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23 June 2016

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Dear Raelene

INFILTRATION TESTING RESULTS FOR AKAROA WASTEWATER DISPOSAL VIA IRRIGATION

1.0 Introduction

Christchurch City Council (CCC) is investigating a land disposal system for treated wastewater from the proposed new Akaroa Wastewater Treatment Plant (WWTP). Options being considered include irrigation to land using drip irrigation or spray irrigation. Pattle Delamore Partners Limited (PDP) carried out a desktop analysis to identify suitable land for this purpose. This analysis is discussed in the CCC consultation report 'Akaroa Treated Wastewater Disposal Options (May 2016)'. Further to this desktop analysis, PDP have been engaged by Beca to carry out site investigations at eight sites to further assess their suitability for discharge of treated wastewater to land. Landowners were approached by CCC regarding the potential use of this land for investigation.

The purpose of this report is to present the findings of the site investigations, discuss the suitability and constraints of each site, and provide recommendations to CCC as to the selection of land for the irrigation of treated wastewater to land. The results of the field work indicated that the field parameters of the soils differ from the desktop assumptions. As a result PDP were also requested to provide renewed details of the storage pond, land area requirement previously reported to CCC in March 2016 and additionally the annual drainage has also been assessed.

2.0 Method

Site investigations were carried out on 30 & 31 May 2016. These were carried out in conjunction with geotechnical investigations by Beca at each site. The PDP investigations involved:

- assessing the soil type at each location (including the depth of the topsoil, presence and depth of any low permeability layer);
- measuring the depth of root penetration to assist in estimating the Profile Available Water; and
- measuring the infiltration rate at the ground surface and, if required, of any low permeability layers at depth.

Test pits were excavated and infiltration tests were carried out at the locations shown in Figure 1, Appendix A. Eight infiltration tests were carried out using a double ring infiltrometer. These were carried out for a target minimum period of 90 minutes. Two infiltration tests, one in the surface soils and one in the less permeable subsoil, were carried out at four locations to determine a representative infiltration rate.

2.1 Double Ring Infiltrometer Test Methodology

A double ring infiltration test involves a small ring positioned inside a larger outer ring. Each ring is sunk into the ground to provide a preferential flow path for water. When both rings are filled, water infiltrates both laterally and vertically from the outer ring leaving infiltration in the vertical direction as the prominent flow path for water in the inner ring. Measurements of the water level in the inner ring are taken periodically and the drop in water level against time is plotted. If necessary, water may need to be added to the rings until a stable infiltration rate is measured (this was not required for the tests). The double ring infiltrometers were covered during periods of rainfall to avoid any inaccuracy of the measurements. The measured infiltration rate for design purposes is the stabilised rate measured over a minimum duration of 30 minutes. The photographs of the tests are shown in Figures 2 - 5.

3.0 Soil Description

The test pit results discussed in Section 4 below provide the detailed summary of the field work. From that work the soils are assessed to be Pawson Hills and Takahe Soils. Table 1 provides a detailed description of the Pawson and Takahe soils. These descriptions are from "General Survey of the Soils of South Island, New Zealand" (DSIR, 1968). Pawson Hills Soils and Takahe Soils are quite similar with the parent material being greywacke loess. The main difference in the profile of these two soils is the pale olive grey mottled orange crumbly/nutty layer directly below the topsoil, which is expected in Pawson Hills Soils. Both of these soils are vulnerable to sheet erosion, slumps on hills or slips on steeper slopes.

Movement of groundwater through the loess can cause tunnel gullies to form and also contribute to land instability, as evidenced by the occurrence of historical landslide features on the southern side of the Takamatua headland. This is consistent with the description of liability of soil erosion of Takahe and Pawson Hills Soils (DSIR, 1968).

Table 1: Soil Description

Soil Name	Parent Material	Topography	Representative Profile(s)	Liability to Soil Erosion
Pawson Hill Soils (mostly silt loams)	Greywacke loess (with minor basalt)	Moderately steep with rolling ridges; few short steep slopes with rock outcrops Up to 1,200 feet (370 m)	6 in. (150 mm) dark grey brown crumb/nutty silt loam; friable 3 in. (75 mm) pale olive grey lightly mottled orange crumb/nutty silt loam; friable 8 in. (200 mm) pale yellow brown lightly mottled orange nutty/blocky silt loam; firm on pale yellow brown (grey veins) prismatic silt loam; very firm.	Sheet if cultivated; slumps on hills; trees survive in gullies and provide protection

Table 1: Soil Description

Soil Name	Parent Material	Topography	Representative Profile(s)	Liability to Soil Erosion
Takahe Soils (silt loams, fine sandy loams)	Greywacke loess of varying thickness overlying basalt	Rolling to easy rolling broad spurs with narrow strips of moderately steep sides Up to 1,000 feet (305 m)	6 in. (150 mm) dark grey brown crumb silt loam; friable 10 in. (250 mm) yellow mottled orange blocky silt loam; friable 12 in. (300 mm) olive grey lightly mottled orange crumb/nutty silt loam; friable on pale yellow brown (grey veins) prismatic silt loam; very firm.	Sheet and tunnel gully; slips on steeper slopes

4.0 Test Pit Results

Table 2 summarises the data of the test pitting including location, depth and soil type. Figure 1, Appendix A shows the locations of the test pits carried out. Photographs of the test pits and materials are included in Figures 14 – 19, Appendix A.

Table 2: Test Pits

Test Pit ID	Locations	Depth of Test Pit (m)	Depth to Low Permeability Layer (m)	Soil Type[1]	Elevation (m amsl)
TP1	Block A	4	0.18	Takahe	99
TP2	Block B	4	0.15	Takahe	143
TP3	Block E	4.1	0.22	Takahe	111
TP4	Block H	4.1	0.27	Takahe	169
TP6	Block D	4	0.25	Pawson Hills	33
TPG	Block G	4.1	0.25	Takahe	59

Note: 1. Soil types from Sheet 9 of "General Survey of Soils of the South Island" DSIR (1968).

Site 1 is a flat section and the soils encountered in TP1 are consistent with the Takahe Soil description. There was a good depth of topsoil at this site and root penetration throughout the topsoil layer and with some continuation into the yellow mottled orange friable subsoil.

Site 2 was a reasonably steep slope, and further up the hill were scattered rocky outcrops. The soils encountered in TP2 were consistent with the Takahe Soil description. There was slightly less depth of topsoil and root penetration at TP2.

Site 3 was a reasonably flat to gentle slope. This site was in the road reserve and there was a good depth of topsoil, which may be a result of the land being worked. The materials encountered are consistent with the Takahe Soil description.

Site 4 was a flat section within a steep area. This site had the greatest depth of topsoil of all the sites investigated and was also at the greatest elevation. It appeared that the materials more closely matched Takahe Soils, rather than Pawson Hills soils.

Site 6 was also carried out in the road corridor at the toe end of a line of trees. This was the only site with an obvious pale olive grey layer directly under the topsoil, indicative of Pawson Hills Soils.

The test pit at Site G was carried out on a steep slope, there was a gully running through this property. It appeared that the materials most closely matched Takahe Soils.

Consistently between all the test pits the topsoil was dark brown friable material with good root penetration. The topsoil was underlain by yellow brown mottled orange nutty friable silt material. Between 1 – 4 m below ground level (bgl) light grey veins were encountered. There were only slight changes with some firm to very firm blocky layers experienced from 2 – 4 m bgl.

Overall, the geology that was observed during the site investigations were in line with the expectations of material recorded in the General Survey of Soils of the South Island (1968), PDP report 'Hydrogeological Review for Proposed Akaroa Wastewater Treatment and Disposal (May 2016)' and nearby borelogs.

5.0 Infiltration Test Results

Eight infiltration tests were carried out at the locations shown in Figure 1, Appendix A. To enable a comparative analysis of the sites, the tests were carried out on the high (loess), intermediate (loess colluvium) and low (alluvial) areas. These areas were defined by Beca and the map indicating these different zones is included in Figure 15, Appendix A. In the week prior to infiltration testing there was 81 mm of rain recorded at the Akaroa EWS station (36593) (Cliflo, 2016).

