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Karaka Rural Urban Boundary Waitemata Aquifer Recharge Assessment

Auckland Council

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Karaka Rural Urban Boundary Waitemata Aquifer Recharge Assessment

Prepared for

Auckland Council

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pdp

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Executive Summary

Pattle Delamore Partners (PDP) has been engaged by Auckland Council (AC) to study the potential groundwater recharge effects on the Waitemata aquifer as a result of proposed land development within the Karaka Rural Urban Boundary (KRUB), presented in Figure 1.

South Auckland has a number of faults formed by tectonic activity, which control the geology and hydrogeology of the region. South of the Glenbrook Fault (Figure 1) the permeable Kaawa aquifer overlies the less permeable Waitemata aquifer. Because it is more permeable, groundwater preferentially flows through the Kaawa aquifer and recharge to the underlying Waitemata is through leakage. The Kaawa and the overlying Tauranga Group aquifers, therefore, act as a buffer for the deeper aquifer to any changes in recharge at ground surface. Consequently, development will have minimal impact on the Waitemata south of the Glenbrook Fault.

North of the Glenbrook Fault there is no Kaawa to act as a buffer for the Waitemata. The Waitemata is shallow and is recharged directly through infiltration. The Waitemata aquifer north of the Glenbrook Fault is, therefore, sensitive to changes in land development and is the focus for the study. Any further reference to the Waitemata refers solely to the Waitemata north of the Glenbrook Fault.

Recharge to the Waitemata is through rainfall infiltration over the areal extent of the aquifer, which accounts for approximately 20% of the KRUB and is shown in Figure 1. It is difficult to quantify a groundwater recharge rate at a given point due to varying local conditions. However, generally recharge to the Waitemata was estimated to be 60mm/yr.

The Waitemata Group consists of sandstone and mudstone sequences. Groundwater within the Waitemata aquifer primarily flows horizontally through fractures in the sandstone beds. Mudstone beds act as low flow barriers between the sandstone beds with leakage occurring between beds. There are two distinct aquifers within the Waitemata that are currently accessed by groundwater users.

Groundwater flows primarily towards the Manukau Harbour, discharging into the Drury Creek, Whangapouri Creek, Oira Creek, Ngakaroa Stream, Whangamaire Stream, and directly to the coast. Where the Waitemata aquifer interacts with surface water catchments some groundwater will discharge into the streams and contribute to stream baseflow.

There are seven surface water catchments, shown in Figure 1, draining through the Karaka RUB, but only three extend north of the Glenbrook Fault. Within the Waitemata, groundwater contributes to the stream baseflow of the Hingaia, Waihoihoi and Hays surface water catchments. The annual groundwater contribution to stream flow from the Waitemata aquifer is approximately 20mm/yr or about 0.1% to 10% of baseflow in these streams.

The available groundwater resource in the aquifer is the residual recharge left after allowance is made for environmental considerations. These are primarily groundwater

contribution to stream baseflow and minimum groundwater throughflow (set at 15% of recharge) to prevent saline intrusion at the coast. After making these allowances the currently available groundwater resource in the Waitemata aquifer within the KRUB (excluding current use), is approximately 1,000m^3/d.

By increasing the imperviousness of the ground through urban development less rainfall will be available for recharge. This will have a direct impact on the groundwater resource available. The interaction between recharge, groundwater throughflow, surface water flow and groundwater abstraction is complex. The method used in this report to determine the effect of development is very general, sufficient only for a preliminary estimate.

Analysis indicates a 50% increase in imperviousness will result in a 50% decrease in recharge to the Waitemata aquifer within the KRUB. If a minimum throughflow to the coast is maintained then the 50% decrease in recharge equates to a 60% decrease in groundwater contribution to baseflow and a 60% decrease in the available groundwater resource within the Waitemata. The maximum allowable amount of imperviousness using the current method of analysis is 85%. Beyond this threshold there is not enough groundwater throughflow to satisfy the prevention of saline intrusion criterion.

