Groundwater Quantity
State of the Environment Monitoring
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Executive summary

Regional councils have responsibilities under the Resource Management Act (1991) to monitor the state of the environment within their region. The Taranaki Regional Council (the Council) monitors the state and trends across the region's groundwater resource using a number of measures, including chemical and microbial water quality, groundwater levels and usage.

The focus of this report is regional groundwater quantity. The report incorporates an assessment of the volume of groundwater currently allocated for abstraction, which is compared against the estimated sustainable yields from the region's predominant aquifers. Water level data collected from a 15 site regional monitoring network is also analysed to assess the range of groundwater level fluctuation across aquifers and the major drivers behind observed fluctuations. An analysis of current state and trends in water level change over time is also presented.

The volume of groundwater allocated for abstraction across the region remains low and the demand for groundwater has remained relatively static over the last decade. As of 30 June 2017, there were only 61 current consents authorising the taking of groundwater. The highest level of allocation is currently seen in the Whenuakura aquifer, where a combined total of 23% of estimated sustainable yield is allocated across areas of the aquifer located within freshwater management unit (FMU) B and FMU-C. The Matemateaonga aquifer has approximately 7% allocated across FMU-A and FMU-B. All other aquifers have insignificant volumes of water allocated (≤1 % of estimated sustainable yield). It is not foreseen that there will be any increases in groundwater demand in the short to medium-term that would be sufficient to place groundwater resources under any significant allocation pressure.

As would be expected, monitored groundwater sites display fluctuations in water level as a result of seasonal variations in rainfall recharge. The observed magnitude of these seasonal changes varies considerably by site, ranging from a few millimetres up to several metres. The magnitude of observed changes is influenced by rainfall patterns, bore depth, aquifer type (confined or unconfined) and hydraulic properties, the overlying land cover, and proximity to a stable surface water boundary or groundwater discharge area (e.g. river or sea).

Data collected over the last two years of monitoring at each site (2015-2017) has been assessed to determine the current state of groundwater levels across monitored aquifers. The assessment shows that current water levels do not differ significantly from historical long-term averages at monitored sites. The analysis also illustrated similarities in spatial and temporal responses to rainfall across some sites.

Water level data collected at each monitoring location has been analysed for trends. This included analysis of long term trends, where a site had a minimum of eight years of data available, and more recent trends using data from the last five year period (2012-2017).

The results of the trend analysis show that at the vast majority of sites, there has been no meaningful change in water level over time. The exceptions to this were site GND0708 (Patea – Whenuakura aquifer), which was found to have experienced a slightly declining trend in water level over both its long-term data record and the most recent five year period. One other site, GND2252 (Waverly – Whenuakura aquifer), was found to have experienced a slightly declining trend in water level over its recent data record. In addition to these sites, there were others where statistically significant rising (4 sites) and declining (2 sites) trends in water level were identified. None of these trends were however deemed environmentally meaningful, given the extremely low rate of annual change (+/- <0.1%).

The slightly declining trend in water levels observed at both sites GND0708 and GND2252 appear to be the result of localised abstraction pressures. While both sites do intersect the Whenuakura aquifer, they are located a significant distance apart from each other and other monitoring sites in the same aquifer do not show a similar decline. It is therefore concluded that the observed trends are not indicative of any widespread reduction in groundwater levels across the aquifer.

The results of the analyses undertaken to produce this report indicate that, overall, there is very limited allocation pressure on groundwater resources across the region and is not anticipated that this will change significantly in the short to medium-term. Analysis of groundwater level data has found isolated impacts of localised abstractions impacting on water levels at specific sites, but overall, groundwater levels remain stable at the majority of monitored locations. The results of the analysis undertaken in preparing this report show that the Council’s policies related to groundwater abstraction and usage have been successful in achieving sustainable management of the region’s groundwater resource.

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1 Introduction

1.1 State of the environment monitoring (SEM)

Regional councils have responsibilities under the Resource Management Act (1991) (the RMA) to monitor the state of the environment within their region. The purpose of state of the environment monitoring (SEM) is to collect sufficient data to produce information on the general health of the environment.

The Taranaki Regional Council (the Council) monitors the state and trends across the region's groundwater resource using a number of measures, including chemical and microbial water quality, groundwater levels and usage. The results of the monitoring undertaken are reported in two separate SEM reports, one covering groundwater quality and the other dealing specifically with groundwater quantity, as reported in this document.

The SEM Groundwater Quantity Programme has three primary objectives:

- To assess the current state of groundwater allocation across the region's major aquifer systems;
- To provide information on the current range of groundwater levels at a selected number of sites across the region's major aquifer systems;
- Identify spatial and temporal trends in water level arising as a result of natural and/or anthropogenic influences, including allocation pressures.

This information can then be used to measure how well management practices, policies and rules are working, and whether environmental outcomes are being achieved.

1.2 Groundwater quantity management

The Regional Policy Statement for Taranaki (2010) (the RPS) sets out the Council's approach to the sustainable management of groundwater use across the Taranaki region. Policies set out in the RPS are intended to protect against adverse effects on groundwater flows arising from over abstraction. It is intended that this be achieved by managing groundwater take volumes within the sustainable yields of specific aquifer units. Polices set out in the RPS also recognise the connection between groundwater and surface water systems and therefore the potential for reduced surface water flows as a result of groundwater abstraction. Policies in the RPS also detail a range of other matters to be considered in relation to the taking and use of groundwater, while promoting its use as a potential alternative to surface water. These recognise the need for groundwater to be available for reasonable domestic, stock watering and firefighting needs, as required by section 14(3) of the RMA, subject to the taking or use not resulting in any adverse effects on the environment.

The main method of policy implementation is through the Regional Freshwater Plan for Taranaki (2001) (the RFWP), which sets out regional rules to allow, regulate and avoid adverse effects on the environment from the taking and use of groundwater. Under Rule 48 of the RFWP, the taking of groundwater of up 50 m^3/day, at a rate not exceeding 1.5 L/s, is permitted, providing several conditions are met. Takes exceeding this volume or rate, or not meeting all associated conditions, require a resource consent. Through the consenting process, the matters set out for consideration under the RPS are assessed, as are the wider environmental effects of any proposed take.

The Council also undertakes a comprehensive programme of consent compliance monitoring. This includes the monitoring of consents authorising the taking of groundwater. The range of monitoring carried out is dependent on the risk associated with the specific take, but in most instances will include requirements to record the volumes of water taken and/or the rates of take. The recording of specific take data is also a requirement under the Resource Management (Measuring of Water Takes) Regulations (2010) for any take exceeding 5 L/s. In any addition to these requirements, the Council may also require monitoring of water levels in a pumping bore, or surrounding bores. The monitoring of groundwater levels is the primary means of assessing the effects of a groundwater take, be those of a specific take or the cumulative impact of multiple takes within an aquifer unit.

1.3 Groundwater quantity monitoring programme

The groundwater quantity monitoring programme is an amalgamation of two SEM groundwater monitoring programmes that were previously delivered separately by the Council, namely the pressures on groundwater resources and groundwater levels monitoring programmes. The two programmes have been amalgamated to provide a more integrated assessment of groundwater allocation pressures and the potentially observable impacts of groundwater takes (reduced groundwater levels).

The revised programme is comprised of two primary components. These include the desk based assessment of groundwater allocation volumes, based on a review of consent information and records held within the Council's water accounting system, and the operation and assessment of data from a regional groundwater level monitoring network.

This is the first report prepared under the revised programme structure.

2 Regional hydrogeology

The Taranaki region hosts an extensive groundwater resource that is widely utilised for potable water supply (predominantly domestic and limited municipal), agricultural (stock water and irrigation) and industrial usage. Aquifer bearing formations can be generally characterised into those of Quaternary and Tertiary age. Figure 1 illustrates the geographical distribution of the major geological units in Taranaki. The aquifer systems in Taranaki are informally named after the geological units they occur in.

Figure 1 Distribution of the main geological units (aquifers) of the Taranaki region (Brown, 2013)

2.1 Taranaki volcanics formation

Quaternary aged volcanic deposits cover a wide area of the Taranaki region, extending from the coastal boundary in the west, to the Tertiary deposits of the Taranaki basin in the east, and bounded to the north and south by the Quaternary marine terrace deposits.

The Taranaki volcanic deposits contain both coarse material (sands, breccia and agglomerates) and fine material (clay, tuff and ash), resulting in irregular lithologies and anisotropic hydrogeologic conditions (Taylor and Evans, 1999). These result in a complex system of unconfined, perched and semi confined aquifers within the volcanic deposits. The water table in the ring plain, which extends radially from Mount Taranaki, is typically encountered between 1 to 10 m below ground level. Seasonal variations in water table depth of up to 5 m are common. Groundwater flow generally reflects surface topography and flows radially from Mount Taranaki. Recharge to the Taranaki volcanic aquifers is mainly by local rainfall infiltration.

Shallow wells and bores drawing water from unconfined aquifers in the volcanics typically yield in the range 0.5-2.5 L/s. Higher yielding confined aquifers are reported from volcanic aquifers in the Kaitake Ranges (19 L/s), New Plymouth (10 L/s), Okato (20 L/s) and Kapuni (8 L/s).

Shallow, unconfined groundwater systems within the Taranaki volcanics also provide baseflow to the many of the rivers and streams that traverse the Taranaki ring plain. A number of streams rising both within the National Park and at lower elevations across the ring plain are known to be spring fed, although the most significant contributions from groundwater occur at elevations within Egmont National Park.

2.2 Marine terrace formations

The marine terrace deposits occur in coastal areas south of Hawera and, to a lesser extent, the coastal areas north of New Plymouth. Basal units are typically marine sands often with conglomerate or shell layers, grading upward to terrestrial sediments.

The marine terrace sediments range up to about 40 m in thickness and contain multiple unconfined aquifers. The water table within the marine terraces generally lies between 1 to 15 m below ground level. Recharge to the marine terrace aquifers is primarily by local rainfall infiltration.

Numerous shallow wells and bores draw from unconfined aquifers contained within the marine terraces, with yields in the range 0.3-2.6 L/s. No confined aquifers occur in the marine terraces.

2.3 Tertiary sedimentary formations

Nine Tertiary sedimentary formations are recognised in the region. The formations as a whole are gently tilted towards the southwest. Seven formations are exposed in the eastern Taranaki hill country and continue beneath the volcanics and marine terraces, while two (Otunui and Mt. Messenger) are fully exposed.

Little is known about groundwater use in the Otunui and Mt. Messenger formations. The Urenui Formation is regarded as an aquiclude/aquitard, and as such is not aquifer-bearing. In all of the other formations, shallow wells and bores draw from unconfined aquifers, and at depth the same formations host more productive confined aquifers.

Higher yielding confined aquifers are reported from the Kiore Formation at Bell Block (35 L/s), Matemateaonga Formation at Kapuni and Eltham (7-20 L/s) and the Whenuakura Formation at Patea and Waverley (8-10 L/s).

2.4 Rainfall and climate variability

The Taranaki region receives regular rainfall throughout the year as a result of its westerly position, its mid-latitude location and topography. Average annual rainfall volumes across the region range from approximately 1,000 mm along some southern coastal margins to in excess of 7,000 mm on the upper slopes of Mount Taranaki. Rainfall volumes increase rapidly with elevation away from the coast and in the Taranaki hill country (Figure 2). The high rainfall volumes across Taranaki generally result in rainfall surpluses being available to recharge the region's groundwater systems, particularly where aquifer recharge zones are located in elevated areas, be it off Mount Taranaki or the eastern hill country.

Variation in global climate patterns have the potential to affect the volume of rainfall seen in Taranaki, as it does elsewhere. The predominant processes include the El Niño-Southern Oscillation cycle (ENSO) and the Inter-decadal Pacific Oscillation (IPO). ENSO and the IPO are natural cycles that operate over timescales of years and decades, respectively.

The ENSO cycle results in interchanging El Niño and La Niña weather patterns. In El Niño years, Taranaki tends to experience reduced rainfall volumes as a result of increased southerly and south-westerly flows. The opposite occurs during La Niña events, where increased occurrences of westerly flows result in higher rainfall volumes being recorded, particularly during winter and spring, and a greater occurrence of heavy rainfall events, often associated with subtropical lows coming from the north Tasman (NIWA, 2008).

The Inter-decadal Pacific Oscillation (IPO) is a Pacific-wide natural fluctuation in the climate, which causes shifts in Pacific Ocean circulation patterns. There are two IPO phases, positive and negative, with phase changes experienced every 20-30 years. In the positive phase, westerly quarter winds over the country and anticyclones in the north Tasman are more prevalent. The most recent IPO reversal occurred 1999-2000, with a shift to a negative phase. This would be expected to encourage more La Niña activity (NIWA, 2008). Thompson et al. (2006) examined rainfall figures from New Plymouth during two distinct IPO phases and concluded that rainfall producing processes at New Plymouth and in the surrounding districts in North Taranaki were not being influenced to any great extent by the phase of the IPO.

Climate change also has the potential to influence future rainfall patterns in Taranaki. While there is a large degree of uncertainty in climate change projections and impacts based on future emissions trajectories, current projections are that Taranaki will see little change in its annual rainfall by mid-century (2050) and a slight increase by 2100. The highest increase in rainfall is likely to be seen in winter months, while there may be small reductions in rainfall during other seasons. It is not currently projected that Taranaki will experience any increase in drought severity through to 2100 (MfE, 2018). Based on the available information, it is not predicted that climate change effects will significantly alter groundwater recharge volumes over the time-scales of current climate change projections.

2.1 Estimates of recharge and sustainable groundwater yields

For the purposes of groundwater accounting, the region has been subdivided into smaller scale groundwater zones. This has been achieved by firstly dividing the region into the four freshwater management units (FMUs) currently proposed by Council in the draft Freshwater and Land Plan for Taranaki (Figure 3). Within each of the four FMUs, groundwater systems are further subdivided by formation into groundwater zones. As FMU boundaries do not necessarily align with geological unit boundaries, many large aquifers span multiple FMUs. The groundwater zone structure is set-out in Figure 4.

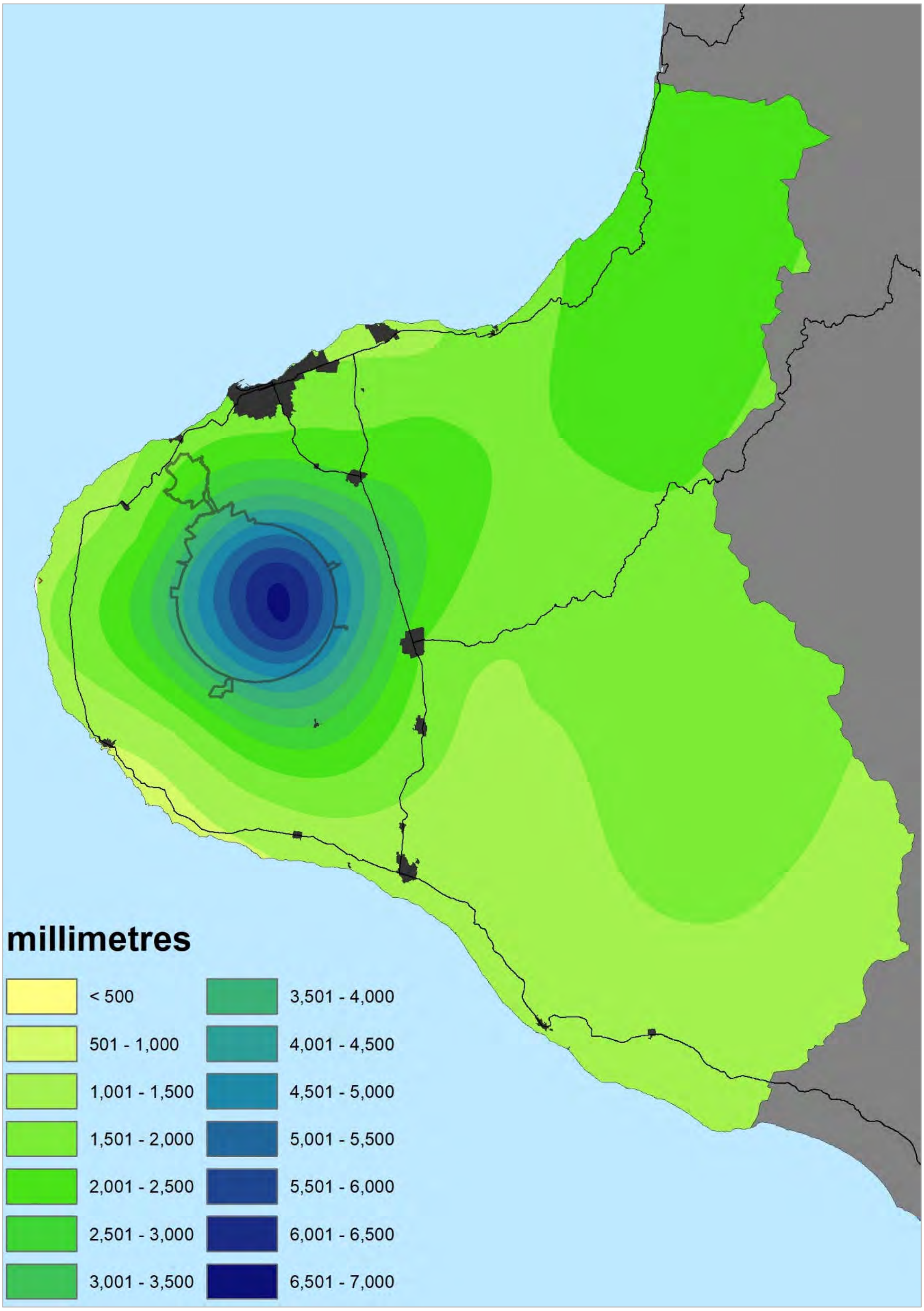


Figure 2 Patterns of rainfall distribution across Taranaki and average annual volumes (2012-2017)

