the Minister.

The Gawler River Reuse Scheme will aim to harvest 1.6 GL/year from the Gawler River Prescribed Watercourse. The Western Mount Lofty Ranges Water Allocation Plan (WMLR WAP) covers the Gawler River Prescribed Watercourse. The Plan states that the extraction limit across the plains for the Gawler River is 10 GL. The implementation plan for the Western Mount Lofty Ranges Water Allocation Plan will address how the unallocated water will be made available.

A further 22 GL of water could be available from tertiary aquifers north of the Northern Adelaide Plains Prescribed Wells Area should a suitable solution for lower cost desalination be identified and brine discharge issues addressed.

The region is well known for best practice approaches to harvesting and storing stormwater. Most of the water currently harvested is already allocated for use by Local Government or industry, however, it is estimated that at least another 5 GL/annum of stormwater could be reliably harvested from Adelaide's Northern urbanised catchments. Preliminary analysis suggests that this could be delivered at a lower price than other water sources in the region.

While some pricing information is included, a comprehensive description of price is beyond the scope of this assessment. It is recognised that demand for water sources in the region will be influenced by the full cost of water access, treatment and delivery.

Generating additional water for economic development in the greater Northern Adelaide region will require investment in infrastructure and a coordinated approach to water management to ensure current and potentially new risks do not undermine investment.

There is currently limited use of desalination to generate water for irrigation in the Northern Adelaide region. If there was to be an increase in the use of desalination to generate water for irrigation, the Northern Adelaide region could utilize water from Gulf St Vincent, regional groundwater or water from the Virginia Pipeline Scheme.

A summary of the current water available from alternate sources in the Northern Adelaide Plains and the future potential volume is provided below.

Source	Current volume available/allocated	Future potential volume
Recycled water	SA Water currently provides 19.5 GL of recycled water to the VPS.	2.5 GL of winter water from the VPS is currently not being used. An additional 20 GL of recycled water could be made available subject to further upgrades to the DAFF plant
Groundwater	There is currently 27.12 GL allocated for extraction from the tertiary aquifers. There was 12.11 GL used in 2013/14. This resource is currently considered to be over-allocated, but not over-used.	Potentially between 2 to 4 GL could be available in the prescribed wells area for additional extraction. A further 22 GL could be extracted further north of the prescribed wells area, but salinity is high.
Natural watercourses and stormwater	The median harvestable volume for the primary study region is estimated at 24 GL. *	It is estimated that at least another 5 GL/annum of stormwater could be reliably harvested from Adelaide's Northern urbanised catchments
Water use efficiency	N/A	A 10% water efficiency gain could make another 3 GL of water available for economic development on existing sites.
Gawler River	The Gawler River Reuse Scheme will aim to harvest 1.6 GL/year once operational.	A total of up to 10 GL of water will be made available from the Gawler River under the Western Mount Lofty Ranges Water Allocation Plan.

* This volume includes 10 GL from the Gawler River.

The data layers, such as infrastructure, water resources and crop potential, included in this report are available at: https://sites.google.com/site/goydernap/home/nap_water_map

Recommendations for future work include:

1. developing a water road map, including establishing supporting governance arrangements;

2. preparing a soil and water management plan for the region;

3. implementing grower extension, education and technical support programs;
4. undertaking additional soil and groundwater monitoring, evaluation and research;
5. conducting land use planning investigations;
6. assessing the supply chain costs of water;
7. developing and implementing a stakeholder communications, engagement and social impact assessment program;
8. identifying additional storage solutions;
9. conducting further catchment runoff and stormwater harvesting research;
10. developing water efficiency incentives; and
11. adopting sustainable food production systems.

1 Introduction

1.1 Background

The Northern Adelaide Plains (NAP) is one of South Australia's premier food producing regions. Fresh produce grown in the area is worth over $250 million per annum to the State's economy, with crops such as tomatoes and capsicums from protected cropping (glasshouse) facilities and potatoes and carrots from field horticulture supplying demand in domestic markets (Jensen Planning and Design, et al., 2013). While local demand is expected to rise incrementally, world demand for food is forecast to rise by 70% by 2050. Of most interest to Australia is the rising demand for high quality food products from the middle class in the Asia Pacific, which is set to increase to 2.5 billion people by 2030 (Kharas & Gertz, 2010).

In the short term, growth in the NAP food production economy is expected in horticulture, which already has the largest area under protected cropping in Australia. However, in the longer-term, intensive agriculture may develop as far north as Port Wakefield across to the base of the Mount Lofty Ranges (MLR) including the western Barossa; with growth in intensive pork, poultry, beef and lamb expected.

Continued growth of agriculture in the region will require access to additional land, energy and water. Water has traditionally been sourced from aquifers in the NAP Prescribed Wells Area (PWA) and recycled water from the Bolivar Wastewater Treatment Plant (WWTP) distributed via the Virginia Pipeline Scheme (VPS). Increased access to water at the right price and quality is essential if food production in the region is to expand. However, increased water use must not repeat past problems, which has led to over extraction and waterlogging in some areas.

1.2 Purpose

The South Australian Government engaged the Goyder Institute for Water Research to undertake the NAP Water Stocktake Project, a project to establish the current and potential water available in the NAP region for supporting future agricultural expansion. A map of the primary and greater study region and water catchments is provided in Figure 1 and Figure 2. The primary study region covers the area from the Gawler River south down through primarily the Light Regional Council, City of Playford and City of Salisbury local government areas. The greater study region extends in an arc from Port Wakefield through the Barossa Valley back to the eastern edge of the City of Playford.

The objectives of the project were to:

- determine the current and potential future water available in the NAP;
- establish the historical and potential future risks and opportunities of water use in the NAP; and
- recommend future work required to sustainably mange additional water use in the region.

The results of the project will be used by the Government of South Australia to inform further scoping of potential public and private sector investment in expanding agriculture in the region.

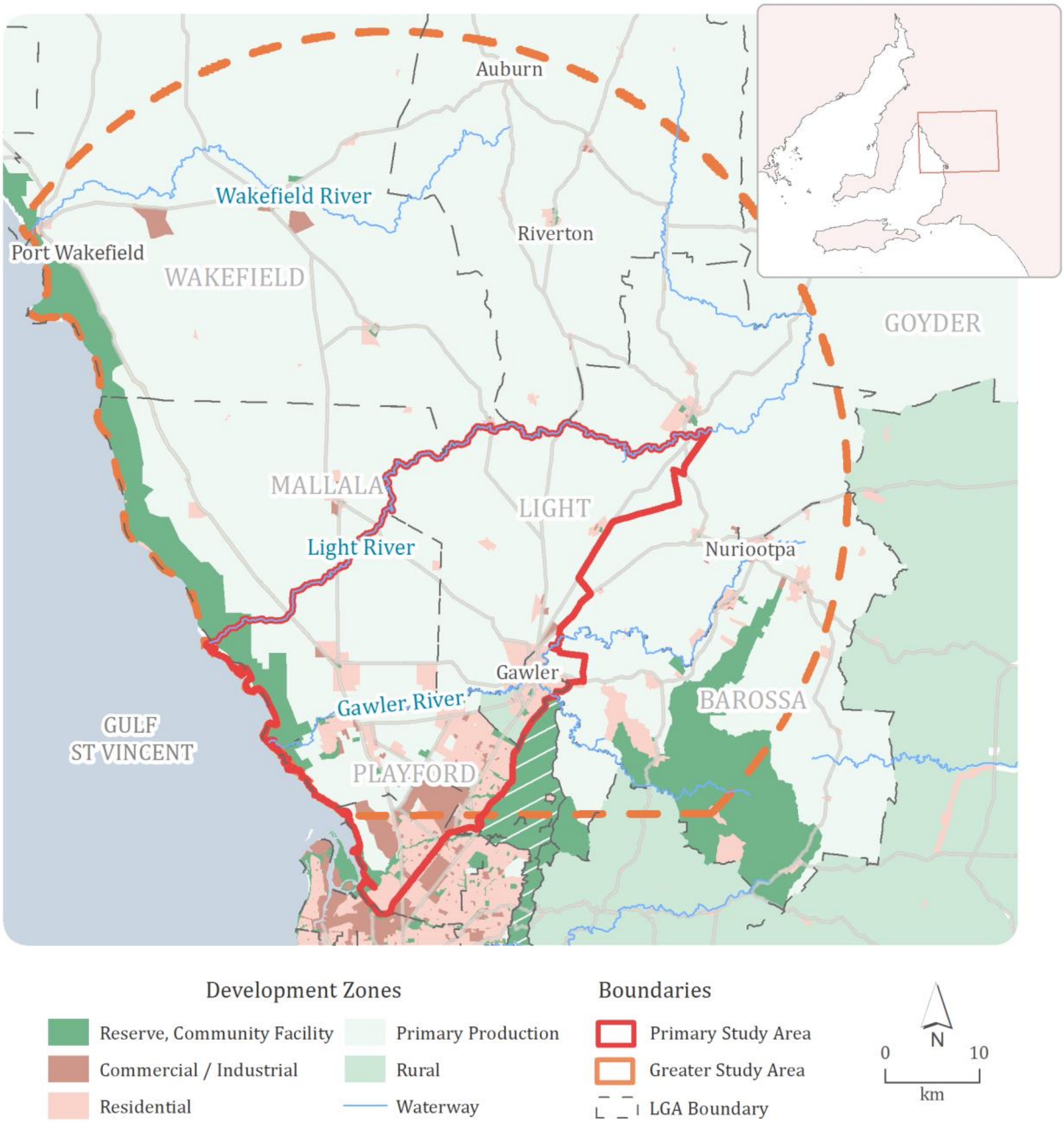

Figure 1. Map of the primary and greater study region for the Northern Adelaide Plains Water Stocktake Project.

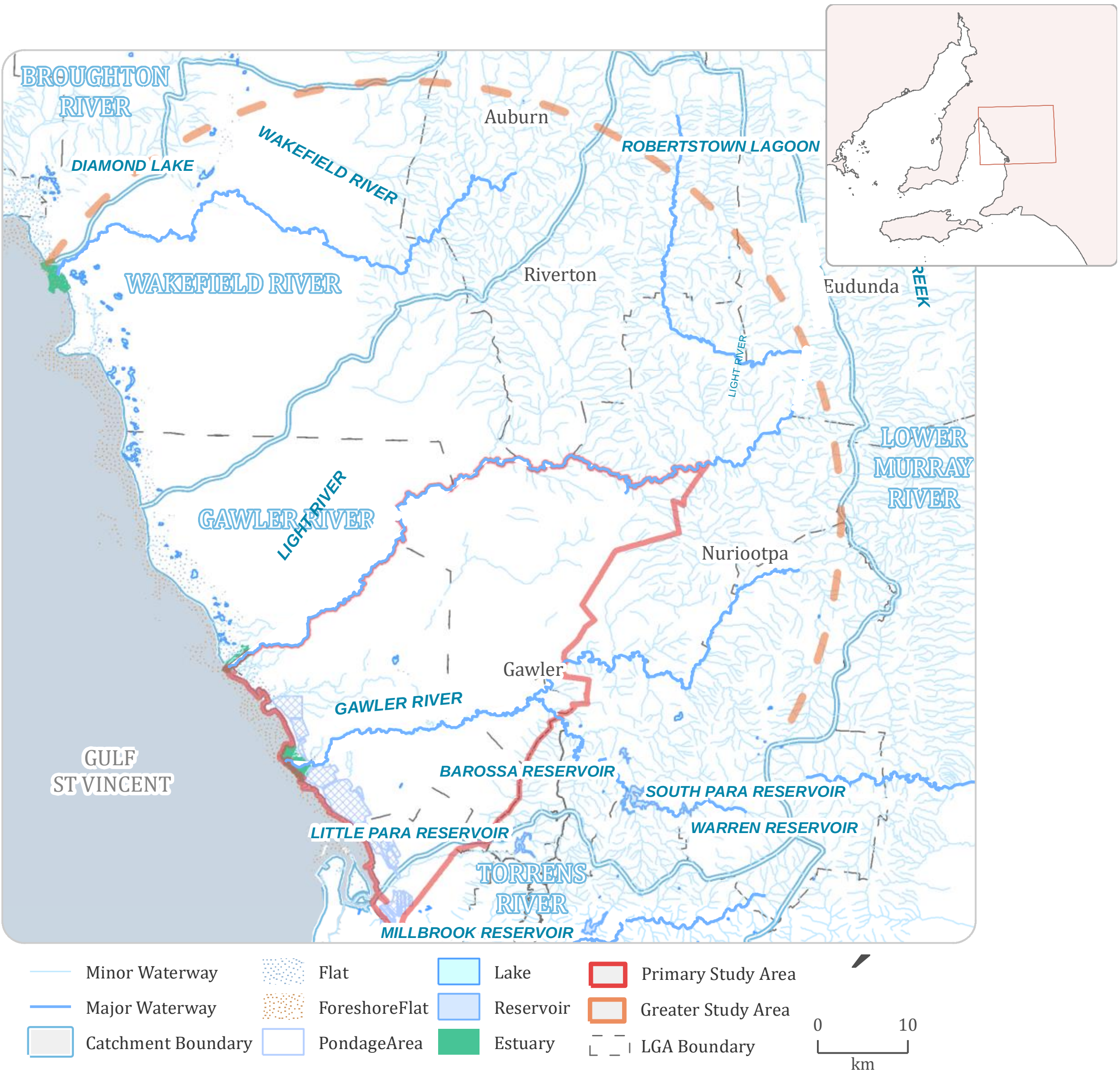

Figure 2. Map of the primary and greater study region for the Northern Adelaide Plains Water Stocktake Project showing water catchments.

2 Recycled water

2.1 Context

The South Australian Recycled Water Guidelines (SA Health, 2012) define recycled water as *"Water generated from sewage, greywater, stormwater, rainwater, industrial or animal processes and treated to a standard that is appropriate for its intended use".*

Recycled water in South Australia can be found in most regions, where it is collected and treated via a range of methods and from a variety of sources including large and small scale sewage treatment works, Community Wastewater Management Schemes (CWMS), winery waste water, septic systems and treated stormwater.

In the NAP, the primary source of recycled water is from the Bolivar WWTP, which is South Australia's largest WWTP[1]. Built in 1965, the plant processes 60% of metropolitan Adelaide's raw wastewater (sewage) and treats approximately 0.14 GL of residential and industrial water per day (SA Water, 2012). This equates to approximately 49 gigalitres (GL) of wastewater treated every year. SA Water owns the Bolivar WWTP, which is operated on its behalf by Allwater.

Three different treatment plants are located on the Bolivar site:

- The Bolivar WWTP treats sewage from most of Adelaide north of the River Torrens. Up to 30% of this wastewater is recycled after further treatment at the Bolivar Dissolved Air Flotation and Filtration (DAFF) plant (see below);

- The Bolivar High Salinity WWTP, which treats sewage from the north-western suburbs. This sewage is relatively saline and not suitable for reuse for irrigation.

- The Bolivar DAFF plant, which treats wastewater from the Bolivar WWTP through a tertiary process of filtration and disinfection, so that it is suitable for recycling for horticulture via the VPS in the NAP (predominantly in the Virginia/Angle Vale area) and dual reticulation at Mawson Lakes (with additional chlorination).

On leaving the Bolivar DAFF plant, recycled water is currently either discharged to the Gulf St. Vincent under Environment Protection Authority licence conditions or directed to the VPS.

The VPS forms a critical part of the treatment train of the Bolivar WWTP, assisting in meeting SA Water's Bolivar WWTP Licence Conditions and operating plan (SA Water, 2015).

The VPS is managed by Trility Pty Ltd under a Build Own Operate Transfer (BOOT) contractual arrangement. The VPS provides irrigation water to a range of horticultural enterprises in the NAP including field crops such as potatoes and onions, as well as shade house and glasshouse production, which includes a number of high technology protected cropping glasshouses for tomatoes, capsicums and cucumbers.

In 2004, SA Water extended the VPS to Angle Vale. Trility pay an access fee to use this infrastructure to transport recycled water to customers. SA Water owns this section of the network and Trility currently operates and maintains it on SA Water's behalf.

SA Water intends to exercise the option for the ownership to transition to SA Water at the BOOT end date of 1 January 2018, whereupon SA Water will become the owner of the scheme. SA Water reserves the option to outsource the operation and maintenance of the VPS either as a separate request to the market or as part of the consideration of the responses to the current Expression of Interest (EOI), which is primarily focussed on seeking interest from the private sector to make the required upgrades to the Bolivar DAFF plant to generate additional recycled water (EOI, closed 24/11/2015).

The VPS is currently at summer supply capacity with some ability to provide additional water to customers in winter (see capacities in Section 2.2 below).

[1] Unless stated otherwise, the majority of information presented in this section of the report is based on the SA Water Expression of Interest documentation (SA Water, 2015).

To increase the amount of recycled water available for horticultural enterprises, an expansion of infrastructure is required. This will involve upgrading the Bolivar DAFF plant and investing in additional pipelines to more widely distribute recycled water.

2.2 Current water availability

The Bolivar WWTP currently processes a total of approximately 49 GL of wastewater per year. Of this water, not all is suitable for reuse due to salinity and other water quality parameters.

SA Water is currently contracted to supply 19.5 GL of recycled water per year from the Bolivar DAFF to the VPS (12.5 GL summer water and 7 GL winter water). The VPS currently distributes approximately 17 GL to about 400 horticultural irrigation customers. The unused 2.5 GL is only available during winter, which would require storage if it cannot be used during this period. A maximum of 0.105 GL can be supplied per day through the VPS, of which users can access a maximum of 0.54% of their contracted volume in a 24 hour period.

A range of water quality analyses have been provided by SA Water as part of the EOI process. Tables of detailed analysis are included in Attachment A, with summary information in Table 1. The summary data illustrates the variable nature of water quality through the year. For example, during the 2014/15 year the following was observed:

- Total Dissolved Solids - 856 mg/L to 1200 mg/L
- Nitrogen (total) – 8.97 mg/L to 13.53 mg/L
- Phosphorus (total) – 1.36 mg/L to 3.53 mg/L
- Sodium – 241.5 mg/L to 329 mg/L

Bolivar WWTP Effluent Weir 1 Summary Report													
2011-12													
EFFLUENT		July	August	September	October	November	December	January	February	March	April	May	June
Total Dissolved Solids	mg/L	988	1,020	1,100	1,100	1,100	1,050	966	998	944	900	878	890
Nitrogen - Total	mg/L	16.15	19.40	20.42	19.67	19.03	16.92	16.22	7.11	9.36	13.85	16.46	17.94
Phosphorus - Total	mg/L	2.90	2.98	3.18	3.88	3.42	2.05	2.43	4.07	3.51	2.85	3.46	2.97
Sodium	mg/L	241.0	276.0	296.0	288.0	270.0	256.0	281.0	252.0	245.0	227.0	234.0	235.0
2012-13													
Total Dissolved Solids	mg/L	1,004	1,100	1,140	1,183	1,100	1,075	970	914	863	824	810	916
Nitrogen - Total	mg/L	15.58	19.96	20.68	16.05	14.76	12.85	13.62	10.91	11.50	10.62	12.02	9.54
Phosphorus - Total	mg/L	3.27	3.48	2.89	2.33	2.96	2.45	2.34	2.29	2.73	1.93	1.49	2.13
Sodium	mg/L	252.0	311.0	298.5	259.0	295.0	281.0	270.0	268.0	242.0	239.0	253.0	247.0
2013-14													
Total Dissolved Solids	mg/L	982	1,040	1,140	1,220	1,080	1,032	1,060	1,120	1,100	1,060	966	1,040
Nitrogen - Total	mg/L	11.00	10.94	12.24	10.73	12.61	10.01	4.02	5.85	7.36	10.11	11.82	10.07
Phosphorus - Total	mg/L	3.06	2.75	3.27	2.45	2.25	1.93	3.26	2.11	2.56	2.19	2.22	2.68
Sodium	mg/L	278.0	301.0	310.0	343.0	303.0	304.0	300.0	258.0	318.0	290.0	251.5	283.0
2014-15													
Total Dissolved Solids	mg/L	1,032	1,160	1,200	1,200	1,040	1,000	992	996	902	856	922	952
Nitrogen - Total	mg/L	12.88	9.86	11.20	11.03	11.40	8.97	11.43	12.96	9.31	13.35	13.53	10.65
Phosphorus - Total	mg/L	2.227	2.120	3.393	3.525	2.683	2.865	1.967	2.237	1.355	2.387	1.775	1.643
Sodium	mg/L	265.0	326.0	328.0	329.0	291.0	280.0	295.0	272.0	244.0	241.5	242.0	253.0

Table 1. Sample of indicative water quality parameters, SA Water Bolivar DAFF plant 2011-2015 (Source: (SA Water, 2015) Bolivar Weir 1 Water Quality Data 2011 to 15.xlsx).

