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Report on

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GS8c – Goulburn Murray Sedimentary Plain

Stage 5 – Assessment through multiple lines of evidence

The Goulburn Murray Sedimentary Plain (GS8c) is located in northern Victoria, within the catchment of the River Murray, encompassing several tributaries, including the Loddon, Campaspe, Goulburn, Broken, Ovens, and Kiewa Rivers (Figure 1). The system consists of unconfined to semi-confined sedimentary aquifers, primarily associated with the Calivil Formation and Renmark Group, which form productive deep leads beneath alluvial and loamy plains, but also includes the Shepparton Formation where it is not encompassed by the overlying GS8a SDL resource unit. From a management perspective, GS8c comprises all groundwater contained within these units, except GS8a groundwater, which is limited to a depth of 25 m in the Shepparton Irrigation Area (MDBA, 2020). Groundwater extraction is focussed in zones of usable water quality, which is generally along the river alignments, and between Broken Creek and the River Murray (Katunga / Nathalia; Figure 1). The resource is shared with NSW, as the formations are continuous below the River Murray. GS8c spans approximately 21,863 km², and has a Sustainable Diversion Limit (SDL) of 223.00 GL/year, and a long-term average recharge of 450.20 GL/year (Table 1). Between 2013 and 2023, average annual groundwater extraction in GS8c was 112.83 GL/year, representing 51% of the SDL, and 25% of recharge (Figure 2). Groundwater use supports irrigated agriculture, particularly in the Katunga, Campaspe, and Loddon Water Supply Protection Areas, and supplements surface water supply during years of below-average rainfall (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 of the median (long-term) water table varies broadly across the SDL, but is shallow (within 10 m of the surface) for most of the unit, and the deeper zones are associated with the Loddon and Broken catchments (Figure 4a). Groundwater flows from south to north and from southeast to northwest (Figure 4b; Figure 5). Long-term (1974–2024) and short-term (2012–2024) median groundwater levels show spatial agreement and are contained within a well-defined fluctuation zone that ranges from a few meters to more than 10 m (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. Throughout the Goulbourn and Broken catchments of GS8c (part of which is located beneath GS8a), the short-term median groundwater levels can be lower than the long-term median water levels, and are close to the base of the 1974–2024 fluctuation zone, particularly where the fluctuation zone sits closer to the ground surface (Figure 5). Effectively this observation represents active management to reduce groundwater levels that rose too close to the ground surface in decades prior to the 1970s, mobilising salts in the unsaturated zone. Groundwater salinity in the Goulburn-Murray region varies significantly, with low-salinity water in upland areas and in Katunga, and increasing salinity in the plains of the west and north, particularly in shallow aquifers affected by evaporation (Figure 6). 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) (Figure 6). While salinity patterns are mostly natural, they highlight that GS8c is dependent on high seasonal rainfall for good groundwater availability and quality (DELWP, 2019a). Monitoring of water level trends was detailed and widespread in the long-term period due to investigation of salinity issues that developed from land use practices prior to the 1970s. Observations show a mixture of stable and declining trends, with multi-decadal variability, and many sites responding to active mitigation measures to reduce groundwater levels (Figure 7; Figure 9; Figure 10). The understanding of temporal salinity trends is relatively strong in GS8c due to historical water quality issues (Figure 8).

MDBA (2020) previously reported recharge for GS8c as 450.20 GL/year, which incorporates diffuse, irrigation, floodplain, and in-stream recharge derived from a calibrated groundwater model. In addition, a recent estimate of the MD-SY2 project using WAVES modelling of diffuse recharge only was 193.08 GL/year (Crosbie et al., 2025). Table 1 shows a storage-to-recharge ratio (S/R) of 2,058 using the groundwater model estimate of recharge and the WERP estimate of storage (Rojas et al., 2022), suggesting high buffering capacity and limited vulnerability to short-term climate variability (above the “low responsiveness” threshold¹ defined in Rojas et al., 2022). With an SDL-to-recharge ratio of 50% and extraction-to-SDL of 51%, current use seems moderate in relation to the available recharge. These characteristics indicate that a reasonable buffer exists to accommodate seasonal and spatial variations in use and recharge.

The productive base shows significant drawdown, with long-term water level declines affecting the Loddon, Campaspe, Goulburn, Broken, and Ovens branches of the resource unit (Table 1; Figure 9; Figure 10). However, as discussed above, some of these declines represent deliberate lowering of the water table after unwanted historic increases, especially in the lower lying plains. Therefore, declining levels are not completely representative of a deteriorating resource condition in GS8c. Management practices include resource condition limits prescribed in each region’s management plan, and enforcement of restrictions on licenced take when conditions approach the limits or exceed a trigger. Statistically significant ($\alpha=0.05$) declines have occurred since 1974 in approximately 69% of the bores with data. In contrast, short-term trends (Figure 10) include far fewer bores and show a less extensive area with declining trends (60% of bores). However, there is a higher proportion of bores in the short-term period with a greater magnitude in declining rates; for example, in the group of bores showing a rate of decline between 0.2 m/year to 0.5 m/year, there are 85 bores in the short-term period (25% of available data; Figure 10), and 187 bores in the long-term period (14% of available data; Figure 9). The short-term period (2012–2024) is characterised by above-average rainfall post-2020 (Figure 3) and a substantial reduction in annual take post-2020 (Figure 2). Crosbie et al. (2023) define the connectivity of the GS8c as variable-connected because both gaining and losing rivers are mapped in GS8c. As a result, threats from reduced river fluxes could also impact groundwater resources of GS8c. The Ovens River is a gaining stream and has both: a) historical impacts to the water table from surface water extraction; and b) stream depletion through pumping of groundwater close to the river (DELWP, 2019a).

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 43% of the productive base asset area, 37% of the river connectivity asset area, and 43% of the GDE asset area (Table 2). In the short-term, these percentages decreased to 27%, 25%, and 26%, 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 38% to 54% for the productive base (Table 2). A similar pattern is observed in the water quality (salinity) ESLT, where recent data gaps have increased from 60% in the long-term to 96% of the short-term asset area classified as having ‘insufficient data’ to determine temporal trends.

The Victorian state-based risk assessment (DELWP) (2019b) assigns varying risk ratings across ESLT values in GS8c. The state-based risk assessment classifies the inherent risk to the productive base as medium, with climate change potentially causing a decline in inflow to, or increase in extraction from, the aquifers. Risks to water quality are assessed as very high as there is the potential for saline groundwater migration into fresher zones due to irrigation or changes in hydraulic gradients. Impacts from climate change could also change the evaporation rate and increase salinity (DELWP, 2019b). Increased salinity is the predominant threat, linked to both extreme wet periods (rising saline water table) and extreme dry periods (increased evaporative concentration causing saline pools in river systems). GDEs in the GS8c area are primarily concentrated along major river channels (DELWP, 2019a). GDEs are classified as low risk overall, with only a few river reaches at moderate to high risk (not PEAs), and management rules are in place to mitigate risks (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. The mitigation measures in place for GS8c include: salinity management, climate change adaptation, improving rural water supply planning, and long-term environmental watering plans. Data availability is generally suitable for water levels but much more limited for water quality and GDE condition.