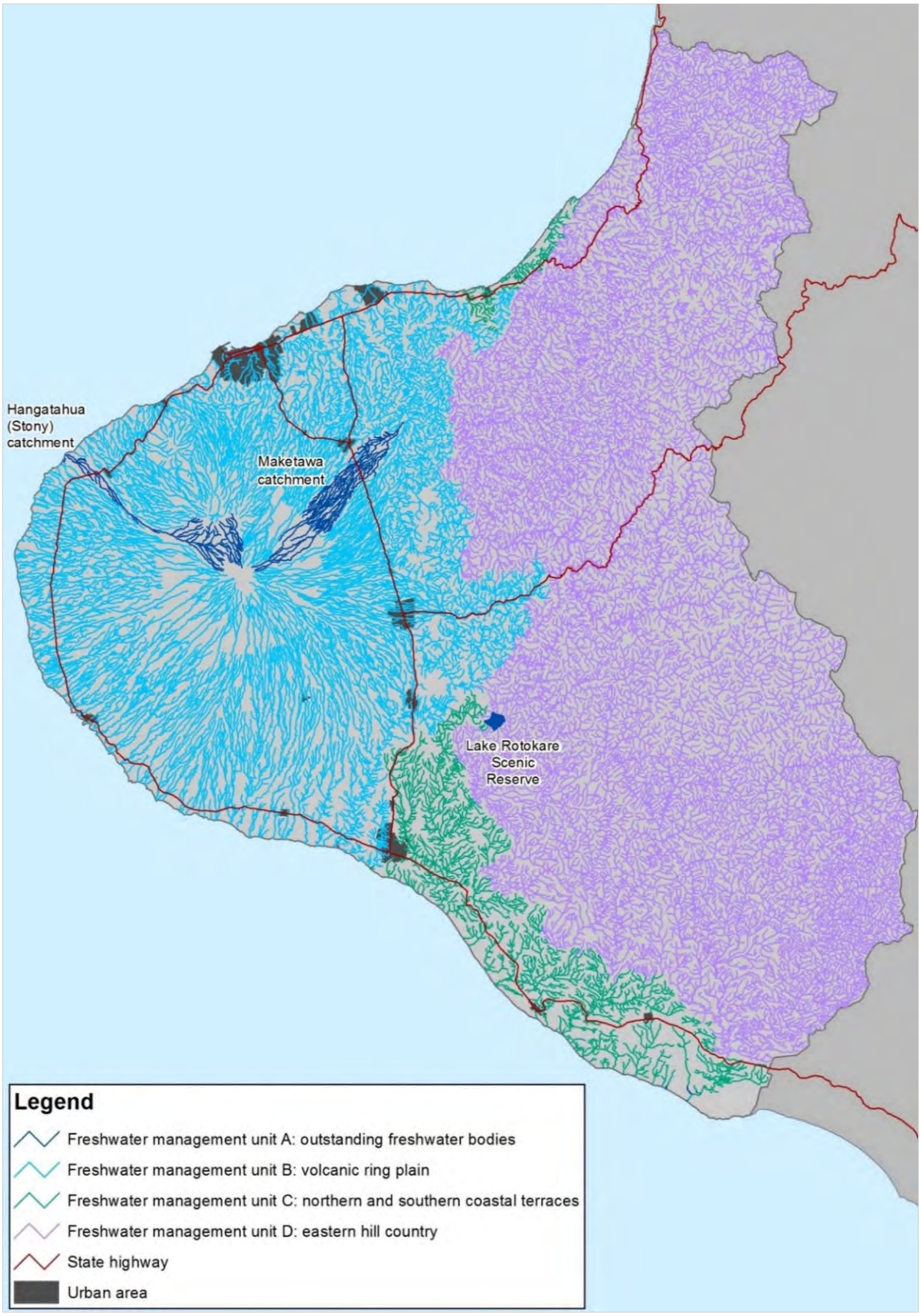


Figure 3 Proposed Freshwater Management Units for the Taranaki region

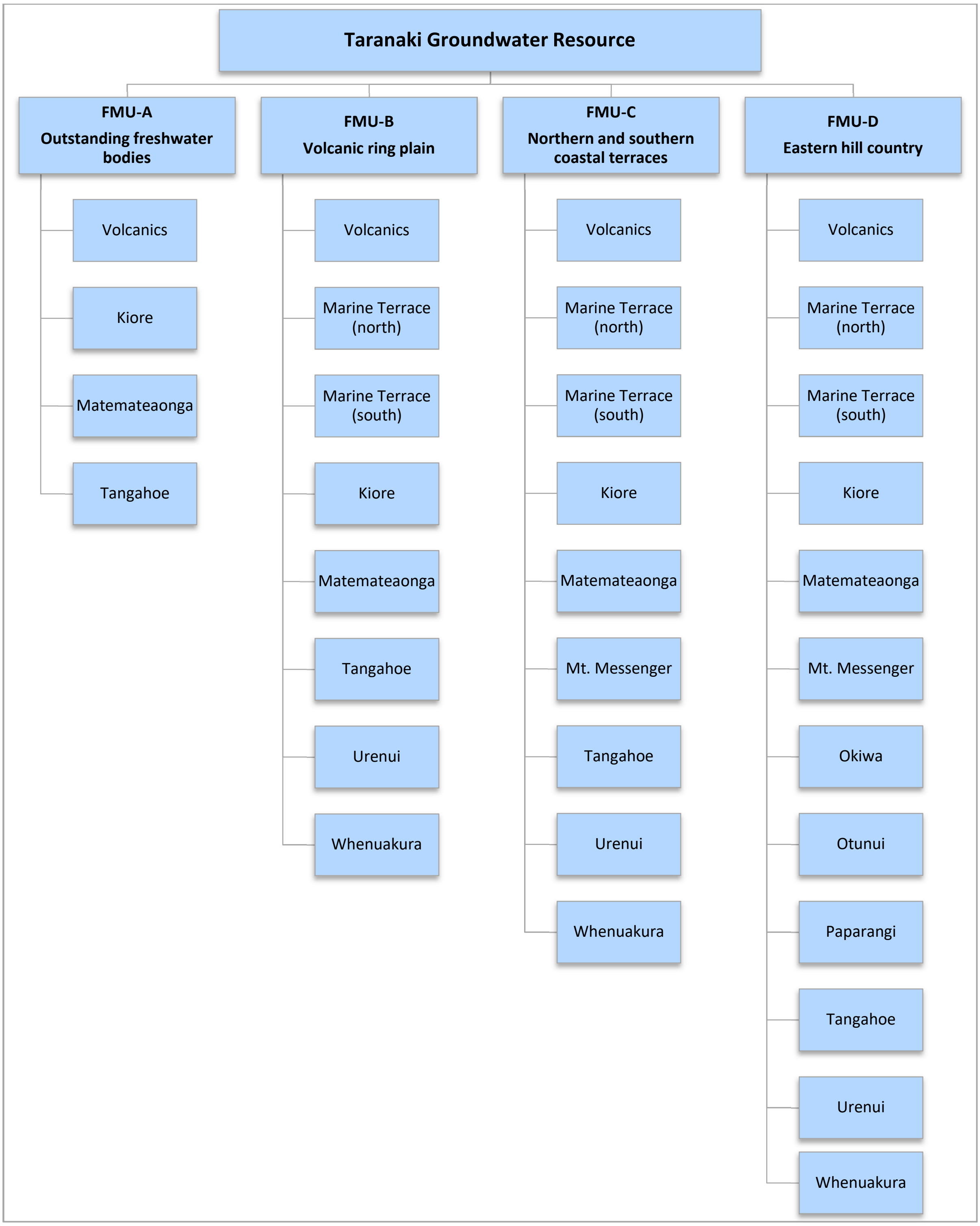


Figure 4 Groundwater zone structure for water accounting purposes

An estimate of sustainable yield has been calculated for each of the groundwater zones (TRC, 2018). These have been calculated by estimating the amount of rainfall likely to recharge each hydrogeological unit (aquifer), on an annual basis. The calculations are therefore based on conservative estimates of 'new' water entering each hydrogeological unit, each year.

The total volume of rainfall potentially recharging each unit was calculated by multiplying average annual rainfall figures by the spatial area of each hydrogeological unit receiving direct recharge from rainfall (i.e. unconfined areas of an aquifer exposed at surface). Sustainable yields have been conservatively set at 15%

of the total average annual rainfall (Table 1). In other words, it is assumed that the remaining 85% of rainfall either evaporates, is discharged as surface run-off or replenishes groundwater storage.

Table 1 Estimates of sustainable yields calculated for all hydrogeological units

Geological age	Hydrogeological unit	FMU-A (ML/yr)	FMU-B (ML/yr)	FMU-C (ML/yr)	FMU-D (ML/yr)	Unit total (ML/yr)
Quaternary	Volcanics	75,079	803,516	2,876	915	**82,387**
	marine terrace (north)	x	32,041	11,604	14,161	**57,805**
	marine terrace (south)	x	8,175	81,788	48,226	**138,189**
Tertiary	Kiore	4,433	89,617	1,162	125,033	**220,245**
	Matemateaonga	9,292	90,438	228	137,131	**237,088**
	Mt. Messenger	x	x	41	199,984	**200,025**
	Okiwa	x	x	x	1,073	**1,073**
	Otunui	x	x	x	53,111	**53,111**
	Paparangi	x	x	x	14,184	**14,184**
	Tangahoe	1,048	67,455	4,358	64,381	**137,243**
	Urenui	x	33	8,492	56,706	**65,231**
	Whenuakura	x	35,191	28,034	38,753	**101,978**
FMU Total		**89,851**	**1,126,468**	**138,583**	**753,657**	**-**

Note: x = hydrogeological unit not present with FMU

3 Groundwater allocation

Groundwater abstraction primarily occurs across a small number of the region's potentially water bearing hydrogeological units, where overlying land use or development has necessitated a particular water supply need that cannot be adequately met by municipal or community supply, or a surface water abstraction.

The typically low yields associated with the region's shallow unconfined aquifers mean that abstraction from wells penetrating them is generally only suitable for low demand uses. As a result, the majority of abstractions from these aquifers are likely to be permitted under rules set out in the RFWP, which set out limits in terms of abstraction rate and volume. The total volume of groundwater allocated across Taranaki is comprised of takes permitted by the RFWP and those authorised by a resource consent.

Estimates of potential permitted take demands were recently developed by the Council, as part of its water quantity accounting system development project. Further details of the methodology used to develop these permitted take estimates can be found in the report detailing this work (TRC, 2017). In summary though, an overall potential permitted take demand was estimated at a catchment basis, based on livestock and dairy shed water demands. The total estimated permitted take demand was proportioned between surface and groundwater sources. The permitted groundwater take estimates were also aggregated and apportioned by hydrogeological unit. This includes an estimate of the volume of permitted groundwater takes sourced from both unconfined aquifers and areas of Tertiary aquifers confined by overlying Quaternary hydrogeological units.

The volume of water allocated through resource consents was calculated using consents data stored in the Council's IRIS database. A total of 61 consents authorising the taking of groundwater were current as of 30 June 2017. The locations of all consented groundwater abstractions are set out in Figure 5. The special conditions attached to each of these consents vary, as a result of standard consent conditions evolving over time. All current consents to abstract groundwater have either a take rate or volume restriction or, in some cases, a combination of both.

Where volume limits are stipulated in the conditions of a consent, this figure was used to calculate the volume of water that could potentially be taken under the consent on an annual basis. Where a take was restricted by rate, the maximum authorised rate of take has been used to calculate the volume of water that could potentially be taken under the consent over the course of a year. Both calculations assume that each take is fully utilised, that is, the maximum volume is taken on a daily or weekly basis, or abstraction occurs 24 hours a day, 365 days of the year for those consents which only specify a limit on the rate of take. Both of these scenarios are highly unlikely, and therefore the calculated usage figures likely represent an overestimation of actual water use.

Table 2 summarises the current levels of groundwater allocation against estimated sustainable yields. The assessment is made for each groundwater zone (as per Figure 4).

The implications and significance of this data is discussed in Section 6.1 of this report.

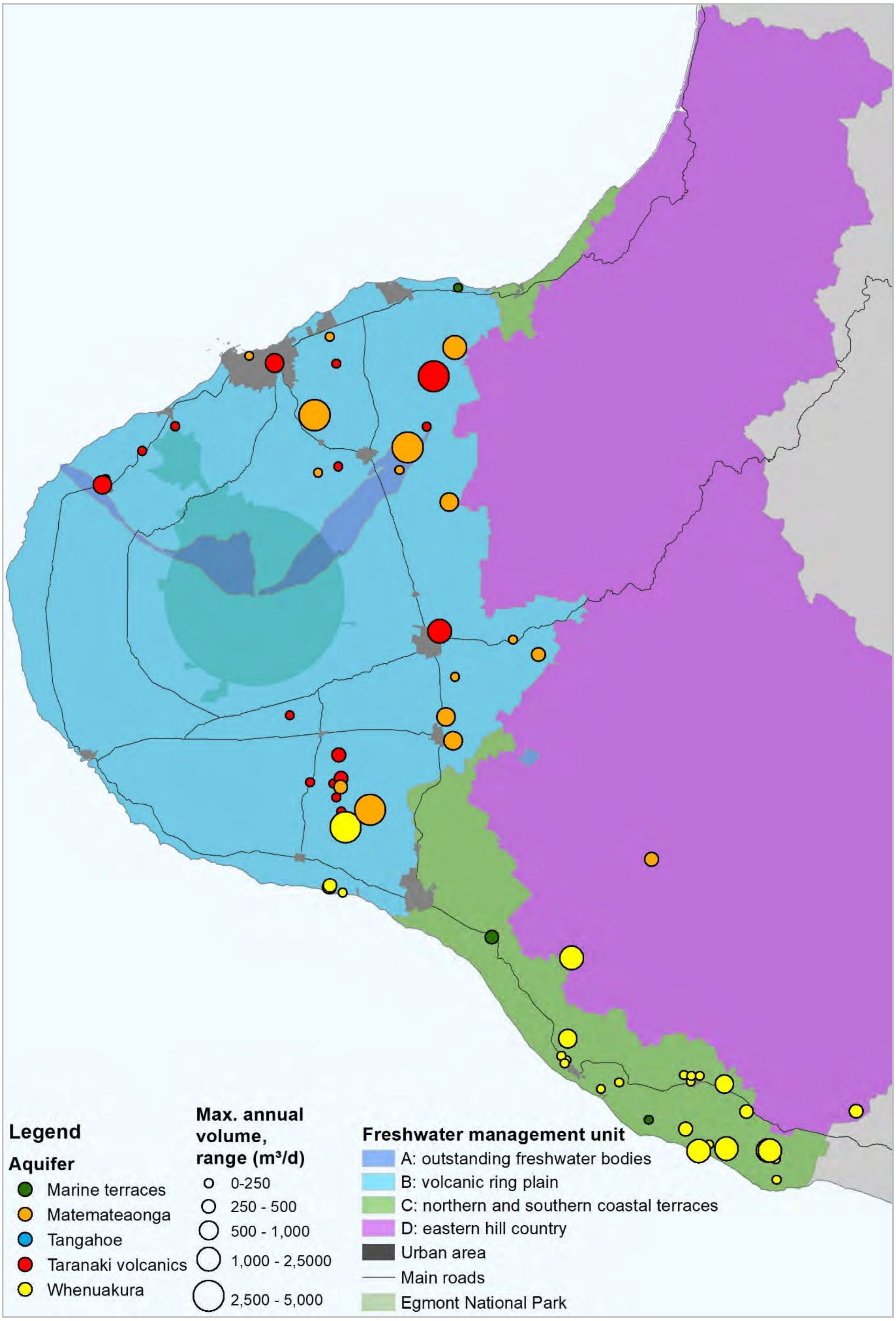


Figure 5 Locations of consented groundwater abstractions as of 30 June 2017

Table 2 Current levels of groundwater allocation across Taranaki in comparison to calculated sustainable yields for each hydrogeological unit within each FMU (as at 30 June 2017)

Geological age	Hydrogeological unit	FMU-A (ML/yr)			FMU-B (ML/yr)			FMU-C (ML/yr)			FMU-D (ML/yr)		
		Sustainable yield	Allocated	% allocated	Sustainable yield	Allocated	% allocated	Sustainable yield	Allocated	% allocated	Sustainable yield	Allocated	% allocated
Quaternary	Volcanics	75,079	52	0.1	803,516	5,221	0.6	2,876	8	0.3	915	0.4	0.0
	marine terrace (north)	x	x	x	32,041	97	0.3	11,604	31	0.3	14,161	6	0.0
	marine terrace (south)	x	x	x	8,175	28	0.3	81,788	452	0.6	48,226	29	0.1
Tertiary	Kiore	4,433	2	0.0	89,617	60	0.1	1,162	0	0.0	125,033	88	0.1
	Matemateaonga	9,292	259	2.8	90,438	3,618	4.0	228	0.3	0.1	137,131	102	0.1
	Mt. Messenger	x	x	x	x	x	x	41	0	0.0	199,984	71	0.0
	Okiwa	x	x	x	x	x	x	x	x	x	1,073	3	0.3
	Otunui	x	x	x	x	x	x	x	x	x	53,111	18	0.0
	Paparangi	x	x	x	x	x	x	x	x	x	14,184	15	0.1
	Tangahoe	1,048	0.7	0.1	67,455	65	0.1	4,358	5	0.1	64,381	63	0.1
	Urenui	x	x	x	33	0	0.0	8,492	0	0.0	56,706	0	0.0
	Whenuakura	x	x	x	35,191	3,232	9.2	28,034	3,875	13.8	38,753	211	0.5

Note: x = hydrogeological unit not present with FMU

4 Regional groundwater level monitoring network

The monitoring of groundwater levels enables the Council to examine the relationships between groundwater recharge and discharge within regional groundwater and surface water systems. Where recharge volumes exceed those discharged, groundwater levels rise. Conversely, if discharge volumes exceed recharge, groundwater levels fall. Fluctuations in recharge are predominantly related to climatic patterns, but can also be artificially influenced by activities such as pasture irrigation onto recharge areas. Discharge volumes are influenced by both natural processes, such as flow from springs and groundwater seepage to rivers and the coast, and the removal of groundwater by abstraction.

The Council monitors groundwater levels at 15 sites across the region. Nine of these sites are classified as long-term sites, where data has been collected for in excess of eight years. Six further sites have been added to the programme since 2012 to improve the spatial coverage of the monitoring network.

The monitoring network now includes sites in all of the region's water bearing formations that are targeted for water supply, but site distribution remains targeted toward areas of greater water use pressure (FMU-B and FMU-C). There are currently no level monitoring sites located within FMU-A or FMU-D, where little groundwater abstraction occurs. The monitoring network includes sites of varying depth in order to monitor water level fluctuations in both unconfined and confined groundwater systems.

The network includes two multi-well monitoring sites, located south of Eltham (sites GND0599 and GND0600) and at Patea (sites GND2252 and GND2253). At each of these sites, two wells have been installed in close proximity to monitor vertically separated aquifer units.

Table 3 sets out the distribution of sites included in the monitoring network by FMU. Specific details of each site are provided in Table 4 and their respective geographical locations are illustrated in Figure 6.

