Australasian Groundwater & Environmental Consultants

Report on

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Wimmera-Mallee Sedimentary Plain
Stage 5

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GS9b – Wimmera-Mallee Sedimentary Plain

Stage 5 – Assessment through multiple lines of evidence

The Wimmera-Mallee Sedimentary Plain (GS9b) SDL resource unit is located in northwest Victoria in the catchment of the River Murray, with numerous rivers (Wimmera, Avoca, Avon, Mackenzie and Richardson) draining the southern half of the unit (Figure 1). The southern rivers do not flow directly to the River Murray, but rather terminate at Lakes Hindmarsh, Albacutya, and Outlet Creek, which are flood-fed key environmental assets. The resource unit pertains to three layered aquifers (from deep to shallow): the Tertiary Confined Sands (equivalent of the Renmark Group), the Murray Group Limestone (MGL), and the Loxton–Parilla Sands. From a management perspective GS9b pertains to all groundwater from the land surface to 200 meters below the surface, or 50 meters below the base of the Tertiary sediments, whichever is deeper (MDBA, 2020), and excludes the West Wimmera Groundwater Management Area. The resource is shared with South Australia, managed under the Groundwater (Border Agreement) Act 1985 (*Vic*). Groundwater extraction is focussed only in two main aquifer zones: in the Tertiary sands in palaeovalleys of the south; and in the Murray Group Limestone (MGL) near Murrayville (Figure 1). Take from the shallow sands near the River Murray is also currently occurring via Salt Interception Schemes (SIS); GS9b has two active stations. GS9b spans approximately 48,246 km², has a Sustainable Diversion Limit (SDL) of 190.10 GL/year, and a long-term average recharge of 59.31 GL/year (other recharge estimates vary; Table 1). Between 2013 and 2023, average annual groundwater extraction in GS9b was 8.08 GL/year, representing 4% of the SDL, and 14% of recharge (Figure 2). Groundwater use supports urban supply in the south (near Avoca and Horsham), and agriculture near Murrayville. Due to minimal drainage across much of GS9b, groundwater take is not sensitive to annual rainfall anomaly (Figure 2). Long-term climate observations show a relatively persistent below-average rainfall signal for the 2000–2010 period, with two cycles of above- and below-average rainfall between 2010 and 2020, and a sustained above-average rainfall period post-2020 (Figure 3).

The depth to water levels in the long-term (median values) varies broadly across the SDL resource unit (Figure 4a), and is dependent on whether the aquifer being monitored is shallow or deep. Heads in the MGL near Murrayville are typically more than 30 m below ground, whereas near Horsham the shallow aquifers have a water table within 10 m of the surface, similar to that below the River Murray (Figure 4a). Groundwater flows from southeast to northwest (Figure 4b), consistent with surface drainage and aquifer morphology, although the three aquifers of GS9b are separated by aquitards. Long-term (1974-2024) and short-term (2012-2024) median groundwater levels show spatial agreement and are contained within a well-defined fluctuation zone several metres thick (Figure 5). The 5th percentile of water levels defines the base of this fluctuation zone and is closely aligned with maximum drawdowns recorded during seasonal pumping. The short-term median groundwater levels can be lower than the long-term median water levels near Horsham (Figure 5b), but they are usually similar in the Murrayville area (Figure 5a). Groundwater salinity in the Wimmera-Mallee is generally highly saline and unsuitable for productive use, resulting in low demand and minimal extraction (DELWP, 2019a). Water quality often sits in RRAM class 3: 4,478 µS/cm to 20,896 µS/cm (equivalent to 3,000 mg/L to 14,000 mg/L), and can exceed 14,000 mg/L below the River Murray (Figure 6). However, there are less extensive zones of fresher water in the licenced areas (Figure 6). Long-term water level trends show declining trends in areas of water allocations, and mainly stable trends below the River Murray, with multi-decadal variability and seasonal responses to pumping (Figure 7; Figure 9). Short-term trends have lower data density, and show the development of declining trends below some parts of the river (Figure 10). The understanding of temporal salinity trends is relatively strong in GS9b (Figure 8) due to the risk of saline groundwater discharge to the River Murray, which is managed through the SIS. The primary aim of the SIS is to intercept saline groundwater; it is disposed of in evaporation basins some distance from the river where it is lost via infiltration or evaporation.

MDBA (2020) previously reported recharge for GS9b as 995 GL/year, which incorporated diffuse recharge from WAVES modelling (Table 1). Recent WAVES modelling for diffuse recharge from the MD-SY2 project estimated a lower value, at 439.17 GL/year; Crosbie et al. (2025). The Stage 2 estimate of 59.31 GL/year (derived from chloride mass balance and regional interpolation; Lee et al., 2024) is considerably lower than other estimates, primarily because groundwater salinity is high in GS9b. The disparate nature of these estimates indicates that there is residual uncertainty for recharge inputs to this diverse suite of three aquifers. As there is no formal reporting for the storage capacity of GS9b, an estimate of the storage-to-recharge ratio (S/R) that can indicate responsiveness[1] (as outlined by Rojas et al., 2022) is not possible. However, as much of the groundwater is saline in this unit, there is an expectation of limited buffering capacity, and some vulnerability to short-term climate variability in the shallow aquifers. This is not as relevant to deep aquifers that were mainly recharged in a wetter climate thousands of years ago. The limitations of salinity and buffering capacity are the main reasons that the extraction-to-SDL (E/SDL) is 4%.

The productive base shows signs of stress, with long-term and short-term water level declines observed across the resource unit (Table 1; Figure 9; Figure 10). Statistically significant (α=0.05) declines have occurred since 1974 in approximately 58% of the bores with sufficient data (Table 1), and rates of decline commonly exceeded 0.2 m/year (Figure 9). In contrast, short-term trends (Figure 10 include fewer bores and a smaller proportion of those bores having declining trends (49% of bores with sufficient data; Table 1), and fewer bores exceeding -0.2 m/year (Figure 10). However, some of these declines represent deliberate lowering of the water table to prevent saline discharge into the River Murray. Therefore, declining levels are only representative of a deteriorating resource condition in GS9b where they occur in areas of agricultural or urban use. Management practices to protect the productive base in the MGL include capping allocation volumes and enforcing management levels for the Border Agreement. The short-term period (2012–2024) is characterised by mainly below-average rainfall, and followed the extended dry period of the Millenium Drought, resulting in a cumulative drying up to 2021 (Figure 3). These conditions have caused a soil moisture deficit that potentially still affects diffuse groundwater recharge, even despite the uptick in rainfall since 2022 (Figure 2). Crosbie et al. (2023) defined the connectivity of most of the GS9b river reaches as "some losing" and "mostly losing", indicating that there is not significant areas of groundwater baseflow to rivers. However, there were reaches of the River Murray near Swan Hill and its tributaries further south (Avoca and Mt William Rivers) that were classified as "mostly not losing", indicating baseflow occurs locally and saline baseflow can impact the river systems. Groundwater-dependent ecosystems (GDEs) in the Wimmera–Mallee region occur where the Parilla Sands aquifer has a shallow water table. These ecosystems are generally saline and include semi-permanent wetlands and deep floodplain pools along the Wimmera River, which receive saline groundwater during dry periods. Certain terrestrial vegetation communities also rely on shallow, often saline groundwater, especially in areas with elevated salinity.

Stage 4 of this BPR technical groundwater review provided a quantitative assessment of resource condition indicators within a 5 km buffer around extraction points (asset area). Long-term groundwater level declines were observed in 37% of the productive base asset area, 55% of the river connectivity asset area, and 42% of the GDE asset area (Table 2). In the short-term, these percentages decreased significantly to 7%, 8%, and 6%, respectively (Table 2). Minimal change is observed in the areas showing improving water level conditions between the long-term and the short-term (Table 2). This means that an increase in uncertainty, as indicated by areas with insufficient data to inform temporal trends, accommodated the reduction in deteriorating areas from long-term to short-term (Figure 11), with uncertain zones increasing from 53% to 83% for the productive base (Table 2). A similar pattern is observed in the water quality (salinity) ESLT, where recent data gaps have increased from 82% in the long-term to 100% of the short-term asset area classified as having 'insufficient data' to determine temporal trends.

[1] S/R ratio: High responsiveness: 29 to 111.
Medium responsiveness: 11 to 333.
Low responsiveness: >333.

