Redefining dryland salinity for a new generation of land managers

Prepared for

Liebe Group

By

Contour Environmental and Agricultural Consulting

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Redefining dryland salinity for a new generation of land managers

Contents

Figures

Tables

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1.0 Summary

Salinity has been a major land degradation issue in the WA wheatbelt ever since widespread clearing of native vegetation began in earnest around the mid-20th century. Rising groundwater and subsequent salinisation of soils and waterways in lower lying areas of the landscape continues to cost the economy significantly in lost production and has severely affected the often-unique biodiversity assets of now fragmented wetland systems.

Considerable knowledge and investment in understanding and managing salinity has occurred, particularly in the period following the implementation of the State Salinity Strategy in 2000, which coincided with a particularly wet year (1999) across many regions including the current project catchment in the northeast agricultural region. The wet year of 1999 led to a spike of groundwater rise and an increase in waterlogged and saline land and generated significant interest in understanding and mitigating the salinity threat.

There had been highly regarded research into salinity in WA stretching back decades, so the mechanisms were already well understood, but certainly the decade until around 2010 saw considerable research and monitoring effort, on-ground works, funding for projects, and extension of knowledge to land managers and stakeholder groups and was a key focus for natural resources management (NRM) in WA at that time. With changing priorities for government funding, and coinciding with a long period of declining rainfall in the broader southwest of WA, groundwater levels in some areas tended to stabilise or became variable (rising and falling depending on sites and location). There was also perhaps a realisation that mitigating salinity was a very costly and often complex task, requiring good cooperation between community sectors, government, and industry, and with multiple approaches and strategies working best in unison and across tenures and property boundaries.

In the project catchment in particular, rainfall declined significantly in the 21st century and relatively few years between 2004 and 2019 were above the long-term median rainfall. There was a notable drop-off in break-of-season autumn rainfall and a slight increase in scattered and erratic summer storm events. It is not surprising that salinity has not been a pressing issue for ongoing generational change on farms and conservation lands. A younger generation of farmers and land managers is now taking over the reins, having cut their teeth in the dry years 2010-2020, and they have different perspectives and priorities than those managing land in the 1990s and early 2000s.

Cropping has become the predominant activity in the project catchment with far less mixed farming, and some of the animal-based solutions to salinity such as perennial fodder plantations may no longer seem relevant or may even be a hindrance to a cropping program. Similarly, some soil conservation earthworks, alley and corridor plantings linking remnant native vegetation, may need reconfiguring to better suit current and future farming systems.

The 2021 season in the project catchment was a turnaround year with exceptional rainfall, the fifth highest since records began in the district, and only comparable to 1999 in terms of rainfall in the era since broadscale land clearing. It is therefore no surprise that the Liebe Group has identified a potential knowledge gap in understanding and mitigating the threat of waterlogging and salinity. The Liebe Group recognises that not only are government resources scarcer in 2022 to study, monitor, extend information, and provide support to on ground works, there is a risk that a spike or advance in salinity may find farmers unprepared or unfamiliar with options and strategies used in the past.

This review has confirmed there has been limited monitoring of salinity in the project catchment for over a decade and that the extensive groundwater monitoring bore network constructed by government in the early 2000s is poorly managed. Data, even on the location of monitoring bores, is uncoordinated between three government departments and the potential ongoing value of this investment in understanding future salinity trends is at risk.

The review has found that there are well-developed sound recommendations to manage salinity in the project catchment based on large investments in research and development in the past. Renewed interest in tackling salinity issues, particularly in direct response to infrequent wet seasons, requires ongoing clear and concise messaging of existing knowledge and, hopefully can lead to ongoing investment in mitigating the threat, as well as encouraging monitoring and further research into the salinity issue.

2.0 Location and project description

2.1 Location

The headwaters of the Moore River commence in the Perenjori, Carnamah and Dalwallinu Shires and drain southwards through Moora. The current project catchment can be described as the northeast corner of the upper catchment (Figure 2-1), an area of 387,000 hectares with approximately 220 farms covering 95 percent of the project catchment. There are also 6054 hectares of reserves.

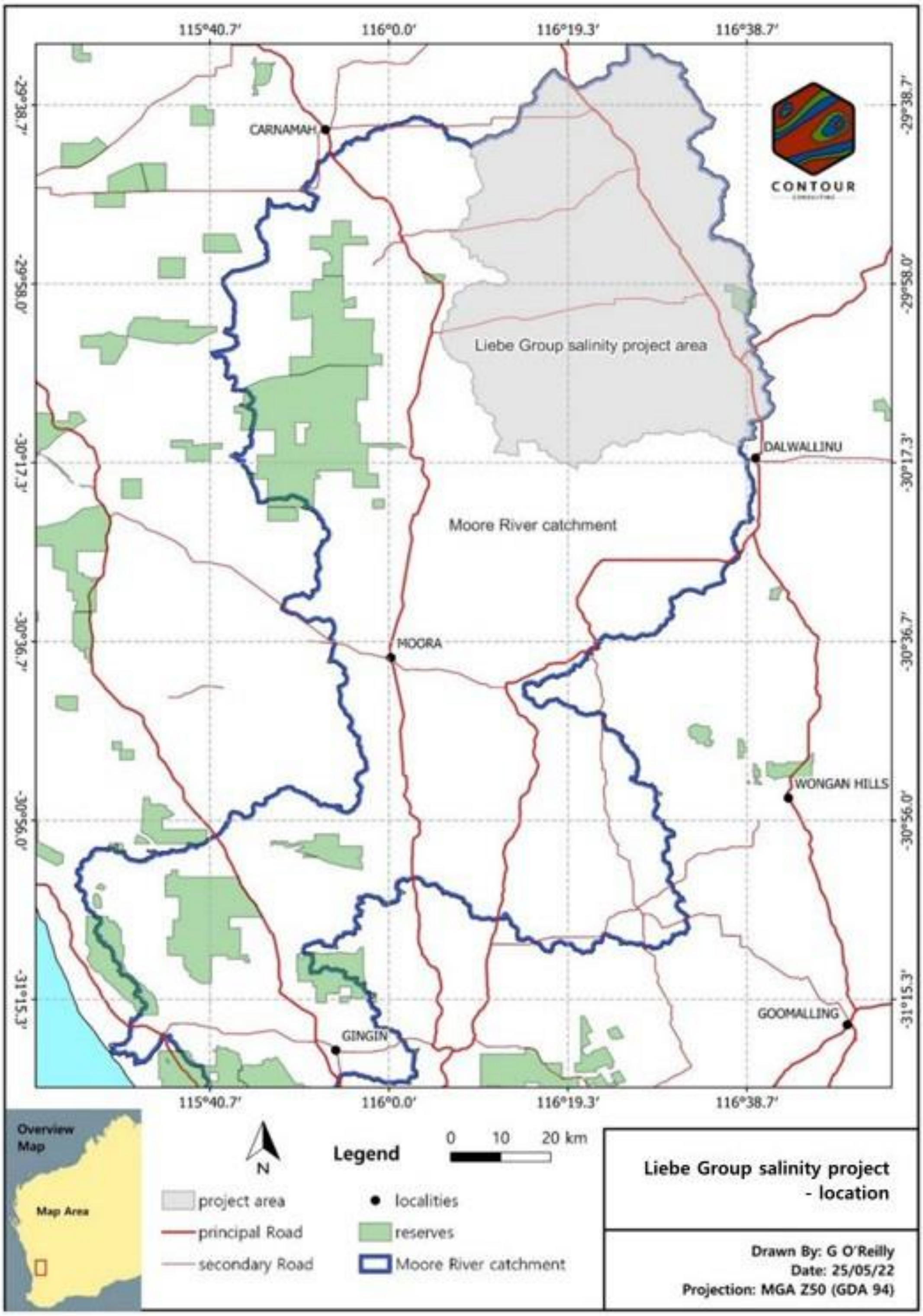

Figure 2.1 **Location of the Liebe Group salinity project 2022-2023**

2.2 Approach

Salinity has been developing in WA since large scale clearing in the agricultural regions began and is forecast to continue to expand for another 50 years or more. Estimates are that it affects between one and two million hectares, potentially rising to five million, and costs over half a billion dollars a year in lost agricultural production alone (Western Australian Auditor General May 2018).

Salinity is a major cause of land degradation, with widespread implications on rural infrastructure, water resources, biodiversity, and productive land. Focusing on the upper northeast of the Moore River catchment area, this project will investigate current understanding and concern about dryland (secondary) salinity given that a new generation of farmers are now in decision-making roles. Many of today's land managers are too young to remember the considerable focus on salinity as an issue in the late 1990s and early 2000s.

This 2022 catchment level review is the first step in the project and will be used to guide the development of management plans for four case study sites. In 2023 broadacre farmers will participate in a salinity masterclass to understand practical and economically viable ways to incorporate rehabilitation activities of high-risk saline areas into modern farming systems.

The timing of the project also coincides with a significant turnaround in rainfall with 2021 being among the wettest years on record, certainly in the era since salinity became a major issue. This follows an extended period of below median rainfall where the focus fell away from salinity as an issue.

This review tries to capture some of the story of salinity in the project catchment and is the first stage of a process initiated by the Liebe Group to deliver appropriate and timely knowledge and advice to the next generation of farmers and land managers.

3.0 Salinity 101

Primary salinity is caused by natural processes and is often a feature of semi-arid areas, including the project catchment, where there is little flushing of water through streams and groundwater, and where evaporation is high. Natural salt pans and lakes, and saline seeps and springs are examples of primary salinity. Secondary or dryland salinity is caused by land management.

3.1 How dryland (secondary) salinity works

The southwest of Australia has had trace amounts of salt deposited by rainfall for millions of years. Native vegetation is very efficient at using nearly all the available water as it infiltrates through the soil profile so that very little water gets below the root zone to 'recharge' the water table. When water does get below the root zone it takes the salt too where it accumulates and concentrates creating saline groundwater above the bedrock but usually well below the surface.

The progressive clearing and replacement of native vegetation with shallow rooted annual crops created a leaky system, with a decrease in transpiration, regular annual recharge, and saline groundwater rise, sometimes dramatically, across the agricultural areas.

Experiments in the 1970s and 1980s, even on partially cleared catchments in WA, confirmed the process and how dramatic changes can be. Groundwater rose as much as 20-25 metres over 13 years (two metres per year) after clearing only 50 percent of native vegetation in a catchment. The rising groundwater inevitably mixed with freshwater streams, turning them salty. Even after 13 years, groundwater level, stream yield, stream salt load, and stream salinity were all still rising (Ruprecht and Schofield 1991).

The annual rate of increase in dryland salinity between 1988 and 1998 was 14,000 hectares per year with one million hectares affected by 1998 (Furby, S, Caccetta and Wallace 2010).

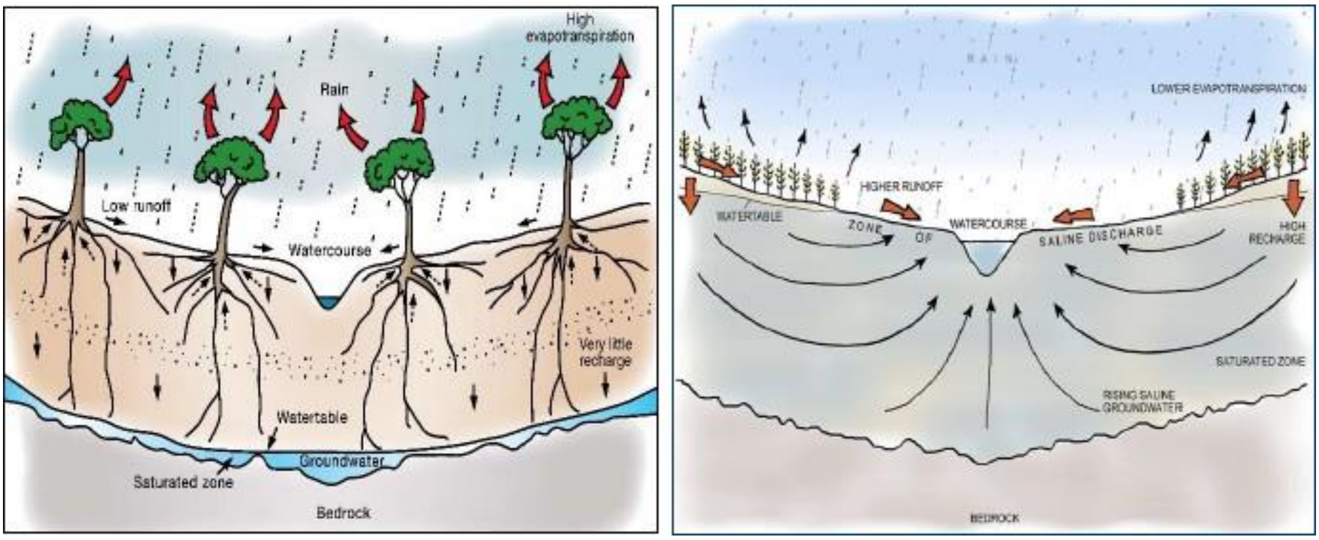

Figure 3.1 **Depiction of how dryland salinity occurs – a healthy balanced system on the left - removing trees on the right leading to a high-water table and bringing salt to the surface. (Smith 2007)**

3.2 Measurement and testing salinity

3.2.1 Units

The Australian standard for electrical conductivity (EC) water salinity is microSiemens per centimetre (µS/cm) or milligrams per litre (mg/L), and for soil salinity, deciSiemens per metre (dS/m) (DPIRD 2021b). Quite often salinity will also be described in milliSiemens per metre (mS/m)

A useful formula to know is 1mS/m = 6mg/L = 6ppm (this conversion is approximate based on the salts present in much of Western Australia).

Table 3-1 below shows the ranges of salinity by salt concentration and some broad use categories (from (Mayer, Ruprecht and Bari 2005))

Table 3.1 Levels of salinity and uses

Salinity status	Salinity (mg/L)	Description and use
Fresh	< 500	Drinking and all irrigation
Marginal	500 –1 000	Most irrigation, adverse effects on ecosystems become apparent
Brackish	1 000 – 2 000	Irrigation certain crops only; useful for most stock
Saline	2 000 – 10 000	Useful for most livestock
Highly saline	10 000–35 000	Very saline groundwater, limited use for certain livestock
Brine	>35 000	Seawater: some mining and industrial uses exist

3.2.2 Measuring salinity

Soil salinity can be measured using handheld electrical conductivity (EC) meters, some of which are relatively inexpensive, starting from around $200. The 1:5 weight-to-volume method is to take one part soil to five parts distilled water (measured accurately), agitate, and allow to settle for up to 24 hours depending on soil type. The sample can then be tested with the EC meter. Samples need to be at 25°C although better meters can compensate for temperature. Calibrations can be applied to correct the result. The most rigorous method of measuring salinity is to send soil or water samples to an accredited laboratory to analyse for TDS (total dissolved solids).

3.2.3 Electromagnetic measurement

Ground electromagnetic (GEM) induction measurements are a rapid and non-intrusive method of measuring soil salinity (Bennett, George and Whitfield 2000). Examples include the EM38 (Geonics Ltd, Canada), a hand-held instrument that measures bulk soil electromagnetic conductivity to a depth of approximately 1.5 metres while another model, EM31, measures conductivity to approximately six metres depth.

The EM38 meter is a relatively easy to use instrument and (DPIRD 2021b) provides useful instruction and tips on calibrating for different soil types.

https://www.agric.wa.gov.au/soil-salinity/measuring-soil-salinity

4.0 Status of salinity response in WA

In response to community concern the WA government released the Salinity Action Plan in 1996 and the State Salinity Strategy in 2000. Between 2003 and 2008, $560 million of federal and state funds were invested in a range of land management initiatives which included salinity management and water quality programs (Western Australian Auditor General May 2018).

After 2008, there was a decline in investment in salinity monitoring, research, and development in WA. The period since has coincided with declining rainfall across the agricultural areas which may have also contributed to lower prioritisation of dryland salinity by government and land managers.

In 2018 concern about the lack of investment in salinity led the WA Auditor General to conclude there is no regular, on-going monitoring and reporting of dryland salinity. As a result, no one accurately knows the extent, impact, cost, and potential spread of dryland salinity. And because of poor coordination, efforts to manage dryland salinity are unlikely to achieve any landscape wide improvement (Western Australian Auditor General May 2018). The questions asked of lead agencies by the audit were:

1. Do agencies know the extent and impact of dryland salinity in the southwest agricultural regions?
2. Are efforts to reduce the impacts of dryland salinity in the southwest regions working?

In response a report was commissioned (GHD 2019) which concluded that, since 2006, there has been limited investment into the economic and environmental impacts of salinity and that studies of feasible and cost-effective management options have not been updated in recent times. It was concluded that:

1. Agencies do not know, accurately, the changes in extent and impacts of secondary dryland salinity since the last quantitative measure in 2000.
2. There has been successful reduction of the impacts of secondary dryland salinity in discrete areas, but at the gross level, reduction of impacts has been very limited.

The 2021 season was among the wettest on record in many areas of the WA wheatbelt and there was a renewed flurry of interest in tackling waterlogging and salinity, prompting agencies to issue warnings about regulatory processes being followed for drain construction, and recommendations for best practice surface water management (Verhagen 2021).