The impact of increased imperviousness on the seven surface water catchments which drain into the KRUB was estimated by incorporating the aquifers north and south of the Glenbrook Fault. Depending on the geology, size of the catchment and proportion of the catchment within the KRUB the decrease in stream baseflow is estimated to be between 3% and 40%. The Oira, Hingaia and Waihoihoi catchments are most sensitive to changes in imperviousness while the Whangamaire, Whangapouri and the Hays are impacted the least.

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1.0 Introduction

Pattle Delamore Partners (PDP) has been engaged by the Auckland Council (AC) to study the potential groundwater recharge effects on the Waitemata aquifer as a result of land development within the Karaka Rural Urban Boundary (KRUB) growth node, presented in Figure 1.

The Karaka RUB is one of five key growth nodes within South Auckland that has been identified within the Auckland Plan as future land development growth nodes.

Groundwater monitoring data suggest water levels in the local area are very sensitive to recharge rates due to climatic variability. AC has therefore expressed concern towards what may be a reduction of groundwater recharge as a result of the proposed development.

1.1 Objectives

The objectives of this study are to;

- Identify areas of groundwater recharge and discharge.
- Estimate groundwater age and movement through aquifer.
- Quantify recharge rates.
- Quantify the contribution of groundwater to stream flow (base flow) throughout the year.
- Evaluate the impact of a range of reduced recharge scenarios on the Waitemata Aquifer and on steam flow through the year.

2.0 Background

2.1 Geology

Local geology is shown in Figure 1. South Auckland has a number of faults and blocks formed by tectonic activity, which control the geology and hydrogeology of the region. Of particular interest in the Karaka RUB area are the Glenbrook and Drury faults, shown in Figure 1. The Glenbrook Fault cuts through the RUB in a roughly east-west direction while the Drury Fault lies just east of the RUB trending in a north-south direction. Conceptual geological models of the area are shown in Figure 2, and the location of each section is illustrated in Figure 1.

Section A-A' shows how the Glenbrook fault divides the RUB into two distinct geological domains. To the north of the fault, the geology consists of thin layers of Tauranga Group sediments overlying Waitemata Group sandstone and mudstone sequences. South of the fault, where the Waitemata Group was downthrown during tectonic activity, the Waitemata Group is overlain by the Kaawa Formation which is in turn overlain by the Tauranga Group sediments. South of the Karaka RUB, the depositional sequence is interrupted by the South Auckland Volcanic Field.

Section B-B' and C-C' illustrate the geological profile perpendicular to section A-A'. East of the RUB is the Drury Fault which delineates the uplifted Hunua Ranges in the east from the Manukau Lowlands where the RUB is situated. The Waipapa Group, composed mainly of greywacke, lies east of the Drury Fault as shown in sections C-C' and B-B'. In places remnant Waitemata Group sequences mantle the Waipapa Group.

2.2 Hydrogeology

Regionally, groundwater flows towards the Manukau Harbour. Locally, the Glenbrook Fault divides the Karaka RUB into two main aquifer units: the Waitemata aquifer to the north and the Kaawa aquifer to the south. Little if any use is made of the deeper Waitemata aquifer south of the Glenbrook Fault. Groundwater preferentially flows through the more permeable Kaawa aquifer.

South of the Fault recharge to the deeper Waitemata is through leakage from the overlying Kaawa aquifer. As the rate of leakage is driven by the vertical hydraulic gradient through the full depth of the overlying aquifers the deep Waitemata resource is insensitive to small or even moderate water level changes at the top of these units. Both the Tauranga Group and the Kaawa aquifers, therefore, provide a buffer to changes in recharge at ground surface. Thus the effect of increase in imperviousness on the deeper Waitemata aquifer resource is expected to be minimal and consequently, the deeper Waitemata has been left out of consideration for this study.

Groundwater flow through the Waitemata aquifer is primarily along the sandstone interbeds and fractures. Permeability is generally considered to be low, with a transmissivity range from 6-62 m^2/d (IP 24). The interlayering of sandstone and siltstone results in confined beds with discontinuous fractures with horizontal permeability being greater than vertical permeability.