The results of the infiltration tests are shown in Table 3 below. The USEPA (1981) report that the double ring infiltration test can over-estimate the true infiltration rate by as much as 40%. Therefore, the likely saturated rates are in the order of 0 to 18 mm/hr.

Table 3: Infiltration Test Results

Infiltration Test ID	Locations	Depth to Low Permeability Layer (m)	Depth Below Ground Level (m)	Test Duration (minutes)	Infiltration Rate (mm/hr)
IT1	Block A	0.18	0	150	20
IT1.5			0.28	120	0
IT3	Block E	0.22	0	180	12
IT3.5			0.28	150	12
IT6	Block D	0.25	0	180	8
IT6.5			0.30	130	0
ITG	Block G	0.25	0	100	30
ITG.5			0.20	90	24

The double ring infiltrometer was sunk in 100 mm at ground level or from the depth below ground, as shown in Table 3. The test pits excavated at the infiltration test locations indicated the presence of a lower permeability layer directly below the topsoil. The sub-surface testing was carried out within this lower permeability layer. The topsoil depth varied from location to location.

5.1 High - Loess

IT1 was carried out in the surface soils for a total of 2 hours 30 minutes, resulting in a stabilised infiltration rate of 22 mm/hr. A plot of the infiltration rate throughout the duration of the test is given in Figure 6, Appendix A.

IT1.5 was carried out to determine the limitations of irrigation of the low permeability layer beneath the topsoil. A small excavation was made, the depth of which was 0.28 m bgl. Topsoil was measured to a depth of 0.18 m bgl. The double ring infiltrometer was sunk in approximately 100 mm into the low permeability material. The test was carried out for 2 hours. The stabilised infiltration rate was measured to be 0 mm/hr. A plot of the infiltration rate throughout the duration of the test is given in Figure 7, Appendix A.

IT3 was carried out (in the surface soils) for 3 hours. The stabilised infiltration rate was measured to be 12 mm/hr. A plot of the infiltration rate over the course of Test 3 is given in Figure 8, Appendix A.

IT3.5 was also carried out approximately 100 mm into the low permeability strata, within a small excavation and at a depth of 0.28 m bgl. The test duration was 2 hours 30 minutes. The test was concluded after the infiltration rate stabilised at 12 mm/hr. A plot of the infiltration rate over the course of IT3.5 is given in Figure 9, Appendix A. Topsoil was measured to a depth of 0.22 m at this site. The subsoil infiltration rate measured was comparatively faster than the other subsoil infiltration rates. The double ring infiltrometer may not have been inserted as deep into the lower permeability layer relative to the other sites.

5.2 Intermediate – Loess Colluvium

IT6 and IT6.5 were carried out in a road reserve. IT6 was carried out for 3 hours. The stabilised infiltration rate was measured to be 8 mm/hr. A plot of the infiltration rate over the course of IT6 is given in Figure 10, Appendix A.

IT6.5 was carried out approximately 100 mm into the low permeability strata, at a depth of 0.30 m bgl. The test was carried out for 2 hours 10 minutes, resulting in a stabilised rate of 0 mm/hr. A plot of the infiltration rate over the course of IT6.5 is given in Figure 11, Appendix A.

ITG was carried out for 1 hour 40 minutes, giving a stabilised rate of 30 mm/hr. A plot of the infiltration rate over the course of ITG is given in Figure 12, Appendix A.

For ITG.5 the double ring infiltrometer was sunk in approximately 100 mm into the low permeability strata, within a small excavation and at a depth of 0.20 m bgl. Topsoil was measured to 0.25 m bgl. The test was carried out for 1 hour 40 minutes, giving a stabilised rate of 24 mm/hr. A plot of the infiltration rate over the course of the test is given in Figure 13, Appendix A. It would be expected that the infiltration rate measured should have been slower. The infiltrometer may not have been inserted far enough into the low permeability layer, the depth of topsoil was greater than previous sites.

5.3 Low - Alluvial

CCC was unable to gain landowner’s permission to excavate in the low alluvial area, Block I (Figure 20, Appendix A). From the nearby bore log, N36/0060, the depth of topsoil is 0.20 m and the subsurface materials are consistent with those observed in the test pits as a part of the preliminary investigations. It is considered that the infiltration rate within this block would be similar to the rates measured within the other sites.

6.0 Assessment of Land for Irrigation Purposes

The infiltration testing that was carried out as per Section 5.0 indicates that the infiltration rates are similar to the design infiltration rates assumed during preliminary viability investigations.

Overall, the infiltration tests carried out indicate that the surface soils at the site are moderately draining. The presence of the low permeability layer in the test pits indicates that, while the sites are suitable for wastewater irrigation, it may be susceptible to field saturation during the winter months which would limit the application rates.

The profile available water (PAW) is a measure of the amount of water potentially available for plant growth that can be stored within the rooting zone of the soil. This is generally reported for a depth of 60 cm for pasture and 100 cm for crops. However if there is a soil layer which limits root penetration (e.g. a pan) at a shallower depth then the PAW is modified to account for the restriction.

The PAW is derived from research and the most reliable source of information is the S-maps database (Landcare Research). However there is no information in the database for the particular hill soils observed at the site. However there is an interim assessment of soils at this location in the interim Canterbury soils maps. This map identifies the soils as Claremont*f* soil, which is described as moderately deep silty loam (Claremont*f* soils are also loess derived soils similar in nature to the Takahe and Pawson soils). The soil report is attached in Appendix B. This indicates that the potential soil rooting depth and depth to the slower permeability horizon is between 50 - 90 cm. It should be noted that the dataset for Banks Peninsula may not be very accurate, with the caveat that the validity of the data is of low confidence. According to the S - maps soil report for the Claremont*f* soil (Appendix B) the PAW is 48 mm within 0 – 30 cm of the surface or until a root barrier. From the test pits that were carried out the depth to the slow permeability horizon was measured between 15 – 27 cm bgl. The potential soil rooting depth was approximately equal to the depth of topsoil. The soils underlying the topsoil were somewhat friable and there was some root penetration into this material, but it did not seem that there was significant growth past this interface.

Note the New Zealand Fundamental Soils layer of the ECan database indicates the soil type for the whole area as Pawson Silt Loam. The potential rooting depth is 60 to 89 cm. Average PAW is given as 75 mm with a range from 60 to 89 mm.

Given that the rooting depth for the pasture appears to be limited to the topsoil layer 15 to 27 cm bgl then the actual PAW for irrigation purposes will be lower than the 72 mm used in the preliminary assessment of the irrigation requirements. After preliminary observations in the field the PAW has been reduced to 48 mm to allow a reassessment of the likely size of the irrigation system, storage ponds and drainage. Note not all possible sites were able to be investigated therefore actual details may vary. Once specific sites have been chosen for irrigation further investigation will be required to confirm these parameters prior to detailed design.

7.0 Impact of Investigations on Potential Irrigation

The results indicate that there will be low permeability sub-soil layers present within all the potential irrigation areas and the PAW is likely to be lower than initially estimated. Based on the soil assessment and the S-maps data PDP recommends that 48 mm for the PAW should be used for the detailed design.

The initial proposed irrigation rates were based on irrigation rates used for Wainui. Irrigation to trees was the chosen irrigation method for Wainui. The ridges were planted in pines whilst the gullies are covered in native trees. The irrigation sites are located on moderately steep lower slopes of Banks Peninsula volcanics with a thick loess cover. The proposed Akaroa irrigation discharge areas were expected to have similar ground conditions to the chosen Wainui irrigation sites, which was confirmed during the assessment of soils.

For Wainui (PDP, 2008), PDP assessed that the weekly application depths to trees should not exceed 37.5 mm/week in summer, and 17.5 mm/week in winter. The measured infiltration rates during the assessment of Wainui ranged between 20 mm/hr to 49 mm/hr (surface soils) and 3 mm/hr to 30 mm/hr (sub-surface soils). These are similar to the measured infiltration rates for Akaroa. The testing at Akaroa indicated topsoil infiltration rates of greater than 20 mm/hr. Infiltration rates of the sub-surface soil ranged from 0 mm/hr to around 30 mm/hr. The bulk hydraulic conductivity of the loess in the area is of a similar magnitude. As a precautionary approach PDP recommends that similar values should be used for the ongoing design.

