Assessment of Soil Related Effects for Burnham Quarry

Prepared for

Burnham 2020 Ltd

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Limitations:

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Executive Summary

The proposed quarry area ("the site") covers an approximate area of 362 hectares, is essentially triangular in shape and is bounded to the south by Grange Road, to the east by Aylesbury Road and to the west by farmland, paddocks and associated relatively remote housing. The site is currently a dairy support farm, irrigated by water supplied by Central Plains Water Limited and comes under their nutrient load and environmental management plan.

This site is Land Use Capability Class (LUC) 4, so it is not impacted by the proposed National Policy Statement (NPS) - Highly Productive Land, which became operative on 17 October 2022. Rehabilitation will progressively restore topsoil over areas already quarried to enable appropriate future uses.

The quarry activity is expected to use a maximum of 40 ha (11%) of the site at any time. Due to the scale of the site, the quarry and farm can co-exist. To ensure successful co-existence it is important that as much irrigated land as possible is maintained during the quarrying operation and that the land is rehabilitated after quarrying, returning its productive capability. Given that most of the irrigation is provided to the farming operation by centre pivot irrigators, minimizing the disruption to centre pivots is important to maximizing irrigated land and re-establishing irrigation during the rehabilitation process, which will be needed to return land to productive pastures.

The predominant soil is a Lismore 1a.1 (80%), a shallow well drained silt that is between 0.3 and 0.4 metres deep over gravels. The remaining 20% of soils are Lismore 2a.1 and Templeton 9a.1, that are also well drained silt soils with varying amounts of stones. When irrigated these soils are suitable for pastoral and arable crop production.

The first stage in preparing a new area for quarrying is to strip the topsoil. The proposed rehabilitation methodology following quarrying will see the 0.3 – 0.4 m thick soils from current stripping areas directly reinstated into areas being rehabilitated, being laid over a combination of silts and aggregate by-products. Soils from the site will be applied so that the re-established soil structure is the same the soil structure on the site before quarry activities occurred, thereby preserving the soil versatility.

The post-quarry landform is expected to remain on average around 10m below current ground level (bgl), being shallower in the south-east and deeper in the north and west. The intention of post-quarry rehabilitation is to ensure post-quarry farm productivity and to provide adequate filtration capacity between re-established pasture and groundwater resources, to limit the risk of pathogen infiltration from any farming activities which might occur on the rehabilitated site.

Glossary of terms

Cultivation: to prepare the land for sowing pasture or crops

Field Capacity: The maximum amount of soil water held in the soil after excess water has drained away.

Gravel: weathered rock fragments deposited as a result of sedimentary and erosive geological processes.

Pea gravel: gravel fragments less than 10 mm diameter

Suitably Qualified Rural Professional: a member of NZIPIM of Primary Management (NZIPIM) or a Certified Nutrient Management Advisor

Sand: The coarsest of the three soil textural classes (sand, silt, and clay); a soil particle between 0.06 and 2.0 mm in diameter.

Silt: The intermediate soil textural class between sand and clay; a soil particle between 0.002 and 0.06 mm in diameter.

Soil wetness and 'wet soil' a generic term to denote water content at or above the soil's plastic limit.

Soil plastic limit: The water content at which soil material becomes plastic (mouldable) and prone to compression and smearing. Although the plastic limit is not manifest in sandy soils, they are prone to compression at high water contents.

Subsoil: The physio-chemically and biologically altered layers below the topsoil that are functioning parts of the soil profile.

Topsoil The uppermost and most physically and biologically altered horizon, of undisturbed soil profiles.

Permanent Wilting point: the minimum amount of water in the soil that the plant requires not to wilt.

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1.0 Introduction

Pattle Delamore Partners Limited (PDP) was commissioned by Burnham 2020 Ltd to undertake a soil management assessment of the underlying ground conditions for a proposed aggregate quarry venture.

Burnham 2020 has purchased an area of active farmland near Burnham (referred to as Burnham Farm), to utilise the underlying strata for aggregate production through quarrying and material processing. During the quarrying activities, the farm area yet to be quarried will continue to be run as a dairy support operation under the management of the previous owner. The quarry will progressively be rehabilitated back to farmland.

The proposed quarry area ("the site") covers an area of 362 hectares, is essentially triangular and is bounded to the south by Grange Road, to the east by Aylesbury Road and to the west by farmland and associated relatively remote housing.

2.0 Purpose of the Report

The purpose of this report is to provide:

- a summary of the soil and Land Use Capability units on Burnham Farm,
- a description of the soil management strategy to rehabilitate the soils for agricultural production following gravel extraction, and
- an assessment of effects relating to soil management and agricultural land use for the proposed activity, with particular reference to the Canterbury Regional Policy Statement, the Canterbury Land and Water Regional Plan, the National Policy for Highly Productive soils, and the National Environmental Standards-Freshwater.

3.0 Overview and Environmental setting

The applicant proposes to undertake gravel extraction on the property in stages over a period greater than fifty years. Up to around 22 ha will be actively quarried at any one time, this excludes the quarry offices, carparks, roads, and infrastructure (permanently located processing plant and stockyards) and the silt management zone. The land will be rehabilitated back to irrigated pasture farmland as quarrying progresses. A landscape plan has identified areas that will be planted in native plants to provide a buffer strip around the site.

3.1 Site description

The site is located within a block of land bound by Grange Road to the south, and Aylesbury Road to the east and is approximately 362 ha. Access to the farm office and yards is at 160 Grange Road.

The site is located within the Selwyn District and is 1 km from Burnham Military Camp and associated housing.

The site is an operational dairy support farm that totals 388 ha and has 375 ha in productive pasture and crops, which includes land on the south side of Grange Road that is not part of the area to be quarried. The current farming operation grazes 1650 heifer calves from 1st Dec to 31st April, and 1650 yearling heifers 1st May to 1st May. The farm also grazes 80 Jersey bull calves from 1st Dec through to heifer mating the following spring. The total stocking rate in the year end 2020 was 12,044 SU and 39.5 SU per grazed hectare. The farm will continue to operate in the short term with a similar stocking policy and stocking rate per productive hectare when the gravel extraction is underway. Total stock numbers will be adjusted to allow for the loss of productive land during quarrying.

The farm currently is fully irrigated by three 515m centre pivots (270 ha), four single span towable pivots (65 ha) and set sprinklers. Water for the irrigation is provided by Central Plains Water Limited (CPWL) at 208 l/second at 4 – 5 bar pressure and is sufficient to provide 5mm of irrigation per hectare throughout the irrigation season, except for when CPWL is under water take restrictions. The farm has soil moisture monitoring and follows irrigation good management practices.

The intention is to continue irrigating the pasture and crops of the farm area that is yet to be quarried, using CPWL water. The farm has a Farm Environment Plan (FEP) and comes under the environmental management of CPWL including their nutrient discharge allowance and FEP audit programme,

There are also 4 irrigation production bores on the property which provided irrigation water prior to the use of CPWL water, pursuant to an existing water permit held by Burnham 2020 Ltd (which it applied to renew on 26 August 2021 and 26 November 2021). Those bores continue to be available as irrigation supply if required and will provide the water supply for the proposed quarrying activities (pursuant to a consent application that is currently in progress).

Each year between 2018/19 and 2020/2021 35 ha of kale and 22 ha of annual forage ryegrass was grown for intensive winter feed and grazed between 1 May and 30 September. Between 2013 and 2017 fodder beet was also grown and the total area of forage crops was the same. Under the National Environmental Standards for Freshwater (NES-F) controls on the expansion of the area of land used for intensive winter grazing came into force from 1 May 2021. The maximum area of intensive winter grazing (kale and annual ryegrass) was 57 ha or 14.7% of the total farm area in the reference period of 1 July 2014 to 30 June 2019. For 2023 onwards the maximum area of intensive winter grazing will be less than 50 ha, all areas will be on less than 10 degrees of slope and can meet the other criteria for a permitted activity. No additional consent is needed under the temporary Intensification provisions in the NES-F.

The property has a farm environment plan (FEP), regular audits and the year ending current nutrient loss was 28 kg N/ha/yr (Overseer v 6.5.1).

The site perimeter along Aylesbury Road, Grange Road, and the property boundaries adjacent to Kivers Road is already fully screened by an evergreen shelter belt approximately 5m high by 3.5m wide. The quarrying operation will maintain the existing planting for a visual screen except where the new quarry entrance on Aylesbury Road will be established. Where there are gaps or poor screening, additional, or replacement planting will be undertaken.

In the SE corner of the site additional planting native will be completed within a 120m setback zone. Irrigation will be provided to ensure planting establishes.

3.2 Gravel Extraction Staging

The site will be extracted and rehabilitated in stages. Timeframes are estimated based on projected demand and are subject to change:

• Years 1-6. Initial extraction. These areas will be used to set up the processing plant area, stockyard, and amenities for the life of the quarry – as a result they will not be rehabilitated until the site's end of life.

• Years 7-10. Extraction towards the SE corner of the site. From the start of this stage the quarry will be progressively rehabilitated.

• Years 10+. Extraction and rehabilitation in a clockwise direction around pivot 1, then into pivot 2 and finally pivot 3, as shown in Figure 1 Appendix C. Areas between and beside pivots will be extracted and rehabilitated with each move into new areas enabling reinstatement behind the leading edge.

3.3 Climate

The long term average rainfall for Burnham Farm is 681 mm/year, average temperature of 11.8^{o}C and annual potential evapotranspiration PET is 916mm/year. Climate data for the property has been sourced from OverseerFM's climate station tool (Overseer version 6.4.3) for the nitrogen losses.

3.4 Groundwater levels beneath the site

A groundwater report is being prepared that provides an assessment of the highest groundwater levels beneath the site (PDP, 2023). Quarrying will be managed to maintain a 1 m separation between the base of the quarry excavations and the highest estimated groundwater levels. The groundwater is shallower in the southern area of the farm and deeper in the more northern and western areas.

4.0 Soils Description

S-Map (Manaaki Whenua Landcare Research) has mapped the area at 1:50,000 and have identified soil type as predominately Lismore 1a.1 (80%). There are Lismore2a.1 and Templeton 9a soils mixed into the Lismore 1a. The proportions of soils may vary across the property as indicated by percentage of stones found in the soil and the depth and colour of the soil. The soils are classed as medium soils in Canterbury maps – Environment Canterbury Soil Types (Appendix A Figure 5)

The profile available water (PAW) is a measure of the capacity of the soil sibling to store water that is potentially available for plant growth. These soil siblings are all considered to have a moderate PAW, making them suitable to grow pasture and a wide range of crops.

Table 1: Soil on Burnham farm (S-map)

S-Map name	% of soil	Depth	Texture	% Stone at 400 mm	Drainage class	PAW at 60 cm (mm)	Soil Order
Lismore_1a.1	80	Shallow	silt	0 – 10%	Well drained	93	Brown
Lismore_2a.1	10	Shallow	silt	10 - 35%	Well drained	75	Brown
Templeton_9a.1	10	Moderately Deep	silt	0	Well drained	105	Pallic

PDP undertook a site investigation in December 2019 with forty-two test pits, logged, sampled to a target depth of 10.0m bgl and backfilled back to ground level. These test pits logs have been used to determine the depth of topsoil and subsoil for this report.

The site works were segregated into three phases based on the requirements of Winstone Aggregates, to gauge a better understanding of the geological resource.

For each phase of work, test locations were positioned using a Trimble Catalyst GPS location device and then scanned by the GPR operator prior to breaking ground. A test location plan is presented in the Appendix A Figure 4.

The average topsoil thickness was between 300mm and 400mm across the three phases of test pits (Table 2). Shallow soils are soils that are 20 – 45 cm deep to gravel or bedrock, therefore these soils are classed as shallow silt soils over gravel for drainage modelling.

The topsoil (A horizon) was identified as a dark brown sandy gravelly silt, dry well graded, sand, fine to coarse gravel, fine to coarse, rounded to subrounded slightly weathered Greywacke with organics, roots, and wood fragments.

Figure 1 shows the texture profile of the siblings found in the map unit. Each horizon is coloured according to its texture (source Soil map unit factsheet (landcareresearch.co.nz)

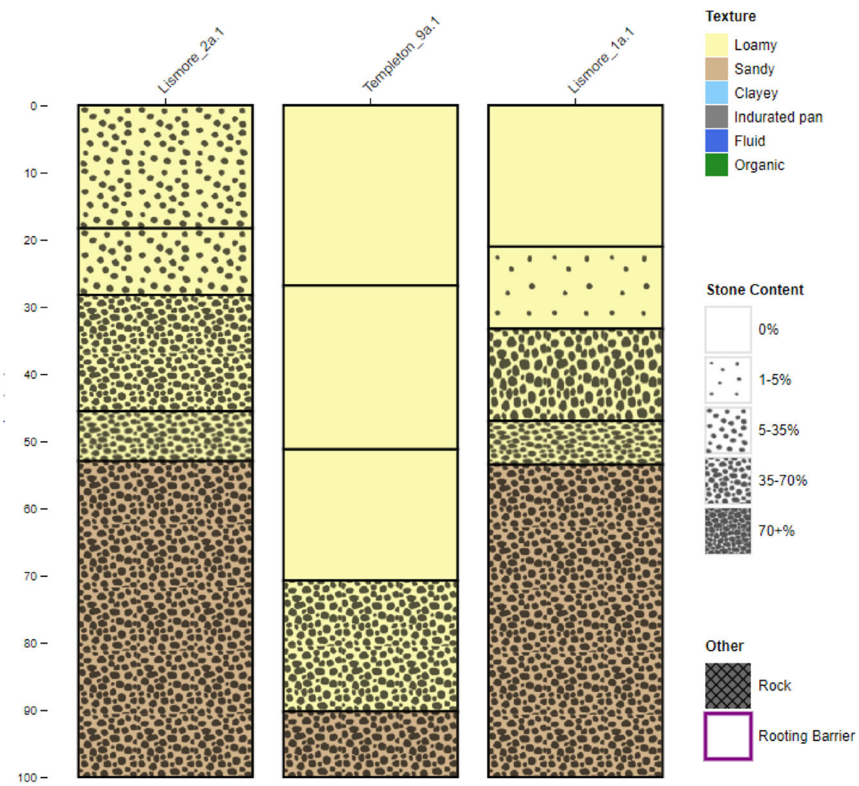

Figure 1 Texture of Soil siblings for the site

5.0 Land Use Capability

The Land Use Capability (LUC) classification is used to assess the long term sustainable capability of land to support production for cropping, pastoral farming, forestry, and soil/water conservation. Additionally, the classification indicates the versatility of the land and its given limitations for use (**Figure 2**).