Within the Waitemata aquifer there are two distinct flow paths that are accessed by groundwater users. Bores drilled up to 100m depth are considered to be accessing the shallow aquifer whereas bores between 100m and 350m depth are in the lower aquifer (Pattle Delamore Partners, 2011, Earthtech, 2009). Observed water levels in local bores indicate a downward gradient: the deeper Waitemata aquifer is recharged through infiltration from the overlying Tauranga Group sediments (where present) and the shallow Waitemata aquifer.

Infiltration is expected to be the dominant factor on groundwater recharge and throughflow within the Waitemata aquifer. Aquifer recharge is assumed to be restricted across the Glenbrook Fault to the south as well as the Drury Fault to the east.

A total of seven surface water catchments drain through the Karaka RUB, but only three extend north of the Glenbrook Fault. The surface water catchments are listed below with the total catchment area, the catchment area within the Karaka RUB and the catchment area within the RUB north of the Glenbrook Fault respectively detailed in brackets:

- Whangamaire (23.2 km^2, 1.03 km^2, 0.00 km^2)
- Whangapouri (50.21 km^2, 8.64 km^2, 0.00 km^2)

- Oira (17.7 Km^2, 6.25 km^2, 0.00 km^2)
- Ngakaroa (39.84 km^2, 7.24 km^2, 0.00 km^2)
- Hingaia (53.99 km^2, 9.92 km^2, 0.38 km^2)
- Waihoihoi (16.68 km^2, 2.89 km^2, 1.54 km^2)
- Hays (30.03 km^2, 2.44 km^2, 2.44 km^2)

3.0 Discussion

Due to the limitations of the data and the general nature of the analysis the calculations presented in this section are intended as preliminary estimates only.

3.1 Recharge and Discharge Zones

The Waitemata aquifer is bound on the south by the Glenbrook Fault, on the east by the Drury Fault and on the north by the Manukau Harbour.

Since there is little or no throughflow from the Kaawa aquifer to the south or the Waipapa aquifer to the east, recharge to the Waitemata aquifer is dependent on rainfall infiltration over the areal extent of the aquifer. Within the RUB the recharge zone to the Waitemata is approximately 10 km^2, which accounts for approximately 20% of the RUB surface area. Figure 1 presents the recharge zone to the Waitemata north of the Glenbrook Fault within the KRUB.

Discharge, in the vicinity of the KRUB, is towards the Manukau Harbour by vertical upward leakage into the Drury Creek, Whangapouri Creek, Oira Creek, Ngakaroa Stream, Whangamarie Stream, and directly to the coast.

3.2 Groundwater Age and Movement through Aquifer

Within the Waitemata aquifer, groundwater moves vertically downward and horizontally towards the Manukau Harbour.

The Waitemata layering results in higher permeability values in the horizontal direction than the vertical. As a consequence, groundwater flows predominantly in the horizontal direction with downward leakage occurring between layers.

Where the Waitemata aquifer interacts with surface water catchments some groundwater will move upwards, discharging into the stream and contributing to baseflow.

Under the gradient conditions typical in the area (1:300) groundwater flows through the Waitemata aquifer at approximately 70 cm per year. As it moves northward it increases in age, with the youngest occurring near the Glenbrook and Drury Faults. The average age of the Waitemata groundwater within the RUB is roughly approximated to be 800 years.

3.3 Recharge Rate

It is difficult to qualify a groundwater recharge rate at a given point due to varying local conditions. Consequently, a broad or catchment based scale is used. A generalised water balance model was developed to determine the groundwater recharge rates in the Karaka RUB. An overview of the methodology can be found in Appendix A.

Table 1 presents the calculated groundwater recharge rates within each surface water catchment that drains into the Karaka RUB. Stream flow data were only available for the Whangamaire and Ngakaroa steams, all other stream flow data were determined by developing area relationships. The calculated recharge rates, therefore, are approximates only. Note, only the Hays, Waihoihoi and Hingaia catchments extend sufficiently far north of the Glenbrook Fault into the Waitemata aquifer.