The price of water from the VPS is based on supply and consumption charges. An annual supply fee of $1,219.54 is charged to each customer for up to three connections per customer. Beyond three connections, the supply fee is charged per each additional connection.

VPS water has consumption charges based on seasonal tiers as follows:

- Spring – 12.20 cents per kilolitre;
- Summer – 15.40 cents per kilolitre;
- Autumn – 12.20 cents per kilolitre;
- Winter – 8.13 cents per kilolitre.

The full cost of this water will be higher for many growers once on-farm pumping and additional water quality treatment are accounted for.

2.3 Potential additional water available

An additional 20 GL of recycled water can be produced from the Bolivar WWTP by upgrading the existing Bolivar DAFF plant. To produce fit for purpose irrigation water, two actions are required:

1. **optimisation** of the Bolivar DAFF plant to enable a further 8 GL of tertiary treated irrigation water, and
2. **expansion** of the Bolivar DAFF plant to treat and produce an additional 12 GL of irrigation water.

Of the 20 GL, 12 GL would be available for summer use and 8 GL for winter use, which would require storage if it is not able to be fully utilised. Distribution of this water may require the following infrastructure: a transfer pipe from the Bolivar DAFF plant to north of the Gawler River; the proposed Northern Adelaide Irrigation Scheme (NAIS); a new pump station; a storage solution such as managed aquifer recharge (MAR); and a distribution network to deliver water to new water users during the peak irrigation season.

Up to an additional 5 GL could become available from the Bolivar WWTP by investing in further upgrades to the tertiary treatment capacity. This upgrade is not presently being considered and it is understood that it would require significant additional investment.

The quality of water from the optimisation and expansion of the Bolivar DAFF plant is expected to be similar to that reported in the EOI process documentation (Attachment A) and in Table 1. It should be noted, however, that SA Water has received feedback from horticulturalists using the VPS, that a reduction in current levels of sodium and salinity would benefit existing and potential new irrigation users.

It is likely that pricing for recycled water through the VPS will be an outcome of a Selective Request for Proposal (SRFP) following the SA Water EOI process. It is not clear how or if current VPS price structures for recycled water will change, although there are some concerns amongst growers in the region that prices will rise.

2.4 Future demand

Whilst the profile of future demand in the NAP region is not yet fully understood, additional use of recycled water for agricultural, or other, uses is expected to benefit the State through an increase in jobs and economic productivity Spoehr *et al*. (2015).

Assuming that horticulture utilises most of the 20 GL that becomes available from an expanded Bolivar DAFF plant, it is reasonable to assume that increased demand will occur over a number of years. The exact timing will be influenced by the successful EOI proponent.

Some of the recycled water available could also be utilised in the northern Adelaide urban expansion areas as water for recreational spaces and green infrastructure. It has become increasingly well accepted that Australia's rapidly growing suburbs will need to incorporate more green infrastructure (see, for example, the Vision 202020 initiative[2]). Whilst Northern Adelaide has well-planned and established stormwater MAR schemes, the capacity of these schemes to fully service recreational green space and additional green infrastructure is limited (see Surface water section of this report). Continued reliance on mains water for irrigation of green infrastructure is not considered sustainable in the long term. Demand for water for open space irrigation and urban cooling purposes may increase in a warming climate.

2.5 Climate risk

The vast majority of wastewater that is treated and subsequently recycled at the Bolivar WWTP is derived from domestic, commercial and industrial use of potable water which is discharged to the sewer network. A review of influent volumes into Bolivar WWTP from 2009 to present shows a minor (<5%) change in inflow volumes between an average to wet rainfall year and a dry rainfall year, and <7% difference between the average winter and average summer month inflows. This demonstrates the relative stability of inflows, and available recycled water from the Bolivar WWTP, however, population growth and expansion of industry will see an increase in total flows into Bolivar.

The main difference between wet and dry years, and hence the main aspect that may be affected by future climate change, is the salinity of the influent. There is a 10% increase in influent salinity during wet winters as opposed to dry winters, which shows that there is a relationship between seasonal rainfall volumes and subsequent groundwater infiltration into the sewer network. With a drying climate the groundwater level is expected to remain low in the short to medium term, resulting in the salinity generally remaining stable at the lower end of the salinity range of the influent although more frequent extreme high rainfall events could cause occasional short term spikes.

In the distant future, influent salinity may trend upwards if groundwater levels increase due to sea level rise and infiltration still occurs. However, it is anticipated that by this stage, advances in the design/installation of wastewater collection infrastructure will be more effective in reducing infiltration and ultimately protecting the quality of the recycled water. The extent to which such new technologies are deployed at a faster rate than the regular mains replacement program will however depend on cost and other broader considerations.

2.6 Summary

There is currently 19.5 GL of recycled water generated by SA Water from the Bolivar WWTP. Of this, 17 GL is being delivered to horticulturalists accessing the VPS.

Optimisation and upgrades to the Bolivar DAFF plant will make an additional 20 GL of recycled water available, bringing the total amount of recycled water available for irrigation to

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[2] http://202020vision.com.au/

39.5 GL. This includes an additional 12 GL during summer and 10.5 GL during winter (which includes currently unused winter water).

Use of this water in the region will require identification of suitable storage solutions, especially for water available during winter.

3 Groundwater

3.1 Context

The NAP PWA lies just to the north of the Adelaide Metropolitan Area and comprises quaternary and tertiary sedimentary aquifers of the St Vincent Basin. There are four main quaternary aquifers (although in some areas, up to six exist), while the tertiary sediments contain up to four confined aquifers which exhibit large variations in thickness, lithology, salinity distribution and yield. Both the quaternary and tertiary aquifers are categorised in order of increasing depth. Figure 3 presents a north-south hydrogeological cross section through the PWA.

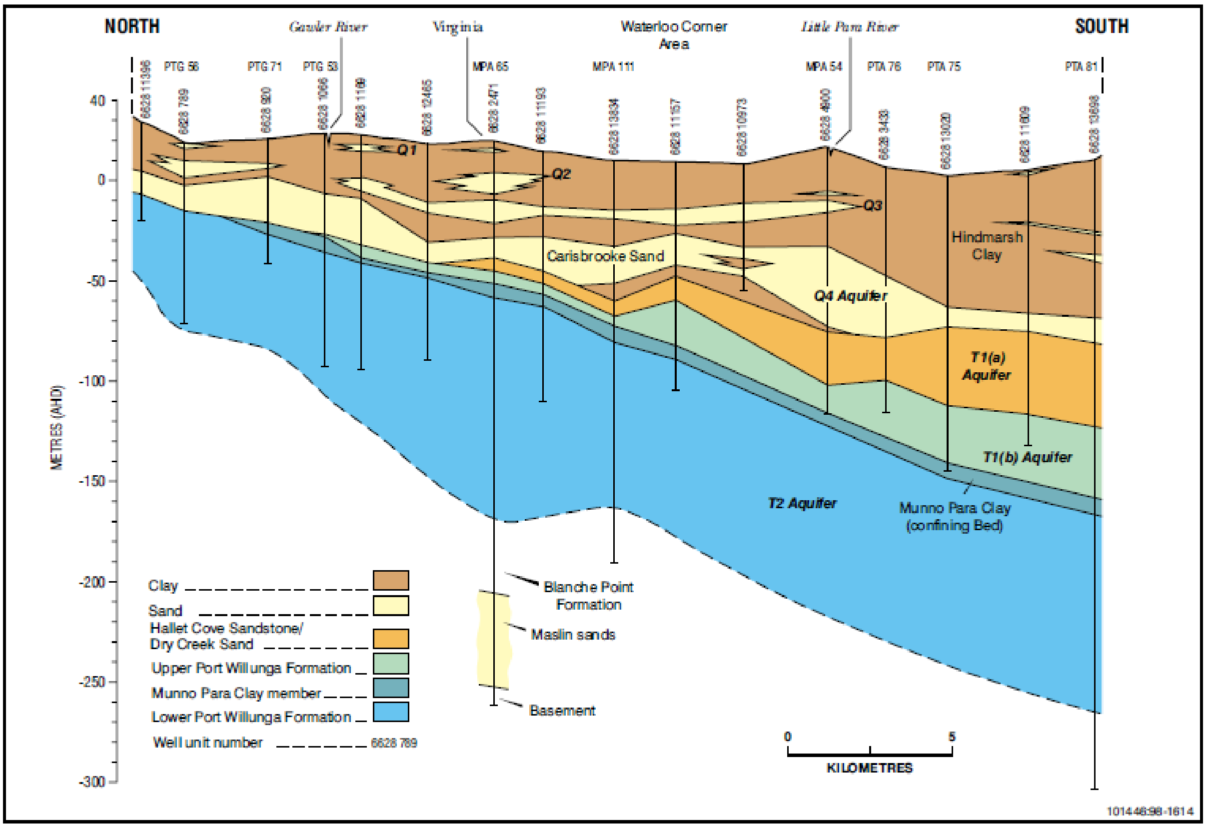

Figure 3. North-south hydrogeological cross section through the NAP PWA.

3.1.1 Shallow Quaternary Aquifers

The Quaternary sediments (predominantly the Hindmarsh Clay) mainly consist of mottled clay and silt with interbedded sand and gravel layers, which form aquifers. The shallowest aquifer is the perched aquifer, which is formed when infiltrating surface water is hindered by a low permeability layer. The waterlogging is caused by a combination of natural shallow aquifers and human impacts. Below this aquifer, there are generally up to four quaternary aquifers (Q1–Q4) over most of the PWA. Salinity in these aquifers is highly variable with yields generally too low for significant irrigation development.

3.1.2 T1 Aquifer

The T1 aquifer is the only aquifer developed in the southern half of the PWA in the vicinity of Waterloo Corner and is absent in the northeast portion of the NAP. This aquifer extends well to the north of the PWA boundary, where it consists mainly of sand and contains higher salinity groundwater. Figure 4 shows the extent, salinity distribution and the location of licenced and other wells extracting from the T1 aquifer.

3.1.3 T2 Aquifer

The second tertiary aquifer comprises the T2 aquifer which underlies the Munno Para Clay confining layer and occurs throughout the entire NAP. It consists of well-cemented limestone of the lower Port Willunga Formation and is the predominant aquifer utilised in the northern part of the PWA between Virginia and Gawler. It does not extend past the northern boundary of the PWA boundary. Figure 5 shows the extent, salinity distribution and the location of licenced wells extracting from the T2 aquifer.

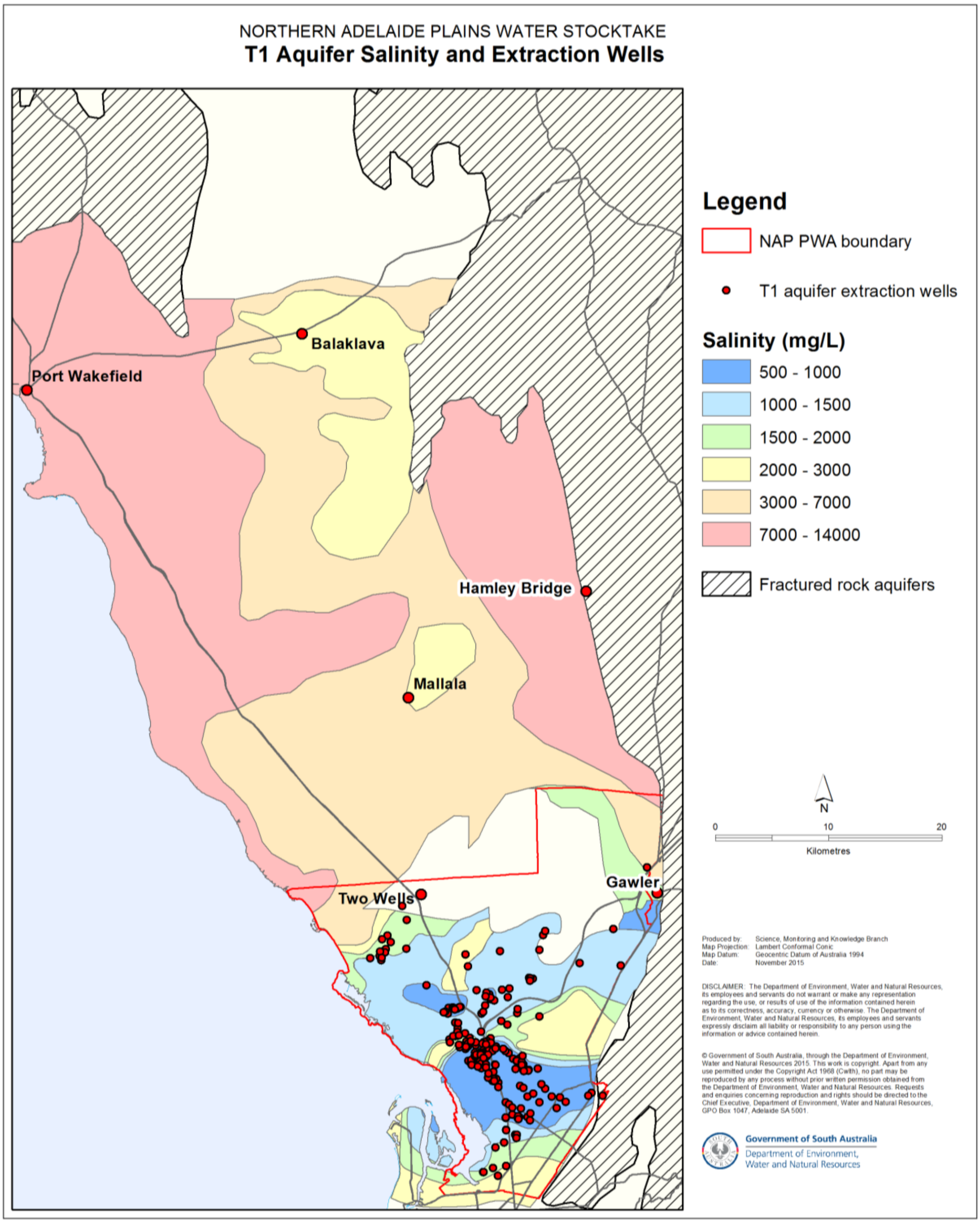

Figure 4. T1 aquifer salinity distribution and extraction wells. In the northern part of the region there is no difference between the T1 and T2 aquifer because of the absence of the Munno Para Clay confining bed.

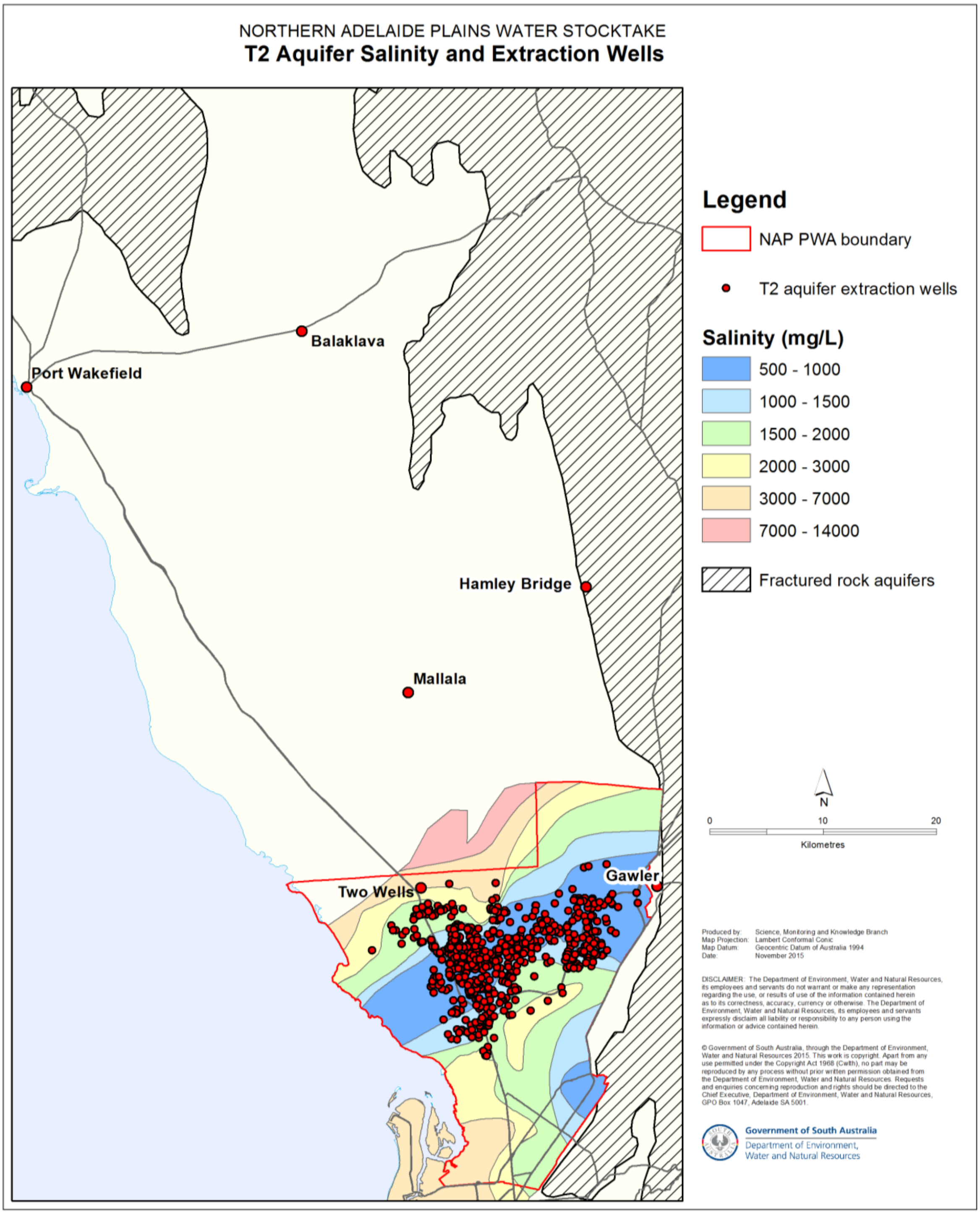

Figure 5. T2 aquifer salinity distribution and extraction wells.

3.1.4 T3 and T4 Aquifers

The distribution of these aquifers is not well known because of their depth and poor water quality. They are thought to occur over most of the NAP in the South Maslin Sand and occasionally North Maslin Sand layer, which directly overlies the basement fractured rock aquifer. Given their poor water quality (more saline than seawater), they are not considered a potential source of additional water for the region.

3.2 Current water availability

The metered use for both the T1 and T2 aquifers since 2005 is presented in Figure 6, along with the current allocation. This shows current levels of extraction based on information from the Department of Environment, Water and Natural Resources (DEWNR) licensing database "Water Information and License Management System" (WILMA) as being 12.11 GL per annum (based on 2013/14 extraction), which consists of 3.46 GL of use in 2013/14 from the T1 aquifer and 8.66 GL from the T2 aquifer.

This is well below the current volume of groundwater allocated for extraction which is 7.26 GL from the T1 aquifer and 19.86 GL from the T2 aquifer (total of 27.12 GL per annum), but additional water is not available because extractions are at current limits (see Section 3.3.1).

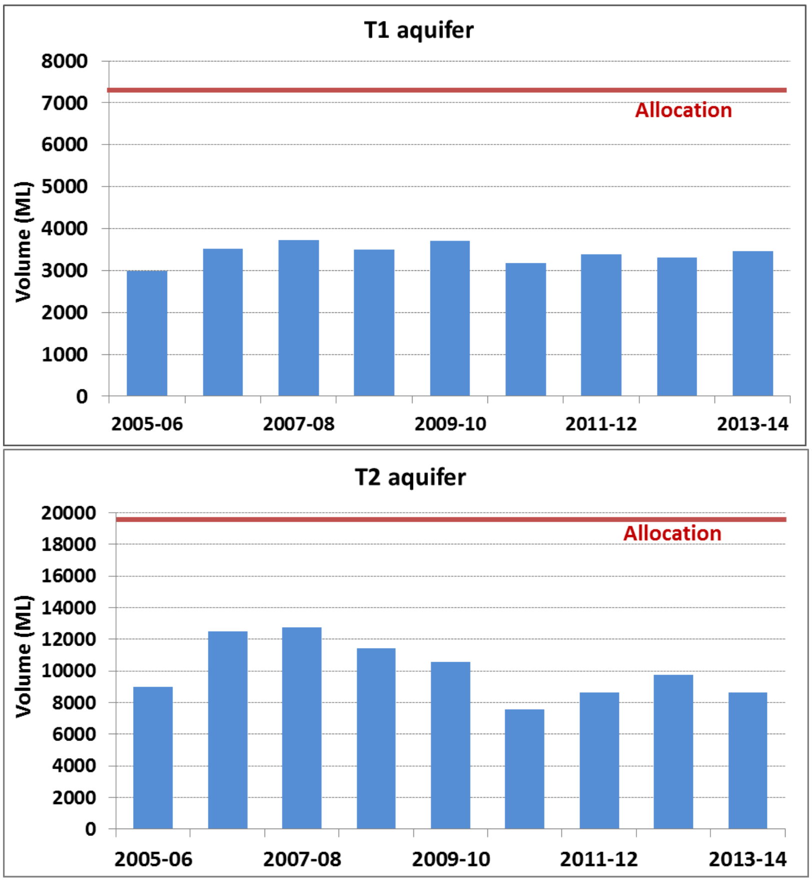

Figure 6. Metered extraction from the T1 and T2 aquifers in the NAP PWA.