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5.0 Climate

The climate of the project catchment is Mediterranean with cool wet winters and warm dry summers. The location of the project in the inland headwaters of the Moore River catchment are typified by being hotter in summer, cooler in winter, and with less summer humidity than areas further down the catchment or closer to the coast (Alderman, Clarke and Natural Heritage Trust (Australia) 2003). For example, Dalwallinu receives 100 mm less annual rainfall than Moora (460 mm), but it receives more summer rainfall than Moora because of scattered summer thunderstorm activity.

5.1 Rainfall

Data from the Bureau of Meteorology (BOM) has been used to look at rainfall 1915-present, based on three recording stations close to the project catchment. Wubin has been recording rainfall since 1922, and this data was averaged using additional data sets from Sunnydale and Buntine. The median annual rainfall over 108 years has been 319 mm. Table 5-1 and Figure 5-1 summarise the rainfall data and shows annual totals have varied between 155 mm and 619 mm. There is generally good reliability of receiving winter rainfall in the July-September period but with high variability in summer.

Table 5.1 Summary of rainfall data for the Liebe Group project catchment

	Monthly rainfall (mm) averaged from (8139 Wubin) 1922- present (8021 Sunnydale) 1957-2012 (8017 Buntine) 1915-2017												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	13	15	25	20	41	58	53	42	21	14	10	8	**320**
Median	5	6	8	11	36	58	49	37	19	10	5	3	**247**
Standard deviation	19	21	37	25	30	34	27	25	14	13	11	11	92
Highest on record	104	96.6	199	156	158	193	138	134	77	70	48	55	619
Year	*1990*	*1918*	*1971*	*1961*	*1999*	*1923*	*1958*	*1932*	*1973*	*1975*	*2012*	*2002*	*1917*
Lowest on record	0	0	0	0	1	3	8	7	1	0	0	0	155
Year	-	-	-	-	*1964*	*2001*	*1937*	*1925*	*2019*	-	-	-	*1976*
No. of years	108	108	108	108	108	108	108	108	108	108	108	108	108

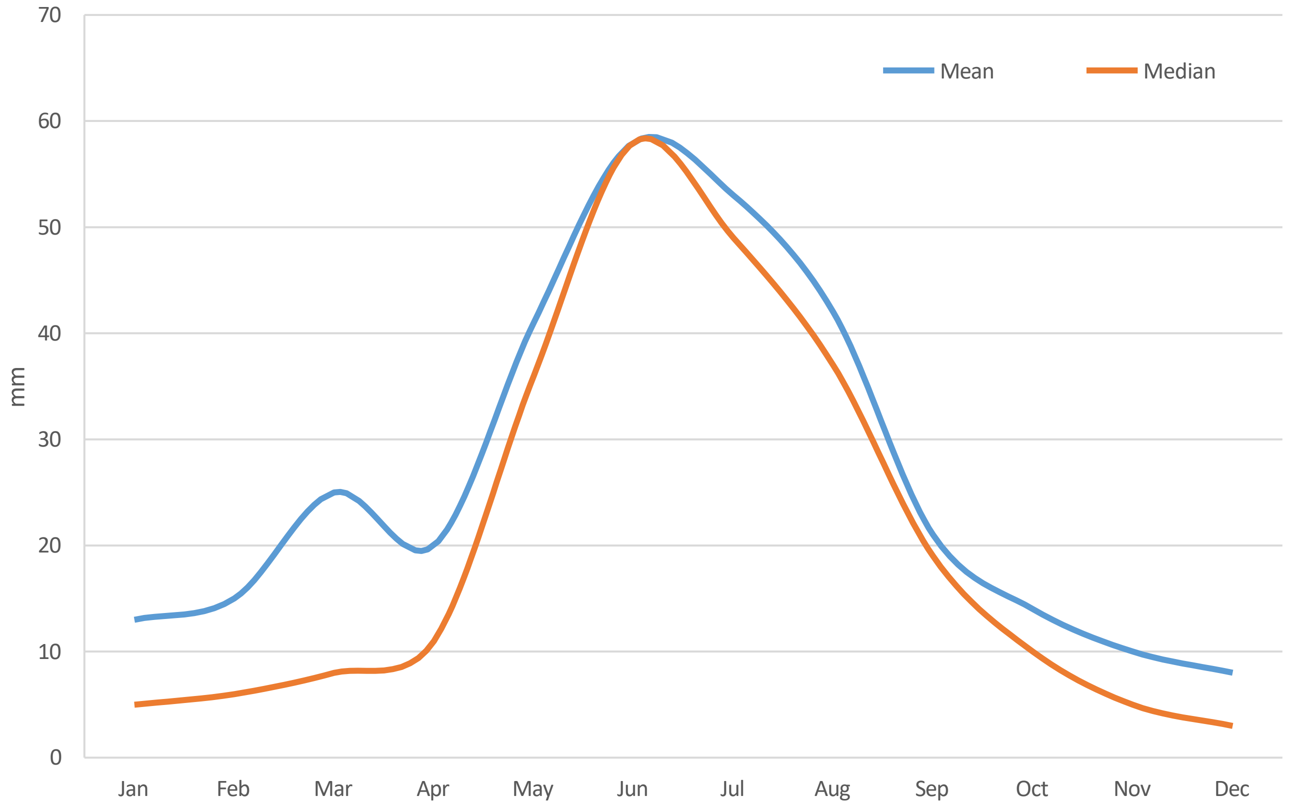


Figure 5.1 **Long term median versus mean rainfall for Liebe Group salinity project catchment**

Figure 5-1 above shows the long term monthly median rainfall against the long-term average rainfall. It is a useful way to highlight reliability of rainfall as the closer the lines are together, the more reliable. Due to the nature of summer rain events, it is expected that summer months would show greater unreliability, and because of cold fronts consistently moving through the southwest land division between June and September, these months have greater reliability, and is the basis of agricultural production systems of the area.

In Figure 5-1, March shows the greatest variability in rainfall (where the median and mean data diverge the most). There is quite often no rainfall in March, yet tropical systems moving south may produce very large rainfall events. In 1999 and again in 2000, for example, March received 145 mm and 153 mm respectively. The difference however is that in 1999 there was a further event in May of 158 mm followed by an average winter, and this was the trigger for a spike in groundwater in the region (Speed and Strelein 2004) that accelerated salinity just at the time when concern about salinity was gaining traction.

Interestingly, March in 2021 was also an exceptional month with 116 mm followed by well above median rainfall in April, May, and July. However, it is unclear without monitoring data at this stage to assess whether rainfall in 2021 has caused groundwater to rise noticeably or that salinity risk is any higher than during the many dry years of the 2000s. It is hoped that the current project will provide some observations from land managers on whether they think salinity expanded in 2021.

Figure 5-2 shows the long term total annual rainfall for each year against the long-term median. It highlights the ups and downs of individual years and those extreme outliers such as wet years in

1999 and 2021. It is interesting to note that the longest period of below median rainfall was 2001-2007, a time when salinity related activity in the current project catchment was perhaps at its peak. The 1970s was also a particularly dry period in the SW corner of Australia, in contrast to the rest of the country. Also worth noting is that, since 2000, even in those years exceeding the median, rainfall was still not much above the long-term average, peaking at 378 mm in 2015. This further highlights what an exceptional year 2021 was.

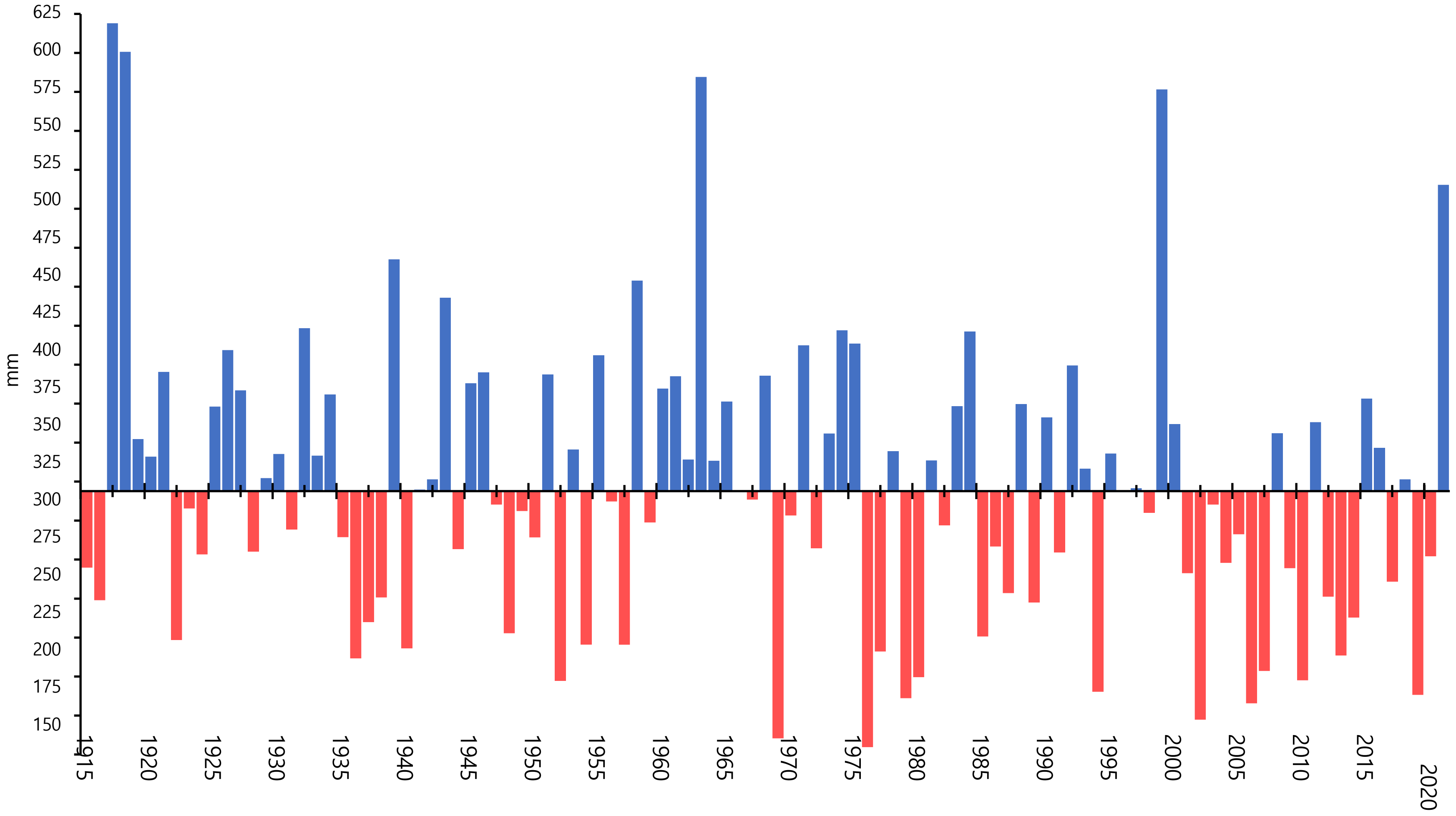


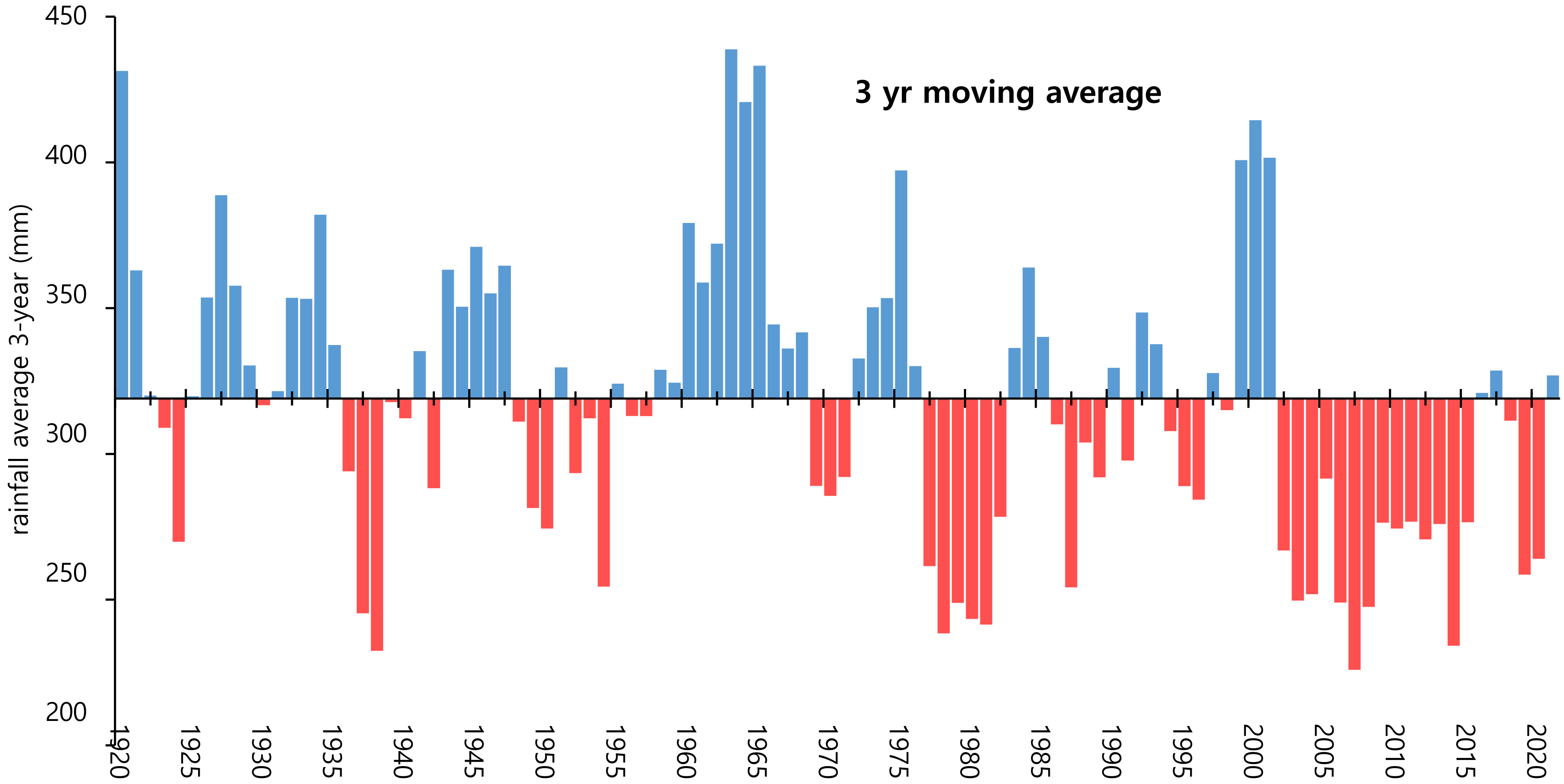
Figure 5.2 **Long term annual rainfall showing years above and below the median rainfall for the Liebe Group salinity project catchment.**

5.1.1 Cumulative (running average) rainfall

In terms of salinity, a useful approach to understanding rainfall and how it affects recharge of groundwater may be to look at longer term trends. Although the extreme events in March and May of 1999 led to a spike in groundwater levels at some locations in the northern agricultural region and raised concern and action on tackling salinity (Beattie and Stuart-Street 2008) (Alderman, Clarke and Natural Heritage Trust (Australia) 2003), these events are rare and it is likely that more subtle changes in groundwater levels are linked to rainfall patterns over consecutive seasons rather than a noticeable annual rise and fall.

One approach is to look at running averages, or accumulations of rainfall, over several years or seasons. This approach is commonly used in pastoral rangeland decision making where there is less defined seasons and dry standing pasture can remain for long periods. It is a useful way of highlighting ‘runs’ of good years or for defining droughts and longer-term trends.

Figure 5-3 below shows the three-year moving average of rainfall against the long-term median as well as the five-year moving average for the project catchment. It shows that in the last century there have been periods of above and below average rainfall, and this accumulation or run of seasons has likely influenced groundwater levels and salinity, at least since widespread broadscale clearing. Apart from periods such as the wet 1960s and dry late 1970s and early 1980s, the other noticeable period is the ongoing lower cumulative rainfall since 2004. Two good years in a row (2015 and 2016) reversed the trend before dry years again in 2019 and 2020. The very wet year in 2021 has seen the three-year average again go above the long-term median but in the longer-term five-year running, declining rainfall year after year remains the trend.