Table 1: Average Groundwater recharge rates (mm/year) within each surface water catchment that drains to the Karaka RUB

Catchment Reach Description	Surface Water Catchment						
	Whangamaire	Whangapouri	Oira	Ngakaroa	Hingaia	Waihoihoi	Hays
Average recharge rate within the Karaka RUB	60	90	60	120	130	100	60
Average recharge rate to Waitemata aquifer within the Karaka RUB	N/A	N/A	N/A	N/A	60	60	50

Notes: 1. Units are mm/year

An approximate average value of 60 mm/yr is used to represent recharge to the Waitemata within the Karaka RUB. This represents approximately 5% of rainfall.

3.4 Groundwater Contribution to Stream Flow

The annual contribution to stream flow from groundwater in the Waitemata aquifer within the relevant surface water catchments is shown in Table 2. These values are based on the approximated recharge values determined in section 3.3; consequently, the baseflow values presented are estimates.

Table 2: Average groundwater contribution to stream flow (baseflow) from the Waitemata aquifer within the Karaka RUB

Surface Water Catchments	Surface Area (km^2)	Average Groundwater Contribution to Baseflow (mm/yr)	Average Groundwater Contribution to Baseflow (m^3/yr)	Per cent Contribution of Total Catchment (%)
Hingaia	0.38	20	7,000	0.1
Waihoihoi	1.54	20	30,000	4
Hays	2.44	20	45,000	8

3.5 Groundwater Available for Abstraction

There is a requirement to maintain a minimum throughflow, estimated to be approximately 15% of the recharge to the groundwater system, to prevent saline intrusion at the coast. Consequently, the approximate available groundwater resource is calculated as the remainder of the recharge volume once the throughflow to the coast and the groundwater contribution to stream baseflow is deducted.

Table 3: Groundwater from the Waitemata aquifer within the Karaka RUB available for abstraction

Surface Water Catchments	Groundwater Contribution to Stream Baseflow		Minimum Residual Groundwater Throughflow to Sea		Approximate Available Groundwater Resource	
	(m^3/d)	(m^3/yr)	(m^3/d)	(m^3/yr)	(m^3/d)	(m^3/yr)
Hingaia	20	7,000	10	3,000	30	10,000
Waihoihoi	90	30,000	40	13,000	120	45,000
Hays	120	45,000	50	20,000	180	65,000
Area west of Hingaia catchment and north of Glenbrook Fault	N/A	N/A	130	50,000	700	300,000
Total	230	85,000	230	85,000	1,000	400,000

Active water takes in the vicinity of the KRUB are predominantly for irrigation and account for approximately half of the available groundwater resource. Effects of Increased Imperviousness on Streams and Groundwater in Waitemata

Because the Waitemata aquifer is reliant on rainfall infiltration as recharge, there is a direct relationship between the proportion of the land used for development and recharge to the groundwater system. Surface imperviousness associated with urban development will create increased surface runoff and a loss of water that would otherwise contribute to recharge. Mitigation options are available, such as requiring the use of soakage systems, but not generally used unless special policy measures are put in place. Table 4 presents the effect an increase in imperviousness would have on recharge. A direct correlation has been assumed between the per cent increase in imperviousness and the per cent decrease in recharge.

Table 4: Effect of Increased Imperviousness on Average Groundwater Recharge

Increased Imperviousness (%)	Average Recharge (mm/yr)	Decrease in Recharge (%)
0	60	0
25	40	25
50	20	50
75	5	75
100	0	100

The interaction between groundwater and surface water flow is dynamic. A decrease in recharge will cause a reduction in groundwater contribution to baseflow as well as reduce throughflow to the harbour. Without a calibrated time dependent model assessing the interaction between recharge, groundwater throughflow, groundwater contribution to baseflow and groundwater abstraction it is not possible to determine the precise effect a decrease in recharge will have on each variable independently. The method presented in this report provides an estimate and is based on the following assumptions:

- Throughflow to prevent saline intrusion is constant and is equal to 15% of current recharge rate.
- The per cent reduction in groundwater contribution to baseflow is equal to the per cent reduction in available groundwater resource.

