PATTLE DELAMORE PARTNERS LTD
Level 4, PDP House
235 Broadway, Newmarket, Auckland 1023
PO Box 9528, Auckland 1149, New Zealand

Tel +9 **523 6900** Fax +9 **523 6901**
Web Site **http://www.pdp.co.nz**
Auckland Wellington Christchurch

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Bernie Chote
Fletcher Residential
Private Bag 92114
AUCKLAND 1142

Dear Bernie

THREE KINGS RENEWAL PLAN CHANGE APPLICATION, STORMWATER MANAGEMENT PLAN, SECOND ADDENDUM, SOAKAGE INVESTIGATIONS

This letter forms a second addendum to the Three Kings Renewal Stormwater Management Plan produced by Pattle Delamore Partners in September 2014. The second addendum summarises further investigations into the properties of the proposed soakage locations within the Option 15H1 plan change development area. The first addendum dated 6 October 2014 identified the durations water would be ponded above ground following rainfall events for low, medium and high soakage rates (for unsaturated materials) and a groundwater limited scenario.

1.0 Background

The first addendum assessed stormwater disposal from the sportsfields through soakage trenches excavated into the scoria at the south side of the field areas. For this conceptual design, five soakage trenches (1m wide by 4m deep of length 50m each) were used (for a total of 250m of actual trench). Infiltration was assumed to occur only through one wall 3m high (towards the perimeter of the site) and through the base of the soakage trenches.

As noted in the first addendum there are two key potential factors affecting the design of the soakage trench:

1. The rate at which water can be conveyed through the walls and floor of the trenches; and
2. The rate at which water can be conveyed into the wider aquifer without locally raising the groundwater level above the surface water ponding level (i.e. local mounding of groundwater).

The more conservative of these two should be taken as the limiting rate. The assessment set out in the first addendum identified that the "groundwater limited" scenario was the limiting rate. This letter reports on further soakage investigations into the extent of scoria deposits and their soakage properties.

In addition to this, the groundwater modelling has assessed the response of the groundwater level within the crater to rainfall. This is discussed further in the PDP memorandum of 23rd December 2014.

2.0 Soakage capacity at soakage trenches

2.1 Information sources

Past information sources were reviewed to identify the surrounding geology and infer the extent of scoria. Key sources of information were:

- Auckland Council, 2014. Drillers logs and soakage test results for boreholes in Barrister, Fyvie, McCullough and Smallfield Aves.

- Fraser Thomas, 1987. Three Kings, Quarry Development Plan [for the extension of the former Mt Roskill Borough quarry].
- Hayward BW., et al, 2011. Volcanoes of Auckland: the essential guide.
- Industrial Geology, Fisher G, 2003. Geological Update for Three Kings quarry [Winstone Aggregates report].
- Pattle Delamore Partners, 2004. Unpublished mapping of central Auckland volcanics for the Global Aquifer Study.
- Winstone Aggregates, borehole logs.

2.2 Investigations

The physical investigation consisted of; air hammer drilled boreholes, trial pits and geological mapping of cut faces. Soakage tests were carried out in both boreholes and trial pits.

Cut faces were mapped based on geological zones observed in photos as well as information and expertise gathered from site visits and other geological reports.

Borehole logs were used to generate geological cross sections through the quarry, extending to the surrounding area. Three cross sections were chosen to target the southern half of the quarry and get information on the east, south and west areas. The cross section locations were placed in close proximity to boreholes of interest to minimise extrapolation errors. Intermediate areas without borehole logs were estimated based on boreholes either side, previous geological cross sections and reports.

Test bores were attempted to be drilled into fractured basalt or scoria. A pneumatic rig was used so the underlying geology was inferred from drillers' comments and the fragments collected at the surface of the test hole. An environmental geologist was onsite supervising all drilling and soakage testing operations.

The test methodology followed for soakage testing was from the Auckland Council Soakage Design Manual: 3.6 Constant-Head Percolation Tests. The holes were pre-soaked for at least 10 minutes before the constant head test was attempted. Two water tankers were used to get to acceptable flow rates over the test duration. The flow rate was increased until a constant head was observed or until the maximum flow rate of the equipment was reached with no constant head. The flow rates were then recorded at various intervals during the test to ensure the flow rate was not changing.