3 yr moving average
rainfall average 3-year (mm)
450
400
350
300
250
200
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
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2020

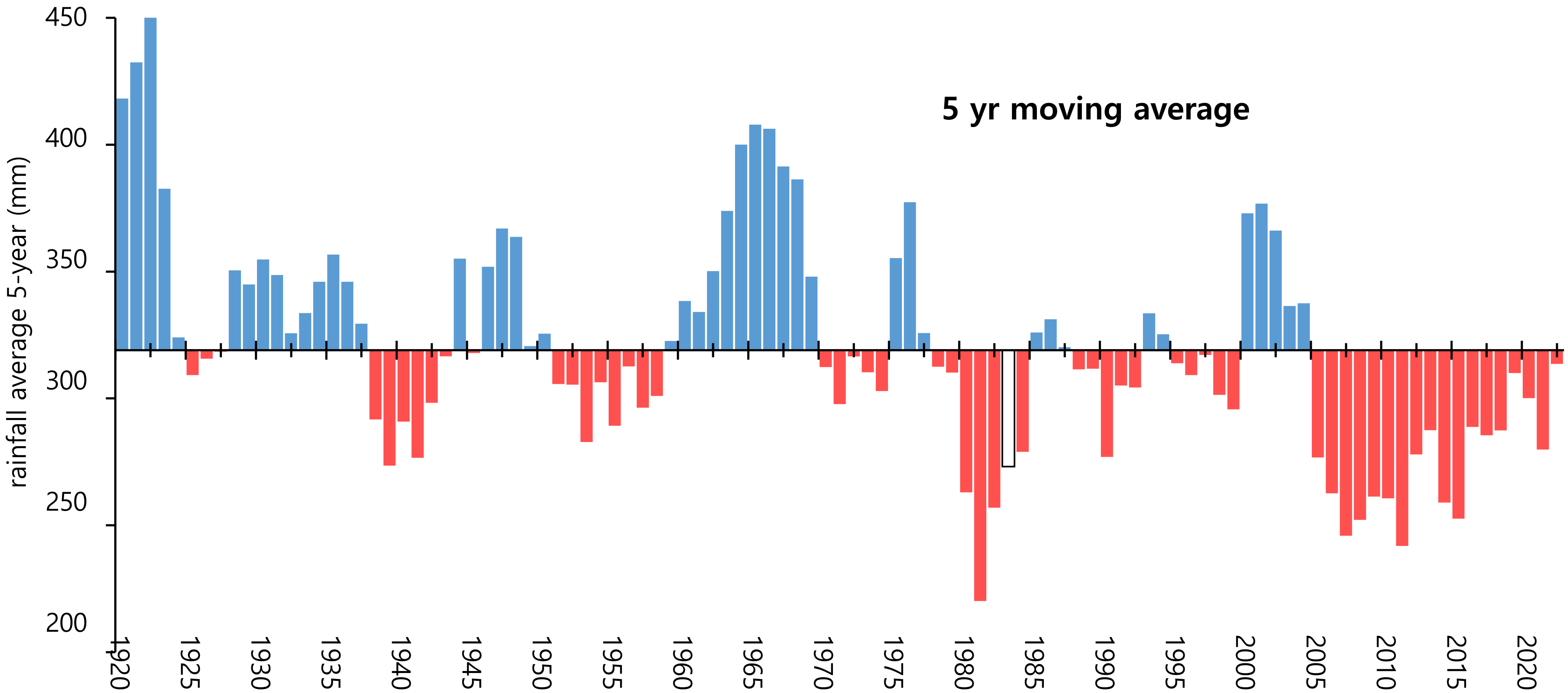


Figure 5.3 **Three-year and five-year moving average rainfall against long term median – Liebe Group salinity project**

5.1.2 Climate change and shifting rainfall patterns

In the last 30 years in the northern agricultural region of WA, annual rainfall has decreased by eight percent, dry years have occurred 12 times and wet years four times, while rainfall has decreased notably in the autumn months affecting the break of the season. Winter rainfall has remained relatively reliable while summer and, importantly, autumn has been unreliable. The season break has, in some years, not occurred until mid-July in the east and north-east areas where the Liebe Group salinity project is located, and there have been more hot days with associated stress for livestock (Bureau of Meteorology and the CSIRO 2019). The stark synopsis is clearly shown in the data analysed for the three nearest rainfall stations over 108 years. Figure 5-4 shows the long term monthly median rainfall against the median over the last 24 years (since 1998). It clearly shows a large deficit in autumn rainfall, particularly in May but especially in June. The six lowest June totals in 108 years of data have all been in the 2000's. The only month during the growing season which has exceeded the long-term median is September. Conversely, every summer month since 1998 has exceeded the long-term median, although cumulative totals are still small in summer compared to winter. While this trend has implications for growing annual crops, it also has implications for groundwater recharge and expansion of salinity. The median rainfall drops from 319 mm per year long term to 275 mm per year in the 21st century.

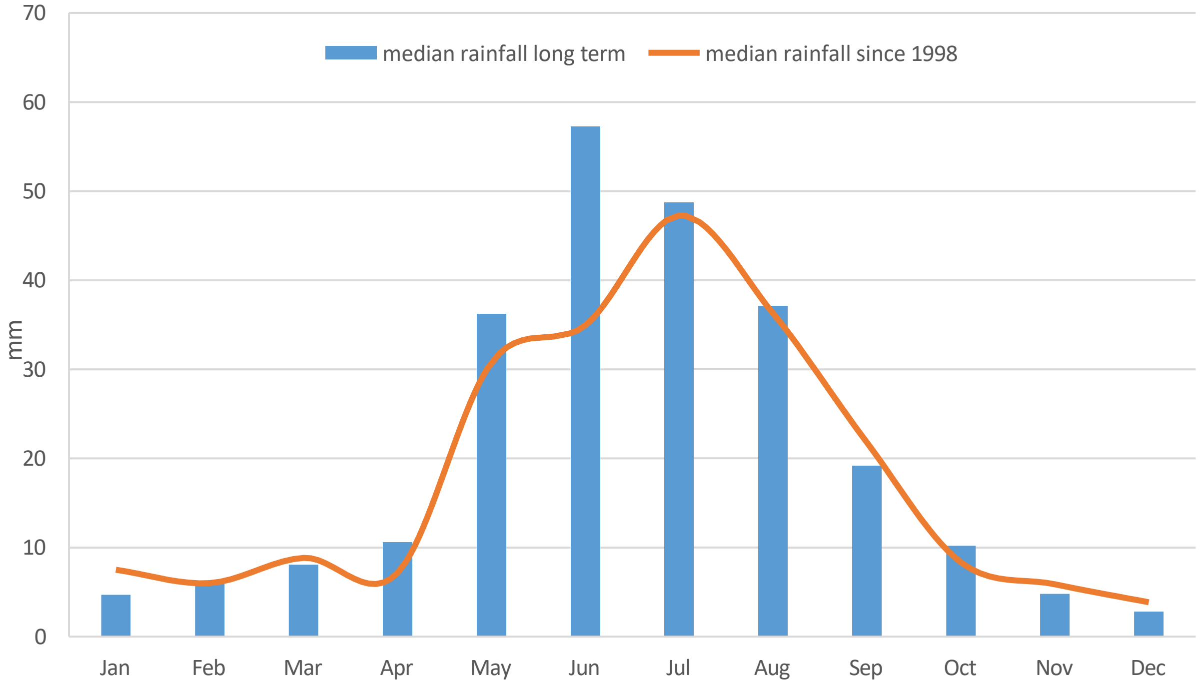


Figure 5.4 **Median long-term rainfall for the Liebe Group salinity project against the median since 1998**

5.1.2.1 Winter versus summer rainfall

As well as a decline in yearly rainfall totals, especially break-of-season rainfall in May and June, there has been a shift in rainfall patterns over the yearly cycle in the project catchment. Figure 5-5 shows the long-term trend of summer (Nov.-Mar.) versus winter (Apr.-Oct.) rainfall. The trend is towards increasing summer rainfall events and declining winter rainfall totals. In the 22 years of the century so far, only four years (less than one in five) have exceeded long-term median winter rainfall (Apr.-Oct.), but twice as many summers since 2000 have been above the long-term summer median than below, 15 summers above the median, and seven below. The main difference in terms of the salinity spike following the 1999 rainfall events is that at that time, very high winter rain followed summer rain. This has not occurred since, although 2021 does show some characteristics of 1999 where good winter rains followed high summer rainfall.

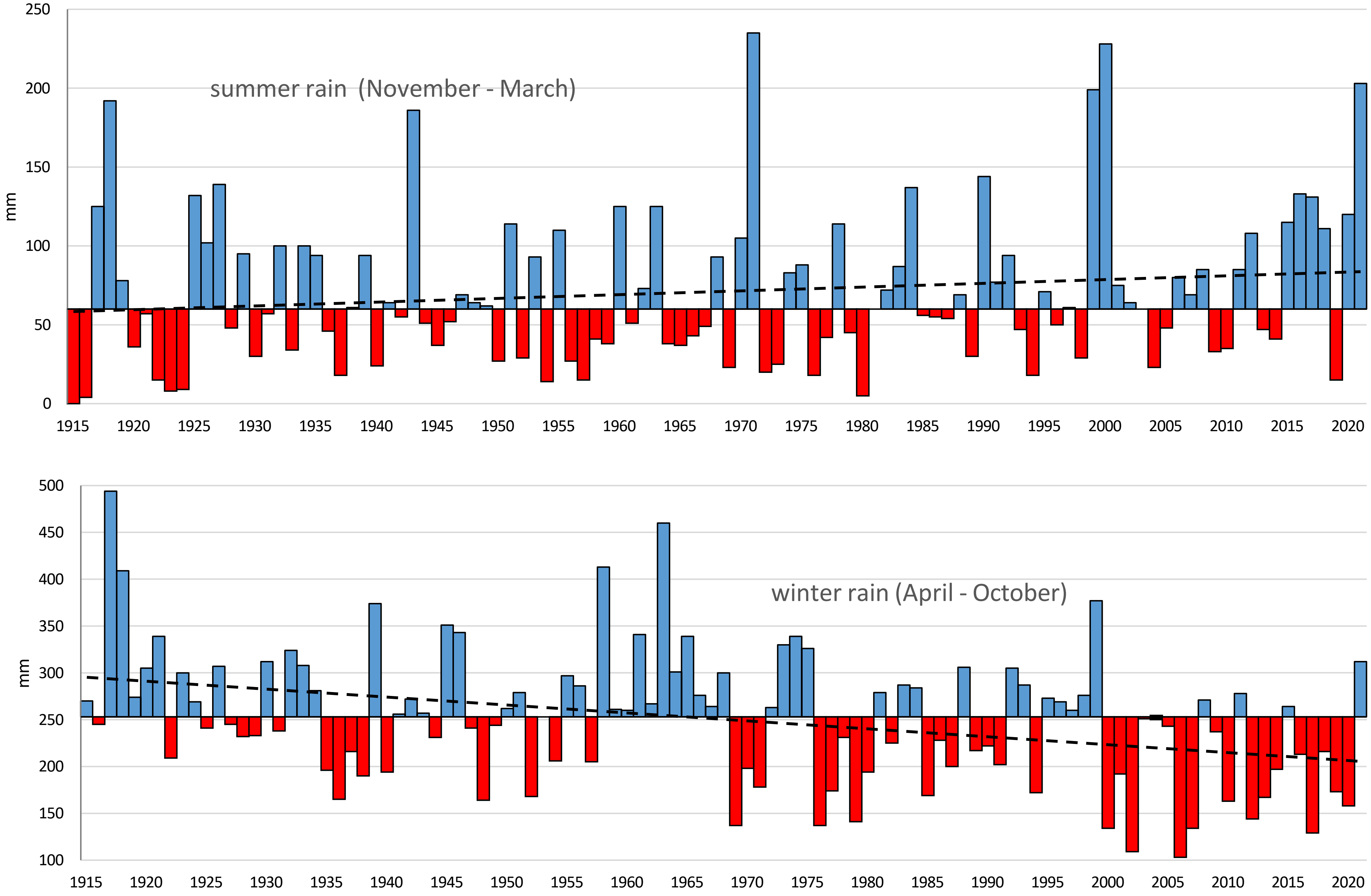


Figure 5.5 **summer versus winter rainfall trends in the Liebe Group salinity project catchment**

6.0 Salinity in the project catchment

6.1 Soil-Landscape

Soil-landscape mapping in WA uses a hierarchy of scale depending on end-user requirements; for example, the current project catchment is in the 'northern zone of ancient drainage' hydrozone, providing a broad regional geological context. Within the hydrozone there are soil-landscape zones, within which there are land systems and sub-systems (Griffin and Goulding 2004).

The project catchment has two soil-landscape zones, Irwin River (271) and Northern Zone of Ancient Drainage (258). There are eight land systems within these zones suitable for mapping at scales around 1:250,000 and many more sub-systems. For example, the largest land system in the project catchment is Upsan Downs (258Ud) covering 221,832 hectares and within that area the largest sub-system (84,998 hectares) is described as gently undulating to undulating rises with long gentle gradients on weathered granite. Yellow and brown deep sand and sandy earths, usually acid, much gravel, some duplexes and loams and minor clay.

Soil landscape data at the subsystem scale is freely available as spatial data and there are now easy to use online tools allowing analysis and generation of graphics on key potentials such as salinity, waterlogging, acidic sub-soils, sub-soil compaction, and suitability for various agricultural systems. As an example, Figure 6-1 shows land general land capability for cropping. Soil-landscape data to subsystem level is available from DPIRD and the online mapping tools are at:

https://maps.agric.wa.gov.au/nrm-info/

In general terms the project catchment is characterised by subdued relief with broad valley floors that have predominantly red or brown loamy to clay soils and coarser textured loamy to sandy soils in upland areas. The general direction of drainage is from east to west. The major drainage lines are populated with hundreds of lakes, not usually a dominant characteristic of valley floors in the northern agricultural region of Western Australia (DEC 2007-2027). Hydrogeological investigations in the catchment have reported intersecting up to 38 m of alluvial sediments at drill sites among lakes in the main drainage lines (Speed and Strelein 2004).

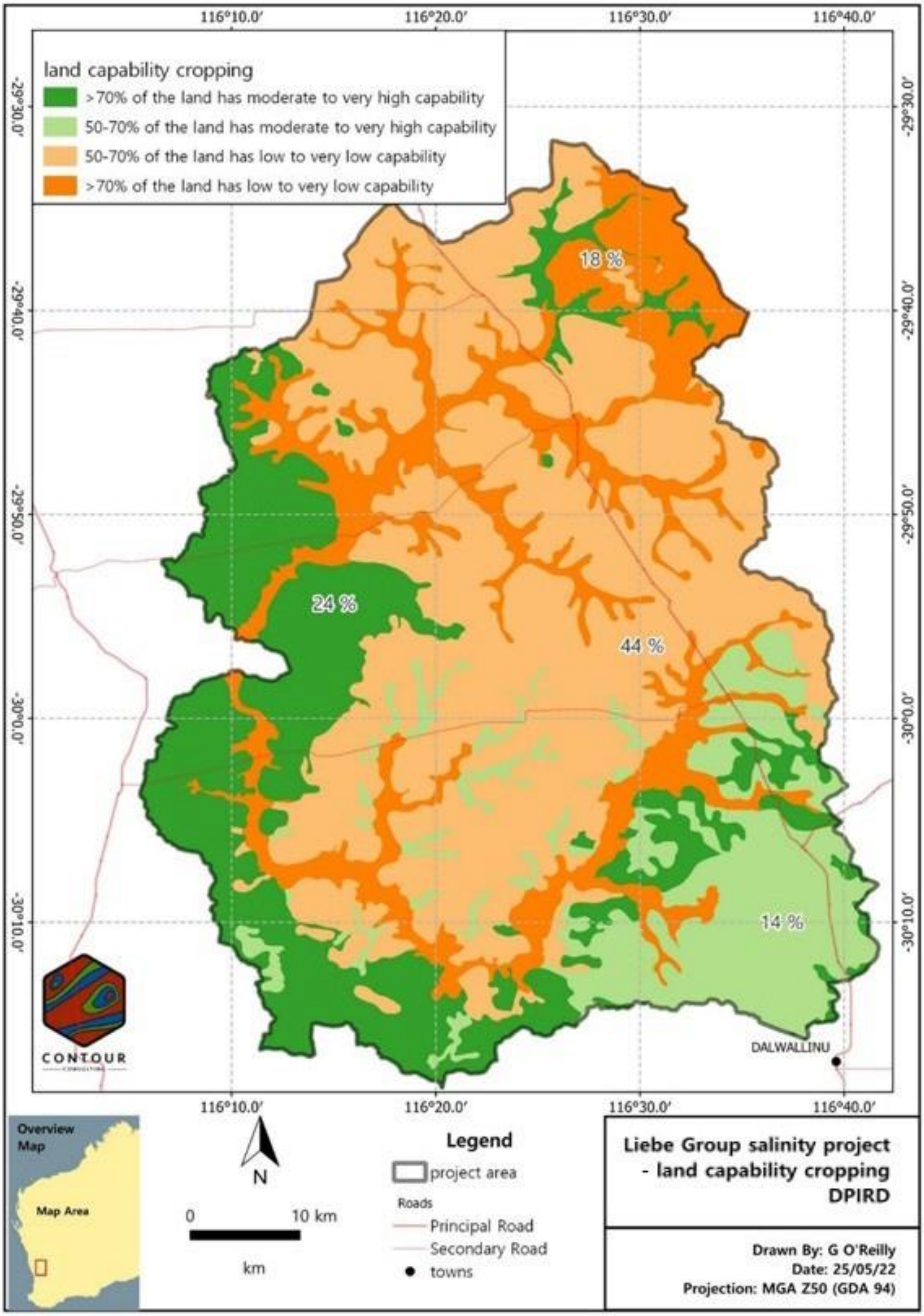


Figure 6.1 Land capability for cropping including percent area in the Liebe Group project catchment area

6.2 Hydrogeology

The Northern Zone of Ancient Drainage hydrozone sits on the Yilgarn Craton; a large raft of Archean continental granitoid rock. Soil profiles are typically up to 30 m of gritty clay saprolite formed by in situ weathering of the crystalline basement rock. The gritty clay saprolite is weathered bedrock and hosts local groundwater systems where the yields are generally low and most of the groundwater, particularly in valley floors, is saline. Most of WA's existing dryland salinity occurs on the Yilgarn Craton (Raper, et al. 2014)

Perched aquifers in deep sands on hillslopes are common and often contain small supplies of fresh groundwater that are suitable for stock, and that can be accessed via soaks or low-yielding windmills. Saline hillside seeps often occur at the downslope end of perched aquifers where the groundwater comes close to the soil surface and salts are concentrated by evaporative discharge.