Table 5 and 6 present the effect an increase in imperviousness would have on the groundwater resource available for abstraction and baseflow, respectively. Due to uncertainty in the catchment stream flow calculations the values shown below are approximates and intended as a general guide only.

Table 5: Effect Of Increased Imperviousness On Available Groundwater Resource within the Waitemata aquifer north of Glenbrook Fault

Increased Imperviousness (%)	Available Groundwater Resource (m^3/d) in Catchments					Decrease in Available Groundwater Resource (%)
	Hingaia Catchment	Waihoihoi Catchment	Hays Catchment	Area West of Hingaia Catchment and north of Glenbrook Fault	Total	
0	30	120	180	700	1,000	0
25	20	90	130	500	800	30
50	10	50	70	300	400	60
75	4	10	20	90	120	90
85	0	0	0	0	0	100

Table 6: Effect Of Increased Imperviousness On Groundwater Contribution To Stream Baseflow within the Waitemata aquifer north of Glenbrook Fault

Increased Imperviousness (%)	Groundwater Contribution to Stream Baseflow (m3/d) in Catchments				Decrease in Available Groundwater Resource (%)
	Hingaia Catchment	Waihoihoi Catchment	Hays Catchment	Total	
0	20	90	120	230	0
25	10	60	90	160	30
50	7	40	50	100	60
75	2	10	20	30	90
85	0	0	0	0	100

An increase in imperviousness of 0% corresponds to current conditions within the KRUB. The groundwater contribution to stream baseflow and the available groundwater resource under a 0% increase in imperviousness is, therefore, the same as those outlined in Table 3.

The maximum reduction in recharge allowed with this method is 85%. It is assumed any reduction above this threshold will allow saline intrusion at the coast.

Any recharge to the groundwater system contributes to stream baseflow as well as throughflow to the coast. Because the recharge is shared, the individual impact on the stream baseflow and available resource is greater. Consequently, for every per cent decrease in recharge there is a greater per cent reduction in groundwater contribution to baseflow and available groundwater resource.

3.6 Effects of Increased Imperviousness within KRUB on Streams

The impact to the wider surface water catchments caused by an increase in imperviousness within the Karaka RUB varies depending on the size and up gradient geology of the catchment. As noted previously there are seven surface water catchments that drain through the Karaka RUB.

This report has focused on the effect development will have on the Waitemata aquifer, north of the Glenbrook Fault. Table 7, however, presents the estimated effect an increase in imperviousness within the Karaka RUB, north and south of the Glenbrook Fault, will have on the individual surface water catchments.

Table 7: Percentage decrease in surface water catchment baseflow caused by decrease in groundwater contribution to stream baseflow within the Karaka RUB

Imperviousness (%)	Surface Water Catchment						
	Whangamaire	Whangapouri	Oira	Ngakaroa	Hingaia	Waihoihoi	Hays
0	0	0	0	0	0	0	0
25	1	3	8	5	10	8	2
50	2	6	15	10	20	20	5
75	3	8	25	15	30	25	7
85	3	9	30	20	40	30	8

Notes: 1. Units are percentage (%)

The impact on the surface water catchments under current conditions is 0%. As the imperviousness increases per cent decrease in surface water catchment baseflow increases to a maximum, indicated at 85% imperviousness. The Oira, Hingaia and Waihoihoi catchments are most sensitive to changes in imperviousness while the Whangamaire and the Hays are impacted the least.

4.0 Conclusion

The Waitemata aquifer accounts for approximately 20% of the Karaka RUB. It is bounded on the south by the Glenbrook Fault, the east by the Drury Fault and the north by the Manukau Harbour.

Infiltration is the dominant factor on groundwater recharge and throughflow in the Waitemata aquifer. Groundwater flows north towards the Manukau Harbour and discharges by vertical upward leakage into the Drury Creek, Whangapouri Creek, Oira Creek, Ngakaroa Stream, Whangamaire Stream, and directly to the coast.