Increasing Limitations to Use ↓

LUC class	Arable Cropping Suitability†	Pastoral Suitability	Production Forestry Suitability *	General Suitability
1	High	High	High	Multiple Use Land
2	↓	↓	↓	
3				
4	Low			
5	Unsuitable			Pastoral or Forestry Land
6				
7		Low	Low	
8		Unsuitable	Unsuitable	Catchment Protection

Decreasing Versatility of Use ↓

Figure 2: Relationship between LUC classes and versatility of use (from Lynn et al., 2009).

A detailed description of the system is provided in the Land Use Capability Survey Handbook, a 3rd edition of which was published in 2009 (Lynn et al., 2009). The LUC classification is based on five inventory factors including rock type, soil type, slope, erosion, and vegetation.

The LUC mapping unit is in three parts:

- <u>The LUC class</u>

  The LUC class is the broadest grouping in the classification, identifying the general degree of limitation to arable use. It comprises eight classes. Classes 1 to 4 are classified on their suitability for cultivation for cropping, with class 1 being the most versatile with few limitations to use, through to LUC class 4 which has limitations, so it is marginal for cultivation for cropping. This site is LUC 4 due to the shallow topsoil over gravels which limits the cultivation options.

- <u>The LUC subclass</u>

  The LUC class is subdivided into one of four subclasses, depending on the major physical limitation to use. There are four limitations; erodibility (e), wetness (w), soil (s), and climate (c). They are denoted by the small letter e, w, s, or c after the LUC class number. This site is suitable for pastoral farming but limited by moderate soil(s) limitations.

- The LUC unit

  The third and most detailed level of classification is the LUC unit. The unit groups areas that require the same kind of management, the same kind and intensity of soil conservation treatment, and are suited to the same kinds of crops, pasture or forestry species which require specific conservation measures and management practices to achieve similar yields.

This site LUC class 4 becomes 4s 7 and is described as terraces and plains with shallow and stony soils of medium to low fertility in seasonally moisture-deficient districts. These soils are often irrigated to overcome the moisture deficits. They are suitable for occasional cropping, pasture farming, tree crops and maybe suitable for viticulture and berry fruit.

The information provided in the soil site investigation (section 4) also confirms these are shallow soils over gravels that are consistent with LUC 4 land.

6.0 Soil Management Plan

A draft Soil Management plan is provided in Appendix C This sets out the key concepts to inform a Soil Management Plan, including an explanation for why each action is required.

The purpose of the Soil Management Plan is to:

a) Ensure that the removal, management, and placement of soil avoids or minimises impacts on the soil properties prior to and following placement, and that the re-established soil retains the soil versatility of the original soil on the site, and

b) to ensure that soil management activities avoid potential adverse effects on the surrounding environment.

Key to the effective reestablishment of the soil on the gravel extraction site are careful pre-planning, adherence to the guidance provided in the Soil Management Plan, and the training of all staff involved.

The main on-ground factors that achieve successful land restoration and retain productive value of the land are preparation of the existing surface to ensure it has the appropriate contour, and careful removal and placement of the soil material and silt so they are not degraded or compacted.

Soil carbon is critical for soil health, it feeds the soil biology and helps retain soil moisture and nutrients. Average soil carbon stocks in New Zealand's agricultural soils are estimated at about 100 tonnes per hectare in the top 300mm. It is important that the topsoil is retained and applied back onto the rehabilitated areas, particularly as the reinstated subsoil (washed silt, pea gravel and other products) will be very low in soil carbon.

The assessment of the site geology has indicated the following materials that could be involved in rehabilitation of the land following quarrying:

- The topsoil depth appears to be uniform across the site at approximately 300mm – 400mm across the site and will contribute to the total post-rehabilitation depth;
- The samples show an average of 4.6% silt of the total extractable volume;
- There are likely to be minor additions to the rehabilitated quarry land from losses of washed products, sand and crushed fines and pea gravel.

However, there are a number of factors which could mean less material is available:

- The samples used may not be fully representative of all the material that is quarried;
- Some of the pea gravel is utilised to produce manufactured sand;
- Up to 50% of the product could be sold as either base course or pitrun, which is not washed so the silt from this portion of the product would not be available for rehabilitation;
- At this stage, the expected average depth of the quarry is 10m, but it is likely to be shallower in the south-eastern corner with higher groundwater and the shallower area will provide less material and therefore less silt, although this could be offset by excavations in other deeper areas of the site.

The reinstated soil will have at least 200mm depth of subsoil and at least 200mm depth of topsoil providing a soil profile depth of at least 400 mm with no significant barriers to plant roots.

If insufficient material is going to be available to create a soil with a depth of 400mm the options, then less material will be sold as pitrun/base course. Under the lease agreement with the farmer running the stock on the property, the soil Olsen P will need to be returned to the levels prior to quarrying. Pasture soil testing is normally to 60 cm. The reinstated subsoil will have very low levels of nutrients, and this is likely to make up 50 percent of the top 60cm of soil, therefore fertiliser will be required before or during pasture establishment.

Pasture is the best vegetation for preparing the soil for agricultural uses. The fine roots of pasture create soil structure and grow into the new subsoil to coat cracks and pores. Generally, after three years in pasture (post quarrying) and with careful stock management to avoid compaction, the soil will be suitable for a range of agricultural uses. The addition of deeper rooting pasture species for example plantain and chicory will help to increase the soil porosity and add organic material.

Temporary or permanent irrigation will be reinstalled on the rehabilitated areas, and pasture will be established as soon as possible after the soils are reinstated. Limitations for arable use should remain the same as the current land-use as the site will have slopes that are less than five degrees, be irrigated and have a similar depth of topsoil.

6.1 Gravel Extraction Staging

The gravel extraction will be staged with removal of topsoil and overburden undertaken incrementally. Staging the gravel extraction reduces the short term loss of productive land on the site and reduces the volume of soil requiring stockpiling and the time the soil is stockpiled. This in turn reduces the potential for soil degradation and soil loss (by overland flow runoff or wind). It's estimated to take approximately 6 years to extract and process the production zone, primary stockyard, and secondary stockyard. In years 7 – 10 extraction will be towards the SE corner of the site and from the start of this stage the quarry will be progressively rehabilitated. Extraction and rehabilitation will proceed together, with each move into new areas enabling reinstatement behind the leading edge.

6.2 Soil Rehabilitation

6.2.1 Subsoil

The subsoil is permitted up to 200mm of the final land surface and a minimum soil thickness (topsoil and subsoil) of 400mm is required over the quarry base. The final re-established subsoil profile should be predominantly fine matrix soil materials, free of stones over 150 mm in diameter and other coarse materials.

The following properties are required for the subsoil material:

- Silts either in slurry form or placed using dump trucks and earthworks machinery.
- The subsoil may include organic forestry residue and dead pasture material that was in the soil from the extraction site and stockpiled sub soil. This site came out of forestry in 2008/2009 and some forestry residues remain, large logs/roots will be removed.
- May include topsoil if there has been mixing of topsoil with subsoil.

- The subsoil material can include up to 35% by volume of gravels (moderately gravelly)[1] of 6-30 mm diameter[2] with fine soil matrix materials.

It is unlikely that large stones would be disposed into the land to be rehabilitated, as generally anything over approximately 30mm has good economic value. However, it is possible that a few larger stones could remain in the rehabilitated soil due to being present in the topsoil or from incidental incorporation into stockpiles.

6.2.2 Topsoil properties

The topsoil should occupy the upper 200-400 mm of the final re-established soil profile. This is to ensure the final re-established soil profile has a topsoil that has organic matter, nutrients, and fine matrix soil materials similar to the original soil profile.

The following properties are recommended for the topsoil material:

- Topsoil removed from the extraction site and stockpiled should be used.
- Coarse organic materials are not permitted in the topsoil (tree roots and forestry residues).
- The topsoil may include up to 10% (by volume) of organic material provided it is thoroughly mixed with the other soil material. If the topsoil is stripped from one area and immediately applied to a rehabilitation zone it may contain organic material from the pasture.
- The topsoil material may have some stones and gravels present in the topsoil that was stockpiled/removed from the extraction site.

6.3 Sequence of soil placement

Soil placement is the single most important operation in the restoration process. The soil must be placed under optimal conditions to specified depths on a platform graded to design levels.

The platform design determines the future landform and must consider materials available, groundwater levels, erosion hazard, slope criteria for restored land use, aspect, microclimate, aesthetics, and most importantly, drainage (Ramsay, 1986). Final slopes of five or less degrees are considered optimal for cropping. Due to the scale of the property the new floor will have a less than five degree slope.

[1] Milne JDG, Clayden B, Singleton PL, Wilson AD. 1995. Soil Description Handbook. Lincoln, New Zealand, Manaaki Whenua Press. 157p. (p46).

[2] Milne JDG, Clayden B, Singleton PL, Wilson AD. 1995. Soil Description Handbook. Lincoln, New Zealand, Manaaki Whenua Press. 157p. (p45).

Once the shape of the existing land surface has been attained, the soil materials need to be placed using light track-driven machinery or lighter quarry machines or flotation tyred machinery. The topsoil material needs to be distributed in such a way as to achieve an approximately uniform stable thickness over the whole area.

Any exposed soil surfaces require protection from wind erosion. Light surface wetting of the soil topsoil via irrigation is an acceptable method. All areas that are not being actively quarried will be maintained in vegetation.

6.4 Irrigation

The farm currently is fully irrigated by three centre pivots, single span towable pivots and set sprinklers. The existing centre pivots will remain in place for as long as possible.

The newly formed boundary slopes will not be irrigated by centre pivots' end guns to avoid topsoil being washed off. Low application rate irrigation (either temporary or permanent) will be installed to establish and maintain newly sown pasture.

The irrigation water is available from CPWL from September to April, this water will extend the timeframe when soil conditions are suitable for rehabilitation and allow new grass to be sown as soon as possible following the topsoil placement. This will prevent dust and soil cracking.

The site is to be progressively stabilised i.e.; each active stage must be remediated as the excavation commences for the next stage. The area of irrigation at the bottom of the pit will progressively expand.

7.0 Assessment of Effects

7.1 Nitrogen loss to groundwater

The nitrogen loss to water as estimated by OverseerFM v6.5.1 for the current farming operation is 28 kg N/ha/year and approximately 10,840 kg N/ha/year for the whole property, as shown by the Overseer report in Appendix B. Nitrogen losses are managed under CPWL's nutrient load.

During quarrying, up to 40 ha of the property will be utilised for that purpose at any one time, of which around 22 ha will occupy the active quarry workings that will progressively move throughout the farm area and the remaining area (around 18 ha will be at a fixed location for access, administration, silt management and processing facilities. The area of the site in which quarry activities are occurring will have a low nitrogen leaching rate, related to the nitrogen content in rainfall (2 kg N/ha/yr, as modelled in OverseerFM v 6.5.1) and any additional input and take-up from planted areas. The areas of native planting generally have low nitrogen loss although it depends on the plant species.

As land will be removed from agricultural production by the quarry operation and with the planting of native vegetation in the buffer zones and on the rehabilitated slope, the nitrogen loss from the proposed operation will decrease. When modelled in Overseer the proposed system with 40 ha of quarry and 23 ha of trees and scrub the nitrogen loss reduces to 24 kg N/ha or 9,385 kg N total, a 14 % reduction from the current operation.

The farming operation will also ensure the nitrogen loss per hectare will reduce further in accordance with any planning requirements or changes to CPWL nutrient load. This will be achieved using plantain (a herb shown to reduce nitrogen leaching on grazed pastures by 7 -20%) and by nutrient and stock management.

Following quarrying the thickness of the soils and gravels above the highest water table level (permanently unsaturated zone) will be reduced from the current minimum depth range of 8 – 12 m across the farm to a depth of 1 m minimum. The intermittently saturated zone within which the water table fluctuates will remain unchanged. However, instead of having 8 – 22 m of strata above the water table this will be reduced to a depth of 1 – 11 m, depending on where the groundwater level is at any time. This is not expected to change the mass of nitrate reaching the water table as no significant attenuation occurs in this zone, but the nitrate will reach the groundwater sooner than is the current case. In conclusion following the rehabilitation of the quarried land, annual losses of nitrate to groundwater will be lower than current losses if the same agricultural land use practices continue due to some of the area being planted in native vegetation.

7.2 Phosphorus loss to water

Phosphorus losses to water are usually from runoff to surface water. This site does not have any surface water. As part of the rehabilitation programme phosphate fertiliser will be used to raise the Olsen P levels to similar levels as before quarrying. Fertiliser applications will be based on individual paddock soil testing and designed to meet pasture demand as determined by the nutrient budgeting software OverseerFM for most macro-nutrients (particularly phosphorus and potassium).

The P leaching vulnerability for Lismore soils has yet to be determined (S-Map fact sheets). Phosphorus leaching can occur after phosphate fertiliser is applied to pasture and crops. To reduce the risk of P loss the farm will use the following good management practices:

- The farm will have a soil testing and monitoring programme to ensure phosphate fertiliser is applied at optimal rates to minimise leaching.

- Only irrigate to meet the moisture needs of the plant and avoiding drainage. Varying the depth of irrigation on a daily basis can minimise the quantity of drainage, which is minimised further by adjusting applications according to weather forecasts. Compared to uniform rate irrigation, the use of variable depth has been shown to decrease P losses by up to 80% (McDowell, 2017)
- The timing of fertiliser or effluent P application to soil can influence P loss, mainly because of the effect soil moisture can have on the propensity for the generation of P leaching. P fertiliser will not be applied to soil at, or close to, field capacity or if heavy rain is predicted, or in the months of May to September included.
- The use of lower water soluble P fertilisers if higher rates of phosphate fertiliser are required.
- The rehabilitated pasture area will use deeper rooting pasture species to take up phosphorous in the subsoil.

The proposed activity will have a less than minor effect on this nutrient loss as the farming activity will not change and there will be a small reduction in farmed area.

7.3 Pathogen loss to water

The ongoing use of Burnham Farm by one- and two-year old dairy heifer replacements creates a source of *E. coli* and other pathogens that can migrate downwards to the underlying groundwater system, particularly during heavy rainfall events. *E. coli* is the indicator organism used to assess compliance with drinking-water standards in New Zealand. During this migration from the ground surface through the sub-surface environment, *E. coli* numbers are reduced by filtration, desiccation, dispersion, dilution, and natural die-off over time. The soil profile contributes to this reduction in *E. coli* numbers.

The topsoil over most of Burnham Farm is described from test pits as a dark brown sandy gravelly silt, well graded, sand, fine to coarse gravel, fine to coarse, rounded to subrounded slightly weathered greywacke with organics, roots, and wood fragments. The average topsoil thickness is 0.3 – 0.4 m.