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

Future projections from the MD-SY2 project indicate that diffuse recharge to GS8c may slightly increase by 2050 due to more intense rainfall events (Crosbie et al., 2025). In contrast, overbank flood recharge for GS8c is expected to decline by 36.2% compared to current conditions (Crosbie et al., 2025). This could reduce the amount of water reaching GS8c in future. As climate projections indicate warmer and drier conditions for GS8c, accompanied by more intense rainfall events, the net effect may reduce recharge in the long term. These changes could particularly affect shallow aquifers with high evapotranspiration losses, increasing reliance on deeper aquifers, and exacerbating lowland salinity issues. Stage 6 of this BPR technical groundwater review found that the future area of drawdown (Area of Influence, AoI²) 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 GS8c groundwater resources as moderate, based on both long- and short-term water level evidence.

Overall, short-term groundwater trends (2012–2024) show a smaller proportion of GS8c displaying declining groundwater levels than in the long-term (1974–2024), indicating a shift towards a more stable resource condition, transitioning from a period of intense management since salinity issues developed prior to the 1970s. Availability of monitoring data has decreased over time, although knowledge of the resource is extensive. Some zones of this aquifer, particularly in the Loddon, Campaspe, Goulburn, and Ovens alluvial channels, continue to see declines in water levels, despite a positive rainfall anomaly after 2020 and a substantial reduction in groundwater extraction. With a recharge rate of 450.20 GL/year and SDL of 223.00 GL/year, the SDL remains conservative in absolute terms, and take is managed to reasonable levels below the SDL. However, high extraction in concentrated zones and continuing salinity concerns increase the risk to ESLT values in specific subregions. The state-based risk assessment highlights very high risk to groundwater salinity from migration of saline water, which could be magnified through climate change impacts. Climate projections forecast reduced episodic (localised) recharge from floodplain and in-stream processes. Collectively, the analysis suggests moderate pressure on the productive base of GS8c, with moderate pressure from climate change and long-term sensitivity to groundwater salinisation pressure, including potential risks to GDEs.

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.

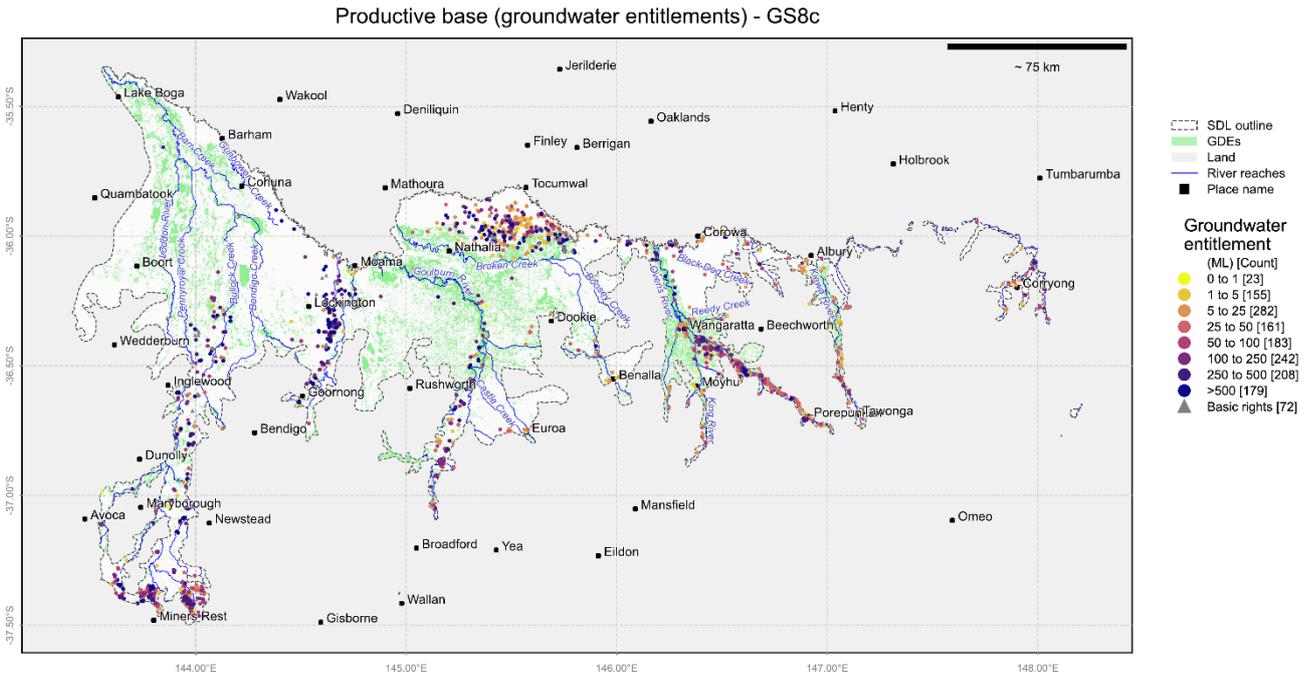


Figure 1 Productive base (groundwater entitlements)

