Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Memo

Date	09/04/19
To	Alastair Picken, Principal Planner
CC	Maureen Whalen, Groundwater Science Team Leader
From	Zeb Etheridge, Senior Groundwater Scientist

Waimakariri land and water solutions programme groundwater allocation options and solutions assessment

1. Summary

In this memo I summarise current state and trends for groundwater quantity for Waimakariri Land and Water Solutions programme and discusses potential future stresses on the groundwater system. I also summarise the results of groundwater modelling undertaken to assess the effects of increased groundwater abstraction and improved irrigation efficiency.

Groundwater consent holders in the Waimakariri zone generally use less than half of their allocated volume. Actual groundwater abstraction rates could increase without any additional water necessarily being allocated, if consent holders consistently start to use a higher proportion of their consented volume.

Increased irrigation efficiency will mean less water applied to the land. Groundwater levels and flows in some of the spring-fed streams are likely to decline as a result of the associated lower recharge rates.

Groundwater levels in the lower Eyre River GAZ are already declining in some areas. Increased groundwater abstraction could also reduce the reliability of water supply wells. Further allocation of groundwater, higher usage rates and/or improved irrigation efficiency for Waimakariri River-fed irrigation schemes could exacerbate this situation.

The Waimakariri Water Zone Committee (WWZC) have recommended (via their Zone Implementation Programme Addendum [ZIPA]) that no further groundwater should be allocated in the Eyre River GAZ (see Figure 8-1 appended for locations) and that groundwater allocation limits for the remaining GAZs should be capped at the current allocated volume + 10%. A new GAZ is suggested for the Lees Valley area and extension of the existing GAZ boundaries, to coincide with the hydrological catchment boundaries, is proposed. Investigation and assessment of on-the-ground actions such as managed aquifer recharge (MAR) is also recommended.

The results of my assessment indicate that:

- Reducing the current allocation limits will avoid the potentially significant declines in stream and river flows that could otherwise occur if they were fully utilised (full utilisation could mean a groundwater abstraction increase of >100% in some GAZs);
- A 10% increase in the current allocation is unlikely to have a significant effect on spring-fed stream and river flows and on well reliability;

- Creating a new Lees Valley GAZ and capping the allocation for the Lees Valley GAZ and the Loburn Fan GAZ at current +10% will help to avoid further declines in Ashley River/Rakahuri flows;
- Extension of the GAZ boundaries will provide a clearer and more robust groundwater management regime;
- Provision of T Blocks, which allow for the transfer of surface water and stream-depleting groundwater in over-allocated surface water catchments will help to recover the over-allocation; and
- Implementation of MAR could improve the resilience of the hydrological system to possible climate change-driven drought severity increases.

All of the above will help to achieve the following WWZC Priority Outcomes:

Outcome 1 – The water quality and quantity of spring-fed streams maintains or improves mahinga kai gathering and diverse aquatic life

Outcome 2 – The Ashley River/Rakahuri is safe for contact recreation, has improved river habitat, fish passage, and customary use; and has flows that support natural coastal processes

Outcome 4 – The zone has safe and reliable drinking water, preferably from secure sources

2. Current state of groundwater

Trend analysis undertaken by Etheridge and Wong (2018) shows that groundwater levels are declining in the Ashley, Kowai and lower part of the Eyre GAZs (see Figure 8-1, appended, for locations). The Ashley zone declines are likely to be mainly (~ 70%) caused by climate-driven declines in Ashley River/Rakahuri flows, with increasing groundwater abstraction making up the balance. Declining Ashley River/Rakahuri flows and Ashley and Kowai GAZ groundwater levels mean that flows in Taranaki Creek, Waikuku Stream and Saltwater Creek are also likely to be declining. Declining groundwater levels in the lower Eyre River GAZ are likely to be reflected in declining flows in the spring-fed streams such as Silverstream. We do not have enough monitoring data for these streams to verify this trend directly, but we know from analysis of stream flow and groundwater level data in the Eyre zone and elsewhere in the region that spring-fed stream flows and nearby shallow groundwater levels are usually strongly correlated.