The project catchment has some very useful monitoring bore and piezometer investigation that helps describe the general hydrogeology in the area. Bores drilled in 2002 as part of the Buntine-Marchagee natural diversity recovery catchment (BMNDRC) program were established in lines across the landscape to create cross-sections allowing hydrogeological profiles to be developed (Speed and Strelein 2004).

It is unclear how much data was collected from these bores after some follow-up 2006 sampling when a further study was commissioned by the Department of Environment and Conservation (DEC) to undertake another hydrogeological study of the catchment (URS 2008). The differences between groundwater levels between 2002 and 2006 in the (URS 2008) report was mostly a downward trend with 38 bores falling in those four years, 10 rising, and four remaining dry since drilling. The report also describes another series of bores established as part of their commissioned work in 2006 but the abridged version available from DBCA do not have locations. Enquiries to DBCA on the location of these bores have been unsuccessful, except that it is believed the bore locations are listed on a CD-ROM held in the State Library of Western Australia Heritage Collection.

Figure 6-2 below describes one of the cross sections described (Speed and Strelein 2004) and, when added to the current satellite image, shows how bores were placed perpendicular to watercourses. It is a very useful schematic to understanding how salinity works in the Liebe Group salinity project catchment.

In Figure 6-2, the first and second bores (BMC1 and 2) intersect some shallow fresh water higher up in the landscape. These perched water tables sometimes form above hard layers, in this case silcrete. They are generally variable in quality and quantity but can be a useful source of fresh water on farms. Bore two (BMC2) drilled through this silcrete layer into the saprolite zone until it hit bedrock. Saprolite is soft decomposing rock above the bedrock, rich in clay, and at this site varies in depth from a few meters to 30 m or deeper. In-between BMC2 and BMC3, the fresh water from the perched aquifer higher up slope creates a seep and not much further down slope the saline groundwater also comes to the surface as a seep.

Continuing downslope, bore BMC3 drills through the very shallow saline water table (1.5 m deep) into a thick colluvium layer. These deep (up to 38 m) alluvial deposits were found to be a feature of the BMNDRC investigations and represent sediment deposited perhaps millions of years ago.

From BMC3 to BMC7 is the salt affected land where the water table affects the growth of vegetation on the surface. Note that salinity (measured in mS/m) increases with depth through the saturated colluvium into the saprolite. BMC7 hit bedrock at 35 m and the water table was at 3.1 m below the surface. That represents a huge volume of saline groundwater.

Moving out onto the other side of the water course into cropping land and the water table drops. Bore BMC6 quickly hit bedrock and was dry in 2002 and 2006.

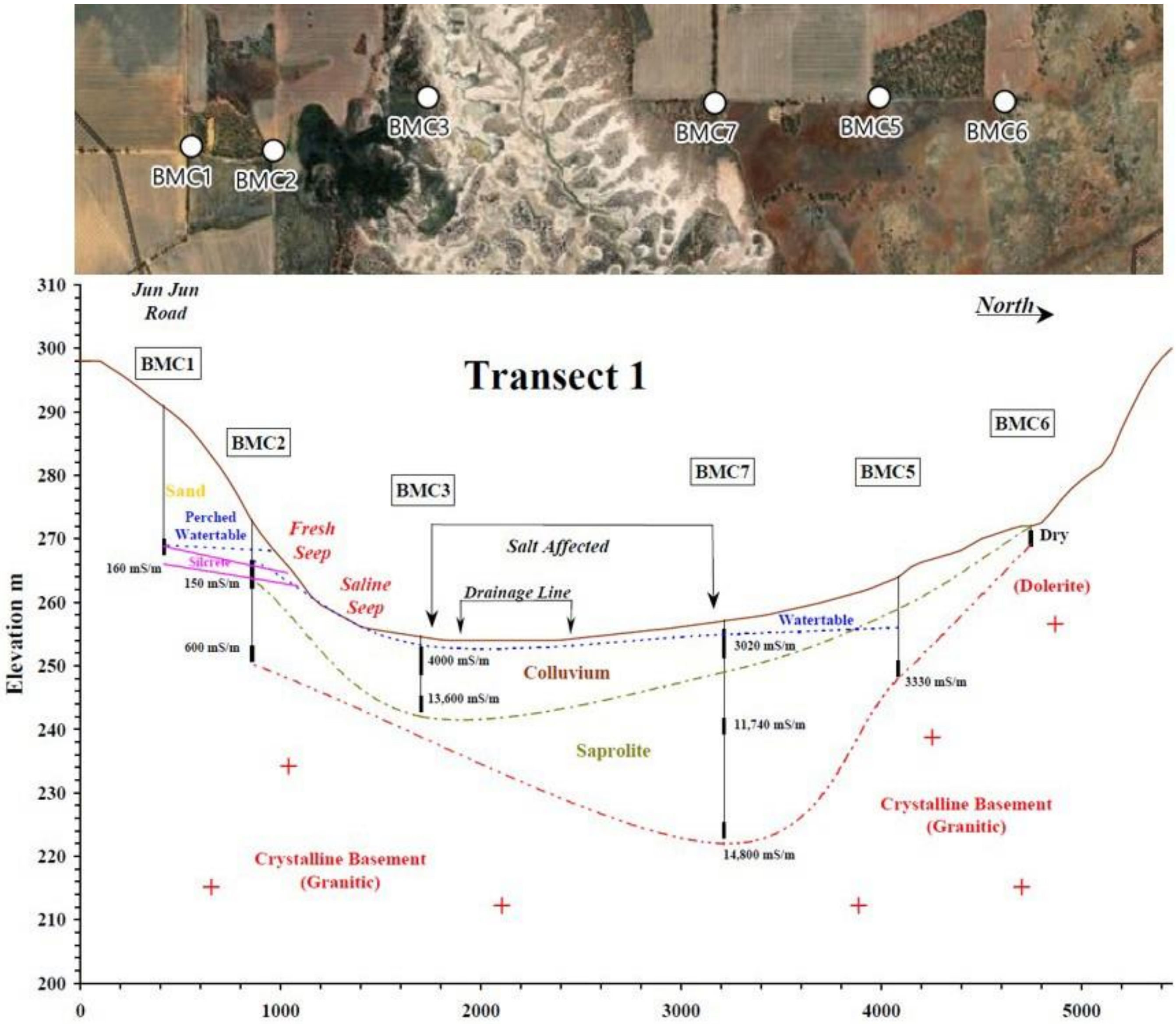


Figure 6.2 **Typical hydrogeological cross section in the project catchment – adapted from (Speed and Strelein 2004)**

6.3 Salinity and waterlogging risk

Salinity risk derived from soil-landscape mapping has been undertaken for the broader southwest land division (van Gool, Tille and Moore 2005) and Figure 6-3 shows the risk for the project catchment. Most of the area (68 percent) is considered very low risk for salinity. The main area of concern is the 10 percent of the catchment considered very high risk, having >70 percent chance of moderate to high salinity. Added to this is a further five percent of high risk with 50-70 percent chance of moderate to high salinity risk. This means that 15 percent of the catchment is, or already is, potentially affected by salinity. A further 15 percent of the catchment is considered low risk but could still have small areas of salinity or potential to become saline. Salinity and waterlogging are closely related, and this is discussed further in tackling salinity. Once again sub-system landscape data has been used to show waterlogging risk in the project catchment in Figure 6-4.

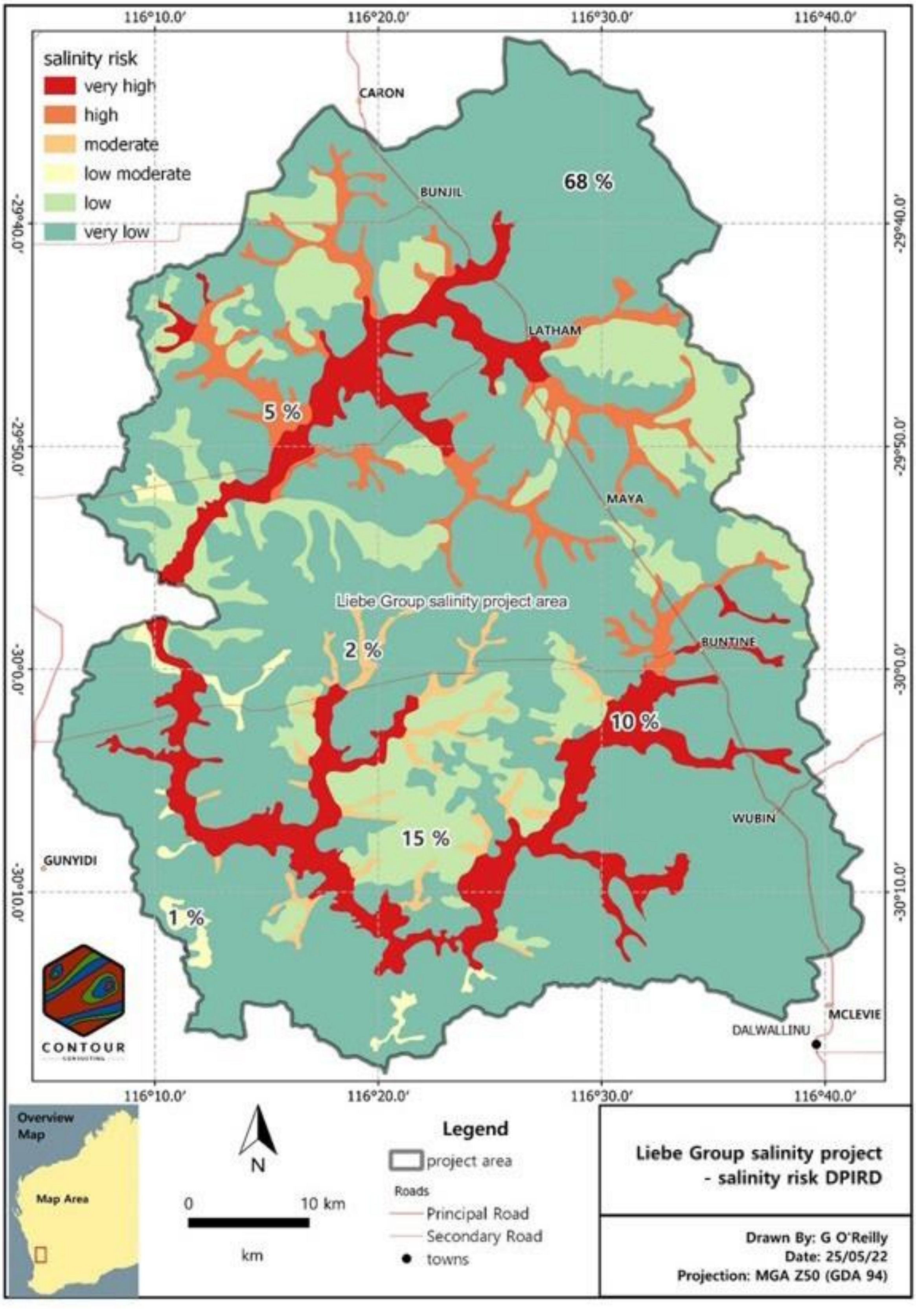


Figure 6.3 General salinity risk in the Liebe Group project catchment

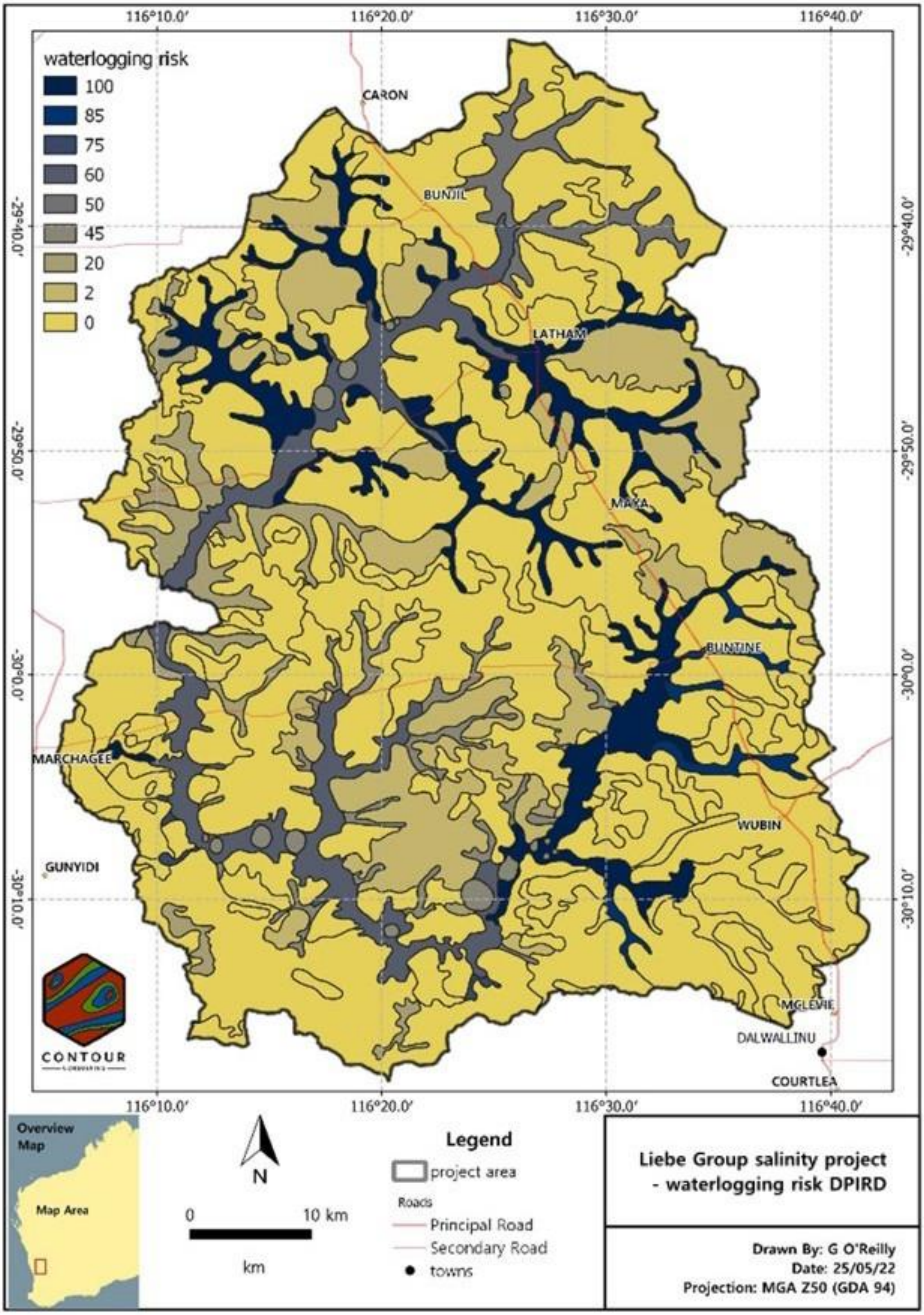


Figure 6.4 **Waterlogging risk in the Liebe Group salinity project catchment**

6.4 The Buntine-Marchagee natural diversity recovery catchment 2002-2010

In response to community concern the WA government released the Salinity Action Plan in 1996 and the State Salinity Strategy in 2000. One aspect of the response was the establishment of a series of natural diversity recovery catchments, managed by the Department of Environment and Conservation (DEC), now the Department of Biodiversity, Conservation, and Attractions (DBCA). One of the catchments was the Buntine-Marchagee natural diversity recovery catchment (BMNDRC) which the current Liebe Group salinity project 2022-2023 falls largely within.

Between 2000 and to around 2010, a significant body of work, including detailed hydrogeological, fauna and flora, and other studies, and an extensive program of on-farm works was undertaken. As much as 12,000 hectares were treated in some way. The large body of information provides a basis for the current catchment review and there is potential for hydrologists to utilise the network of ground water monitoring sites established in the BMNDRC for ongoing study of salinity trends in the area.

6.4.1 Biodiversity

Substantial loss of biodiversity has occurred across the WA wheatbelt over the past 100 years. Secondary salinity has especially impacted biodiversity values of wetland ecosystems and this was the basis for selecting the BMNDRC for the recovery program.

The most pronounced physical changes to wetlands have been associated with native vegetation clearing, resulting in altered hydrology (generally more water in wetlands than is natural) and changes to water quality including salinisation. Broadscale clearing may have ceased, but salinisation and fragmentation processes will continue to be expressed for many decades (Lyons, et al. 2007)

The BMNDRC has unique wetland biodiversity values and faces threats from changed hydrology and increased sedimentation and erosion. The catchment contains a threatened ecological community (TEC) "Herbaceous plant assemblages on Bentonite Lakes" (Endangered) as listed in the *Biodiversity Conservation Act 2016* as well as declared rare plants *Caladenia drakeoides* and *Frankenia parvula* as well as several priority listed plants.

There are five wetland types in the BMNDRC:

- primary saline wetlands and braided channels
- gypsum wetlands
- fresh/brackish wetlands with river red gum (*Eucalyptus camaldulensis*) woodlands
- bentonite wetlands
- freshwater claypans

6.4.2 Conclusions of the BMNDRC

A review of the Buntine-Marchagee NDRC in 2010 identified waterlogging as the primary threat degrading the biodiversity assets in valley floors in the project catchment — basically, by drowning riparian vegetation (Wallace, et al. 2011). Ponding of surface water in valley floors is leading to increased rates of recharge to groundwater, which ultimately increases the area of shallow saline groundwater.