The Victorian state-based risk assessment (DELWP, 2019b) assigns varying risk ratings across ESLT values in GS9b. The state-based risk assessment classifies the inherent risk to the productive base as high and very high for the risk of climate change leading to a decline in groundwater availability for consumptive users or Aboriginal uses of water. The risk of increased take, land use, or extreme events leading to a decline in groundwater for Aboriginal uses of water was medium. Risks to water quality are assessed as very high as there is the potential for saline groundwater mixing and reduced freshwater influx. Independent future climate projections indicate a potential increase in diffuse recharge (Crosbie et al., 2025), which may improve availability, but is unlikely to dilute salinity. The risk of climate change or land use and interception leading to elevated levels of salinity which result in adverse impacts on consumptive users and Aboriginal uses of water was assessed by the state as very high (DELWP, 2019b). The medium risks to water quality are land use change or extreme events which affect water condition and have adverse impacts on consumptive users or Aboriginal uses of water. GDEs in the GS9b area are reliant on brackish groundwater and the risk to them from climate change is assessed as high (DELWP, 2019b). Although river connectivity is not formally assessed outside of the GDE context, it likely carries risks similar to other ESLT values based on observed trends. Despite moderate density of monitoring along the River Murray, data gaps remain in the sedimentary plain of the Wimmera-Mallee.

Future projections from the MD-SY2 project indicate that diffuse recharge to GS9b may slightly increase by 2050 due to more intense rainfall events (Crosbie et al., 2025; there are no overbank flood or in-stream recharge forecasts for GS9b from that study). Groundwater-surface water connectivity is complex, and varies spatially and temporally. Given the uncertainty of future climate changes to rainfall and recharge, it is not clear what impact this could have on connection. Climate change is expected by the state (DELWP, 2019b) to alter rainfall, groundwater recharge, and runoff, further affecting surface water connectivity and limiting inflows to rivers, terminal lakes, and wetlands in the Wimmera-Mallee. There are both fresh (generally non-groundwater-dependent) and saline (generally groundwater-dependent) wetlands and lakes in GS9b. Stage 6 of this BPR technical groundwater review found that the future area of drawdown (Area of Influence, AoI[2]) is projected to expand under climate change scenarios, as the median future AoI (P50) exceeds the present AoI, indicating likely increases in deteriorating areas (Figure 12). The Stage 6 assessment classified the pressure from future climate change on GS9b groundwater resources as low, based on both long- and short-term water level evidence, the moderate forecast for recharge change, and the low E/SDL ratio (Table 1).

Overall, short-term groundwater trends (2012–2024) show a smaller proportion of total bores that display declining groundwater levels than in the long-term (1974–2024), and a slight improvement in the magnitude of declining trends (Table 1), indicating a moderate shift towards a more stable resource condition. However, the resource is extremely limited by high salinity groundwater presence and limited buffering capacity, resulting in E/SDL being just 4%. The SDL of 190.10 GL/year for GS9b applies to a multi-layered aquifer system with diverse flow controls. Although recharge is estimated to be between 59.31 GL/year and 439.17 GL/year, the MGL aquifer of GS9b is disconnected from modern recharge. The state-based risk assessment highlights very high to high risks to groundwater availability and salinity from climate change and land use change. Climate projections forecast a modest increase in diffuse recharge, but this is not relevant to the confined MGL, and sensitivity to this is assessed as low in this review. Collectively, the analysis suggests there is moderate pressure on the productive base of GS9b, with long-term sensitivity to groundwater salinisation, including potential risks to GDEs that rely on brackish water, in a setting where surface water resources are scarce.

[2] Area of influence is defined as the area impacted by drawdown caused by groundwater extraction. For the quantitative assessment of Stage 4, this is equivalent to the percentage asset area showing a deteriorating resource condition, which is a statistically significant declining trend in groundwater level.

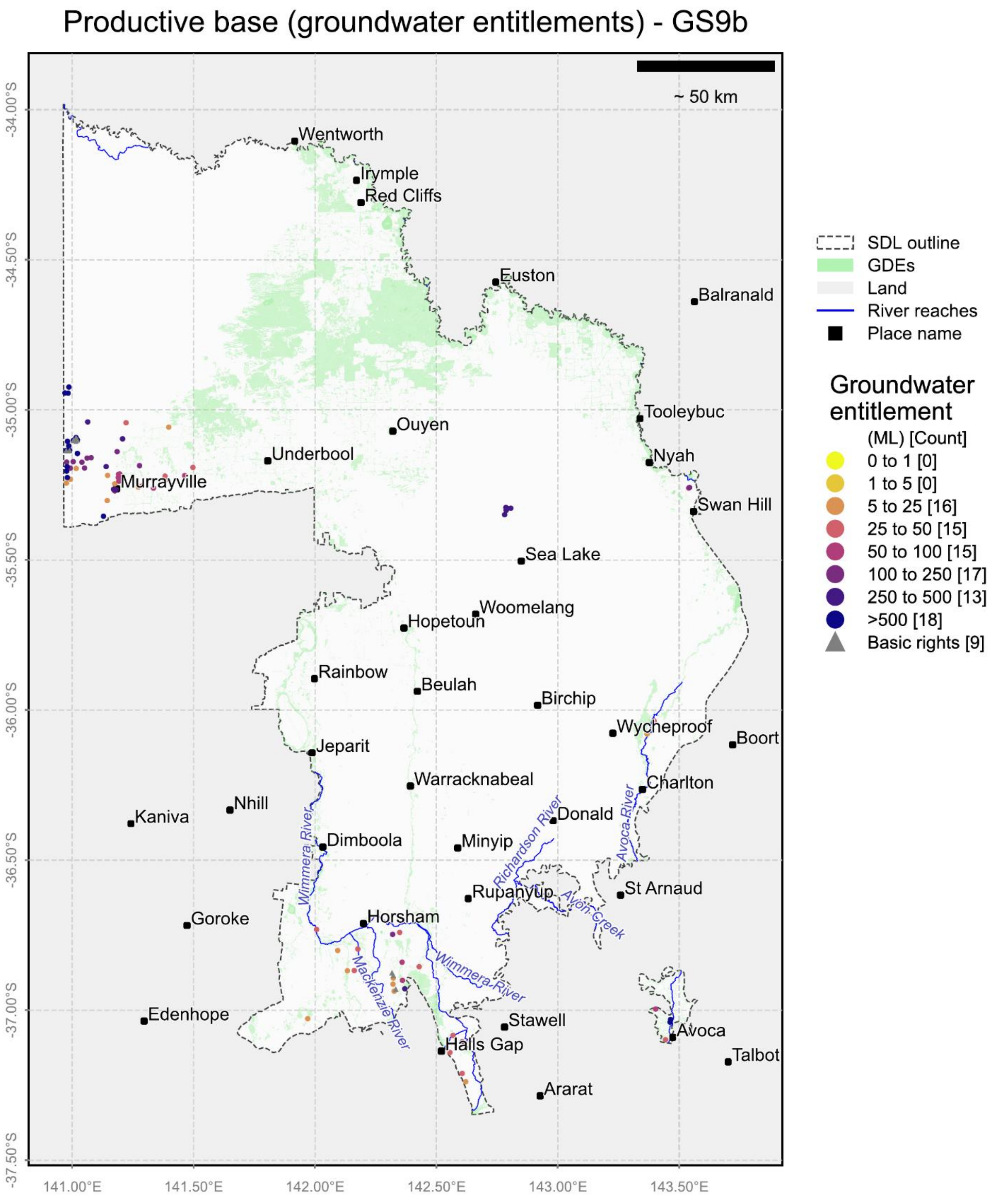


Figure 1 Productive base (groundwater entitlements)