3. Irrigation recharge and groundwater usage

Irrigation recharge

Etheridge and Wong (2018) concluded that water leakage from the irrigation and stockwater network has been sufficient to counteract the effects of increased abstraction in the Waimakariri zone since 1999. The increase in irrigated land area, with an associated increase in land surface recharge coupled with low efficiency irrigation, also appear to have offset the effects of the generally dryer climate trend we have seen from the start of the millennium.

Waimakariri Irrigation Limited (WIL) shareholders and Spencer-Bower-Pratley irrigation scheme water users are improving irrigation efficiency to meet the industry-agreed GMP standards for land and water management. Increased irrigation efficiency will mean that less Waimakariri River water will be applied to the land, and this will reduce drainage to and recharge of the aquifer system. Groundwater levels and flows in some of the spring-fed streams are likely to decline to some degree as a result of this.

Groundwater usage

Etheridge and Wong (2018) estimated average groundwater usage as a proportion of the consent limit on a GAZ-by-GAZ basis using water metering data available up to 2016 (when the study was undertaken). Their results (summarised in Table 3-1 below) show that on average groundwater consent holders use around 43% of their maximum consented annual take rate. Although there is some uncertainty around these estimates,[1] these data highlight the potential for significantly higher groundwater abstraction to occur within current consent limits. This could happen in the event of an extended drought, the risk of which is being exacerbated by accelerating climate change. Higher groundwater abstraction rates would reduce flows in spring-fed streams and rivers and reduce the reliability of shallow wells.

Table 3-1 Groundwater use as a % of consent limit

GAZ	Estimated use ratio
Eyre River	40%
Cust	40%
Ashley	55%
Loburn Fan	55%
Kowai	55%
Waimakariri zone (all GAZ)[2]	43%

4. Current groundwater allocation

I have provided our current estimates of groundwater allocation for each GAZ under two different scenarios as per Vattala (2019). Scenario one provides the current allocation based on the consented annual volume specified on consent documents or a volume based on a calculated 212-day annual volume if consents do not have an annual volume. Scenario two derives annual volumes for all groundwater consents by applying the discounting method provided in Schedule 9 of the LWRP to the scenario one annual volume. These two scenarios provide two ends to a range of allocation possibilities from a conservative to an incautious limit.

Groundwater allocation limits in the Ashley, Cust, Kowai and Loburn GAZs currently allow for significant increases in groundwater allocation, as shown in Table 4-1.

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[1] A significant number of consents do not have annual volume limits; annual volumes need to be estimated for these takes based on daily rates and the assumption that water is used over a 212-day irrigation season for irrigation takes. Our water metering data was also relatively limited at the time of the study.

[2] Average for all water takes across whole zone

Table 4-1 Current allocation (as of 12 March 2019)

Groundwater Zone	Allocation limit (m^3/year)	Possible range of total allocated[3]
Ashley	29,400,000	35 – 72%
Cust	56,300,000	21 – 40%
Eyre River	99,070,000	76 – 119%
Kowai	17,400,000	39 – 72%
Loburn	40,800,000	0.04 – 2.2%

5. Groundwater modelling approach

We used our numerical model of the Waimakariri – Christchurch aquifer system (see Etheridge and Hanson, 2019) to assess the effects of the following on spring-fed stream flows and well reliability:

- improvements in irrigation efficiency and the associated reduction in groundwater recharge;
- higher usage of existing consents; and
- granting of new groundwater take consents, up to the current allocation limits.

The modelling scenarios I used to evaluate these effects are summarised in Table 5-1.