Ponding of surface water increases soil moisture content and saturation, increasing the likelihood of run-off during, and shortly after, ponding occurs, leading to stripping of soil and nutrients (erosion). The review of the BMNDRC recognised that better surface water management on surrounding farms was one way of lessening the impact on the five key wetlands.

Where sediment and nutrient stripping are reduced on farms as part of surface water management planning, either through revegetation, maintaining ground cover, perennial farming systems, or conservation earthworks, downstream nutrient, turbidity, and sedimentation impacts on biodiversity assets is greatly reduced. Properly designed surface water management has long been recognised as a means of reducing water erosion, recharge, waterlogging, and flood damage (Bligh 1989).

6.5 Groundwater trends

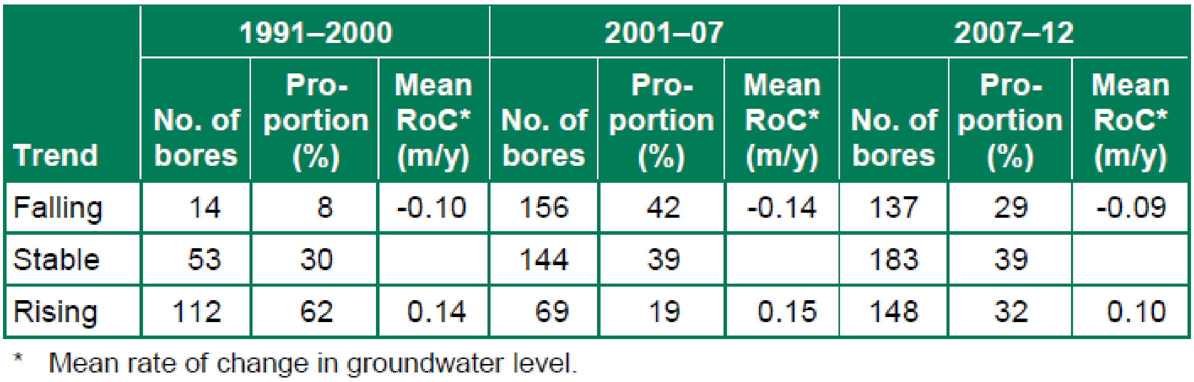
6.5.1 Historical trends and 2007-2012 analysis

The Northern Zone of Ancient Drainage is regarded as having extensive salinity that continues to expand, but more slowly than prior to 2000 (Raper, et al. 2014). Groundwater levels analysed in this zone between 2007-2012 were found to be variable and the salinity risk moderate.

Prior to 2000, rainfall was above the long-term mean over much of the hydrozone. Rising groundwater trends dominated and were widespread in both weathered granite and paleochannel aquifers. There was significant episodic rise in groundwater at all sites in the northern part of the hydrozone in response to very wet conditions in 1999.

From 2001 to 2007, rainfall was well below average over most of the hydrozone and there was a change from predominantly rising groundwater trends to equal proportions of falling and stable water tables, with rising trends in the minority. Figure 6-5 shows the results of the 2007-2012 groundwater trend analysis (Raper, et al. 2014) as compared with earlier periods.

By 2012 there were relatively even numbers of monitoring bores either rising or falling but with mean rates of change only in the order of 0.1 metres since 2007. Figure 6-6 shows the hydrograph for one bore close to the project catchment (Carnamah) alongside accumulated monthly residual rainfall. It clearly shows the trend representative of many areas across the hydrozone with a peak after 1999 followed by a drying cycle with some rises again around 2010.



Trend	1991–2000			2001–07			2007–12		
	No. of bores	Pro-portion (%)	Mean RoC* (m/y)	No. of bores	Pro-portion (%)	Mean RoC* (m/y)	No. of bores	Pro-portion (%)	Mean RoC* (m/y)
Falling	14	8	-0.10	156	42	-0.14	137	29	-0.09
Stable	53	30		144	39		183	39	
Rising	112	62	0.14	69	19	0.15	148	32	0.10

* Mean rate of change in groundwater level.

Figure 6.5 **Groundwater trends in the Northern Zone of Ancient Drainage – from (Raper, et al. 2014)**

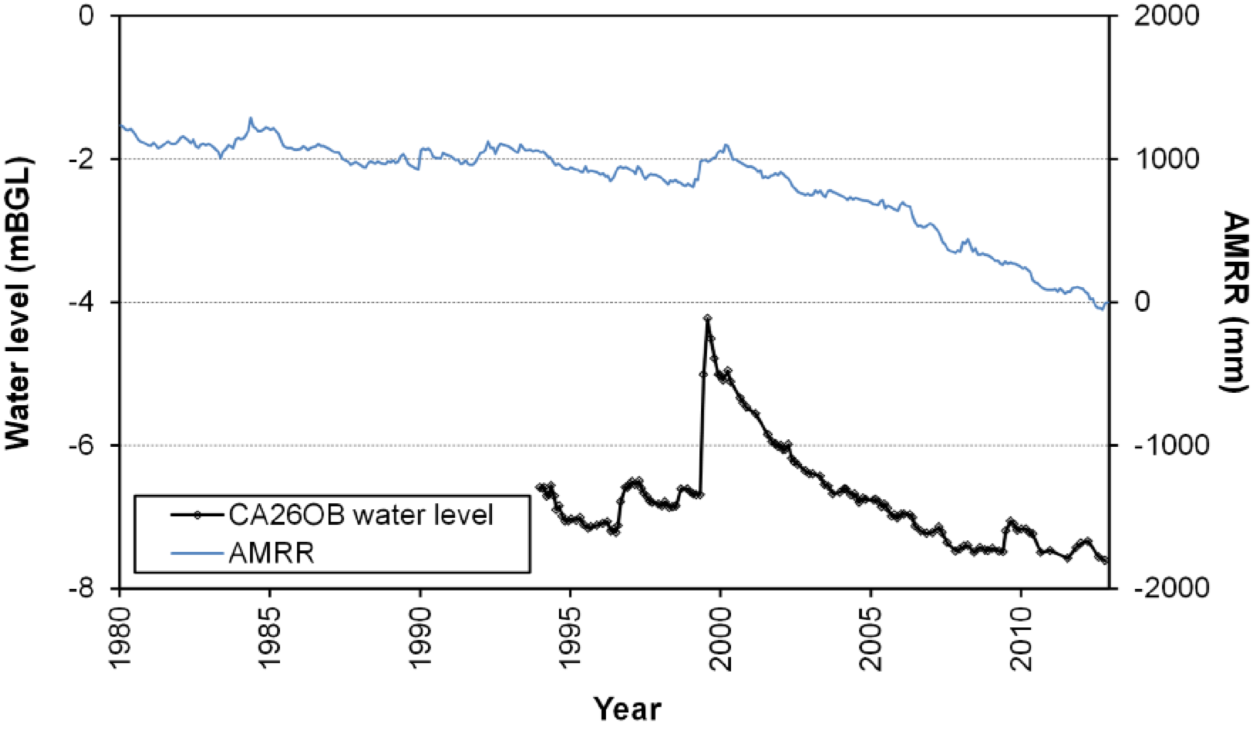


Figure 6.6 **Hydrograph for bore CA26OB with accumulated monthly residual rainfall for Carnamah (CA26OB) – from (Raper, et al. 2014)**

Salinity trends were reviewed for the northeast agricultural region (Blake, Clarke and Stuart-Street 2012) as part of a study into the extent and management of unproductive soils. Saline soils were the predominant reason for soils being non-arable and represented four percent of the region (94,320 hectares). In the south-eastern area of the region where the project catchment is located, it was concluded that salinity risk remains unchanged and is still considered to have an extreme salinity hazard. It was found that groundwater rise is dominated by recharge from episodic rainfall. The frequency of rainfall will determine the time frame of the risk. It will take many decades for a post-clearing equilibrium to be established and the full extent of salinity to manifest. (Blake, Clarke and Stuart-Street 2012).

In the project catchment, a series of bores were installed in 2002 as part of the DEC natural diversity catchment program (BMNDRC). The bores were reviewed (Speed and Strelein 2004) and many were assessed again in 2006 (URS 2008) where groundwater levels were measured comparing

2002 to 2006. There were 10 bores where groundwater had risen (on average by 0.23 m) and a much higher number of bores (38) where groundwater levels dropped during that time (on average by 0.69 m). Four monitoring bores were dry to the depth drilled in both 2002 and 2006. Figure 6-7 shows the distribution BMNDRC bores in relation to potential case study farms in the current Liebe Group project, and whether they had rising or falling water tables between 2002 and 2006.

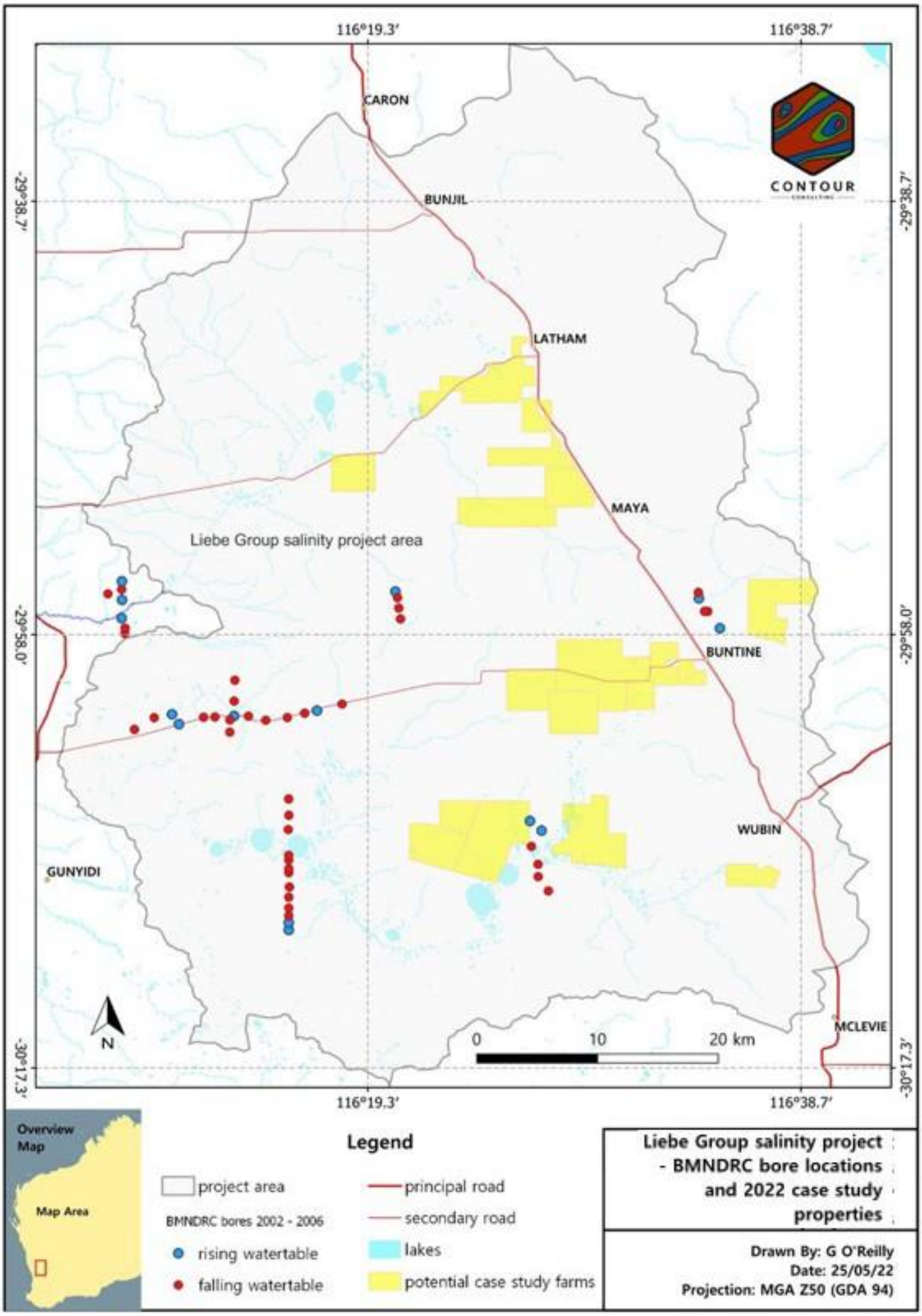


Figure 6.7 **Location of BMNDRC bores installed in 2002 and groundwater trend when measured in 2006 by (URS 2008)**

6.5.2 Pithara drill logs

Despite a decline in monitoring of groundwater levels in areas affected by dryland salinity since the early 2000s, some recent results from near the project catchment are available. The Resource Condition Monitoring (RCM) program (Speed, Kendle and Gibbon 2008) established representative groundwater monitoring sites at a soil landscape zone level, and regular monitoring has been maintained 2007-2021 at a series of nine bores just to the southeast of the project catchment. Figure 6-8 shows the location of the bores and Figure 6-9 the drill logs provided by Russell Speed (DPIRD) through the Liebe Group for this review. No bores show dramatic change in groundwater level over 13 years. Bores with shallower water tables do show some seasonal fluctuations, especially soon after construction, and again around 2016, but are virtually at the same, or around the same level in 2007 and 2020. Deeper water tables have shown only small trends over 13 years with changes in the order of about one metre rise for the deepest section of the water table and a relatively steady state for other bores. One bore, with a water table at about 9 m shows a slight drop over 13 years.

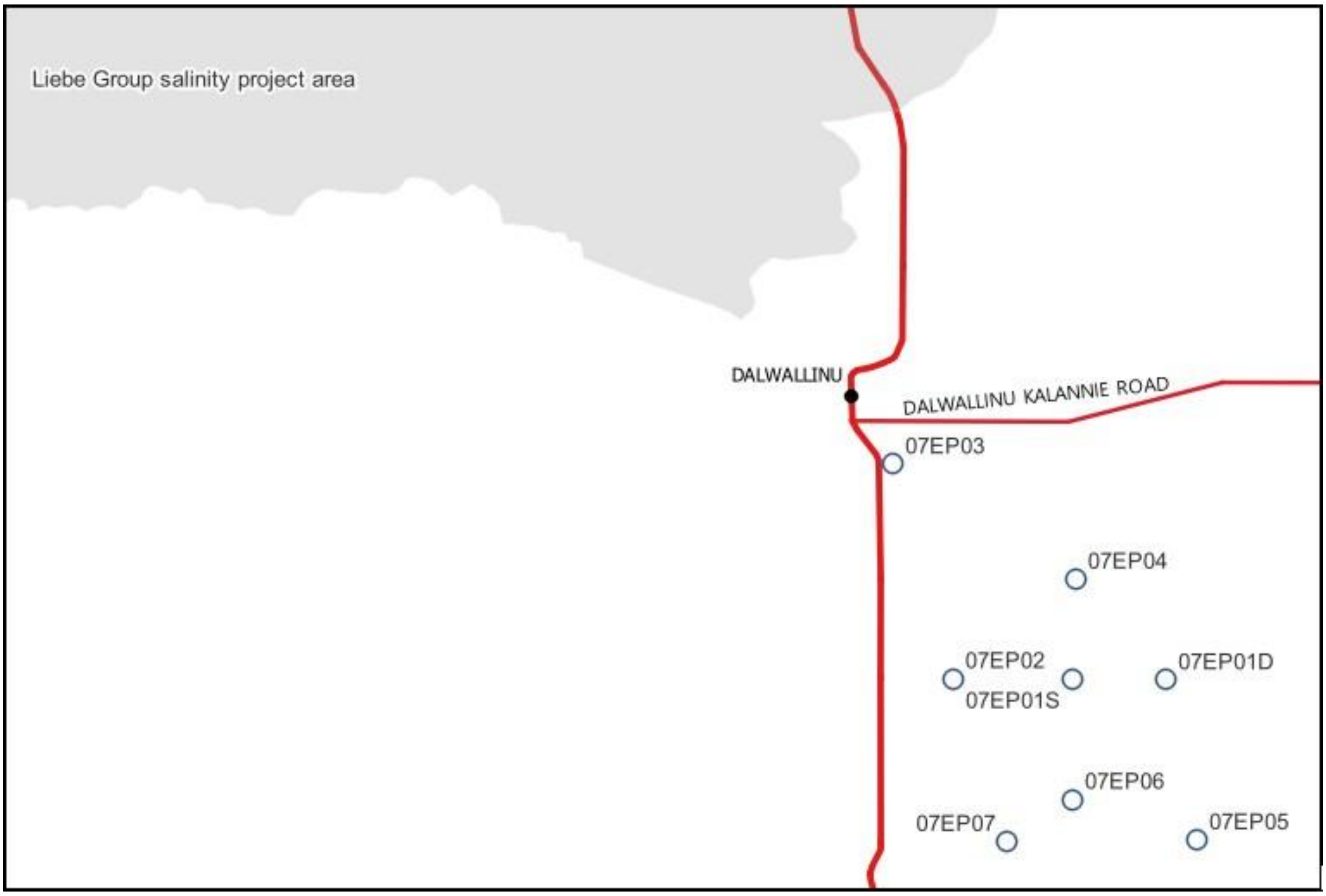


Figure 6.8 Location of DPIRD RCM bores 2007-2020 in relation to the project catchment