If irrigation to pasture is chosen, the maximum daily application depth would be suited to approximately 7 mm/day in summer and no irrigation, especially to Block A and D, in winter subject to a soil moisture balance being used to determine the actual daily application depth. An assessment of the impacts no irrigation in winter has on the storage requirements and drainage has been carried out in Section 8.

The surface infiltration rates (mm/hr) are sufficiently high that spray irrigation can be used with minimal chance of instantaneous runoff when the soils are moist. However, if the soils are allowed to dry out then most New Zealand soils can be described as repellent to moisture. The initial application of irrigation (or rainfall) does not penetrate but sits on the surface and could result in some runoff. This can be accounted for by testing to see how strongly the soil repels the water (hydrophobicity) prior to detailed design.

The observations indicate that all the sites are suitable for irrigation, although the sites with the very poorly drained sub-soil may need to be limited irrigation to irrigation in summer, spring and autumn only. These areas with poorly drained sub-soils are Block A and Block D, as shown in Figure 21, Appendix A.

Further testing to determine the erodibility of the soils, depth to groundwater, and a water balance assessment are suggested before a recommendation could be made as to whether a higher application depth could be considered acceptable.

From an irrigation perspective this means that the irrigation will probably need to be managed with more frequent applications and lower application depths to minimise the potential for ponding to occur on the low permeability layer. If ponding were to occur the soils may become saturated impacting the soil structure and risking runoff from the land. The poorly drained layers are relatively close to the soil surface. It may be possible to deep rip these soils to help improve the sub-soil drainage allowing higher application rates.

The area required for irrigation is unlikely to change significantly from initial estimates. However if water cannot be irrigated as frequently as originally estimated over winter then the storage volume will increase. This is assessed further in the next section. The irrigation of pasture would normally be carried out on an irrigation rotation where part of the area is irrigated each day. The PAW of the soils is estimated at 48 mm. It is not normally acceptable to apply more than half the PAW in a single application (i.e. 24 mm in this situation). Therefore, as an initial design estimate it is likely that the irrigation area would be split into a minimum of 5 zones with a maximum application depth of 24 mm. As detailed above, increased storage will be required to account for no irrigation during winter. This would only be required if the sub-surface rates cannot be modified.

8.0 Soil Moisture Balance

A soil moisture balance was performed to determine the effectiveness of the land that had been chosen for the potential irrigation of treated wastewater to pasture. Based on the S-maps GIS information that was entered into the soil moisture balance model, the depth to the impeded drainage layer and the maximum rooting depth is 71 cm. From these inputs the profile available water (PAW) was calculated to be 72 mm. After observations in the field, it has been reduced to 48 mm. The irrigation to trees option, as previously discussed in a PDP letter, 24 March 2016, is not limited by the PAW. Presented in Table 4 below is the storage required for two irrigable areas (27 and 37.25 ha) and the two different irrigation methods (drip and K-line), based on the revised PAW of 48 mm. Assumptions to calculate the area and storage are the same as those used in a PDP letter, 24 March 2016.

Table 4: Storage Required for Pasture Irrigation of Different Land Areas PAW 48 mm

Irrigation	Storage Required for Irrigable Area (in 1000 x m^3)	
	27 ha	**37.25 ha[1]**
Drip	35	28
K-Line	32	25

Notes:

1. This is the total area identified as being available, at this time, below 140 m above sea level.

The maximum area requirement for the originally estimated volume storage pond (30,000 m^3) was based on a 3 m deep, 100 m by 100 m pond (PDP, 2016). Using similar proportions and retaining a depth of 3 m the maximum storage (35,000 m^3) would require a revised area of approximately 110 m by 110 m pond. The land requirements for a pond of this size, with a buffer of 5 m, would be 1.3 ha. The increase of land from what was originally estimated (1.2 ha (PDP, 2016)) due to the revised PAW, is 0.1 ha.

Presented in Table 5 are the storage requirements with the additional constraint of no irrigation in winter (May – August).

Table 5: Storage Required if no irrigation to Pasture in winter of Different Land Areas PAW 48 mm

Irrigation	Storage Required for Irrigable Area (in 1000 x m^3)	
	27 ha	**37.25 ha[1]**
Drip	49	47
K-Line	48	46

Notes:

1. This is the total area identified as being available, at this time, below 140 m above sea level.

If there is no irrigation during winter the maximum storage pond volume is 49,000 m^3. Using similar proportions, the revised area would equate to a 130 m by 130 m pond. The land requirements for a pond of this size, with a buffer of 5 m, would be 1.8 ha. This is 0.5 ha more than year –round irrigation, and 0.6 ha more than what was initially estimated.

In terms of the risk to the land stability from the drainage through the topsoil to the underlying strata, this will increase as a result of irrigation. From the soil moisture balance for the current un-irrigated situation the annual drainage is estimated to average 210 mm.

Table 6 shows the annual drainage for the two irrigable areas and the two different irrigation methods.

Table 6: Drainage for Pasture Irrigation of Different Land Areas

Irrigation	Annual Drainage (mm/year)	
	27 ha	37.25 ha[1]
No irrigation	210	
Drip	484	423
K-Line	437	389

Notes:

1. This is the total area identified as being available, at this time, below 140 m above sea level.

For the drip irrigation options the drainage increases by 274 mm for the 27 ha block or 213 mm for the 37.25 ha block. For the spray irrigated options the drainage increases by 227 mm for the 27 ha block and 179 mm for the 37.25 ha block, respectively.

Table 7 shows the annual drainage for the two irrigable areas and the two different irrigation methods, if there is no irrigation to land in winter.

Table 7: Drainage for Pasture Irrigation of Different Land Areas (no winter irrigation)

Irrigation	Annual Drainage (mm/year)	
	27 ha	37.25 ha[1]
No irrigation	210	
Drip	454	391
K-Line	407	359

Notes:

1. This is the total area identified as being available, at this time, below 140 m above sea level.

For the drip irrigation options the drainage increases by 244 mm for the 27 ha block or 181 mm for the 37.25 ha block. For the spray irrigated options the drainage increases by 197s mm for the 27 ha block 149 mm for the 37.25 ha block, respectively.

The soil moisture balance was carried out using the combined rainfall and evapotranspiration data measured from 2008 to 2015 at the Akaroa EWS (Electronic weather station) and forecasted data from NIWA's virtual climate station network. Climate change has not been included.

9.0 Recommendations

The tests indicate that irrigation of the soils that were investigated will be possible. However not all land could be investigated so these recommendations should be considered indicative until all potential sites have been investigated.

For detailed design (and subject to a preferred irrigation method) the following is recommended:

- PAW = 48 mm;
- Application Rates for irrigation to trees should not exceed 37.5 mm/week in summer, and 17.5 mm/week in winter;
- Application Rates for irrigation to pasture should not exceed 7 mm/day in summer;
- Application to pasture, especially Block A and Block D, should be limited to irrigation in summer, spring and autumn only.

More detailed investigations of the soils will be required prior to detailed design (and subject to a preferred irrigation method) to confirm:

- Application Rates (mm/hr) by measuring the hydrophobicity of the soil;
- Application depths (mm) and return periods; and
- Extent of low permeability layers over selected irrigation areas and potential to modify the permeability (e.g. by ripping).

These tests are in addition to general agricultural soil tests to determine the current nutrient state of the soils and appropriate measures to maximise growth of trees or pasture to maximise nutrient and water uptake from the applied treated wastewater.

10.0 Limitations

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Beca. 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.