The process described earlier in this report whereby, following the completion of quarrying, existing soils from the farm will be stripped and placed over the quarried areas, with an additional silty subsoil layer, will aid in the removal of *E. coli*. Crops will be planted to help develop the soil structure and it is expected that 1 – 2 years after the completion of quarrying the topsoil will have the same, or better bacterial removal rates than currently exist.

7.4 Nutrient loss to surface water

Burnham Farm is located near the middle of the Canterbury Plains, approximately 6.5 km north of the Selwyn/Waikirikiri River and 12.5 km south of the Waimakariri River. Therefore, there will be no overland flow from the farming operation on this site to surface water.

7.5 Soil loss to water

Soil management for quarry activities typically requires measures to avoid the risk of soil loss to water. However, at this site there are no surface waterways on, or immediately adjacent to, the property. The quarry site and the rehabilitated site will mostly be below the surrounding ground level so overland flow to a waterway will not occur from these areas. The bunds created around the boundary of the property to screen the quarry will be covered or vegetated with grass to reduce soil damage and loss caused by wind and rain.

The Lismore soils these are well drained soils with moderate permeability over gravels with rapid permeability. The depth of topsoil is not expected to change, therefore it is expected that rainwater will drain through the profile to the groundwater rather than pond. Areas of obviously impeded drainage, which show by way of surface ponding, will be examined to establish if any moisture restricting layer exists and appropriate ripping or subsurface aeration undertaken to shatter such compacted layers.

7.6 Soil Productivity

Following full establishment of the pasture vegetation, the soil should be capable of production similar to land that has been cultivated for cropping and re-grassed. As the pasture establishes over the first year, soil properties will improve due to the positive impacts of the pasture cover. These will include development of soil aggregates and soil biological activity.

In general, soil properties are likely to change more rapidly in the first few years following re-establishment, and then slow as the soil settles towards longer term equilibrium conditions.

Under established land use, soil quality changes commonly occur over decades depending on the intensity of land use, at which point contemporary land management practices are likely to have a greater impact on the soil rather than the soil property changes associated with the reestablishment of the soil.

7.7 Effects of disturbance on soil properties and productivity

Any soil disturbance (as part of any activity) is likely to result in disruption to soil properties. Soil disturbance or disruption can occur with any land use practice (e.g., cultivation for cropping). Adherence to the Soil Management Plan (most importantly during the removal and placement of the subsoil and topsoil materials) will ensure the effects are minimised and are no more than the soil disturbance effects resulting from land use practices such as cultivation for cropping, forest harvesting and intensive pastoral use.

The effects on soil properties are likely to be predominantly soil physical effects related to soil compaction, loss of soil structure and degradation of soil aggregates during removal, transport and storage, and compaction of the soil material during placement. In turn, these can lead to impeded soil drainage (reducing air and water flow pathways in the soil), reduced soil water storage capacity, and reduced soil pores for biological activity. Soil fertility is not considered to be of primary concern as this can be remedied with the addition of fertiliser. If the steps set out in the Soil Management Plan, then effects on soil properties following restoration will be minimised.

Re-vegetation to pasture should be undertaken as soon as practicable after topsoil placement. This will minimise possible deterioration of soil structure and development of erosion problems on bare cultivated soils.

To encourage the rapid recovery of the soil structure, only light weight stock such as sheep and Calves/Rising 1 year cattle will be grazed on the pastures and no stock grazed in July and August in the first year after sowing the new pastures. A management system which promotes grass harvesting (hay and/or silage) over the first two years after rehabilitation is to be encouraged. This helps prevent recompacting the soil. Across the grazed area of the property the stocking rate will remain at the same level as the current stocking. Good management of wet soil to avoid degradation of soil structure will be important, especially managing stock movement on the soils during wet periods when the soil is saturated and susceptible to pugging and compaction.

The applicant intends to return the land to a productive agricultural standard. The farm will continue to operate, in the short term, a similar stocking policy and stocking rate per grazed hectare when the gravel extraction is underway. Total stock numbers will be adjusted to allow for the loss of productive land.

The land will be returned to productive use incrementally as works progress so to have as little impact on the productivity of the site's soil as possible. Based on the guidance provided in the Soil Management Plan, the method of extraction has been designed to achieve this goal.

In the long term, the aim is that the land will be suitable for a range of uses. Following post extraction rehabilitation (including establishment of the pasture vegetation) the soil resource will be capable of supporting at least the same range of land uses as the current soil resource and the life supporting capacity of the soil will be retained.

7.8 Dust

Soil management related potential for dust is associated with soil removal and placement, soil storage, transport, and post placement management. Mitigations are provided in the dust mitigation section of the Air Quality Assessment for storage and transport. This property has existing irrigation and will re-establish irrigation for the final placement of soil and to establish pasture, reducing the risk of dust problems.

The existing shelter belts will be retained, and any gaps planted and there will be a 120m setback, planted in native vegetation, from neighbouring dwellings.

8.0 Soil monitoring

Many physical, biological and, to a lesser degree, chemical soil properties show up as visual characteristics. Changes in land use or land management can markedly alter these. Research in New Zealand and overseas shows that many visual indicators are closely related to key quantitative (measurement-based) indicators of soil quality. A ‘miniVisual Soil Assessment’ (VSA) has been adapted for New Zealand farmers from the Soil Quality Management Assessment (SQMS) developed by Plant & Food Research, the Visual Soil Assessment produced by the Soil Management Initiative (UK) and Manaaki Whenua - Landcare Research visual soil assessment field guide. It is based on the visual assessment of key soil ‘state’ and plant ‘performance’ indicators of soil quality, presented on a score card. A miniVSA has been selected as an appropriate monitoring tool for this site for the following reasons:

- monitors soil structure and porosity
- turbidity
- includes soil biology (earthworm count)
- is simple to do and can be carried out by a farmer or Rural Professional
- is usually carried out annually in late winter/early spring for pasture farming.

A good soil structure provides greater resistance to compaction and maintains the necessary soil porosity for roots to access air, water, and nutrients. The structure & porosity score along with the turbidity score assess the structure and stability of soil aggregates. Earthworms are an important biological indicator. Through their feeding and burrowing activities, earthworms can enhance nutrient availability, increase the infiltration and movement of air and water, and improve the structural condition and stability of soils.

Scores for each test are recorded on a score sheet. To allow comparative assessment of the soil quality of the re-established soil a control site in a paddock on an undisturbed site will be included in ongoing soil monitoring to differentiate between the effects of contemporary land use management and effects associated with the re-establishment of the soil.

Annual monitoring using miniVSA (Appendix C) in the areas rehabilitated within the last three years from the start of Phase 2 (i.e years 7 -10) shall be implemented. If the soil Quality Assessment in the VSA is ranked as poor three years after rehabilitation, a plan will be developed and implemented to improve the soil quality.

Additional soil testing to inform farm management and nutrient management will be carried out and this will be included in the soil Management Plan.

9.0 Statutory and planning documents related to soils and nutrient loss

9.1 National Policy Statement for Highly Productive Land

The NPS-HPL identifies LUC 1, 2 or 3 land as highly productive. As this site is LUC 4, it is not subject to the proposed National Policy Statement (NPS) - highly productive land which became operative on 17 October 2022.

Canterbury Water Management Strategy

The site is located within the area managed by the Selwyn/ Te Waihora Zone Committee. The committee have generated a Zone Implementation Programme (ZIP) for this zone. ZIPs are non-statutory documents that are being completed by each of the Zone Committees within the Canterbury region. ZIPs contain zone-specific recommendations for water management to achieve the CWMS targets.

The Selwyn Te Waihora ZIP addresses critical issues in the sub-regional area such as setting limits for nutrients and the health of Te Waihora. Improving the health of the lake includes actions such as effective riparian management of lowland streams, grazing management, sediment removal, habitat enhancement and nutrient stripping via wetlands. Healthy lowland streams, best practice nutrient and water management, and the integration of kaitiakitanga into water management are all recognised as priority outcomes in the zone.

The issues regarding the quality of water include farm nutrient management in both irrigated and non-irrigated contexts, sedimentation problems e.g., gravel pits and stock water and lastly urban and rural water quality management issues i.e., the setting of nutrient load limits.

This property is covered by an audited Farm Environment Plan (FEP), and they are proposing to operate at or below the nitrogen loss reductions required under the Canterbury Land and Water Plan they can be considered to be meeting these requirements.

9.2 National Environmental Standard for Freshwater 2020 (NES-F)

The National Environmental Standards for Freshwater 2020 partially came into force on 3 September 2020. Parts of the standards have later enforcement dates.

The purpose of the NES is the 'regulation of activities that pose risks to the health of freshwater and freshwater ecosystems'. The NES sets out requirements that need to be complies with. These standards are set to:

a. Protect existing inland coastal wetlands;

b. Protect urban and rural streams from in-filling;

c. Ensure connectivity of fish habitat (fish passage);

d. Set minimum requirements for feedlots and other stockholding areas;

e. Improve poor practice intensive winter grazing of forage crops;

f. Restrict further agricultural intensification until the end of 2024; and

g. Limit the discharge of synthetic nitrogen fertiliser to land and require reporting of fertiliser use.

Regulation 22 - Use of land as dairy support

The area of dairy support will decrease and is therefore it is a Permitted Activity under Regulation 22.

Subpart 3 - Intensive Winter Grazing;

Regulation 26 condition 3 requires Freshwater Farm Plans, these are not yet available for Canterbury so they cannot comply with Regulation 26 condition 3, therefore they need to comply with condition 4.

(a) at all times, the area of the farm that is used for intensive winter grazing must be no greater than 50 ha or 10% of the area of the farm, whichever is greater; and

(b) the slope of any land under an annual forage crop that is used for intensive winter grazing is 10 degrees or less,

(d) livestock must be kept at least 5 m away from the bed of any river, lake, wetland, or drain (regardless of whether there is any water in it at the time); and

(e) on and from 1 May to 30 September of any year, in relation to any critical source area that is within, or adjacent to, any area of land that is used for intensive winter grazing on a farm:

(i) the critical source area must not be grazed; and

(ii) vegetation must be maintained as ground cover over all of the critical source area; and

(iii) maintaining that vegetation must not include any cultivation or harvesting of annual forage crops.

The proposal meets Regulation 26, Condition 4, by having a maximum of 35 hectares of intensive winter grazing, flat ground less than 3 degrees of slope, and no waterways or criteria source areas and therefore it is a Permitted Activity under Regulation 26.

Regulation 29 provides further conditions for land used for intensive winter grazing. The regulations are designed to mitigate the effects of grazing livestock on forage crops between 1 May and 30 September. The current operation grazes about 35 ha of winter forage crop for intensive winter grazing and this is less than the maximum area of 57 ha grazed in the 2014 – 2019 reference period, therefore intensive winter grazing on this farm is a permitted activity under the Freshwater NES.

Subpart 4 Regulation 33 Application of synthetic nitrogen fertiliser to pastoral land.

The proposal meets Regulation 33 by not exceeding the nitrogen cap for application of nitrogen. The current farm activities and proposed farm activity comply with the permitted activity rule for application of synthetic nitrogen fertiliser as a maximum of 190 kg N/ha/year is applied.

In summary this farm is a Permitted activity under the Freshwater NES.

9.3 Canterbury Regional Policy Statement

The Canterbury Regional Policy Statement provides an overview of the significant resource management issues facing the region and sets out objectives and policies to achieve the integrated management of the natural and physical resources of Canterbury.

Policy 7.3.7 relates to avoiding, remedying, or mitigating any adverse effects on freshwater quality. The proposal is consistent as nitrogen losses from the property will be appropriately managed through the farms FEP and the quarry will not increase the nitrogen load to groundwater.

Objective 15.2.1 and Policy 15.3.1 are concerned with the maintenance of soil quality. This proposal is consistent with maintaining soil quality and soils will be appropriately managed through the Soil Management Plan.

9.4 Canterbury Land and Water Plan

The Canterbury Land and Water Plan states quarry sites need to be "appropriately managed or rehabilitated once extraction ceases". Rehabilitation at Burnham Farm will progressively restore topsoil over areas already quarried to enable appropriate future uses.

Due to the scale of the site, the farming activity doesn't need to be completely replaced by quarry activities – the quarry and farm can co-exist. To ensure successful co-existence, it is important that the land is rehabilitated to restore its productive capability and as much irrigated land as possible is maintained during quarrying activities. Given that most of the irrigation is provided to the farming operation by centre pivot, minimizing the disruption to centre pivots is important in maximizing the area of irrigated land and re-establishing irrigation during the rehabilitation process will be needed to return land to productive pasture. During quarrying, up to around 22 ha of the property will be utilised for active extraction and rehabilitation at any one time.

Most of the LUC NZLRI classes 1 – 3 versatile soils, in the Selwyn District, are in the Selwyn – Waihora zone. The Selwyn – Waihora Zone in the Canterbury Water Management Strategy stretches from Te Waihora up to Springfield and the Rakaia to the Waimakariri Rivers, it excludes the hill and high-country areas of the Selwyn District. This catchment is approximately 281,400 ha.

The Land Use Capability map of this area is shown in Figure 3, attached to this report. Within the Selwyn District there are approximately 133,800 ha of land that are classified as LUC 1, 2 or 3 versatile land and a further 80,200 ha that is LUC 4, providing a total of 213,900 (76% of the catchment) that is LUC 1 to 4 land that can be used for pastural farming and cropping.

The proposed quarry will use a maximum of 40 ha of land at one time, which corresponds to 0.05% of the LUC 4 soils in the catchment and less than 0.02% of the LUC 1 to 4 land in the Selwyn – Waihora zone. It is proposed to progressively rehabilitate this area to enable its use for primary production.

There will be native planting equating to over 23 hectares, which will be progressively planted over the life of the quarry. This area will provide biodiversity and ecological benefits to the area.

9.4.1 Nutrient Management:

The use of land for farming (s9RMA) is permitted under rules 5.41 and/or 5.60 of the Land and Water Regional Plan and the discharge of contaminants from farming (s15RMA) is consented under rule 5.62 therefore, a separate Farming Land Use consent is not required for this property.

Nutrient Management is assessed under the Selwyn Te Waihora sub -region rules 11.5.6 – 11.5.19 as these prevail over the regional rules 5.41 – 5.64. The property is irrigated with water from an Irrigation Scheme (Central Plains Water Limited) and the Irrigation Scheme holds a discharge consent that includes this property so Rules 11.5.15 and 11.5.16 apply.