The metered extraction from the various quaternary aquifers is about 540 ML/yr, which is also well below the allocated volume of 3.16 GL ML, but this is due to the poor quality (high salinity) of this resource.

The salinity ranges of the groundwater extracted are presented in Figure 7 for the 2013-14 water use year. It shows that most of the groundwater extracted in the NAP PWA is below 1000 mg/L (TDS).

The differences between groundwater allocations and use should be viewed with a consideration of the changes in groundwater levels over past decades. Between 1969 and

1999, extractions from the T2 aquifer have created long-standing groundwater level depressions centred on Virginia where intensive irrigation occurs. After a slight recovery in water levels from 2002 to 2005, below-average rainfall from 2006 led to increased extraction and a slight downward trend in water levels. Over the last five years, levels either stabilised or rose. Near the coast in the south-west of the PWA, industrial extraction has recently significantly decreased leading to a recovery of water levels in this area.

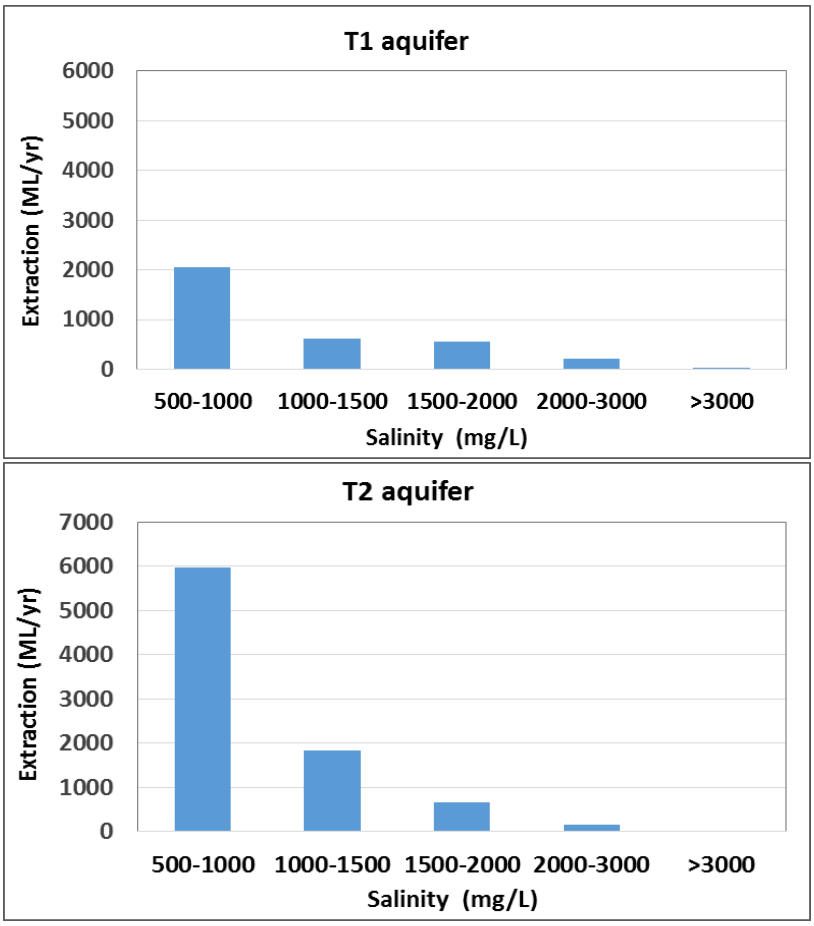

Figure 7. Salinity ranges of groundwater extraction in the NAP PWA.

3.3 Potential additional water availability

3.3.1 Northern Adelaide Plains Prescribed Wells Area

A groundwater modelling exercise carried out to determine sustainable yields for the whole of the Adelaide Plains (Watt, et al., 2014) found that use of the full current allocations from both aquifers would have adverse impacts on the resource. The T1 aquifer would experience continually declining water levels, while the T2 aquifer would be depressurised over a significant area. While current rates of groundwater use are considerably lower than allocated volumes, the modelling indicates that parts of these aquifers are over-allocated.

The modelling exercise recommended a range of extraction limits for the Central Adelaide WAP consultation process. These are 3,520 – 3,840 ML/yr for the T1 aquifer, and 15,900 – 16,800 ML/yr for the T2 aquifer. These volumes represent a small increase over current levels of extraction, but there will likely be spatial constraints on where this water can be extracted due to salinity limitations.

3.3.2 North of the Northern Adelaide Plains Prescribed Wells Area

There is little use of water for irrigation north of the NAP PWA because of generally high salinities. Areas of potentially usable groundwater below 3,000 mg/L in the T1 aquifer occur in the vicinity of Balaklava where recharge from the Wakefield River has probably occurred historically in wetter climates. Limited extractions for irrigation occur in the Balaklava area where salinities are 2000 mg/L. There is potential for further extraction from the T1 aquifer, but depending on the proposed use, some desalination or dilution may be necessary.

Figure 8 presents order of magnitude estimates of the potential yield from the T1 aquifer north of the NAP PWA according to salinity range. Further investigations will be required to refine these estimates if necessary.

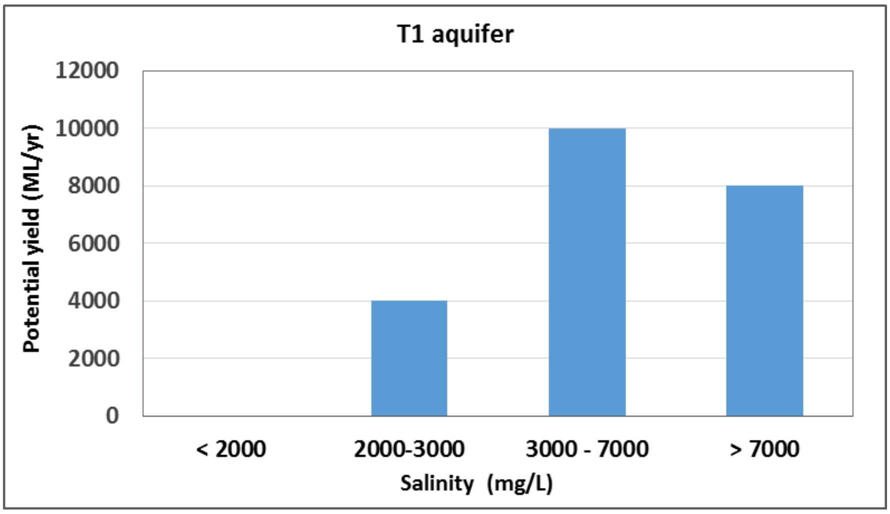

Figure 8. Salinity ranges of groundwater potential north of the NAP PWA.

3.4 Climate risk

Two reports (DEWNR, 2014; Goyder Institute for Water Research, 2015) have considered the potential impact of climate change on the unconfined quaternary aquifers in the Adelaide area. The Department of Environment, Water and Natural Resources (DEWNR, 2014) examined the impacts of projected future rainfall changes in the Adelaide metropolitan area on the elevation of the watertable in the uppermost quaternary aquifer in a central western suburb of Adelaide. This analysis indicated potentially steep declines in watertable levels in response to a large number of future rainfall scenarios projected by a range of climate models.

Goyder Institute Technical Report 14/28 (Goyder Institute for Water Research, 2015) examined the impact of projected climate change on groundwater recharge to the unconfined aquifer in the Cox Creek catchment in the Western Mount Lofty Ranges (MLR). This study found groundwater recharge to shallow aquifers to be susceptible to changes in rainfall and potential evapotranspiration, reducing by up to 44% under some projected future climates. Based on these findings, the shallow and unconfined quaternary aquifers of the NAP and to the North of the NAP are assessed as having a moderate to high sensitivity to climate change.

For the confined tertiary aquifers (T1 and T2) in the NAP and the study area to the north, the sensitivity to climate change is assessed as low. The groundwater within the confined tertiary aquifers in the study area has a different relationship to contemporary climate conditions compared to the unconfined quaternary aquifers. The deeper confined tertiary aquifers are mostly recharged by water flowing laterally from connected aquifers rather than by downwards infiltration of contemporary rainfall. Hence, water recharging the tertiary aquifers is not as susceptible to climate change in the coming decades.

Tertiary aquifer water (pressure) levels may be affected indirectly by climate change due to declining water levels in the adjacent aquifers that are more directly recharged by contemporary rainfall. A second DEWNR report (2013) discusses outcomes of an unpublished modelling investigation that found tertiary aquifer pressures in the central NAP would decline by less than 1 metre over a period of ninety years after a theoretical decline of 10 metres in aquifer levels in the adjacent fractured rock aquifers of the Western MLR. A similar modelling exercise (Bresciani, et al., 2015, in prep) reports that tertiary aquifer groundwater levels in the Northern and Central Adelaide Plains showed very little change over a period of decades in response to changing recharge and boundary conditions that could occur under projected climate change. The tertiary aquifers to the north of the NAP PWA are similarly confined and expected to respond to climate change in a similar way to those within the NAP and Central Adelaide Plains areas.

3.5 Summary

Within the NAP PWA, there is currently 7.26 GL of groundwater allocated for extraction from the T1 aquifer and 19.86 GL of groundwater allocated in the T2 aquifer. There was 3.46 GL of use in 2013/14 from the T1 aquifer and 8.66 GL from the T2 aquifer. However, this resource is currently considered to be over-allocated (27.12 GL).

Recent modelling of sustainable yields recommended extraction limits of approximately 3.5 – 3.8 GL/yr and 16 - 17 GL/yr for the T1 and T2 aquifers respectively, including the Kangaroo Flat area (total 20.8 GL). These volumes indicate that there could be some increase in extraction by current licensees (or by transfer of allocation from current licensees), although any such increases would only be possible in the zones beyond the major better water quality extraction zones. Potentially between 2 to 4 GL could be available in these zones for increased extraction, although this is subject to the finalisation of the Adelaide Plains Water Allocation Plan and subsequent decisions by the Minister.

The WAP for this region has been reviewed and is currently being amended. The quantum and location of any increased extraction cannot be quantified until the WAP is confirmed. Trading of water between licence holders is likely to continue to be the main option for increasing the economic development opportunity of this resource.

The tertiary aquifer to the north of the NAP PWA contains an estimated 22 GL of water that could be extracted per annum, however, the salinity is poor and not suitable for agriculture without augmentation, for example with desalination technology or blending with fresh water. Of the 22 GL, 4 GL is considered to be in the 2,000 to 3,000 mg/L range, 10 GL in the 3,000 to 7,000 mg/L range and 8 GL above 7,000 mg/L.

There is limited water available from the shallower quaternary aquifer in the region. Small volumes are currently used for limited applications such as stock and domestic use.

4 Surface water

4.1 Context

The NAP region is characterised by gentle undulating plains and floodplains of two major rivers; the Gawler and the Light that originate in the hills in the east, which are outside the NAP, and drain to the Gulf St Vincent in the west. In addition to the runoff generated from developed areas and smaller creeks, the major surface water resources are predominantly those of the Lower Light and Gawler Rivers, the latter of which has much more substantial, albeit highly variable flow. The two rivers lose water to groundwater (recharge) in certain sections and gain from groundwater in other sections. It is highly likely that in the gaining sections of the rivers, groundwater contribution is critical in maintaining persistent pools and their dependent ecosystems.

Annual rainfall across the region ranges from 600 – 700 mm in the upper parts of the Barossa Prescribed Water Resources Area in the north down to 200 – 300 mm across the majority of the plains. The Gawler Belt, which extends from the North East down to Adelaide City experiences annual rainfall in the range 400 – 500 mm. This low rainfall translates to minimal surface water resources being generated within the region, with the minor creeks being ephemeral with highly variable flows, with the exception of the Gawler River.

The main surface water catchments within the NAP, as described below, are the Light River, the Gawler River, Dry Creek, Smith Creek, Adams Creek and the Little Para River catchments. Figure 9 shows the location of the Light River and Gawler River catchments.

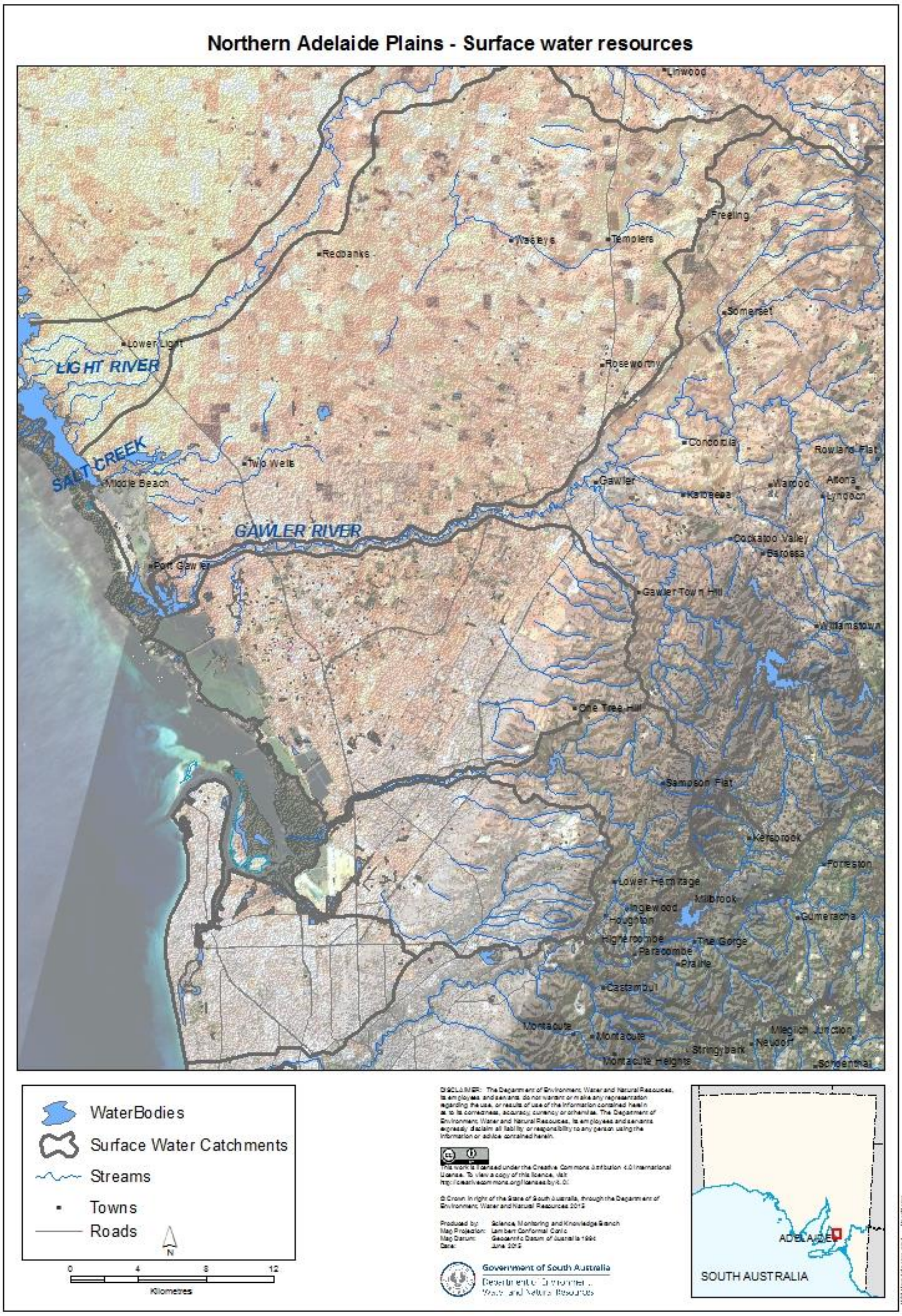

Figure 9. Surface water catchments of the Northern Adelaide Plains.

4.2 Major surface water catchments

4.2.1 Gawler River

Catchment area: 1,050 km^2 comprised of 340 km^2 for the South Para, 710 km^2 for the North Para and the relatively narrow Gawler River zone over the NAP to the coast.
Average total discharge volume (Gawler River): 17.82 GL (2005 – 2015, site A5050510)
Average total discharge volume (North Para River): 6.35 GL (2010 – 2015, site A5051004)
Average total discharge volume (South Para River): 4.57 GL (2005 – 2015, site A5050503). NB: Streamflow is influenced by three on-stream reservoirs upstream of the gauging station.

The Gawler River catchment includes the sub-catchments of the North and South Para rivers. The Gawler River extends for 30 km to the coast from the confluence of these two rivers. Farm dams and water supply reservoirs in the North and South Para catchments have altered the flow regime of the Gawler River. The river is perched along its entire length across the floodplain, with its capacity reducing from 450 m^3/s near Gawler to 70 m^3/s near Virginia and to 10 m^3/s near the coast. This reduction in capacity means that the Gawler River frequently floods and inundates the surrounding plain for extended periods after flood events, creating a lens of freshwater over saline groundwater. The Gawler River receives water from reservoir overflow and releases, in addition to localised surface water runoff and flows into an estuary, which terminates at Buckland Park Lake, with delta creeks at Port Gawler. It is classified as a tide dominated creek in the lower reaches. Buckland Park is an estuarine wetland, which was artificially created by damming the deltaic mouth of the Gawler River system. There is considerable variation in the filling and drying regime of the wetland from year to year. The wetland is often filled during the winter period with flood flows from the Gawler River. These flows have the effect of reducing salinity levels in the wetland. The upstream development of the catchment has also altered the flow regime of the estuary.

The Gawler River, downstream of the junction of the North and South Para rivers, is a Prescribed Watercourse in the Western MLR Prescribed Water Resources Area. Extraction limits and minimum and maximum threshold flows rates have been set through the Western MLR WAP (AMLR NRM Board 2013). Specifically, 10 GL per annum is the extraction limit defined in the WAP, with water allowed to be extracted at flows rates of between 500 to 690 L/s. The South Para River catchment is also specified in the Western MLR Prescribed Water Resources Area (PWRA) and each Surface Water Management Zone (SWMZ) has respective limits (see Table 5.6, page 109-110 AMLR NRM Board (2013)).

4.2.2 Light River

Catchment area: 1,820 km^2
Average total discharge volume: 3.98 GL (2002 – 2014, site A5050532)

The Light River is an unregulated ephemeral river system, mainly used for stock and domestic purposes. There are three main sections: upper, middle and lower. The upper section of the river, from Hamley Bridge to the Redbanks Fault is cut down to the bedrock and has formed a series of permanent pools. At Redbanks, the river changes from a gaining stream to a losing stream and here the river changes from a deep channel to a wide floodplain. The river becomes an estuary approximately four kilometres from the coast and changes from a deep freshwater channel to a narrow, shallow box shaped channel with a series of tidal channels. Two permanent pools link the freshwater section of the river to the estuary.

Most of the catchment is used for dryland agriculture, with cereal, grain legume and canola cropping, as well as sheep and cattle grazing. The Light River catchment has comparatively low water resource development potential, owing to the typically low volume flows within the catchment. There are currently only a few farm dams, predominantly in the upper catchment. Despite this, the watercourses have been modified significantly by land use practices such as vegetation clearing and grazing.

The ephemeral nature of the Light River means it is particularly reliant on sufficient periodic surface flows to flush the permanent pools, which increase in salinity during dry periods.

4.3 Minor surface water catchments

4.3.1 Dry Creek

Catchment area: 105 km^2
Average total discharge volume: 3.78 GL (2001 – 2013, site A5041051)

The Dry Creek catchment is bounded by the Little Para River catchment to the north and east, and the River Torrens catchment to the south and extends to the top of the Hills Face escarpment. The upper catchment is rural but gives way to a predominantly industrial catchment characterised by salt fields, which are earmarked for development and several constructed wetlands. A number of ephemeral creeks emanating in the MLR, discharge into Dry Creek, which in turn discharges into Barker Inlet.

The Dry Creek wetlands are composed of many separate sections running from the eastern edge of the suburb to the sea outlet of Dry Creek. They form part of the storm water management system for the City of Salisbury and the City of Port Adelaide Enfield and are connected to numerous drains that run across the Adelaide Plains including the eponymous Dry Creek, as well as being the outflow point for storm water pipes. The Dry Creek PWA was identified in 2010 and will be included in the new updated NAP WAP currently under development.