Table 3 Distribution of groundwater level monitoring sites by FMU across Taranaki (Hydrogeological units in bold text represent those with the greatest level of water use pressure)

Hydrogeological unit	Number of monitoring locations			
	FMU-A	FMU-B	FMU-C	FMU-D
Volcanics	0	4	0	0
marine terrace (north)	x	1	0	0
marine terrace (south)	x	0	1	0
Kiore	0	0	0	0
Matemateaonga	0	2	1	0
Mt. Messenger	x	x	0	0
Okiwa	x	x	x	0
Otunui	x	x	x	0
Paparangi	x	x	x	0
Tangahoe	0	1	0	0
Urenui	x	0	0	0
Whenuakura	x	1	4	0

Note: x = hydrogeological unit not present with FMU

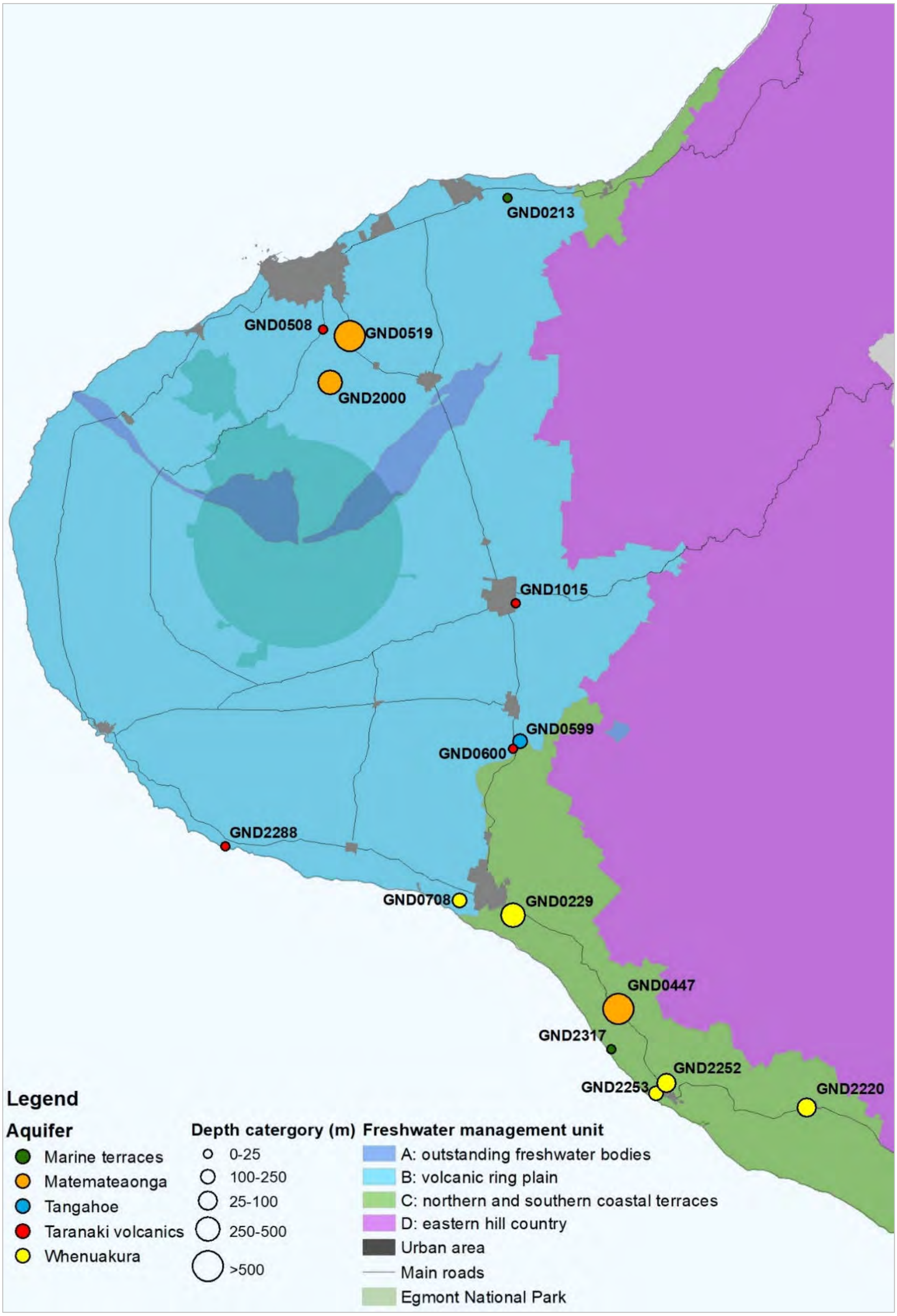


Figure 6 Monitoring site locations

Table 4 Details of sites included in the regional groundwater monitoring network

Site code	Name	Altitude (m AMSL)	Total depth (m BGL)	Screened interval (m BGL)	FMU	Aquifer	Aquifer type	Total length of data record (Years)	Period of manual data records	Period of continuous data records
GND0213	Motunui	54	22	18 - 21	B	marine terrace (north)	Unconfined	34	-	10 Jan 83 - current
GND0229	Kiwi-1	95	297	68 - 297	C	Whenuakura	Confined	19	29 May 98- 10 Jun 14	10 Jun 14 – current
GND0447	Manutahi-1	82	1,383	542 - 562	C	Matemateaonga	Confined	23	28 Oct 94 - 19 Mar 13	19 Mar 13 – current
GND0508	Carrington Rd.	120	14	8 - 14	B	Taranaki volcanics	Unconfined	14	25 Jun 03- 12 Dec 12	12 Dec 12 – current
GND0519	Mangamahoe-1	145	795	644 - 766	B	Matemateaonga	Confined	22	28 Oct 94 - 27 Sep 13	27 Sep 13 – 13 Jan 16*
GND0599	Eltham-7	216	83	79 - 82	B	Tangahoe	Confined	21	17 Dec 96 - 22 Mar 13	22 Mar 13 – current
GND0600	Eltham-7A	216	20	16 - 19	B	Taranaki volcanics	Unconfined	21	26 Nov 96 - 22 Mar 13	22 Mar 13 – current
GND0708	Nolan Rd.	70	94	82 - 94	B	Whenuakura	Confined	19	28 Jul 98 - 22 Mar 13	22 Mar 13 – current
GND1015	Stratford Landfill BH3	300	8	2 - 8	B	Taranaki volcanics	Unconfined	2	-	30 Jun 15 – current
GND2000	Scout Rd.	251	464	228 - 291	B	Matemateaonga	Confined	8	-	11 Jun 13 – current
GND2220	STDC Swinbourne St.	90	200	123 - 172	C	Whenuakura	Confined	5	-	28 Nov 12 – current
GND2252	Patea Sentinel (Lower)	37	154	148 - 154	C	Whenuakura	Confined	5	-	22 Nov 12 – current
GND2253	Patea Sentinel (Upper)	37	96	93 - 96	C	Whenuakura	Confined	5	-	22 Nov 12 – current
GND2288	Oeo Landfarm	39	7	4 – 7	B	Taranaki volcanics	Unconfined	2	-	27 Aug 15 – current
GND2317	Vanners Landfarm	31	13	8 - 13	C	marine terrace (south)	Unconfined	2	-	21 Dec 15 – current

* Equipment failure resulted in lost data between 13 Jan 2016 and 30 June 2017

4.1 Data collection

The method of water level data collection and frequency is variable across the network and by site. Historically, water level measurements at long-term monitoring sites (with the exception of GND0213) were obtained by manual water level measurement, at approximately monthly intervals. In some cases, collection of these manual measurements was intermittent which has resulted in gaps in the data record at some sites.

Data at site GND0213 has been recorded electronically since 1983 using a pressure transducer. Since records began, the frequency of measurement at the site has ranged from weekly to 15 minute intervals.

From 2012, pressure transducers were installed at all monitoring sites to enable the electronic measurement and recording of water level data. Data across all sites is now recorded at 15 minute intervals. Water level data is downloaded from the sites at quarterly intervals. The electronic level measurements are compensated for both barometric pressure and manual water level measurements taken at the time of the data download.

All groundwater level measurements are referenced to a standard datum of metres above mean sea level (m AMSL).

The groundwater level data is stored in the Council's time series data management system.

5 Results

5.1 Influences on observed groundwater level fluctuation

Almost all monitored sites show some fluctuation in groundwater levels as a result of seasonal variation in rainfall volumes and discharge processes. Given that the majority of groundwater recharge occurs during winter and spring, it is common to see annual peaks in groundwater levels over these periods. Conversely, when rainfall volumes reduce over summer, and soil moisture deficits are high, groundwater levels decline. As a result, minimum levels are generally recorded in late summer/early autumn. Any variation in seasonal (or annual) drivers generally result in a corresponding groundwater level response. The Taranaki region generally receives regular and plentiful rainfall however, meaning aquifers are regularly replenished.

Table 5 presents a summary of the annual ranges in water levels observed at each monitoring location across the length of their respective data records. The minimum annual water level change represents the smallest difference between the highest and lowest water level recorded over a calendar year, over the course of a site's monitoring record. Conversely, the maximum range represents the largest difference in water level observed. The average annual water level range across all sites included in the monitoring network is illustrated in Figure 7.

Table 5 Summary of observed annual variations in observed water level by site across the monitoring network (sorted by min to max average annual range)

Site code	Name	Aquifer	Aquifer type	Minimum annual water level range (m)	Maximum annual water level range (m)	Average annual water level range (m)
GND0213	Motunui	marine terrace (north)	Unconfined	2.8	6.0	4.8
GND0229	Kiwi-1	Whenuakura	Confined	0.1	0.5	0.3
GND0447	Manutahi-1	Matemateaonga	Confined	0.1	0.4	0.2
GND0508	Carrington Rd.	Taranaki volcanics	Unconfined	1.6	5.3	3.4
GND0519	Mangamahoe-1	Matemateaonga	Confined	0.0	0.4	0.2
GND0599	Eltham-7	Tangahoe	Confined	0.4	1.6	0.9
GND0600	Eltham-7A	Taranaki volcanics	Unconfined	0.3	3.9	1.7
GND0708	Nolan Rd.	Whenuakura	Confined	0.2	1.5	0.7
GND1015	Stratford Landfill BH3	Taranaki volcanics	Unconfined	3.5	3.8	3.7
GND2000	Scout Rd.	Matemateaonga	Confined	0.2	0.8	0.4
GND2220	STDC Swinbourne St.	Whenuakura	Confined	7.1	11.5	9.2
GND2252	Patea Sentinel (Lower)	Whenuakura	Confined	0.4	1.8	1.1
GND2253	Patea Sentinel (Upper)	Whenuakura	Confined	0.4	1.3	0.9
GND2288	Oeo Landfarm	Taranaki volcanics	Unconfined	0.9	1.8	1.3
GND2317	Vanners Landfarm	marine terrace (south)	Unconfined	0.2	0.9	0.6

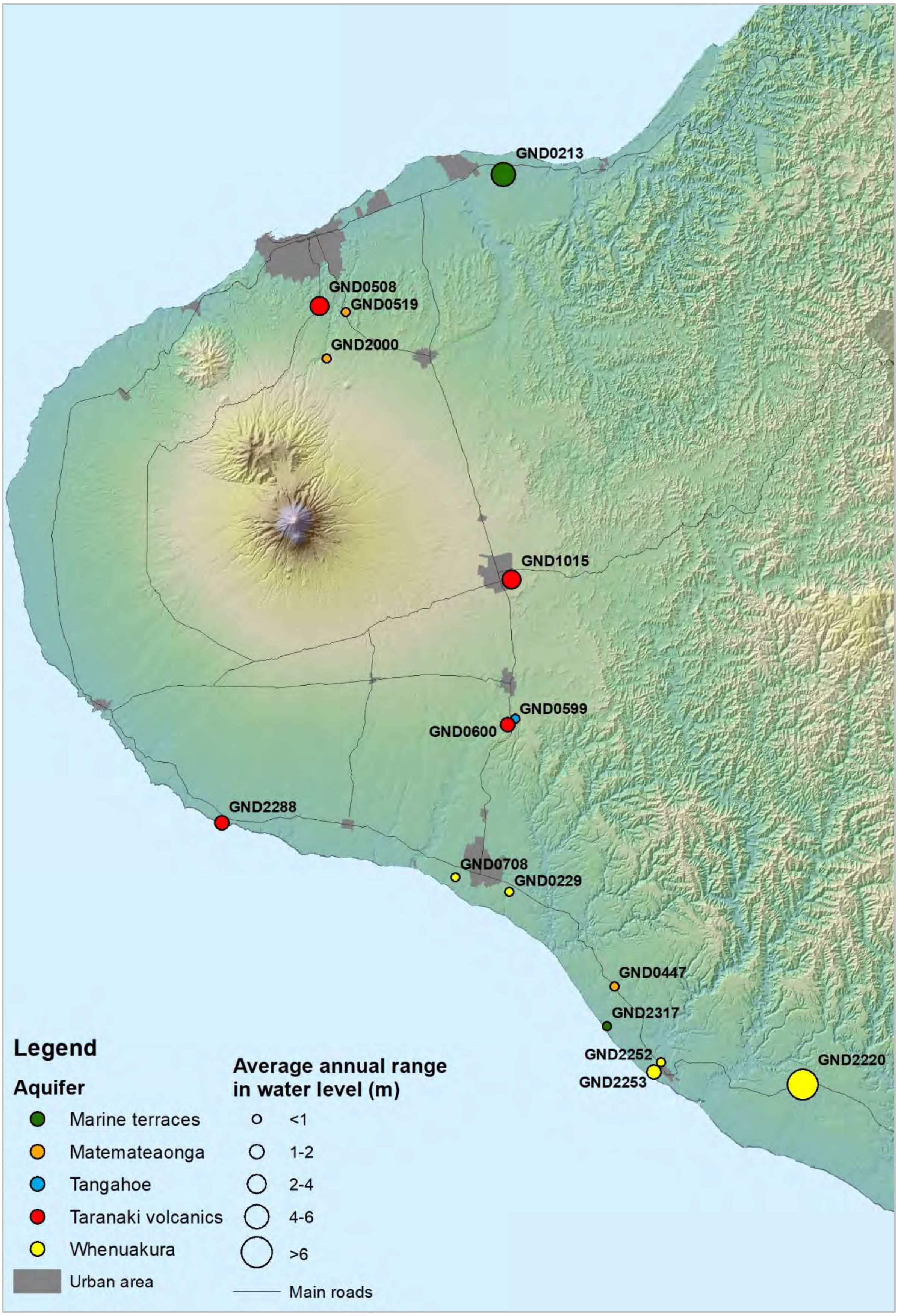


Figure 7 Plot showing observed ranges in average annual water level fluctuation by site and aquifer

The impact of seasonal fluctuations in rainfall recharge on groundwater levels are more subdued in confined aquifers, which are disconnected from direct rainfall recharge by overlying low permeability strata. As result, the magnitude of level fluctuations are typically much less than those seen in shallow unconfined groundwater systems, where the water table is close to the surface and receiving direct rainfall recharge. The magnitude of seasonal fluctuations and the speed of level response to rainfall is also influenced by factors other than aquifer confinement. These include the permeability and storage characteristics of strata in which the groundwater resides, its water storage capacity, the depth to the water table and the overlying land cover. Monitoring locations located close to a stable surface water boundary, such as a river or the sea, generally show less pronounced seasonal fluctuations in water level in comparison to similar sites located further away from such an influence. This is illustrated in the much smaller seasonal variations seen at shallow coastal sites in comparison to shallow sites located further inland.

Figure 8 presents a comparison of the water level response to rainfall at site GND0213, which intersects a shallow unconfined aquifer in the northern Marine Terrace, and site GND2253, which intersects a confined aquifer within the Whenuakura Formation at Patea. The figure illustrates the difference between these aquifers in terms of the speed and magnitude of response to rainfall events and associated recharge. Water level levels at site GND0213 show a rapid response to rainfall events. There is also pronounced seasonal pattern in the data from this site, with a range of up to 6 m between annual minimum and maximum water levels. The plot also illustrates that when low winter peak levels are recorded, the subsequent summer minima is often also reduced. This indicates the impact of variations in seasonal recharge on annual cycles in groundwater level, and the potential for compounding seasonal effects.

In comparison, the plot of water level data from site GND2253 shows very little correlation to local rainfall events. This is because the aquifer is disconnected from localised rainfall by its confining layer. While it is likely there is some leakage through the confining layer, the majority of recharge to the aquifer occurs where it is exposed at surface in the eastern hill country, several kilometres to the east of the site. While there is seasonality visible within the water level record, the magnitude of seasonal range in water level is much smaller, generally less than 1 m.

The variation in the range and fluctuation in water levels observed at these two sites is also clearly evident in the differing shape of the box plots for each site presented in Figure 9.

The factors described above can be characterised as 'natural' influences on groundwater levels. In addition to these, groundwater levels can also be significantly influenced by anthropogenic factors, most significantly the effects of groundwater abstractions. The effects of abstraction on water can occur over the both the short and long-term. In simplistic terms, the short-term impact of an abstraction is the localised drawdown (lowering) of groundwater levels as water is removed from the aquifer during pumping. If the volume of groundwater abstracted from an aquifer exceeds the volume of water recharging it, a long-term decline in groundwater level is likely. Natural and anthropogenic influences on groundwater levels generally combine during summer months to exacerbate effects, as water demand is high and aquifer recharge volumes are low.

Site GND2220 is an observation well located near South Taranaki District Council (STDC) Swinbourne Street production well (GND2242), which is part of the network of production wells that service the township of Waverly. The groundwater level data from the site is plotted alongside total daily abstraction data from the Swinbourne Street production well in Figure 10. The short-term effects of the abstraction on local water levels is evident in the steep and repeated drawdown of water level when abstraction is occurring. The magnitude of the water level drawdown at site GND2220 is in the range of 5 to10 m. The water level trace from the site is typical of abstraction influence, whereby a rapid drop in water level occurs on pump start-up, followed by gradually reducing rate of drawdown over time as the pumping and aquifer recharge rates approach an equilibrium. The plot also illustrates the rapid initial recovery in water levels when pumping stops, with the recovery rate reducing over time. While the data from site GND2220 illustrates the short-term drawdown and recovery of water levels at the site in response to abstraction, further analysis of the data shows that water levels are stable over the longer-term, indicating a sustainable level of abstraction from the aquifer. The analysis of trends in water level is discussed further in the following sections of this report.

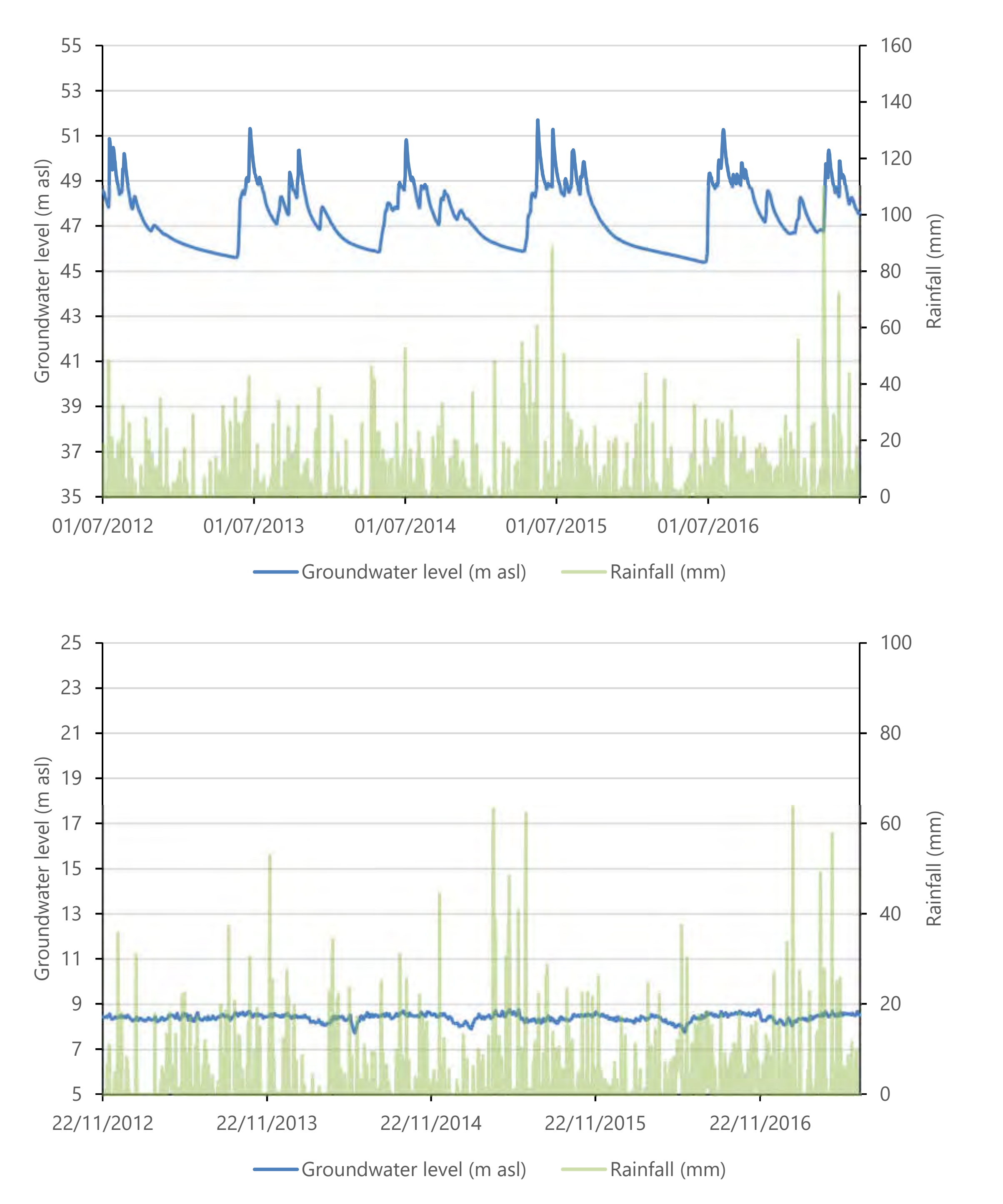


Figure 8 Comparison of hydrographs from sites GND0213 (top) and GND2253 (bottom) illustrating variation in observed water level fluctuation in response to rainfall between unconfined (GND0213) and confined aquifers (GND2253)