This property has been assessed by Central Plains Water limited as meeting the required 22% reduction in nitrogen loss from the baseline, that was required by 1 January 2022 for dairy support land. The proposed quarry activity will further reduce nitrogen loss to water. Nitrogen loss reductions are checked as part of scheduled Farm Environment Plan (FEP) audits.

9.5 Land and Water Regional Plan including Proposed Plan Change 7

The Canterbury Land and Water Regional Plan aims to provide clear direction on how land and water are to be managed in the region.

The LWRP contains objectives, policies and rules as required under section 67(1) of the RMA. The objectives, policies and rules in this Plan manage land, water, and biodiversity within the region in conjunction with other non-statutory methods. They are consistent with the vision and principles in the Canterbury Water Management Strategy (CWMS).

This Plan operates at two levels. There is a region-wide section, which contains the objectives, policies and rules that apply across the region. There are also ten sub-region sections.

The sub-region sections contain policies and rules which are specific to the catchments covered by that section. The policies and rules in the sub-region sections implement the region-wide objectives in the Plan in the most appropriate way for the specific catchment or catchments covered by that section. As there are no policies relevant to this proposal in the Selwyn sub-region (Section 11) Region-wide policies apply.

Region-wide Policies 4.1 and 4.2 refer to water bodes meeting freshwater outcomes and consider cumulative effects. Modelling of the proposal has shown the nitrogen loss for the property will likely decrease from the 2009-2013 baseline as part of the proposal which is consistent with these policies.

Policy 4.13 is focused on minimising the discharge of contaminants to surface water and groundwater. The proposal is generally consistent with this policy, in that the nutrient load will not increase.

Policy 4.14 is concerned with discharges that may enter groundwater. A conservative irrigation application rate to ensure the irrigation does not exceed the soil water holding capacity will be used.

Policy 4.40 and 4.41 are concerned with farm environment plans. A FEP is held by the property.

10.0 Conclusion

The soil management measures described in this report are designed to ensure that appropriate site rehabilitation will be implemented at the completion of each stage of quarry extraction. Whilst timing of stage completion can adapt to fluctuations in aggregate demand, the sequence of extraction activity forms the basis for how rehabilitation efforts occur. The soil management strategy will achieve the following:

- Progressive rehabilitation of the site throughout the stages of extraction.
- Stabilisation of quarry faces and grassing of completed and restored extraction areas to create a free draining and stable landform.
- Ensure any areas where works have been completed are left in a safe and stable condition.
- The site is rehabilitated in a way which enables pastural farming to occur in the future.
- Ensure that any areas where work is completed has adequate drainage and water infiltration for irrigated pasture farming
- Work with the farm to ensure the least disturbance to farming operations including irrigation of pasture
- Mitigation of any potential adverse environmental effects.

11.0 References

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Humphries RN 2021 Good Practice Guide for Handling Soils in Mineral Workings Part Two: Model Methodology Soil Replacement with Bulldozers and Dump Trucks

Milne JDG, Clayden B, Singleton PL, Wilson AD. 1995. Soil Description Handbook. Lincoln, New Zealand, Manaaki Whenua Press. 157p. (p45 and p46).

PDP – Proposed Burnham Quarry – Air Quality 2023

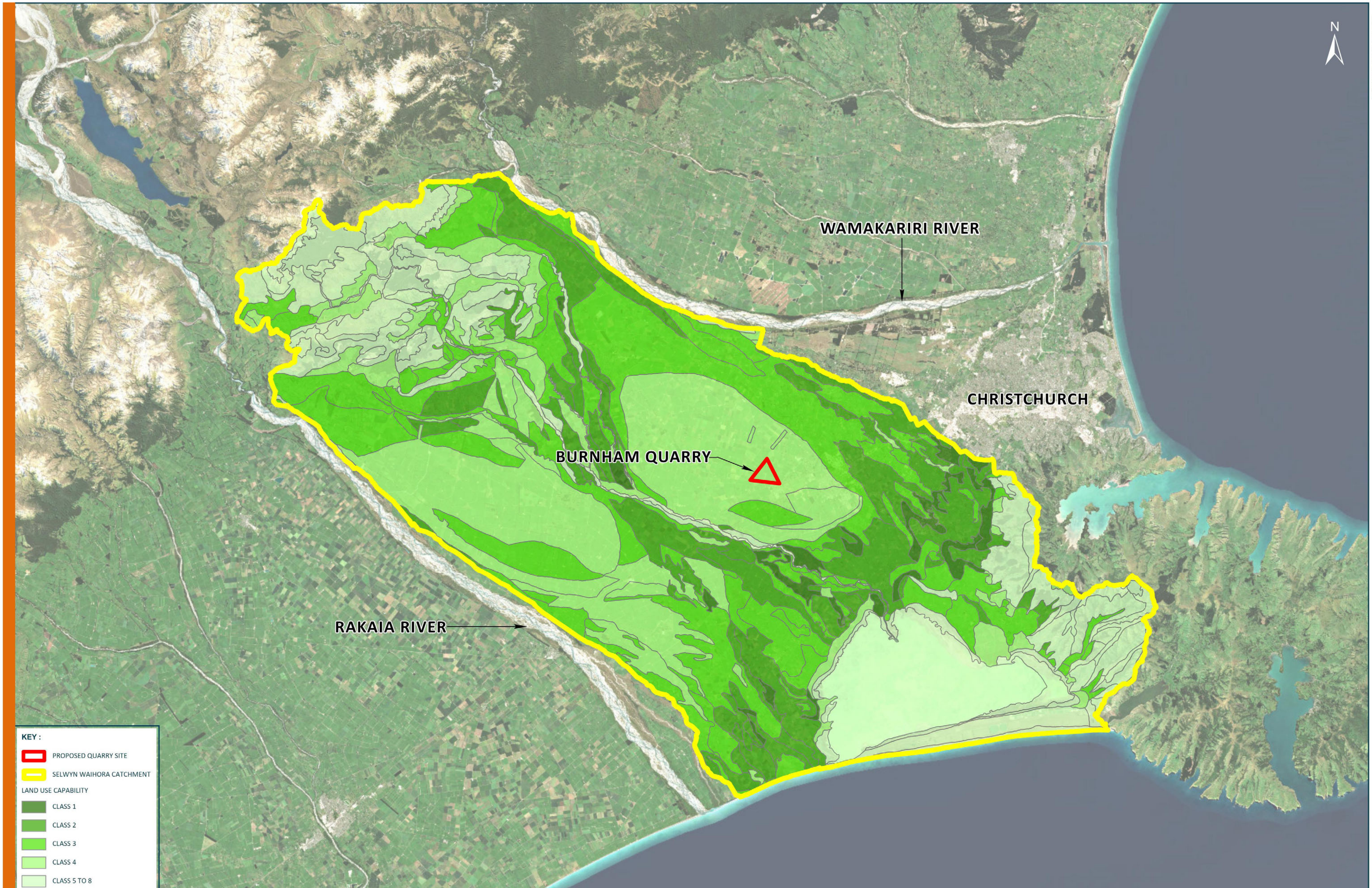
Ramsay W.J.H 1986 Bulk soil handling for quarry restoration. Soil and land use management Volume 2, No. 1. Pp30-39.

Shepherd, T.G. 2000: Visual Soil Assessment. Volume 1. Field guide for cropping and pastoral grazing on flat to rolling country. Horizons.mw & Landcare Research, Palmerston North

S-map fact sheets - reports (landcareresearch.co.nz)

Soil map unit factsheet (landcareresearch.co.nz)

Appendix A: Figures



SCALE : 1:350,000 (A3)

NO.	REVISION	DATE	BY
A	ISSUED	DEC 22	CB

SOURCE:
1. AERIAL IMAGERY (FLOWN 2017-2020) SOURCED FROM THE LINZ DATA SERVICE www.linz.govt.nz/about-linz/linz-data-service/help/using-linz-data/attributing-aerial-imagery-data AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.
2. CADASTRAL/TOPOGRAPHICAL INFORMATION AND INSET DERIVED FROM LINZ DATA.

CLIENT
BURNHAM 2020 LTD

FIGURE
FIGURE 3: SELWYN WAIHORA LAND USE CLASSIFICATION

PROJECT
BURNHAM QUARRY

pdp

0 200 400

METRES

SCALE : 1:12,500 (A3)

NO.	REVISION	DATE	BY
A	ISSUED	DEC 22	CF

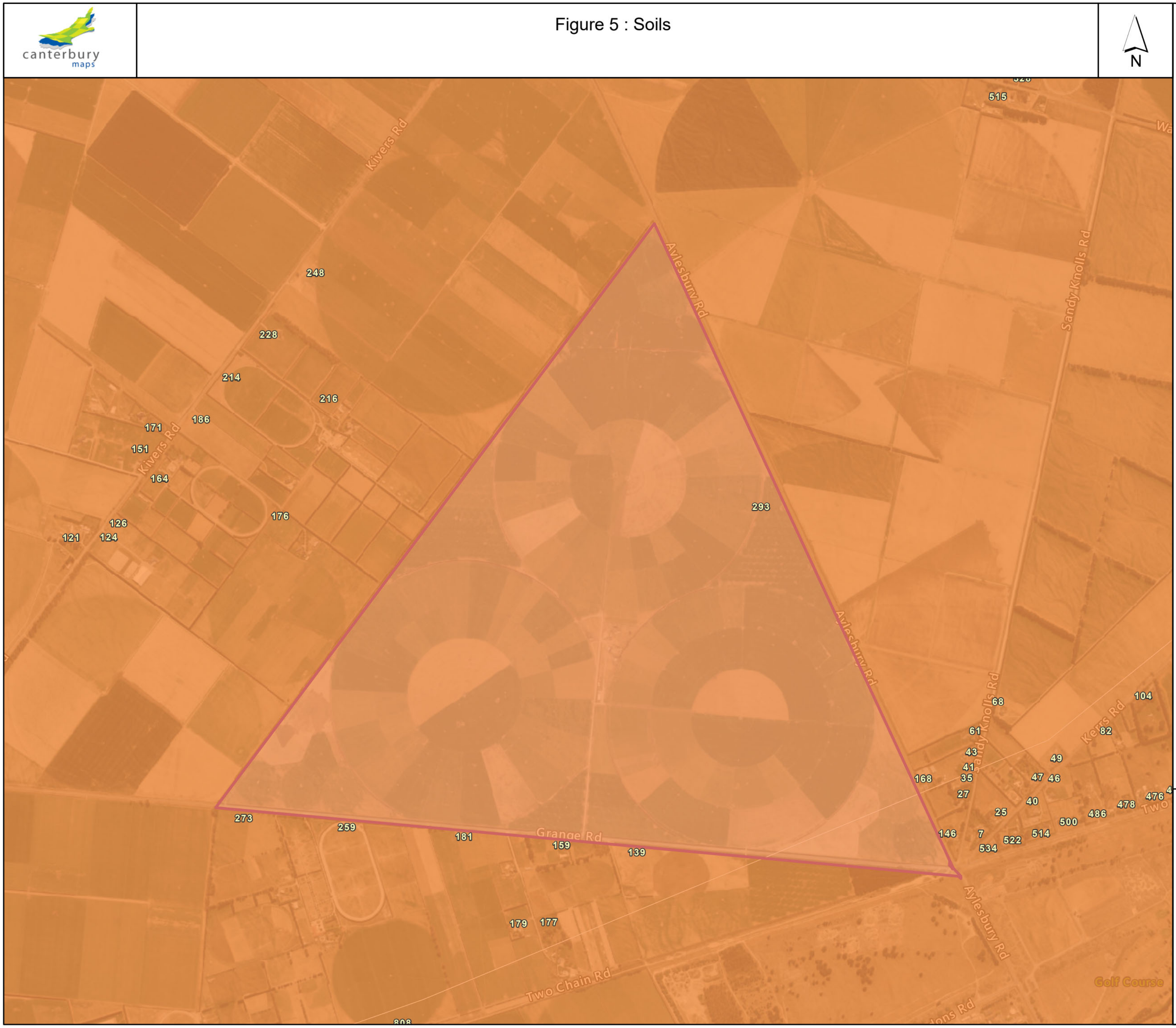
SOURCE:
1. AERIAL IMAGERY (FLOWN 2017-2020) SOURCED FROM THE LINZ DATA SERVICE www.linz.govt.nz/about-linz/linz-data-service/help/using-linz-data/at ribut ng-aerial-imagery-data AND LICENCED FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 INTERNATIONAL LICENCE.
2. CADASTRAL/TOPOGRAPHICAL INFORMATION AND INSET DERIVED FROM LINZ DATA.

CLIENT
BURNHAM 2020 LTD

FIGURE
FIGURE 4: TEST PIT LOCATIONS

PROJECT
BURNHAM QUARRY

Figure 5 : Soils



Burnham Farm
Medium
S - Map Data - Soils

Legend note: if you have a large number of layers on the map, they may not all be visible in the legend.

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0 0.2 0.4 0.6 0.8 Kilometres

Scale: 1:14,000 @A3

Map Created by Canterbury Maps on 10/05/2023 at 5:11 PM

Appendix B: Overseer report

CAMDEN GROUP - AYLESBURY GRAZING LTD (BURNHAM)

139 Grange Rd, Burnham 7675, New Zealand

OverseerFM

Year ending 2020

Analysis type	Year end
Is publication	No
Application version	5.0.1.1
Printed date	10 May 2023, 5:16PM
Model version	6.5.1

Farm details

N 28 kg/ha | 10,839 kg — P 0.3 kg/ha | 114 kg — GHG 14,605 kg/ha | 5,681.3 tonnes — NCE: 18 — v6.5.1

Total area	388.8 ha
Productive block area	375.00 ha
Nitrogen conversion efficiency (NCE)	18%
N Surplus	281 kg/ha
Region	Canterbury

Total liveweight brought (kg/ha grazed)	842
Total liveweight reared (kg/ha grazed)	1871
Total liveweight sold (kg/ha grazed)	2601

Percent male beef animals	4
Beef / dairy grazing stock rate (RSU)	12044

Analysis comments

DATE	BY	TYPE	COMMENT
26 Jun 2019, 9:00AM	Ravensdown Admin	General	Property description, location and valuation numbers: -43.603552, 172.291260

Blocks

NAME	TYPE	AREA (HA)	N LOSS	N LOSS/HA	N IN DRAINAGE (PPM)	N SURPLUS/HA	P LOSS	P LOSS/HA	BLOCKED AREA %	N FARM LOSS %
Lism_1a.1 Pivot	Pasture	200	5,646	28	14	299	21	0.1	53	52
Lism_1a.1 Spinners	Pasture	105	2,932	28	14	293	11	0.1	28	27
Kale to Pasture	Crop	35	848	24	12	194	7	0.2	9	8
Pasture to Kale	Crop	35	1,393	40	19	231	12	0.3	9	13
Other sources	Other	-	21	-	-	-	63	-	-	-

Farm soils

S-MAP REF/NAME	GROUP/ORDER	DRAINAGE CLASS	MODIFIED	TOTAL AREA (HA)	% OF PROD. BLOCKS	BLOCKS
Lism_1a.1	Sedimentary/Brown	Well	Yes	375	100	4

Enterprises

STOCK NUMBERS

NAME	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Beef	1712	1712	1777	1777	1712	3279	3286	3279	3164	1632	1632	1632

RSU

NAME	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Beef	828	929	1018	951	761	1236	1268	1294	1507	1169	536	547

Irrigators

NAME	AREA COVERED	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
LINEAR AND CENTRE PIVOT Linear and centre Pivot 1	200 ha				✓	✓	✓	✓	✓	✓			
SOLID SET Solid set 2	105 ha				✓	✓	✓	✓	✓	✓			
LINEAR AND CENTRE PIVOT Pivot	70 ha				✓	✓	✓	✓	✓	✓			

Structures

No structures exist.