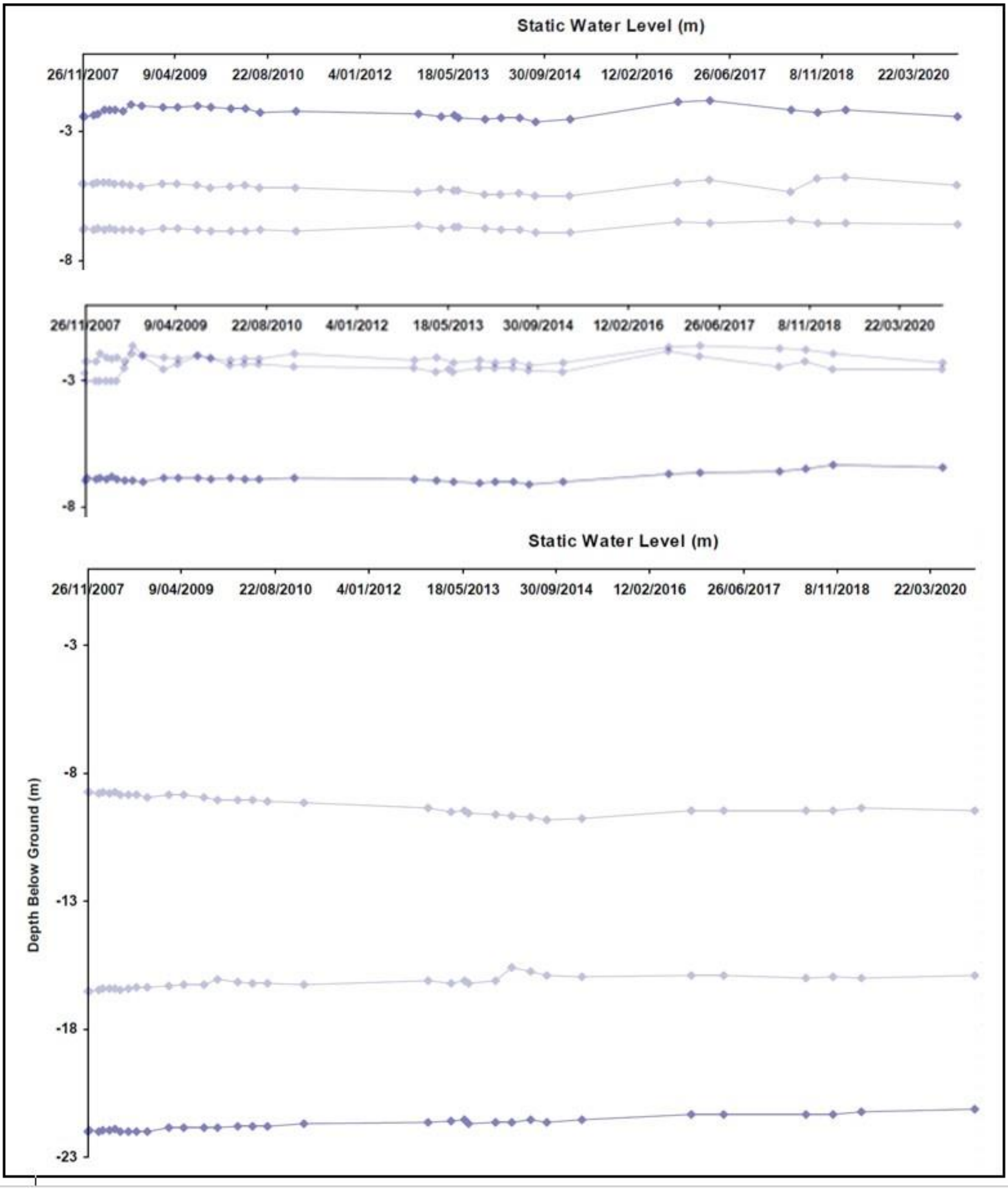


Figure 6.9 **Hydrographs of Pithara bores (DPIRD RCM project) with groundwater levels 2007-2021 (Liebe Group and Russell Speed DPIRD)**

6.6 Observations of land managers

A survey of landholders was undertaken in the BMNDRC in 2003 (CALM & Colmar Brunton, 2005). Given that 94 percent of catchment is privately owned, and 73 percent of the 13 percent remnant vegetation is on private property, landholder and community consultation and involvement was considered vital for the success of the biodiversity recovery program. Seventy percent of the 84 landholders within the catchment participated in the survey.

The 2003 CALM survey identified salinity as the greatest on farm-threat. Earthworks (banks and drains) are the main way landholders were attempting to combat salinity, although fencing and revegetating sandy seeps were also widely used. Most landholders felt these methods helped alleviate the impacts of salinity.

Another commissioned report (URS 2008) documented observations made by landholders in the project catchment. One landholder, with an extensive knowledge of the farm history, indicated that clearing of the BMNDRC wetland sub catchment area began in the early 1900s. Most of the remaining native vegetation was left because it was in areas of shallow bedrock. From 1993, minimum tillage and no burning practices were implemented but regular burning of native vegetation was common practice prior.

It was reported by landholders and subsequently confirmed by URS that remnants of an old river channel exist high in the catchment. At a location east of one of the homesteads, coarse well-rounded quartz river gravel was observed. Unfortunately, (URS 2008) doesn’t give any further detail of where exactly this might be.

Another landholder reported that most clearing occurred in the mid 1950’s. They also recalled that a key wetland in the BMNDRC became inundated between 1963 and 1966 following a period of high rainfall; so much so that, water skiing on the lake was popular.

It was also reported that during the 1999 floods, the drainage associated with the valley floor braided lakes flooded and began to flow. At the time, landholders estimated the flow rate at the Gunyidi-Wubin Road was about 242 megalitres per day (ML/day). Interestingly they only measured a flow rate of 91 ML/day at the crossing on the Miling Road, just a few kilometres downstream.

During past storm events, it was indicated that at least 180 to 200 mm of rain was required over 24 to 48 hours to get the main braided drainage channel to flow. This has been a rare event and occurs after low pressure cyclonic systems. The last flow occurred in 1999 following tropical cyclones Elaine and Vance.

A later study, submitted as a masters thesis at the University of WA, utilised a sub catchment in the BMNDRC where a transect of bores had been established in 2002 (Bourke 2011). The study included further landholder observations of land clearing in one part of the project catchment. In 1959, 70 percent of the Nabappie sub catchment remained uncleared native vegetation but with evidence of frequent burning. This was confirmed by historic aerial photographs. Burning native vegetation was common until the early 1980s. Most vegetation clearing occurred around 1966 to 1968 and groundwater rose dramatically within 10 years, coinciding with a run of wet years.

These observations show a rich oral history exists in the project catchment and the current project will hopefully add further landholder input to that knowledge base.

6.6.1 Using freely available historic imagery sequences

At a local catchment or paddock scale, satellite imagery can be a useful tool for the new generation of land managers to observe areas of salinity over time in terms of extent and general appearance, but also changes such as when on ground works were implemented. Platforms like Google Earth™ have a feature that allows users to compare historical images with more recent views. Figure 6-10 shows a typically salt affected area in the project catchment between 2003 and 2018 with no groundwater drainage constructed. The spread of salinity appears stable but with some expansion to the area unable to be cropped. The faint lines visible in the 2003 image were possibly the edge of non-cropping soil up to the wet year in 1999. A cropped area to the east is showing signs of salinity affecting production in the 2018 image.

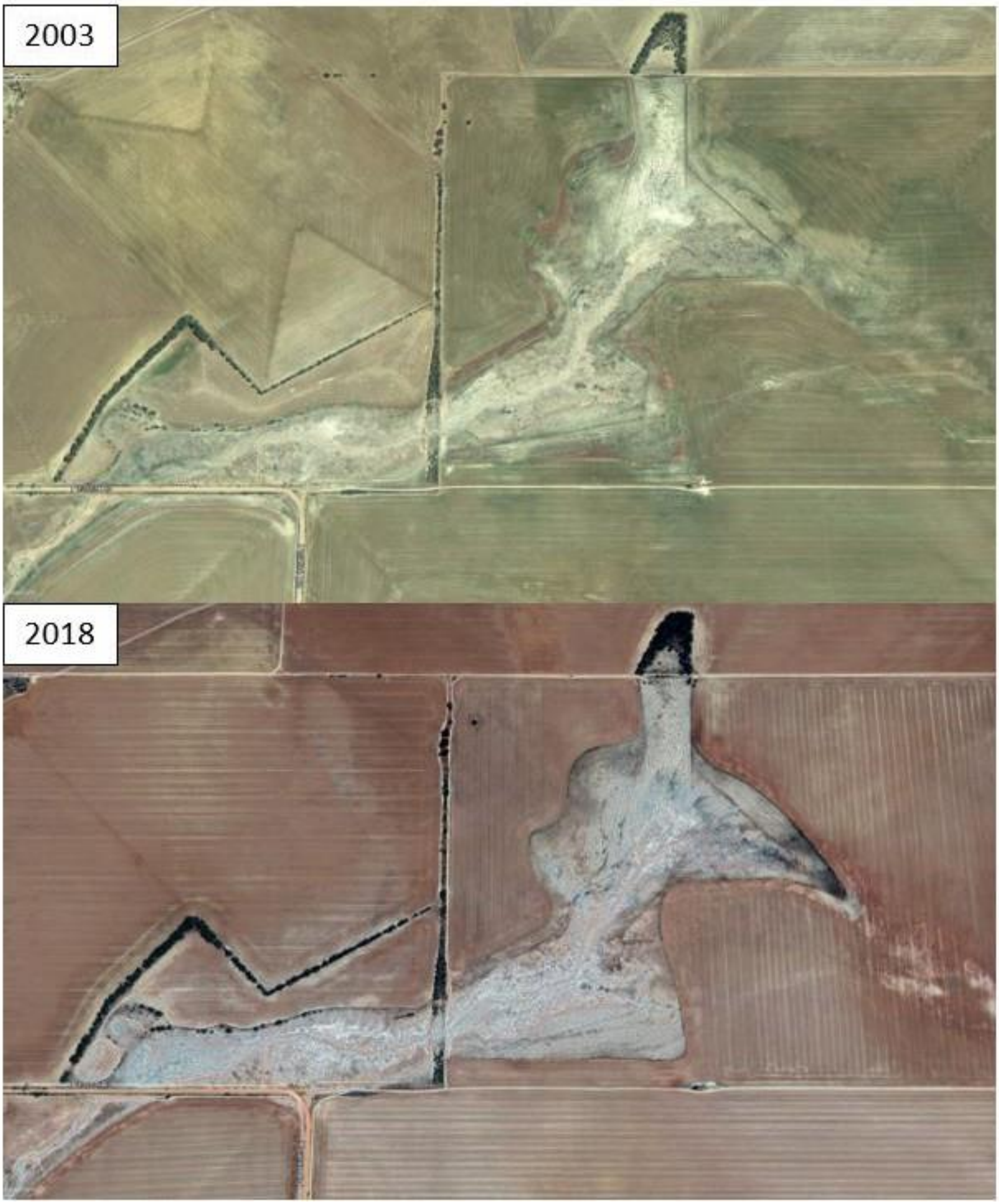


Figure 6.10 Changes to salinity 2003-2018 at a typical saline scalded area in the project catchment

6.7 Liebe Group involvement with salinity

The Liebe Group have been involved, along with its various research partners, in numerous salinity related projects over the years and a useful summary was recently published in the Group's newsletter, largely because of the renewed interest in the topic (Liebe Group 2020).

In the early 2000s there was considerable interest in sub-tropical perennial pastures for increasing out-of-season production, but also potentially utilising excess water that would otherwise recharge and cause salinity lower in the landscape. Liebe Group were involved with several trials on members properties, such as those in 2001 at Jibberding where Rhodes grass was found to be the best performer. Much of what was learnt in the many trials of perennial pastures in the early 2000s from around WA can be found in (Moore, Sanford and Wiley 2006).

Also east of Wubin, Liebe Group members were involved in trials of saltbush as an alternative for lowering water tables at a time when farmers were spending $5-10 per metre on constructing deep drains. Their trials found even single rows of saltbush could lower water tables although only modestly but enough to reduce salinity locally and allow less salt tolerant pasture species to establish (Barrett-Lennard 2002).

Later Liebe members were involved in trials of new prospective perennial legume for bridging summer feed gaps in low rainfall zones such as Tedera, sown at Liebe's long term research site 2006 to 2009 (Real 2011), and which Liebe Group is still undertaking trial work even now:

https://www.liebegroup.org.au/tedera-trial

Other areas Liebe Group has been involved include raised bed farming trials, trials of cropping into slender ice plant, and assisting with delivery of project advice and incentives delivered on-ground to assist farmers managing saline land.

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7.0 Tackling salinity

7.1 What information is needed?

As discussed in section 6.2 understanding what is under the soil surface down to bedrock is what matters in understanding salinity at the farm or paddock scale. The project catchment, like much of WA, has an ancient and complex hydrogeology. Broad flat wheatbelt valleys can have layers underneath that may not follow the shape of the land. There may be sediments accumulated over millions of years; layers of soft clayey saprolite now saturated with groundwater, as well as criss-crossed dikes, and sills (rock intrusions in fissures or between layers that sometimes act as barriers pushing groundwater to the surface). There may be perched aquifers above hard silcrete layers and other anomalies that make it hard to assess salinity risk and take appropriate management actions. Despite this, most actions taken by land managers are quite often not based on detailed understanding of the underlying geology because that information is simply not available at the fine scale required or because people prefer to use observation or trial and error.

7.1.1 Bore information

There are numerous production and observation boreholes to various depths and specifications in the project catchment, as well as old wells, soaks, etc. that can be used to better understand hydrology at the paddock or farm scale.

There have been several programs of constructing and analysing data from observation bores and piezometers (Speed & Strelein, 2004) (Abbott, 2011) (URS, 2008) (Speed, Kendle and Gibbon 2008) which have contributed to understanding hydrology and salinity in the area.

The Department of Water and Environmental Regulation (DWER) are custodians of borehole and water information and enquiries about borehole location and information from known drilling programs for this review were directed to the online Water Information Reporting (WIR) system maintained by DWER and supported by the state government 'Royalties for Regions' program.

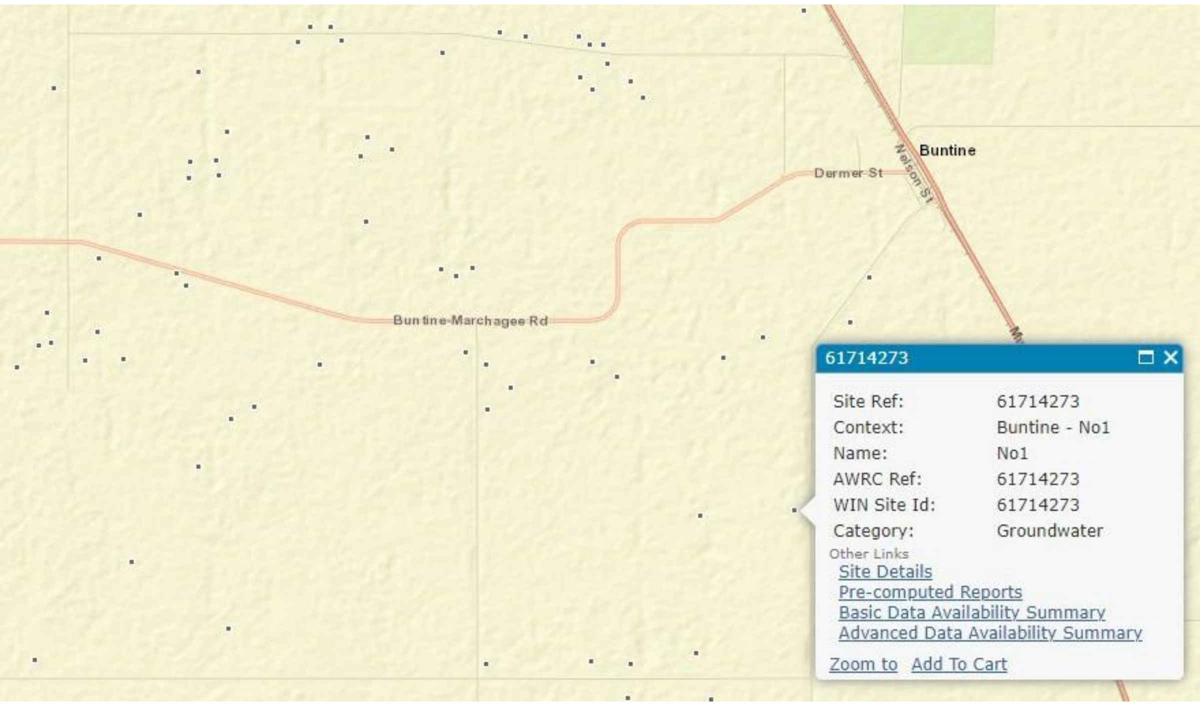
https://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx

Figure 7-1 below shows a typical screen shot from WIR within the project area; the dots representing known drilling or other sites where discrete water level has been recorded at some stage. However, it seems to be a very incomplete resource and many of the sites have little or no useful or reliable information. Furthermore, none of the main drilling programs from recent times have monitoring bore locations and data available on this site, despite DBCA informing the review that their sites were registered with DWER. Furthermore, there are other bore networks maintained by DPIRD whose locations are also not on the DWER online database, including the Pithara bores discussed in this review (section 6.5.2). Other DPIRD hydrological sites can be located at:

https://catalogue.data.wa.gov.au/dataset/hydrological-bores

It was found during this review that a 2006 bore drilling program in the project catchment has no readily available location data and enquiries to DBCA who commissioned the work were directed to a CD-ROM held in the State Library of Western Australia Heritage Collection.