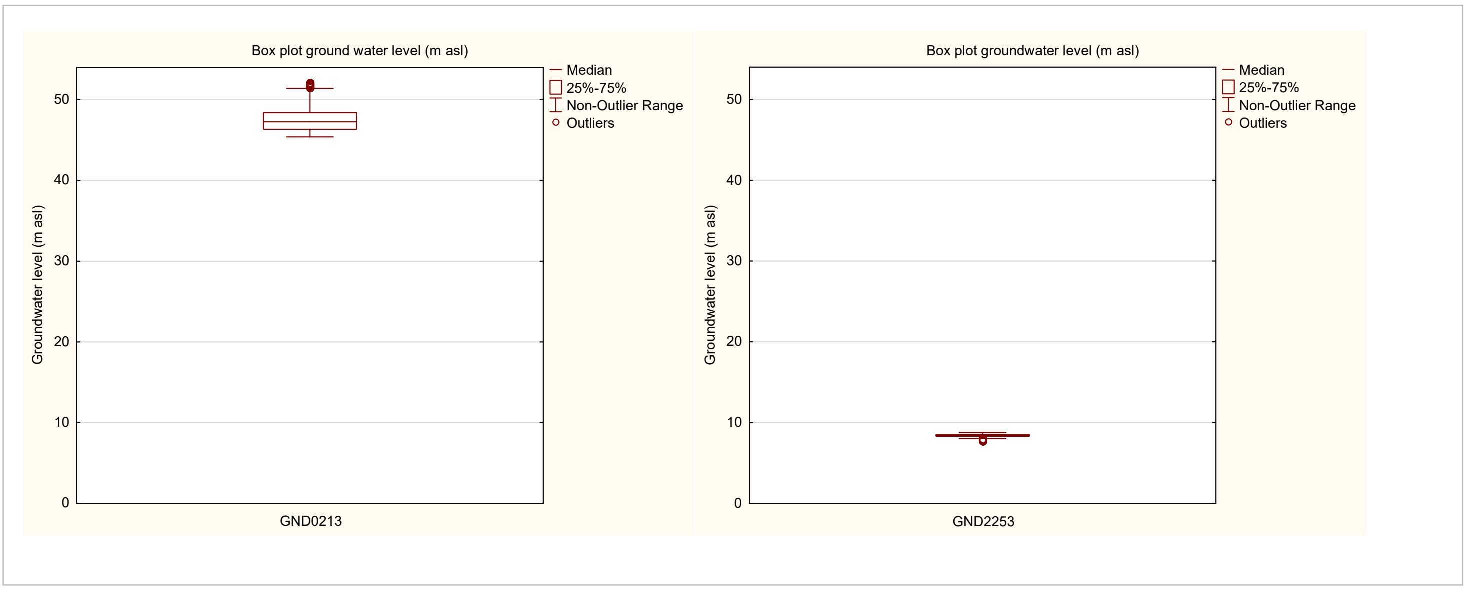


Figure 9 Comparative box plots from GND0213 (L) and GND2253 (R) illustrating variation in observed water level fluctuation between unconfined (GND0213) and confined aquifers (GND2253)

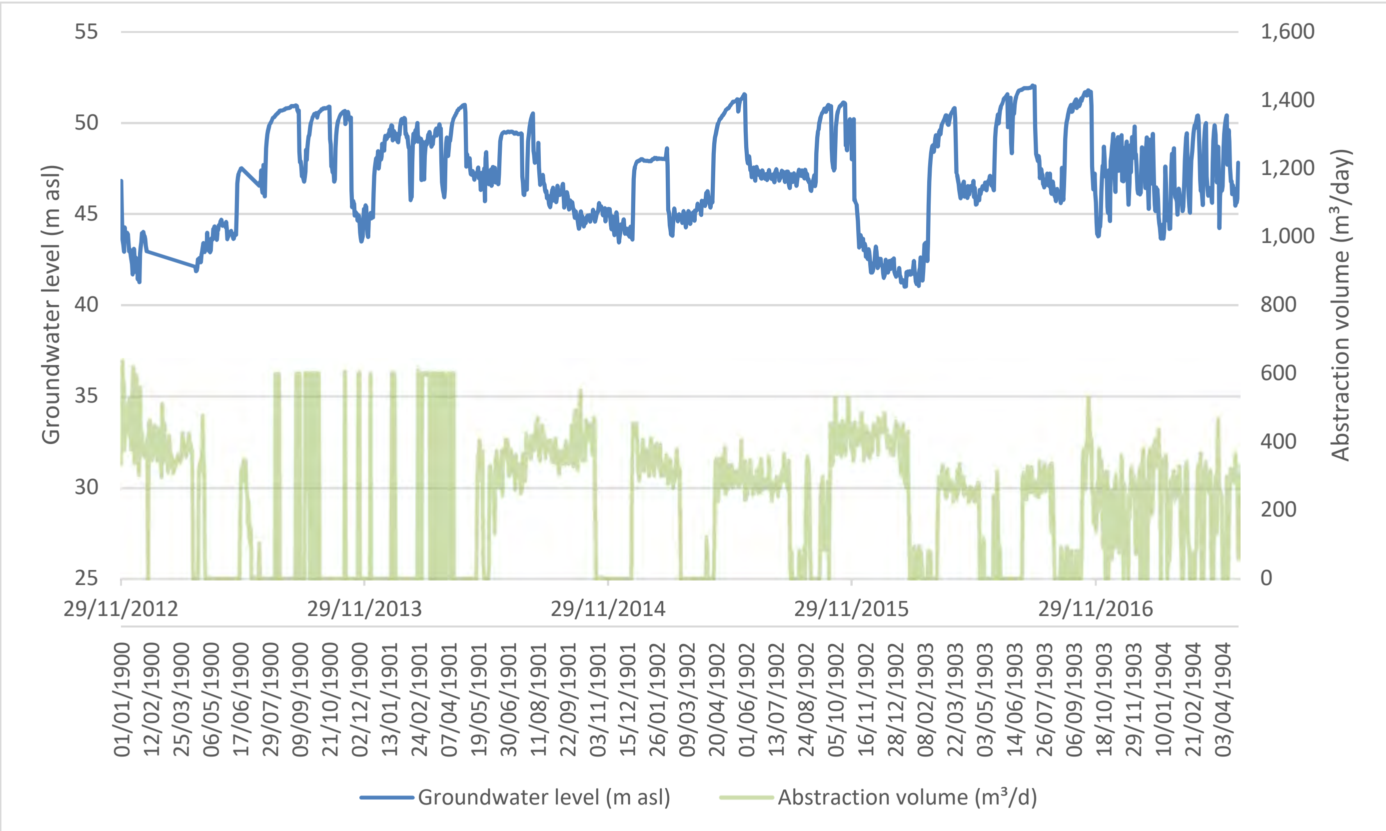


Figure 10 Water level data from GND2220 plotted against the total daily abstraction volume from the Swinbourne St. water supply well (GND2242)

5.1 Current state of water levels at monitored sites (2015-2017)

The current state of groundwater levels across the region have been assessed using the most recent two years of data analysed (2015-2017). Averaging data over a two yearly time period for the assessment of state is consistent with the reporting frequency of this programme and reduces the influence of extremes experienced over any single year. The data analysed is presented in the form of envelope plots. These plots compare mean monthly groundwater levels over the 2015-2017 period with the mean monthly levels averaged over a site's entire data record. Also plotted are the historical monthly minimum and maximum levels, which provide further context when assessing recent data. Plots have been compiled for each site with a long-term data record, with the exception of site GND0519 where equipment failure resulted in the loss of recent data (Figure 11). For consistency with the statistical analysis presented in the following section of this report, a long-term record is defined as being a minimum of eight years.

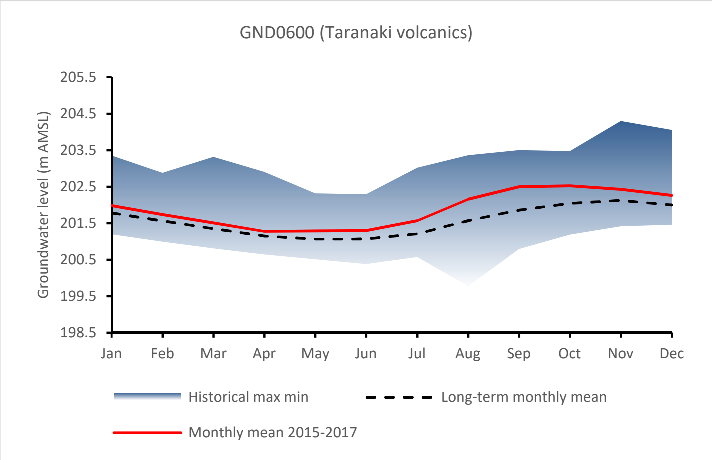
Across the majority of sites intersecting confined aquifers, current groundwater levels do not differ significantly from historical long-term averages at each monitored site. Where there are small observable deviations from historical averages, there is no consistent pattern across sites or aquifers. Sites within the Matemateaonga aquifer show increased (GND0447) spring water levels when compared to historical data, while at site GND2000 they were however consistent with historical averages for spring, but higher during winter months. Within the Whenuakura aquifer, there was very little deviation in away from historical averages at site GND0229. Within the same aquifer, site GND0708 showed reduced winter water levels and summer values close to historical minimums. Trends in water level observed at site GND0708 are discussed further in the following section of this report.

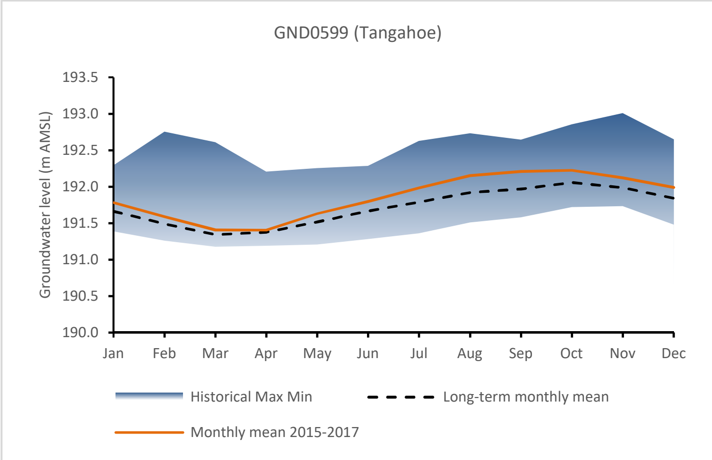
Current water levels at sites intersecting unconfined aquifers display a greater degree of similarity in their recent variations in water level compared to historical averages. There are also a greater degree of similarity in monthly patterns observed across sites, compared to those observed at confined aquifer sites. This is to be expected given that recharge to these aquifers is provided by localised rainfall. If sites experience similar rainfall patterns, then similar level responses are more likely.

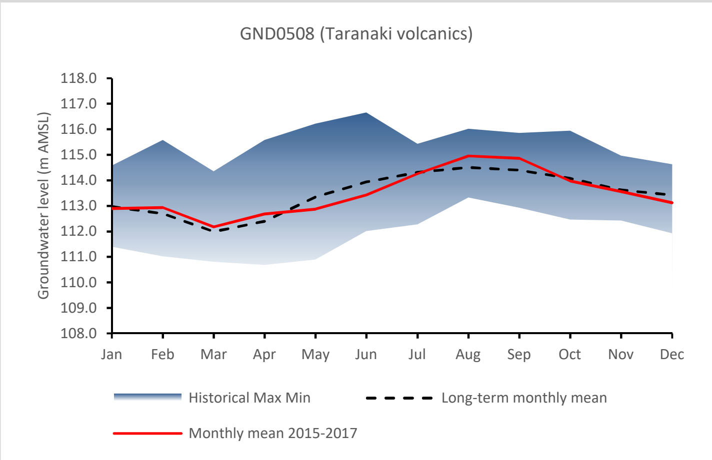
Water levels in the unconfined Taranaki volcanics (GND0600 and GND0508) and northern marine terrace aquifers (GND0213) all show recent summer water levels slightly above long-term averages. Sites GND0508 and GND0213 also show similar monthly patterns in groundwater levels, with both having recent winter water levels below those seen historically. Conversely, early spring highs at both sites exceeded historical averages for that time of year. Both of these sites are located in North Taranaki and are therefore exposed to similar rainfall patterns. The similarity observed across these sites in recent times are also evident in their long-term monthly mean values.

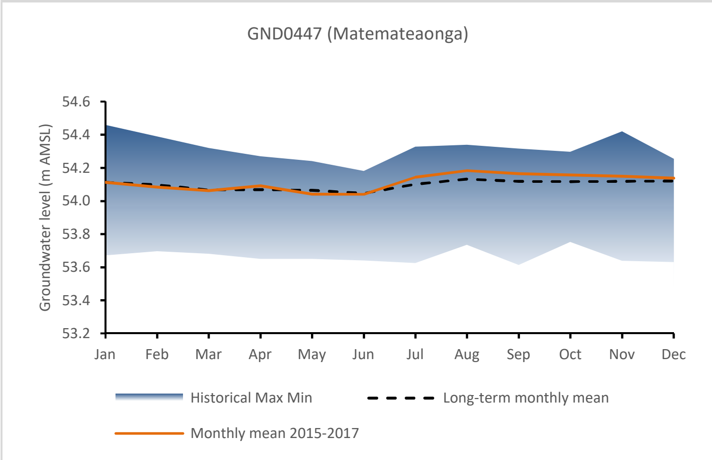
Sites GND0599 and GND0600 are a well pair located in close proximity to each other, but intersect different aquifers. GND0599 is screened between 79-82 m BGL and is classified as intersecting the Tangahoe aquifer. GND0600 intersects the shallow Taranaki volcanics and is screened from 16-19 m BGL. Interestingly, the sites show very similar patterns in average monthly water levels over both their current and long-term data records, although the actual water level in GND0600 is on average 10 m beneath that observed in site GND0599. This suggests that GND0599 is only semi-confined and is being recharged by leakage from the overlying Taranaki volcanics formation. It may also suggest that the sediments confining the lower aquifer are not laterally extensive, constituting a more direct shallow recharge pathway. Under either circumstance, the primary driver of recharge to both aquifers is localised rainfall, resulting in the consistent patterns in water level fluctuation observed across the sites.

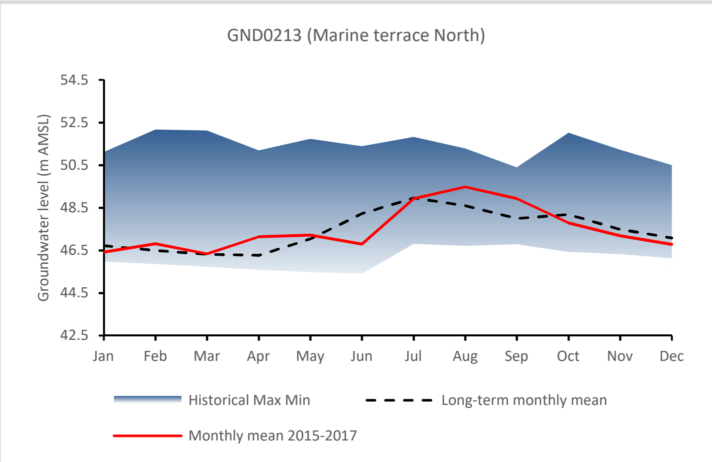
In summary, the assessment of data shows that current water levels at monitored sites do not differ significantly from historical long-term averages. The analysis of monthly mean level data has also illustrated similarities in spatial and temporal responses to rainfall across some sites.

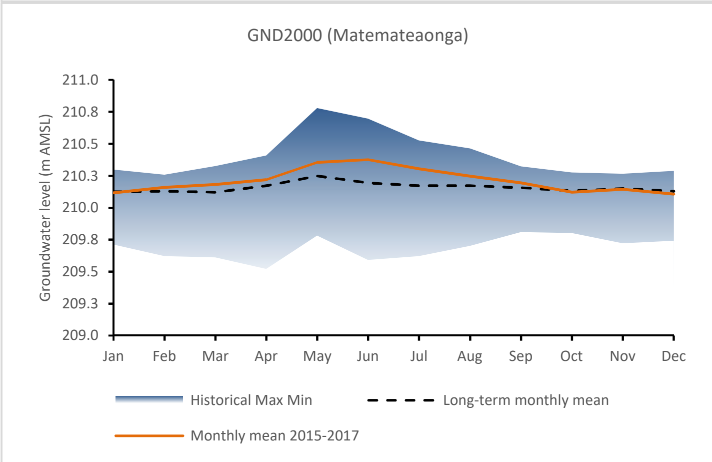

GND0600 (Taranaki volcanics)
Groundwater level (m AMSL)
205.5
204.5
203.5
202.5
201.5
200.5
199.5
198.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Historical max min
Long-term monthly mean
Monthly mean 2015-2017


GND0599 (Tangahoe)
Groundwater level (m AMSL)
193.5
193.0
192.5
192.0
191.5
191.0
190.5
190.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Historical Max Min
Long-term monthly mean
Monthly mean 2015-2017


GND0508 (Taranaki volcanics)
Groundwater level (m AMSL)
118.0
117.0
116.0
115.0
114.0
113.0
112.0
111.0
110.0
109.0
108.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Historical Max Min
Long-term monthly mean
Monthly mean 2015-2017


GND0447 (Matemateaonga)
Groundwater level (m AMSL)
54.6
54.4
54.2
54.0
53.8
53.6
53.4
53.2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Historical Max Min
Long-term monthly mean
Monthly mean 2015-2017


GND0213 (Marine terrace North)
Groundwater level (m AMSL)
54.5
52.5
50.5
48.5
46.5
44.5
42.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Historical Max Min
Long-term monthly mean
Monthly mean 2015-2017


GND2000 (Matemateaonga)
Groundwater level (m AMSL)
211.0
210.8
210.5
210.3
210.0
209.8
209.5
209.3
209.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Historical Max Min
Long-term monthly mean
Monthly mean 2015-2017

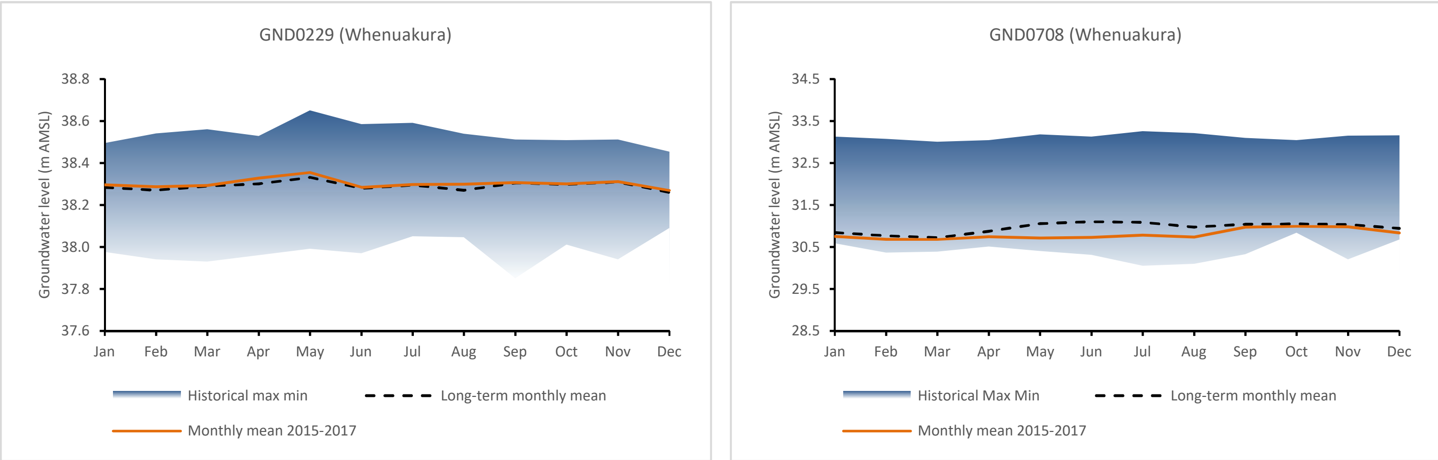


Figure 11 Envelope plots comparing monthly average water levels at each site over the period 2015-2017 with a long-term averages and extreme values. Sites with their monthly means (2015-2017) displayed as a red line are classified as intersecting unconfined aquifers and orange lines representing confined aquifer sites. Each plot is titled with site code and aquifer name in brackets.