Supplements

CATEGORY	FEED	SOURCE	DRY WEIGHT?	AMOUNT	DESTINATION
Silage	Baleage	Purchased (225)	Yes	225 tonnes	Beef (225)
Baleage	-	Lism_1a.1 Pivot (197)	Yes	197 tonnes	Off farm (197)
Baleage	-	Lism_1a.1 Spinners (156)	Yes	156 tonnes	Off farm (156)
Silage	Pasture average quality silage	Purchased (461)	Yes	461 tonnes	Beef (461)

Crops

CROP/PASTURE	AREA (HA)	YIELD	GROWN (T/DM/YR)	INTAKE (T/DM/YR)	SUPPLEMENTS (T/DM/YR)
Ryegrass/white clover	305.0	-	7793	5208	353
Kale	35.0	525 T/ha dry matter	-	-	-
Pasture	35.0	-	-	-	-

Fertiliser

MANUFACTURER/MATERIAL	NAME	TOTAL APPLIED (KG)	N	P	K	S	CA	MG	NA
Ravensdown cropping	Ammo 31	37,500	11,513	-	-	5,400	-	-	-
Ravensdown other	Urea	140,000	64,400	-	-	-	-	-	-
Ravensdown cropping	Cropmaster DAP	10,500	1,848	2,100	-	105	-	-	-
Ravensdown other	Potassium chloride	5,250	-	-	2,625	-	-	-	63
Ravensdown super	Superphosphate	126,375	-	11,374	-	13,901	25,275	-	-
TOTAL		**319,625**	**77,761**	**13,474**	**2,625**	**19,406**	**25,275**	-	**63**

GHG - Total farm emissions

METHANE GHG EMISSIONS	N20 GHG EMISSIONS	C02 GHG EMISSIONS	TOTAL GHG EMISSIONS
3675.3 eC02/tonnes/yr	1417.9 eC02/tonnes/yr	588.2 eC02/tonnes/yr	5681.3 eC02/tonnes/yr

Farm nutrient budget

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	10,839	28
Phosphorus	114	0.3

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Foliar sprays	0	0	0	0	0	0	0
Fertiliser, lime and other	200	35	7	50	65	0	0
Irrigation	10	0	6	10	37	9	38
Supplements	34	5	32	4	8	3	2
Rain/clover fixation	99	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	28	0.3	9	59	31	1	7
As product	45	11	3	5	23	1	1
As prunings	0	0	0	0	0	0	0
Transfer	0	0	0	0	0	0	0
Effluent exported	0	0	0	0	0	0	0
To atmosphere	93	0	0	0	0	0	0
As supplements and crop residues	17	2	16	2	4	1	1

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	113	0	3	-5	1	0	0
Standing plant material	19	2	12	1	2	1	1
Inorganic mineral	0	2	-21	0	-1	-2	-2
Crop framework	0	0	0	0	0	0	0
Inorganic soil pool	5	20	24	0	53	13	51
Change in supplement storage	0	0	0	0	0	0	0
Root and stover residuals	25	2	0	5	0	0	0

Blocks

Lism_1a.1 Pivot

Pasture - Flat, 200 ha

N	28 kg/ha | 5,646 kg

P	0.1 kg/ha | 21 kg

BLOCK DETAILS

Area	200 ha	Average temp	Using farm climate (11.9 °C)	Average rainfall	Using farm climate (667 mm/yr)	Annual PET	Using farm climate (917 mm/yr)
Distance from coast	29 km						

SOILS

100% LISM_1A.1
200 ha Brown

PASTURE

Pasture growth	**25,550 kg DM/ha/yr**	Removed	**985 kg DM/ha/yr**
Utilisation	**70 %**	Beef	**30.88 rsu/ha**
Intake	**17,196 kg DM/ha/yr**		

SUPPLEMENTS

Harvested (DM)	**197 tonnes**

CROP MANAGEMENT

Block type	**Pasture**	Hydrophobic condition	**Use default**
Topography	**Flat**	Susceptibility to pugging	**Occasional**
Pasture type	**Ryegrass/white clover**	Is compacted	**No**
Cultivated in last 5 years	**No**	Naturally high water table	**No**
Animals present	**Yes**		

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
RSU/HA												
Beef	1.93	2.74	2.73	2.55	2.24	3.64	3.74	3.81	4.11	2.81	0.27	0.31
FERTILISER APPLIED (KG/HA)												
N	-	31	25	25	25	25	25	25	25	-	-	-
P	-	-	2	28	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-	-
S	-	14	3	34	-	-	-	-	-	-	-	-
IRRIGATION APPLIED (MM)												
Avg applied (mm)	-	-	-	60	65	75	95	70	35	-	-	-
LINEAR AND CENTRE PIVOT 1 (LINEAR AND CENTRE PIVOT): OVERSEER DEFAULT (FIXED) | N:2.5 P:0.1 K:1.6 S:2.5 CA:9.3 MG:2.2 NA:9.5												
Supplied (mm)	-	-	-	63	68	79	100	74	37	-	-	-
Applied (mm)	-	-	-	60	65	75	95	70	35	-	-	-
Depth (mm)	-	-	-	5	5	5	5	5	5	-	-	-
Return (days)	-	-	-	1	1	1	1	1	1	-	-	-

NUTRIENT BUDGET

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	5,646	28
Phosphorus	21	0.1

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	208	30	0	51	67	0	0
Irrigation	10	0	7	10	39	9	40
Supplements fed on blocks	32	4	30	3	8	3	2
Rain/clover fixation	123	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	28	0.1	10	56	30	1	6
As product	48	12	3	6	24	1	1
Transfer	7	1	5	0	1	0	0
Effluent exported	0	0	0	0	0	0	0
To atmosphere	100	0	0	0	0	0	0
As supplements and crop residues	18	2	18	2	4	1	1

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	171	7	0	6	0	0	0
Inorganic mineral	0	2	-20	0	-1	-2	-2
Inorganic soil pool	0	11	22	0	57	14	54

Lism_1a.1 Spinners

Pasture - Flat, 105 ha

N	28 kg/ha | 2,932 kg

P	0.1 kg/ha | 11 kg

BLOCK DETAILS

Area	105 ha	Average temp	Using farm climate (11.9 ℃)	Average rainfall	Using farm climate (667 mm/yr)	Annual PET	Using farm climate (917 mm/yr)
Distance from coast	29 km						

SOILS

100% 105 ha — LISM_1A.1 Brown

PASTURE

Pasture growth	**25,550 kg DM/ha/yr**	Removed	**1486 kg DM/ha/yr**
Utilisation	**70 %**	Beef	**30.27 rsu/ha**
Intake	**16,845 kg DM/ha/yr**		

SUPPLEMENTS

Harvested (DM)	**156 tonnes**

CROP MANAGEMENT

Block type	**Pasture**	Hydrophobic condition	**Use default**
Topography	**Flat**	Susceptibility to pugging	**Occasional**
Pasture type	**Ryegrass/white clover**	Is compacted	**No**
Cultivated in last 5 years	**No**	Naturally high water table	**No**
Animals present	**Yes**		

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
RSU/HA												
Beef	1.89	2.68	2.67	2.5	2.2	3.57	3.66	3.74	4.03	2.76	0.27	0.3
FERTILISER APPLIED (KG/HA)												
N	-	31	25	25	25	25	25	25	25	-	-	-
P	-	-	2	28	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-	-
S	-	14	3	34	-	-	-	-	-	-	-	-
IRRIGATION APPLIED (MM)												
Avg applied (mm)	-	-	-	60	65	75	95	70	35	-	-	-
SOLID SET 2 (SOLID SET): OVERSEER DEFAULT (FIXED) | N:2.5 P:0.1 K:1.6 S:2.5 CA:9.3 MG:2.2 NA:9.5												
Supplied (mm)	-	-	-	63	68	79	100	74	37	-	-	-
Applied (mm)	-	-	-	60	65	75	95	70	35	-	-	-
Depth (mm)	-	-	-	5	5	5	5	5	5	-	-	-
Return (days)	-	-	-	1	1	1	1	1	1	-	-	-

NUTRIENT BUDGET

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	2,932	28
Phosphorus	11	0.1

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	208	30	0	51	67	0	0
Irrigation	10	0	7	10	39	9	40
Supplements fed on blocks	32	4	30	3	8	3	2
Rain/clover fixation	126	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	28	0.1	10	55	30	1	7
As product	48	12	3	6	24	1	1
Transfer	7	1	5	0	1	0	0
Effluent exported	0	0	0	0	0	0	0
To atmosphere	98	0	0	0	0	0	0
As supplements and crop residues	28	4	27	3	6	2	1

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	167	7	0	6	0	0	0
Inorganic mineral	0	2	-22	0	-1	-2	-2
Inorganic soil pool	0	10	16	0	56	14	53

Kale to Pasture

Crop - 35 ha

N	24 kg/ha | 848 kg

P	0.2 kg/ha | 7 kg

BLOCK DETAILS

Area	35 ha	Average temp	11.9 ℃	Average rainfall	667 mm/yr	Annual PET	917 mm/yr	Latitude	-43.603552	Longitude	172.29126
Distance from coast	29 km										

SOILS

100% 35 ha — LISM_1A.1 Brown

PASTURE

Pasture growth	25,550 kg DM/ha/yr	Removed	0 kg DM/ha/yr
Utilisation	70 %	Beef	32.15 rsu/ha
Intake	17,885 kg DM/ha/yr		

ARTIFICIAL DRAINAGE

Drainage method	None

CROP MANAGEMENT

Block type	Crop	Crop rotation final month	September
Cultivated area	100 %	Years in pasture	8
Headlands and tracks	0 %	Prior land use	Grazed pasture
Other areas	0 %		

CROPS

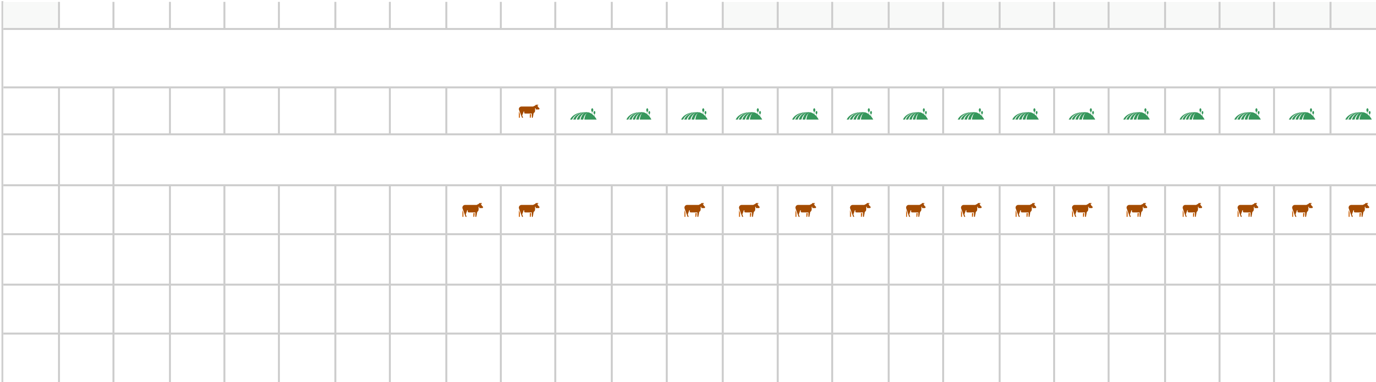
Kale

Category	Fodder
Crop type	Kale
Sown	November - Year 1
Yield	525T
Cultivation practice at sowing	Direct drilled

Pasture

Category	Permanent pasture
Crop type	Pasture
Sown	July - Year 1
Cultivation practice at sowing	Minimum till
Defoliation management	Grazing only

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Grazed pasture	Kale								Pasture														
RSU/HA																								
Beef	-	-	-	-	-	-	-	-	-	-	-	-	2.65	2.33	3.79	3.89	3.97	4.28	2.93	0.29	0.32	2.01	2.85	2.84
FERTILISER APPLIED (KG/HA)																								
N	-	53	46	46	-	-	-	-	-	-	-	-	25	25	25	25	25	25	-	-	-	-	31	25
P	-	60	-	-	-	-	-	-	-	-	-	-	28	-	-	-	-	-	-	-	-	-	-	2
K	-	75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S	-	3	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-	-	-	-	-	-	14	3
IRRIGATION APPLIED (MM)																								
Avg applied (mm)	-	-	-	-	-	-	-	-	-	-	-	-	60	65	75	95	70	35	-	-	-	-	-	-
PIVOT (LINEAR AND CENTRE PIVOT): OVERSEER DEFAULT (FIXED) | N:2.5 P:0.1 K:1.6 S:2.5 CA:9.3 MG:2.2 NA:9.5																								
Supplied (mm)	-	-	-	-	-	-	-	-	-	-	-	-	63	68	79	100	74	37	-	-	-	-	-	-



NUTRIENT BUDGET

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	848	24
Phosphorus	7	0.2

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	208	30	0	51	67	0	0
Irrigation	10	0	7	10	39	9	40
Supplements	32	4	30	3	8	3	2
Rain/clover fixation	2	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	24	0.2	4	162	27	1	6
As product	50	12	3	6	25	1	1
Transfer	7	1	5	0	1	0	0
To atmosphere	102	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-184	-49	0	-66	0	0	0
Standing plant material	231	21	184	14	23	15	8
Inorganic mineral	0	2	-47	0	-1	-2	-2
Inorganic soil pool	23	56	-56	0	76	6	54
Root and stover residuals	-2	-8	-55	-48	-35	-5	-8