4.3.2 Little Para River

Catchment area: 124 km^2
Average total discharge volume: 1.42 GL (2005 – 2015, site A5040503)

The Little Para River is located between Dry Creek and the Gawler River. It originates in the MLR and flows in a generally northerly direction to the Little Para Reservoir. From the reservoir, the river flows west across the Adelaide Plains, discharging to the Gulf St Vincent south of Bolivar. The Barker Inlet-Port River estuary complex is a large tide-dominated estuary incorporating smaller estuaries such as Little Para Creek and Dry Creek. Freshwater runs into the estuary through a series of small creeks with stormwater filtration wetlands also contributing to flows.

Downstream of Salisbury, the river is semi-perched with extensive meanders, typical of other rivers in the area. The catchment is highly modified by agricultural practices. The underground, water-dependent ecosystems of the Little Para River require the maintenance of the natural discharge regime whereby approximately 1.2 GL of surface water flow is lost as groundwater recharge to the shallow sandy Quaternary (Q1) aquifer. These recharge events usually occur over the winter period (AMLR NRM Board, 2010).

The Little Para reservoir was originally conceived primarily as a water supply dam but its dam wall was later increased in height to provide flood mitigation for developing areas to the west. Despite the capacity of this dam, urban and rural catchments downstream of the dam contribute significantly to instream flood flows across the plains.

The Little Para River is prescribed in the Western MLR PWRA and each Surface Water Management Zone has respective limits defined in the WAP for the Western MLR (see Table 5.6, page 109-110 AMLR NRM Board (2010)).

4.3.3 Smith Creek

Catchment area: 174 km^2
Average total discharge volume: 1.26 GL (2010 – 2014, site A5051005)

The Smith Creek catchment extends from the top of the Hills Face escarpment above Smithfield in the east to the salt evaporation lagoons along Gulf St Vincent in the west. The northern boundary is defined by a ridge running parallel to the Gawler River. Smith Creek and the man-made extension to Smith Creek form the major stormwater outfalls to the area. The creek is maintained in a natural condition within a drainage reserve to Uley Road; downstream of this point, the watercourse is man-made. Smith Creek terminates at the Stebonheath Flow Control Park (FCP).

4.3.4 Adams Creek

Catchment area: 74 km^2. NB: This is the catchment area of the Helps Road Drain, of which Adams Creek is a major tributary.
Average total discharge volume: Unknown - DEWNR does not monitor this creek.

The Helps Road drain is an artificially constructed channel, approximately 15 km in length, of which Adams Creek is a major tributary. Two flood mitigation dams have been constructed on Adams Creek. Flows from the greater catchment are intercepted by a series of artificial drains, with the Helps Road drain transporting waters west across the plains and out into Barker Inlet. The catchment has a high degree of urbanisation, and is primarily residential with some industrial and commercial development.

4.4 Urban stormwater

The Dry Creek, Little Para River, Smith Creek and Adams Creek catchments contribute to MAR schemes operated by the Cities of Salisbury, Playford and Tea Tree Gully. These MAR schemes are important storage mechanisms in being able to effectively and efficiently capture, store and reuse urban stormwater.

The urban area of the three Councils covers approximately 46,000 ha. It has a population of approximately 220,000 with a growth forecast to 300,000 in the next 30 years. The area falls from east to west and has five significant waterways, Smith Creek, Helps Road Drain, Little Para River, Dry Creek and Torrens River. In addition, the Gawler River, which forms a northern boundary of the City of Playford, is significant in the context of this study. These catchments receive between 440 and 560 mm of rainfall per annum, predominantly in winter. There is approximately 1200 mm of evaporation, predominantly in summer. The median catchment run-off from the primary study region is 36.1 GL, although year to year variability about this volume is significant (Table 2).

Aquifer Storage and Recovery (ASR) trials first commenced in the early 1990’s in Paddocks Reserve (City of Salisbury) and Andrew’s Farm (City of Playford), demonstrating the potential of aquifers in the NAP to be injected with stormwater, and for this water to be recovered at a later stage without impacting the sustainability of regional groundwater resources.

A range of studies have been published over the last twenty years, investigating the potential to sustainably manage urban and peri-urban stormwater by injecting stormwater into underground aquifers through MAR. Two of these studies investigated the catchment yield potential, wetland storage and water treatment and aquifer injection requirements for a range of existing and proposed MAR schemes (see: Wallbridge & Gilbert (2009) and Waterproofing Northern Adelaide Subsidiary (2010)). The Waterproofing Northern Adelaide (WNA) study (Waterproofing Northern Adelaide Regional Subsidiary, 2010) details the catchments and operational requirements of both existing MAR schemes and additional schemes where commitments had been made to proceed with construction, as well as other sites with MAR potential. Sub-catchments of importance to the NAP are shown in Figure 10.

Since the 2010 WNA study, a number of additional MAR sites have been completed and are now operational. Data compiled by Wallbridge & Gilbert (2009) on the potential harvest volumes of each of the catchments is contained in Table 2. Current MAR schemes have several years of operational data (as provided by City of Playford and City of Salisbury, 2015). It is considered that the last decade (2005-2015) is perhaps more indicative of catchment harvest (yield) potential and that this potential is lower than the values modelled in Wallbridge & Gilbert (2009).

A summary of 2014-2015 MAR scheme water capture and storage data is contained in Table 2. It should be noted that catchments are highly variable in yield depending on factors such as the component of urban versus rural catchment, annual rainfall variability, seasonal factors such as soil moisture and vegetation and intensity of rainfall. Previous studies (Wallbridge & Gilbert, 2009) also highlight differences in modelling approach with respect to the potential catchment run-off and the harvestable yield of a catchment.

Most of the water currently harvested is already allocated for use by Local Government or industry, however, it is estimated that at least another 5 GL/annum of stormwater could be reliably harvested from Adelaide’s Northern urbanised catchments. Preliminary analysis conducted by the City of Salisbury suggests that this could be delivered at a lower price than other water sources in the region. With respect to cost, consideration may also need to be given to whether the infrastructure costs for use of stormwater on the NAP may be offset by the avoided costs of the infrastructure required to manage and dispose of stormwater to Gulf St Vincent.

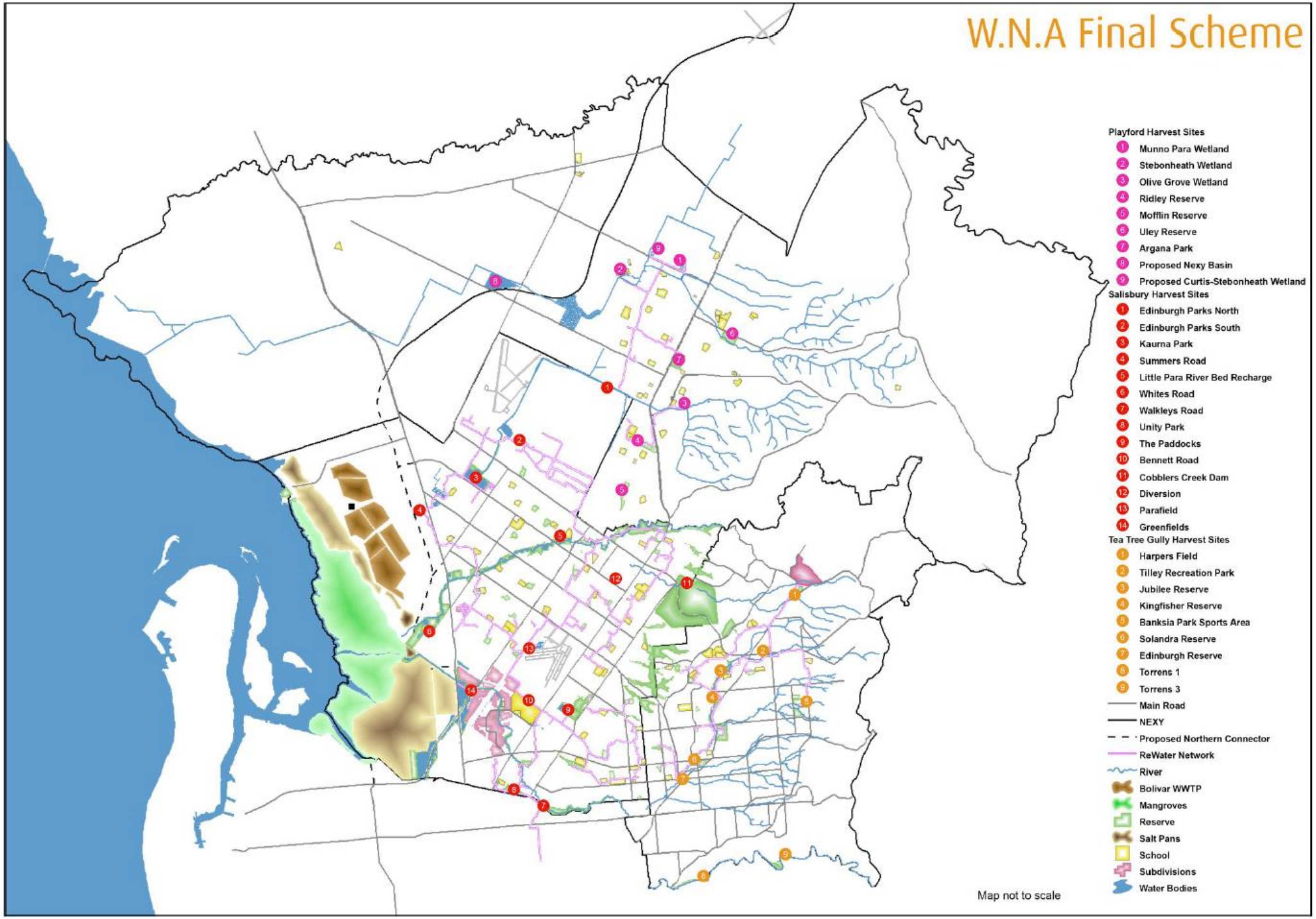

Figure 10. Sub-catchments and location of MAR schemes for each of the Council areas within the NAP region. Source: Waterproofing northern Adelaide Regional Subsidiary (2010).

CATCHMENT	SITE	Median Catchment Runoff (ML/a)	HARVEST VOLUME (ML/a) W&G (2009)	Licensed Volume EPA (2015)	Current Harvest (Avg 3 yrs)
Gawler River	*Dawson Road*		0.12		
	Gawler River (rural linear corridor		4.74	1.60	
	Buckland Park		0.86		
	Gawler Racecourse		0.31		
	Total	**10.90**	**6.02**	**1.60**	**0.00**
Dry Creek	*Bennet Road Drain*		0.48	0.35	0.18
	Greenfields 1 & 2 (upgraded)		3.27	1.02	0.40
	Paddocks		0.58	0.21	0.06
	Parafield		0.86	1.24	0.62
	Wynn Vale dam		0.35	0.00	0.00
	Montague Road MAR (Pooraka upgrade)		1.91	1.37	0.50
	Cheetham Saltworks		0.78	0.00	
		11.50	**8.23**	**4.18**	**1.74**
Smiths Creek	*Evanston South*		0.19	0.00	0.00
	Blakeview		0.31	0.00	0.00
	Munno Para West		1.24	1.20	0.50
	Andrews Farm		0.40	1.10	0.40
	Andrews Farm South		0.50	0.60	0.25
	NEXY retarding basin		0.85	1.00	0.30
	Total	**5.02**	**3.49**	**3.90**	**1.45**
Adams Creek	*Olive Grove*		0.30	0.20	0.05
	Edinburgh Parks North		0.63	0.56	0.00
	Edinburgh Parks South		0.76	1.25	0.39
	Kaurna Park		0.55	0.83	0.33
	Springbank Park		0.40	0.00	0.00
	Burton West		0.31	0.00	0.00
	Summer Road		0.58	0.00	0.00
	Total	**5.02**	**3.53**	**2.83**	**0.77**
Little Para	*Moss Road*		0.70		
	Pioneer Park		0.16		
	Whites Road		1.05	1.30	0.41
	Bolivar		0.33		
	Total	**3.66**	**2.24**	**1.30**	**0.41**
	TOTAL ALL SCHEMES (ML)	**36.10**	**23.50**	**13.81**	**4.37**

Table 2. Summary of 2014-2015 MAR scheme water capture and storage data. Current harvest data is the average over the last 3 years, which have been drier than average. Source: Wallbridge & Gilbert, 2009; City of Playford and City of Salisbury pers. comm..

Future supply

The Dry Creek area has been identified by the 30 Year Plan for Greater Adelaide for investigation for future urban growth, which could significantly impact on both constructed and natural wetlands by increasing run-off from a larger area of impervious surfaces. Urbanisation in the Barossa Valley could also increase run-off in some areas creating a need to balance harvesting opportunities with flood mitigation.

Changing run-off in the broader Northern Adelaide region is being assessed by a current City of Salisbury and City of Playford project called the “Northern Urban Catchments - Stormwater Yield Review”. This project will determine the reliable volume of stormwater that can be sourced each year from the following urbanised catchments in Northern Adelaide:

- Smiths Creek;
- Adams Creek;
- Greater Edinburgh Parks;
- Little Para River; and
- Dry Creek.

The study will consider operational optimisation and investment upgrades of current stormwater schemes within these catchments, as well as future opportunities for stormwater harvesting, treatment and storage. The study will produce estimates for 2015, 2025 and 2050, aligning with the Adelaide and Mt Lofty Ranges NRM Board study *Potential demand for treated stormwater and recycled water in Greater Adelaide (*GHD, September 2013).

4.5 Emerging threats

The main threat to the water resources of the Light River is the impact of increasing upstream water extraction from farm dams.

The Gawler River is under pressure from a range of agriculture-related activities including urbanisation, which could further alter the flow regime. This could in turn be further exacerbated by climate change (see section 4.6). Presently, the horticultural industry has reliable access to recycled water which means that irrigation demand may not be as responsive to changing rainfall patterns in the future. However water quality issues, in particular salinity, may pose greater challenges in the future.

4.6 Climate risk

Two reports provide indications of the vulnerability of surface water catchments in the Adelaide area to climate change. Goyder Institute Technical Report 14/27 (Westra, et al., 2014) reports on a modelling investigation of flows in the Onkaparinga River catchment in the Western MLR. Similarly, DEWNR Technical Report (Osti, et al., 2015, in prep) examined the change in flow within all the major reservoir catchments in the MLR. Both of these studies found surface water runoff to be highly sensitive to rainfall and potential evapotranspiration changes under a range of projected climate change scenarios.

A recent modelling study on the Parafield stormwater harvesting scheme operating within the Dry Creek catchment indicated that impervious urban catchments are much less susceptible to changes in rainfall due to climate change than predicted for pervious rural catchments and this was attributed to negation of high soil moisture deficits and initial and continual losses (Clark, et al., 2015). Clark, et al. (2015) also tested the effect of urban development in the catchment that is expected to increase the current catchment impervious area by 20% (from 38% to 46%).

It was found that the increase in harvestable volumes through urbanisation more than compensated for expected reductions in rainfall due to climate change using a high emission pathway future climate model. Therefore, while run-off in the broader Mount Lofty Ranges catchment may be sensitive to changes in rainfall and evaotranspiration, continued urban development and infill of Adelaide’s northern suburbs and further development of the Gawler township region may therefore result in a climate resilient source of stormwater.

4.7 Summary

The median harvestable volume from the catchment is estimated at 24 GL per annum. This covers flows from rivers and creeks such as the Gawler River, Dry Creek, Smiths Creek and Adams Creek. Data is still being collected to confirm the quantity of water that the EPA has licensed for capture and storage through MAR schemes from these water courses.

The region is well known for best practice approaches to harvesting and storing stormwater in urban areas. Most of the water currently harvested is already allocated for use by Local Government or industry, however, it is estimated that at least another 5 GL/annum of stormwater could be reliably harvested from Adelaide's Northern urbanised catchments. Preliminary analysis suggests that this could be delivered at a lower price than other water sources in the region.

5 Water use efficiency gains

5.1 Context

While there is an understanding of the potential for some crop specific water use efficiency gains, no single comprehensive assessment has been undertaken of the potential water use efficiency gains across the entire horticulture sector in the NAP.

The region has significant numbers of low or medium technology irrigation enterprises that lend themselves to water efficiency improvements. Some of this infrastructure was not designed with water use efficiency in mind and some has been modified with equipment that does not optimise water use. Scheduling practices on a large number of farms would also provide substantial improvement.

The potential gains from improving on-farm practices were demonstrated in a recent study by Hortex (Robertson, 2015). This revealed that changes to water use, fertigation and pest management (nematodes) for medium technology protected cropping could significantly improve the productivity capacity of farms by 2.5-3 times.

Work done outside of the region in the South Australian Riverland, as part of the South Australian River Murray Sustainability Irrigation Industry Improvements Program, found that water use efficiency gains of 10-20% were achievable, despite significant gains that had already been made in recent decades (pers comm. B. Fee, PIRSA 2015).

5.2 Potential additional water availability

It is estimated that for protected cropping facilities in the NAP, 10% water savings could be generated from adoption of new management techniques while an extra 20% (total 30%) could be achieved through implementation of best practice irrigation technology and programmed irrigation using computerised systems (Robertson, 2015). The latter also leads to more efficient fertiliser use and improves overall cost efficiency. Expert opinion suggests that water efficiency gains of at least 10% could also be possible for field horticulture (pers. comm. B Robertson 2015).

Given that horticulture in the region currently uses at least 29.1 GL (17 GL from Bolivar and 12.11 GL of groundwater), a 10% water efficiency gain could make up to another 3 GL of water available for economic development. Increasing water trade in the region could be one way to encourage greater water use efficiency.

5.3 Climate risk

The sensitivity to climate change of water use efficiency savings as a potential source of water is assessed to be high. DEWNR Technical Note 2013/09 (Pitt, et al., 2013) examined the increased irrigation water demands in the NAP that would occur in response to projected climate change. If there is no change to the type of irrigated crops produced in the NAP, additional irrigation water will have to be added to compensate for the reduction in rainfall and the increased evapotranspiration demand of the crops in the projected warmer, drier climate. As a result, potential water savings due to efficiency improvements are likely to be overcome by the increased irrigation water demand to compensate for the change in climate.

5.4 Summary

The region has significant numbers of low or medium technology irrigation enterprises that lend themselves to water efficiency improvements. Based on work undertaken elsewhere in South Australia, it is believed that irrigation efficiency gains of 10-20% are possible. Given that horticulture in the region currently uses at least 29.6 GL, a 10% efficiency gain could make up to another 3 GL of water available for economic development. Efficiency gains may be consumed in the future by increased irrigation demand to compensate for a change in climate, however, this will occur over the long term (decades) compared with growth in water demand for horticultural production which is more likely in the short term (coming 10 years).

6 Alternate water sources

6.1 Barossa Infrastructure Limited

6.1.1 Overview

Information related to Barossa Infrastructure Limited (BIL) is derived from the BIL website and Annual Reports. BIL is an unlisted public company. The scheme cost in 2000 was approximately $30 million, funded by shares (approximately 1/3) and a long term bank loan (approximately 2/3).

The objective of the BIL scheme is "*To provide a high quality water supply in the Barossa which, when applied in environmentally and viticulturally appropriate quantities, sustains crop yield and quality through dry periods at a cost that is lower than other quality water sources.*"

The need for supplementary irrigation in the Barossa grew out of historical water supply challenges related to use of inferior quality (saline) water, either groundwater or surface water, annual variation in rainfall and catchment water harvesting at sustainable levels. There have also been concerns about the use of deep aquifer water for irrigation leading to the importation of salt to surface soils.

The BIL scheme consists of 189 kilometres of distribution network delivering water to approximately 290 customers across 450 square kilometres in the Barossa Valley, including land surrounding towns such as Greenock, Lyndoch, Nuriootpa and Tanunda (Figure 11). The vast majority of customers use the water for vineyard irrigation.

The BIL scheme pumps from the Warren Reservoir into its supply network. SA Water is the owner and operator of the connection and Warren Reservoir, which is supplemented with water from the Mannum Adelaide Pipeline and Warren Transfer Main. The majority of water used by BIL is from River Murray Water Access Entitlements of Annual Water Allocations transported by SA Water. BIL also accesses about 250ML of reclaimed water from the Nuriootpa STED scheme.

6.1.2 Current volume of water available

BIL has capacity in its pipeline infrastructure to supply 10 GL per annum to customers in the Barossa Valley. The environmental approval for the supply of water recently increased from 8 GL per annum to 9 GL in the 2015/2016 water year, commencing on 1 October 2015.

The breakdown of the cost of water from the BIL scheme is provided in Table 3. In addition to usage charges, customers pay an annual infrastructure levy. An example of this levy and the payment structure is provided in Table 4.