5.2 Statistical trend analysis

The groundwater level data collected has been analysed to identify trends in groundwater level change at each site. The statistical analysis was conducted using Time Trends (2017; version 6.1). The analysis was carried out using the non-parametric Seasonal Kendall Slope Estimator (SKSE). The SKSE was used to represent the magnitude and direction of trends in water level without the influence of seasonal variations. The SKSE is expressed as metres per year of water level change. To enable comparison of water level fluctuation across sites, the SKSE is also calculated as a percentage relative to the median value of each dataset. This statistic is termed the Relative Seasonal Kendall Slope Estimator (RSKSE). Positive RSKSE values indicate an increasing trend (rising water levels) and negative values a decreasing trend (declining water levels).

The SKSE calculations are accompanied by a Seasonal Kendall test, which assesses the statistical significance of the trend identified. The test is used to determine whether the likelihood that the trend identified, upward or downward, is a real change and has not arisen by chance. The value outputted from the test used to make the assessment is termed a P-value. Various P-value thresholds are commonly used to assess the significance of identified trends, but in the case of this assessment, a P-value of <0.05 is used to define a trend as being statistically significant. In relative terms, this means that there is less than a 5% chance of calculations apparently finding a trend when in fact there is not one.

It is recognised that the statistical significance of a trend does not necessarily imply a 'meaningful' trend i.e. one that is likely to be relevant in a natural resources management sense. Ballantine and Davies-Colley (2009) have determined a 'meaningful' trend as one for which the RSKSE is statistically significant and has an absolute magnitude >1% change per year. They propose that a 1% change per annum, which corresponds to 10% change per decade, represents a degree of change that is likely to become noticeable or detectable to water users and casual observers within a human lifespan.

Trend analysis has been carried out on data over two specific lengths of data record as follows:

- **Long-term trends:** Analysis conducted using the full record of water level data available from each monitoring site, where a minimum of eight years of data has been collected prior to 30 June 2017; and
- **Short-term (recent) trends:** Analysis conducted using the most recent five years of water level data available from each monitoring site, which generally covers the period 1 July 2012 to 30 June 2017.

The exceptions to the trend periods used above are at site GND0519 where, as a result of equipment failure, the loss of recent data means that the long-term trend period ceases at 13 January 2016 and the short-term trend period spans 13 January 2011 to 13 January 2016.

Once trends were calculated, various combinations of statistical significance (P-value) and the magnitude of any trend identified (RSKSE) have been used define a trend classification at each site as follows[1]:

Rising trend: P-value <0.05 and RSKSE >1%;
Slightly rising trend: P-value <0.05 and RSKSE between 0.2 and 1%;
No significant change: P-value <0.05 and RSKSE between <0.2% or a P-value of >0.05;
Slightly declining trend: P-value <0.05 and RSKSE between -0.2 and -1%; and
Declining trend: P-value <0.05 and RSKSE <-1%.

Sufficient data was available for short-term trend analysis to be undertaken at 12 of the 15 sites currently monitored as part of the regional groundwater level monitoring network. Of these sites, nine also had sufficient data available to enable analysis of long-term trends. No trend analysis was possible on data from sites GND2288 and GND2317.

The results of the trend analysis carried out are summarised below in Table 6 and are illustrated in Figure 12. Further detailed results of the trend analysis are included in Appendix I.

Table 6 Comparison of long-term and recent trends in water level by site

Site code	Name	Long-term trend classification		Short-term trend classification	
GND0213	Motunui	No significant change	↔	No significant change	↔
GND0229	Kiwi-1	No significant change	↔	No significant change	↔
GND0447	Manutahi-1	No significant change	↔	No significant change	↔
GND0508	Carrington Rd.	No significant change	↔	No significant change	↔
GND0519	Mangamahoe-1	No significant change	↔	No significant change	↔
GND0599	Eltham-7	No significant change	↔	No significant change	↔
GND0600	Eltham-7A	No significant change	↔	No significant change	↔
GND0708	Nolan Rd.	Slightly declining trend	↘	Slightly declining trend	↘
GND2000	Scout Rd.	No significant change	↔	No significant change	↔
GND2220	STDC Swinbourne St.	-	-	No significant change	↔
GND2252	Patea Sentinel (Lower)	-	-	Slightly declining trend	↘
GND2253	Patea Sentinel (Upper)	-	-	No significant change	↔

[1] Adopted from PDP (2013).

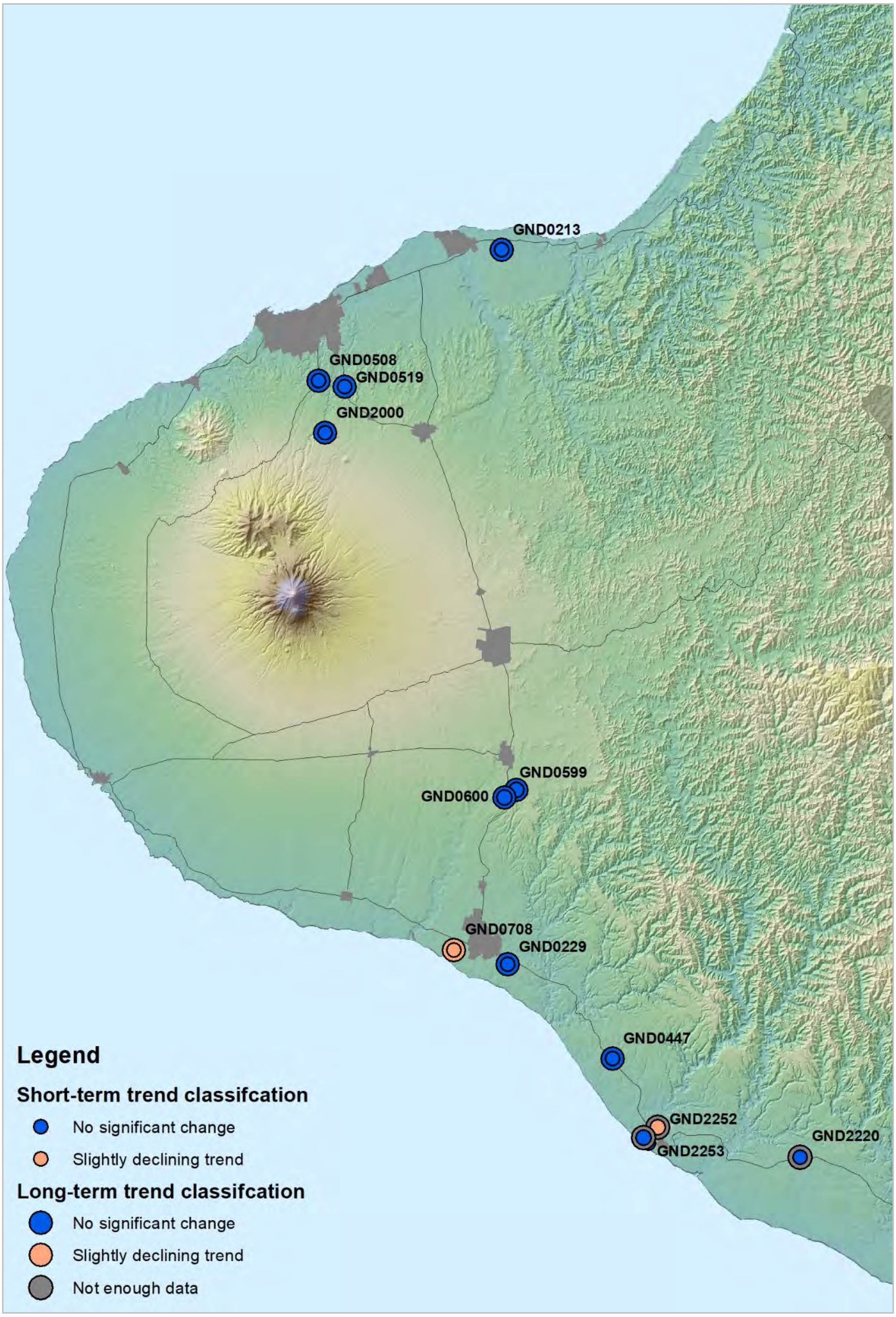


Figure 12 Spatial plot showing combined long-term and short-term trend classification by site and aquifer

The results show that for 9 of the 10 sites with sufficient data to enable long-term trend analysis, there has been no meaningful change in groundwater level over the full period of their respective data records. The exception to this was site GND0708, which has shown a slightly declining trend (the water level is falling) over its 19 year data record.

Site GND0708 intersects the Whenuakura aquifer near Hawera. The well is screened between 82 and 94 m BGL and the aquifer is confined in this location.

While the long-term trend identified at GND0708 has a strong statistical significance, the reduction in in water level over the trend period is relatively minor, at 0.4% per year.

Statistical analysis of the data from site GND0708 also indicates that the slight decline in groundwater level has continued over the most recent five year period. The annual rate of water level decline over this period was 0.3%, which was similar to the rate of change recorded over the longer-term. This is reflective of a relatively linear rate of decline in water level at the site over its entire data record, as illustrated in Figure 13.

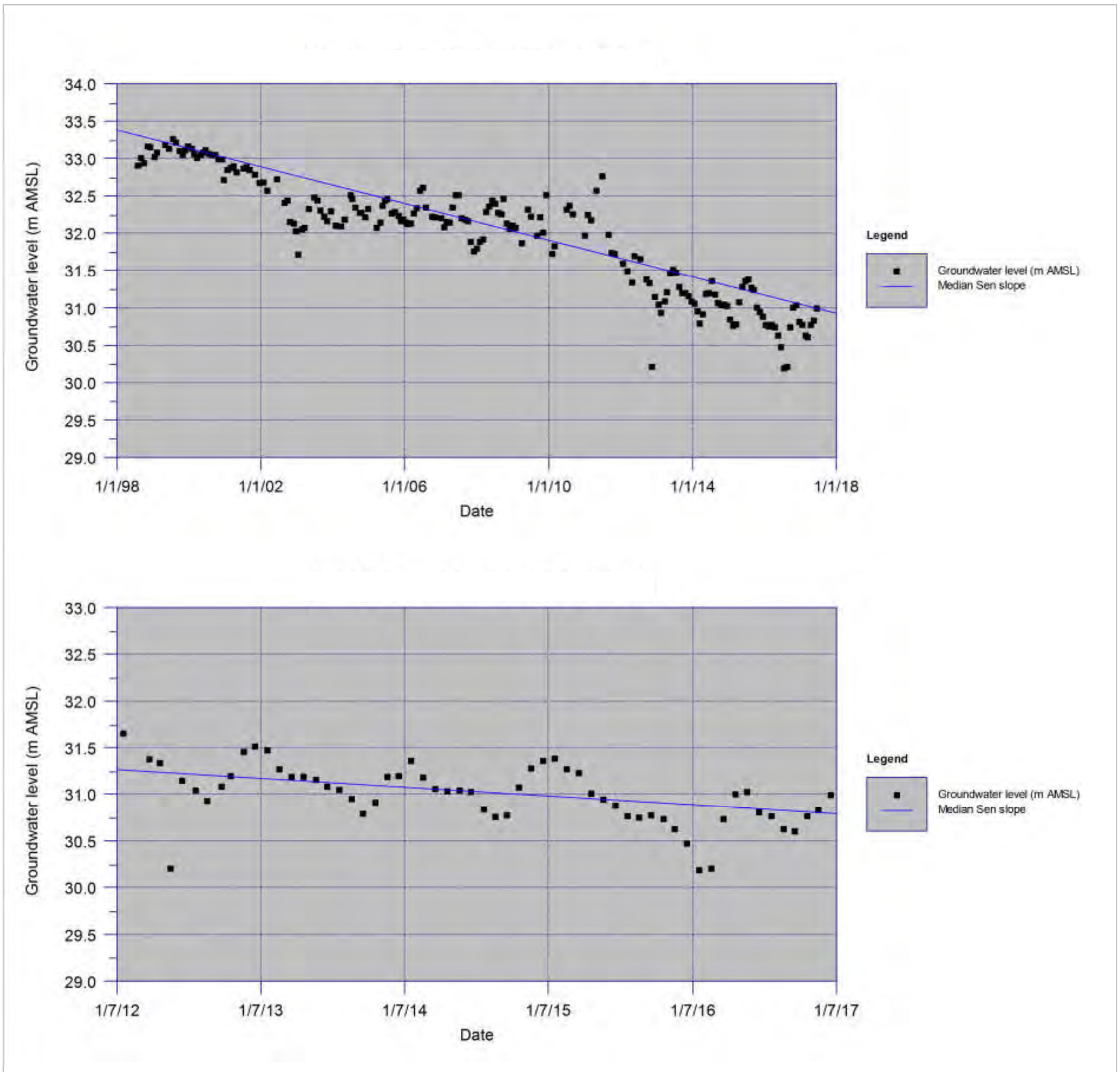


Figure 13 Plot of water level data and fitted trend lines illustrating the slightly declining trend in groundwater level at site GND0708 over both its long-term (top) and short-term data record (bottom)

The only other site to show any statistically significant and meaningful trend in its data record was GND2252, where a slightly declining trend in water level was identified.

GND2252 is located at Patea, South Taranaki. The well was installed to enable monitoring of water levels within the 'lower' water supply aquifer, from which municipal wells abstract water to supply the township of Patea. This data could then be used to assess the potential for saline water intrusion into the supply aquifer as a result of abstraction. For this purpose, the well was installed between the municipal water supply wells and the coast. It is screened from 148 m to 154 m BGL. A second well was installed to monitor drawdown effects in the 'upper' supply aquifer (GND2253). This well is screened from 93 m to 96 m BGL. Both the upper and lower supply aquifers are located within the Whenuakura Formation.

The data record from this site only covers the five year period from period 2012-2017 and therefore the trend identified is representative of relatively recent change. The annual rate of water level decline at the site was 0.7% (Figure 14). Longer-term trends at the site could not be assessed given the lack of data.

In addition to the sites discussed above, which were found to have statistically significant and meaningful trends in water level over time, there were additional sites where statistically significant trends in water level were also identified during the analysis. These included both rising (4 sites) and declining (2 sites) trends in water level. None of these trends were however deemed environmentally meaningful. In all cases these trends returned RSKSE values an order of magnitude below the 0.2% threshold set to represent meaningful change. When trend slope is assessed across all sites without consideration of statistical significance, indicative increases in groundwater level are apparent over the short-term period at 73% of sites and at 56% of sites over the longer-term.

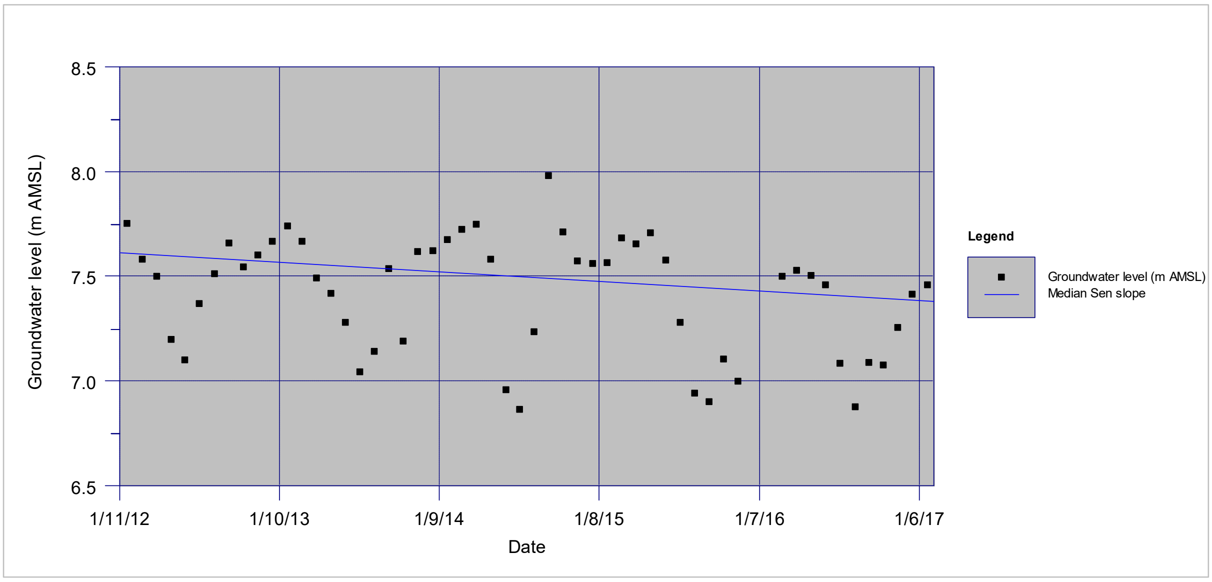


Figure 14 Plot of short-term water level data and fitted trend line illustrating the slightly declining trend in groundwater level at site GND2252

The implications and significance of changes in groundwater level are discussed further in Section 6.2 of this report.

6 Discussion

6.1 Allocation pressures

The volume of groundwater allocated for abstraction across the Taranaki region remains low, with only 61 consents authorising the taking of groundwater current as of 30 June 2017. The demand for groundwater has been relatively static over the last decade, with total current groundwater allocation (40,422 m^3/d) 25% higher than allocated in 2013 (32,343 m^3/d), but 8% less than was allocated in 2008 (44,042 m^3/d) (TRC, 2015). The majority of the increase in allocated groundwater volumes over the more recent period (2013-2017) are associated with consents issued for irrigation (including both recreational and agriculture use) and manufacturing purposes.

The highest level of allocation is currently seen in the Whenuakura aquifer, where a combined total of 23% of estimated sustainable yield is are allocated across areas of the aquifer located within freshwater management unit (FMU) B and FMU-C. The Matemateaonga aquifer has approximately 7% allocated across FMU-A and FMU-B. All other aquifers have insignificant volumes of water allocated (≤1% of estimated sustainable yield).

The relatively low demand placed on groundwater resources for abstractive purposes across Taranaki is likely due to several factors. Firstly, most areas of Taranaki receive regular and plentiful rainfall, with a steep rainfall gradient inward from coastal areas. The high rainfall experienced in Taranaki also means that, outside of coastal areas, soil moisture deficits are generally low and when there is a deficit, it is generally short lived. As a result Taranaki has not seen the rapid increase in water demand for pasture irrigation, as has been seen elsewhere in New Zealand. The rainfall characteristics and topography within Taranaki also means there is an abundance of surface water systems, which means rivers and streams are generally accessible when water supply is needed. Where available, surface water supplies are typically preferred to groundwater sources, given they can be obtained at a much lower capital cost. The low yields from Taranaki aquifers often mean that multiple bores are required to supply high demand uses, making the use of groundwater uneconomic. Surface water systems are generally able to sustain the majority of current water demand in Taranaki, although several catchments are fully allocated.

Notwithstanding the above, there is potential for growth in groundwater demand in the future. Any significant growth would likely be driven by a shift in current land use, development of new land uses or industrial activities that require greater higher water inputs than those activities that predominate currently. If more surface water systems across the region reach their allocation limit in coming years, any future increases in regional water demand may necessitate the need for more groundwater sourced water supply.