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[3] Note that these estimates are currently being revised as part of a Resource Consents Inventory process

Table 5-1 Model scenarios

Scenario name	Description	Purpose	Modelling method
GMP	Irrigation efficiency assumed to increase by 20%	Evaluate the effects of increased irrigation efficiency associated with implementation of GMP.	Use of spatially distributed soil water budget (SWB) model to estimate land surface recharge rates following irrigation efficiency improvements. Application of SWB model results to steady state numerical groundwater model and assessment of median stream flow declines relative to status quo model.
Full abs	Full abstraction. Assumes all consented wells use 100% of consented volume[4]. Excludes Permitted Activity water takes (e.g. domestic and stockwater)	Explores potential effects of increased abstraction within current consent limits. This scenario could potentially eventuate as a result of climate change, for instance, if drought length and severity increases.	Increase abstraction rate from all wells in numerical groundwater model up to the maximum rate specified in their consents. Current usage is estimated at 43%: model abstraction rates therefore increased by 230%. Run model at steady state and assess median stream flow declines relative to status quo model

[4] We modelled this under steady state conditions by averaging the irrigation season water take rate over a full calendar year and applying this as the continuous long-term abstraction rate for all consented wells

Scenario name	Description	Purpose	Modelling method
Full abs allo	Full abstraction, full allocation. Assumes all consented wells use 100% of consented volume in all GAZs bar Loburn, which is not included in the model. There is also currently no GAZ for Lees Valley, so the effects of any additional abstraction from this area have not been assessed.	Explores the maximum likely effects of groundwater abstraction that could potentially occur under current LWRP rules	Increase abstraction rate from all wells in numerical groundwater model up to the maximum rate specified in their consents and then add on an additional percentage based on the proportion of the LWRP allocation limit that has been consented. This means that the additional consented groundwater abstraction is taken from existing consented wells in the model (i.e. modelling assumes same spatial distribution of abstraction as current). E.G. for Ashley GAZ: 35% of the current allocation limit has been granted via water take consents. Current usage is estimated at 43% Abstraction rates for all wells within the Ashley GAZ were therefore increased by 520% to simulate full allocation and full abstraction
Full allo cur use	Full allocation at current usage rates. As per Full_abs_allo scenario but assumes consent holders use same % of consent volume (e.g. 43%) as currently used	Assesses the effects of increased groundwater abstraction up to the current LWRP limits, assuming usage rates remain the same as present (assumes no increase in water usage due to climate change etc.)	Increase abstraction rate from all wells in numerical groundwater model by adding on an additional percentage based on the proportion of the LWRP allocation limit that has been consented. E.G. for Ashley GAZ 35% of the current allocation limit has been granted via water take consents. Abstraction rates for all wells within the Ashley GAZ were therefore increased by 286% to simulate full allocation.

6. Model results

Stream flows

Modelling results for stream flows (Table 6-1) have been classified as follows:

- ≥10% decline = significant decline in stream flow
- <10% decline = minor decline in flows, within modelling error margin

Using this classification:

- Flows in the Cust River and Cust Main Drain are expected to reduce by more than 10% following successful implementation of GMP
- Full usage of current allocated water could cause flows in Ohoka Stream, Cust River, Cust Main Drain and Taranaki Creek to reduce by more than 10%
- Allocation of groundwater up to the current allocation limits combined with full usage of all allocated water could cause significant flow reductions in the Cam River, Ohoka Stream, Cust River, Cust Main Drain, No. 7 Drain, Taranaki Creek and Waikuku Stream.
- Allocation of groundwater up to the current allocation limits but with usage at the current average usage rates could cause flows in Ohoka Stream, Cust River, Cust Main Drain and Taranaki Creek to reduce by more than 10%

These flow declines are assumed to apply at all stream flow rates[5]; e.g. mean, median and low flows are all assumed to decline by the percentages shown in Table 6-1. Although this is unlikely to be the case, our modelling method did not allow us to evaluate changes in the flow regime.