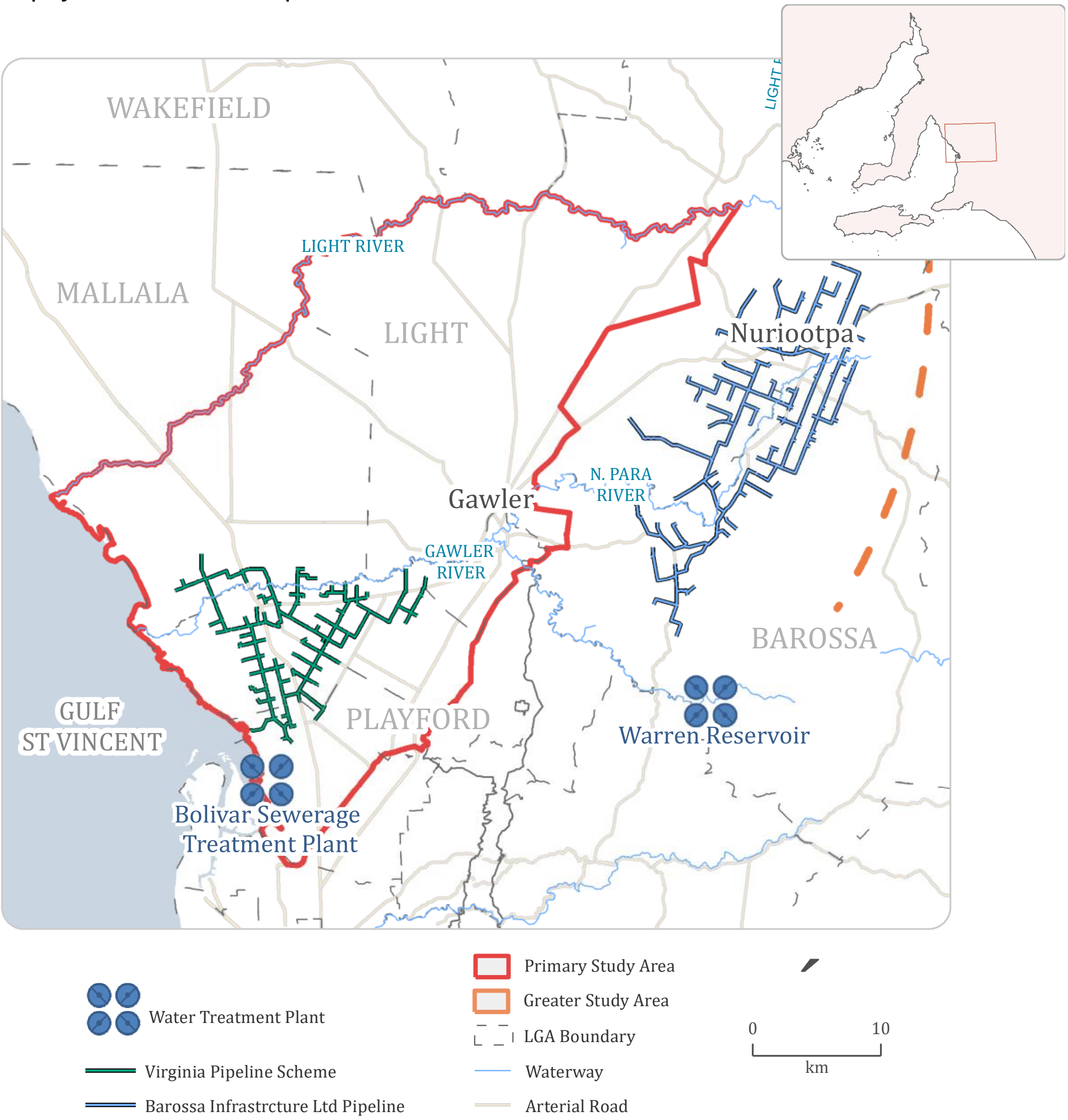

Figure 11. Map of Barossa Infrastructure Ltd (blue) and Virginia Pipeline Scheme (green) pipeline networks.

	2015/16 ($/ Megalitre)	2014/15 ($/ Megalitre)
Premium	720	800
Off Peak	920	1,000
Not taken	480	500
Spot *	1,250	1,350
Excess water charge	3,600	4,000
CWMS Premium	650	730
CWMS Off Peak	850	930

Table 3. Summary of water charges for users in the Barossa Infrastructure Limited scheme (Source: BIL website). * Price on the temporary water trade market.

Payment No.	Timing	Water infrastructure Levy per Megalitre	Share payment* schedule per Megalitre
1	30 June 2016	$1,000.00	$1750.00
2	30 June 2017	$2,000.00	NIL
3	30 June 2018	$1,500.00	NIL
4	30 June 2019	$1,500.00	NIL
5	30 June 2020	$1,500.00	NIL
6	30 June 2021	$1,500.00	NIL
7	30 June 2022	$1,500.00	NIL
8	30 June 2023	$1,500.00	NIL

Table 4. Levy and payment structure for users of the Barossa Infrastructure Limited scheme (Source: BIL Website). * Share payment is the cost of becoming a shareholder in the BIL scheme.

Use of BIL System to deliver Recycled Water

BIL has an agreement with the Barossa Council to take approximately 0.25 GL of recycled water per year from the Nuriootpa CWMS. Recycled water is blended with BIL's regular non-potable irrigation supplies through the Gomersal Road pump house throughout the year, with the majority of water taken by customers over the winter period.

Future demand

Despite the increase in water supply to the region, there remains additional demand for water from the BIL scheme. As such, BIL continues to be active in seeking alternative water sources to maintain the sustainability of viticulture in the Barossa Valley.

Two potential sources of water for the region are from the Gawler River and Bolivar. The Gawler River re-use scheme is in the construction phase. Recycled water from Bolivar has been considered as a potential source of water. However, there are anecdotal reports from growers in the Barossa Valley about a reluctance to use the water because of salinity concerns. As such, use of recycled water from Bolivar may be seen as a water security measure for drier seasons.

Environmental issues addressed
There are a variety of potential risks associated with the use of supplementary water in the Barossa Valley. Issues that were considered in the design of the scheme include the potential for:

- a rise in regional water tables;
- effects on the salt budget and the potential for increases in the salt load entering surface drainage as base flow;
- the creation of perched water tables with adverse effects on plant growth, and for migration off-site; and
- the effects of any environmental implications of inter-basin transfer of water (e.g. salinity and chlorine residuals).

BIL reports that to date there have been no detrimental impacts on the environment. BIL has a report on the shallow water table prepared every two or three years to study the impact of the imported water from the River Murray.

The average salinity of the water supplied to customers is 300 parts per million, well inside the limit of 800 parts per million.

6.2 Gawler Water Reuse Scheme

The Gawler River is a prescribed watercourse managed within the Western MLR WAP.

Information related to the description of the Gawler Water Reuse Scheme has been derived from Supplementary Agenda Paper Item 6.1 & ITEM 11.1.1 for the meeting of Light Regional Council on 26 August 2014 (Light Regional Council, 2014) and advice received from DEWNR.

The Gawler Water Reuse Scheme (GWRS) will harvest urban stormwater from the Gawler River into wetlands where it will be cleaned, prior to being injected into an aquifer for storage. The water will then be extracted for use in irrigation and to a lesser extent supply for reserves, sports fields and school ovals. The project is strategically important because it provides the catalyst for an expanded regional non-potable water system connecting the Barossa with a food bowl north of the Gawler River. It is also seen as helping water proof premium food and wine production areas in the Barossa.

Light Regional Council received up to $10.7 million from the Australian Government under the National Urban Water & Desalination Plan for the GWRS. A water supply agreement and an operations & maintenance agreement have been negotiated with Seppeltsfield Wines Pty Ltd who will operate and maintain the scheme through the Asset Trust. Funding for the project is based on Council borrowing at least 50% of the project funds from the Local Government Finance Authority (LGFA) (estimated at $11 million) and combining this with the Commonwealth grant to on-lend it to Seppeltsfield Wines to design and construct the scheme infrastructure.

The Gawler River Reuse Scheme will aim to harvest 1.6 GL/year from the Gawler River Prescribed Watercourse. This will be undertaken using a temporary authorisation granted to the Light Regional Council under section 128 of the Natural Resources Management Act

2004. The water will be injected into the T2 aquifer from which it is expected 1.28 GL/year will be extracted and supplied to Seppeltsfield Wines.

The Western Mount Lofty Ranges Water Allocation Plan (WMLRWAP) covers the Gawler River Prescribed Watercourse. The Plan states that the extraction limit across the plains for the Gawler River is 10 GL. The implementation plan for the Western Mount Lofty Ranges Water Allocation Plan will address how the unallocated water will be made available.

6.3 Potable water supplies

The SA Water potable supply network is available throughout many parts of the NAP. A small number of protected cropping growers currently access potable water to supplement irrigation water from other supplies. The number of growers accessing this water is small because of the cost compared to other sources. For example, water from the Virginia Pipeline Scheme costs <20c/kL whereas potable water supplies are in excess of $3/kL. Therefore, while potable water supplies represent an additional source of water, growers are unlikely to access it in large volumes because of the cost, unless SA Water establishes a different water product. However, one way that growers could use potable water is to shandy (combine) it with other lower quality water sources, such as low-moderate salinity groundwater.

The SA Water mains water supply is dependent on water from the River Murray, Mount Lofty Ranges and the Adelaide Desalination Plan. While the Murray Darling Basin Plan provides a degree of security to River Murray flows to South Australia and to the water and salinity levels at the pipeline offtake points within South Australia, the flows within the Murray Darling system remain susceptible to climate change. Future restrictions in supply due to severe droughts within the MDB catchment area remain a possibility. The report of the South East Australian Climate Initiative (CSIRO, 2012) provides an indication of the vulnerability to climate change of flows within the MDB system. However, due to the level of protection provided by the Basin Plan and the addition of the climate-independent Adelaide desalination plant to the supply mix for the SA Water metropolitan water supply, the climate change sensitivity of the SA Water supply is assessed to be low.

6.4 Rooftop harvesting

The climate change sensitivity of roof runoff capture and rainwater tanks is assessed to be low (Clark, et al., 2015). However, this is a subjective assessment and a reference report is not cited. The majority of rainfall projections for Adelaide indicate a likely reduction in mean annual rainfall. While roof runoff and rain water tank supplies will clearly be impacted by changes in rainfall, many roof runoff capture facilities are limited by the storage capacity of tanks rather than by the roof runoff volume. Furthermore, the impacts of the projected changes in rainfall patterns (timing, seasonality, intensity) on roof runoff and capture volumes has not yet been modelled for the projected changes in rainfall in the study area. Further information on the impact of climate change on rainfall is available from downscaled SA Climate Ready data at: https://data.environment.sa.gov.au/Climate/SA-Climate-Ready/SitePages/Home.aspx

6.5 Desalination

There is currently limited use of desalination to generate water for irrigation in the NAP region. It is understood that some reverse osmosis is used to improve the quality of recycled water or groundwater, although there is no known estimate of the quantity of water being desalinated or the quantity of brine being generated and disposed.

If there was to be an increase in the use of desalination to generate water for irrigation, the NAP region could utilize water from Gulf St Vincent, regional groundwater or water from the VPS. Seawater is an abundant resource for any proposed desalination plants located along the coast. Sea water can possess salinity > 35,000 mg/L, while brackish ground water concentrations could be in the ranges of 2,500–3,000, 3,000–15,000 and > 15,000 mg/L.

Additional supporting information describing desalination techniques, supporting technologies, energy considerations and environmental challenges is contained in Attachment 2.

7 Potential risks of increased water use

This stocktake identifies additional water sources that may be available to support the potential expansion of agriculture in the NAP and surrounding region. However, past experience in the region suggests that it is also important to understand and manage the risks associated with the use of additional water so that expansion can be managed sustainably. The past 60 years of irrigation in the NAP provides lessons and information about several important risks of using water for irrigation. In particular, the topography, soil types and the quality of both groundwater and recycled water sources pose risks to soil, groundwater and aquifer condition, as well as to crop viability and yield.

7.1 Rising shallow water tables

The NAP has a fairly flat topography, with some areas at risk of inundation. Water table levels are generally quite shallow. Approaching the coastal zone, water tables are typically near the surface (Australian Water Environments, 2015). These features of the region mean there are significant risks of waterlogging of soils, salinisation of soils, reductions in crop yield and damage to surface infrastructure such as roads and building foundations. The problems are particularly severe in the area of Buckland Park to Waterloo Corner on the western side of Port Wakefield Road.

Increasingly shallow water tables have been a significant concern for irrigators in the NAP for at least ten years. Some irrigators have recently reported major losses of production due to waterlogged soils, leading to the potential significant risk of loss of jobs and increased production costs.

Recharge from irrigation and runoff from infrastructure such as glasshouses are contributing factors in rising shallow water tables. The addition of extra irrigation recharge to the soil from the use of additional sources of water (or the concentration of extra runoff from new infrastructure) could increase these risks, unless planned and/or carefully managed.

7.2 Groundwater quantity and quality

Declining trends in quality and availability of groundwater pose a risk when additional water sources are used for irrigation, because these separate sources are often shandied together to improve water quality to a level suitable for crops. Therefore, groundwater could be a limiting factor to agricultural development in some areas, if it is needed to be blended with other water sources to achieve the appropriate quality. Conversely, good quality alternative water sources could enhance the opportunity to use poorer quality groundwater where it has not traditionally been considered suitable for crops.

It is well-understood that historical groundwater extraction from the T2 aquifer has created a long-standing cone of depression in ground water pressure levels around Virginia. Similarly, pumping from the T1 aquifer has resulted in a cone of depression centred on Waterloo Corner. DEWNR monitoring indicates that groundwater and salinity levels in both the T1 and T2 aquifers have been reasonably stable over the past 10 years. However, a risk has been identified that the lateral inflow of more saline groundwater toward the cones of depression could be causing salinity increases in some irrigation wells (Department for Water, 2010).

Leaky wells may also pose a risk to groundwater quality. A study commissioned by the AMLR NRM Board in 2013 found that up to 300 NAP wells are at risk of being leaky, based on the age and type of construction (SKM, 2013). Leaky wells have the potential to cause localised salinity impacts on neighbouring wells. This may be particularly significant where wells have been covered by residential areas, without proper decommissioning.

The availability and projected trends in groundwater quality need to be taken into account when assessing the risks of increasing use of alternative water sources. Appropriate monitoring of groundwater condition and trends will be needed in order to align with the planning and use of alternative water sources.

7.3 Soil salinity

Over the last 15 years, the use of recycled water from Bolivar for irrigation in the NAP has provided an opportunity to identify the risks of using such water, in terms of impacts on soil and crops. Green (2010) has pointed out that in the NAP, the combination of moderately saline irrigation water, high salinity shallow groundwater, and naturally high soil salinity means that adequate irrigation water must be applied to ensure leaching of salts from the root zone. Insufficient flushing of salts from the soil profile can cause soil sodicity and other soil degradation problems.

The application of irrigation water can lead to increased downward recharge, exacerbating the existing rising shallow water table problems. The balancing of these two factors is difficult, but is critical to managing the soil and groundwater of the NAP sustainably. If irrigation in the NAP becomes more widespread due to the availability of water from alternative sources, these risks will increase, depending on the salinity level of the new water sources. Additional information and support such as capacity building and training as well as use of sensor technology may be required to help irrigators achieve the optimal balance between applying sufficient water for leaching salts, and preventing excessive recharge to the shallow aquifers.

7.4 Suitability of alternative water sources for crops

A number of recent studies have highlighted the risks to some crops associated with the quality of reclaimed water currently available in the NAP. For example, research by Rawnsley (2011) showed that the salinity of available recycled water can be above the salt tolerance for almonds.

Currently, some irrigators shandy the water available through the VPS with groundwater to make it more suitable for their crops. If more water becomes available for irrigation through alternative sources, the risks to crop viability will need to be carefully considered in light of the quality of the additional water. Appropriate selection of crops or rootstocks, and sound soil management and irrigation practices will be critical to managing the application of additional water. There is likely to be a need for increased landholder education, information and technical support services, particularly where new water sources have different salts and nutrient composition to the existing available recycled water.

7.5 Impacts of recycled domestic wastewater

In 2012, the AMLR NRM Board commissioned a review of literature about the impacts of recycled domestic wastewaters on natural resources, including soils and water. The review indicated that soil and groundwater contamination and impacts on crops have been reported around the world as a result of synthetic organic compounds, heavy metals, inorganic compounds and residual chlorine present in recycled wastewater (Van Leeuwen, et al., 2012).

The risk of these impacts depends primarily on the level of wastewater treatment. In the case of the NAP, the tertiary treatment used at Bolivar should mitigate most risks. The study also identified that lack of data limited the conclusions that could be drawn. In doing so, it was recognised that knowledge gaps may exist in response to data gaps, so uncertainties remain regarding the impact of irrigation with recycled water in the NAP. As such the Australian Guidelines for Water Recycling should be consulted, which outlines the process for managing the range of risks associated with the use of recycled water.

7.6 Disposal of wastewater from intensive agriculture

Some irrigators in the NAP have raised concern about the disposal of wastewater from activities such as hydroponics, aquaculture and nurseries. This wastewater can be highly acidic and nutrient-rich, causing problems such as algal blooms in drains and creeks, and affecting the shallow water table. If these industries become more widespread due to the increased availability of water, there would be a need to manage these risks, such as by research into small-scale on-farm treatment options. Additional compliance monitoring may also be required.

7.7 Community perceptions and engagement issues

Whilst the expansion of irrigation and development of new economic opportunities are generally viewed favourably, there are social risks associated with rapid change in communities. Historically, the NAP community has tended to be relatively suspicious of change, especially when driven by local or State government. In addition, there are particular communication challenges in the NAP because of the high number of people for whom English is not their first language. These risks point to the need for carefully planned communications and engagement, and adequate assessment of the social and economic impacts of the changes that could occur with increased agricultural development.

Even if scientific investigations indicate minimal actual risks from using alternatives water sources such as treated stormwater and wastewater, there may still be marketing risks because of public perceptions about these water sources. This will need to be taken into account in communications, engagement and marketing activities

8 Discussion and key findings

8.1 Key findings

A summary of current water available from alternate sources in the Northern Adelaide Plains and the future potential volume is provided in Table 5.

Recycled water
Recycled water in the NAP region is generated primarily from SA Water's Bolivar WWTP. The total volume of untreated wastewater inflows into Bolivar is approximately 50 GL per annum.

SA Water currently provides 19.5 GL (12.5 GL summer water and 7.0 winter water) of recycled water from Bolivar for the VPS, of which 17 GL is used by local farmers. The unused 2.5 GL is water only available during winter, which would require storage if it cannot be used during this period.

There is 20 GL of treated wastewater available from Bolivar each year in addition to the contracted 19.5 GL. Additional investment to upgrade the treatment capacity is required at Bolivar to generate this water. SA Water has recently closed an EOI process seeking interest from the private sector to make the required upgrades to the Bolivar DAFF plant to generate the 20 GL. Of this 20 GL, 12 GL would be available for summer use and a further 8 GL for winter use, which again would require storage if it is not able to be utilised during this period.

Up to an additional 5 GL could become available from the Bolivar Wastewater Treatment Plant with further significant upgrades to the tertiary treatment capacity. This upgrade is not presently being considered by SA Water.

Groundwater
Within the NAP PWA, there is currently 7.26 GL of groundwater allocated for extraction from the T1 aquifer and 19.86 GL of groundwater allocated in the T2 aquifer. There was 3.46 GL of use in 2013/14 from the T1 aquifer and 8.66 GL from the T2 aquifer. This resource is currently considered to be over-allocated (27.12 GL), but not over-used (12.11 GL, 2013/14).

Recent modelling of sustainable yields recommended extraction limits of approximately 3.5 – 3.8 GL/yr and 16 - 17 GL/yr for the T1 and T2 aquifers respectively, including the Kangaroo Flat area (total 20.8 GL). These volumes indicate that there could be some increase in extraction by current licensees (or by transfer of allocation from current licensees), although any such increases would only be possible in the zones beyond the major better water quality extraction zones. Potentially between 2 to 4 GL could be available in these zones for increased extraction, although this is subject to the finalisation of the Adelaide Plains Water Allocation Plan and subsequent decisions by the Minister.

The WAP for this region has been reviewed and is currently being amended. The quantum and location of any increased extraction cannot be quantified until the WAP is confirmed. Trading of water between licence holders is likely to continue to be the main option for increasing the economic development opportunity of this resource.

The tertiary aquifer to the north of the NAP PWA contains an estimated 22 GL of water that could be extracted per annum, however, the salinity is high and not suitable for agriculture without augmentation, such as with desalination technology or blending (shandying) with fresh water. Of the 22 GL, 4 GL is considered to be in the 2,000 to 3,000 mg/L range, 10 GL in the 3,000 to 7,000 mg/L range and 8 GL above 7,000 mg/L.