Climate change also has the potential to influence future rainfall patterns in Taranaki and, as a result, the volume of water recharging its groundwater systems. This could impact both the regional water demand and the volume of groundwater available for allocation. It is currently projected however that Taranaki will see little change in its annual rainfall volumes in the short to medium-term, and potentially a slight increase in rainfall by 2090, particularly over winter months, when the majority of groundwater recharge occurs. If current predictions are realised, it's unlikely that the volume of groundwater available for allocation across the region will change significantly into the future.

6.2 Groundwater levels

Groundwater level data is currently collected from 15 monitoring sites across the region. The length of data records from these sites is variable. Sites have been classified as having long-term records where data has been collected for a minimum of eight years, while short-term sites have a minimum of five year's data available. The method of data collection has also varied over the course of the programme, with electronic data capture replacing manual monthly measurements.

The data collected illustrates the natural variability in water levels across the region's aquifers. Monitoring of water levels at sites intersecting unconfined aquifers, primarily in the Taranaki volcanics and marine terrace hydrogeological units, show strong response to seasonal rainfall patterns. This generally results in water levels rising during periods of the year with higher rainfall (winter, spring) and falling during drier periods (summer, autumn). The magnitude of seasonal fluctuations and the speed of level response to rainfall is also influenced by factors other than aquifer confinement though: these include the permeability and storage characteristics of strata in which the groundwater resides, its water storage capacity, the depth to the water table and the overlying land cover and proximity to a stable surface water boundary.

The impact of seasonal fluctuations in rainfall recharge volumes on groundwater levels are more subdued in confined aquifers, which are disconnected from direct rainfall recharge by overlying low permeability strata. As a result, the magnitudes of level fluctuations are typically much less than seen in shallow unconfined groundwater systems where the water table is close to the surface and receiving direct rainfall recharge.

The water level data from some specific sites also illustrate the influence of water abstraction on groundwater systems, whereby drawdown of water levels occurs as a result of pumping, with a corresponding rebound in water level when pumping stops.

Data collected over the last two years of monitoring at each site (2015-2017) has been assessed to determine the current state of groundwater levels across monitored aquifers. The assessment shows that current water levels do not differ significantly from historical long-term averages at monitored sites. The analysis also illustrated similarities in spatial and temporal responses to rainfall across some sites.

Trend analysis was carried out on the data collected at all sites with a minimum of five years' data. This data was used to assess short-term (recent) trends in groundwater level change. Where a site had a minimum of eight years of available data, an analysis of the full data record from that site was also conducted to assess longer-term trends in groundwater level. The results of the trend analysis were assessed against a set criteria of statistical significance (P-value) and trend magnitude (RSKSE) to define trend classification.

The results of the trend analysis show that at the vast majority of sites, there has been no meaningful change in water level over time. The exceptions to this were site GND0708 (Patea – Whenuakura aquifer), which was found to have experienced a slightly declining trend in water level over both its long-term data record and the most recent five year period. One other site, GND2252 (Waverly – Whenuakura aquifer), was found to have experienced a slightly declining trend in water level over its recent data record. In addition to these sites, there were others where statistically significant rising (4 sites) and declining (2 sites) trends in water level were identified. None of these trends were however deemed environmentally meaningful, given the extremely low rate of annual change (+/- <0.1%).

The slightly declining trend in water levels observed at site GND2252 is likely due to the ongoing abstraction of water from the lower aquifer (Whenuakura Formation) for municipal supply purposes. Over the same time period, the majority of water taken to supply the township of Patea was taken from the lower aquifer. Analysis of water level data from site GND2253, screened across the upper aquifer at the same location, did not show any corresponding decline in water level. This indicates the decline in water levels is isolated to the lower aquifer, and that the decline has not been sufficient to induce any significant leakage from the overlying upper aquifer.

The risk of saline intrusion as a result of the abstraction remains low. If the current rate of water level decline were to continue (-5 cm/yr), it would take nearly a century for hydraulic head within the lower aquifer to reduce below the elevation of mean sea level. In isolation, the reduction of the hydraulic head below mean sea level is not enough to cause saline intrusion, but it would increase the risk of it occurring. The structural and hydraulic properties of the aquifer would ultimately dictate whether or not it did occur and the rate of any saline water ingress. Given the difficulty in accurately forecasting the likelihood of saline intrusion occurring, the monitoring of groundwater at coastal locations provides the best opportunity to identify high risk situations arising from prolonged periods of low groundwater levels and/or changing groundwater quality (PDP, 2011). The continued monitoring of water level (and water quality) change in the Patea sentinel wells (GND2252 and GND2253) is therefore the best approach to assessing the ongoing risk of saline intrusion.

Localised abstraction pressure is also the likely cause of observed declines in water level at site GND0708, although the specific location of the abstraction(s) likely impacting on water levels are not clear. The Council has records of five other known bores that take water from the Whenuakura aquifer within a 3.5 km radius of GND0708, however there are no current consents to take groundwater from any of these bores. In order to be complying with the permitted water take rule set out in RFWP, the maximum volume of water being taken from these bores should not be exceeding 50 m^3/day. Further investigation is required to assess whether the permitted takes limit is being complied with at these sites, or whether other unregistered bores (and associated water takes) exist in the area.

The slightly declining trend in water levels observed at both sites GND0708 site GND2252 appear to be the result of localised abstraction pressures. While both sites do intersect the Whenuakura aquifer, they are located a significant distance apart from each other and other monitoring sites in the same aquifer do not show a similar decline. It is therefore concluded that the observed trends are not indicative of any widespread reduction in groundwater levels across the aquifer.

In summary, analysis of groundwater level data has found isolated impacts of localised abstractions impacting on water levels at specific sites, but overall, groundwater levels remain stable at the majority of monitored locations. The results of this analysis undertaken in preparing this report show that the Council’s policies related to groundwater abstraction and usage have been successful in achieving sustainable management of the region’s groundwater resource.

7 Response

The Council has implemented a number of responses in light of the results obtained through monitoring associated with this programme. These are detailed below.

- The Council has a developed a groundwater accounting system that maintains a register of all current consents authorising the taking of the groundwater, the volume of water being taken and the proportion of sustainable yield allocated across each aquifer and FMU.
- An investigation will be undertaken in an attempt to locate the cause(s) of the observed water level drawdown at site GND0708. This will include a survey of known bores to establish their current use, and a search to locate any unregistered bores. The results of this work will dictate any further actions required.

8 Recommendations

It is recommended:

1. THAT any of the planned responses outlined in Section 7.0 be implemented as proposed, where not already completed; and
2. THAT the Council's regional groundwater level monitoring network be extended as further suitable sites are identified. Sites intersecting aquifers where current monitoring coverage is limited should be prioritised, as should sites to the west of Mount Taranaki.

Glossary of common terms and abbreviations

The following abbreviations and terms may be used within this report:

Anisotropic	Different physical properties in all directions.
Aquifer	A permeable water-bearing geological formation through which water moves under natural conditions and which yields water to wells at a sufficient rate to be a practical source of water supply.
Bore	Bore means a hole drilled into the ground and completed for the abstraction of water or hydrocarbons to a depth of greater than 20 metres below the ground surface.
Confined aquifer	When an impermeable formation, such as clay, overlies an aquifer so that air and water are no longer in contact and the pressure is no longer equal to atmospheric pressure. Water in a well will stand at a different level to the water table.
Heterogeneity	The quality or state being diverse in physical character or content.
Heterogeneous	See Heterogeneity.
Hydraulic head	A measurement of liquid pressure above a specified datum.
m	Metres
m AMSL	Metres above mean sea level
m asl	Metres above sea level (the equivalent of m AMSL in this report)
Permitted activity	An activity that can be undertaken without the need for a resource consent, provided specified conditions are met, as set out in the RFWP.
Policy	A specific statement that guides or directs decision making. A policy indicates a commitment to a general course of action in working towards the achievement of an objective.
Recharge	The addition of water from other sources to an aquifer, e.g., seepage from rivers, percolation of rainfall.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RFWP	Regional Freshwater Plan for Taranaki (2001).
RMA	Resource Management Act 1991 and including all subsequent amendments.
Saline intrusion	The movement of saline water into freshwater aquifers.
Sustainable yield	The quantity of groundwater that can be abstracted from an aquifer for a prolonged period without depleting the resource or causing other adverse effects on groundwater quality or other groundwater users.
Unconfined aquifer	Groundwater which is freely connected to the atmosphere and which is free to rise and fall in the saturated zone, or water of an unconfined aquifer, or water under water table conditions.
Water table	The upper level of an underground surface in which the soil or rocks are permanently saturated with water.
Well	A hole dug, augured or drilled, tapping the water-table or springs to a depth of 20 metres or less below the ground surface.
Yield	The volume of water per unit of time able to be abstracted from a bore or well.

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Appendix I

Results of water level trend analysis by site

Results of recent trend analysis (5 years data):

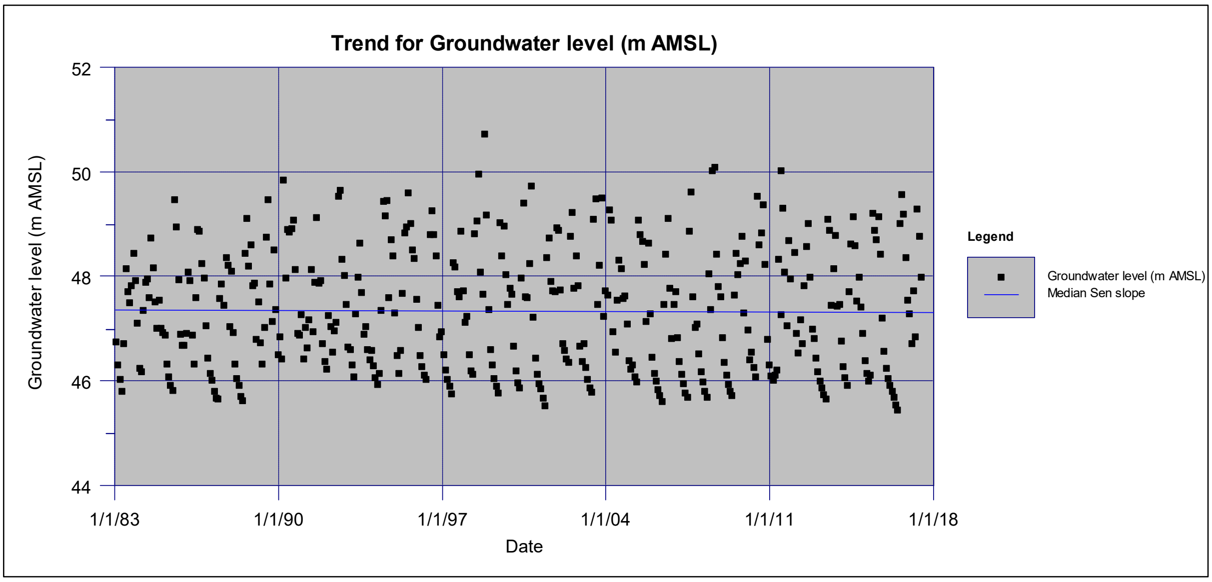
Site code	Name	Sample size	P-value	Median Sen slope (annual)	RSKSE
GND0213	Motunui	60	0.104	0.140	0.295
GND0229	Kiwi-1	56	0.757	0.003	0.007
GND0447	Manutahi-1	57	0.007	0.028	0.052
GND0508	Carrington Rd.	60	0.437	0.057	0.050
GND0519	Mangamahoe-1	54	0.000	-0.052	-0.075
GND0599	Eltham-7	60	0.525	0.017	0.009
GND0600	Eltham-7A	60	0.525	0.011	0.006
GND0708	Nolan Rd.	59	0.000	-0.095	-0.305
GND2000	Scout Rd.	59	0.000	0.038	0.018
GND2220	STDC Swinbourne St.	55	0.693	0.103	0.218
GND2252	Patea Sentinel (Lower)	54	0.004	-0.050	-0.667
GND2253	Patea Sentinel (Upper)	56	1.000	-0.001	-0.007

Results of long-term trend analysis (full data record – minimum of 8 years):

Site code	Name	Sample size	P-value	Median Sen slope (annual)	RSKSE
GND0213	Motunui	413	0.537	-0.002	-0.004
GND0229	Kiwi-1	160	0.004	0.005	0.012
GND0447	Manutahi-1	211	0.000	0.021	0.038
GND0508	Carrington Rd.	134	0.000	0.097	0.086
GND0519	Mangamahoe-1	121	0.000	-0.008	-0.011
GND0599	Eltham-7	208	0.020	-0.007	-0.004
GND0600	Eltham-7A	212	0.524	0.005	0.003
GND0708	Nolan Rd.	193	0.000	-0.123	-0.382
GND2000	Scout Rd.	84	0.000	0.067	0.032

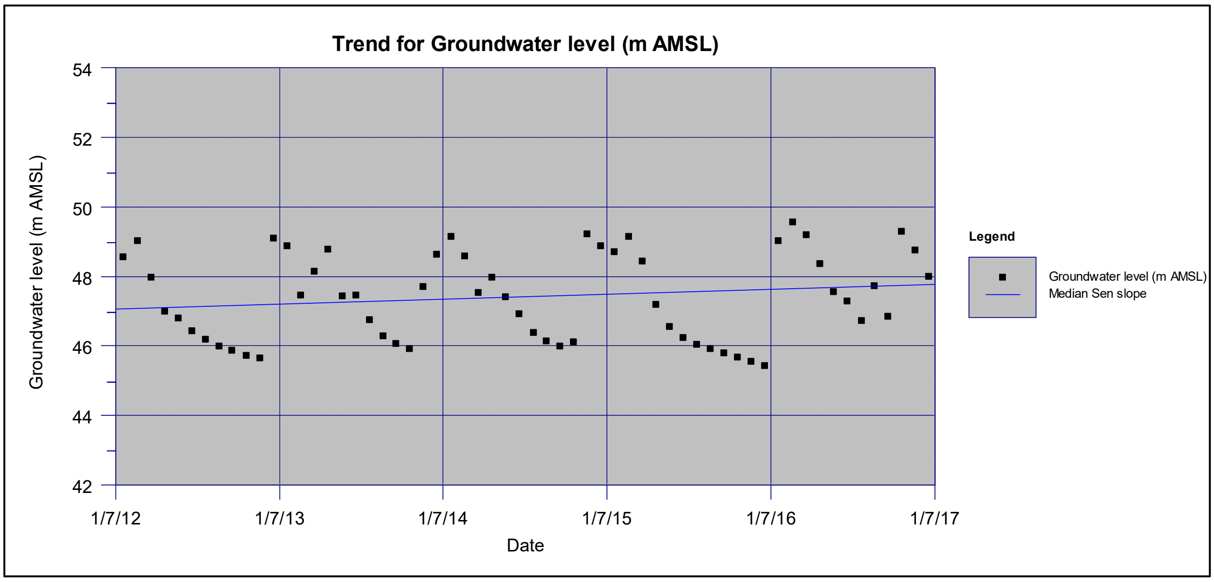
GND0213: Motunui

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	413	-148	56688.67	-0.6174	0.536969

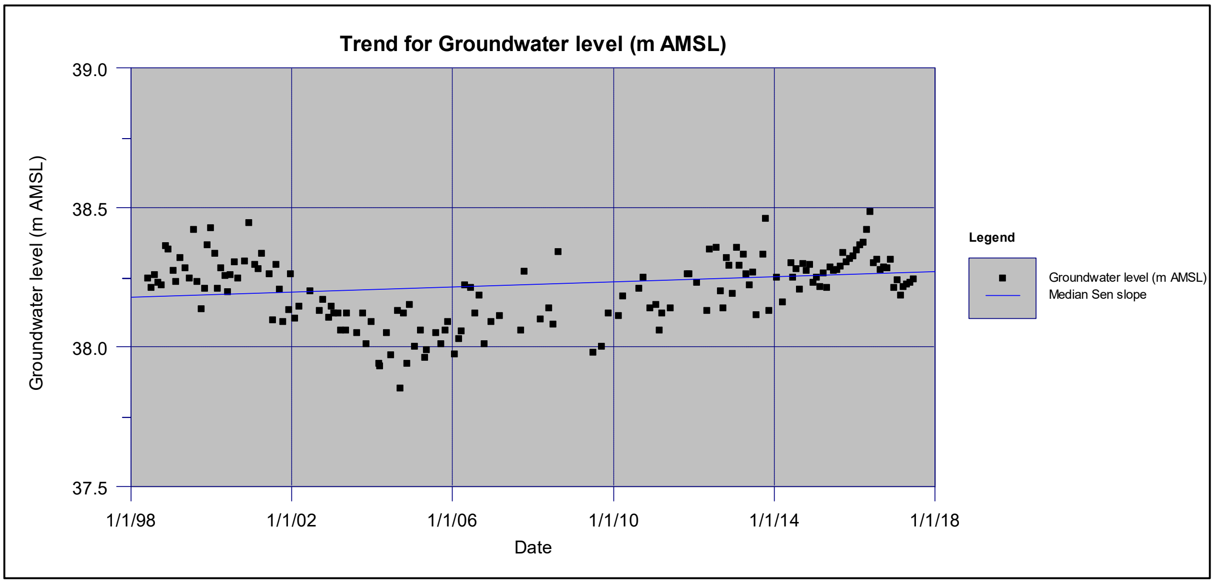
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	60	24	200	1.626346	0.103876

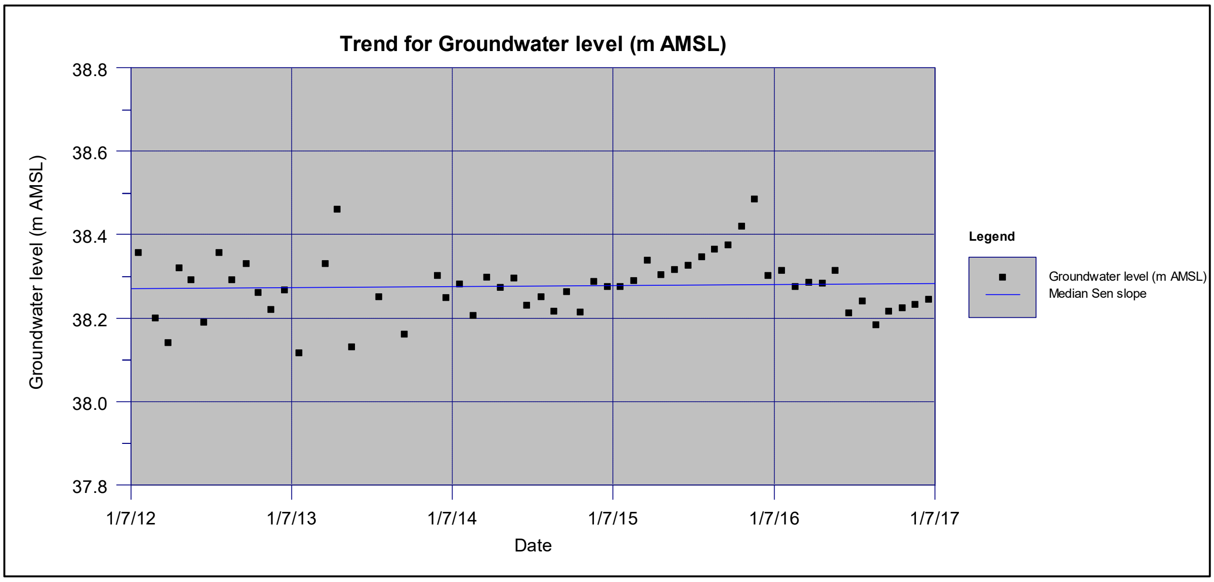
GND0229: Kiwi-1

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	160	173	3663	2.841908	0.004484