Table 6-1 Model stream flow results

Scenario name	Stream	Median flow decline (%)
GMP	Cam River at Youngs Rd	1
	Courtenay Stream at Neeves Rd	0
	Greigs Drain	0
	Northbrook at Marsh Rd	0
	Ohoka Stream at Island Rd	0
	Silverstream at Island Rd	0
	Southbrook at Marsh Rd	1
	Cust River at Oxford	**16**
	Cust Main Drain at Threlkelds Rd	**12**
	No. 7 Drain	1
full_abs	Cam River at Youngs Rd	4
	Courtenay Stream at Neeves Rd	4
	Greigs Drain	3
	Northbrook at Marsh Rd	3

[5] We made this assumption because we have no information to assess whether increased abstraction is likely to affect low flows more than median flows, for instance.

Scenario name	Stream	Median flow decline (%)
	Ohoka Stream at Island Rd	**17**
	Silverstream at Island Rd	5
	Southbrook at Marsh Rd	8
	Cust River at Oxford	**11**
	Cust Main Drain at Threlkelds Rd	**16**
	No. 7 Drain	5
	Ashley River/Rakahuri	1
	Saltwater Creek	5
	Taranaki Creek	**1%**
	Waiuku Stream	8
full_abs_allo	Cam River at Youngs Rd	**10**
	Courtenay Stream at Neeves Rd	6
	Greigs Drain	5
	Northbrook at Marsh Rd	8
	Ohoka Stream at Island Rd	**30**
	Silverstream at Island Rd	7
	Southbrook at Marsh Rd	**21**
	Cust River at Oxford	**27**
	Cust Main Drain at Threlkelds Rd	**54**
	No. 7 Drain	**14**
	Ashley River/Rakahuri	3
	Saltwater Creek	9
	Taranaki Creek	**33**
	Waiuku Stream	**21**
full_allo_cur_use	Cam River at Youngs Rd	3
	Courtenay Stream at Neeves Rd	1
	Greigs Drain	1
	Northbrook at Marsh Rd	2
	Ohoka Stream at Island Rd	**11**
	Silverstream at Island Rd	1
	Southbrook at Marsh Rd	6
	Cust River at Oxford	**11**
	Cust Main Drain at Threlkelds Rd	**23**
	No. 7 Drain	5
	Ashley River/Rakahuri	1
	Saltwater Creek	2
	Taranaki Creek	**10**
	Waiuku Stream	7

Loburn GAZ

As noted above, our modelling results do not account for the effects on stream flow which could occur if groundwater abstraction in the Loburn Fan increased. The current Loburn GAZ allocation limit is equivalent to 1.3 m^3/s, of which roughly 1% (130 L/s) is currently allocated. The following information is relevant when considering whether this allocation limit is appropriate:

- Groundwater from the Loburn GAZ is likely to discharge to the Ashley River/Rakahuri
- The lower/mid reaches of Ashley River/Rakahuri dry-out when flows at the Gorge recorder site fall below 2.5 m^3/s
- The effect of increased groundwater abstraction from the Loburn GAZ on the Rakahuri would be greatest at low flows, when the river is sustained by groundwater discharge
- If increased groundwater abstraction from the Loburn GAZ up to the current allocation limit (1.3 m^3/s) caused an equivalent decline in low flows in the Rakahuri, this would have a very significant impact on the duration, frequency and length of dry reaches
- Flows in the Rakahuri are currently declining due to dryer climatic conditions in recent decades (see Etheridge and Wong, 2018)
- Well yields in the Loburn GAZ are very low, typically < 1L/s. The potential for the current allocation limit to be fully utilised is therefore limited.

Based on the above, increased groundwater abstraction from the Loburn GAZ up to the current allocation limits could have a very significant effect on low flows in the Rakahuri if a substantial groundwater resource was found and exploited. Capping the allocation limit at or close to the current allocated volume is unlikely to have a significant effect on the local economy because low well yields discourage exploitation of the groundwater resource.