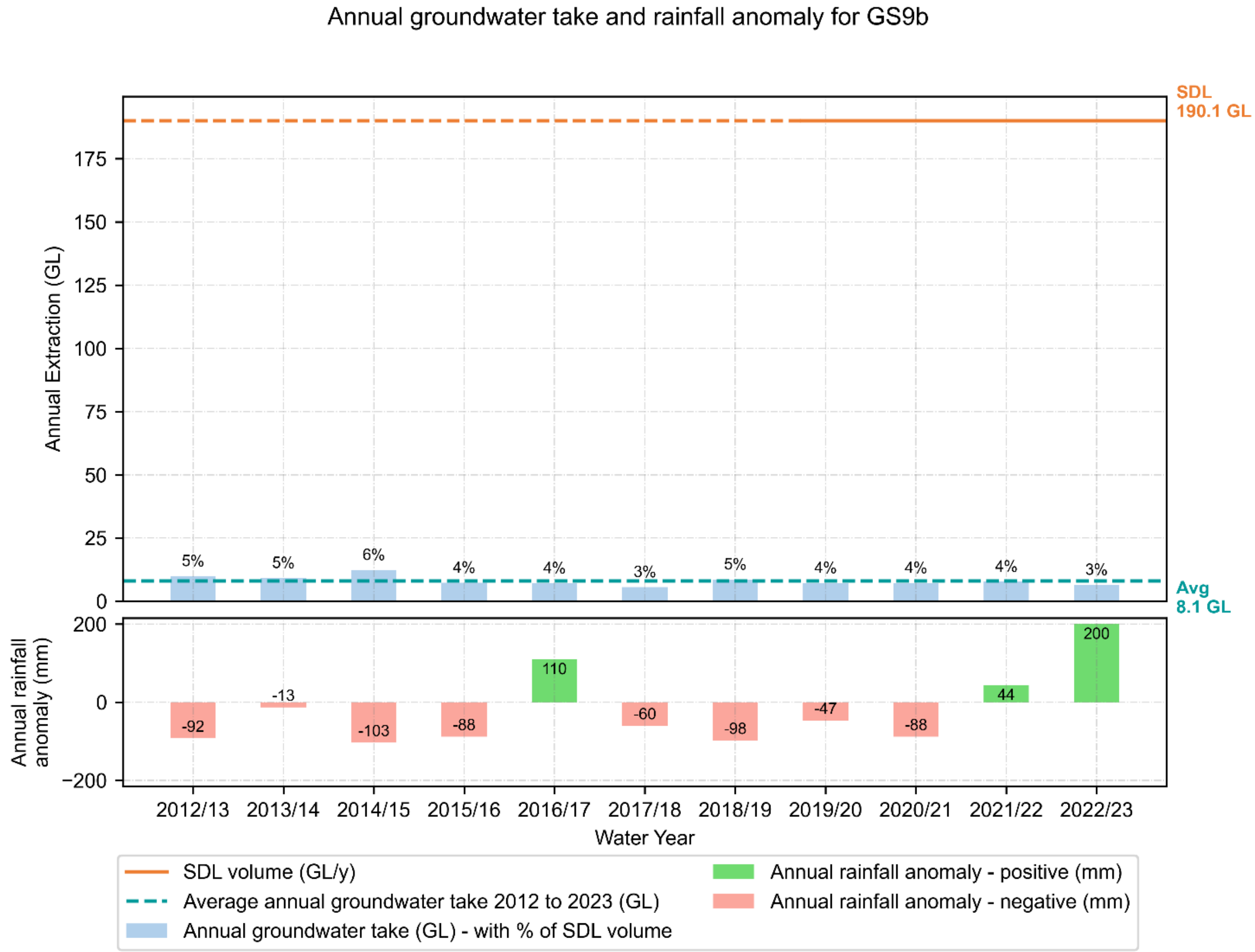


Figure 2 Groundwater take in the SDL since 2012

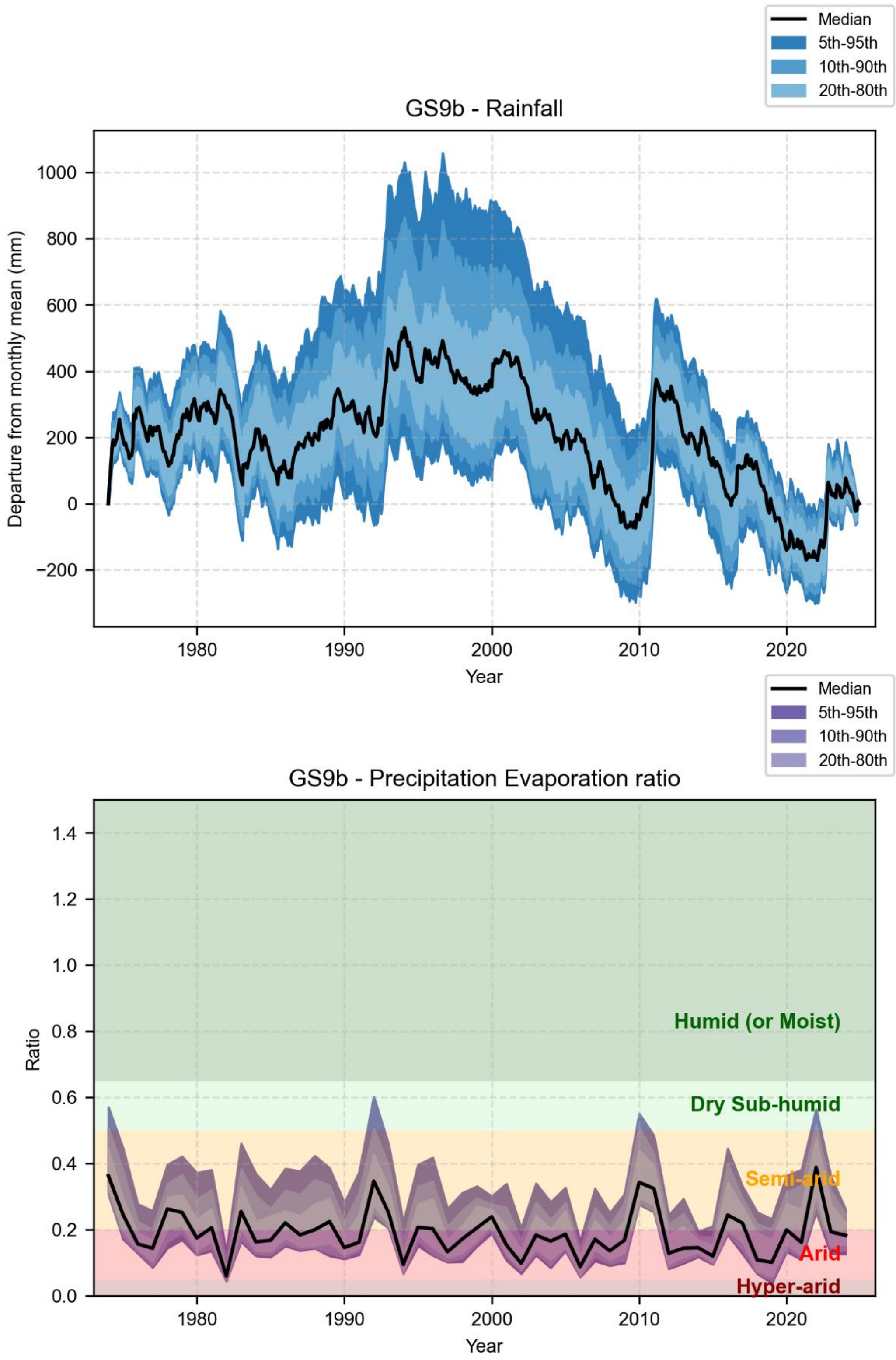
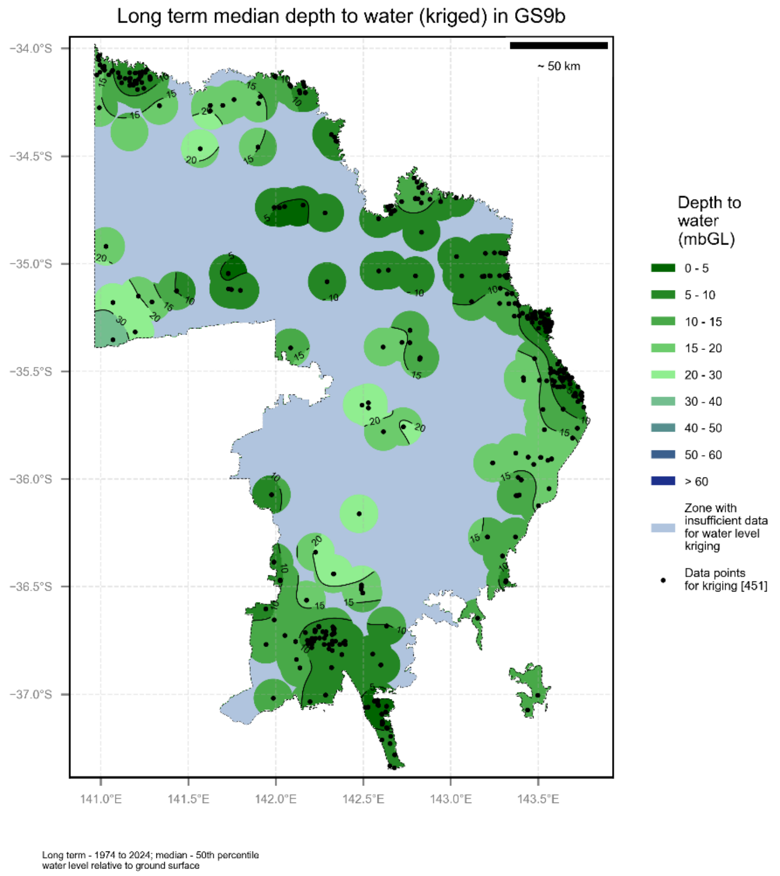