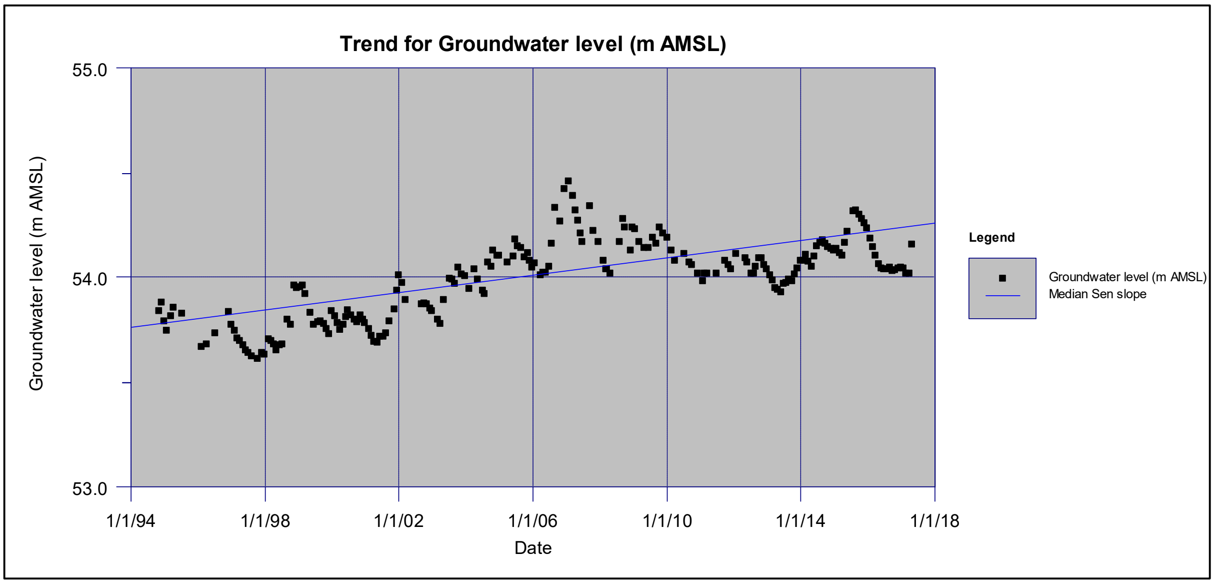
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	56	5	167	0.309529	0.756919

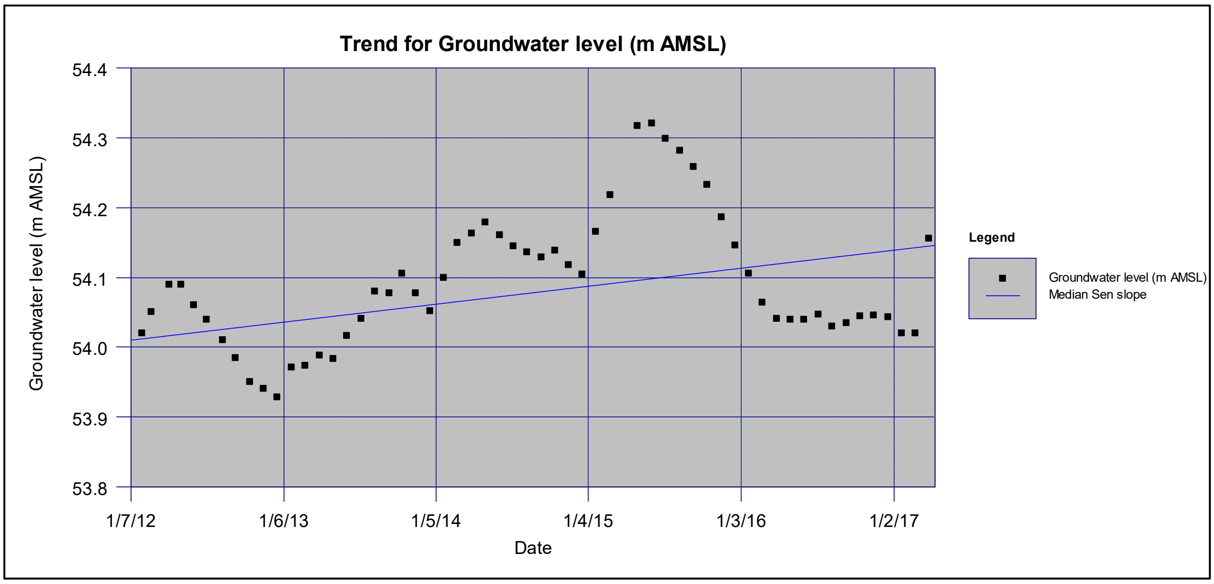
GND0447: Manutahi-1

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	211	969	8213.667	10.68088	0

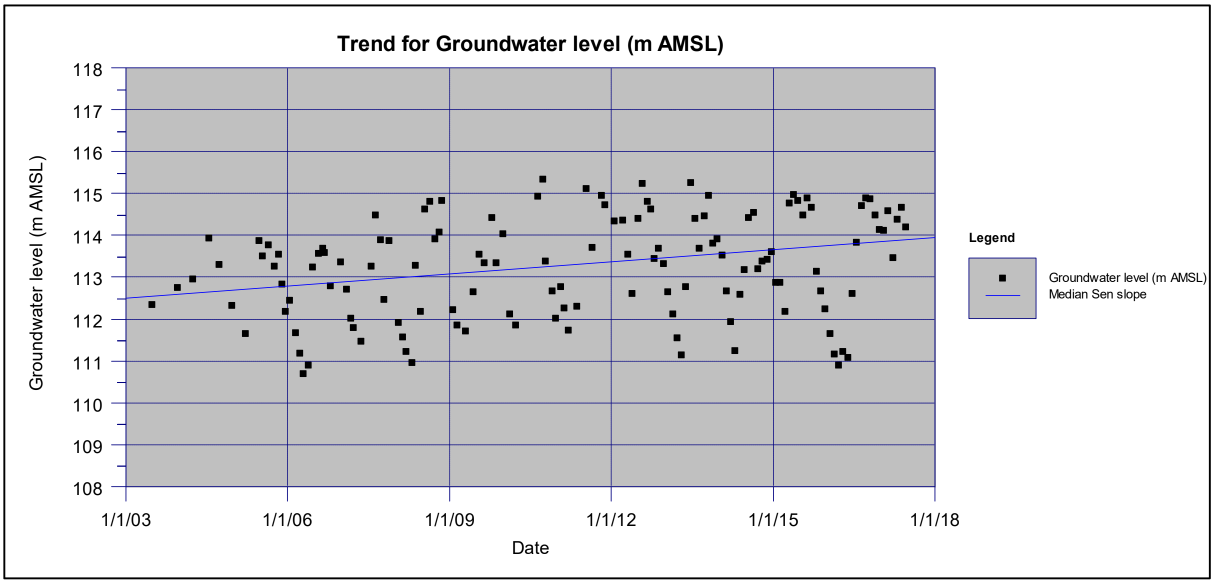
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	57	37	179	2.690766	0.007129

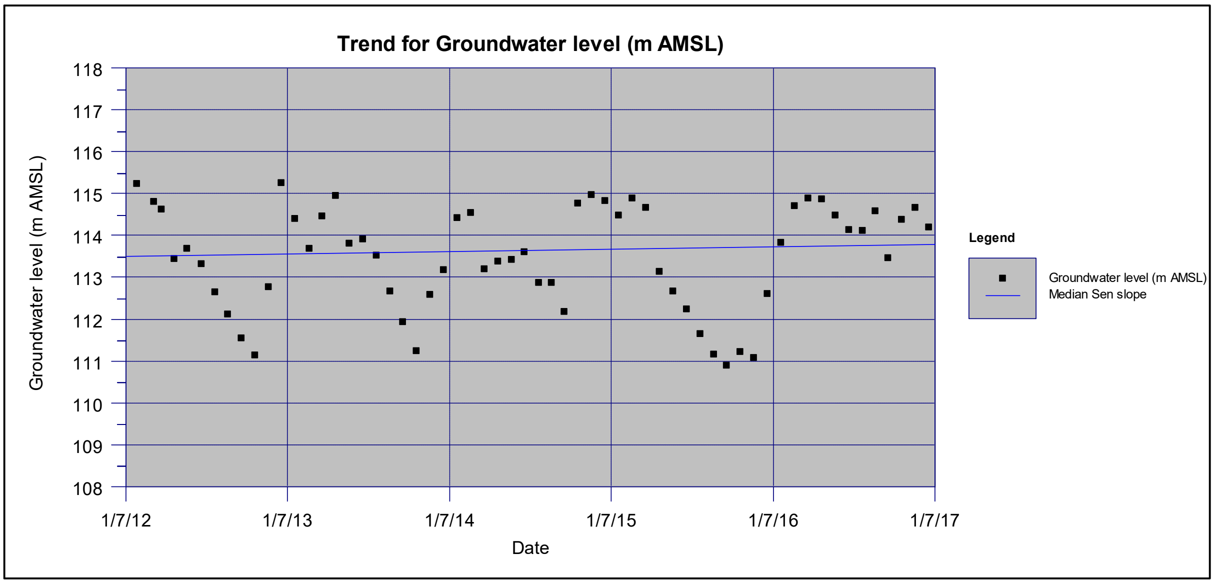
GND0508: Carrington Road

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	134	189	2111.667	4.091148	0.000043

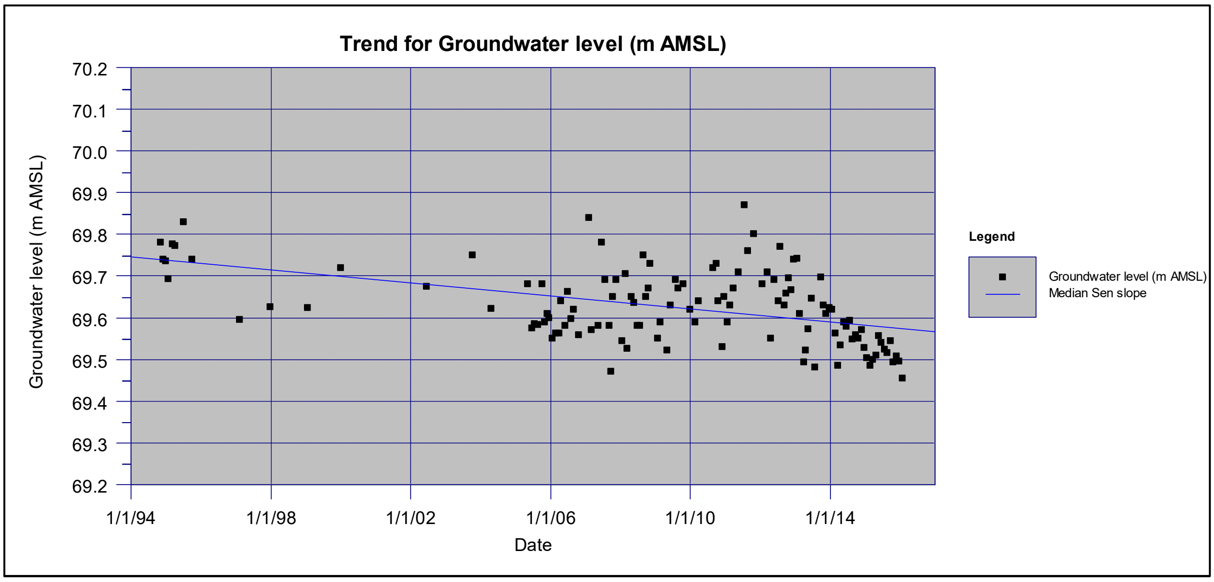
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	60	12	200	0.777817	0.436677

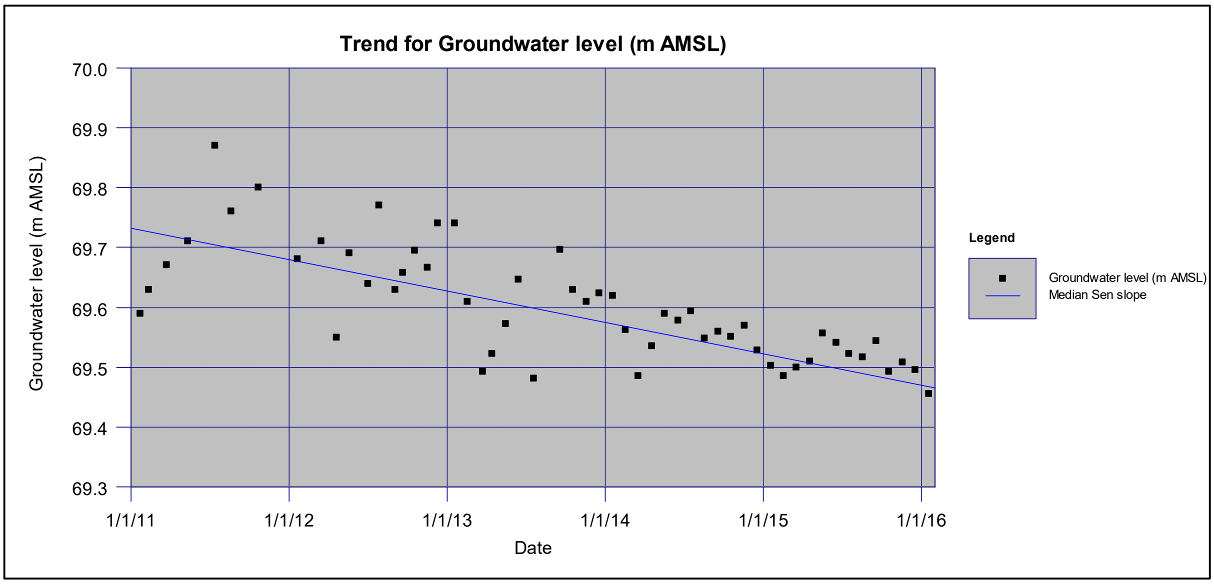
GND0519: Mangamahoe-1

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	121	-183	1607.667	-4.53914	0.000006

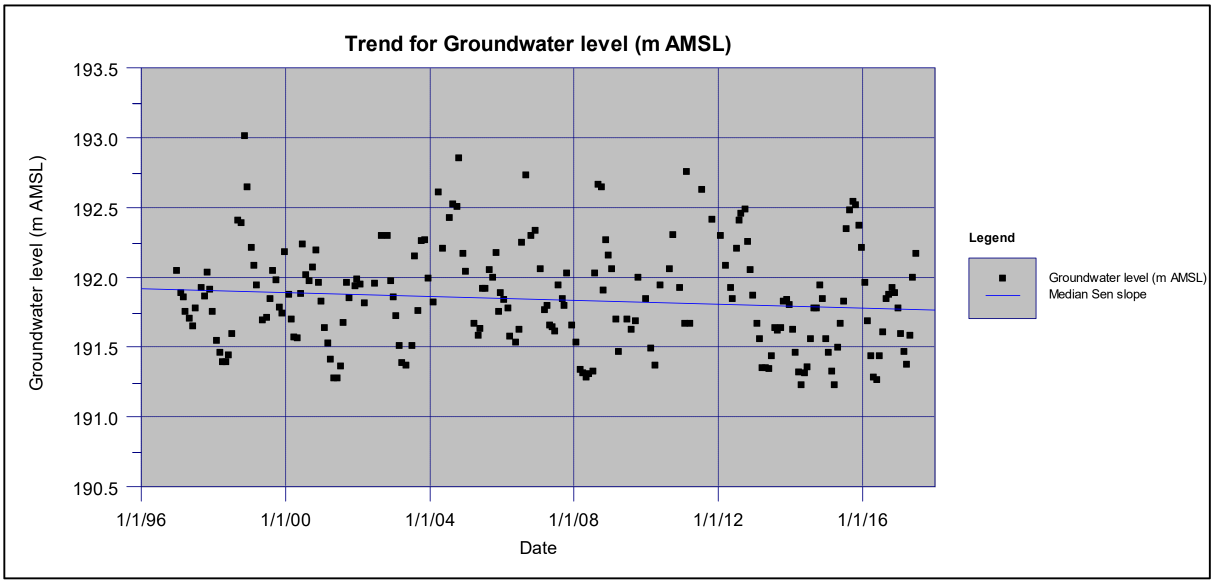
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	53	-72	144	-5.91667	0

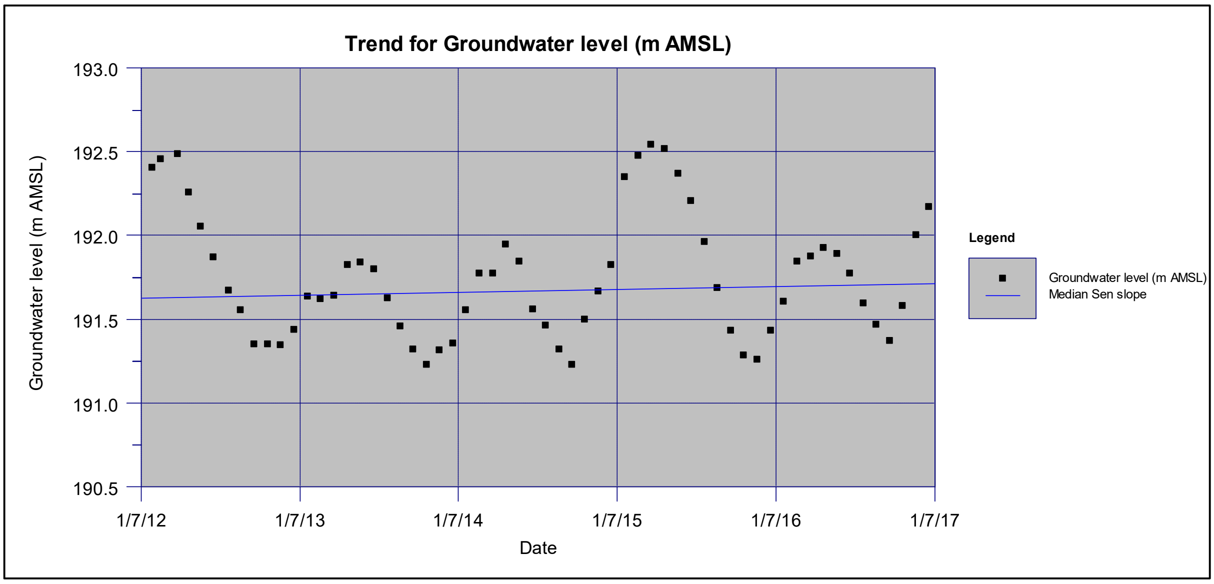
GND0599: Eltham-7

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	208	-204	7628	-2.32429	0.02011

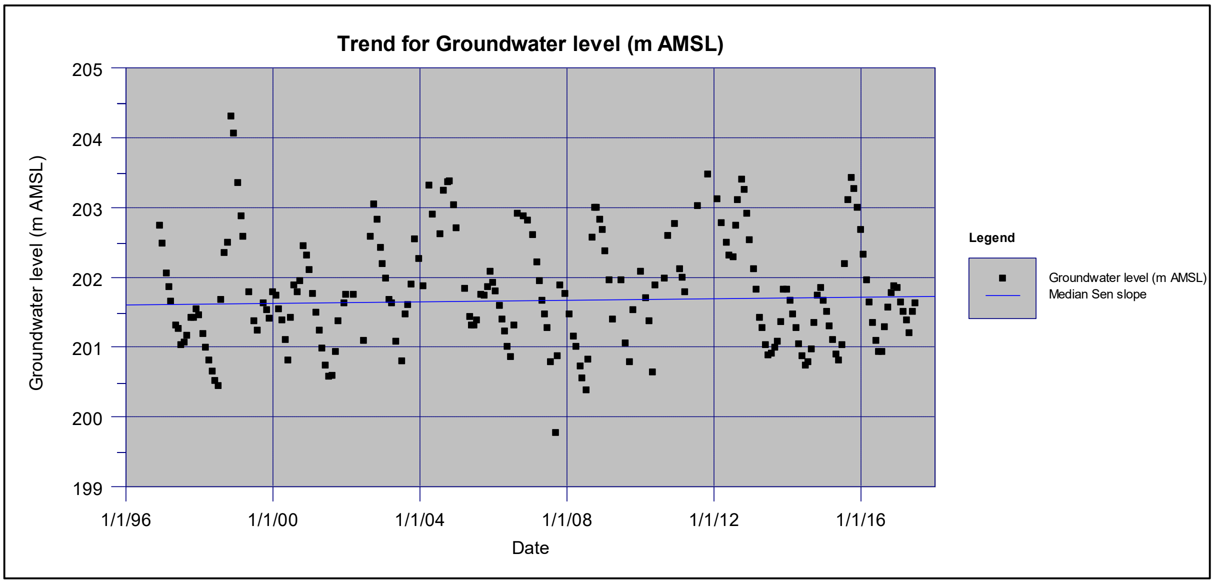
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	60	10	200	0.636396	0.524518