Annual groundwater take and rainfall anomaly for GS8c

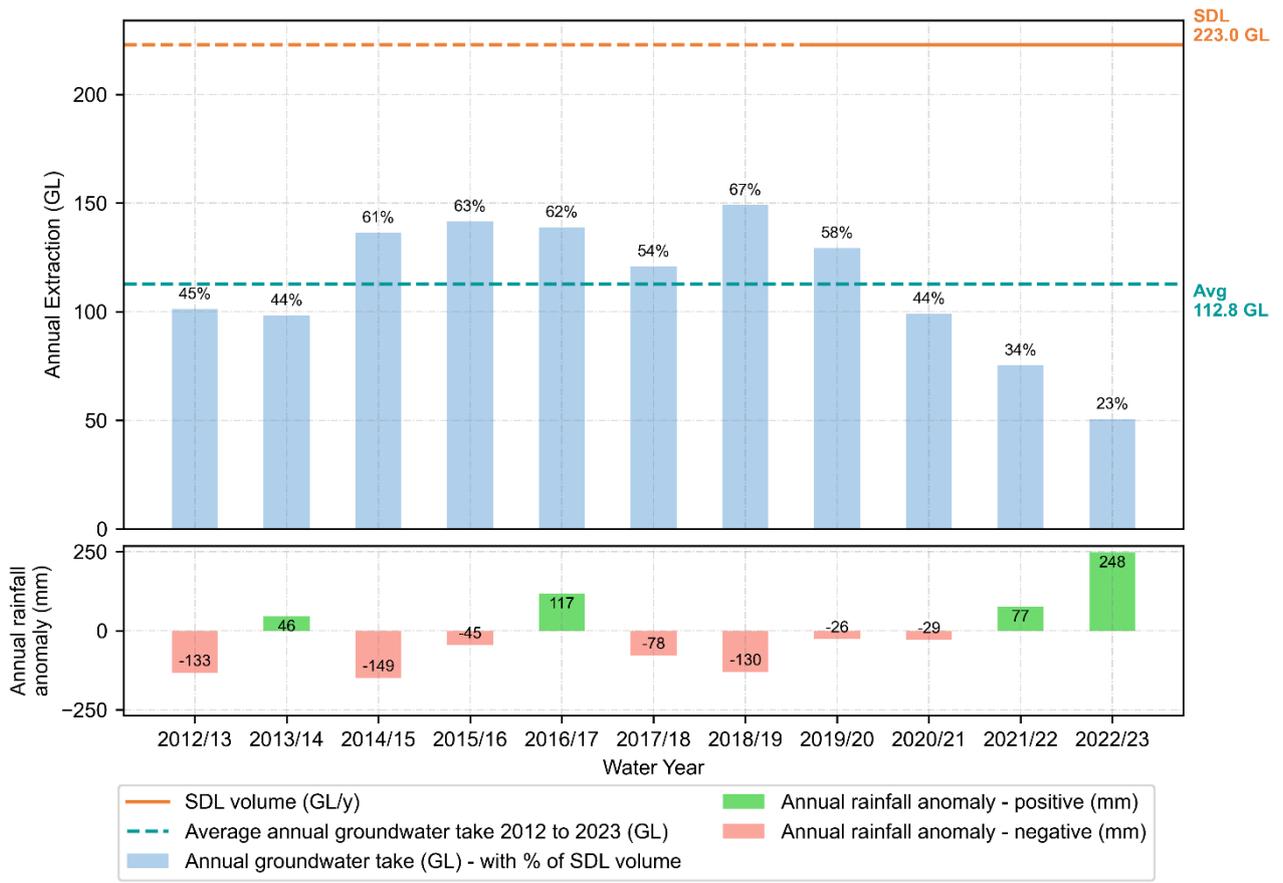


Figure 2 Groundwater take in the SDL since 2012