This report has been prepared by PDP on the specific instructions of Beca for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

11.0 References

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Yours faithfully

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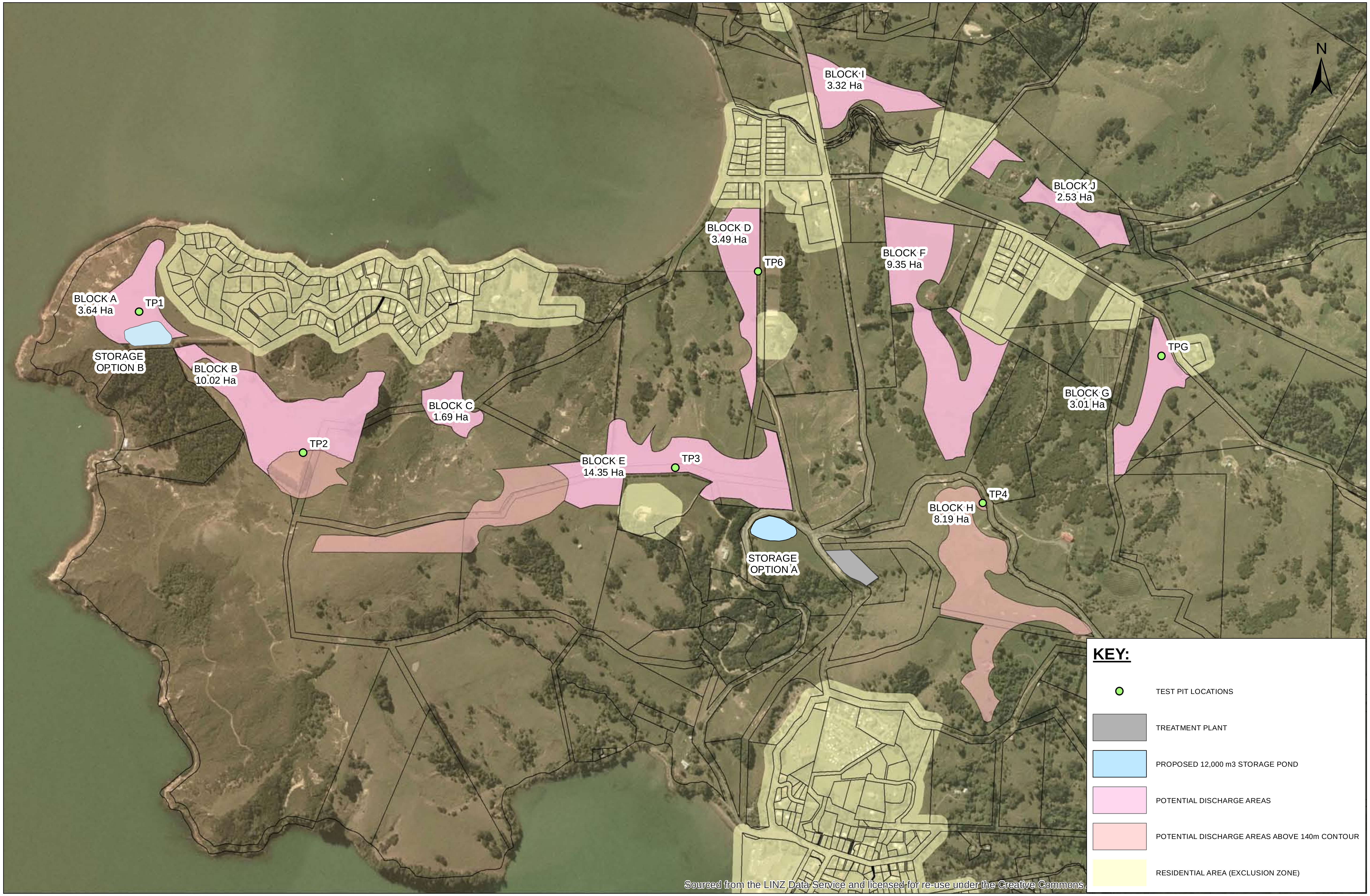
Appendix A: Figures



SOURCE:
1. CADASTRAL DATA AND AERIAL IMAGERY SOURCED FROM LAND INFORMATION NEW ZEALAND (LINZ) MAY NOT BE SPATIALLY ACCURATE.

FIGURE 1: TEST PIT LOCATIONS

SCALE: 1:10,000 (A3)

0 125 250 375 500
METRES

PATTLE DELAMORE PARTNERS LTD

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ISSUE DATE: 10/06/16 VERSION: 3

Infiltration Test Photographs

Figure 2: Infiltration Test IT1 (left) and subsurface Test IT1.5 (right) within Children's Bay land.

Figure 3: Infiltration Test IT3 (left) and subsurface Test IT3.5 (right) within CCC road corridor.

Figure 4: Infiltration Test IT6 within CCC road corridor, subsurface test IT6.5 not shown.

Figure 5: Infiltration Test ITG (left) and subsurface Test ITG.5 (right) within Paul le Lievre land.