Pasture to Kale

Crop - 35 ha

N	40 kg/ha | 1,393 kg
P	**0.3 kg/ha | 12 kg**

BLOCK DETAILS

Area	35 ha	Average temp	11.9 ℃	Average rainfall	667 mm/yr	Annual PET	917 mm/yr	Latitude	-43.603552	Longitude	172.29126
Distance from coast	29 km										

SOILS

100% LISM_1A.1
35 ha Brown

PASTURE

Pasture growth	3,964 kg DM/ha/yr	Removed	0 kg DM/ha/yr
Utilisation	70 %	Beef	5.12 rsu/ha
Intake	2,775 kg DM/ha/yr		

ARTIFICIAL DRAINAGE

Drainage method	None

CROP MANAGEMENT

Block type	Crop	Crop rotation final month	September
Cultivated area	100 %	Years in pasture	8
Headlands and tracks	0 %	Prior land use	Grazed pasture
Other areas	0 %		

CROPS

Kale

Category	Fodder
Crop type	Kale
Sown	November - Reporting year
Yield	525T
Cultivation practice at sowing	Direct drilled

Pasture

Category	Permanent pasture
Crop type	Pasture
Sown	July - Reporting year
Cultivation practice at sowing	Minimum till
Defoliation management	Grazing only

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Grazed pasture													Kale								Pasture		
RSU/HA																								
Beef	-	-	-	-	-	-	-	-	-	-	-	-	2.47	-	-	-	-	-	-	-	-	-	-	2.65
FERTILISER APPLIED (KG/HA)																								
N	28	26	26	26	26	26	28	-	-	-	31	-	-	53	46	46	-	-	-	-	-	-	31	28
P	-	-	-	-	-	-	-	-	-	-	-	-	28	60	-	-	-	-	-	-	-	-	-	2
K	-	-	-	-	-	-	-	-	-	-	-	-	-	75	-	-	-	-	-	-	-	-	-	-
S	-	-	-	-	-	-	-	-	-	-	14	-	34	3	-	-	-	-	-	-	-	-	14	3
IRRIGATION APPLIED (MM)																								
Avg applied (mm)	-	-	-	-	-	-	-	-	-	-	-	-	60	45	75	95	70	35	-	-	-	-	-	-
PIVOT (LINEAR AND CENTRE PIVOT): OVERSEER DEFAULT (FIXED) | N:2.5 P:0.1 K:1.6 S:2.5 CA:9.3 MG:2.2 NA:9.5																								
Supplied (mm)	-	-	-	-	-	-	-	-	-	-	-	-	63	47	79	100	74	37	-	-	-	-	-	-

NUTRIENT BUDGET

LOSSES FROM ROOT ZONE

	TOTAL LOSS (KG/YR)	LOSS PER HA (KG/YR)
Nitrogen	1,393	40
Phosphorus	12	0.3

NUTRIENTS ADDED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Effluent added	0	0	0	0	0	0	0
Fertiliser, lime and other	203	90	75	54	67	0	2
Irrigation	10	0	6	10	37	9	38
Supplements	32	4	30	3	8	3	2
Rain/clover fixation	20	0	2	4	2	4	18

NUTRIENTS REMOVED (KG/HA/YR)	N	P	K	S	CA	MG	NA
Leaching, runoff and direct losses	40	0.3	7	8	50	2	8
As product	30	7	2	4	15	0	1
Transfer	3	0	3	0	1	0	0
To atmosphere	62	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0

CHANGE IN POOLS (KG/HA/YR)	N	P	K	S	CA	MG	NA
Organic pool	-149	-20	0	-39	0	0	0
Standing plant material	-24	-4	-50	-4	4	-3	-3
Inorganic mineral	0	4	-9	0	-1	-2	-2
Inorganic soil pool	27	72	104	0	8	12	48
Root and stover residuals	275	35	57	102	36	5	8

Appendix C: Soil Management Plan

Draft Soil Management Plan

Prepared for

Burnham 2020 Ltd

July 2023

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Quality Control Sheet

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Limitations:

This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Burnham 2020 Ltd and others (not directly contracted by PDP for the work), including Environment Canterbury. 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 Burnham 2020 Ltd 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.

Executive Summary

This document is intended to be used by Winstone Aggregates for the management of soils on Burnham Farm that are affected by their quarrying activity.

The purpose of this report is to provide a description of the soil management strategy to rehabilitate the soils to an equivalent standard following gravel extraction so as to:

a) Ensure that the removal, management, and placement of soil avoids or minimises impacts on the soil properties prior to and following placement, and that the re-established soil retains the versatility of the original soil on the site, and

b) Ensure that soil management activities avoid potential adverse effects on the surrounding environment.

Key points

- Soil placement is the single most important operation in the restoration process. The soil must be placed under optimal conditions to specified depths on a platform graded to design levels.
- The aim of the soil rehabilitation is to provide a soil that has similar or better (less stones) physical properties as the soil before quarrying. These physical properties include: well drained, moderate over rapid permeability suitable for irrigated pasture production.
- The reinstated soil will have at least 200mm depth of subsoil and at least 200mm depth of topsoil providing a soil profile depth of at least 400 mm with no significant barriers to plant roots.
- The site is to be progressively stabilised i.e.; each active stage must be remediated as the excavation commences for the next stage. The area of irrigation at the bottom of the pit will also progressively expand.
- Within three years following full establishment of the pasture vegetation, the soil should be capable of production similar to land that has been cultivated for cropping and re-grassed.
- A monitoring programme will be included as part of this plan and if the above are not achieved the Soil Management Plan will be adapted.

This soil management plan is intended to be a living document that will be updated as knowledge of the site increases and as technologies and practices evolve. Annual soil quality (soil condition) monitoring is recommended for the newly rehabilitated soil areas, to ensure soil quality is maintained for agricultural production. This information from this monitoring will be used to adapt this Soil Management Plan if needed.

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Appendix A: miniVSA

1.0 Soil Management Plan

1.1 Introduction

This soil management plan is intended to be a living document that will be updated as knowledge of the site increases and as technologies and practices evolve.

The purpose of the Soil Management Plan is to:

a) Ensure that the removal, management, and placement of soil avoids or minimises impacts on the soil properties prior to and following placement, and that the re-established soil retains or exceeds the soil versatility of the original soil on the site, and

b) ensure that soil management activities avoid potential adverse effects on the surrounding environment.

1.2 Key Concepts for Restoration

Key to the effective reestablishment of the soil on the gravel extraction site are careful pre-planning, adherence to the guidance provided in the Soil Management Plan, and the training of all staff involved.

The main on-ground factors that achieve successful land restoration and retain productive value of the land are preparation of the existing surface to ensure it has the appropriate contour, and careful removal and placement of the soil material and silt so they are not degraded or compacted.

Soil carbon is critical for soil health, it feeds the soil biology and helps retain soil moisture and nutrients. Average soil carbon stocks in New Zealand's agricultural soils are estimated at about 100 tonnes per hectare in the top 300mm. It is important that the topsoil is retained and applied back onto the rehabilitated areas, particularly as the reinstated subsoil (washed silt, pea gravel and other products) will be very low in soil carbon.

The reinstated soil will have at least 200mm depth of subsoil and at least 200mm depth of topsoil providing a soil profile depth of at least 400 mm with no significant barriers to plant roots.

Under the lease agreement with the farmer running the stock on the property, the soil Olsen P will need to be returned to the levels prior to quarrying. Pasture soil testing is normally to 60 cm. The reinstated subsoil will have very low levels of nutrients, and this is likely to make up 50 percent of the top 60cm of soil, therefore fertiliser will be required before or during pasture establishment.

Pasture is the best vegetation for preparing the soil for future agricultural use. The fine roots of pasture create soil structure and grow into the new subsoil to coat cracks and pores. Generally, after three years in pasture (post quarrying) and with careful stock management to avoid compaction, the new soil is suitable for a range of agricultural uses. The addition of deeper rooting pasture species for example plantain and chicory will help to increase the soil porosity and add organic material.

Temporary or permanent irrigation will be reinstalled on the rehabilitated areas, and pasture will be established as soon as possible after the soils are reinstated. Limitations for arable use should remain the same as the current land-use as the majority of the site will have slopes that are less than five degrees and be irrigated.

1.3 Gravel Extraction Staging

The site will be extracted and rehabilitated in stages. Timeframes are estimated based on projected demand and are subject to change:

- Years 1-6. Initial extraction. These areas will be used to set up the processing plant area, stockyard, and amenities for the life of the quarry – as a result they will not be rehabilitated until the site's end of life.
- Years 7-10. Extraction towards the SE corner of the site. From the start of this stage the quarry will be progressively rehabilitated.
- Years 10+. Extraction and rehabilitation in a clockwise direction around pivot #1, then into pivot #2 and finally pivot #3, as shown in Figure 1. Areas between and beside pivots will be extracted and rehabilitated with each move into new areas enabling reinstatement behind the leading edge.

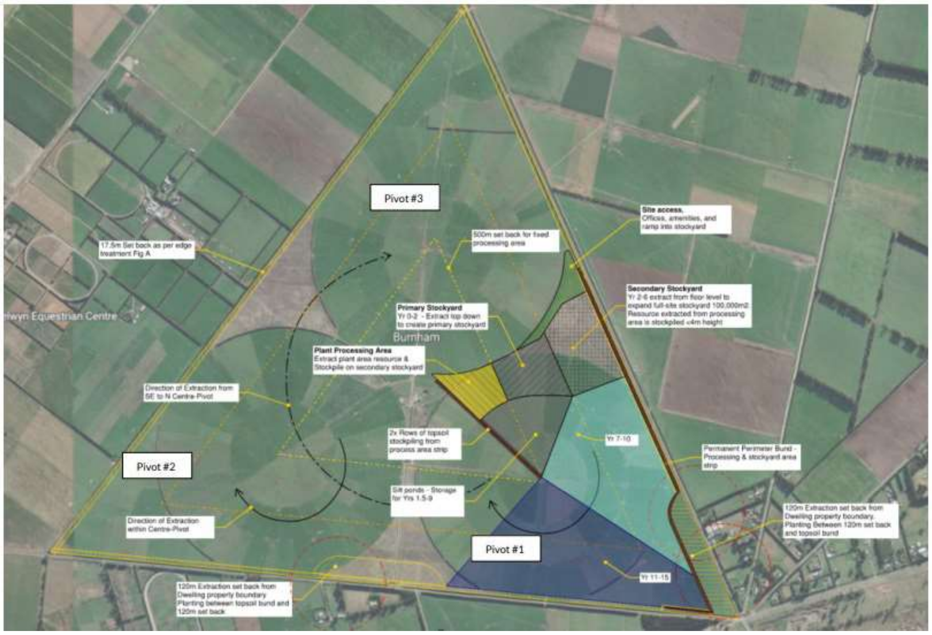

Figure 1: Quarry layout

The gravel extraction will be staged with removal of topsoil and subsoil (referred to as overburden in other reports for the site) undertaken incrementally. Staging the gravel extraction reduces the short term loss of productive land on the site and reduces the volume of soil requiring stockpiling and the time the soil is stockpiled. This in turn reduces the potential for soil degradation and soil loss (by overland flow runoff or wind).

1.3.1 Soil Removal and Placement

Before any soil removal (also referred to as lifting or stripping) activities are carried out, existing vegetation should be killed or reduced through mowing or grazing, to reduce green vegetative materials being incorporated into the soil that will be stockpiled and used to rehabilitate the site.

All topsoil material must be removed from all land prior to the commencement of any trafficking of the area and stockpiled in a secure predesignated area or applied directly to the area being rehabilitated. Where practicable, subsoil and topsoil layers are to be kept separate to enhance utilisation of this material for future rehabilitation works.

Topsoil should be recovered to the full width of the strip without mixing with the underlying subsoil (not more than 20% of the lower horizon should be exposed at the layer junction within the strip). The thickness and identification of the horizon junction must be verified before and during stripping. The full thickness of the topsoil horizon should be stripped progressively along the strip before the underlying subsoil horizon.

Topsoil is removed using an excavator and trucks or it could be removed using scrapers. The early face extraction will be excavators and later extraction is likely to include a loader conveyor. Extreme care needs to be taken to avoid shearing and compressive force on the soil (i.e., the inherent structure of the topsoil should be maintained as much as possible). New technology is likely to aid extraction but this maybe more than ten years away.

Light track-driven machinery (e.g., tracked excavators and dozers) are required for the soil removal and placement to avoid the considerable compaction and shearing of soil by large heavy rubber tyred machines (this does not preclude the use of cropping machinery, as long as any machinery does not have a detrimental compacting effect on the soil). Alternatively, flotation tyred machines could be used. Short hauls should be aimed for with minimal handling of all soil materials. This can be achieved using a designated centralised storage and service area.

All areas that are not being actively quarried will be maintained in vegetation.

There is approximately 400mm of top soils and horizon layers above the gravels and the gravels have a stone size of up to 150mm. Some of these stones are present in the topsoil and will remain in the rehabilitated soil. Trees and vegetation including large root systems, timber from the historical pine tree plantation, old fences, large stones (>150mm diameter), debris, and all obstructions of whatever kind, whether natural or artificial, encountered within the area of the works need to be removed and disposed of on-site or transported off site to an approved fill.

Avoiding soil compaction

For a soil to be returned to productive agricultural use, compaction needs to be minimised. Compacted soils have less porosity and hence lower drainage and aeration, lower plant available water (more prone to drought) and more resistant to plant root growth. To minimise compaction[1]:

- The dump trucks should normally only operate on the 'basal'/non-soil layer, and their wheels must not run on to the soil layers;
- The excavator should normally operate on the topsoil layer;
- The adoption of a bed/strip system avoids the need for the trucks to travel on the soil layers;
- Soil moisture is between 50% and 75% of field capacity when moved.
- Cultivation should aim to minimise the number of passes over the site to avoid soil compaction.
- If possible, cultivation and levelling of the soil surface should be along the contour.

[1] Good Practice Guide for Handling Soils in Mineral Workings Part One: Introduction July 2021 Institute of Quarrying

As an overarching principle, the handling of the topsoil material should only be undertaken when soil moisture is between 50 – 75% of the field capacity to avoid soil compaction (soil too wet) or loss of soil by wind erosion (soil too dry). Compaction is the main risk to being able to return the soil to a usable condition. Soil moisture levels can be determined by either the probes/tapes installed in the existing pasture areas on the property or using the soil plasticity test[2].

1.3.2 Soil Storage

1.3.2.1 Phase 1 (Years 1 - 6)

These areas will be used to set up the processing plant area, stockyard, and amenities for the life of the quarry – as a result they will not be rehabilitated until the site's end of life Initially topsoil and overburden will be used to create permanent bunding. Excess topsoil stripped from the processing and stockpile areas will be stockpiled in windrows along the boundary of the first extraction area. The topsoil should be stored in separate stockpiles from any soil taken from lower down in the profile (referred to as subsoil).