There were difficulties in maintaining open holes at some locations due to scoria collapsing into the holes. In Borehole B4 an attempt was made to keep an open hole with placement of clay down hole in the upper part of the hole – this may have affected soakage results. As a result of these difficulties, trial pits were excavated in selected locations so the type of material could be directly observed and tested.

2.3 Results

2.3.1 Existing information

Volcanoes of Auckland

This book describes the sequence of events forming the Three Kings volcanic complex. Of note are the presence of eight different scoria cones within the Winstone and former Council quarry areas (refer Attachment A). A moderate sized scoria cone was located in the centre of the current Council sportsfield, another of similar size was on the southern boundary of the Winstone quarry, a further one near the south east corner of the Winstone quarry and two small cones were present around Barrister Ave.

Auckland Council

Auckland Council carried out soakage investigations for drainage of roads to the west of the current reserve in June 2014. The results are summarised in Table 1.

Table 1: Auckland Council Soakage results

Location	Test capacity, L/s	Driller's description of materials	Comment
6 Barrister Ave	36.7	0 – 5.5 m basalt/rock 5.5 – 15m Scoria	
17 Smallfield Ave	< 2 L/s (refer note 2)	1.6 – 14.2m Scoriaceous rock	Driller notes hole "constantly caving". Soakage rate too low for rock type – result considered to be affected by blockage
27 Fyvie Ave	17 L/s (refer note 2)	1.6 – 10.5m Scoriaceous rock	Driller notes hole "constantly caving"
56 Smallfield Ave	47.6 L/s minimum	1.5 – 7.0m, Basalt rock/ fractured	
68 McCullough Ave	4.5 L/s	1.2 – 9.0m, basalt rock/ scoria 9 – 15m clay	Potential clay smearing of the rock/scoria?
Corner of Smallfield and Henshaw Aves	33 L/s	0.6 – 10.5m, basalt/ fractured rock/ scoria	
Robinson Reserve	27 L/s	0.4 – 9m, basalt/ fractured rock/ scoria	

1. Where a flow rate is denoted "minimum", no constant head could be achieved with the available flow from the hydrant /water cart test set-up.
2. Where flow rate is low in scoria that is noted as "caving", it is inferred that the drilling action has affected the soakage test rate.

Fraser Thomas report

The Fraser Thomas report investigated the extent of scoria remaining under the Council land to the south and west of the Winstone quarry. Ground levels at the time are inferred to be approximately 2m lower than current levels on the Council reserve. Investigations at the time included inspection of the rock surface (which was exposed across the current reserve area) and two boreholes (which went down into scoria for 10 to 12m).

Scoria was identified across the current Council reserve (sportsfield) to the west and the Council land to the south. A 10m wide basalt extrusion was noted running north / south through the Council land to the south, with several smaller width intrusions across the current Council reserve. The extent of scoria beneath the Council land (above the

groundwater level of RL 56m and allowing for access benches) was estimated to be 315,000m^3. Further scoria reserves were identified below the groundwater table and under surrounding houses.

2.3.2 Mapping and Sections

Some materials are visible in cuttings within the current quarry faces. Photographs are attached to this addendum are marked up to show these units.

In addition to existing information, PDP boreholes and mapping, information from Winstone Aggregates boreholes and Industrial Geology geological sections has been used for development of the geological cross sections. The geological cross sections are attached as Sections A-A', B-B', C-C'.

2.3.3 PDP Soakage testing

Scoria was identified from geological faces and PDP boreholes over much of the former Mt Roskill Borough quarry. However soakage tests within the air drilled boreholes were variable. Scoria with coarse gravel sized particles was identified in the area adjacent to Barrister Ave. A borehole in this area gave a soakage rate of 35 L/s. The driller reported a number of holes were caving in (which is thought to indicate evenly graded scoria) – however these boreholes gave soakage rates of about 5 L/s. It is unclear if this is the result of layers of fine particles within the scoria or has been artificially lowered as a result of the drilling crushing the scoria into fine particles and blocking voids in the scoria.