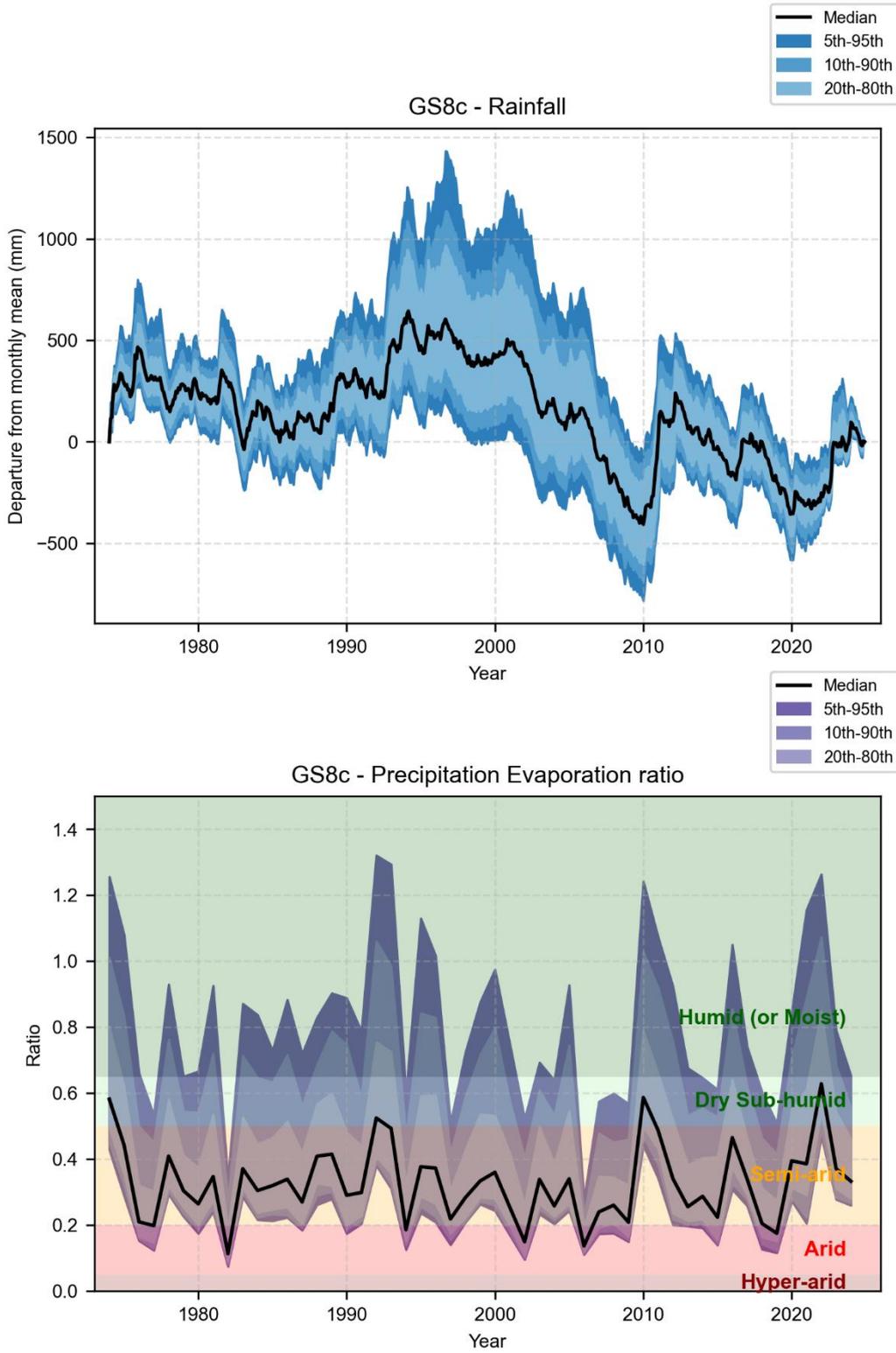


Figure 3 Historical climate trends

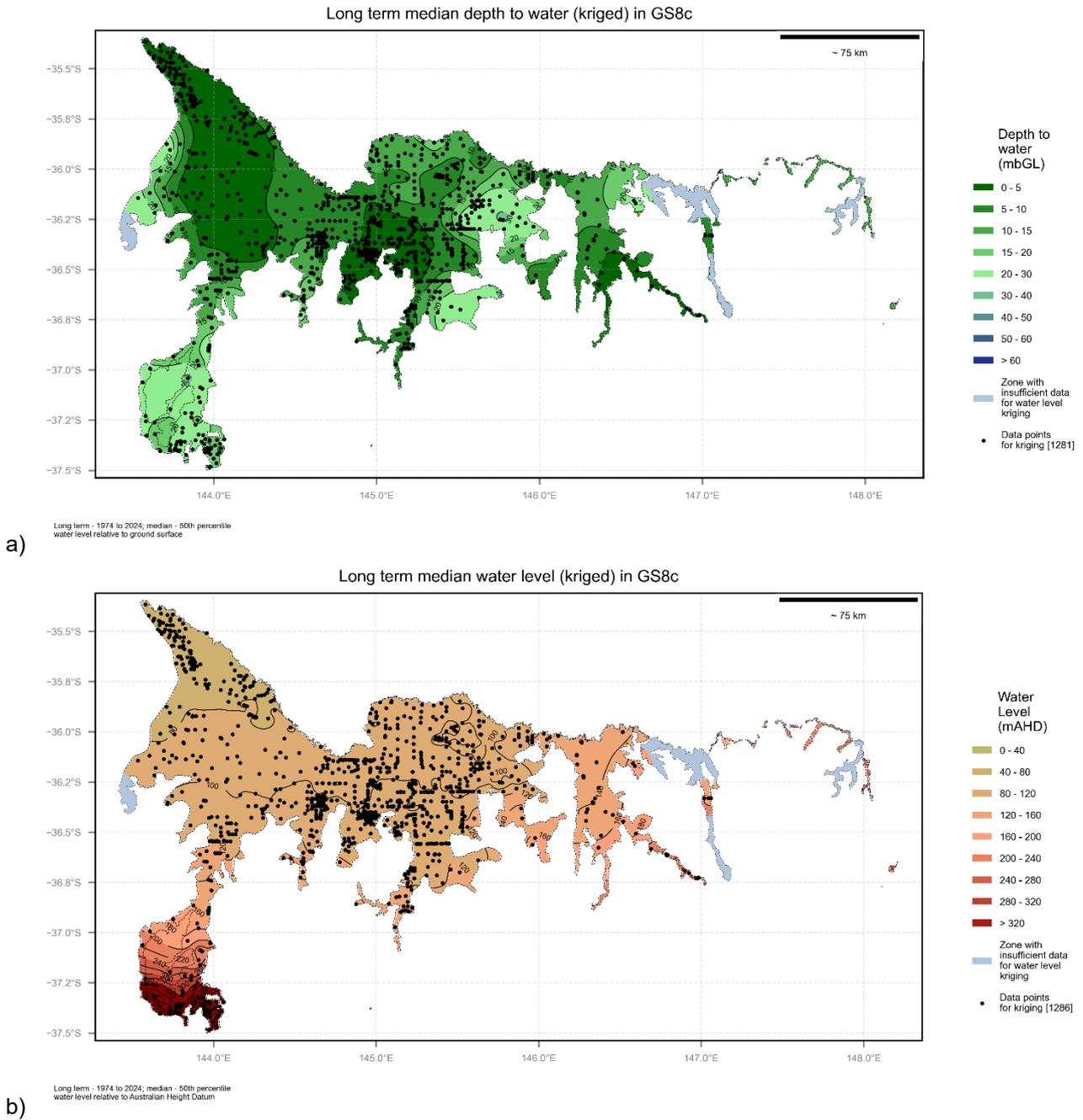
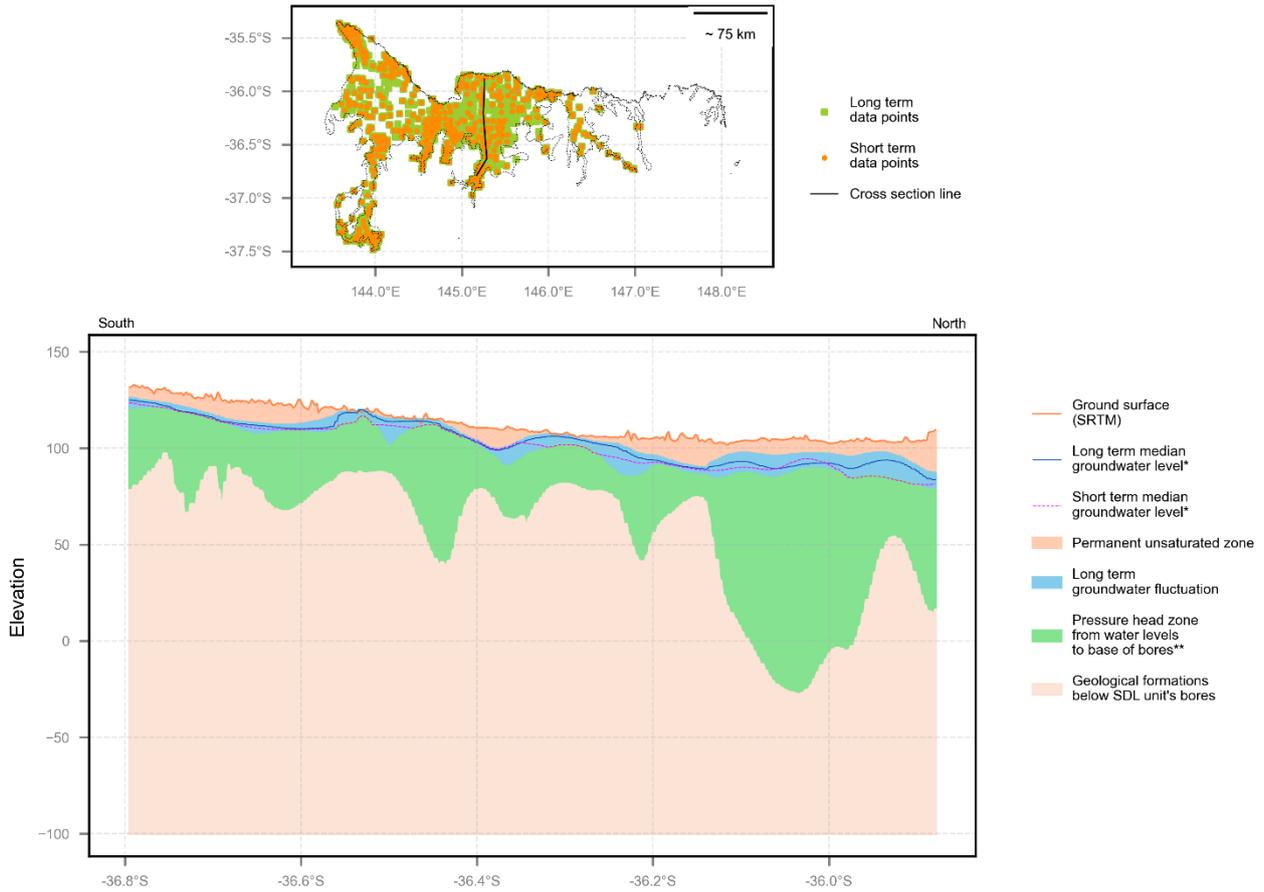