Infiltration Test Plots

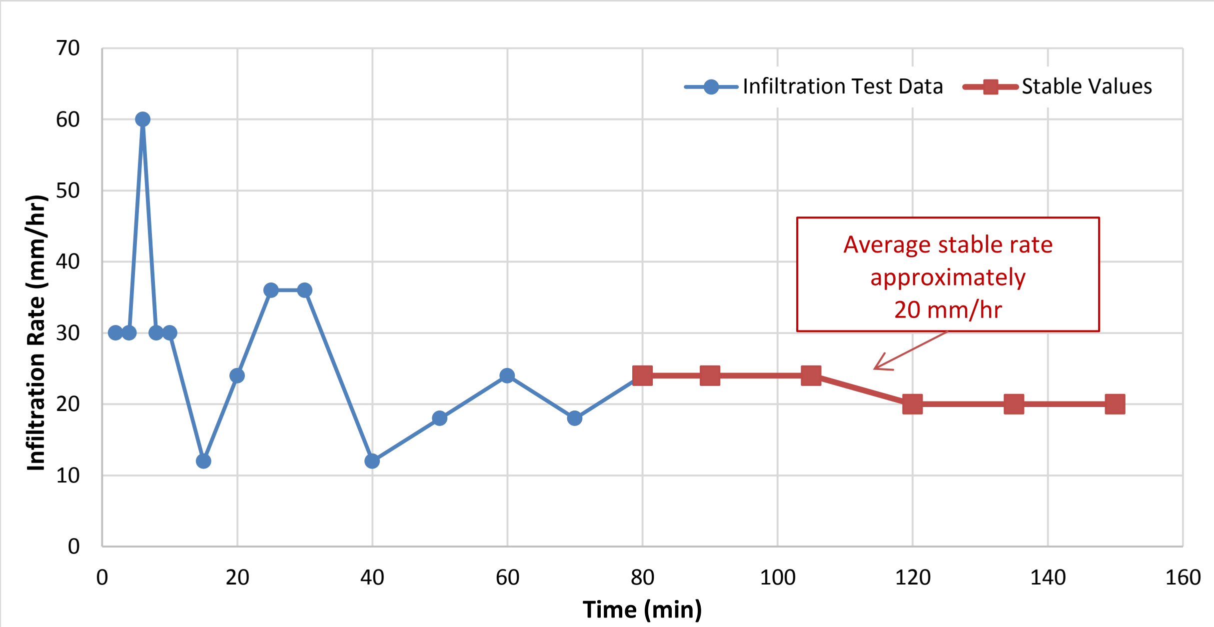


Figure 6: Infiltration Rate during Test IT1

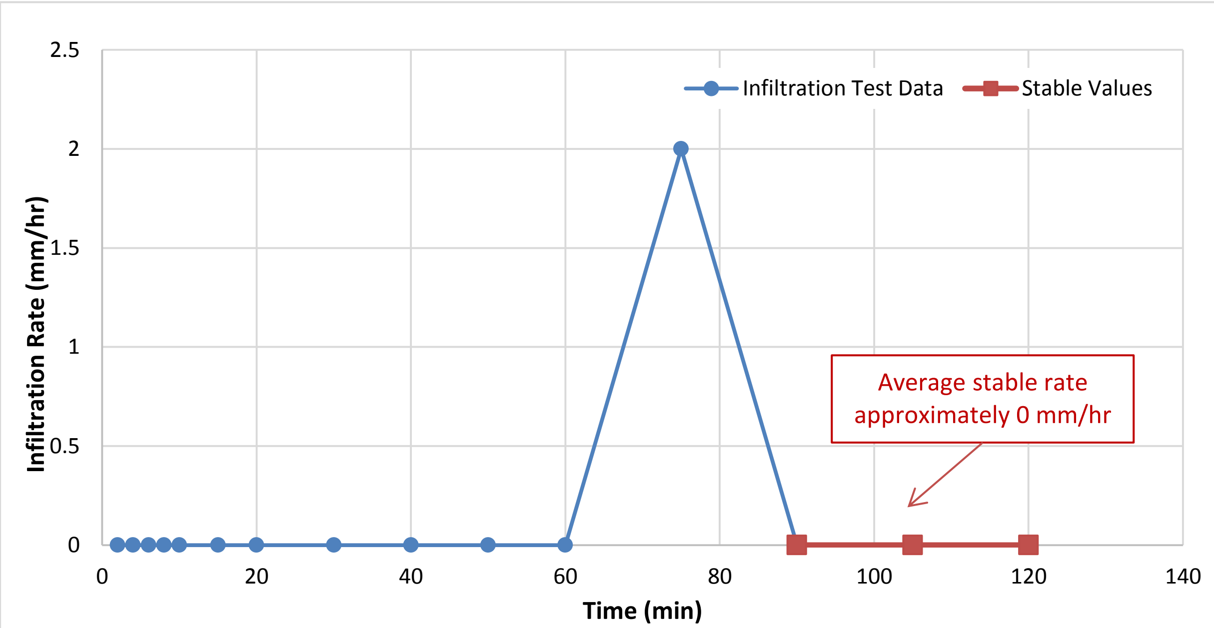


Figure 7: Infiltration Rate during Test IT1.5

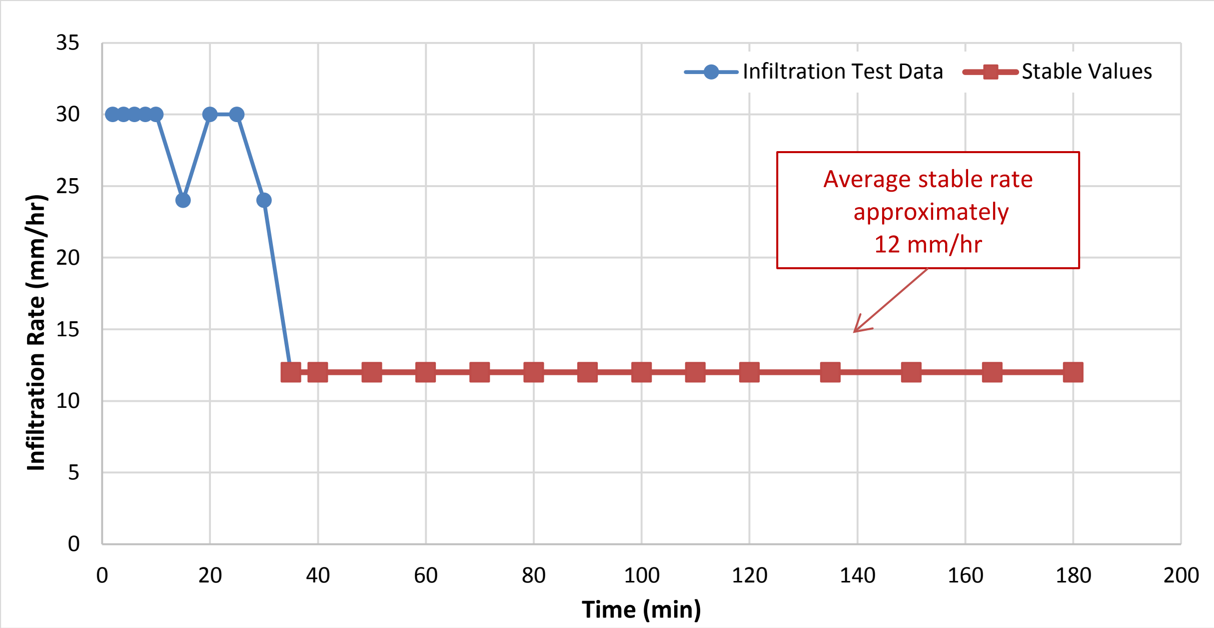


Figure 8: Infiltration Rate during Test IT3

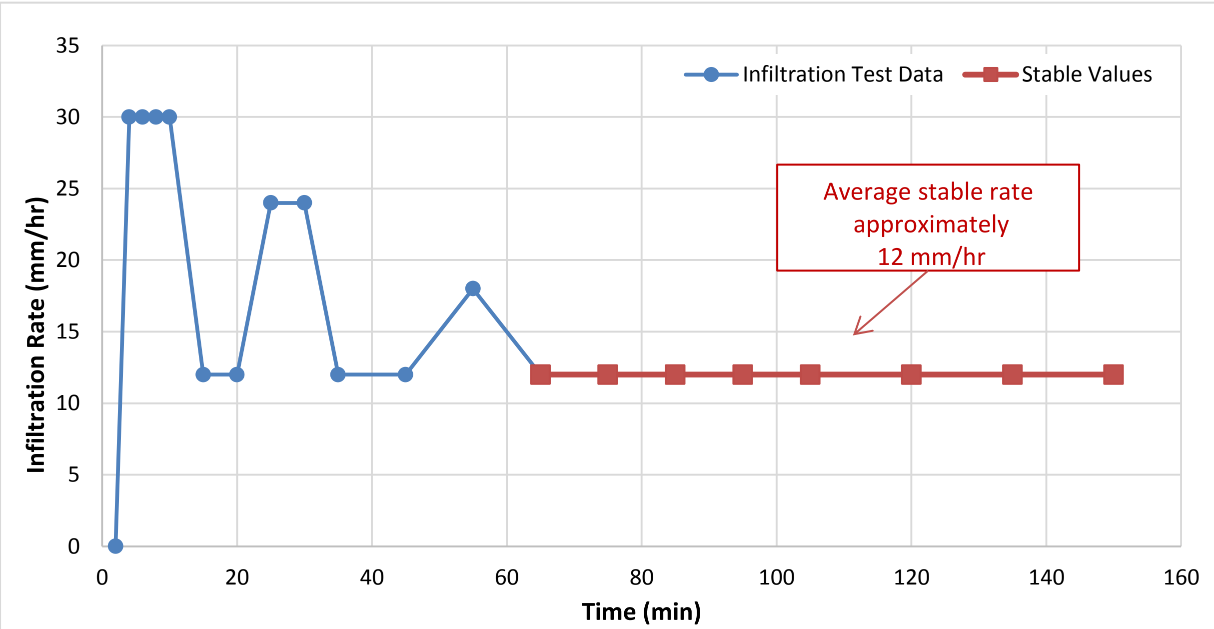


Figure 9: Infiltration Rate during Test IT3.5

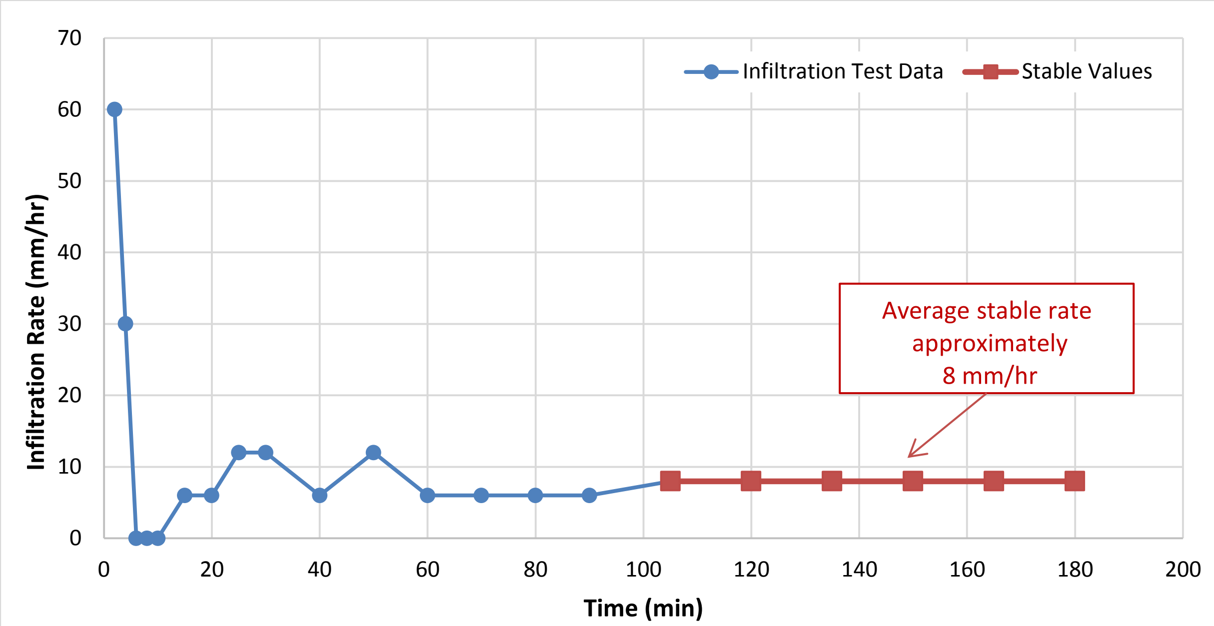