Lees Valley proposed GAZ

A groundwater allocation limit has not been set for the Lees Valley area. This means that new groundwater take consents could potentially be granted here. The following information is relevant when considering whether an allocation limit should be set for this area:

- Groundwater from Lees Valley discharges to the Ashley River/Rakahuri above the Ashley Gorge
- Any increase in groundwater abstraction would therefore reduce river flows at and below the Gorge. This could increase the duration, frequency and length of dry reaches in the lower/mid reaches of the Rakahuri.
- Well yields appear to be low in Lees Valley area. The potential for increased groundwater abstraction is therefore likely to be limited.

As per the Loburn Fan, increased groundwater abstraction from the Lees Valley area could have a significant effect on low flows in the Rakahuri. Capping the allocation limit at or close to the current allocated volume is unlikely to have a significant effect on the local economy because the existing low well yields are likely to discourage exploitation of the groundwater resource. A new GAZ would need to be defined to manage groundwater allocation in Lees Valley.

Groundwater levels and well reliability

Our modelling of well reliability in the Waimakariri zone (see Etheridge and Hanson, 2019 for method details) indicates that:

- Up to 20% of wells could potentially be unreliable in a 1/20 year drought at present
- This could increase to around 25% if water was allocated up to the current limits and if all consent holders consistently abstracted their full consented flow rates
- Reliability would only reduce marginally (by a few percentage points) under the full allocation scenario if all consent holders abstracted at the current average usage rates (which are much lower than consented rates, as discussed previously).

7. Solutions assessment

The Waimakariri Zone Implementation Programme Addendum (ZIPA) includes the following recommendations:

- Recommendations 5.1 - 5.5 state that:
  - ➢ groundwater allocation limits should be capped at current + 10% in Loburn Fan, Kowai, Ashley and Cust GAZs and at the current allocated volume in the Eyre River GAZ; and that
  - ➢ an allocation should be provided for the substitution of existing surface water or stream-depleting groundwater takes with non-stream depleting groundwater takes to help recover over-allocation of surface water
- Recommendation 5.6 proposes a Lees Valley Groundwater Allocation Zone with an allocation limit capped at the current allocated volume + 10%.
- Recommendation 5.7 proposes that Groundwater Allocation Zone boundaries should be extended further inland, to the edge of surface water catchment boundary.
- Recommendation 3.24 supports investigation and assessment of on-the-ground actions such as MAR to address nitrate issues, as discussed previously.

Figure 8-2 appended shows the new GAZ boundaries recommended in the ZIPA. I have evaluated the groundwater allocation limits for each GAZ in Table 7-1 below based on the ZIPA recommendations. I have also provided a T (transfer) block to provide for the substitution of existing surface water or stream-depleting groundwater takes with non-stream depleting groundwater takes. I used the following approach to calculate the T block sizes:

If $A_s + A_G \leq A_L$, $T = A_S$, otherwise $T = A_L - A_R$

Where: A_s= total current allocation of surface water and stream-depleting groundwater within each GAZ; A_G = total current allocation of non-stream-depleting groundwater within each GAZ; A_L = total LWRP allocation limit for each GAZ; T = T block volume; and A_R = GAZ allocation limit based on ZIPA recommendations.

The outcome of this method is that the T block allocations are large enough to accommodate all surface water and stream depleting groundwater takes within each GAZ, capped at the current LWRP allocation limits for each GAZ. The assumption behind this approach is that actual uptake of the T block allocation will be controlled by revisions to the Regional Plan rules and policies rather than the T block size itself.