Water information has been identified as an important step in redefining a new direction for salinity in WA (Western Australian Auditor General May 2018) (GHD 2019) and each agency (DWER, DPIRD, and DBCA) has a role to play, but it can generally be concluded that this review has found monitoring bore information in the project area is lacking, incomplete, inconsistent, and certainly difficult for land managers to find, understand, or utilise in their decision making.



Site Ref: 61714273
Context: Buntine - No1
Name: No1
AWRC Ref: 61714273
WIN Site Id: 61714273
Category: Groundwater

Figure 7.1 **Screen capture of borehole information in the project area from DWER's water information reporting website**

7.1.2 Geophysical data

Geophysical data using airborne or ground-based electromagnetic sensors are important tools in geology and routinely used in WA mineral exploration. Sensors such as the on-ground EM38 meter (Geonics Ltd., Canada) have also been used to map salinity at the farm or paddock scale (Bennett, George and Ryder 1995) and airborne systems have been used to produce property plans for tackling salinity through targeted earthworks and revegetation (George and Smith 1998) (Reid, Munday and Fitzpatrick 2007).

The current review has found that use of electromagnetic sensors to map hydrology and salinity in WA farming properties is not commonplace. (DPIRD 2021b) suggests that there are contractors with vehicle mounted EM38 sensors that can produce salinity maps but at the time of completion of the current review, only one operator, based in Esperance, was identified. In this case though the service provided combines EM38 data with gamma radiometric sensors to map various physical and chemical soil profile characteristics (Bryce and Pluske 2020).

In discussing why detailed geophysical information has never been widely adopted to paddock scale dryland salinity in the way it has been utilised by the mining industry (Abbott 2011) suggests that land managers dealing with dryland salinity need to know what to do and where to do it in a way that exerts maximum impact relative to the cost of implementation. Simply put, while airborne and ground-based geophysical surveys are much cheaper than installing arrays of observation bores, farmers continue to rely primarily on observation and other sources of information.

7.2 Vegetation strategies

7.2.1 Perennial farming systems

Perennial farming systems aim to increase perennial plants in farming systems to increase water use and reduce recharge, the primary cause of salinity. Examples include establishing perennial pasture grasses and forbs, as well as shrub and tree plantations used for fodder (NACC 2017) (Honeysett, Milthorpe and Wynne 2004) (Barrett-Lennard and Malcolm 1995).

In the project area there are examples of perennial farming systems including a 21-hectare tagasaste plantation established in 1988 as a strategy to utilise an excess of fresh groundwater (Abbott 2011).

The trend away from mixed farming enterprises in the project catchment to an increasingly cropping-only focus over recent years suggests that interest in perennial farming systems may not be a focus for the new generation of farmers. However, it is worth noting there is a large amount of information available, some of which is included in the references as part of the suite of strategies to tackle salinity.

7.2.2 Salt tolerant plants

In terms of non-cropping areas already, or at risk of, salinisation, there has also been considerable work done trialling salt-tolerant pastures and fodder (Barrett-Lennard and Malcolm 1995) (Honeysett, Milthorpe and Wynne 2004) (DPIRD 2021a). Species and varieties such as tall wheat grass, puccinellia, and the pasture legume Messina ‘Neptune’ have been shown to have tolerance of salinity and waterlogging, but most options available may be limited in the project catchment, preferring rainfall ≥375mm (DPIRD 2021a). Small shrubs and forbs in the Chenopodiaceae family (saltbush and samphire) are the most likely group of plants with grazing potential in the salt affected areas of the project catchment.

7.2.3 Revegetation

Revegetation, usually with indigenous trees and shrubs, provides many benefits for biodiversity, shelter, aesthetics, and erosion. Recovering saline land by revegetation is not feasible at the scale required and, even if it were possible, would likely make farming unviable (Ruprecht and Schofield 1991). However, there can be salinity benefits from strategic plantings of woody species. Studies in the wheatbelt (McConnell 1998) have shown that most heavier soils have a saturated zone that rises and falls vertically faster than flows laterally, so the best place for trees on heavy soils is usually upslope in the recharge zone. Sands and gravels though can have higher lateral flow of groundwater so strategic planting down gradient can assist with utilising excess groundwater.

A comprehensive guide to suitable trees and shrubs for revegetation projects in the project catchment is available (Wilcox, et al. 2015) and there are lots of useful resources including case studies from within the project catchment (NACC 2018). Satellite imagery shows many farms have examples of revegetation, especially from the period of the DBCA-led recovery catchment program, when 712,000 seedlings were established on farms in the area (Mullan 2009). There are blocks and corridors linking remnant vegetation patches, alleyway and boundary strips, and plantings in saline areas are also common. As you would expect, satellite images show most saline plantings have better success on the less saline margins.

7.2.3.1 Carbon opportunities

For the next generation of land managers, revegetation may also have potential to be part of a carbon offset for a polluting activity or be part of an emissions reduction scheme. The carbon opportunities in the project catchment have been tested (Ritson, et al. 2015), with lower carbon credit returns generated for plantings on saline land. There may still be opportunities however given saline degraded land has little value for agriculture and the 2015 modelling was made with a carbon price of \$20 per tonne CO_2 while the current price (March 2022) is \$31 per tonne CO2 (Reputex Energy 2022).

Farmers are increasingly looking at ways to offset their carbon emissions for various personal and marketing reasons or are entering arrangements with companies and organisations to offset the emissions of others. There is also potential in the project catchment to contribute to the federal governments carbon emission targets and attract payments through the Emissions Reduction Fund (Australian Government 2021). The environmental plantings category requires mixed species revegetation to be established for either 25 or 100 years. The federal government will pay one Australian carbon credit unit (ACCUs) for each tonne of carbon sequestered, as based on modelling.

There is considerable work in developing and coordinating a carbon project and Liebe Group is potentially in a good position to provide that service on a catchment scale. For example, new environmental plantings at many sites on group members farms could be pooled into one project with future potential earnings going back into a community fund.

The move away from livestock in the project catchment has led to natural regeneration on farms in areas not cropped. Species like River red gum (*Eucalyptus camaldulensis*) will readily regenerate in wetter, mildly saline areas. In more saline areas and in bush remnants and revegetation sites, trees and shrubs can regenerate and grow unimpeded by livestock and this change is likely to be beneficial to lessening the impact of salinity.

7.3 Conservation earthworks

The aim of surface or conservation earthworks is to re-direct surface, and sometimes shallow sub-surface water, safely away from paddocks into dams or waterways to reduce waterlogging, erosion, recharge, and, ultimately, salinity. Waterlogging is a major potential hazard to susceptible commercial crops and grasses in saline environments because salinity is caused by the presence of a shallow water table and/or by major decreases in the hydraulic conductivity of soil caused by sodicity (McFarlane, George, et al. 2016).

There is a clear relationship between waterlogging and salinity and the unexpected very wet year of 2021 prompted long time WA hydrology experts like Richard George to remind farmers through various farm media outlets that the combined impact of waterlogging and salinity on yield is greater than either one alone, and that deep drains are not the only solution (Verhagen 2021).

"It is recommended that growers implement other water management practices to compliment deep drainage because it is important to take action to prevent fresh water from accumulating in susceptible areas and laying there for more than three days to support crop survival. Water management structures that remove surface and subsurface water, such as shallow relief drains or raised beds, will limit the amount of excess water entering and/or residing in the soil profile and aid the effectiveness of groundwater drains. These surface water and drainage structures have different tasks that need to complement each other"

A review of the BMNDRC program (Wallace, et al. 2011) discussed the importance of surface water management on farms surrounding the identified wetlands in the program as a key part of reducing the threat of waterlogging and salinisation.

An important consideration for the Liebe Group project catchment in terms of the need for surface water management is the relatively low rainfall and the move away from livestock. There is less compaction and more ground cover because of stubble retention so that water may be recharging more where it falls rather than accumulating in low lying areas causing waterlogging.

It is also important to consider the simplest option first. For example it may be that deep ripping through a problem area is all that is needed to get water moving.

7.3.1 Grade banks and seepage interceptor drains

Grade banks, seepage interceptor drains and reverse interceptor drains (Bligh 1989) (McFarlane and Cox 1990) (Keen 1998) are used to:

- divert runoff across slopes to waterways or dams at non-erosive velocities.
- reduce effective slope length. They effectively break up a long-slope into a series of shorter-slopes. Reducing the length, velocity, and erosivity of run-off.
- increase runoff duration and decrease peak flow rates by forcing run-off to take a longer route at lower flow velocity.
- reduce peak flow rate at the catchment outlet or critical design point where erosion is most likely to begin.
- increase infiltration and reduce runoff.

The difference between seepage interceptor drains (reverse interceptor drains) and normal grade banks is that interceptor drains divert surface flow but also capture and divert the shallow sub-surface seepage that often occurs on duplex soils, which have a permeable topsoil overlying a shallow clay subsoil. Figure 7-2 shows a typical reverse interceptor drain.

Figure 7.2 Reverse interceptor drain (from (McFarlane and Cox 1990)

7.3.1.1 Channel outlets

Drop structures, also known as a grade control, sill, or weir, are often required where a grade bank enters a dam, deep drain, or waterway, allowing water to pass to the lower elevation while controlling the energy and velocity of the water. Commonly used materials to absorb the energy and lessen erosion include concrete, rocks or road base, gabions and geo-textiles, or any other suitable materials at hand.

7.3.1.2 Grade bank spacing and length

Maximum bank spacings to reduce erosion have been determined through experience in the wheatbelt and great southern regions of WA. The northeast agricultural region, being subject to greater intensity of summer storms, needs to have a closer spacing than other regions (Bligh 1989). It is recommended that for most slopes likely to be encountered in the area, a maximum spacing of 200 m should be maintained. Banks should not exceed 800 m in length unless constructed higher than the standard height of 0.5 m because of the increased catchment area.

7.3.2 Grassed waterways

Grassed waterways are defined low-velocity natural or constructed structures that safely move surface water across the natural landscape. They are designed to handle water flow into and out of dams, the end of grade banks, and other surface water disposal structures. (DPIRD 2021c) recommends that grassed waterways are part of a whole farm water and salinity management program.

Grassed waterways should, according to (Bligh 1989) and (Keen 1998):

- Never be cultivated or overgrazed as maintaining ground cover is crucial to slowing and spreading water flow.
- Have side levees constructed to confine flow within the waterway and include drop structures at entry points such as the end of grade banks.
- Not utilise native trees and shrubs as they are not as effective as a good grass cover in protecting waterways in areas where large summer flows are frequent. Stubble and other debris washed off paddocks during floods, catches around stems and trunks, increasing their resistance to flow and can create greater depth of flow and erosion.
- Be top-dressed as required to maintain good ground cover.
- Be constructed below every dam unless water is being diverted by a grade bank to a nearby stable waterway.

Figure 7-3 below shows a good example of a grade bank and grassed waterway in the project catchment disposing of excess surface water into the creek system.

Figure 7.3 **Grade bank and grassed waterway in the project catchment**

7.4 Case Study: Integrated Water Management 2005-2011

The recommended approach to reducing surface water flow is always firstly using sound soil management practices such as maintaining year-round ground cover (Alderman, Clarke and Natural Heritage Trust (Australia) 2003). However, there is often a need, especially in Australian agricultural landscapes with light soils subject to erratic large rainfall events, to manage the surface flows with earthwork structures.

The combination of plant-based and engineered approaches is termed Integrated Water Management (IWM) and has been a key approach to reducing salinity and other changes to hydrology in the project catchment in the past. The legacy of contour banks and grassed waterway levies, revegetation, alley plantings of mallees and saltbush, and fenced off remnant vegetation, are a visual reminder of the extensive work undertaken.

Starting in 2005, the then Department of Environment and Conservation (DEC) implemented the IWM project in partnership with the Northern Agricultural Catchment Council (NACC) on several farming properties in the current project catchment to address salinity and other changes in landscape hydrology. The focus was on working with landholders and other stakeholders to protect biodiversity in the recovery wetlands as well as contributing to agricultural productivity. An important feature of IWM was that it combined engineering and plant-based approaches (Deutekom 2012). The IWM approach gave DEC the opportunity to address multiple threatening processes at the same time. The aim was to reduce salt, nutrient, and sediment export from farms into sensitive downstream areas but also reduce water logging, erosion, and salinity and, in several cases, also helped to protect public infrastructure by improving culvert design and placement. DEC and NACC staff worked with eight landholders, the Shire of Coorow, the Coorow Land Conservation District Committee (LCDC) and others over six years to treat a target area of 19,000 hectares with the IWM approach The project was widely regarded as very successful and highly awarded (Mullan 2009) (Deutekom 2012) and the statistics are impressive:

- 115 kilometres of grade banks
- 49 kilometres of waterway levies
- 104 kilometres of fencing
- five dams
- two public road floodway upgrades
- one major culvert on a sealed public road
- four kilometres of gully erosion repair
- removal of eight kilometres of obsolete earthworks; and
- establishment of 712,000 seedlings.

A local earth moving contractor obtained national accreditation for undertaking conservation earthworks, and at one stage a substantial culvert under the Buntine-Marchagee Rd was even moved and upgraded. (Mullan 2009)

The project was reviewed by NACC (Deutekom 2012) using social science research techniques and interviews and a documentary film was produced:

(https://youtu.be/cjf9Cc4yvXs)

Slowing water flows and changing the way water flowed through the landscape was a big motivator for landholders to participate in IWM. Some landholders also saw IWM as an opportunity to redesign paddocks and make them align with natural features

When asked about ‘before’ and ‘after’ changes, landholders revealed similar responses. Again, water management was mentioned as being significantly improved. Landholders stated having less gully erosion, less water logging, and less washouts. Additionally, one landholder mentioned better and earlier trafficability on paddocks. However, others mentioned increased difficulty in accessing paddocks and moving their machinery around. One landholder described it as *"fixing up the erosion but that the other on ground thing was that it was more difficult to operate my paddocks because of smaller pieces and – as farmers – we like large paddocks"*. Revegetation was mentioned by most landholders as being an important on-ground change in the IWM project.

Other challenges were brief time scales involved to get work done, farm work overlapping with IWM work, and issues surrounding fence construction.

One landholder, with a mixed enterprise, was keen to keep his livestock out of the remnant vegetation, preventing it from further degrading, and was therefore keen to fence it off in the IWM project. Another landholder, with only a cropping programme, mentioned that it was easier to take fences out and redesign paddocks without sheep.

Another landholder remarked "*The tree planting has been quite impressive, and those areas are starting to improve; they look better now. There was a bit of a scalded area and it's now got trees on it and it looks very good. There are certainly more kangaroos living in there, which is a negative, but hopefully there's more birds living in those areas where the trees are planted. So overall I see a lot of improvement there".*

Figure 7-4 below shows a recent satellite image of the original demonstration site for the IWM project, constructed in 2005/06 with grade banks feeding into a levied grassed waterway. Figure 7-5 is the corresponding Google Streetview™ image from November 2020 where improved culverts were installed along the Buntine-Marchagee Rd.

Figure 7.4 Location of initial demonstration site in the IWM on-ground works project 2005-2011

Figure 7.5 **Grassed waterway constructed in 2005 flowing under the Buntine-Marchagee Road (GoogleMaps™ Nov 2020)**

7.5 Groundwater drains

Groundwater drains (also called deep drains) are designed to intercept the water table allowing saline water to drain away from the area. They can be open allowing surface runoff to enter, or be leveed, which helps prevent erosion of the drain batters. Groundwater drains are usually 1-3 m deep and have a gradient of less than 0.2 percent (DPIRD 2022).

It is important to note that groundwater drains and other engineered disposal such as siphons, pumping, relief bores, etc., require the Commissioner of Soil and Land Conservation to be notified. (DPIRD 2022) recommends subsurface water management is part of an integrated water and salinity program.

7.5.1 History of groundwater drains in the project catchment

Deep drains have existed in the project catchment for many decades and are visible on 1985 satellite imagery. Imagery sequences in the project catchment show the ongoing development of groundwater drains. There were only a few drains visible in the 1980s but there is now at least 317 km of linked drains through multiple properties disposing into waterways or salt lakes as shown below in Figure 7-6.