There is limited water available from the shallower quaternary aquifer in the region. Small volumes are currently used for limited applications such as stock and domestic use.

Natural watercourses and stormwater

The median harvestable volume from the catchment is estimated at 24 GL per annum. This covers flows from rivers and creeks such as the Gawler River, Dry Creek, Smiths Creek and Adams Creek. Data is still being collected to confirm the quantity of water that the EPA has licensed for capture and storage through MAR schemes from these water courses.

The region is well known for best practice approaches to harvesting and storing stormwater. Most of the water currently harvested is already allocated for use by Local Government or industry, however, it is estimated that at least another 5 GL/annum of stormwater could be reliably harvested from Adelaide's Northern urbanised catchments. Preliminary analysis suggests that this could be delivered at a lower price than other water sources in the region.

It should also be noted that current MAR schemes are designed to capture low flows. With increased rainfall intensity and less frequency, the efficacy of low flow capture is likely to decrease. Consideration of alternative engineering design, including associated risks, would be beneficial in assessing opportunities to enhance stormwater capture. In addition, the costs to build, maintain and operate require further evaluation as the cost recovery for any new schemes are likely to be high per kL recovered. The current charges are approximately $2.50/kL for existing schemes that are considered to be the 'low hanging fruit' in terms of complexity and delivery to customers.

Water use efficiency

Water use efficiency gains are likely to be possible for protected cropping facilities and field horticulture within the NAP PWA. It is estimated that for protected cropping facilities, 10% water savings could be generated from adoption of new management techniques while an extra 20% (total 30%) could be achieved through implementation of best practice irrigation technology and programmed irrigation using computerised systems. The latter also leads to more efficient fertiliser use and improves overall cost efficiency. Expert opinion suggests that water efficiency gains of at least 10% could also be possible for field horticulture.

Given that horticulture in the region currently uses at least 29.6 GL (17.5 GL from Bolivar and 12.1 GL of groundwater), a 10% water efficiency gain could make another 3 GL of water available for economic development on the existing sites.

Other water sources
Barossa Infrastructure Limited (BIL) provides 8.8 GL of River Murray water to Barossa region farmers. It is understood that this system is almost fully allocated. Through additional infrastructure it may be possible to use parts of the BIL scheme to transport Murray water into the greater Northern Adelaide region.

The Gawler River Reuse Scheme will aim to harvest 1.6 GL/year from the Gawler River Prescribed Watercourse. This will be undertaken using a temporary authorisation granted to the Light Regional Council under section 128 of the Natural Resources Management Act 2004. The water will be injected into the T2 aquifer from which it is expected 1.28 GL/year will be extracted and supplied to Seppeltsfield Wines.

The Western Mount Lofty Ranges Water Allocation Plan (WMLRWAP) covers the Gawler River Prescribed Watercourse. The Plan states that the extraction limit across the plains for the Gawler River is 10 GL. The implementation plan for the Western Mount Lofty Ranges Water Allocation Plan will address how the unallocated water will be made available.

Desalination is of significant interest for the region. Small scale desalination is already used to improve the quality of water provided to growers or extracted from groundwater, although there are some reports of poor brine disposal practices. Large scale desalination could be of use to improve the quality of water from the tertiary aquifer to the north of the NAP PWA, or to generate water for agriculture from Gulf St Vincent. The major drawback of desalination is currently the cost to generate water of sufficient quality for horticulture, disposal of the brine discharge and management of any environmental impacts.

Some growers currently use the potable water supply network to access water for irrigation. The major limitation to use of potable water for horticulture is price. For example, water from the VPS is understood to cost 16c/kL compared to at least $3/kL for potable water and at least $2.50/kL for stormwater from MAR schemes.

An additional option not considered in detail in this assessment is the potential and practicality for various fresh water sources to dilute salinity of groundwater or recycled water.

Pricing
This report has focussed on determining the current and potential availability of water in the region. While some pricing information is included, a comprehensive description of price would require a detailed life cycle analysis which is beyond the scope of this assessment. It is recognised that demand for water sources in the region will be influenced by the full cost of water access, treatment and delivery. For example, the annual supply charge and consumption charge for recycled water from the Virginia Pipeline Scheme does not include the cost to pump and filter water on farm, construction and lining of dams or any additional treatment costs.

Risks
Any increased use of water in the greater Northern Adelaide region needs to be aware of the risks of water management identified over recent decades. Key risks to consider will include:

- waterlogging of soils;
- management of salinised or sodic soils;
- disposal of brine from desalination;
- over allocation of water resources; and

- potential impacts of climate change on reduced catchment runoff and groundwater recharge.

Table 5. Summary of current water available from alternate sources in the Northern Adelaide Plains and the future potential volume.

Source	Current volume available/allocated	Future potential volume
Recycled water	SA Water currently provides 19.5 GL of recycled water to the VPS.	2.5 GL of winter water from the VPS is currently not being used. An additional 20 GL of recycled water could be made available subject to further upgrades to the DAFF plant
Groundwater	There is currently 27.12 GL allocated for extraction from the tertiary aquifers. There was 12.11 GL used in 2013/14. This resource is currently considered to be over-allocated, but not over-used.	Potentially between 2 to 4 GL could be available in the prescribed wells area. A further 22 GL could be extracted further north of the prescribed wells area, but salinity is high.
Natural watercourses and stormwater	The median harvestable volume for the primary study region is estimated at 24 GL. *	It is estimated that at least another 5 GL/annum of stormwater could be reliably harvested from Adelaide's Northern urbanised catchments
Water use efficiency	N/A	A 10% water efficiency gain could make another 3 GL of water available for economic development on existing sites.
Gawler River	The Gawler River Reuse Scheme will aim to harvest 1.6 GL/year once operational.	A total of up to 10 GL of water will be made available from the Gawler River under the Western Mount Lofty Ranges Water Allocation Plan.

* This volume includes 10 GL from the Gawler River.

8.2 Recommendations for additional work

During the compilation of this report a range of future activities were identified that are necessary to manage provision of additional water in the region, covering planning and governance, research and development, and community and stakeholder engagement.

Recommendations for additional work include the following:

- **Water road map and regional governance** - Develop a water road map to determine how alternate water sources in the region can most effectively be used to benefit economic development and sustainable use of land and water resources. This should include establishing the necessary governance arrangements to facilitate current and ongoing water use and consider alternate scenarios for industry development in the region.

- **Soil and water management plan** - Develop an overarching soil and water management plan for the NAP, endorsed by relevant local councils and regulatory and approval agencies, to ensure that new water sources are used in optimal locations and can underpin sustainable growth in agricultural production. To be effective, the management plan must be linked with a detailed monitoring and evaluation plan that is able to identify unintended and adverse consequences. Evaluation should be linked to action as necessary to rectify issues and practices before they produce longer term damage.

- **Grower extension, education and technical support programs** - Augment the existing irrigator extension, education and technical support programs, with a focus on new or changed water uses, to mitigate the risks arising from irrigation and to improve efficiency. This may include localised advice to ensure that irrigation practices are matched to local soil and groundwater conditions.

- **Soil and groundwater monitoring, evaluation and research** - Develop an enhanced program of soil and groundwater monitoring, evaluation and research, with a focus on the risks associated with irrigation using alternative water sources.

- **Land use planning** - Investigations into land use planning measures that can prevent foreseeable, unintended consequences e.g. rising groundwater levels.

- **Supply chain costs for water –** Undertake further investigations to understand the supply chain costs for water infrastructure, including energy and infrastructure costs. Analysis also required on the tipping points for investment in alternate water sources.

- **Stakeholder communications, engagement and social impact assessment program** - Develop a communications, engagement and social impact assessment program aligned with planning and proposals for expansion and development of new areas and types of irrigated horticulture. This should allow for the need to continue to improve communications and engagement with growers from non-English speaking backgrounds and any structural adjustment requirements that arise in the region.

- **Storage solutions** - Further investigation into surface and groundwater storage solutions in the region. This would need to consider issues such as storage of additional water from the Bolivar WWTP, management of MAR schemes to capture low flows, and whether water stored in aquifers through MAR schemes can be used to generate groundwater credits.

- **Catchment runoff and stormwater harvesting** – Research to improve understanding of catchment runoff and stormwater harvesting, including testing the robustness of assumptions about climate risk impacts on surface water run-off and expanding harvesting needs to account for environmental flows requirements.

- **Water efficiency incentives** – Water efficiency measures could generate an estimated 3 GL of water savings for the region. Further work is required to better understand the potential incentives that could be offered to growers to encourage adoption of water efficiency measures, learning from experience in the Murray-Darling Basin.

- **Sustainable food systems** – A key feature of South Australia's strategic plan is premium food and wine production from our clean environment. Expanding water use in the NAP needs to occur within this broader State objective, requiring adoption of food production environmental management systems that address sustainable water and land management practices.

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Attachment A

Disclaimer: *The data contained in this report has been prepared for SA Water's own internal use only. SA Water accepts no liability for and gives no undertakings, guarantees or warranties concerning the accuracy, completeness or fitness for use of the data for any purpose. In the event the data is requested by an external party, approval for its release will be subject to the conditions of use set out in SA Water's Policy on Release of Water Quality Data.*

Bolivar WWTP Effluent Weir 1 Summary Report
2011-12

EFFLUENT		July	August	September	October	November	December	January	February	March	April	May	June
Dissolved Oxygen	mg/L	13.7	9.5	8.5	5.2	7.3	7.1	6.2	3.9	6.2	11.6	9.6	6.6
Turbidity	NTU	37.0	42.0	30.5	34.0	16.0	41.0	47.0	2.0	6.4	39.5	48.0	32.0
Temperature	degrees C	14.0	18.8	16.7	18.0	21.5	20.3	22.4	21.5	19.4	17.7	14.0	11.0
Biochemical Oxygen Demand	mg/L	8.7	8.0	7.2	4.0	6.8	11.2	26.4	3.0	5.4	9.2	9.4	10.0
Suspended Solids	mg/L	55.0	43.6	70.8	57.0	71.0	79.3	77.4	11.0	23.4	63.0	49.4	47.4
Chemical Oxygen Demand	mg/L	75.0	140.0	120.5	139.0	72.0	137.5	77.0	117.0	44.0	73.0	54.0	59.0
pH	pH units	8.6	8.2	8.0	7.8	8.0	8.4	9.3	7.9	7.9	8.6	8.7	8.6
Total Dissolved Solids (by EC)	mg/L	988	1,020	1,100	1,100	1,100	1,050	966	998	944	900	878	890
Colour - True (456nm)	HU	50.0	48.0	48.5	45.0	42.0	43.5	26.0	33.0	36.0	38.5	43.0	42.0
E.coli	/100mL	271	101	29	64	143	430	133	774	502	355	233	73
Ammonia as N	mg/L	0.50	0.50	0.55	0.54	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
TKN as Nitrogen	mg/L	4.67	4.77	5.13	5.00	5.76	5.56	9.30	3.38	3.66	7.04	5.91	4.27
Nitrate as Nitrogen	mg/L	13.80	21.90	15.00	15.00	11.40	6.94	7.65		5.48	5.13	11.10	12.80
Nitrite as Nitrogen	mg/L	0.071	0.060	0.374	0.151	0.071	0.100	0.349	0.095	0.100	0.100	0.100	0.100
Nitrate + Nitrite as N	mg/L	11.46	14.64	15.28	14.67	13.28	11.37	6.92	4.56	5.70	6.82	10.55	13.68
Nitrogen - Total	mg/L	16.15	19.40	20.42	19.67	19.03	16.92	16.22	7.11	9.36	13.85	16.46	17.94
Phosphorus - Total	mg/L	2.90	2.98	3.18	3.88	3.42	2.05	2.43	4.07	3.51	2.85	3.46	2.97
Alkalinity as Calcium Carbonate	mg/L	135.0	121.0	144.0	151.0	149.0	144.0	96.0	186.0	173.0	157.0	140.0	137.0
Total Hardness as CaCO3	mg/L	213.0	240.0	242.0	257.0	240.0	225.0	177.0	244.0	244.0	186.0	211.0	210.0
Bicarbonate	mg/L	140.0	148.0	176.0	185.0	182.0	175.0	67.0	227.0	211.0	183.0	157.0	156.0
Chloride	mg/L	370.0	390.0	422.0	417.0	405.0	396.0	392.0	387.0	351.0	350.0	329.0	365.0
Sulphate	mg/L	122.0	134.0	138.0	139.0	139.0	137.0	124.0	124.0	136.0	126.0	130.0	128.0
Calcium	mg/L	36.6	40.4	40.2	42.5	38.4	37.7	32.4	40.5	40.0	31.2	36.4	35.0
Magnesium	mg/L	29.5	33.7	34.5	36.6	34.9	31.8	23.4	34.6	35.1	26.3	29.2	29.7
Potassium	mg/L	32.6	31.7	32.6	37.5	37.1	34.4	35.8	35.6	38.2	33.6	38.3	33.5
Sodium	mg/L	241.0	276.0	296.0	288.0	270.0	256.0	281.0	252.0	245.0	227.0	234.0	235.0
Sodium Adsorption Ratio - Calculation		7.19	7.76	8.27	7.82	7.59	7.43	9.19	7.03	6.82	7.24	7.01	7.06
Aluminium - Total	mg/L	0.4740	0.7340	3.5290	1.8110	1.4180	1.1290	0.2010	0.3540	0.7150	0.2090	0.5700	1.3720
Antimony - Total	mg/L	0.0005	0.0005	0.0005	0.0006	0.0005	0.0005	0.0007	0.0005	0.0005	0.0005	0.0005	0.0005
Arsenic - Total	mg/L	0.0055	0.0025	0.0035	0.0029	0.0035	0.0029	0.0023	0.0039	0.0048	0.0052	0.0038	0.0026
Beryllium - Total	mg/L	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Boron - Soluble	mg/L	0.2610	0.2890	0.3600	0.3120	0.3160	0.2380	0.2120	0.2620	0.2340	0.2480	0.2150	0.2200
Cadmium - Total	mg/L	0.0003	0.0004	0.0009	0.0004	0.0005	0.0004	0.0002	0.0002	0.0004	0.0005	0.0005	0.0005
Chromium - Total	mg/L	0.0113	0.0134	0.0941	0.0289	0.0320	0.0252	0.0051	0.0031	0.0140	0.0036	0.0091	0.0147
Cobalt - Total	mg/L	0.0009	0.0010	0.0021	0.0015	0.0015	0.0013	0.0008	0.0005	0.0009	0.0009	0.0011	0.0011
Copper - Total	mg/L	0.0322	0.0298	0.1367	0.0512	0.0630	0.0475	0.0219	0.0102	0.0281	0.0173	0.0252	0.0330
Iron - Total	mg/L	0.4715	0.5354	3.8250	1.5600	1.4980	1.0350	0.1589	0.1768	0.7247	0.1526	0.5236	1.2140
Lead - Total	mg/L	0.0059	0.0069	0.0239	0.0060	0.0078	0.0087	0.0021	0.0039	0.0045	0.0027	0.0048	0.0044
Lithium - Total	mg/L	0.0074	0.0079	0.0107	0.0096	0.0080	0.0083	0.0092	0.0082	0.0079	0.0067	0.0068	0.0073
Manganese - Total	mg/L	0.0366	0.0501	0.1294	0.0642	0.0532	0.0514	0.0119	0.0189	0.0348	0.0141	0.0436	0.0352
Mercury - Total	mg/L	0.00003	0.00005	0.00024	0.00003	0.00008	0.00016	0.00011	0.00006	0.00012	0.00004	0.00006	0.00010
Molybdenum - Total	mg/L	0.0060	0.0068	0.0075	0.0063	0.0075	0.0062	0.0074	0.0074	0.0069	0.0090	0.0080	0.0066
Nickel - Total	mg/L	0.0113	0.0091	0.0220	0.0123	0.0113	0.0148	0.0091	0.0109	0.0114	0.0098	0.0090	0.0083
Selenium - Total	mg/L	0.0007	0.0007	0.0012	0.0011	0.0009	0.0006	0.0008	0.0004	0.0008	0.0005	0.0004	0.0005
Silver - Total	mg/L	0.0005	0.0006	0.0044	0.0011	0.0016	0.0012	0.0003	0.0001	0.0006	0.0001	0.0004	0.0007
Tin - Total	mg/L	0.0011	0.0012	0.0064	0.0017	0.0021	0.0021	0.0008	0.0005	0.0018	0.0005	0.0005	0.0013
Thallium - Total	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Vanadium - Total	mg/L	0.0031	0.0057	0.0070	0.0060	0.0061	0.0067	0.0080	0.0048	0.0080	0.0100	0.0080	0.0054
Zinc - Total	mg/L	0.0778	0.0786	0.2098	0.0870	0.0972	0.0837	0.0174	0.0490	0.0589	0.0423	0.0605	0.0659
Algae - total	cells/mL	11270	2856	18281	1800	8456	4245	33858	1426	3333	500	3159	1212

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Bolivar WWTP Effluent Weir 1 Summary Report
2012-13