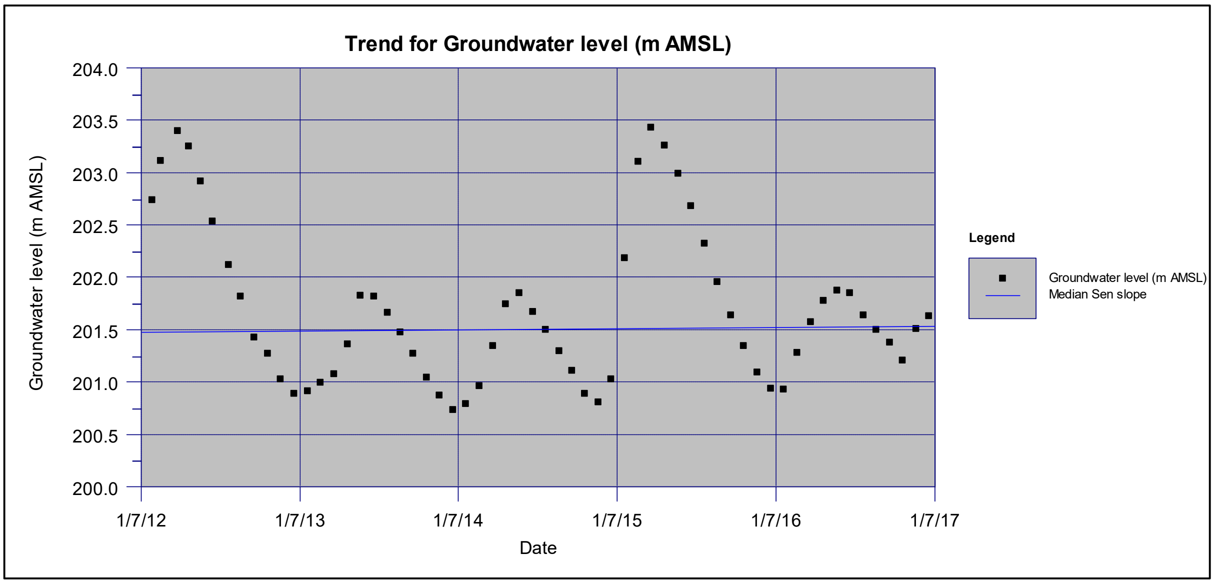
GND0600: Eltham-7A

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	212	58	8005.333	0.637067	0.524081

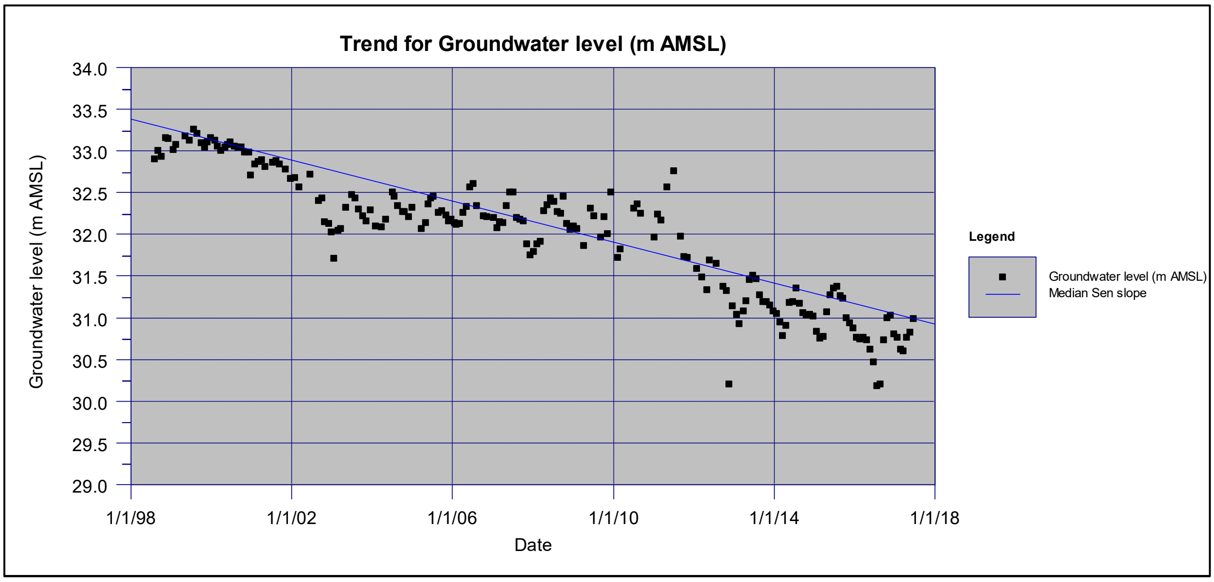
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	60	10	200	0.636396	0.524518

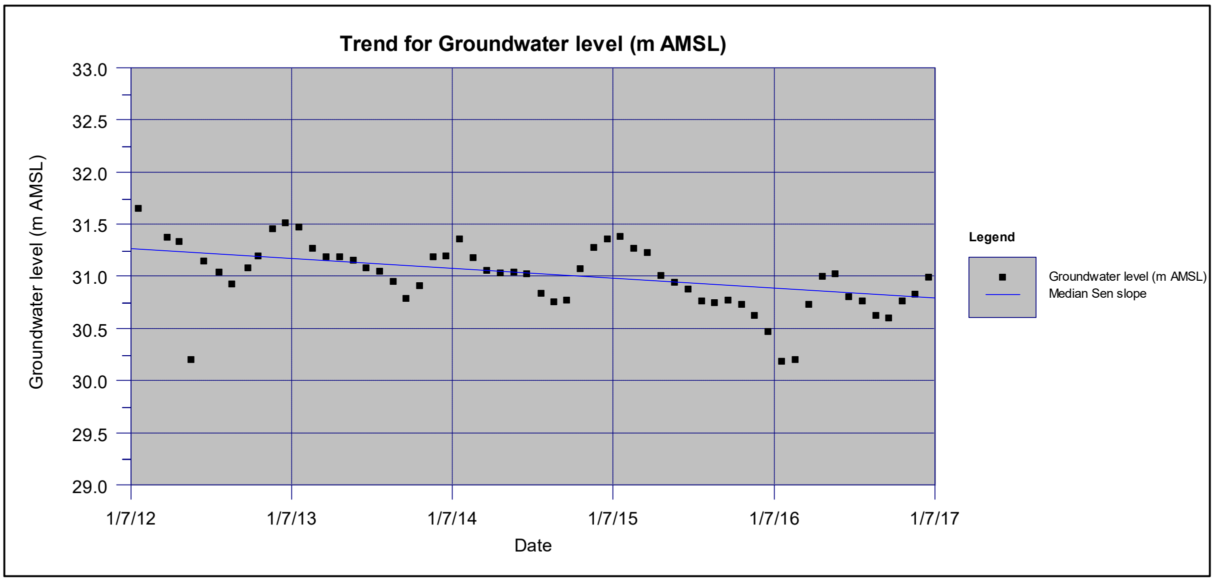
GND0708: Nolan Road

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	193	-1155	6121.666667	-14.749285	0

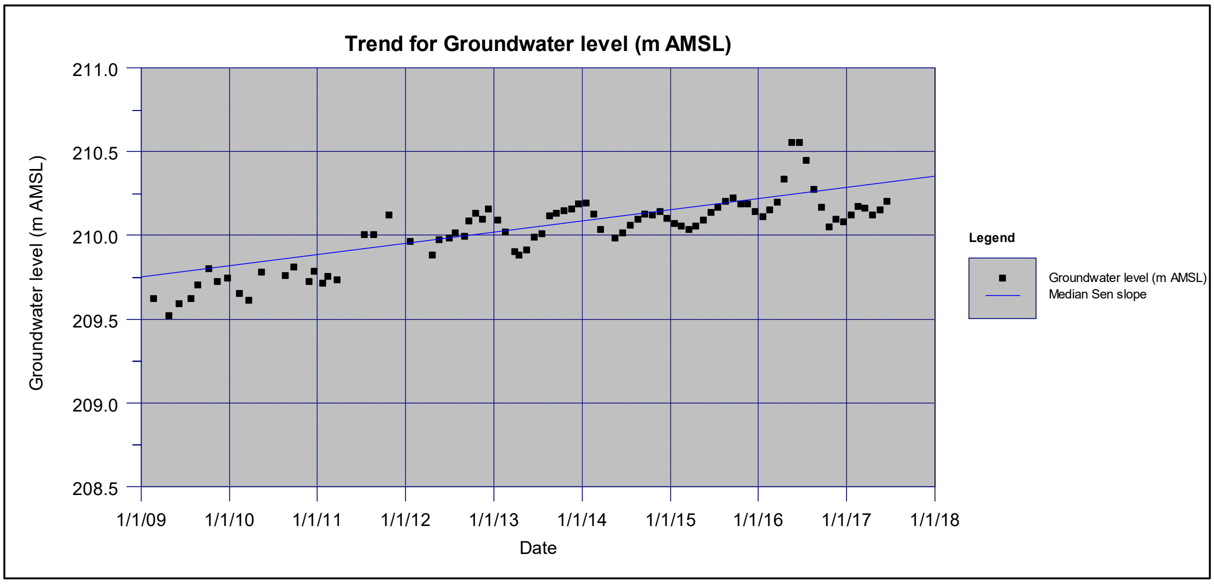
Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	59	-80	192	-5.70133	0

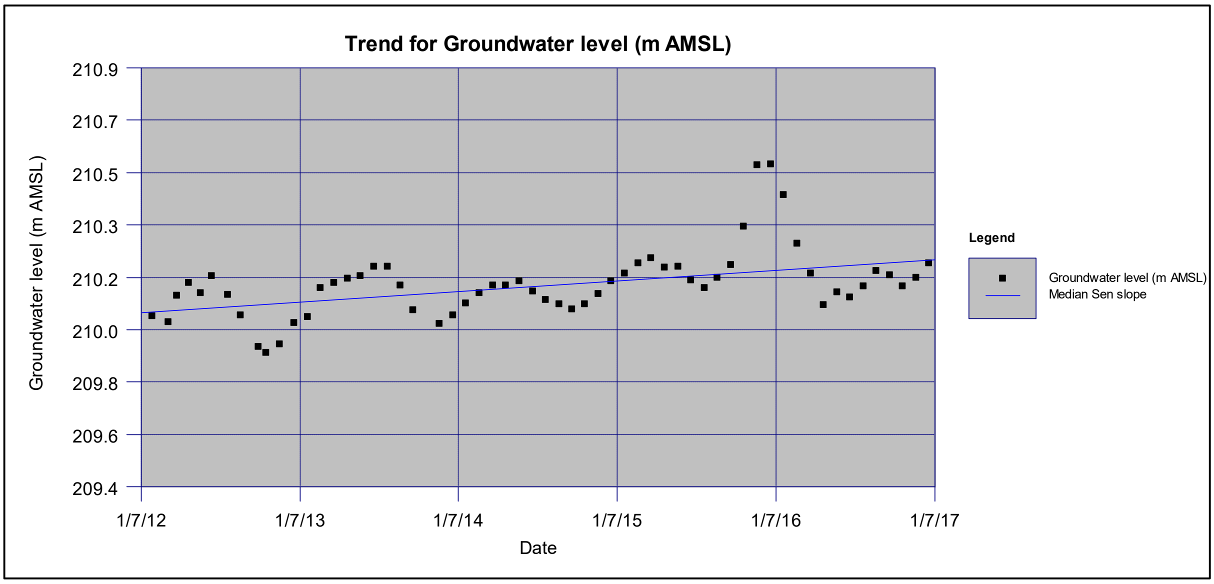
GND2000: Scout Road

Long-term trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	84	182	540	7.789	0

Short-term (recent) trends:

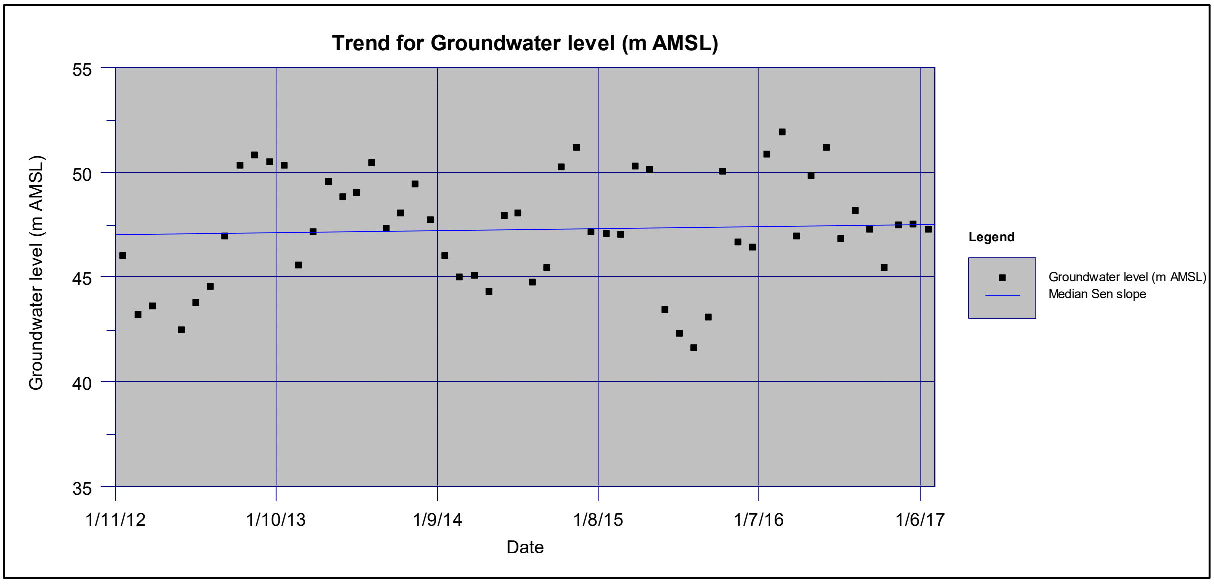


Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	59	54	192	3.824946	0.000131

GND2220: STDC Swinbourne Street

Not enough data for long-term trend analysis

Short-term (recent) trends:

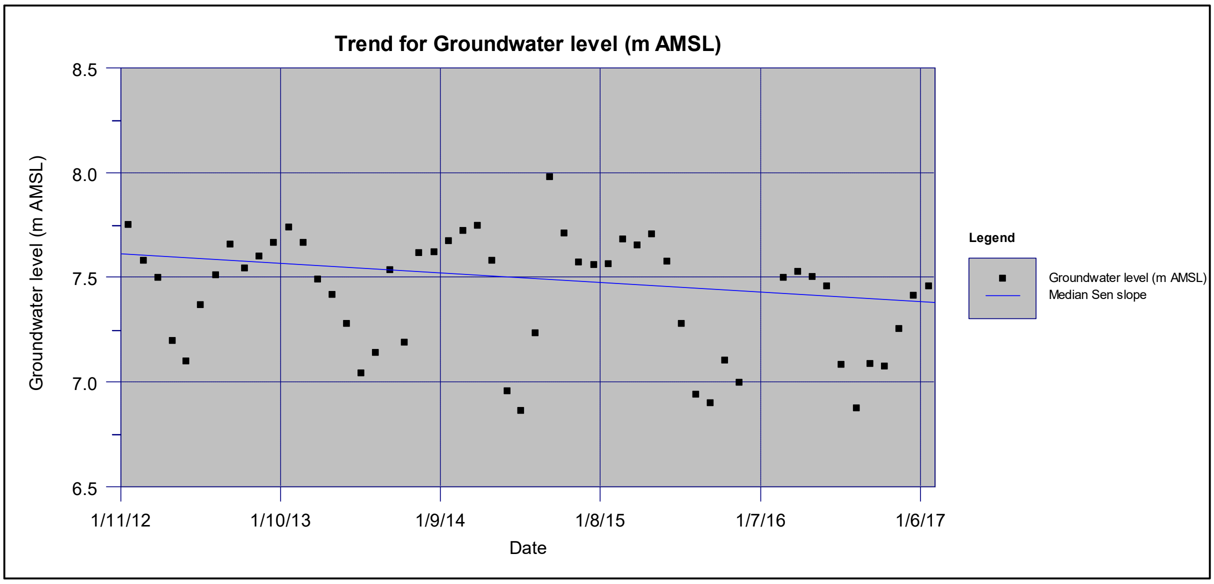


Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	55	6	160	0.395285	0.692633

GND2252: Patea Sentinel (Lower)

Not enough data for long-term trend analysis

Short-term (recent) trends:

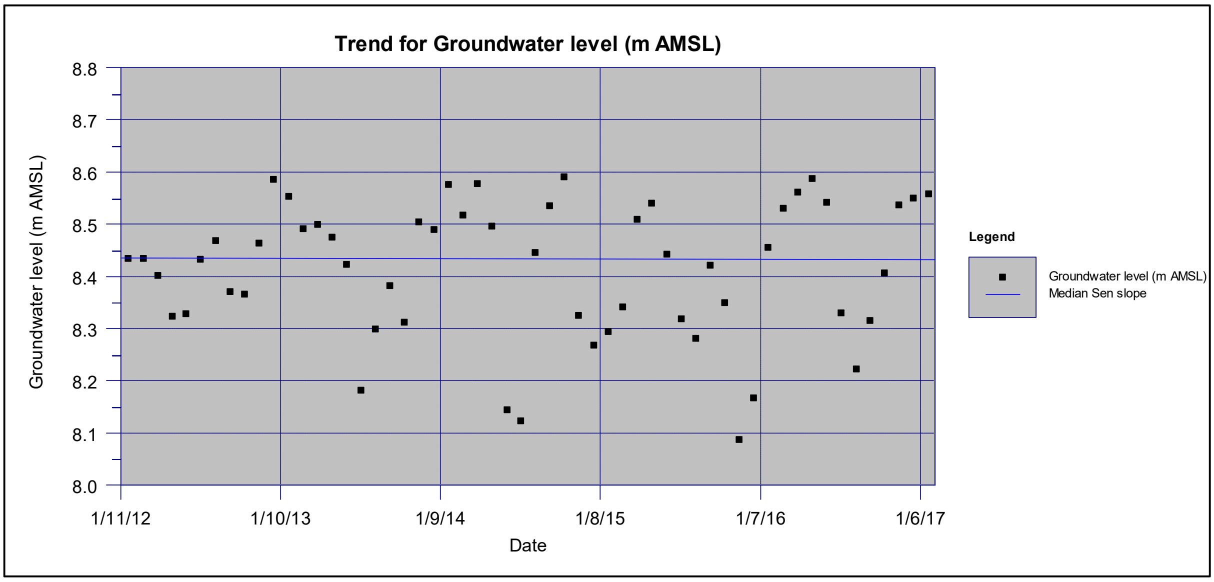


Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	54	-37	155	-2.89159	0.003833

GND2253: Patea Sentinel (Upper)

Not enough data for long-term trend analysis

Short-term (recent) trends:



Groundwater level (m AMSL)	Sample size	Kendall statistic	Variance	Z	P
Unadjusted	56	0	168	0	1