To remove this uncertainty, trial pits were excavated directly into the scoria immediately on the boundary of the current quarry. Pits in both the black, medium and coarse gravel sized scoria and the red scoria (boulder, gravel and sand sized particles) gave high soakage rates. These pits coincide with the location of two different moderate sized scoria cones along the southern boundary of the Winstone quarry.

The location of investigation holes and pits are summarised on Figure 1 with test results given in Tables 2 and 3.

Table 2: PDP Soakage results, former Council quarry

Location	Test capacity, L/s	Driller's description of materials
BH B1	5	1.5 – 10m Scoria, caving
BH B2		1.5 – 10m Scoria
BH B3	38	0.5 – 10m Scoria/ rock
BH B4	5	1.5 – 18.8m, scoria 18.8 – 20m scoria/ fractured rock
BH B5	<5	1.5 – 3.0m scoria, 3.0 – 20m basalt

1. Where flow rate is low in scoria that is noted as "caving", it is inferred that the drilling action has affected the soakage test rate.

Table 3: PDP Soakage results, trial pits

Location	Test capacity, L/s	PDP description
Trial pit 1	15 L/s minimum (672 L/m^2/minute minimum)	Black scoria: medium and coarse gravel sized
Trial pit 2	21, 21, 21, 23 L/s (285 L/m^2/minute)	Red scoria: sand, gravel and boulder sized particles
Trial pit 3	5 L/s (62 L/m^2/minute)	Red scoria /fill?
Trial pit 4	7.2 L/s (86 L/m^2/minute)	Red scoria /fill?

1. Where a flow rate is denoted "minimum", no constant head could be achieved with the available flow from the hydrant /water cart test set-up.

2.4 Discussion

Existing information, mapping and a series of soakage tests have been carried out to identify soakage characteristics near potential discharge points. Soakage rates vary depending upon the type of volcanic material present and the extent of voids or fracturing within the material.

Three main types of material are identified:

- Scoria – with variable sizes and grading of particles. May be coloured black or red.
- Basalt – grey rock, with variable fracturing.
- Tuff – ash particles welded together to form a matrix.

Auckland Council have put down five boreholes along or close to Smallfield Ave which is immediately west of the current council sportsfield. These holes are in scoria and basalt from the drillers logs. We interpret these all as being scoria deposits of different episodes. Four of them have soakage rates at 27 L/s or higher. A further hole on Fyvie Ave is also in scoria and has a soakage rate of 17 L/s. One hole on Smallfield Ave had a soakage rate of less than 2 L/s, but was described as "constantly caving" by the driller – this is considered inconsistent with the remainder of the results and not representative of the expected soakage rate.

One hole at the intersection of Fyvie and Smallfield Ave is recorded as various layers of basalt only and may represent a separate flow. A hole further afield on the corner of McCollough and Fyvie Ave appears to have encountered tuff in the lower part of the hole. Overall we characterise the Smallfield Ave area as being underlain by scoria.

PDP drilling was primarily used to identify the extent of scoria beneath the former Mt Roskill Borough quarry to the south of the current Fletcher's quarry. The drilling method employed is thought to affect the extent of local voids and soakage rates. More weight is therefore put on the soakage results from the trial pit testing and exposed geological faces.

Trial Pit 1 is in the black scoria (medium and coarse gravel sized particles) and relates to the cone in the south-east corner of the Winstone quarry. In all of these deposits, soakage is expected to be "high".

Trial pit 2 in red scoria (boulders to sand sized particles) gave a soakage rate of approximately 20 L/s. This corresponds to the "high" soakage rate assessed in the first addendum. This corresponds to the cone on the southern edge of the Winstone quarry. Borehole B2, Auckland Council's borehole on Barrister Ave and the exposure below Barrister represent a separate cone of red scoria (coarse gravel sized particles).