1.3.2.2 Phase 2 (Years 7 – 10 start of rehabilitation)

Where possible topsoil will be moved directly from the areas that are about to be quarried to the rehabilitated areas to avoid double handling and storage of topsoil. Where the soils are to be directly replaced (without storage in mounds), the initial strip of the topsoil will have to be stored temporarily to access the lower subsoil layer and enable the sequential movement of materials. The stored topsoil material would normally be placed on top of the subsoil layer.

If there is additional topsoil, areas that are suitable for the temporary stockpiling of topsoil materials need to be identified as part of pre-planning and scheduling. Stockpiles should be kept for as short a period as possible to minimise loss of soil structure and soil biology. Soils in the temporary stockpile areas will also need to be protected from compaction, degradation, and soil loss (as dust).

Monitoring of stockpiles will be required to ensure wind is not creating dust plumes. This can be managed by wetting the soil surface using a water cart or sprinklers. For any longer term topsoil stockpiles, the stockpile should be covered or vegetated with grass to reduce soil damage and loss caused by wind and rain.

[2] A useful field method of deciding whether a soil is sufficiently dry to be moved safely is the spade test: plasticity is determined by hand-rolling a sample from the relevant horizon on the back of a spade to see if a thread of 3 mm diameter can be formed without crumbling. If a thread can be formed the soil is too wet for working (Ramsay, 1986).

Where possible soil used to re-establish soil structure on rehabilitated extraction faces will be used from nearby bunds, to minimise material handling. However, any appropriate soils may be used provided that the re-established soil structure is equivalent to the soil structure on the site before quarry activities occurred.

1.3.3 Phase 3 (Years 10+)

Extraction and rehabilitation in a clockwise direction around pivot number 1, then into pivot 2 and finally pivot 3. Areas between and beside pivots will be extracted and rehabilitated as the quarry moves past them. (Figure 1)

1.4 Soil Rehabilitation

1.4.1 Preparation of the Receiving Surface

The receiving soil surface should be levelled to provide an even surface. Light track-driven machinery (e.g., tracked excavators and dozers) or flotation tyred machinery should be used to prepare the receiving surface to minimise soil compaction.

Cultivation should avoid creating concentrated areas of compaction (e.g., wheel track lines up and down the slope), and aim to minimise the number of passes over the site.

Soil removal and placement is not to take place during heavy rainfall (50mm in 24 hours) or if there is ponding of rainfall.

1.4.2 Boundary slope

Quarry extraction cut faces will be pulled back to a maximum 1:2 batter slope, the soil structure reinstated, and vegetated with native plantings, which will be fenced to exclude stock. Temporary irrigation may be provided over these areas to establish plantings. Vegetation is intended to provide an ‘ecological’ ring around the perimeter of the Site.

1.4.3 Subsoil

The subsoil is permitted up to within 200mm of the final land surface and a minimum soil thickness (topsoil and subsoil) of 400mm is required over the quarry base. The final re-established subsoil profile should be predominantly fine matrix soil materials, free of rocks and other coarse materials. The depth of subsoil will vary across the site. The deeper the quarry the more silt will be available for rehabilitation, therefore the depth of the subsoil will be greater in the northern corner where groundwater is deeper.

The following properties are required for the subsoil material:

- Silts either in slurry form or placed using dump trucks and earthworks machinery.

- The subsoil may include organic forestry residue and dead pasture material that was in the soil from the extraction site and stockpiled sub soil. This site came out of forestry in 2008/2009 and some forestry residues remain, large logs/roots will be removed.
- The subsoil material will not contain rocks.
- The subsoil material can include up to 35% by volume of gravels (moderately gravelly)[3] of 6-20 mm diameter[4] with fine soil matrix materials. The current subsoil predominately has 10 % or less stones in the top 400mm with about 10% of the soil having up to 35% stones. The intention is to replicate this in the rehabilitated soil with the majority of the soil having 10% or less stones.
- In areas where the depth of the rehabilitated soil is deeper than 400mm additional small stones and gravel can be added as a layer over the base if there is no alternative use for them.

1.4.4 Topsoil properties

The topsoil should occupy the upper 200-400 mm of the final re-established soil profile. This is to ensure the final re-established soil profile has a topsoil that has organic matter, nutrients, and fine matrix soil materials similar to the original soil profile.

The following properties are recommended for the topsoil material:

- Topsoil removed from the extraction site and stockpiled should be used.
- Coarse organic materials are not permitted in the topsoil (tree roots and forestry residues).
- The topsoil may include up to 10% (by volume) of organic material provided it is thoroughly mixed with the other soil material. If the topsoil is stripped from one area and immediately applied to a rehabilitation zone it may contain organic material from the pasture.
- The topsoil material may have some stones and gravels present in the topsoil that was stockpiled/removed from the extraction site or from contamination from the subsoil or storage of silt, however no stones/gravel should be intentionally added.

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[3] Milne JDG, Clayden B, Singleton PL, Wilson AD. 1995. Soil Description Handbook. Lincoln, New Zealand, Manaaki Whenua Press. 157p. (p46).

[4] Milne JDG, Clayden B, Singleton PL, Wilson AD. 1995. Soil Description Handbook. Lincoln, New Zealand, Manaaki Whenua Press. 157p. (p45).

The restored topsoil and sub soil combined should ideally achieve the following outcomes:

i. A minimum of 400 mm of plant growth medium with little or no limitations to root penetration.

ii. Soil strength to be such that there is no serious limitation to cultivation and movement of machinery, i.e., no visually obvious contrasting compacted layers within the restored soil profile, especially between the subsoil and the topsoil, and no visually obvious compaction or sealing between the topsoil and subsoil.

iii. Be at least moderately well or well drained where the inherent soil drainage characteristics of the land allow.

1.5 Sequence of soil placement

Soil placement is the single most important operation in the restoration process. The soil must be placed under optimal conditions to specified depths on a platform graded to design levels.

The platform design determines the future landform and must consider materials available, groundwater levels, erosion hazard, slope criteria for restored land use, aspect, microclimate, aesthetics, and most importantly, drainage (Ramsay, 1986). Final slopes of five or less degrees are considered optimal for cropping and horticultural purposes. Due to the scale of the property the new floor will have a less than five degree slope.

Once the shape of the existing land surface has been attained, the soil materials need to be placed using light track-driven machinery or flotation tyred machinery.

Between the placed subsoil and topsoil, the surface needs to be ripped along the contour (if any) or otherwise treated to reduce any subsurface compaction and eliminate slippage surfaces and root restricting or water perching layers. Sharp interfaces between texturally contrasting materials must be avoided.

Topsoil placement operations need to be carried out when the soil materials are in a dry condition. Vehicular traffic and soil handling should be kept to a minimum and all soil compaction needs to be rectified by appropriate tillage/ripping treatments prior to establishment of a plant cover. Special care is required to avoid continually using the same vehicle tracks when redistributing the soil materials, or if this is not possible then the excessively tracked areas should be ripped.

The topsoil material needs to be distributed in such a way as to achieve an approximately uniform stable thickness over the whole area.

Any exposed soil surfaces require protection from wind erosion. Light surface wetting of the soil topsoil via irrigation is an acceptable method. All areas that are not being actively quarried will be maintained in vegetation.

1.6 Irrigation and Pasture Establishment

The farm currently is fully irrigated by three centre pivots, single span towable pivots and set sprinklers. The existing centre pivots will remain in place for as long as possible. Irrigation will be installed at the bottom of the pit prior to the soil and grass rehabilitation.

The newly formed boundary slopes will not be irrigated by centre pivots' end guns to avoid topsoil being washed off. Low application rate irrigation (either temporary or permanent) will be installed to establish and maintain newly sown pasture.

The irrigation water is available from CPWL from September to April, this water will extend the timeframe when soil conditions are suitable for rehabilitation and allow new grass to be sown as soon as possible following the topsoil placement. This will prevent dust and soil cracking.

The site is to be progressively stabilised i.e.; each active stage must be remediated as the excavation commences for the next stage. The area of irrigation at the bottom of the pit will also progressively expand.

1.7 Soil health

The aim of the restoration is to have a healthy well-functioning soil. There are a number of indicators for a healthy soil including good soil structure, appropriate water storage and drainage, readily available plant nutrients and a populations of earthworms and microorganisms.

Storage of topsoil in bunds over a number of years is likely to reduce the soil biology. Topsoil that is not required for bund development will require storage in Phase 1. The introduction of specific microorganisms into soils has been performed for many decades. There is a range of commercially available products that enhance the soil biology and should aid the soil rehabilitation process if soils do need to be stored. The use of these products will be assessed before the first stage is rehabilitated.

From Phase 2 onwards soil will be moved from the areas about to be quarried to the rehabilitated site as soon as possible, minimising the storage time and protecting the soil biology.

1.8 Nutrient and Pasture Management after Soil Rehabilitation

Following the placement of the new soil profile, a nutrient management specialist should advise on fertiliser and lime applications, as determined by soil tests, to ensure the Olsen P and soil pH are the similar to before extraction.

Phosphorus leaching can occur after phosphate fertiliser is applied to pasture and crops. To reduce the risk of P loss the farm will use the following good management practices:

- The farm will have a soil testing and monitoring programme to ensure phosphate fertiliser is applied at optimal rates to minimise leaching.
- Only irrigate to meet the moisture needs of the plant and avoiding drainage. Varying the depth of irrigation on a daily basis can minimise the quantity of drainage, which are minimised further by adjusting applications according to weather forecasts. Compared to uniform rate irrigation, the use of variable depth has been shown to decrease P losses by up to 80% (McDowell, 2017)
- The timing of fertiliser or effluent P application to soil can influence P loss, mainly because of the effect soil moisture can have on the propensity for the generation of P leaching. P fertiliser will not be applied to soil at or close to field capacity or if heavy rain is predicted, or in the months of May to September included.
- The use of lower water soluble P fertilisers if higher rates of phosphate fertiliser are required.
- The rehabilitated pasture area will use deeper rooting pasture species to take up phosphorous in the subsoil.

Suitable pasture species for the local conditions should also be sown. Pasture roots help create soil structure and penetrate the subsoil. This helps ensure the cracks needed for drainage and air supply in the soil are kept open. Ideally deeper rooting species such as plantain and chicory should be included with a mixture of grass and clover species to help build soil structure.

Re-vegetation to pasture should be undertaken as soon as practicable after topsoil placement. This will minimise possible deterioration of soil structure and development of erosion problems on bare cultivated soils. Weather permitting, seeding should occur within two weeks following topsoil placement.

To improve the soil structure a mixture of pasture species is recommended, including grasses, clovers and deeper rooting plantain and chicory.

Pasture establishment may be required outside the irrigation season to minimise dust If pasture is established in winter months cool season active species will be used (for example Italian Ryegrass) and permanent species may need to be drilled into the area later.

To encourage the rapid recovery of the soil structure, only light weight stock such as sheep and Calves/Rising 1 year cattle will be grazed on the pastures and no stock grazed in July and August in the first year after sowing the new pastures. A management system which promotes grass harvesting (hay and/or silage) over the first two years after rehabilitation is to be encouraged. This helps prevent recompacting the soil. Across the grazed area of the property the stocking rate will remain at the same level as the current stocking. Good management of wet soil to avoid degradation of soil structure will be important, especially managing stock movement on the soils during wet periods when the soil is saturated and susceptible to pugging and compaction.

Areas of obviously impeded drainage, which show by way of surface ponding, should be examined to establish if any moisture restricting layer exists and appropriate ripping or subsurface aeration undertaken to shatter such compacted layers.

1.9 Reducing dust

Soil management related potential for dust is associated with soil removal and placement, soil storage, transport, and post placement management. Mitigations are provided in the dust mitigation section of the Air Quality Assessment for storage and transport. This property has existing irrigation and will re-establish irrigation for the final placement of soil and to establish pasture, reducing the risk of dust problems.

The existing shelter belts will be retained, and any gaps planted and there will be a 120m setback, planted in native vegetation, from neighbouring housing.

Table 1: Summary of mitigations to reduce dust during soil removal and placement
Soil removal and placement
All exposed areas are monitored, stabilised, and wetted to ensure dust is not objectionable beyond the property boundary.
Irrigation will be used in dry conditions to reduce the dust levels before removal and after soil placement (rehabilitation)
Areas are incrementally backfilled at regular intervals and re-grassed with suitable grass species as soon as possible, or the soil stabilised until ready to be re-grassed. This will limit potential for dust generation by minimising exposed surfaces.
Post placement management
Revegetation using grass to prevent bare soil and sheet (surface) erosion.
Addition of nutrients (fertiliser) to increase fertility and promote and maintain even revegetation and to return the soil fertility to the levels prior to quarrying.
Soil moisture management via irrigation and soil moisture monitoring to promote and maintain revegetation.

2.0 Summary of Soil Disturbance Activities

Any soil disturbance (as part of any activity) is likely to result in disruption to soil properties. Soil disturbance or disruption can occur with any land use practice (e.g., cultivation for cropping). Adherence to the Soil Management Plan (most importantly during the removal and placement of the subsoil and topsoil materials) will ensure the effects are minimised and are no more than the soil disturbance effects resulting from land use practices such as cultivation for cropping, forest harvesting and intensive pastoral use.

The effects on soil properties are likely to be predominantly soil physical effects related to soil compaction, loss of soil structure and degradation of soil aggregates during removal, transport and storage, and compaction of the soil material during placement. In turn, these can lead to impeded soil drainage (reducing air and water flow pathways in the soil), reduced soil water storage capacity, and reduced soil pores for biological activity. Soil fertility is not considered to be of primary concern as this can be remedied with the addition of fertiliser. If the steps set out in the Soil Management Plan, summarised in Table 2 below are followed, then effects on soil properties following restoration will be minimised.

A summary of the key aspects of the soil management plan is provided in the table below.

Table 2: Summary of Soil Disturbance Activities
Soil Removal
Where practicable, subsoil and topsoil layers are to be kept separate to enhance utilisation of this material for future rehabilitation works.
Handling of the topsoil material when soil moisture is 50 -75% of field capacity. This helps maintain soil aggregates and avoid soil smearing and compaction. Soil moisture content can be determined by either soil moisture probes/tapes or hand held device or plasticity test (hand rounding soil to see if a thread of 3 mm diameter can be formed without crumbling or is too wet to form easily)
This site came out of forestry in 2008/2009 and some forestry residues remain, large logs/roots will be removed.
Soil placement
Handling of the topsoil material when soil moisture is 50 -75% of field capacity. This helps maintain soil aggregates and avoid soil smearing and compaction.
Sequential replacement of the soil material to approximate the original subsoil and topsoil. This will maintain air and water flow pathways similar to an undisturbed soil profile.