Figure 3 Historical climate trends



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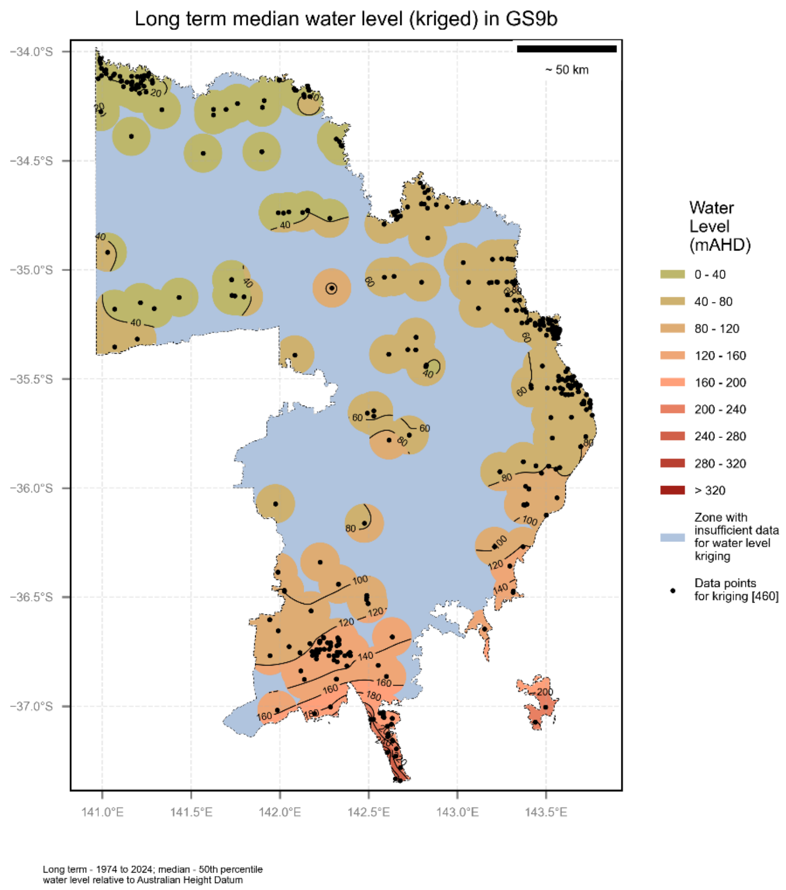

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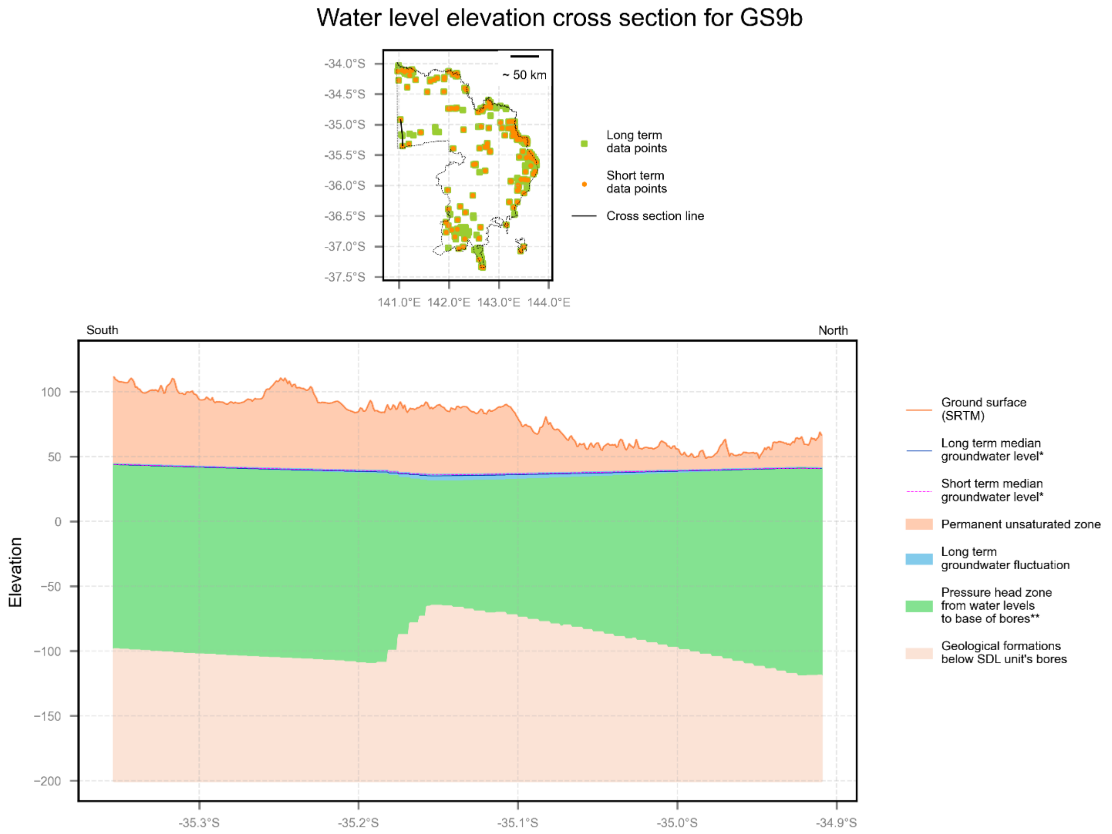
Figure 4 Long-term median (a) depth to water and (b) water level elevation



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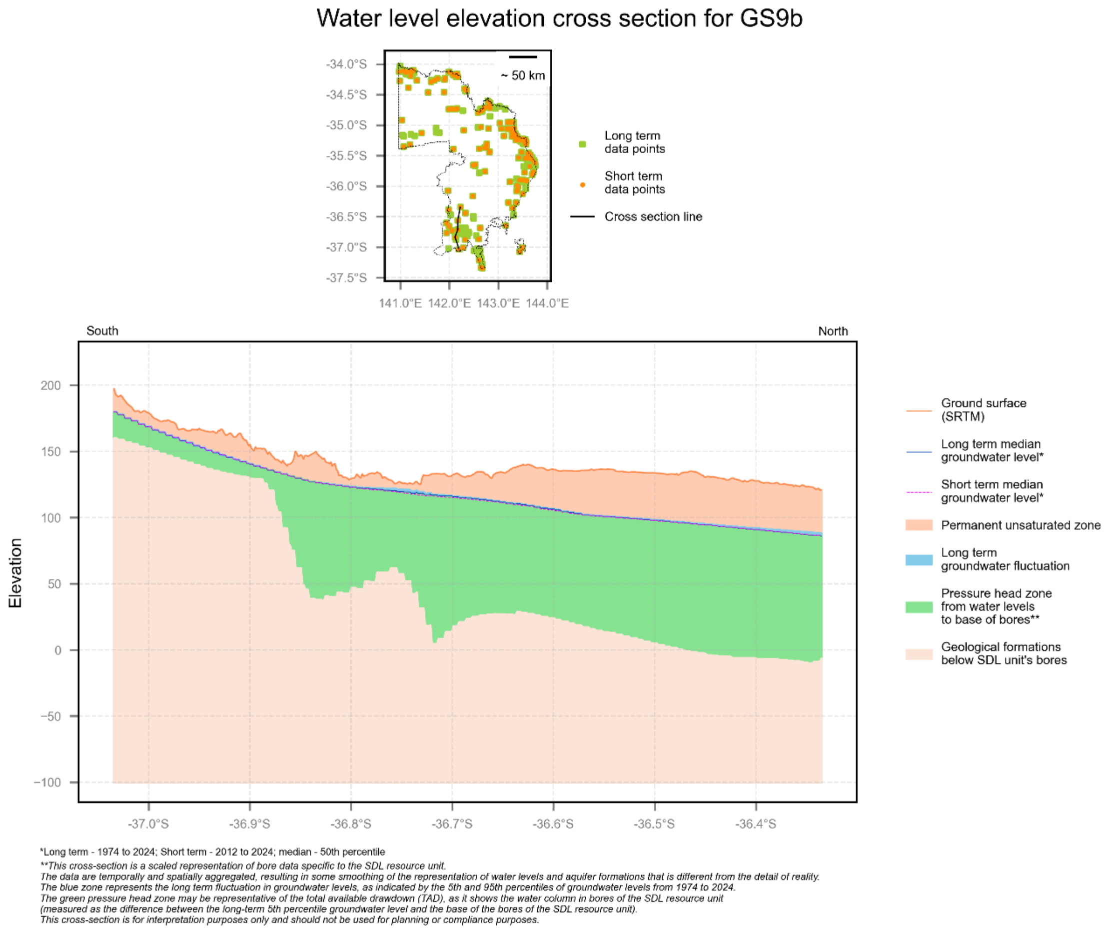