The mapping and cross sections identify scoria deposits over much of the quarries with the following of note for soakage:

- Scoria and basalt layers in the eastern quarry face running east toward Mt Eden Road (refer photograph 1)
- Black scoria in the south face spreading south under the former council quarry east of the basalt (refer photograph 2)
- Red scoria in the existing 35m by 20m hole in the south-west corner of the Winstone quarry (refer photograph 4) with further scoria under Barrister Ave behind (refer photograph 5)
- Scoria in the western quarry face heading west under Three Kings Reserve (refer photographs 5 and 6)

The groundwater mounding assessment presented in the first addendum was carried out on the basis of the average volcanic rock parameters for storage and hydraulic conductivity across the crater. The subsequent soakage investigations have confirmed the presence of scoria deposits at a number of points and inferred its extent by the geological cross sections. This has been used to refine the discharge locations so that they will be made to coarse scoria. The scoria deposits receiving water also have higher than the average storage and hydraulic conductivity and are considerably larger than the trench dimensions previously assessed. We therefore consider that the mounding assessment carried out is conservative.

3.0 Soakage into the wider groundwater system

Since the first addendum report PDP have analysed data from two groundwater level records from monitoring wells 2B and 5B within the quarry. Transducers recorded groundwater levels at 3 minute time steps from April to November 2014 so as to monitor the short term groundwater level response to rainfall.

The data showed that the groundwater level responded quickly to rainfall. When this data was used to verify the groundwater model response to a 54mm rainfall event in June, the average storage of the combined volcanic rock units (basalt, scoria, tuff) within the cone was confirmed at 8%. This storage value gave a modelled short term groundwater rise greater than the measured rise. Conservatively, the average model rock parameters were not modified. This is further discussed in Section 3.4 of the PDP memorandum on groundwater modelling dated 23 Dec 2014.

4.0 Proposed soakage locations

Soakage will be directed to the scoria deposits with "high" soakage rates. These correspond with the red scoria in the existing hole in the south west corner of the quarry (and possibly running a trench toward the scoria below Barrister Ave) and secondly the south-eastern face of black scoria in the quarry.

The following soakage locations for the main field flood storage area are proposed:

- A 100m long trench – in red scoria along the southern edge of the sportsfield in the 15H1 scheme
- The 35m by 20m hole into red scoria in the south-west corner of the quarry – this is approximately below Wetland A in the 15H1 scheme
- A 100m long trench – in black scoria along the southern edge of the sportsfield in the 15H1 scheme
- Extensions to these trenches could be made by extending trenches south under the former Council quarry

The extent of these proposed soakage areas is greater than that used in the mounding assessment in the first addendum and is expected to provide high soakage rates. If required, additional trenches can be constructed into the scoria deposits to the south and south west.

The wetland channel on the east side of the development would also have soakage discharges to:

- A 50m trench in scoria at about RL60m under wetland cell 2
- An extension to this trench (using a horizontal bore) may be possible from wetland cell 2 toward Kings Way
- A 100m trench in scoria at about RL 60m under wetland cell 3

Soakage characteristics in these areas are expected to be similar to other scoria deposits and reduce the amount of floodwater reaching the soakage areas listed above.

5.0 Conclusions

Soakage testing has characterised the scoria as having "high" soakage rates in unsaturated conditions. The soakage trench capacity is therefore controlled by the "groundwater limited" scenario (mounding assessment) described in the first addendum. For the proposed soakage locations to scoria deposits, the mounding assessment is conservative in terms of the storage and permeability parameters used.

The ability to provide soakage, either at soakage trenches themselves, or to the wider aquifer will be managed by ensuring there are sufficient soakage areas distributed around the perimeter of the development and storage to ensure soakage occurs without groundwater mounding longer than 24 hours and interference between dispersal trenches.

Monitoring of groundwater levels has confirmed the overall modelled groundwater response within the crater to rainfall and confirms the assessed short term rises in groundwater level within the crater.

6.0 Limitations

This report is based on the observation and sampling of a series of boreholes, trial pits and geological exposures at the site and published information. The geological information and associated environmental conditions have been interpolated between the boreholes, trial pits and geological exposures based on geological experience, and accordingly the interpolated conditions cannot be guaranteed to be accurate.

This report has been prepared on the basis of information provided by Auckland Council and others (not directly contracted by PDP for the work). PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

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Yours faithfully

PATTLE DELAMORE PARTNERS LIMITED

Roger Seyb

Encl - Figure 1: Geology and Test locations
Cross Sections A-A', B-B', C-C'
Photographs 1 to 8