An approximate average recharge rate of 60 mm/yr was calculated using water balance model analysis based on the three surface water catchments which drain through the Waitemata aquifer within the Karaka RUB. The rate calculated is similar to values used for the Waitemata aquifer elsewhere in Auckland and represents approximately 5% of the average rainfall in the area.

Within the Karaka RUB groundwater contribution from the Waitemata aquifer to stream flow varies depending on the catchment. The approximate contribution to Hingaia baseflow is 20m^3/d, to the Waihoihoi baseflow is 90m^3/d and to the Hays baseflow is

120m^3/d. These flows represent approximately 0.1%, 4% and 8% or the total surface water catchment stream baseflow, respectively.

Available groundwater resource is calculated based on recharge, but must also consider a minimum groundwater throughflow to prevent saline intrusion at the coast. Consequently, the current approximate average groundwater available as a resource, from the Waitemata aquifer within the Karaka RUB, is as follows: 30m^3/d in the Hingaia catchment; 120m^3/d in the Waihoihoi catchment, 180m^3/d in the Hays catchment; and, 700m^3/d in the area west of the Hingaia catchment and north of the Glenbrook Fault.

By increasing the imperviousness of the ground through urban development, less rainfall will be available for recharge. Because the Waitemata aquifer is entirely reliant on rainfall infiltration as recharge, there is a direct relationship between the proportion of the land available for development and water resource availability. However, the interaction between recharge, groundwater throughflow, surface water flow and groundwater abstraction is complex. The method used in this report to determine the effect of development is general, sufficient only for a preliminary estimate.

In approximating the effect of increased imperviousness on the available groundwater resource, a minimum groundwater throughflow to the sea to prevent saline intrusion is maintained. Consequently, while an increase in imperviousness of 50% will result in a decrease in recharge by the same amount, the impact on the available groundwater resource and the groundwater contribution to stream baseflow is a 60% reduction. As the imperviousness increases the per cent of recharge needed to maintain the minimum groundwater throughflow increases. The maximum reduction in recharge is 85%. Beyond this threshold there is not enough groundwater throughflow to satisfy the prevention of saline intrusion criterion.

The impact of increased imperviousness on the seven surface water catchments which drain into the Karaka RUB, through the Kaawa and Waitemata aquifers, is estimated to be between 3% and 40%, depending on geology, size of the catchment and proportion of the catchment within the Karaka RUB. The Oira, Hingaia and Waihoihoi catchments are most sensitive to changes in imperviousness while the Whangamaire, Whangapouri and the Hays are impacted the least.