b)

Figure 5 South to north distribution of water levels in the SDL resource unit near a) Murrayville and b) Avoca

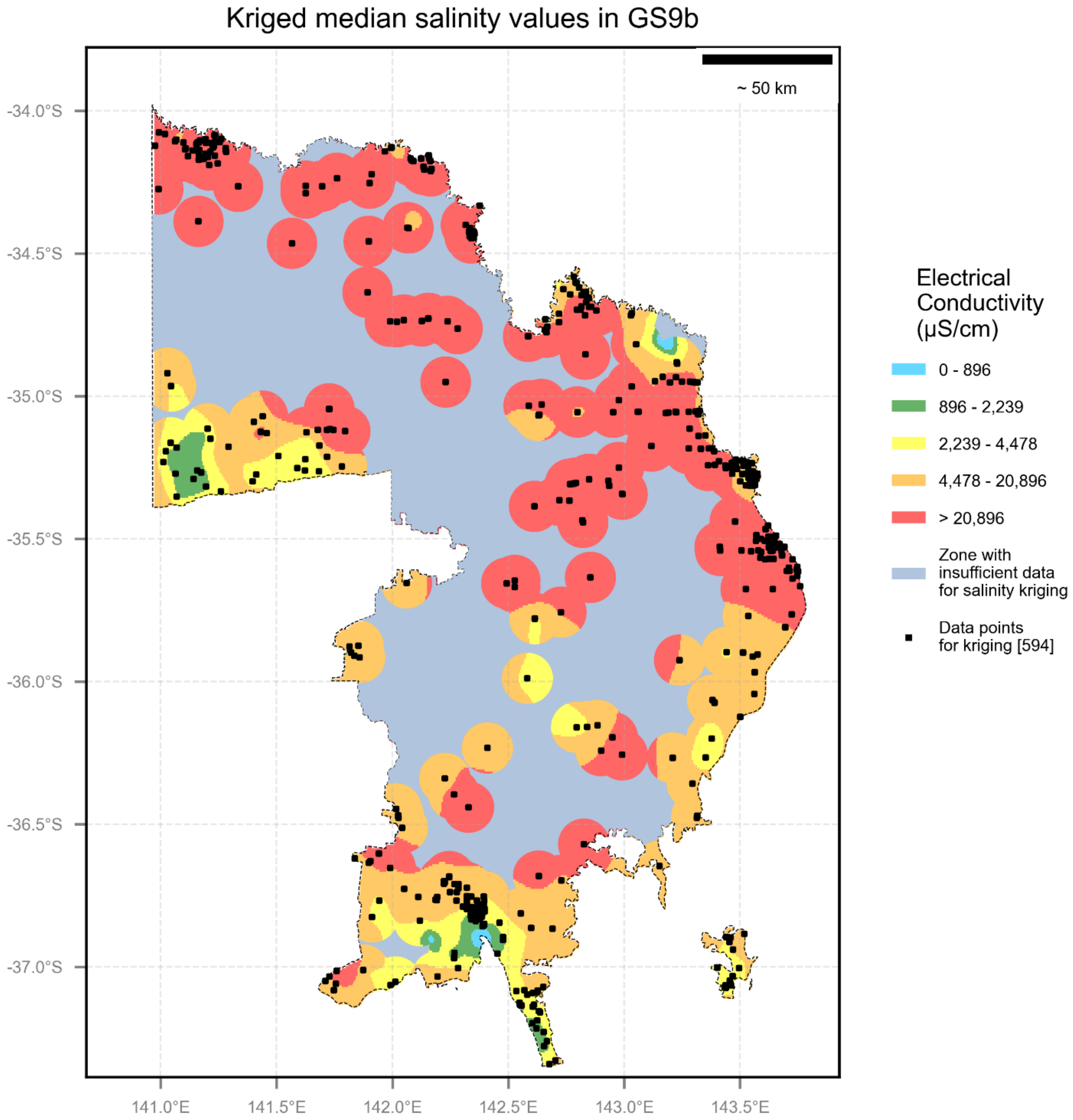


Figure 6 Groundwater salinity distribution

Table 1 Table of groundwater metadata for the SDL resource unit

Parameter	Unit	Long-term (1974 to 2024)	Short-term (2012 to 2024)	SDL resource unit data
SDL volume	GL/y	-	-	190.10
SDL resource unit area	km²	-	-	48,246
Average annual take (2013 to 2023)	GL/y	-	-	8.08
Number of groundwater entitlement bores	-	-	-	103
SDL resource unit storage estimate*	-	-	-	Not available
Recharge estimate (SY1)	GL/y	-	-	995.00
Recharge estimate (Stage 2)	GL/yr	-	-	59.31
Diffuse recharge estimate (SY2 - WAVES)	GL/yr	-	-	439.17
Extraction/SDL (E/SDL) (Stage 2 result)	-	-	-	0.04
SDL/Recharge (SDL/R) (Stage 2 result)	-	-	-	3.21
SDL/Recharge (SDL/R) (SY2 or modelled recharge)	-	-	-	0.43
Storage/Stage 2 Recharge (S/R)	-	-	-	-
Storage/SY2 or modelled Recharge (S/R)	-	-	-	-
Number of bores in the SDL unit	-	18,263	18,263	-
Number of bores for water level trend analysis	-	548	227	-
Number of bores for water level trend with sufficient data	-	474	144	-
Number of bores with decreasing water level trend	-	273	70	-
Number of bores with increasing water level trend	-	73	26	-
Number of bores with no statistically significant water level trend	-	128	48	-
Mean water level trend magnitude	m/y	-0.04	-0.03	-
Minimum water level trend magnitude	m/y	-1.73	-0.51	-
5%ile water level trend magnitude	m/y	-0.2	-0.16	-
10%ile water level trend magnitude	m/y	-0.15	-0.14	-
50%ile water level trend magnitude	m/y	-0.03	-0.03	-
90%ile water level trend magnitude	m/y	0.03	0.04	-
95%ile water level trend magnitude	m/y	0.1	0.09	-
Maximum water level trend magnitude	m/y	1.61	1	-
Number of bores for salinity trend analysis	-	623	106	-
Number of bores for salinity trend with sufficient data	-	242	65	-
Number of bores with decreasing salinity trend	-	26	3	-
Number of bores with increasing salinity trend	-	72	0	-
Number of bores with no statistically significant salinity trend	-	144	62	-
Mean salinity trend magnitude	µS/cm/y	270	-704	-
Minimum salinity trend magnitude	µS/cm/y	-2,356	-6,371	-
5%ile salinity trend magnitude	µS/cm/y	-500	-3,225	-
10%ile salinity trend magnitude	µS/cm/y	-294	-2,638	-
50%ile salinity trend magnitude	µS/cm/y	105	-533	-
90%ile salinity trend magnitude	µS/cm/y	1,036	606	-
95%ile salinity trend magnitude	µS/cm/y	1,656	963	-
Maximum salinity trend magnitude	µS/cm/y	6,760	5,144	-