Table 7-1 Current and ZIPA-based allocation limits[6]

GAZ	Current allocation limit (m³/year)	ZIPA-based allocation limit (m³/year)	Transfer (T) Block (m³/year)
Ashley	29,400,000	11,349,884	18,050,116
Cust	56,300,000	13,247,877	29,088,946
Eyre River	99,070,000	75,326,541	23,743,459
Kowai	17,400,000	7,425,638	9,202,867
Loburn	40,800,000	16,046	N/A
Lees Valley	N/A	25,102	N/A

Under our Regional Plan (LWRP) rules a proportion of stream-depleting groundwater take allocated volume is assigned to the stream and the remainder to the groundwater unit. This proportion is based on the estimated stream depletion rate for each groundwater take, in accordance with the LWRP Schedule 9 rules. Whilst site-specific stream depletion assessments have been undertaken for some groundwater takes in the Waimakariri zone, no such assessments have been undertaken for many. We estimated stream depletion rates for these takes using a generic set of aquifer properties, based on local aquifer property data held within our database. The parameters used in our stream depletion assessments may be conservative (i.e. overestimate the stream depletion rate). This means that a higher proportion of the existing groundwater take consented volumes could be allocated to surface water, and a lower proportion to groundwater, than may ultimately be the case when site-specific stream depletion assessments are undertaken. The knock-on effect of this is that more accurate stream depletion assessments in the future could lead to designation of some of the GAZs as over-allocated. This issue could be addressed by including plan provisions which allow for renewal of existing groundwater takes even when the GAZ is over-allocated.

Although we have not modelled the effects of a 10% increase in abstraction explicitly, the results of our full-abs scenario, which assessed the effects of increasing the groundwater abstraction rate by 230% (from 43% to 100% usage) indicate that a 10% increase in abstraction is likely to have a very small effect on spring-fed stream flows.

The modelling results presented in Section 6 show that reducing current allocation limits will help to avoid the significant reduction in spring-fed stream and river flows and declines in shallow water supply well reliability that could potentially occur if groundwater continues to be allocated up to the current allocation limits.

Provision of T Blocks, which allow for the transfer of surface water and stream-depleting groundwater in over-allocated surface water catchments to non-stream-depleting takes will help to recover the over-allocation. Whilst the T block theoretically allows for more groundwater allocation in large parts of the Waimakariri zone, the effects of this allocation increase are expected to be beneficial for stream flows because the transfer is only available from surface water takes and stream depleting wells to wells which do not deplete stream flows significantly over the course of an irrigation season. A well interference assessment will

[6] Internal data source: P:\Groundwater\Waimakariri\Groundwater\Solutions work\Spreadsheets\GW quantity\190321 GW ZONE allocation SUMMARY current and ZIPA.xlsx

be required as per Schedule 12 of the LWRP, which means that the reliability of existing wells will be protected.

MAR could improve well reliability and stream flows in some areas, by enhancing groundwater storage over winter such that more is available over subsequent dry periods when aquifers are depleted by natural drainage and groundwater abstraction.

I consider that extension of the GAZ boundaries will provide a clearer and more robust groundwater management regime by including all areas within an allocation zone.

All of the above will help to achieve the following WWZC Priority Outcomes:

Outcome 1 – The water quality and quantity of spring-fed streams maintains or improves mahinga kai gathering and diverse aquatic life

Outcome 2 – The Ashley River/Rakahuri is safe for contact recreation, has improved river habitat, fish passage, and customary use; and has flows that support natural coastal processes

Outcome 4 – The zone has safe and reliable drinking water, preferably from secure sources

8. References

Etheridge, Z and Hanson, M. 2019. Waimakariri Land and Water Solutions Programme Numerical Groundwater Model Conceptualisation, Design, Development and Deployment Technical Report No. R19/77.

Etheridge, Z and Wong R. 2018. The current state of groundwater quantity in the Waimakariri Zone (2016) Environment Canterbury Report No. R18/81

Vattala, D 2019. Resource consent inventory for Waimakariri Land and Water Solutions Programme (version 2). Environment Canterbury Report No. R19/10.