5.0 References

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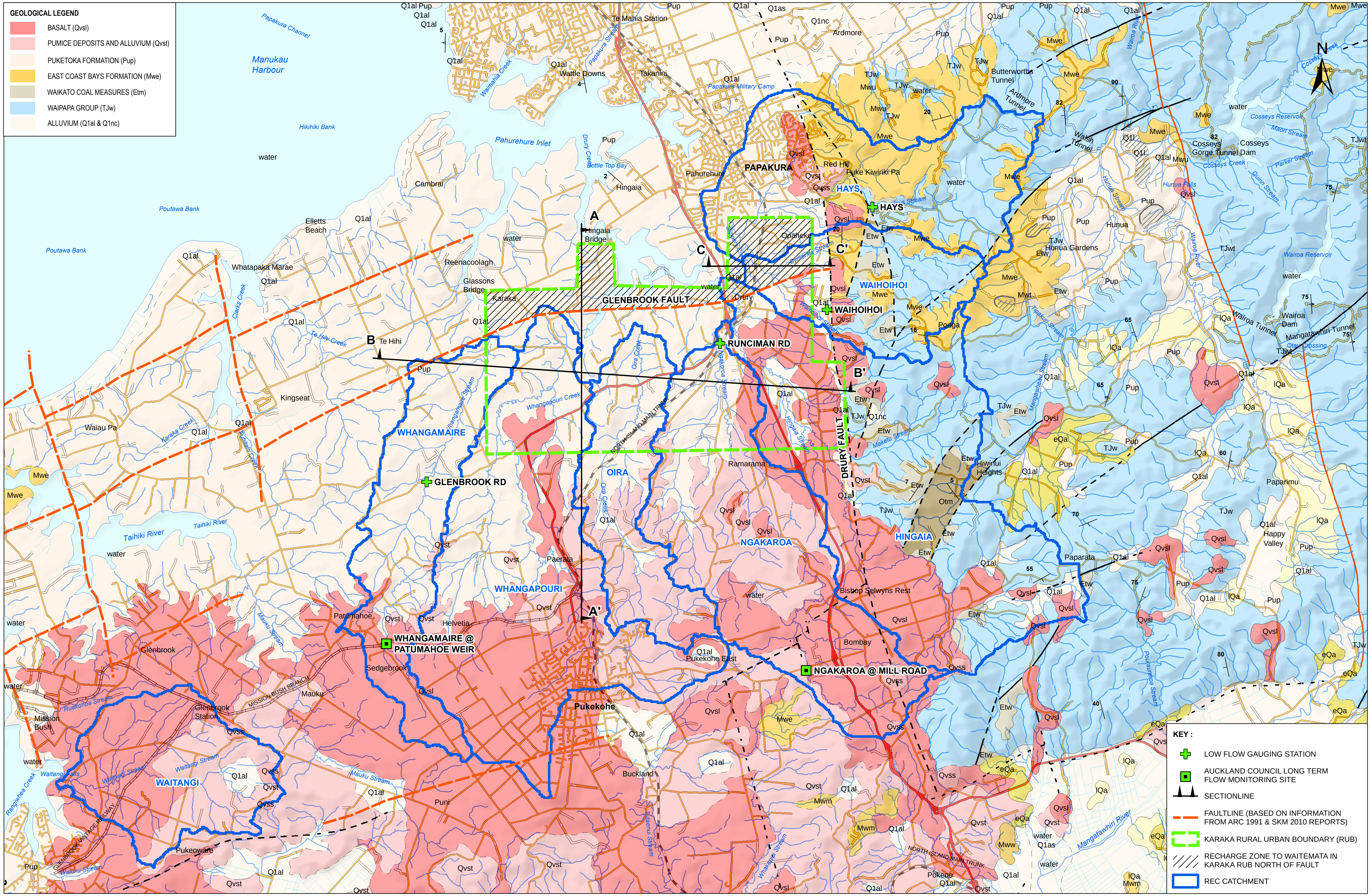

SOURCE:
1. GEOLOGICAL MAP SOURCE: EDBROOKE, S.W. (COMPILER) 2001: GEOLOGY OF THE AUCKLAND AREA. INSTITUTE OF GEOLOGICAL & NUCLEAR SCIENCES 1:250,000 GEOLOGICAL MAP 3. INSTITUTE OF GEOLOGICAL & NUCLEAR SCIENCES LIMITED.
2. FAULTLINES BASED ON INFORMATION SOURCED FROM THE AUCKLAND REGIONAL COUNCIL REPORT "DRURY - BOMBAY GROUNDWATER INVESTIGATION AND INTERIM MANAGMENT PLAN" 1991 AND SKM REPORT "KARAKA NORTH - REVIEW OF HYDROGEOLOGY" 2010.
3. REC CATCHMENTS DERIVED FROM THE MINISTRY OF ENVIRONMENT REC DATASET, DATED 17 OCT 2011.
4. KARAKA RUB DIGITISED FROM UNITARY PLAN RUB CONSULTATION 'OPTIONS FOR FUTURE GROWTH AND A RUB'.
5. TOPOGRAPHY INFORMATION DERIVED FROM LINZ.