Figure 4 Long-term median (a) depth to water and (b) water level elevation

Water level elevation cross section for GS8c



*Long term - 1974 to 2024; Short term - 2012 to 2024; median - 50th percentile
 **This cross-section is a scaled representation of bore data specific to the SDL resource unit.
 The data are temporally and spatially aggregated, resulting in some smoothing of the representation of water levels and aquifer formations that is different from the detail of reality.
 The blue zone represents the long term fluctuation in groundwater levels, as indicated by the 5th and 95th percentiles of groundwater levels from 1974 to 2024.
 The green pressure head zone may be representative of the total available drawdown (TAD), as it shows the water column in bores of the SDL resource unit (measured as the difference between the long-term 5th percentile groundwater level and the base of the bores of the SDL resource unit).
 This cross-section is for interpretation purposes only and should not be used for planning or compliance purposes.

Figure 5 South to north distribution of water levels in the SDL resource unit

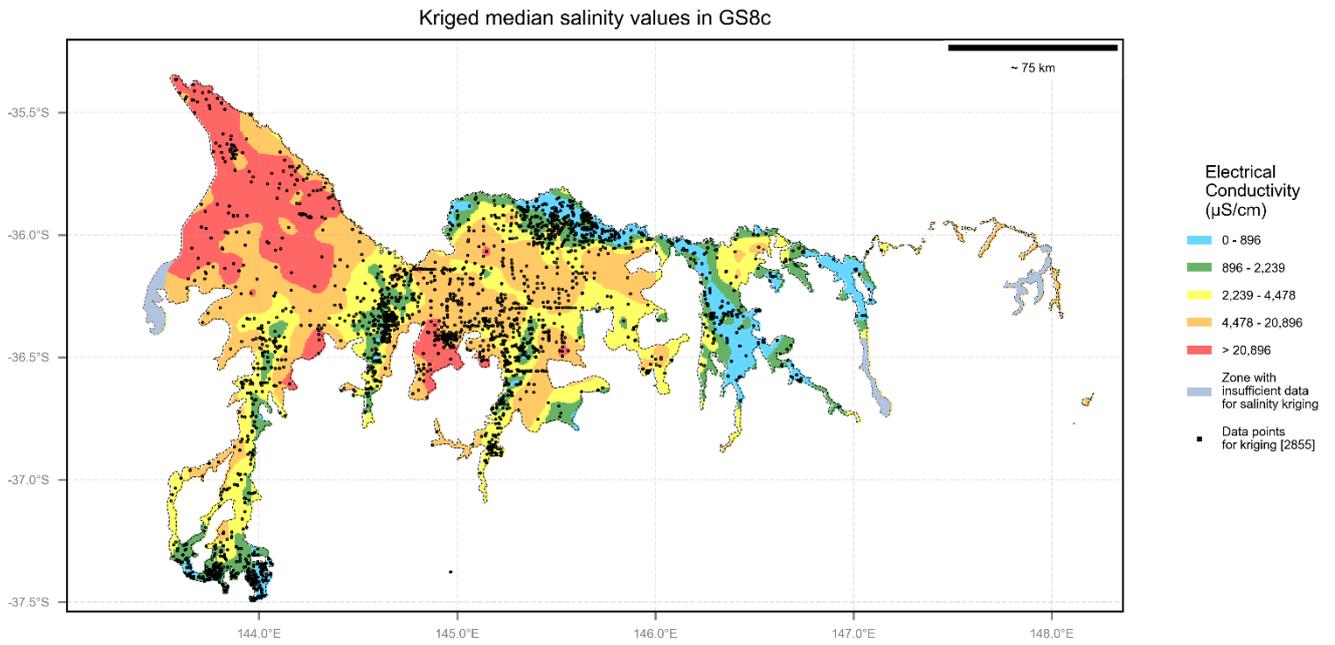


Figure 6 Groundwater salinity distribution

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	-	-	223.00
SDL resource unit area	km ²	-	-	21,863
Average annual take (2013 to 2023)	GL/y	-	-	112.83
Number of groundwater entitlement bores	-	-	-	1,505
SDL resource unit storage estimate*	GL	-	-	926,497
Recharge estimate (SY1)	GL/y	-	-	450.20
Recharge estimate (Stage 2)	GL/y	-	-	450.20
Diffuse recharge estimate (SY2 - WAVES)	GL/y	-	-	193.08
Extraction/SDL (E/SDL) (Stage 2 result)	-	-	-	0.51
SDL/Recharge (SDL/R) (Stage 2 result)	-	-	-	0.50
SDL/Recharge (SDL/R) (SY2 or modelled recharge)	-	-	-	0.50
Storage/Stage 2 Recharge (S/R)	-	-	-	2,058
Storage/SY2 or modelled Recharge (S/R)	-	-	-	2,058
Number of bores in the SDL unit	-	51,174	51,174	-
Number of bores for water level trend analysis	-	1,587	1,088	-
Number of bores for water level trend with sufficient data	-	1,322	344	-
Number of bores with decreasing water level trend	-	909	205	-
Number of bores with increasing water level trend	-	114	23	-
Number of bores with no statistically significant water level trend	-	299	116	-
Mean water level trend magnitude	m/y	-0.08	-0.15	-
Minimum water level trend magnitude	m/y	-2.43	-3.43	-
5%ile water level trend magnitude	m/y	-0.41	-0.45	-
10%ile water level trend magnitude	m/y	-0.29	-0.36	-
50%ile water level trend magnitude	m/y	-0.07	-0.1	-
90%ile water level trend magnitude	m/y	0.1	0.07	-
95%ile water level trend magnitude	m/y	0.18	0.15	-
Maximum water level trend magnitude	m/y	2.35	1.89	-
Number of bores for salinity trend analysis	-	2,899	340	-
Number of bores for salinity trend with sufficient data	-	837	16	-
Number of bores with decreasing salinity trend	-	104	2	-
Number of bores with increasing salinity trend	-	240	0	-
Number of bores with no statistically significant salinity trend	-	493	14	-
Mean salinity trend magnitude	µS/cm/y	64	-81	-
Minimum salinity trend magnitude	µS/cm/y	-1,491	-538	-
5%ile salinity trend magnitude	µS/cm/y	-323	-525	-
10%ile salinity trend magnitude	µS/cm/y	-162	-389	-
50%ile salinity trend magnitude	µS/cm/y	10	-17	-
90%ile salinity trend magnitude	µS/cm/y	391	-2	-
95%ile salinity trend magnitude	µS/cm/y	557	69	-
Maximum salinity trend magnitude	µS/cm/y	4,310	280	-

Note: *Groundwater resource storage estimate source: WERP (RQ8b).