Table 2 Table of results from spatial analysis of RCI trends in ESLT asset areas

ESLT Value	Asset area (m2)	Long-term				Short term			
		Proportion of asset area with improving/ stable RCI trends	Proportion of asset area with deteriorating RCI trends	Proportion of asset area with uncertain RCI trends	Trend grouping	Proportion of asset area with improving/ stable RCI trends	Proportion of asset area with deteriorating RCI trends	Proportion of asset area with uncertain RCI trends	Trend grouping
Productive base	3,003,540,581	10%	37%	53%	Insufficient data	10%	7%	83%	Insufficient data
GDEs	1,932,978,443	5%	42%	53%	Insufficient data	7%	6%	87%	Insufficient data
River connectivity	1,874,653,770	6%	55%	40%	Deteriorating trends	10%	8%	82%	Insufficient data
Water quality	2,574,546,035	13%	4%	82%	Insufficient data	0%	0%	100%	Insufficient data

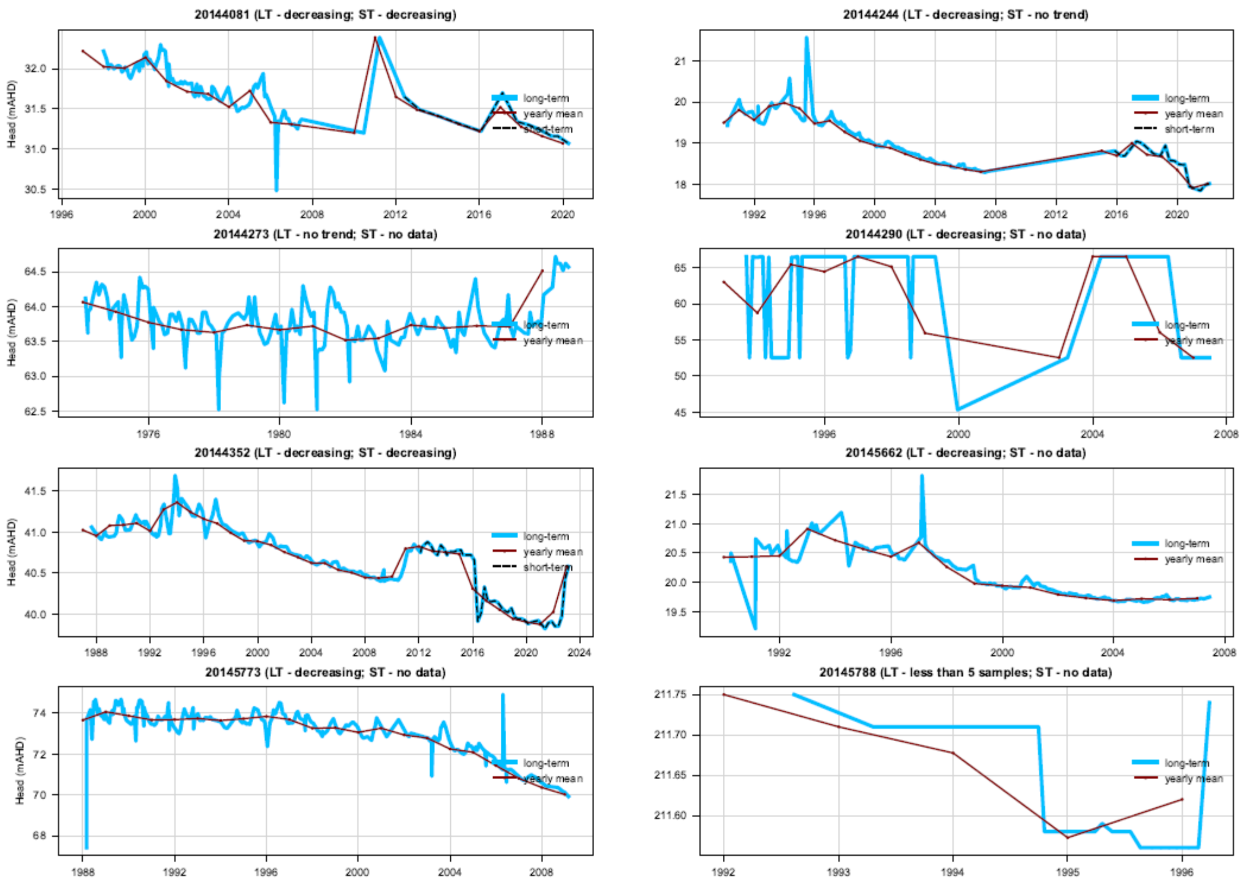


Figure 7 Representative groundwater hydrographs for the SDL resource unit

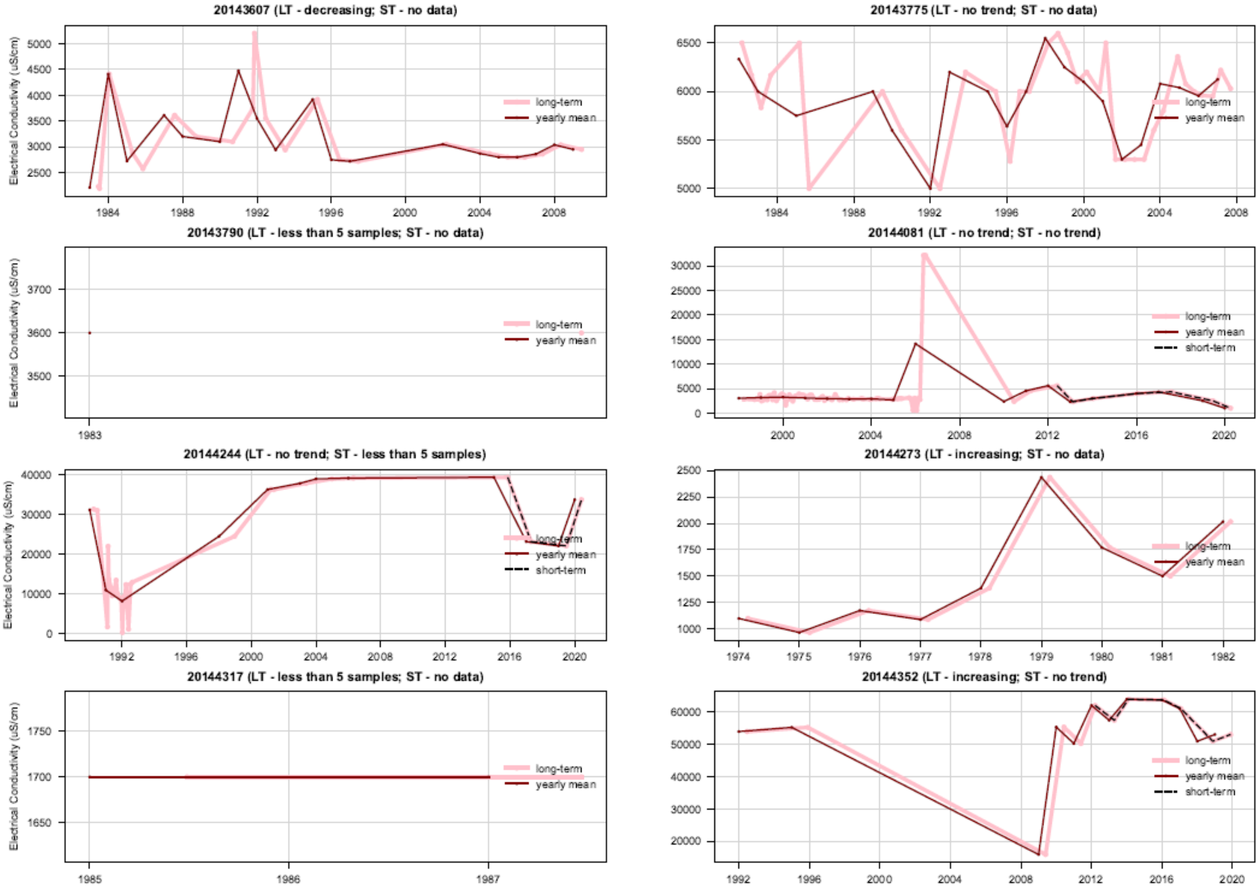


Figure 8 Representative groundwater salinity time series for the SDL resource unit