Figure 10: Infiltration Rate during Test IT6

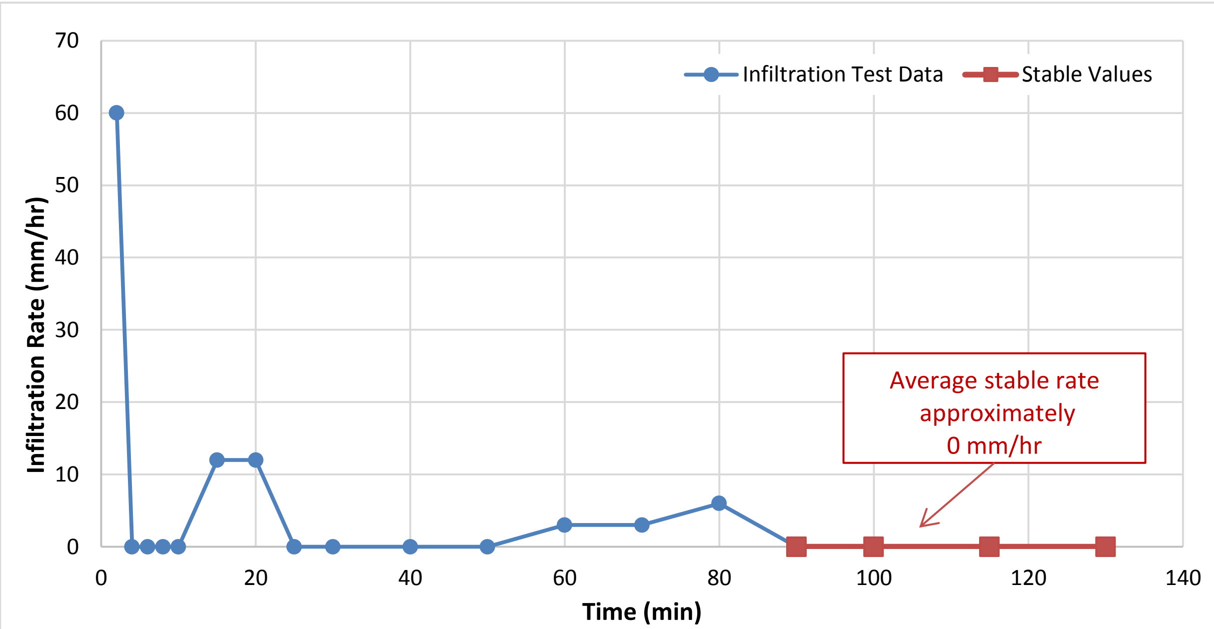


Figure 11: Infiltration Rate during Test IT6.5

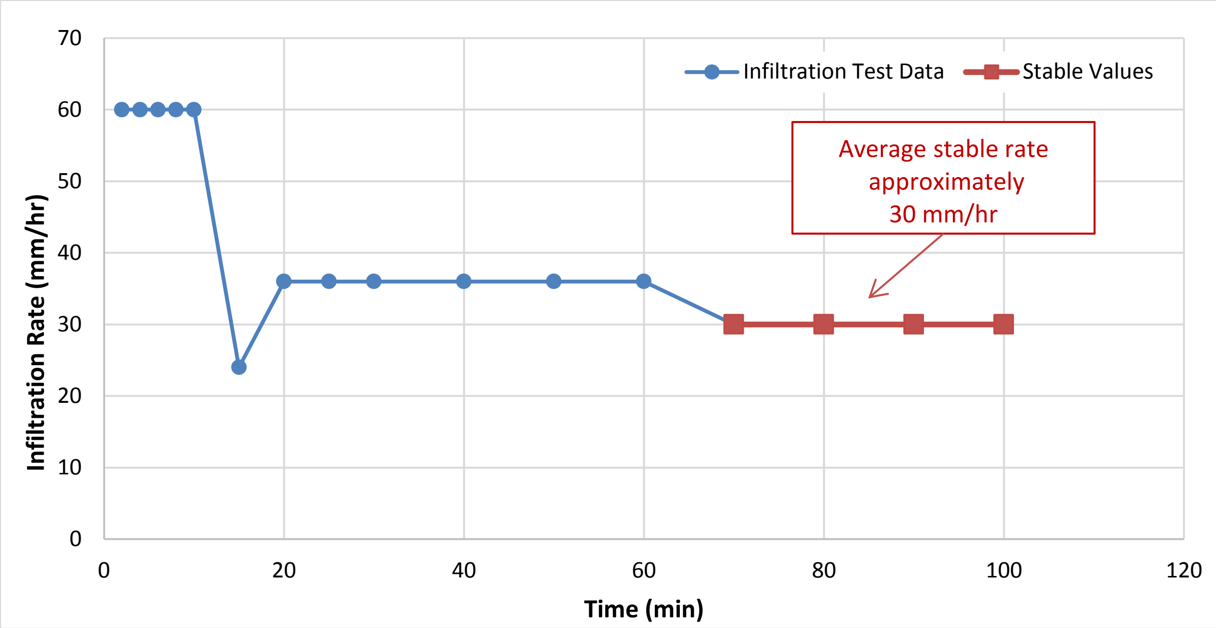


Figure 12: Infiltration Rate during Test ITG

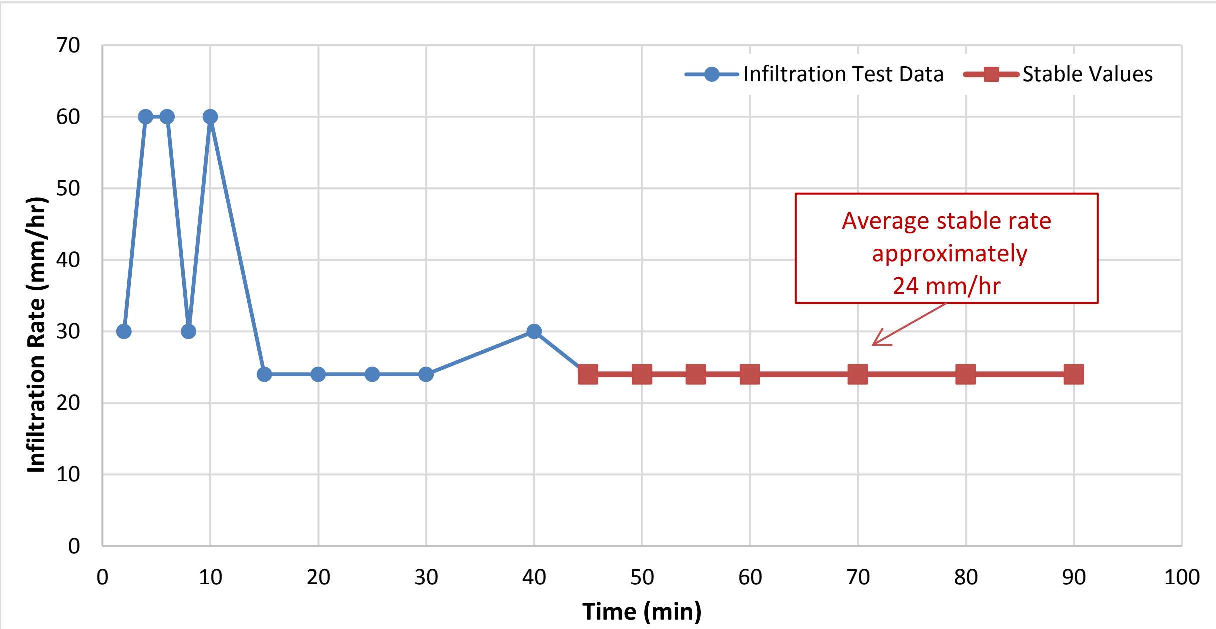


Figure 13: Infiltration Rate during Test ITG.5

Test Pit Photographs

Figure 14: Test Pit 1 – test pit (left) and very firm layer at 1.3 m bgl (right).