FIGURE 1 : SITE LOCATION AND GEOLOGY

SCALE: 1:100,000 (A3)

0 0.5 1 2 3
KILOMETRES

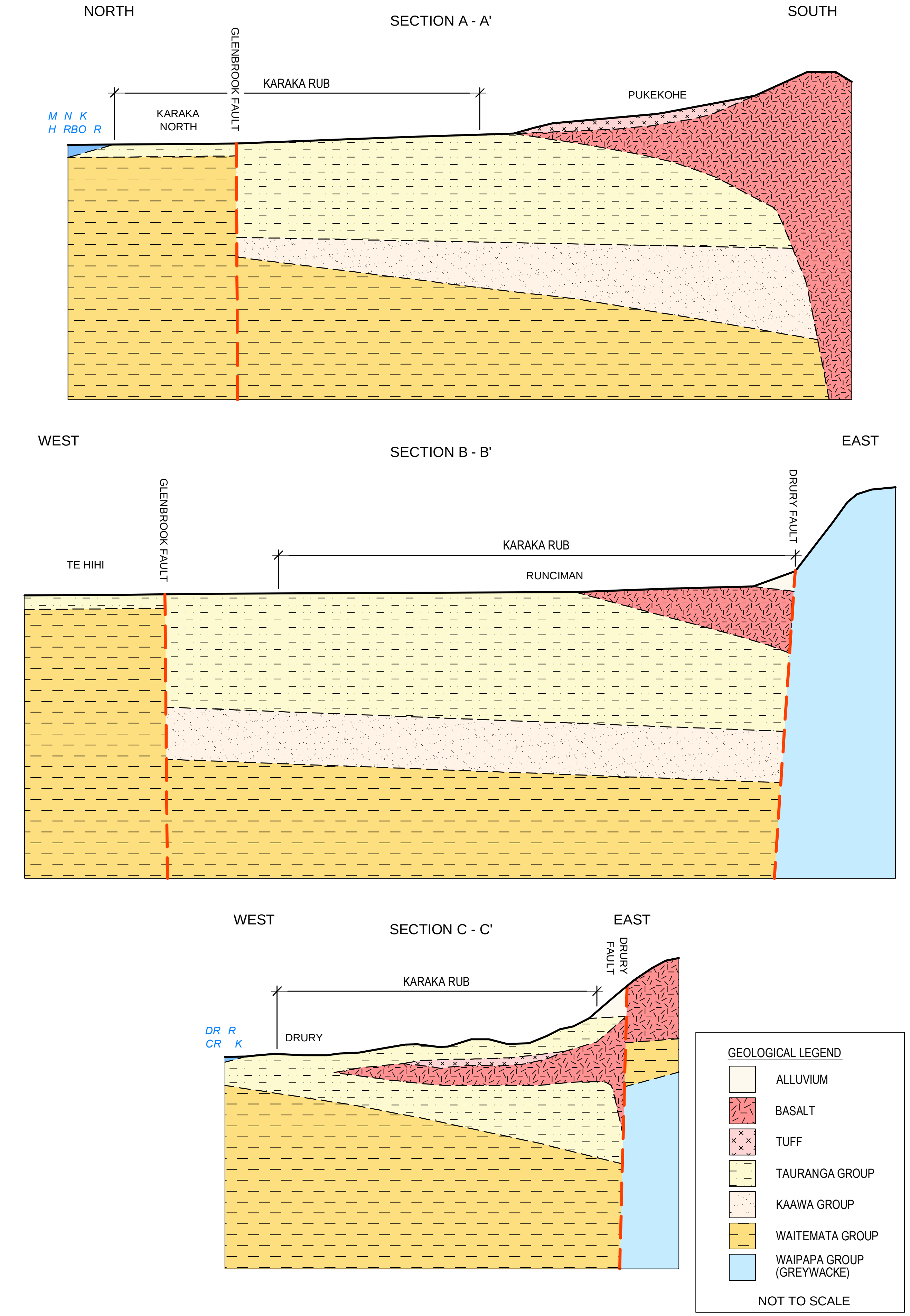

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FIGURE 2 : CONCEPTUAL GEOLOGICAL SECTIONS