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	15,838,732,895	19%	43%	38%	Variable trends	19%	27%	54%	Insufficient data
GDEs	12,011,959,757	17%	43%	40%	Variable trends	19%	26%	55%	Insufficient data
River connectivity	15,076,397,223	20%	37%	43%	Variable trends	17%	25%	57%	Insufficient data
Water quality	14,925,221,946	31%	9%	60%	Insufficient data	4%	0%	96%	Insufficient data

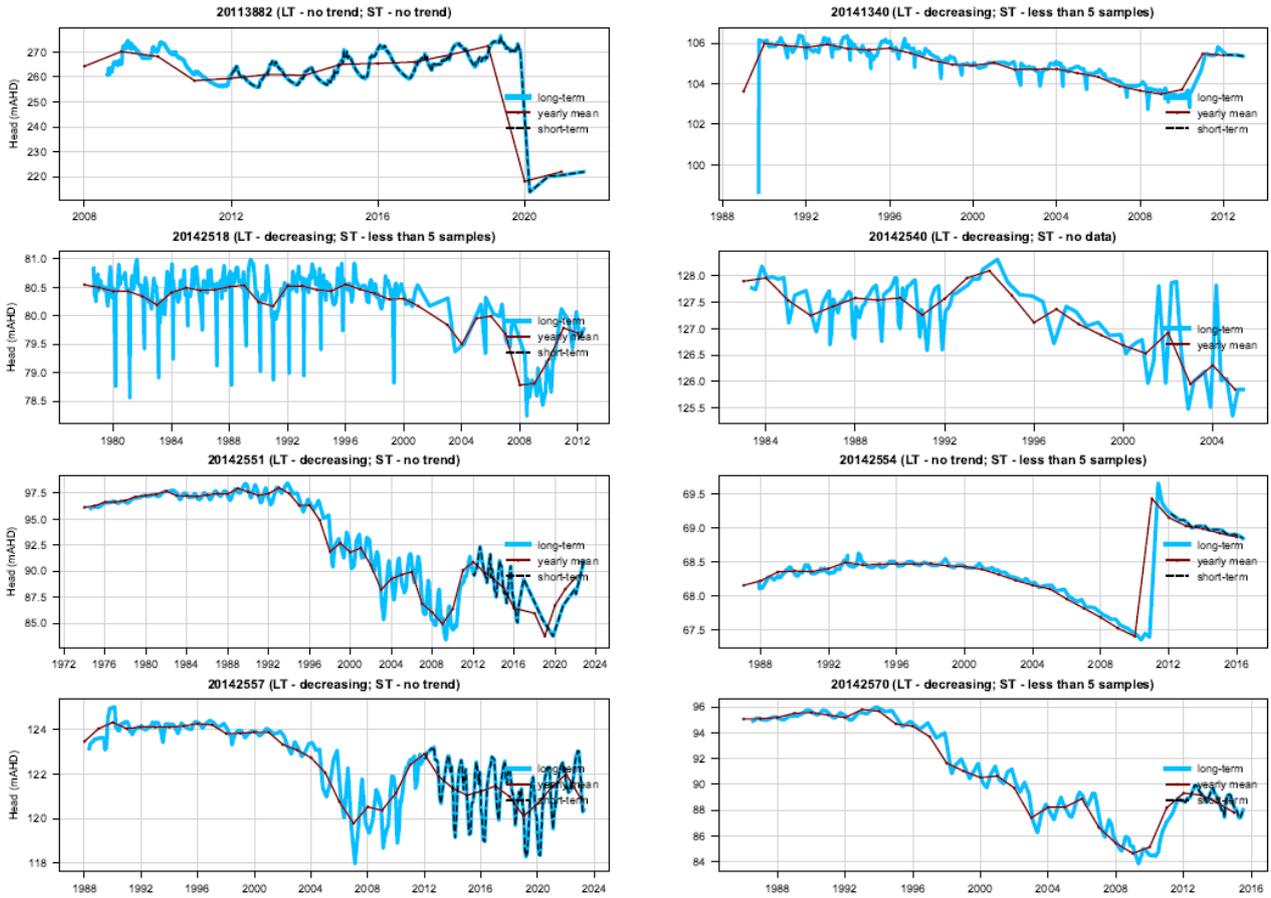


Figure 7 Representative groundwater hydrographs for the SDL resource unit

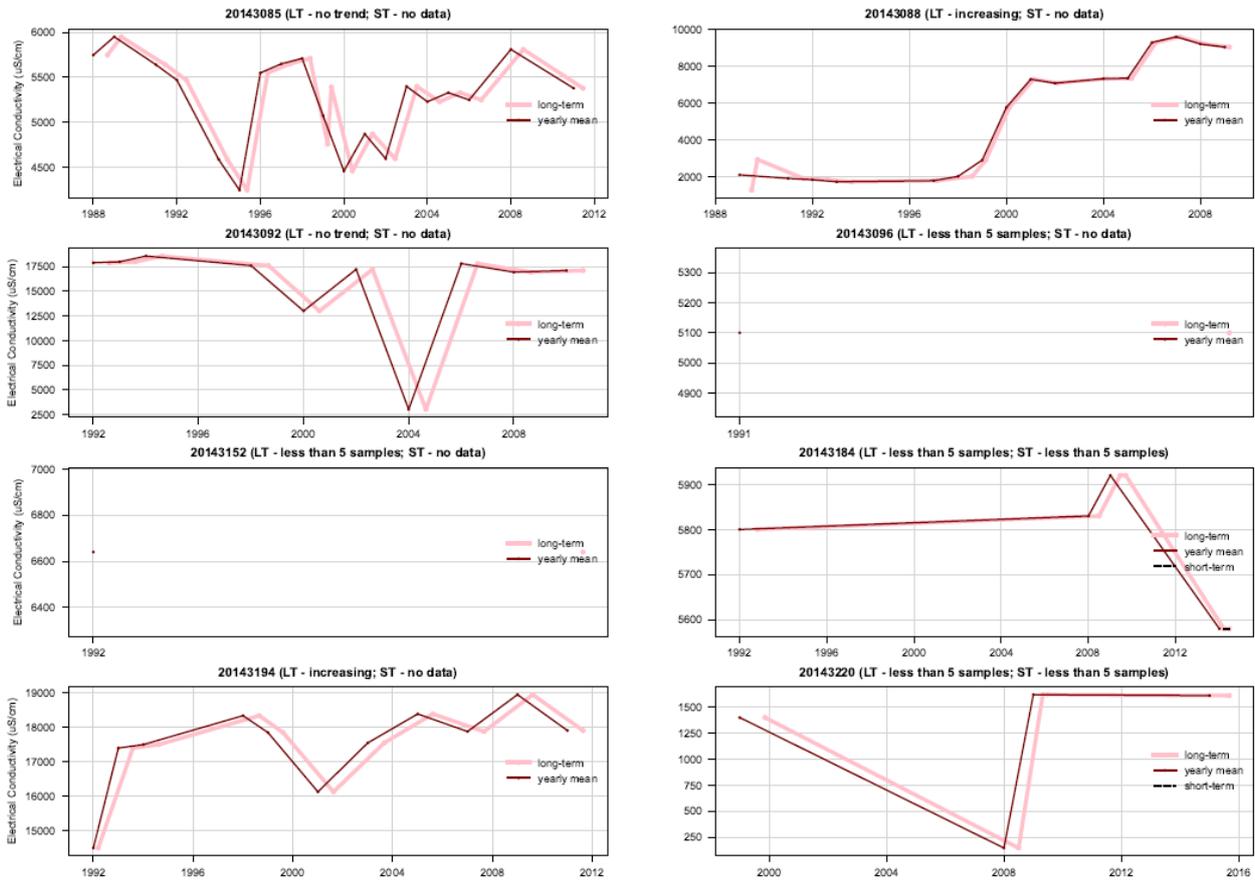


Figure 8 Representative groundwater salinity time series for the SDL resource unit

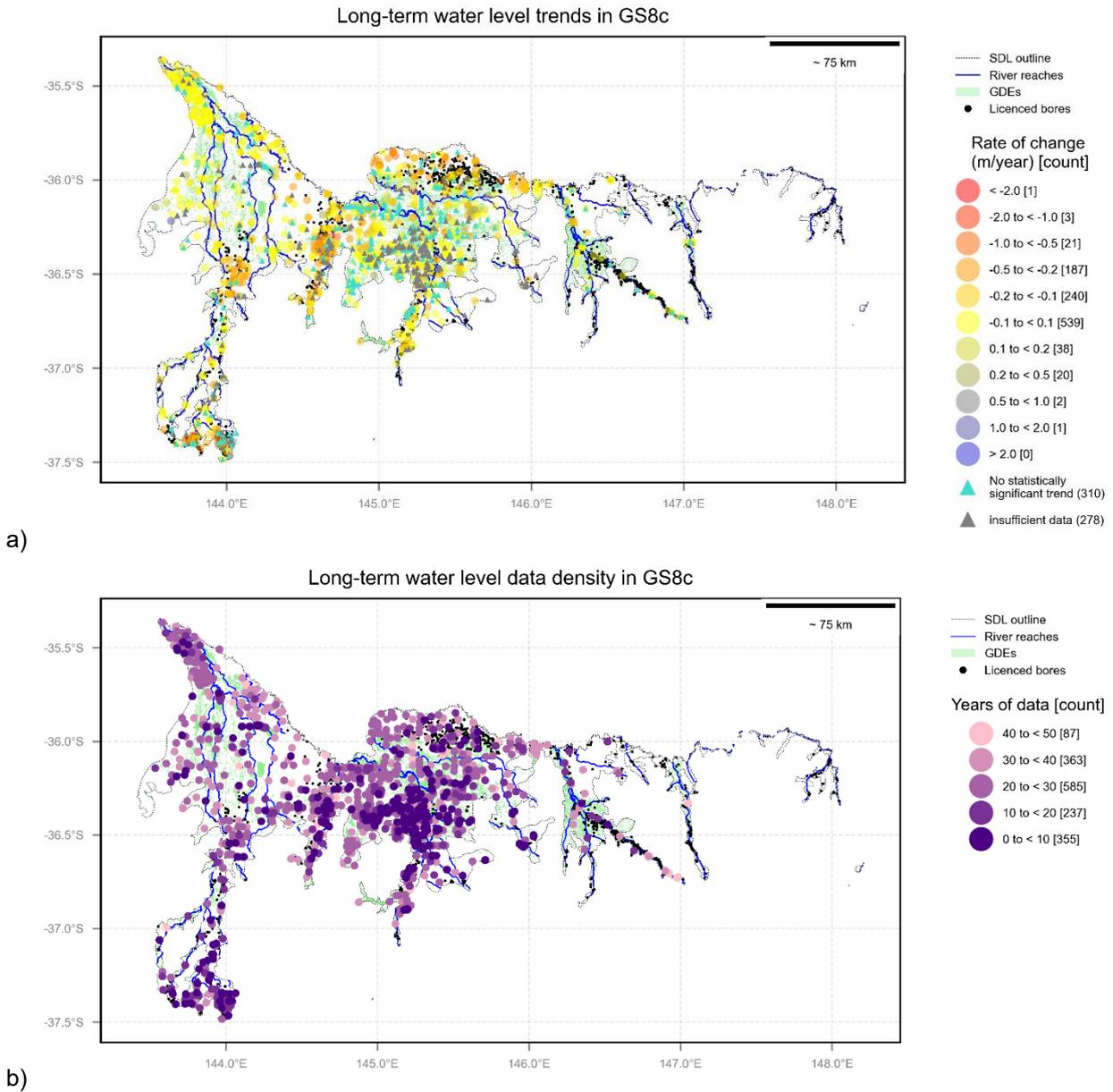


Figure 9 Long-term (1974 to 2024) groundwater level trends (a) and data availability (b)