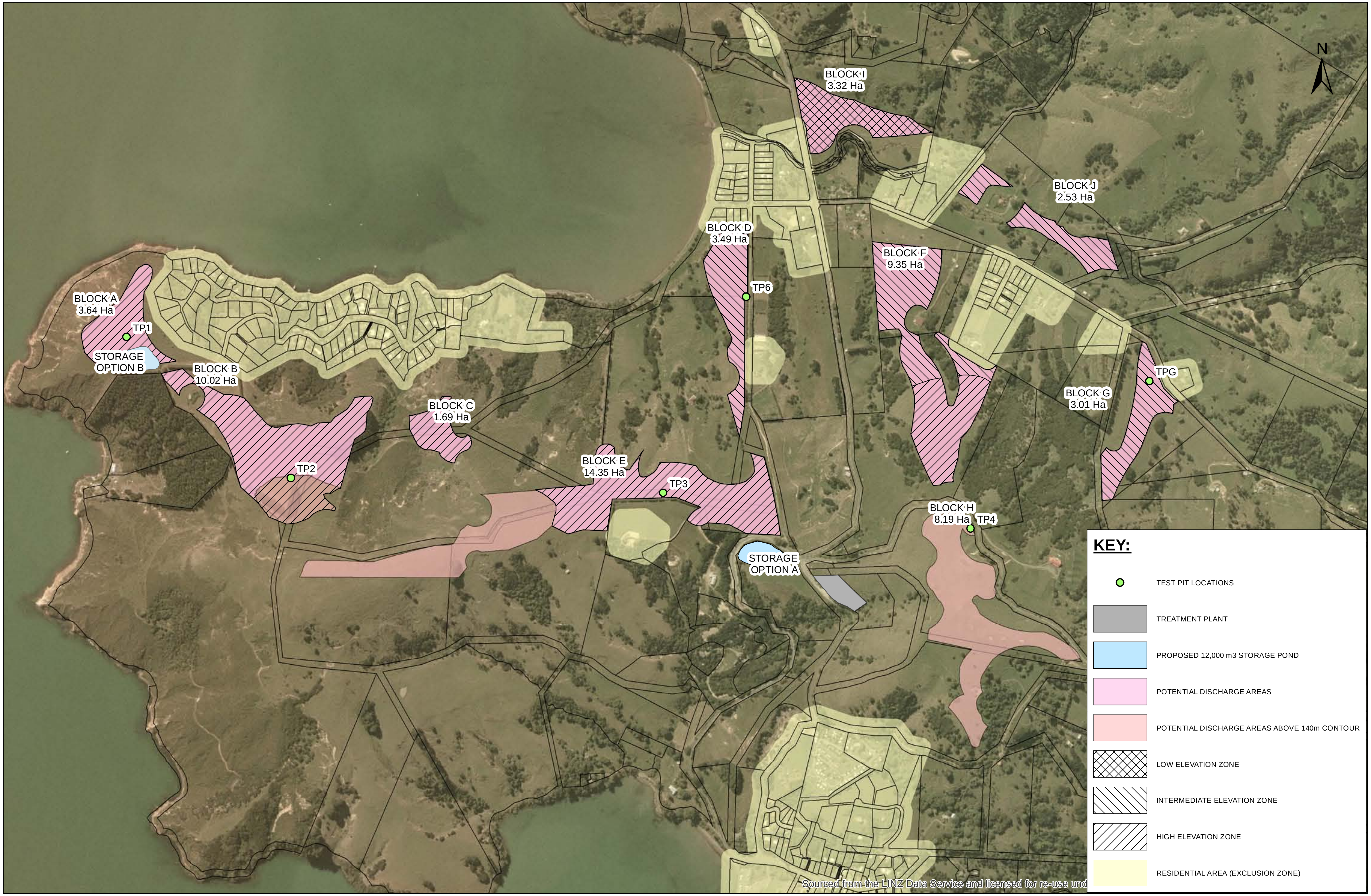
Figure 15: Test Pit 2 - test pit (left) and nutty/crumby silt material indicative of subsoil (right).

Figure 16: Test Pit 3 – test pit (left) and light grey material at 4.1 m bgl (right).

Figure 17: Test Pit 4 - test pit (left) and nutty/crumby silt material indicative of subsoil (right).

Figure 18: Test Pit 6 - test pit (left) and nutty/crumby silt material indicative of subsoil (right).

Figure 19: Test Pit G - test pit (left) and material indicative of subsoil (right).



SOURCE:
1. CADASTRAL DATA AND AERIAL IMAGERY SOURCED FROM LAND INFORMATION NEW ZEALAND (LINZ) MAY NOT BE SPATIALLY ACCURATE.

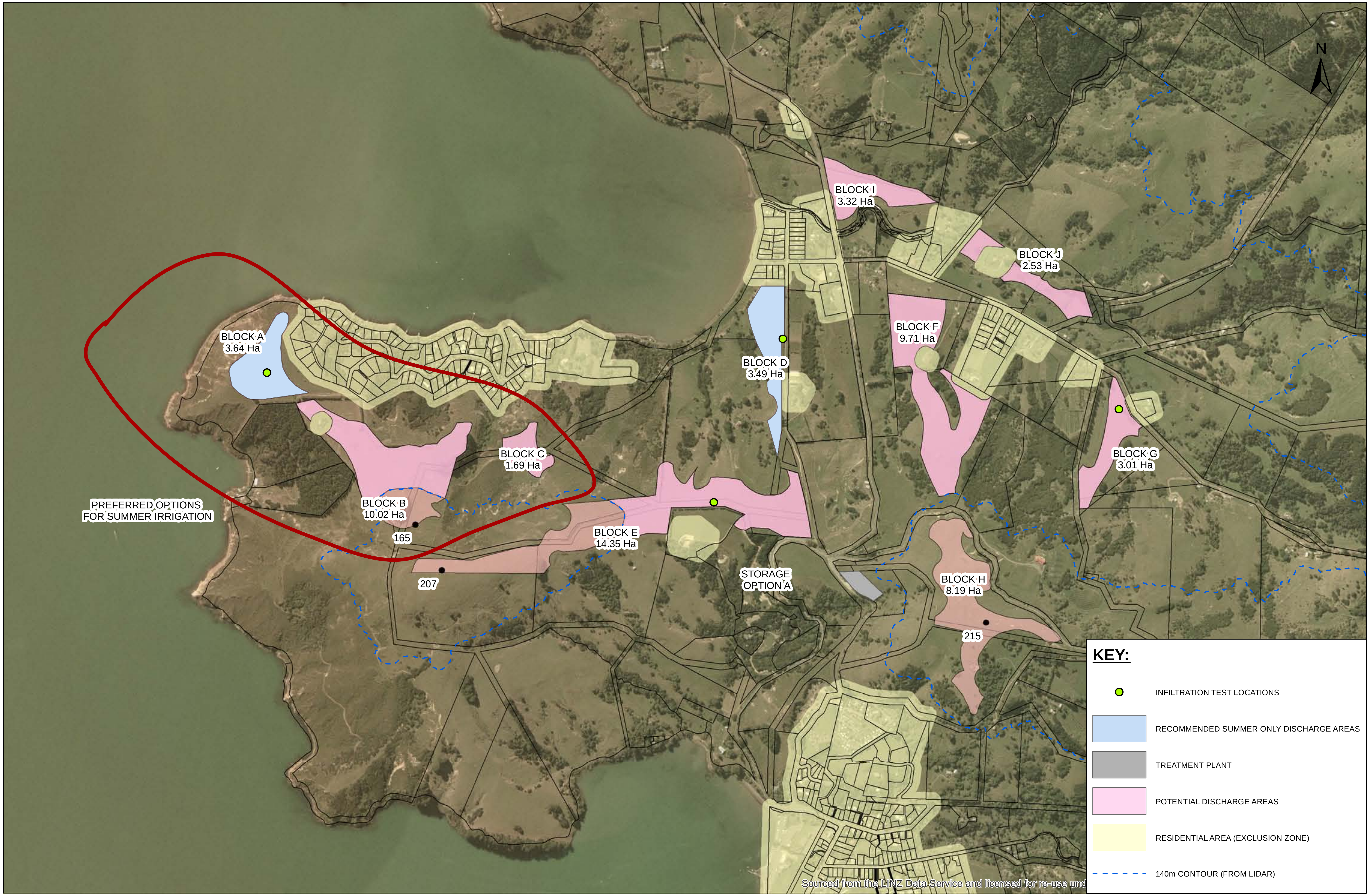
FIGURE 20: ELEVATION ZONES

SCALE: 1:10,000 (A3)

0 125 250 375 500
METRES

PATTLE DELAMORE PARTNERS LTD

C02239201Z006_FIG14_BECA_PERMEABILITY_ZONES.mxd
ISSUE DATE: 10/06/16 VERSION: 1



SOURCE:
1. CADASTRAL DATA AND AERIAL IMAGERY SOURCED FROM LAND INFORMATION NEW ZEALAND (LINZ) MAY NOT BE SPATIALLY ACCURATE.