Table 2: Summary of Soil Disturbance Activities
Minimise soil handling and where possible in phase 2 onwards move soil directly from the newly stripped areas to the area to be rehabilitated.
The dump trucks should operate on the 'basal'/non-soil layer, and their wheels must not run on to the soil layers The excavator should operate on the topsoil layer The adoption of a bed/strip system avoids the need for the trucks to travel on the soil layers
Soil storage
If soil needs to be stored, minimise the time stored to protect the soil structure and soil biology.
Vegetation of long term soil stockpiles with grass to protect from wind and water (rain).
Transport
Short hauls should be aimed for with minimal handling of all soil materials to help retain soil aggregates.
Whether possible the transport of soil using vehicles is minimised, by using conveyors and by locating silt ponds and storage areas close to where the silt/soil will be used for rehabilitation.
Preparation of receiving surface
The receiving soil surface should be levelled to provide as even a surface as is possible. .
Use of light track-driven machinery or flotation tyred machinery should be used to minimise soil compaction.
Cultivation for pasture establishment should avoid creating concentrated areas of compaction (e.g., wheel track lines up and down the slope).
Cultivation should aim to minimise the number of passes over the site to avoid soil compaction.
Fill and soil properties
Coarse organic materials should be avoided or removed from the soil material before placement.
If soil is stored minimise the inclusion of organic material (<10% by volume) to minimise anaerobic conditions in the soil from decomposition.

Table 2: Summary of Soil Disturbance Activities
Soil placement
Sequential placement of fill, subsoil, and topsoil to approximate an undisturbed soil profile
Use of light track-driven machinery for soil placement to minimise soil compaction and degradation of soil aggregates.
Post placement management
Revegetation using grass to develop soil structure. This will increase the ability of the soil to store air and water, improve moisture movement and improve soil biological activity.
Addition of nutrients (fertiliser) to increase fertility and promote and maintain even revegetation.
Soil moisture management via irrigation to promote and maintain revegetation.

3.0 Soil Management Training

Soil management training of all staff involved, and activities monitoring is undertaken to ensure the effective reestablishment of the soil on the gravel extraction site.

3.1 Soil removal

Operator performance in the lifting phase is important, and on-site guidance on soil horizon recognition and on machine routing, is required.

3.2 Soil placement

Operator performance in the placement phase is crucial, and additional details will be provided in the Soil Management Plan

The staged and incremental reinstatement of the excavated area allows for iterative checking and refinement of placement procedures to ensure the quality of the replaced soil profile. Annual inspection in the first three years following the start of the Phase 2, of by a Soil Scientist or Rural Professional.

Assessment should include (but is not limited to) the following:

- Visual assessment of the placed soil profile, examining for abrupt horizon boundaries, compacted layers, smeared layers, visual evidence of restricted water movement. Additionally, confirmation of the presence and % content of gravels and soil colour (using a Munsell soil colour chart) should be recorded for the fill (if feasible), the subsoil, and topsoil.
- Topsoil and subsoil samples for soil chemical analysis.

4.0 Monitoring and Recording

Monitoring is undertaken to ensure the effective reestablishment of the soil on the gravel extraction site.

4.1 Fill and soil material

Fill and soil material details are logged and include:

- Class of material
- Name of supplier
- Name of the transporter
- Vehicle type and registration number
- Weight
- Fill/soil material inspector and approver name(s)
- Date

4.2 Soil storage

Soil storage (soil stockpile) details are logged and include:

- Date stockpiled
- Class of material
- Stockpile maximum height

4.3 Soil placement

Assessment should include (but is not limited to) the following:

- Visual assessment of the placed soil profile, examining for abrupt horizon boundaries, compacted layers, smeared layers, visual evidence of restricted water movement. Additionally, confirmation of the presence and % content of gravels and soil colour (using a Munsell soil colour chart) should be recorded for the fill (if feasible), the subsoil, and topsoil.
- Topsoil and subsoil samples for soil chemical analysis.

4.4 Post placement soil monitoring

Within three years following full establishment of the pasture vegetation, the soil should be capable of production similar to land that has been cultivated for cropping and re-grassed. As the pasture establishes over the first year, soil properties will improve due to the positive impacts of the pasture cover. These will include development of soil aggregates and soil biological activity.

In general, soil properties are likely to change more rapidly in the first few years following re-establishment, and then slow as the soil settles towards longer term equilibrium conditions.

Under established land use, soil quality changes commonly occur over decades depending on the intensity of land use, at which point contemporary land management practices are likely to have a greater impact on the soil rather than the soil property changes associated with the reestablishment of the soil.

Annual soil quality (soil condition) monitoring is recommended for newly rehabilitated soil areas for the first three years following the completion of the rehabilitation areas, to ensure soil quality is maintained for agricultural production. This information from this monitoring will be used to adapt the Soil Management Plan if needed.

The assessment of soil, beyond indicators of soil fertility, provides greater insight into the health of the soil and can help to guide management for improved soil performance. A 'miniVisual Soil Assessment' (VSA) has been adapted for New Zealand farmers and is based on the visual assessment of key soil 'state' and plant 'performance' indicators of soil quality, presented on a score card. VSA has been selected as an appropriate monitoring tool for this site for the following reasons:

- monitors soil structure, turbidity and porosity;
- includes soil biology (earthworm count);
- is simple to do and can be carried out by a farmer or Rural Professional;
- is usually carried out annually in spring for pasture farming.

To allow comparative assessment of the soil quality of the re-established soil following extraction, soil monitoring should include baseline sampling and analysis of the original soils on the site. Additionally, a control site in a paddock on an undisturbed site will be included in ongoing soil monitoring to differentiate between the effects of contemporary land use management and effects associated with the reestablishment of the soil.

Annual monitoring using VSA of selected soil properties in the topsoil and subsoil in the areas rehabilitated within the last three years is planned, from the start of Phase 2.

A detailed soil monitoring schedule/plan should be developed, and assessment undertaken by a suitably qualified person. The following provides guidance for inclusion in a soil monitoring plan.

To allow comparative assessment of the soil quality of the re-established soil following extraction, soil monitoring should include baseline sampling and analysis of the original soils on the site. Additionally, a control site in an adjoining undisturbed site that will not be quarried (suggest under pivot 3 in area that will be last to be quarried) should be included in ongoing soil monitoring to differentiate between the effects of contemporary land use management and effects associated with the reestablishment of the soil.

Initially, annual monitoring of selected soil properties in the topsoil and subsoil following re-establishment is recommended. This should be undertaken by a rural professional for the first three years following re-establishment and then every 3 to 5 years.

The suggested soil properties are commonly used to assess the impacts of land management on soils under a given land use. They should not be considered definitive (i.e., alternative soil properties for monitoring can be considered) but do provide a research based representation of soil chemical, biological and physical condition (soil quality). There are a range of soil properties that could be monitored, Winstone propose to monitor the following:.

Table 3 : Suggested Soil Properties to Monitor

Term	Definition	Target range for Agricultural production	Timing
miniVSA	See score card includes soil biology, soil structure and porosity	Score >3	Spring after rehabilitation
pH*	A measure of the acidity or alkalinity of a soil.	5.5 – 6.3[1]	Before regrassing
Total carbon	A measure of the total amount of all forms (organic and inorganic) of carbon in the soil.	>2.5%	
Anaerobically mineralisable nitrogen	A laboratory measure of the amount of nitrogen that can readily be supplied to plants through the decomposition of soil organic matter. An indicator of soil biological activity.	50 – 250 ug/N/g [1]	
Olsen P[2]	A measure of the amount of phosphorus available for plant and microbial uptake.	20 – 30 and equal or better than before quarrying	Spring before quarrying and after rehabilitation

Table 3 : Suggested Soil Properties to Monitor

Term	Definition	Target range for Agricultural production	Timing
Bulk density	Bulk density gives a measure of how densely a soil is packed. Soils typically have about half of their volume comprised of voids (pore spaces). If these voids are lost through compaction, bulk density increases.	0.6 - 1.4 Mg/m3	Before regrassing

Notes

1. *Provisional Targets for Soil Quality Indicators in New Zealand*
2. *Required in the lease agreement for the rehabilitated area to be the same as prior to quarrying.*

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Appendix A: Title

Cropping farm soil quality - mini visual soil assessment (miniVSA) method

There are many functional benefits of maintaining or building soil quality. These include improvements in root development, drainage, water holding capacity and reduced runoff risk. Soil quality is positively correlated with yield.

Equipment
Spade, tarpaulin, 2 x clear containers (1-2 L), 2 L water, score sheet, camera (photos are an important tool to compare differences over time).

When to sample
Be consistent with the time of the year that you carry out the assessment. The best time is early spring when there is enough moisture for earthworms to be active. If the soil is very wet, wait for it to drain for a few days.

Where to sample
Select the paddock/s that you want to monitor. Identify two areas in the paddock (avoiding wheel tracks) and an undisturbed area near the paddock (e.g. a grass verge) to carry out the VSA.

Who to sample
Anyone can carry out a MiniVSA to see how soils respond to different stages of the rotation and management decisions BUT results are relative and can only be used for on-farm comparisons (e.g. to compare the same paddock over time or different paddocks on the farm at different stages of the rotation). This test works best when carried out by the same person who can ‘get their eye in’ for the farm.

Observations
- Where in the paddock you have dug the hole.
- How easy was it to dig, were there any hard layers (pans) or visible surface crusting? Use a pocket knife to feel for tightness down the profile.
- If there are roots, how far do they go down? If there is a compacted layer you might see roots grow out at a right angle or just clean stop. Do they have a rhizosheath (a layer of soil and microbes stuck to the root) or are the roots bare?
- Are there any mottles in the top soil (an indication of compaction and/or water logging)?

1. Dig a hole using the farmer spade method (Figure 1) in an undisturbed area of the paddock e.g. a grass verge

Place the soil on a tarp. Record the soil’s texture if you know it. Fine texture (silt and clay) have a greater capacity to hold organic matter than coarse/light (sand) texture soils. Record any general observations (refer to lower left panel).

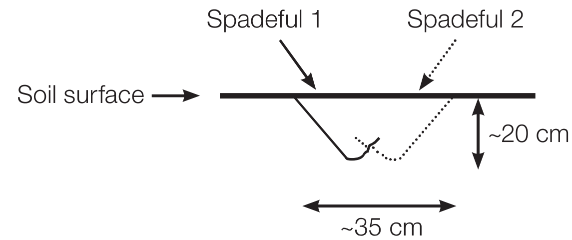

Figure 1. The farmer spade method.

2. Score structure and porosity

Scoring an undisturbed area near the paddock of interest provides a point of comparison as it represents what the soil can look like. Part clods by hand and look for signs of nutty aggregates as opposed to smooth compacted faces. Use clods from the top 5-7 cm when scoring. Put aside a clod from the top 5-7 cm for the turbidity test.

Score based on the description of soil structure and porosity outlined in Table 1 below. Score to half values if appropriate (e.g. 1.5). Refer to Figures 2 and 3 for examples of a high and low score.

Table 1. Soil structure and porosity score guide.

Condition	Description	Score
Good condition	Good distribution of nutty aggregates with no significant clodding.	2
Moderate condition	Soil contains some nutty aggregates but also a significant proportion of coarse firm clods and/or fine non-aggregated soil.	1
Poor condition	Very few nutty aggregates. Soil dominated by coarse compacted, very firm clods and/or fine non-aggregated soil.	0

Figure 2. A high score (2) may look like the sample above.

Figure 3. A low score (0) may look like the sample above.

3. Repeat steps 1 and 2 in the paddock

4. Score turbidity

Partially fill the clear containers with water and gently submerge a clod from the top 5-7 cm from the undisturbed verge in one container and from the hole dug in the paddock in the other container. If there is something growing, use this to lower the clod into the container. Let the soil sit for a minute and observe. If the behavior of the paddock soil is very similar to the undisturbed soil this is a good sign (the undisturbed soil is in the containers to the right in Figure 4)*. The cloudier the water becomes with suspended soil (i.e. becomes turbid), the lower the score. Take a photo and save for future reference. Score based on the descriptions in the turbidity table (Table 2).

Table 2. Turbidity score guide.

Condition	Description	Score
Good condition	Low turbidity. Water remains clear or has a similar turbidity to the undisturbed soil.*	2
Moderate condition	Medium turbidity. Water becomes cloudy but it does not happen immediately (within 1 minute).	1
Poor condition	High turbidity. Water immediately becomes cloudy with suspended matter compared to the undisturbed soil.	0

* Minimal pore spaces due to extreme compaction may also result in low turbidity. Refer to observation notes and score 2 if you suspect low turbidity is a result of compaction (if it is, give a score of 0).

High score **Low score**

Figure 4. Samples showing the difference between a high and low turbidity score.

5. Score earthworms

Sort through the soil sample taken using the farmer spade method (Figure 1) and count the number of earthworms. Look around the roots since earthworms often reside amongst the roots just below the shoot. Score based on Table 3. To convert to earthworms per m^2, multiply the number of earthworms found in the soil sampled using the 'farmer spade method' (Figure 1) by 16.

Table 4. Earthworm score guide.

Total earthworm count	Score
>8	2
4-8	1
2-4	0.5
<2	0

6. Total your scores

On the score sheet add up 1, 2 and 3 for each site in the paddock (aim to do two sites in the paddock) and for the undisturbed soil. Where two sites where scored in the paddock add the totals from site One and Two and divide by 2.

How are you tracking?

5-6	
3-4	
1-2	

Compare contrasting paddocks on the farm, e.g. paddocks with different tillage histories, paddocks that have been winter grazed compared to those that have not, paddocks in a depletive stage of the rotation compared to those in a more restorative stage (i.e. where there has been less soil disturbance and more below ground returns of organic matter from roots).

Cropping farm soil quality - visual soil assessment score sheet

Date:	Assesor:
Paddock name:	
Current crop:	Establishment method:
X crop:	Establishment method:
Soil type:	
Soil texture:	
Soil moisture and seasonal conditions:	

	Site one	Site two	Undisturbed site
General comments *Draw a map of where in the paddock you dig the holes*			
1. Structure and porosity score			
2. Turbidity score			
3. Earthworm score			
Total score per site (add 1, 2 and 3)			
Average score for paddock (Site one plus Site two total score divided by 2)			
Earthworms/m^2	Multiply the number of earthworms found in the soil sampled using the 'farmer spade method' by 16. Site one: Site two:		