Reviewed by:	Jens Rekker, JH Rekker Consulting Ltd Carl Hanson, Groundwater Science Manager	30 May, 2019
Approved for release:	Tim Davie, Chief Scientist	June 21, 2019

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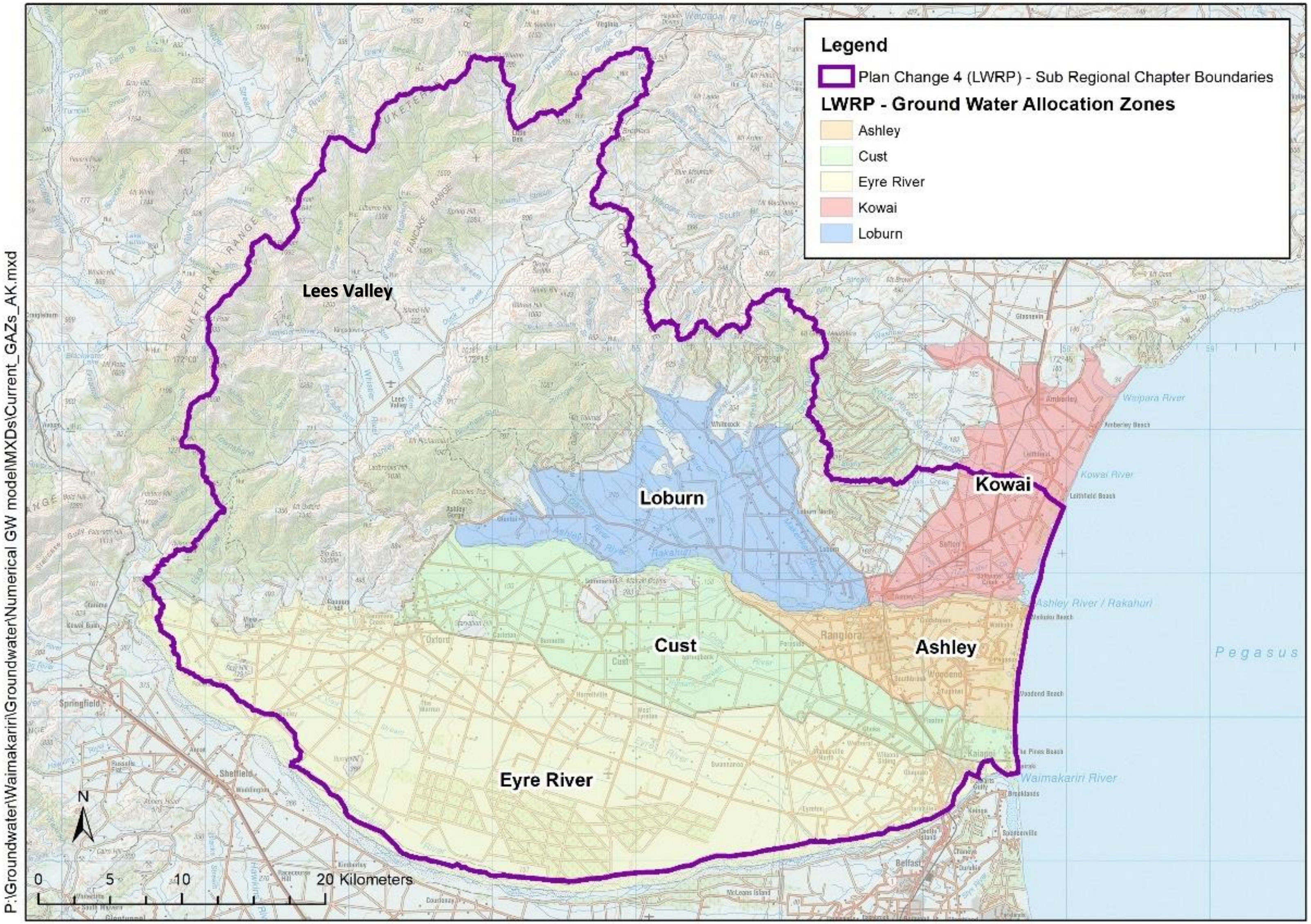