FIGURE 21 : RECOMMENDED SUMMER ONLY DISCHARGE AREAS

SCALE: 1:12,000 (A3)

0 125 250 375 500
METRES

PATTLE DELAMORE PARTNERS LTD

C02239201Z007_summeronly.mxd
ISSUE DATE: 13/06/16 VERSION: 1

Appendix B: S-maps Soil Report

SOIL REPORT

Report generated: 9-Jun-2016 from http://smap.landcareresearch.co.nz

Family: Claremont*f*

Claremont*f* moderately deep silty loam over clay

***** Important *****
Please read the limitations section on page 1.

Smap ref: Clar_2a.1

Key physical properties

Depth class (diggability)		Moderately deep (50 - 85 cm)
Texture profile		Silty loam over clay
Potential rooting depth		50 - 90 (cm)
Rooting barrier		Pan
Topsoil stoniness		Stoneless
Topsoil clay range		18 - 25 %
Drainage class		Poorly drained
Aeration in root zone		Limited
Permeability profile		Moderate over slow
Depth to slowly permeable horizon		50 - 90 (cm)
Permeability of slowest horizon		Slow (< 4 mm/h)
Profile available water	(0 - 100cm or root barrier)	Moderate (95 mm)
	(0 - 60cm or root barrier)	Moderate (85 mm)
	(0 - 30cm or root barrier)	Moderate (48 mm)
Depth to hard rock		No hard rock within 1 m
Depth to soft rock		No soft rock within 1 m
Depth to stony layer class		No significant stony layer within 1 m

Key chemical properties

Topsoil P retention	Low (22%)

Limitations

This S-map factsheet has been associated with a polygon from the interim soil layer which is of lower accuracy than S-map. The NZLRI polygon linework has a nominal scale 1:63,360 but for inland Canterbury, NZLRI soils are based on the General Soil Survey of the South Island 1:253,440 scale ("4 inch to mile") that mapped soil sets rather than soil types. Thus the soil information contained in this factsheet may not accurately represent the actual soil at this location.

About this publication

- This information sheet describes the *typical average properties* of the specified soil.
- For further information on individual soils, contact Landcare Research New Zealand Ltd: www.landcareresearch.co.nz
- Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
- The information has been derived from numerous sources. It may not be complete, correct or up to date.
- This information sheet is licensed by Landcare Research on an "as is" and "as available" basis and without any warranty of any kind, either express or implied.
- Landcare Research shall not be liable on any legal basis (including without limitation negligence) and expressly excludes all liability for loss or damage howsoever and whenever caused to a user of this factsheet.

Family:Claremont *f*

Claremont*f* moderately deep silty loam over clay

***** Important *****
Please read the limitations section on page 1.

Smap ref: Clar_2a.1

Additional factors to consider in choice of management practices

Vulnerability classes relate to soil properties only and do not take into account climate or management

Contaminant management

MGM N Loss Category	Fragipan soil on hilly slopes
MGM P Loss Category	High risk of Runoff to surface water
N leaching vulnerability	Medium
P leaching vulnerability	Medium
Relative Runoff Potential	Very high
Bypass flow	Medium
Dairy effluent (FDE) risk category	C
Septic tank installation category	A1

Additional information

Soil classification	Fragic Perch-gley Pallic Soils (PPX)
Family	Claremont*f*
Sibling number	2
Profile texture group	Silty
Soil profile material	Stoneless soil
Rock class of stones/rocks	Not applicable
Rock origin of fine earth	From hard sandstone rock
Parent material origin	Loess

Characteristics of functional horizons in order from top to base of profile:

Functional Horizon	Thickness	Stones	Clay*	Sand*
Loamy Fine Slightly Firm	18 - 35 cm	0 %	18 - 25 %	5 - 10 %
Loamy Fine Slightly Firm	10 - 35 cm	0 %	18 - 28 %	5 - 10 %
Clayey Fine Firm	10 - 35 cm	0 %	35 - 45 %	5 - 10 %
Loamy Coarse Firm	10 - 50 cm	0 %	18 - 28 %	5 - 10 %

* clay and sand percent values are for the mineral fines (excludes stones). Silt = 100 - (clay + sand)

Family: Claremont*f*

Claremont*ƒ* moderately deep silty loam over clay

***** Important *****
Please read the limitations section on page 1.

Smap ref: Clar_2a.1

Soil information for OVERSEER

The following information can be entered in the OVERSEER® Nutrient Budget model. This information is derived from the S-map soil properties which are matched to the most appropriate OVERSEER categories. Please read the notes below for further information.

Soil description page

Click the 'Soil moisture values' option. Enter the 'Sibling name': Clar_2a.1

From the 'Soil order' dropdown box select: Pallic

Soil water properties	0-30 cm	30-60 cm	> 60 cm	
Wilting point (15 bar)	19	23	28	mm per 10 cm
Field capacity	35	35	38	mm per 10 cm
Saturation	47	43	44	mm per 10 cm

From the 'Natural drainage class' dropdown box select: Poorly drained

Depth to impeded drainage layer: 71 cm (to an impermeable layer)

Maximum rooting depth: 71 cm (to a physical root barrier)

Top soil horizon chemical and physical parameters

Anion storage capacity (ASC) or phospate retention (PR): 22 %:

Bulk density: 1220 kg/m³

Clay: 21 %

Sand: 7 %

Sub soil [average from 10 to 30 cm]

Subsoil clay: 21 %

Is compacted
(this depends on management so cannot be obtained from S-map)

Considerations when using Smap soil properties in OVERSEER

- The soil water values are estimated using a regression model based on soil order, parent rock, soil functional horizon information (stone content, soil density class), as well as texture (field estimates of sand, silt and clay percentages). The model is based on laboratory - measured water content data held in the National Soils Database and other Landcare Research datasets. Most of this data comes from soils under long-term pasture and may vary from land under arable use, irrigation, etc.

- Each value is an estimate of the water content of the whole soil within the target depth range or to the depth of the root barrier (if this occurs above the base of the target depth). Where soil layers contain stones, the soil water content has been decreased according to the stone content.

- S-map only contains information on soils to a depth of 100 cm. The soil water estimates in the > 60 cm depth category assume that the bottom functional horizon that extends to 100 cm, continues down to a depth of 150cm. Where it is known by the user that there is an impermeable layer or non-fractured bedrock between 100 and 150 cm, this depth should be entered into OVERSEER. Where there is a change in the soil profile characteristics below 100 cm, the user should be aware that the values provided on this factsheet for the > 60 cm depth category will not reflect this change. For example, the presence of gravels at 120 cm would usually result in lower soil water estimates in the > 60 cm depth category. Note though that this assumption only impacts on a cropping block, as OVERSEER uses soil data from just the top 60 cm in pastoral blocks.

- OVERSEER requires the soil water values to be non-zero integers (even though zero is a valid value below a root barrier), and the wilting point value must be less than the field capacity value which must be less than the saturation value. The S-map water content estimates provided on this page have been rounded to integers and may be assigned minimal values to meet these OVERSEER requirements. These modifications will result in a slightly less accurate estimate of Available Water to 60 cm (labelled PAW in OVERSEER) than that provided on the first page of this factsheet, but this is not expected to lead to any significant difference in outputs from OVERSEER.