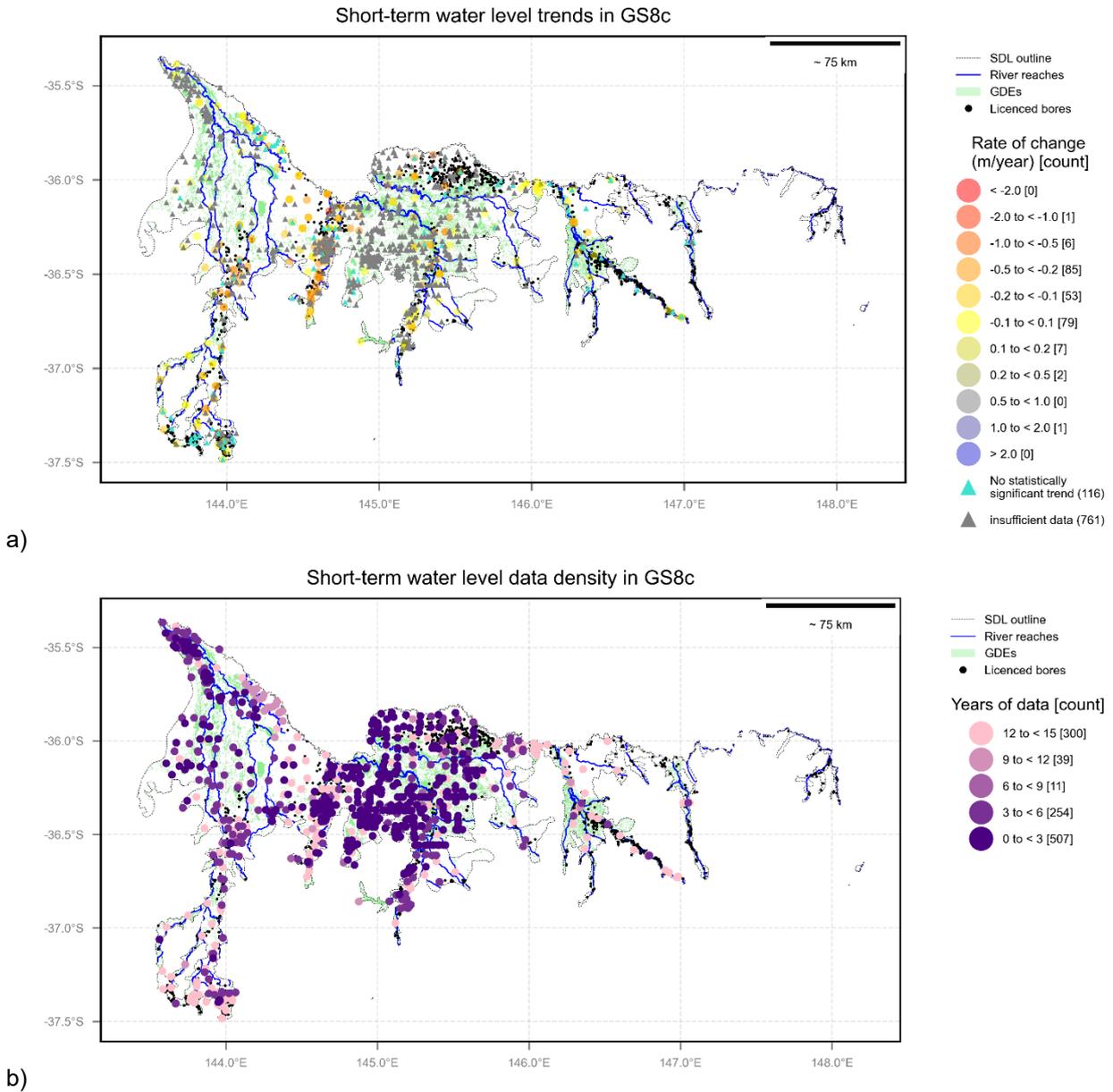


Figure 10 Short-term (2012 to 2024) groundwater level trends (a) and data availability (b)

Ternary plot for GS8c

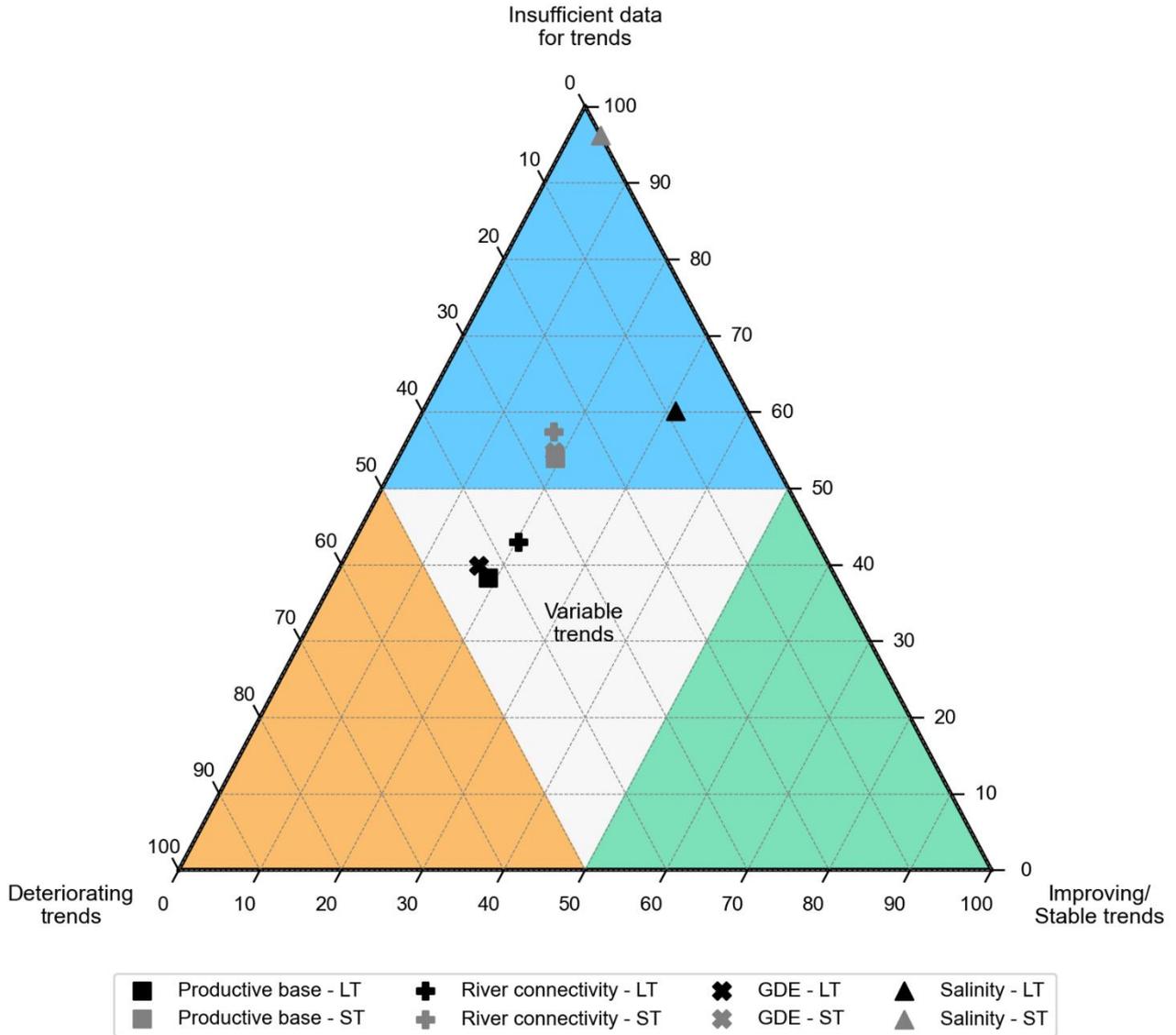


Figure 11 Stage 4 assessment outcome: trends in resource condition indicators for ESLT values



Figure 12 Estimates for change in area of influence (AoI) due to climate change

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