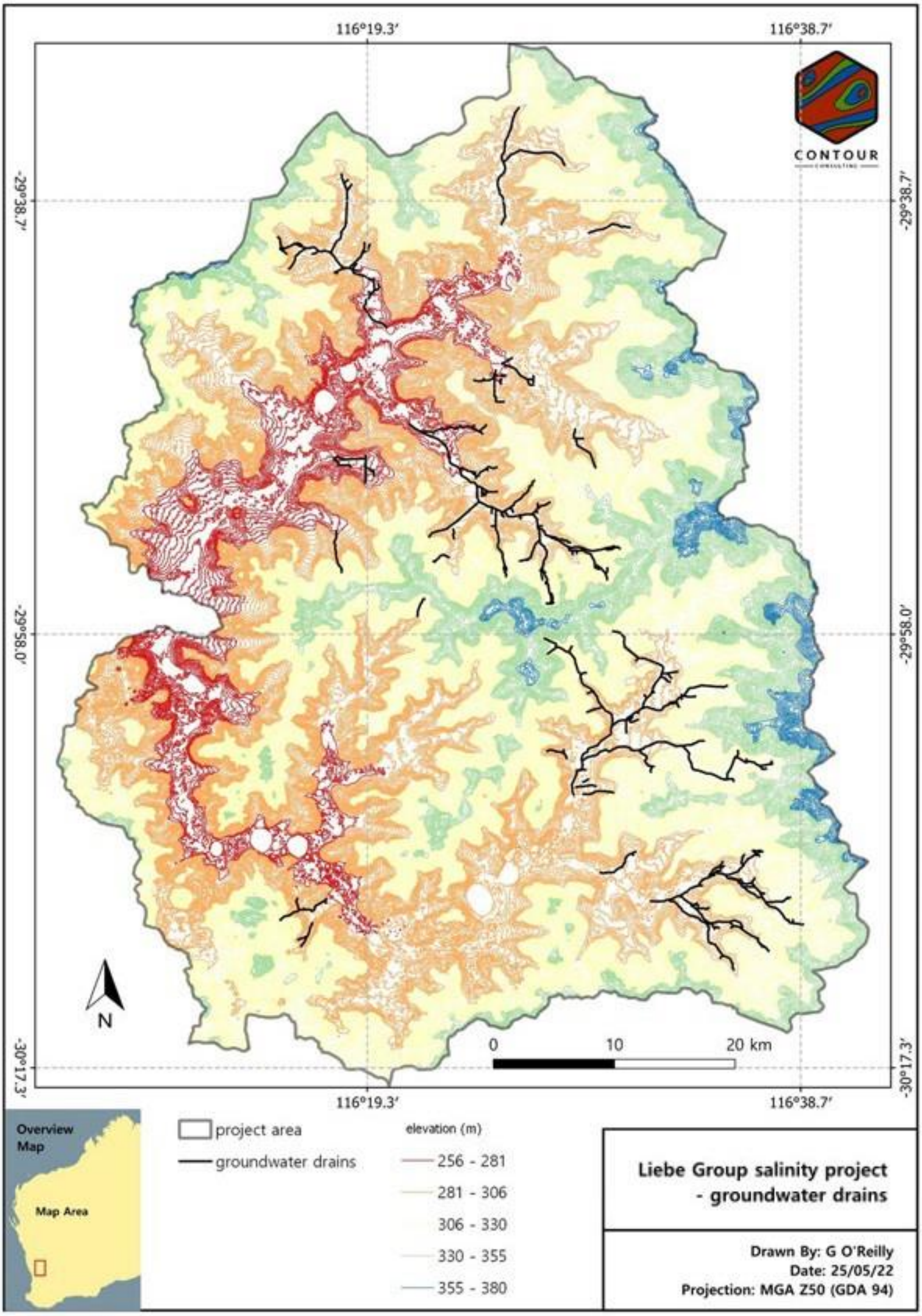


Figure 7.6 **Groundwater drains in the Liebe group salinity project catchment**

A review of deep drains occurred as early as 1985 (P. R. George 1985) and a study was undertaken in the project catchment area 3 km SW of Buntine in the early 1990s that found very limited benefit except within 10 m of the drains themselves (Speed and Simons 1992). It was noted that the spoil from the drains occupied four metres of that space anyway and constructing surface water management structures (grade banks and leveed waterways) that empty into the deep drains constructed may be a better option to reduce waterlogging and salinity.

Many landholders in the northern agricultural region were motivated to drain by the very wet year of 1999 after seeing rapidly expanding areas of salt affected land and waterlogging (Beattie and Stuart-Street 2008). Most farmers relied on advice from other landholders and contractors and the results tended to be highly variable. Some farmers reported improved productivity of the land around drains, and most were happy with their investment. A minority reported no change or ongoing decline and continued spread of salinity.

Every study and review of groundwater drains concludes that detailed and independent site investigation is required to firstly diagnose the problem and design the appropriate response. For example, understanding that salinity may be a result of a shallow water table, a perched water table, seepage behind a sill or dike structure, or perhaps inherently saline soil. Soil permeability is an important factor in the rate and ability of groundwater to move through pores in the soil profile to reach the drain and DPIRD recommends soil pits be dug intermittently along the course of any proposed drain to better understand the soil profile.

It has been found that loamy and silty-sand topsoils and upper soil profiles are more predisposed to erosion than medium to heavy clay subsoils. In more saline environments, the combination of soil erosion caused by dispersion and slaking, as well as windblown material, can quickly silt up some ground water drains. Channel silting can be most noticeable where the drain is open to surface water runoff (Cox 2010). Figure 7-7 shows a typical drain in the project catchment where silting and erosion has occurred near a road culvert.

Figure 7.7 Typical groundwater drain in the Liebe Group salinity project catchment. From Google™ Streetview ™

7.5.2 How groundwater drains work?

It is recommended (DPIRD 2022) that leveed groundwater drains are used:

- on agricultural land where there are areas with suitable soils, low slope, shallow water tables, and waterlogging or surface salinity problems.
- alone or with other practices.
- clear of flow lines, streams, creeks, and rivers.
- where a small quantity of surface water flows overland outside of the structure, but is not diverted, concentrated, or confined by the structure.
- where a suitable outlet is available to dispose of the quantity and quality of water collected.

7.5.3 Effectiveness

In terms of the primary purpose of drains; alleviating the spread of salinity, there is not a great deal of scientific evidence available, especially considering the extensive construction of groundwater drains in the wheatbelt. However, the studies that are available have led to the general recommendation that drains can draw down groundwater level to the bottom of the drain up to 100 metres either side under ideal conditions, but sometimes as little as 10 m either side (Keen 1998).

One of the best designed investigations was undertaken just outside the project catchment at Pithara, 25 km ESE of Dalwallinu, as part of the 2004 Engineering Evaluation Initiative (EEI), managed by the Department of Water (Cox 2010). There were 18.7 kilometres of 2.5-metre-deep drains constructed to de-water a 13,200-hectare catchment. Outflows, water quality, and effect of ground water levels were measured over two years. It was found the drains did not sufficiently lower the water table beneath the land targeted for salinity recovery.

Construction of the Pithara drains did produce a small reduction in groundwater levels adjacent to the drains. The greatest effect was confined to within 50 m, although some groundwater response was measured as far as 175 m away. At 20 m from the drain, the measured water level reductions were of the order of 0.5 m. At 50 m and beyond, the effect of drains on groundwater levels was less obvious. A water balance calculated for the site found that the drain removed groundwater approximately equivalent to the local recharge over an area 100 m either side of the drain. However, this discharge to the drain was rapidly replaced by recharge from the surrounding regional aquifer (GHD 2017). In other words, a single drain cutting through a valley floor may remove a significant amount of groundwater but there is a continual replacement from the surrounding groundwater reservoir and from direct yearly winter recharge. In a wet year or run of years the drainage system may not cope as it is barely working in a normal year.

The author of the Pithara drain study summed it up nicely:

"The main problem with ground water drains is the unrealistic expectation that drains can de-water a regional-scale aquifer with only local-scale drainage efficiency" (Cox 2010).

The recommendation of the EEI project was that, like drainage schemes worldwide, wheatbelt ground water drains should be regularly spaced and parallel to each other, to maximise the catchment area that each drain can reach. (Cox 2010) suggests parallel drains with 150 to 250 metres spacing could lower and control the water table enough to recover once-saline land for dryland cereal cropping.

There is some evidence in the project catchment that there is more cropping now than in the past adjacent to some drains. For example, Figure 7-8 below shows an area that had some drainage visible in an older satellite image, though not extensive or in good condition. A later image shows the drains had been refurbished or reconstructed, and that other drains and disposal areas added, and the area cropped appears increased. The problem is there are too many unknown factors to assume the drains have been the effective intervention. For example, the cropping program may have become a greater priority, and the areas in the first satellite image were arable but were not cropped. It could be that the significant decline in rainfall over 20 years has dropped the water table with or without drains. It could also be that the drains are placed higher in the landscape and are, in fact, adequate for de-watering the sub catchment they occupy. Either way it is a good result for this landholder.

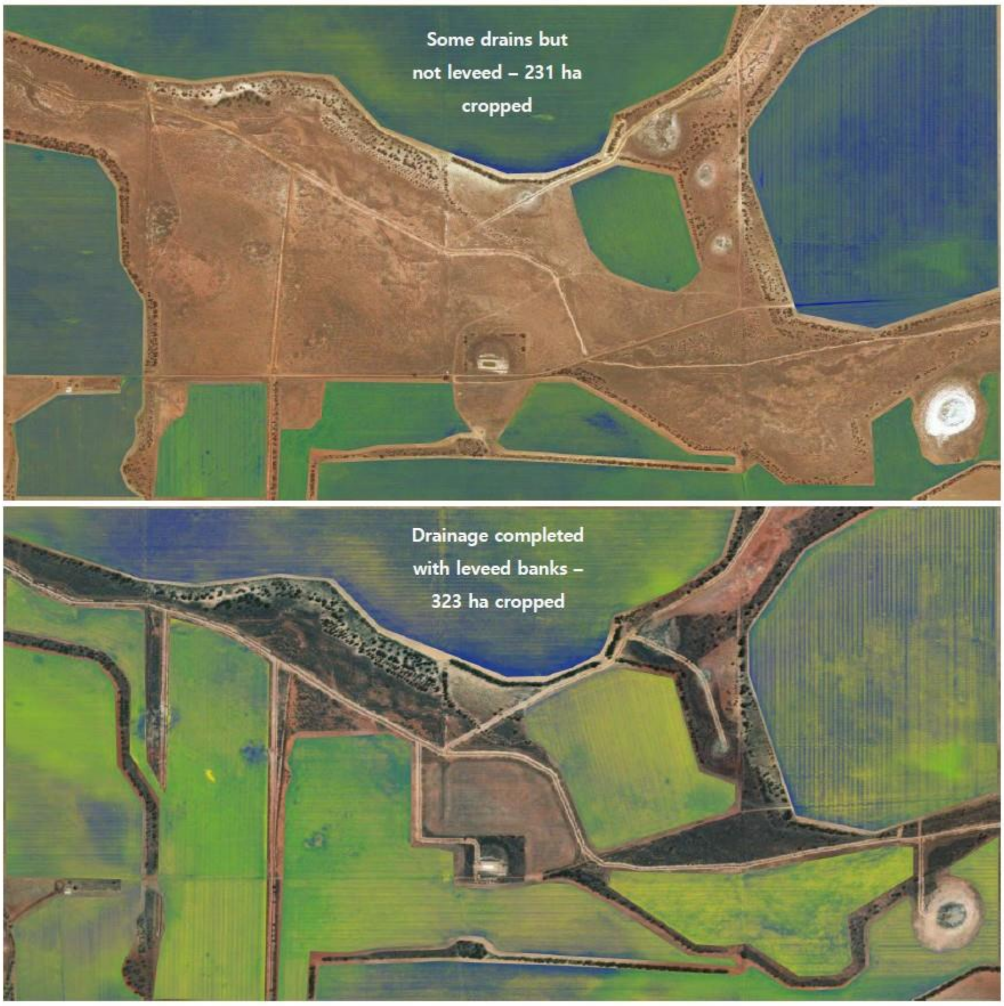


Figure 7.8 **Increased cropping area following drain construction on a farm in the project catchment**

7.5.4 Maintenance

As channels fill with sediment and become shallower the efficiency at draining groundwater decreases, necessitating maintenance to restore the original depth. Maintenance of groundwater drains has been investigated (Beattie and Stuart-Street 2008) and it was found that half of landholders who had drains constructed between 1987 and 2007 had not undertaken any maintenance. Others undertook maintenance when possible or on sections such as around culverts. Costs incurred for maintenance ranged from $1000/km to over $2,000/km.

7.5.5 Governance – managing drain networks

Drain networks rely on crossing property boundaries and require cooperation and organisation for construction and maintenance. A poorly maintained down slope drain could lead to flooding or waterlogging. The potential for downstream impacts is a major reason that groundwater drains require notification and assessment by the Commissioner of Soil and Land Conservation under the *Soil and Land Conservation Act 1945*

A review of deep drainage research in WA for the period 2003-2015 was undertaken to provide land managers and policymakers better understanding of the impacts, benefits, and consequences of deep drainage (GHD, 2017). They found that governance arrangements varied greatly. There were systems of drains in poor condition and in need of maintenance; were at risk of flooding and potentially causing damage to land and infrastructure, but with no obviously accountable body. Other drainage networks relied on neighbour cooperation where the potential for a breakdown in relations could pose a risk to the long-term management of the drainage system. In other cases, there were local active catchment management groups involved in managing drains which had disbanded or lost impetus.

One scheme was held up as a best-practice example of having an ongoing governance structure in place. The Fence Road scheme administered by the Shire of Dumbleyung and a Local Land Drainage Advisory Committee had features such as access arrangements and a funding mechanism.

It is unclear what governance strategies are in place for the several groundwater drains crossing property boundaries in the project catchment at this time, though neighbour cooperation is likely to have played a significant role. Governance of existing or potential drain networks to avoid downstream impacts may even become an aspect of the current project that the Liebe Group could play a future role in.

8.0 Next steps

This catchment review has tried to provide a kick start to the Liebe Group salinity project 2022-2023. It tells the story of salinity in the project catchment and brings together in one document some of the history of research, projects, programs, observations, and reviews, undertaken in or near the project area, or which have direct relevance to the project.

The next step is to look at what farmers are doing on their land, including what has occurred in the past, and what might be planned in the future. It is hoped that local knowledge and observation will add to the salinity story.

The surprise wet year of 2021 has led some landholders to consider undertaken salinity control measures such as groundwater drainage and it is hoped the Liebe Group salinity project can provide support and advice to those landholders on the various aspects of drainage; regulatory, geophysical, governance of drain networks, and the importance of surface water management to complement groundwater drainage.

The review has confirmed a lack of coordination of the network of monitoring bores and other water information sites in the project catchment. Data on location and measurement are in various repositories including historical archives, and it is hoped the Liebe Group salinity project will provide some impetus for agencies to identify, consolidate, and hopefully revisit some of the work previously done in the project catchment.

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9.0 Glossary

BMC	Buntine Marchagee Catchment – an abbreviated version of BMNDRC
ACCU	a financial instrument awarded to eligible energy efficiency, renewable energy generation and carbon sequestration projects that result in a reduction of Greenhouse Gas (GHG) emissions.
BMNDRC	Buntine Marchagee Natural Diversity Recovery Catchment – a salinity program that was active in the project catchment approximately 2000-2010 and managed by DEC (now DBCA).
Contour Consulting	Contour Environmental and Agricultural Consulting.
CSIRO	Commonwealth Scientific & Industrial Research Organisation
DAFWA	Department of Agriculture and Food, Western Australia. Now DPIRD
DBCA	Department of Biodiversity, Conservation and Attractions. Formerly DEC formerly CALM
DEC	Department of Environment and Conservation. Formerly CALM and now DBCA
DPIRD	Department of Primary Industry and Regional Development formerly DAFWA
DWER	Department of Water and Environmental Regulation
dike	A dike is a sheet of rock that formed in a fracture in a pre-existing rock body
EC	Electrical conductivity – a measure of salinity
EEI	Engineering Evaluation Initiative – A Dept of Water led program in the early 2000s looking at engineered solutions to dryland salinity
GIS	Geographic Information Systems.
GPS	Global Positioning System.
halophytes	salt tolerant plants
hydrozone	Broad regional classification of WA based on hydrogeology
IWM	Integrated Water Management – a sub-project of the NDRC program funding on-ground works on farms in the early 2000's
LCDC	Land Conservation District Committee
leveed drain	A groundwater drain with the channel completely enclosed within levee banks
mg/L	measure of salinity, expression of the mass of salts dissolved in one litre of water
milliSiemens	A unit of electrical conductivity that is the reciprocal of

	resistance. The electrical conductivity of water is directly related to its salinity and is reported in the units of millisiemens per metre (mS/m)
ML	Megalitre = 1,000,000 litres and ML/day = measure of flow rate
NRM	Natural Resources Management
NDRC	Natural Diversity Recovery Catchment (six catchments identified in the early 2000's under the state salinity strategy for recovery of biodiversity. Managed by DBCA
observation bore	A shallow bore with slotted intake section across the saturated interface that provides a direct measurement of actual depth to the water table.
open drain	A dual-purpose groundwater/surface water drain that is not completely enclosed within levee banks
paleochannel	a remnant of an inactive river or stream channel that has been filled or buried by younger sediment.
perched aquifer	An aquifer found higher in the regolith, separated from other aquifers by a had layer like silcrete
recharge	The addition of water to the groundwater system (mm)
regolith	The soil and subsoil profile down to bedrock
RCM	Resource Condition Monitoring – a program of groundwater monitoring using observation bores in the Perth basin
siemens	A measure of electrical conductivity directly related to salinity. See mS/m
silcrete	A zone rendered hard by secondary cementation with silica.
sills	a tabular sheet intrusion that has intruded between older layers of rock
saprolite	A soft, earthy, clay-rich, thoroughly decomposed regolith formed in-situ by chemical weathering of igneous or metamorphic rocks
sodic soils	Soil containing sufficient exchangeable sodium ions to adversely affect soil stability and land use. Sodic soils are subject to dispersion resulting in erosion – commonly found on broad, flat landscapes with poor drainage
sodicity	a measure of the exchangeable sodium in relation to other exchangeable cations in soil – soils prone to dispersion and waterlogging,
TEC	Threatened Ecological Community (listed in the WA Biodiversity Conservation Act 2016)
TDS	Total dissolved solids – a measure of salinity in soil or water
WA	Western Australia.
waterlogging	The accumulation of excess water in the root zone of the soil

water table	Surface of unconfined groundwater at which the pressure is equal to atmospheric pressure
WIR	Water information Reporting – an online repository of water information maintained by DWER at https://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx

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