EFFLUENT		July	August	September	October	November	December	January	February	March	April	May	June
Dissolved Oxygen	mg/L	5.3	6.5	8.4	7.4	6.2	6.3	6.7	7.3	8.8	7.7	9.6	6.8
Turbidity	NTU	24.0	9.8	17.0	12.0	85.0	12.0	44.4	43.0	87.0	75.0	63.0	49.0
Temperature	degrees C	11.5	11.8	13.7	16.7	20.2	22.4	22.7	22.3	21.2	17.5	14.1	13.0
Biochemical Oxygen Demand	mg/L	5.4	2.8	6.4	5.3	6.2	5.0	9.3	13.2	10.8	6.6	7.8	8.6
Suspended Solids	mg/L	31.8	22.6	65.2	56.7	69.8	46.8	94.8	114.4	116.3	102.4	84.6	94.0
Chemical Oxygen Demand	mg/L	98.0	118.0	107.0	121.0	191.0	174.0	161.5	214.0	135.0	125.5	110.0	103.0
pH	pH units	8.2	7.8	8.3	8.1	7.8	8.1	8.7	9.4	9.1	8.8	9.0	8.5
Total Dissolved Solids (by EC)	mg/L	1,004	1,100	1,140	1,183	1,100	1,075	970	914	863	824	810	916
Colour - True (456nm)	HU	52.0	44.0	42.5	39.0	38.0	44.0	40.0	29.0	32.0	35.5	35.0	44.0
E.coli	/100mL	85	41	85	75	106	98	180	210	455	362	122	215
Ammonia as N	mg/L	0.64	0.50	0.51	0.78	0.85	0.69	0.53	0.51	0.50	0.54	0.59	0.60
TKN as Nitrogen	mg/L	3.77	3.46	5.12	3.85	4.01	4.50	5.77	5.81	6.39	4.93	5.64	5.63
Nitrate as Nitrogen	mg/L	10.10	16.20	16.00	11.60	13.30	8.59	7.43	4.81	3.33	5.48	5.78	4.06
Nitrite as Nitrogen	mg/L	0.091	0.118	0.083	0.139	0.103	0.099	0.100	0.157	0.087	0.102	0.100	0.137
Nitrate + Nitrite as N	mg/L	11.80	16.50	15.58	12.22	10.78	8.36	7.92	5.11	5.11	5.71	6.36	4.03
Nitrogen - Total	mg/L	15.58	19.96	20.68	16.05	14.76	12.85	13.62	10.91	11.50	10.62	12.02	9.54
Phosphorus - Total	mg/L	3.27	3.48	2.89	2.33	2.96	2.45	2.34	2.29	2.73	1.93	1.49	2.13
Alkalinity as Calcium Carbonate	mg/L	173.0	160.0	161.0	166.0	158.0	185.0	176.0	165.0	184.0	173.0	170.0	202.0
Total Hardness as CaCO3	mg/L	219.0	279.0	262.5	223.0	255.0	251.0	231.0	207.0	194.0	207.5	206.0	227.0
Bicarbonate	mg/L	211.0	195.0	185.5	202.0	193.0	226.0	177.0	127.0	170.0	184.0	179.0	228.0
Chloride	mg/L	381.0	430.0	459.5	456.0	431.0	435.0	389.5	373.0	343.0	301.5	312.0	363.0
Sulphate	mg/L	145.0	157.0	181.0	143.0	172.0	132.0	114.5	130.0	115.0	126.0	115.0	128.0
Calcium	mg/L	37.6	45.8	43.6	38.3	43.4	44.3	39.8	39.0	35.5	39.0	39.5	42.7
Magnesium	mg/L	30.4	40.0	37.4	30.9	35.6	34.2	32.0	26.5	25.6	26.8	26.0	29.3
Potassium	mg/L	32.7	38.9	35.6	31.9	38.0	38.4	40.5	42.6	40.3	41.1	42.0	36.9
Sodium	mg/L	252.0	311.0	298.5	259.0	295.0	281.0	270.0	268.0	242.0	239.0	253.0	247.0
Sodium Adsorption Ratio - Calculation		7.41	8.10	8.01	7.55	8.04	7.71	7.74	8.12	7.56	7.22	7.68	7.13
Aluminium - Total	mg/L	0.9920	0.6080	1.2580	0.5040	3.3920	1.0780	1.8900	1.1760	3.2980	1.9740	2.0980	1.9460
Antimony - Total	mg/L	0.0005	0.0005	0.0005	0.0005	0.0007	0.0005	0.0008	0.0005	0.0005	0.0005	0.0008	0.0012
Arsenic - Total	mg/L	0.0036	0.0031	0.0026	0.0020	0.0030	0.0030	0.0031	0.0021	0.0043	0.0028	0.0022	0.0031
Beryllium - Total	mg/L	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Boron - Soluble	mg/L	0.3990	0.4070	0.3965	0.3740	0.3420	0.2880	0.3095	0.2760	0.3070	0.2785	0.2530	0.3590
Cadmium - Total	mg/L	0.0004	0.0006	0.0006	0.0003	0.0007	0.0003	0.0004	0.0003	0.0004	0.0004	0.0004	0.0003
Chromium - Total	mg/L	0.0152	0.0055	0.0112	0.0053	0.0582	0.0158	0.0175	0.0114	0.0370	0.0182	0.0250	0.0193
Cobalt - Total	mg/L	0.0010	0.0009	0.0011	0.0010	0.0021	0.0015	0.0017	0.0011	0.0016	0.0014	0.0015	0.0013
Copper - Total	mg/L	0.0326	0.0239	0.0314	0.0198	0.0915	0.0307	0.0345	0.0299	0.0570	0.0334	0.0461	0.0331
Iron - Total	mg/L	0.9751	0.4941	1.0160	0.4009	3.3160	0.9317	1.2215	0.7152	2.6320	1.5009	1.7000	1.4860
Lead - Total	mg/L	0.0047	0.0033	0.0043	0.0031	0.0212	0.0071	0.0073	0.0045	0.0103	0.0070	0.0088	0.0072
Lithium - Total	mg/L	0.0096	0.0103	0.0102	0.0079	0.0105	0.0094	0.0079	0.0077	0.0082	0.0075	0.0076	0.0082
Manganese - Total	mg/L	0.0262	0.0188	0.0299	0.0296	0.0924	0.0564	0.0477	0.0175	0.0600	0.0440	0.0589	0.0640
Mercury - Total	mg/L	0.00008	0.00013	0.00007	0.00007	0.00003	0.00005	0.00010	0.00020	0.00018	0.00005	0.00012	0.00008
Molybdenum - Total	mg/L	0.0094	0.0081	0.0084	0.0056	0.0068	0.0064	0.0060	0.0060	0.0057	0.0065	0.0057	0.0064
Nickel - Total	mg/L	0.0118	0.0094	0.0104	0.0091	0.0188	0.0131	0.0136	0.0114	0.0157	0.0122	0.0121	0.0107
Selenium - Total	mg/L	0.0007	0.0015	0.0008	0.0007	0.0008	0.0008	0.0014	0.0006	0.0006	0.0004	0.0005	0.0005
Silver - Total	mg/L	0.0005	0.0002	0.0005	0.0002	0.0034	0.0010	0.0007	0.0005	0.0016	0.0007	0.0011	0.0008
Tin - Total	mg/L	0.0013	0.0006	0.0009	0.0007	0.0044	0.0011	0.0015	0.0008	0.0028	0.0018	0.0018	0.0015
Thallium - Total	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Vanadium - Total	mg/L	0.0070	0.0067	0.0081	0.0051	0.0091	0.0071	0.0101	0.0076	0.0116	0.0105	0.0146	0.0114
Zinc - Total	mg/L	0.0606	0.0630	0.0695	0.0589	0.1306	0.0624	0.0441	0.0253	0.0597	0.0504	0.0684	0.0517
Algae - total	cells/mL	247365	126909	252200	45025	95956	28695	1619880	1314750	2500000	1394250	1492000	1204333

Disclaimer: *The data contained in this report has been prepared for SA Water's own internal use only. SA Water accepts no liability for and gives no undertakings, guarantees or warranties concerning the accuracy, completeness or fitness for use of the data for any purpose. In the event the data is requested by an external party, approval for its release will be subject to the conditions of use set out in SA Water's Policy on Release of Water Quality Data.*

Bolivar WWTP Effluent Weir 1 Summary Report
2013-14

EFFLUENT		July	August	September	October	November	December	January	February	March	April	May	June
Dissolved Oxygen	mg/L	10.1	10.7	10.0	10.2	10.2	7.2	4.6	7.8	7.6	6.9	7.7	7.2
Turbidity	NTU	87.0	54.0	64.0	260.0	74.0	72.0	34.5	40.0	77.0	78.0	86.5	200.0
Temperature	degrees C	12.8	12.3	16.3	14.3	19.3	21.6	20.3	21.5	19.7	16.7	15.4	12.7
Biochemical Oxygen Demand	mg/L	6.4	6.8	6.0	4.4	14.4	21.5	7.6	12.2	12.0	10.0	8.2	7.8
Suspended Solids	mg/L	75.6	63.2	69.0	60.6	87.2	74.0	34.6	65.6	71.2	74.0	79.6	131.0
Chemical Oxygen Demand	mg/L	95.0	189.0	63.0	82.0	171.0	200.0	129.0	176.0	133.0	139.0	98.5	155.0
pH	pH units	8.2	8.5	8.6	8.4	8.9	9.1	8.1	8.9	8.7	8.3	8.5	8.1
Total Dissolved Solids (by EC)	mg/L	982	1,040	1,140	1,220	1,080	1,032	1,060	1,120	1,100	1,060	966	1,040
Colour - True (456nm)	HU	41.0	40.0	46.0	20.0	36.0	66.0	28.5	33.0	33.0	39.0	36.0	43.0
E.coli	/100mL	47	25	75	203	15	34	250	241	107	227	210	117
Ammonia as N	mg/L	0.71	0.55	0.50	0.30	0.11	0.29	0.28	0.04	0.10	0.08	0.04	0.31
TKN as Nitrogen	mg/L	3.97	3.56	5.28	3.78	6.27	7.25	3.41	5.32	5.38	4.91	4.56	4.97
Nitrate as Nitrogen	mg/L	8.10	7.27	6.69	7.12	5.41	2.14	0.71	0.85	1.60	4.39	6.41	5.65
Nitrite as Nitrogen	mg/L	0.250	0.071	0.264	0.108	0.118	0.085	0.243	0.064	0.112	0.210	0.119	0.167
Nitrate + Nitrite as N	mg/L	7.04	7.37	6.97	6.95	6.34	1.79	0.60	0.54	1.98	5.20	7.26	5.24
Nitrogen - Total	mg/L	11.00	10.94	12.24	10.73	12.61	10.01	4.02	5.85	7.36	10.11	11.82	10.07
Phosphorus - Total	mg/L	3.06	2.75	3.27	2.45	2.25	1.93	3.26	2.11	2.56	2.19	2.22	2.68
Alkalinity as Calcium Carbonate	mg/L	175.0	193.0	208.0	163.5	172.0	169.0	209.5	195.0	221.0	189.0	174.5	202.0
Total Hardness as CaCO3	mg/L	228.0	252.0	258.0	270.0	222.0	207.0	278.5	258.0	276.0	233.0	202.0	225.0
Bicarbonate	mg/L	213.0	218.0	237.0	200.0	160.0	161.0	255.5	209.0	244.0	203.0	212.5	247.0
Chloride	mg/L	386.0	423.0	455.0	469.0	405.0	403.0	410.0	421.0	429.0	402.0	362.0	341.0
Sulphate	mg/L	118.0	138.0	140.0	197.5	140.0	133.0	132.0	145.0	135.0	121.0	120.5	128.0
Calcium	mg/L	41.1	45.2	44.2	44.7	38.7	36.6	44.5	47.8	50.6	42.3	37.3	42.4
Magnesium	mg/L	30.4	33.9	35.9	38.6	30.5	28.1	31.6	33.6	36.4	31.0	26.4	29.0
Potassium	mg/L	39.2	39.0	39.2	43.0	41.9	42.3	42.4	41.0	45.0	39.0	34.6	38.5
Sodium	mg/L	278.0	301.0	310.0	343.0	303.0	304.0	300.0	258.0	318.0	290.0	251.5	283.0
Sodium Adsorption Ratio - Calculation		8.02	8.24	8.40	9.08	8.85	9.19	6.79	6.99	8.33	8.26	7.71	8.21
Aluminium - Total	mg/L	3.1390	1.3400	1.6360	2.2390	1.9890	1.5420	1.2170	1.2690	1.5370	2.6780	2.7755	9.1730
Antimony - Total	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0007	0.0006
Arsenic - Total	mg/L	0.0023	0.0029	0.0033	0.0016	0.0026	0.0034	0.0036	0.0035	0.0031	0.0034	0.0029	0.0038
Beryllium - Total	mg/L	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Boron - Soluble	mg/L	0.3140	0.4000	0.4080	0.4385	0.4560	0.4610	0.5075	0.4560	0.5020	0.4150	0.4165	0.4480
Cadmium - Total	mg/L	0.0005	0.0004	0.0007	0.0006	0.0004	0.0004	0.0003	0.0003	0.0003	0.0005	0.0005	0.0015
Chromium - Total	mg/L	0.0342	0.0193	0.0327	0.0283	0.0220	0.0239	0.0165	0.0177	0.0206	0.0283	0.0292	0.1082
Cobalt - Total	mg/L	0.0014	0.0011	0.0013	0.0016	0.0013	0.0012	0.0008	0.0012	0.0011	0.0016	0.0014	0.0029
Copper - Total	mg/L	0.0555	0.0337	0.0553	0.0499	0.0404	0.0442	0.0268	0.0301	0.0346	0.0461	0.0468	0.1823
Iron - Total	mg/L	3.1730	1.0540	1.3510	2.0046	1.5600	1.3590	1.0888	1.0170	1.4410	2.1170	2.3440	8.4460
Lead - Total	mg/L	0.0109	0.0076	0.0097	0.0077	0.0064	0.0057	0.0048	0.0055	0.0059	0.0082	0.0079	0.0276
Lithium - Total	mg/L	0.0081	0.0110	0.0100	0.0102	0.0079	0.0067	0.0079	0.0076	0.0079	0.0084	0.0090	0.0133
Manganese - Total	mg/L	0.0648	0.0495	0.0530	0.0416	0.0423	0.0407	0.0333	0.0367	0.0492	0.0702	0.0630	0.1650
Mercury - Total	mg/L	0.00007	0.00004	0.00006	0.00011	0.00008	0.00008	0.00007	0.00008	0.00011	0.00007	0.00012	0.00026
Molybdenum - Total	mg/L	0.0046	0.0061	0.0060	0.0058	0.0051	0.0059	0.0061	0.0050	0.0042	0.0051	0.0043	0.0062
Nickel - Total	mg/L	0.0117	0.0091	0.0114	0.0128	0.0121	0.0132	0.0148	0.0137	0.0138	0.0132	0.0152	0.0245
Selenium - Total	mg/L	0.0005	0.0008	0.0009	0.0008	0.0008	0.0008	0.0004	0.0004	0.0003	0.0006	0.0005	0.0019
Silver - Total	mg/L	0.0017	0.0008	0.0014	0.0015	0.0009	0.0011	0.0008	0.0014	0.0010	0.0011	0.0013	0.0056
Tin - Total	mg/L	0.0025	0.0015	0.0023	0.0024	0.0016	0.0017	0.0009	0.0010	0.0016	0.0020	0.0023	0.0077
Thallium - Total	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Vanadium - Total	mg/L	0.0077	0.0085	0.0164	0.0104	0.0106	0.0093	0.0068	0.0091	0.0078	0.0091	0.0071	0.0136
Zinc - Total	mg/L	0.1107	0.0700	0.0857	0.0744	0.0407	0.0469	0.0309	0.0361	0.0349	0.0610	0.0636	0.2480
Algae - total	cells/mL	565333.3	1064600	593000	814400	2252000	3440000	475800	1713000	654250	1137400	750500	621750

Bolivar WWTP Effluent Weir 1 Summary Report
2014-15

EFFLUENT		July	August	September	October	November	December	January	February	March	April	May	June
Dissolved Oxygen	mg/L	8.5	9.3	6.9	5.9	6.6	6.1	6.0	7.5	8.7	7.4	8.0	6.4
Turbidity	NTU	26.0	21.0	71.0	110.0	75.0	85.0	31.9	120.0	69.0	141.0	44.0	96.0
Temperature	degrees C	11.0	12.2	15.1	17.8	19.7	21.8	21.8	22.2	19.0	15.1	13.7	12.4
Biochemical Oxygen Demand	mg/L	5.0	7.4	13.2	9.4	12.4	8.4	11.8	21.0	8.2	7.4	12.4	8.2
Suspended Solids	mg/L	44.6	46.0	147.6	148.2	153.8	155.6	153.3	118.4	79.0	138.2	90.4	76.8
Chemical Oxygen Demand	mg/L	69.0	119.0	114.0	135.0	166.0	167.0	119.5	176.0	103.0	148.5	56.0	113.0
pH	pH units	8.0	9.0	8.7	7.9	8.4	9.1	8.7	9.3	9.2	8.9	8.6	8.6
Total Dissolved Solids (by EC)	mg/L	1,032	1,160	1,200	1,200	1,040	1,000	992	996	902	856	922	952
Colour - True (456nm)	HU	40.0	35.0	44.0	45.0	37.5	41.0	22.0	33.5	27.0	36.0	37.0	39.0
E.coli	/100mL	43	25	162	73	75	578	76	33	105	111	116	104
Ammonia as N	mg/L	0.21	0.03	0.43	0.42	0.35	0.18	0.10	0.06	0.04	0.27	0.07	0.41
TKN as Nitrogen	mg/L	3.66	4.20	7.22	5.99	5.90	5.95	7.27	10.09	6.98	8.78	7.49	5.57
Nitrate as Nitrogen	mg/L	9.42	6.97	3.50	5.14	5.64	3.04	3.87	2.81	1.45	4.22	5.32	4.71
Nitrite as Nitrogen	mg/L	0.1130	0.0970	0.1465	0.2410	0.1610	0.1160	0.1035	0.1960	0.1090	0.1955	0.2130	0.3680
Nitrate + Nitrite as N	mg/L	9.23	5.66	3.98	5.04	5.52	3.02	4.16	2.88	2.31	4.59	6.03	5.07
Nitrogen - Total	mg/L	12.88	9.86	11.20	11.03	11.40	8.97	11.43	12.96	9.31	13.35	13.53	10.65
Phosphorus - Total	mg/L	2.227	2.120	3.393	3.525	2.683	2.865	1.967	2.237	1.355	2.387	1.775	1.643
Alkalinity as Calcium Carbonate	mg/L	173.0	194.0	216.5	206.0	180.0	197.0	149.5	173.0	177.0	173.5	160.0	189.0
Total Hardness as CaCO3	mg/L	216.0	242.0	249.0	254.0	228.0	206.0	219.5	199.0	195.0	198.5	209.0	201.0
Bicarbonate	mg/L	211.0	219.0	249.5	251.0	216.0	203.0	162.5	184.0	92.0	180.5	173.0	209.0
Chloride	mg/L	371.0	429.0	467.5	416.0	378.0	387.0	382.0	390.0	343.0	286.5	319.0	335.0
Sulphate	mg/L	124.0	143.0	143.5	139.0	133.0	130.0	150.5	120.0	121.0	117.0	115.0	103.0
Calcium	mg/L	40.9	42.8	42.3	43.7	40.9	36.9	40.4	39.1	37.3	37.7	38.7	35.3
Magnesium	mg/L	27.6	32.7	34.8	35.1	30.6	27.7	28.8	24.6	24.8	25.4	27.4	27.5
Potassium	mg/L	35.3	36.5	36.7	39.9	39.5	38.5	38.7	38.9	40.7	38.7	36.5	39.5
Sodium	mg/L	265.0	326.0	328.0	329.0	291.0	280.0	295.0	272.0	244.0	241.5	242.0	253.0
Sodium Adsorption Ratio - Calculation		7.85	9.13	9.05	8.99	8.39	8.49	8.67	8.39	7.60	7.47	7.28	7.76
Aluminium - Total	mg/L	1.2120	0.5740	2.1070	4.3560	2.4090	2.7150	1.0590	1.1350	0.3980	2.9425	1.7390	4.6840
Antimony - Total	mg/L	0.0009	0.0005	0.0015	0.0009	0.0005	0.0006	0.0005	0.0005	0.0006	0.0005	0.0005	0.0008
Arsenic - Total	mg/L	0.0023	0.0019	0.0032	0.0034	0.0025	0.0034	0.0020	0.0022	0.0026	0.0027	0.0020	0.0028
Beryllium - Total	mg/L	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Boron - Soluble	mg/L	0.5020	0.5930	0.6395	0.4640	0.3530	0.3090	0.2915	0.2380	0.2680	0.1735	0.1890	0.2340
Cadmium - Total	mg/L	0.0003	0.0003	0.0008	0.0008	0.0004	0.0007	0.0003	0.0002	0.0002	0.0005	0.0003	0.0003
Chromium - Total	mg/L	0.0102	0.0066	0.0293	0.0524	0.0321	0.0409	0.0106	0.0095	0.0034	0.0245	0.0141	0.0240
Cobalt - Total	mg/L	0.0009	0.0007	0.0013	0.0018	0.0014	0.0018	0.0011	0.0009	0.0008	0.0013	0.0010	0.0012
Copper - Total	mg/L	0.0232	0.0176	0.0480	0.0718	0.0430	0.0629	0.0201	0.0200	0.0146	0.0419	0.0237	0.0468
Iron - Total	mg/L	1.0490	0.4999	1.8645	3.2240	2.1840	2.0400	0.7166	0.6338	0.3091	2.2974	1.2400	2.5000
Lead - Total	mg/L	0.0050	0.0040	0.0106	0.0140	0.0079	0.0112	0.0037	0.0030	0.0016	0.0080	0.0050	0.0075
Lithium - Total	mg/L	0.0095	0.0090	0.0102	0.0090	0.0065	0.0069	0.0062	0.0049	0.0058	0.0076	0.0074	0.0103
Manganese - Total	mg/L	0.0348	0.0344	0.0828	0.1038	0.0568	0.0775	0.0374	0.0317	0.0106	0.0588	0.0602	0.0757
Mercury - Total	mg/L	0.00003	0.00005	0.00013	0.00017	0.00006	0.00013	0.00015	0.00003	0.00004	0.00008	0.00009	0.00004
Molybdenum - Total	mg/L	0.0066	0.0058	0.0063	0.0051	0.0041	0.0054	0.0050	0.0055	0.0047	0.0045	0.0058	0.0055
Nickel - Total	mg/L	0.0087	0.0062	0.0119	0.0156	0.0113	0.0160	0.0109	0.0094	0.0093	0.0112	0.0081	0.0092
Selenium - Total	mg/L	0.0011	0.0010	0.0014	0.0010	0.0025	0.0008	0.0014	0.0005	0.0015	0.0006	0.0018	0.0006
Silver - Total	mg/L	0.0005	0.0003	0.0012	0.0020	0.0014	0.0019	0.0005	0.0004	0.0001	0.0009	0.0004	0.0007
Tin - Total	mg/L	0.0015	0.0007	0.0031	0.0040	0.0005	0.0023	0.0011	0.0005	0.0005	0.0016	0.0009	0.0005
Thallium - Total	mg/L	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Vanadium - Total	mg/L	0.0097	0.0068	0.0106	0.0107	0.0107	0.0179	0.0086	0.0069	0.0039	0.0077	0.0070	0.0065
Zinc - Total	mg/L	0.0674	0.0553	0.0783	0.1172	0.0625	0.0919	0.0311	0.0260	0.0116	0.0819	0.0574	0.0681
Algae - total	cells/mL	18363	22568	17025	24940	10683	3787	11523	667	1641	1841	6633	1188

Attachment B

Desalination techniques

Commercial desalination technologies are differentiated by their separation technique. There are three main types: membrane separation, thermal distillation and electrochemical desalination. Hybrids of thermal and membrane processes also exist.
A modern desalination plant consists of two main components—the energy supply, which may be from the national grid or a standalone power plant and the desalination unit that removes minerals from water. The choice of desalination processes suitable for the semi-arid NAP region will be governed by the energy requirement, water availability, source water quality and the cost of produced water.