Figure 8-1 Current GAZ boundaries

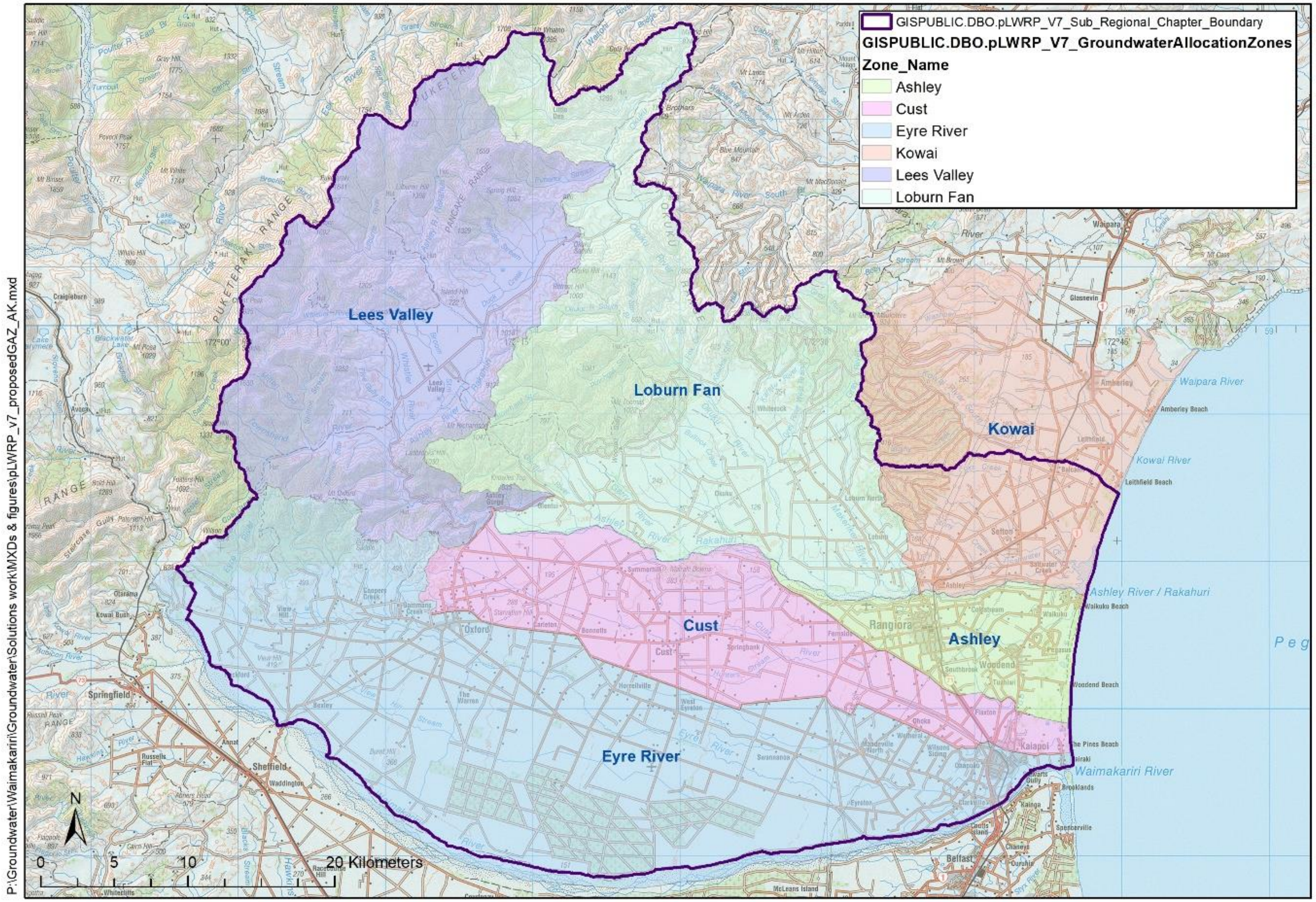

Figure 8-2 Proposed GAZ boundaries