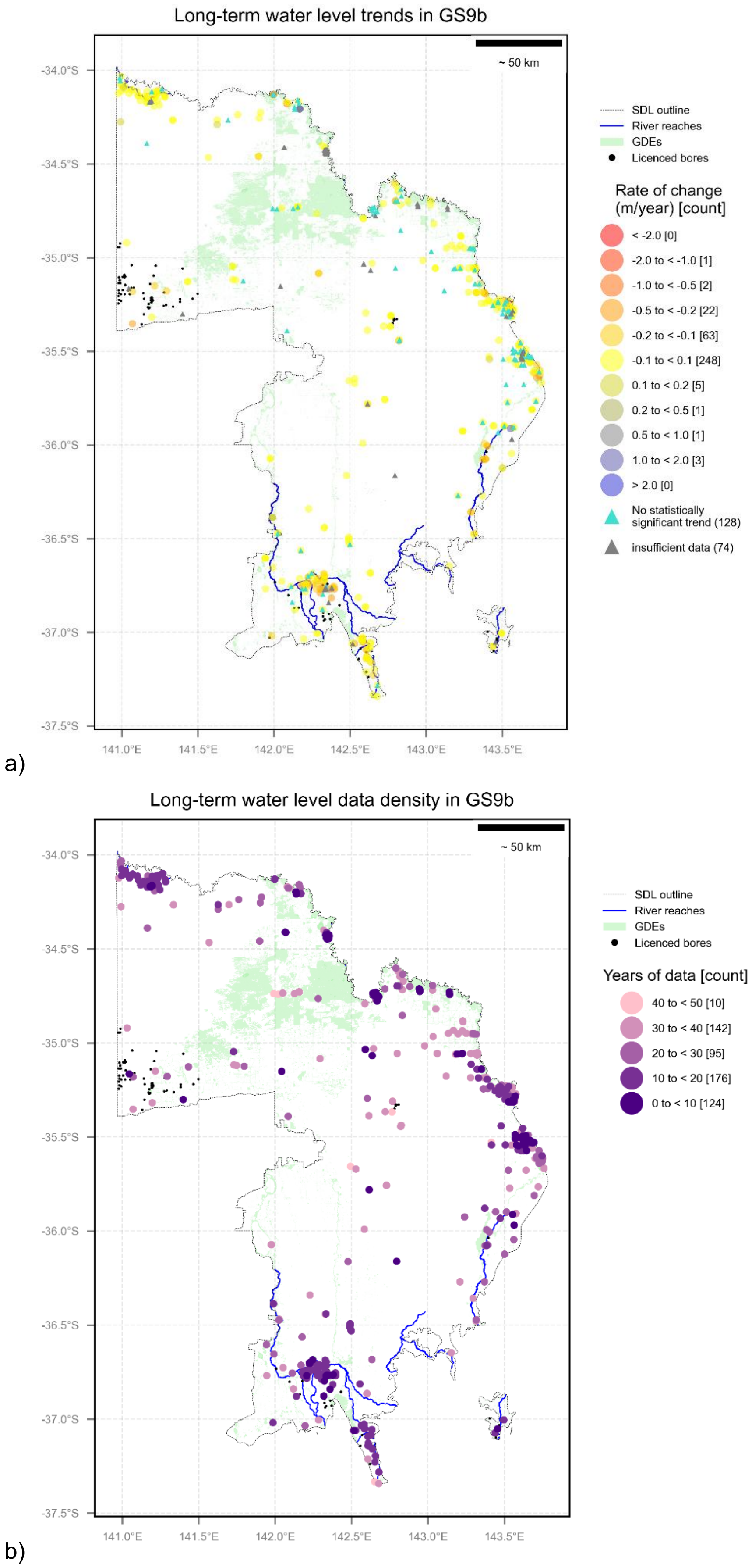
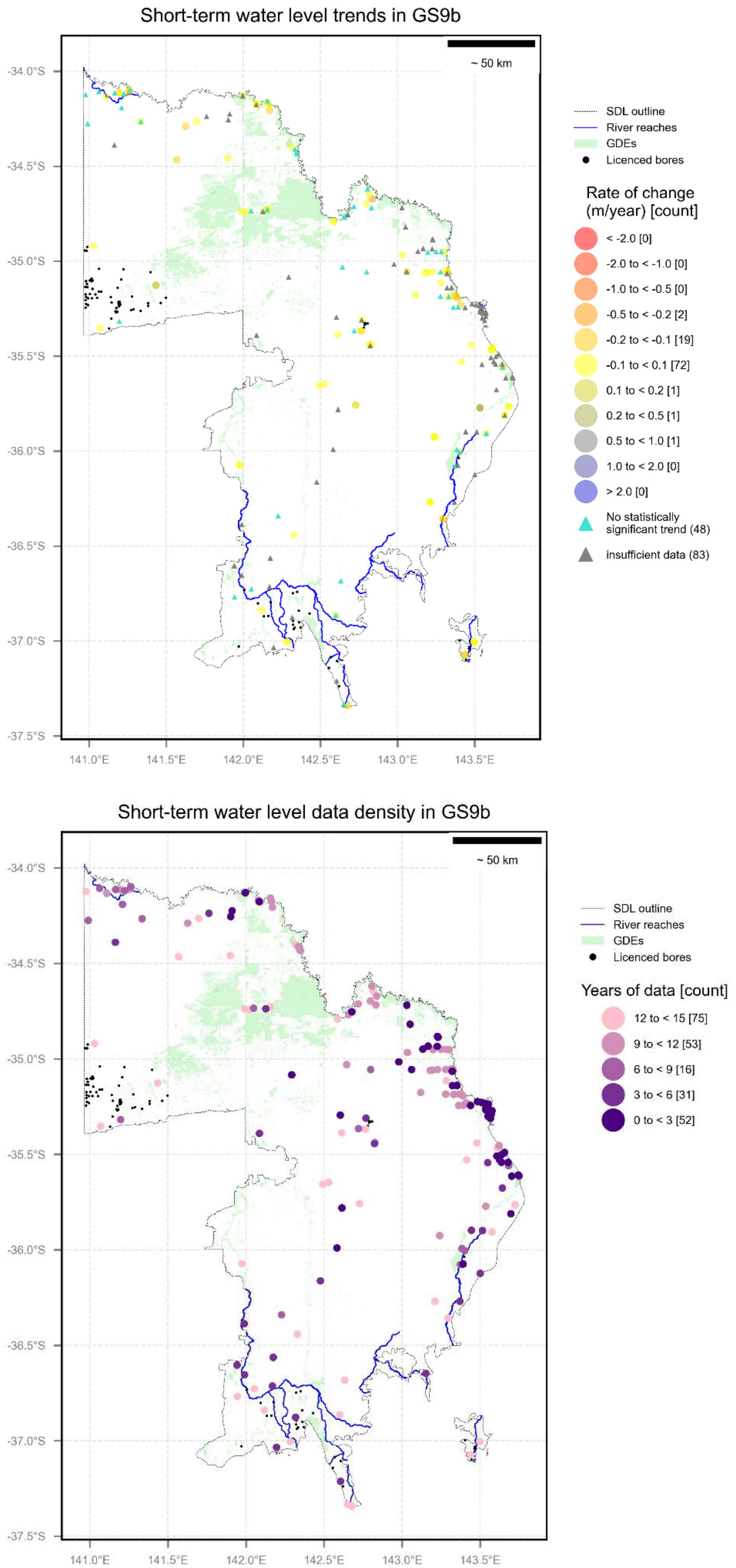


Figure 9 Long-term (1974 to 2024) groundwater level trends (a) and data availability (b)



a)

b)

Figure 10 Short-term (2012 to 2024) groundwater level trends (a) and data availability (b)