Membrane-based desalination

Membrane driven processes include reverse osmosis electrodialysis, forward osmosis and membrane distillation and pervaporation (Quist-Jensen, et al., 2015). Reverse osmosis has been the most established method with large scale plants in operation across Australia (Burn, et al., 2015). Electrodialysis and forward osmosis are two emerging technologies, with small scale electrodialysis plants in operation and forward osmosis being extensively tested and researched for commercial viability (Checkli, et al., 2016). Other membrane-based processes such as microfiltration, nanofiltration and ultrafiltration are used as supporting technologies that pre-treat feed water, which is saline water (sea water or brackish water).

Reverse osmosis

Reverse osmosis is currently the most established large scale desalination option for both seawater and brackish water due to recent advancements in optimization of membrane performance. The main parts in a reverse osmosis plant are pre-treatment process, high pressure pumps, membrane assembly and a post treatment process. Saline water, pressurized using pumps to overcome its osmotic pressure, is forced through a membrane which retains salts producing fresh water whilst leaving the concentrated brine as a reject. The brine concentration can range between 20–70% (Mezher, et al., 2011) depending on the feed water concentration. If reverse osmosis plants are located near the coastal area in the NAP region, brine could be discharged into Gulf St. Vincent subject to environmental requirements, however, any inland plants would need to consider alternate brine disposal options.

The energy requirement for seawater desalination by reverse osmosis is higher compared to that of brackish water due to the higher osmotic pressure requirement of seawater (2800 kPa for a salinity of 35,000 mg/L vs 140 kPa for a salinity of 1600 mg/L of brackish water). In Australia, seven major desalination plants aim to produce 1.8 ML/day, with the Adelaide Desalination Plant (ADP) currently producing 0.30 ML/day (Palmer, 2015). The water recovery rates can vary from 55 to 60% (Molina, et al., 2009). The ADP has shown an average water recovery of 48.6% (December 2013-December 2014) (Blesing & Pelekani, 2015).

The main practical difficulty associated with reverse osmosis is the membrane deterioration due to fouling and scaling which can be aggravated by alternating operation. Feed water needs to be pre-treated, which increases operating costs, and a significant proportion of the feed is returned to the source (ocean or inland water sources) as a waste stream.

Forward osmosis
In contrast to high pressure driven reverse osmosis, forward osmosis is driven by natural osmosis, thus the energy consumption is significantly lower (Zhao, et al., 2012b; Cath, et al., 2006; McCutcheon, et al., 2006). Two solutions - the saline feed and the draw solution with significantly higher, high osmotic concentration, are separated by a semi-permeable membrane. Due to the concentration gradient, water from the saline feed (low salt concentration) permeates through the membrane to dilute the draw solution (high salt concentration). Water is recovered from the draw solution by methods such as heating, nanofiltration and electrodialysis (Zhao, et al., 2012a).

Apart from low energy consumption, forward osmosis offers advantages such as lower fouling tendency, easier fouling removal and higher water recovery compared to reverse osmosis, nanofiltration and ultrafiltration (Zhao, et al., 2012b; Elimelech, 2007). Selection of an appropriate draw solution and tailored FO membranes are essential for this novel technology to be feasible. A recent project funded by the National Centre of Excellence in Desalination (NCEDA) introduced fertilizer drawn forward osmosis (Phuntsho, et al., 2012). In this study, a concentrated fertilizer solution was used as the draw solution, which was diluted with the fresh water component in salty water. The diluted fertilizer draw solution was directly used for irrigation. Studies have shown that 1 kg of fertilizer can extract 11–29 L of water from a seawater feed (Burn, et al., 2015).

Electrodialysis
Electrodialysis is an electricity driven process in which salt ions are moved selectively through a membrane leaving fresh water behind (Strathmann 2010). Electrodialysis is mainly applied for brackish water desalination (salinity < 3,000 mg/L Total dissolved solids) and has high recovery rates of 85–94% and produces concentrates of 140–600 mg/L (Malek, et al., 2016). Electrodialysis can treat a wide range of quantities starting from 0.002–145 ML/day. Reverse electrodialysis is also used as a measure for reducing membrane scaling (Post, et al., 2008) (Montana, et al., 2013). The supplied voltage is reversed intermittently which in turn reverses the direction of ion flow. Reverse electrodialysis can be combined with reverse osmosis and forward osmosis to increase brine recovery (Kwon, et al., 2015). Compared to reverse osmosis, electrodialysis and reverse electrodialysis processes could be disadvantageous due to system design complexity, increased membrane fouling and poor electrode life.

Membrane distillation and pervaporation
Membrane distillation is an emerging process based on thermal diffusion which utilizes a vapour pressure gradient across a hydrophobic membrane (Wang & Chung, 2015; Gryta, 2011). The hydrophobic nature of the membrane prevents liquid feed entering into membrane pores but allows the volatile components of the hot feed that vaporizes at the liquid /vapour interphase to permeate through its dry pores. The vapours are collected and condensed thereafter. Compared to conventional membrane-based processes, membrane distillation offers advantages such as 100% (theoretical) rejection of organic ions, macromolecules and non-volatile compounds, lower operating pressures and temperatures, and independence from feed concentration and membrane mechanical properties.

Membrane distillation is suitable for high salinity applications such as concentration of brines, recovery of soluble components and to achieve zero liquid discharge through membrane distillation crystallization (Ji, et al., 2010). Various modes of membrane distillation can be identified based on the method of permeate collection (Direct contact membrane distillation), mass transfer mechanism through the membrane (air gap or, sweep gas membrane distillation) and the cause for driving force formation (vacuum membrane distillation). Without heat recovery mechanisms, the energy requirement for membrane distillation is ~ 628 kWh/Ton of clean water (Khayet, 2011) which is disadvantageous compared to reverse osmosis. Pervaporation is a similar process to membrane distillation with the principle difference being the active involvement of the membrane in desalination (Bolto, et al., 2011).

Thermal desalination

Thermal desalination processes depend on phase transition by energy addition—evaporation and condensation to separate fresh water from saline water. Multi-stage flash distillation and multiple-effect distillation are the main commercially available thermal desalination technologies. Thermal desalination plants are popular for large scale desalination in the Middle East due to low energy costs and availability of cogeneration plants (Mezher, et al., 2011). Thermal desalination methods are prone to scale formation limiting top brine temperature. Vapour compression and solar humidification and dehumidification offer small scale options suitable for remote applications.

Multi-stage flash distillation

In multi-stage flash distillation, pre-heated saline water in tubular heaters is further heated in a brine heater before being introduced to a vessel at lower ambient pressure (stage) compared to the brine heater. Due to this, low pressure water is subjected to sudden boiling, which forms vapour that is condensed in the feed pre-heat tubes. The fraction of steam formed in the vessel depends on the magnitude of the pressure thus only a low percentage of heated water is converted to steam. The remainder is introduced to the next stage with even lower pressure and the process continues (typically between 4–40 stages) until the water which has turned into brine cools down. Multi-stage flash distillation plants require high energy electrical and thermal energy inputs resulting in a high specific energy consumption (Hamad, et al., 2000) and associated high carbon footprint. The brine discharge can be 15–20% concentrated and 7–15 °C higher in temperature compared to the feed (Sommariva, et al., 2004).

Multiple-effect distillation

The multi-effect distillation process occurs in a series of evaporators (effects) at reduced ambient pressure. The pre-heated feed water at boiling point is sprayed on evaporator surfaces which are tubes from which the water is evaporated. The first effect is heated by steam from a steam power plant or boiler while the latter streams are heated by the steam generated in the first effect. As only a fraction of water is converted to steam, the remainder forms the brine solution. Multi-effect distillation is less competitive compared to multi-stage flash distillation due to severe scaling and high capital and operating costs (Mezher, et al., 2011). Similar to multi-stage flash distillation, multi-effect distillation requires both electrical and thermal energy, however the electrical energy requirement is lower in addition to lower greenhouse gas emissions (Hamed & Miyamura, 2010).

Vapour compression

The vapour compression process is similar to multi-effect distillation but used for small and medium scale desalination plants for resorts and industrial supply (Al-Karaghouli & Kamerski, 2011). In vapour compression the heat for saline water evaporation is supplied by a vapour compressor in contrast to the direct heat exchange from steam or a boiler in multi-effect distillation. Vapour is condensed either by mechanical compression (Mechanical Vapour Compression) or by a steam jet (Thermal Vapour Compression). Mechanical vapour compression and thermal vapour compression plants could produce 3 and 20, ML/day respectively. Vapour compression plants are compact and can be designed as portable units. Their pre-treatment requirements are lower, with high water recovery and a simpler operation. However, the energy requirements can be higher compared to reverse osmosis and the need for an expensive compressor and auxiliary heater for the start-up could be disadvantageous.

Solar humidification and dehumidification

The solar humidification and dehumidification process can be applied as an inexpensive decentralized small scale desalination method (Narayan, et al., 2010). In this process, ambient air or water is humidified using solar heat followed by dehumidification in a condenser leaving a distillate. This cycle is followed by solar still technology as a direct desalination technology utilizing only the heat from solar radiation without the need of electricity. Solar humidification and dehumidification is relatively simple and has lower operating costs however this method requires large solar collection areas, high capital costs and is prone to weather related damage.

Electrochemical desalination

Capacitive deionization

Capacitive deionization is a novel technology in which salt ions are held in a pair of externally charged electrodes made of nanomaterials with high surface area (Porada, et al., 2013). As only the minority component (the salts) is removed from water, pressurising water using large energy inputs is not required. Thus, the energy consumption is significantly low in capacitive deionization, offering a cheap alternative to high pressure driven reverse osmosis. Capacitive deionization can desalinate brackish water up to concentrations of 2,500–3,000 mg/L with the potential for extension to treat concentrations up to 15,000 mg/L. The process may be particularly suitable for the Northern Adelaide region due to the tolerance of the unit to variable feed water, lack of scaling by silica, production of lower volumes of brine and a requirement of direct current electricity (< 2 V) which is ideal to be driven by photovoltaics. A solar-powered commercial scale capacitive deionization plant was successfully operated in the outback town Wilora, a remote location in Northern Territory (Zhang, et al., 2013). Recent developments in nanomaterials (Wimalasiri, et al., 2015) and use of ion exchange membranes (Li & Zou, 2011) have shown significant potential for commercial applications. Capacitive deionization can produce ~ 1 ML/day at a small scale commercial plant (Mossad, et al., 2013) which can supply enough water for a small town.

Supporting technologies

Several processes are used as pre-treatment options in major desalination plants. These include micro filtration, ultrafiltration and nanofiltration (Zhou, et al., 2015) all of which utilize membranes for separation and ion exchange (Hu, et al., 2015) and resins to remove undesirable ions from water. These processes are widely applied for reducing the salt ion concentrations of brackish as well as seawater prior to be fed to a reverse osmosis process. Microfiltration and ultrafiltration operates via a sieving mechanism under lower pressures compared to reverse osmosis. Microfiltration reduces turbidity and removes suspend solids and bacteria. Ultrafiltration removes water contaminants that cause colour such as dissolved organic compounds, bacteria and viruses. Nanofiltration operates by sieving combined with solution diffusion and is used or water softening, removal of sulphates and viruses. Ion exchange is mostly applicable for the selective removal of organic and inorganic ions that result in membrane fouling thus is mostly used for the final polishing of water that has had salts removed under other techniques. Ion exchange becomes expensive for salinities > 15,000 mg/L due to increased chemical costs for the regeneration of resins.

Use of renewable energy for desalination

Whilst grid energy is the major source for energy in desalination, alternative methods such as solar (Shatat, et al., 2013), wind, tidal (Ma & Lu, 2011), geothermal energy and industrial waste are also utilised (Ghaffour, et al., 2015). Renewable energy based desalination plants currently in operation are limited to small production capacities with daily capacities ranging from several to 100 kL (IEA-ETSAP and IRENA, 2012). The hot dry climate and proximity to the sea in the Northern Adelaide region favours the use of solar and tidal energy combined with wind and geothermal energy. The use of these sources will be affected by the intermittence of the demand and the availability of the resource combined with the requirements of the desalination technology being used (Rowlinson, et al., 2012). However, the use of a combination of renewable sources which can feed the national grid can ensure a consistent energy supply.

Solar energy can be captured directly in solar stills or indirectly with conversion to electricity by photovoltaics (PV) (Shatat, et al., 2013) and integrated with both thermal and membrane desalination processes. Sundrop farms located on the Spencer Gulf near Port Augusta produces 860 ML/year of fresh water to irrigate 2,000 m^2 of greenhouse using reverse osmosis powered by solar energy (Sundrop Farms, 2014).

Kurnell sea water desalination plant in the south of Sydney is supplied with electricity from the grid, which is offset by a wind farm (El Saliby, et al., 2009). The potential for geothermal energy driven desalination by small scale reverse osmosis and multi-effect distillation in regional Western Australia has been explored in a National Centre of Excellence in Desalination Australia (NCEDA) funded project (Christ, et al., 2014). The research suggested that the use of geothermal energy is sensitive to the costs associated with the establishment of wells and geothermal fields.

Energy and operating costs of desalination

The costs of desalination depend on the size and type of desalination plant, feed water source and quality, the necessity of feed water pre-treatment, process automation and controls, the location of the plant, geographical and climate conditions of the location, skilled labour, energy costs and lifetime of the project. The energy costs could constitute 30–50 % of the operating costs. A recent review by Burn et al. (2015) identified reverse osmosis, electrodialysis and capacitive deionization as commercially available methods to supply water for agriculture in Australia. Other methods such as forward osmosis, membrane distillation and solar humidification and dehumidification are at experimental level with several pilot scale plants being demonstrated. Their energy consumptions and costs are listed in **Table 6**.

In Australia, the water production cost using reverse osmosis could be between AU$ 0.36–0.6/kL. This value could be lowered by operating at off-peak periods and using alternative energy sources to grid power. A pilot scale electrodialysis plant in Western Australia produces desalinated water for agriculture at a cost of AU$ 0.1/kL with the energy cost at AU$ 0.1/kWh (Goodman, et al., 2013). Capacitive deionization processes require significantly lower energy compared to reverse osmosis processes and have less maintenance issues compared to electrodialysis. Thus, the solar operated capacitive deionization produced water cost could be below AU$ 0.1/kL.

Technologies	**Energy use kWh/kL**	**Total, US$/kL**	**Reference**
Reverse osmosis	Brackish, 0.7–2.0	Brackish, 0.39–1.5	(Martinez, et al., 2009)
	Sea, 1.6–12	Sea, 0.55–1	(Papadakis, et al., 2007)
	Submarine, 2–2.5	Solar, 1.3 large plant, 2–6.5 small plant	(Pacenti, et al., 1999) (Al-Hallaj, et al., 2006) (Yermiyahyu, et al., 2007)
Electrodialysis	Brackish, 1.6–2.3	0.47	(Martinez, et al., 2009)
Capacitive deionization	Brackish 0.13–0.59	Not available	(Mossad, et al., 2013)
Forward osmosis	Brackish, 0.25	Not available	(McGinnis & Elimelech, 2007)
Direct contact membrane distillation	Sea, 40	Solar, 15–18	(Saffarini, et al., 2012a) (Saffarini, et al., 2012b)
		Geothermal, 13	(Walton, et al., 2000)
		Solar pond, 0.4–1.3	(Zuo, et al., 2011)
		Waste heat, 1.1–1.5	(Galvez, et al., 2009)
Airgap membrane distillation	Sea,	Solar 18.3	(Zuo, et al., 2011)
		Waste heat, 5.3	
Vacuum membrane distillation	Sea, 1.2–3.2	Solar, 16	(Saffarini, et al., 2012a) (Saffarini, et al., 2012b)
		Waste heat, 2	
Solar humidification and dehumidification	Brackish	Solar, 3–6.4	(Yuan, et al., 2011)
		Geothermal, 1.2	(Bourouni, et al., 2001) (Eslamimanesh & Hatamipour, 2010)

Table 6. Energy consumption and costs in potential desalination techniques. Adapted from Burn et al. (2015).

Disposal of brine

Desalination plant discharges consist of 98.5 % of brine and 1.5 % filter wash and cleaning water. The disposal of brine is a major environmental concern because brine can be about twice the concentration of seawater. The concentrated brine is removed by five main methods (Afrasiabi & Shahbazali, 2011) which include,

1. surface water/ocean discharge;
2. discharge to the sewer;
3. deep well injection;
4. land application; and
5. evaporation/crystallization.

Environmentally safe disposal of brine mainly depends on the location of the desalination plant. For plants situated near the coast or a brackish water source, disposal is relatively easy compared to inland desalination plants. The selection of an appropriate disposal method is affected by a number of factors (National Water Commission, 2011) including the cost, geographical conditions, availability of energy, corrosion and pipeline integrity, environmental regulations, the characteristics of the concentrate, soil conditions and public perceptions. In the NAP region, discharge to the sea could be viable along Gulf St. Vincent subject to environmental requirements. Most inland reverse osmosis plants in Australia discharge brine into sewers or evaporation ponds (National Water Commission, 2011). These two options lack long term sustainability considering the large volumes of brine produced.

The estimated building cost of evaporation ponds could be AU$12,000/ML and require 600 m^2/ML of land at a cost of AU$ 20/m^2 (Dillon, et al., 2009). Land application could be possible, however, salts can affect plant growth. Injection to aquifers may require drilling to high depths ~ 1,500–2,000 m. The aquifer storage transfer and recovery project (ASTR) in Salisbury in the NAP region showed that a completed well could cost AU$330/m (combined costs of drilling casing and cementing) which is comparable to AU$660/m to install a 200 mm diameter well, which is 407 m deep in Chowilla floodplain (Magarey & Osei-Bonsu, 2008).

Value addition and resource recovery from brine

Recycling and reuse of brine could bring economic benefits and opportunities for food and energy production (Qadir, et al., 2015; AFFA, 2002). Resource recovery from brine can be done through:

- salt harvesting as a high valued product for agriculture at a value of AU$
- -25–250/T;
- irrigation of salt tolerant crops such as pistachios, olives and almonds (saline bore water with 4,500 mg/L total dissolved solids is used near Quorn in South Australia);
- integration with aquaculture (Jenkins, 1998),
- decentralized renewable energy generation, and
- sequential concentration of saline streams via a range of steps including income generating crops, aquaculture, potable water and industrial salt production.

Such applications need a paradigm shift towards the reuse of brine instead of disposal. Sundrop Farms Systems in the Spencer Gulf near Port Augusta is an example for the productive use of saline water for horticulture (Sundrop Farms, 2014).

Profitable horticulture based on solar energy and seawater desalination- Sundrop Farms

The Sundrop Farms production system produces fresh water for greenhouse irrigation by seawater desalination (Sundrop Farms, 2014). This system is based on a 20 ha greenhouse facility which aims to produce 15,000 T of tomatoes annually. Cucumbers and capsicums have also been profitable crops since 2010. The reverse osmosis system is powered by solar energy and the hot water is used to sterilize the air supplied to the greenhouse which reduces the use of pesticides. Brine is concentrated to produce salts for livestock. This technology is particularly suited for arid regions with abundant sunlight year around that are also close to the coast or saline water resources and consumer end-markets.

Environmental challenges

The environmental issues related to desalination plants originate mainly from power supply systems and the process design and controls (Miller, et al., 2015). The main environmental issues could include:

- emissions of air pollutants and greenhouse gases during power generation;
- impingement and entrainment of aquatic organisms and suspended solids at intakes;
- discharge of highly concentrated brine;
- discharge of water at elevated temperatures; and
- pollution from chemicals and cleaning wastewater.

Emissions of air-borne pollutants depends on the source of energy supply—mainly from fossil fuel driven power plants. The NAP region can be consistently supplied with electricity from the grid while alternative power generations can be fed to the grid. The ecological impacts of the intakes could be significant in the Gulf of St. Vincent due to the region’s unique marine flora and fauna. For example, entrapment of marine organisms could affect the biodiversity and local fishing resources of the region. Thus both intakes and outfalls would need to be placed with appropriate environmental impact assessments and be rigorously monitored (Kampf & Clarke, 2013). The brine concentrations from reverse osmosis plants can reach up to 65,000–80,000 mg/L and the immediate environmental issue from discharges of such salinity is the formation of brine under-flow (Hodges, et al., 2010) which involves the development of a thin layer of hypersaline water along the seabed which depletes oxygen and adversely affects sea bottom life and in turn the shallow eco system. This issue can be overcome by efficient diffuser designs and suitable diffuser location placements (Dickie, 2007).

Chemical discharges contain heavy metals, anti-scalants, anti-foaming agents, coagulants and cleaning chemicals. These chemicals can result in eutrophication, low biodegradation, and an alteration in the pH balance of receiving bodies. In most cases, neutralization and dilution by mixing with brine avoids the pollution effects from chemical cleaning waste.

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