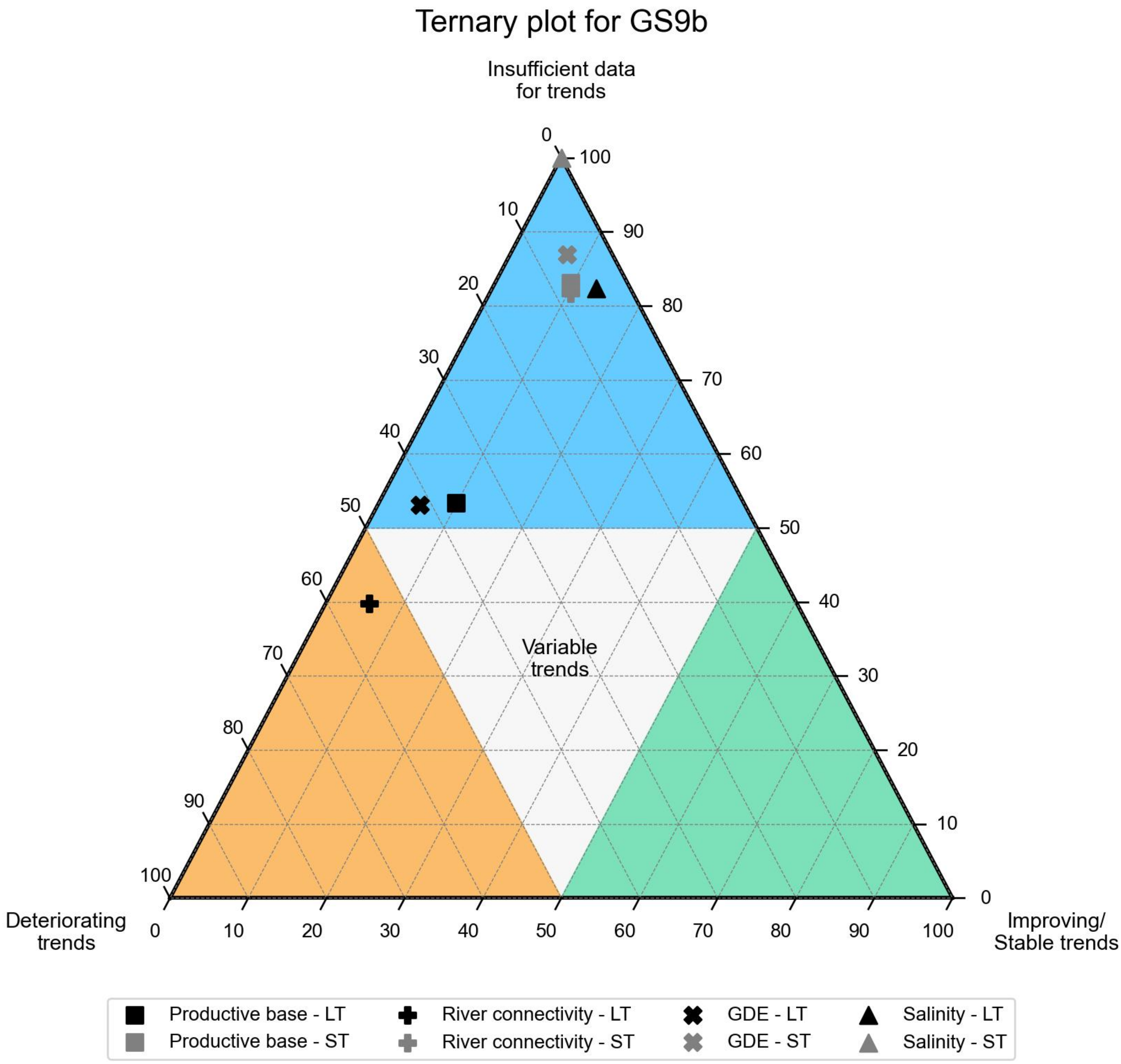
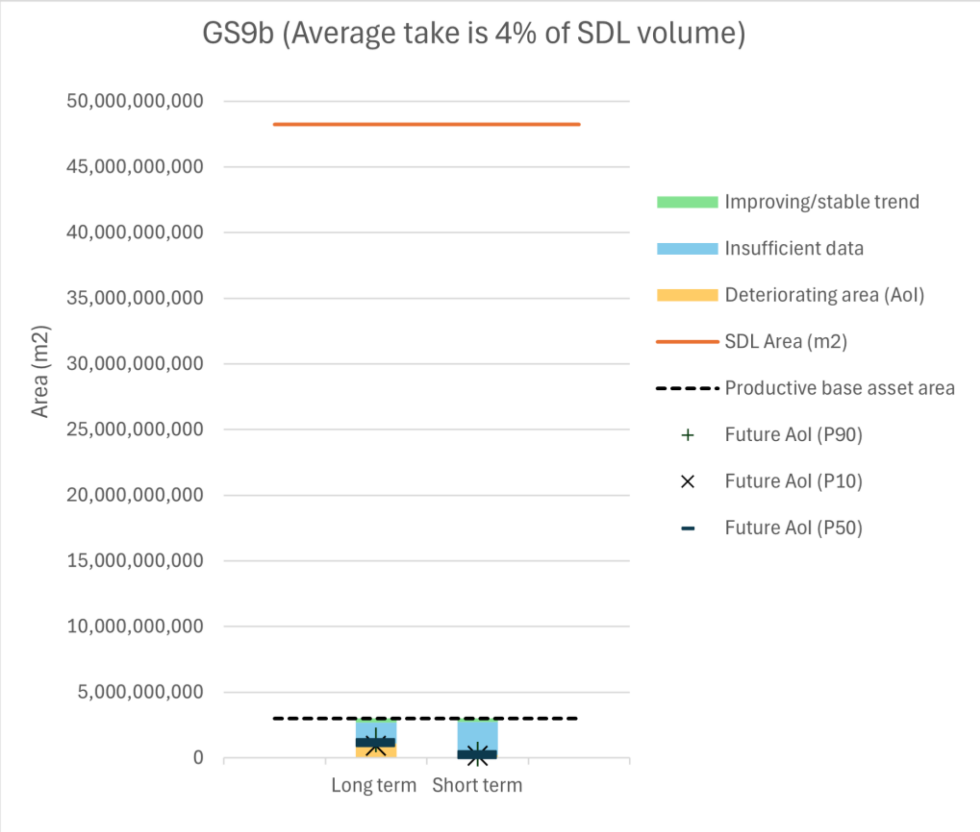


Figure 11 Stage 4 assessment outcome: trends in resource condition indicators for ESLT values



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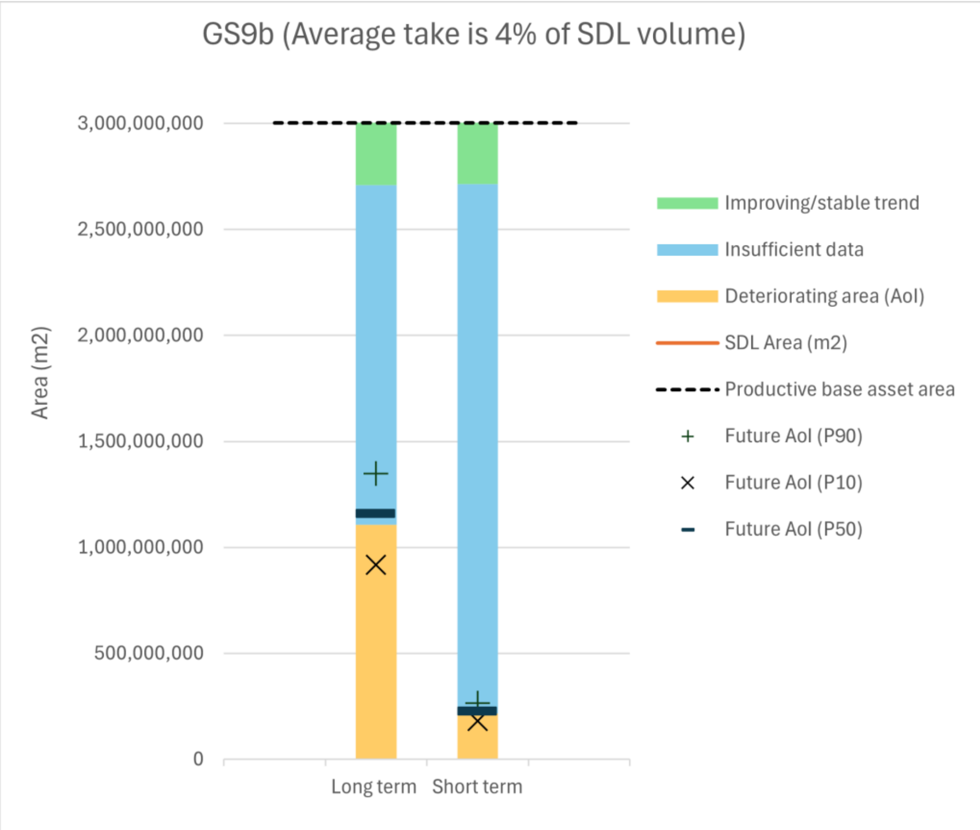

b)

Figure 12 Estimates for change in area of influence (AoI) due to climate change (a) including, and (b) excluding the scale of the SDL area

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