Nelson North Wastewater Treatment Plant – Land Application and Managed Aquifer Recharge Review

Prepared for

Stantec NZ

June 2023

PATTLE DELAMORE PARTNERS LTD
Level 5, PDP House
235 Broadway, Newmarket, Auckland 1023
PO Box 9528, Auckland 1149, New Zealand

Office +64 9 **523 6900**
Website **http://www.pdp.co.nz**
Auckland Tauranga **Hamilton** Wellington
Christchurch Invercargill

Quality Control Sheet

TITLE	Nelson North Wastewater Treatment Plant – Land Application and Managed Aquifer Recharge Review
CLIENT	Stantec NZ
VERSION	Final
ISSUE DATE	12 June 2023
JOB REFERENCE	A03671201
SOURCE FILE(S)	A03671201R001_final.docx

DOCUMENT CONTRIBUTORS

Prepared by

SIGNATURE

Ella Boam

Reviewed by

SIGNATURE

Aslan Perwick

Approved by

Alan Pattle

Limitations:

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

This report has been prepared by PDP on the specific instructions of Stantec NZ. 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.

Abbreviations

Table A: Abbreviations

Abbreviation	Definition
AOI	Area of Interest
BPO	Best Practicable Option
LA	Land Application
MAR	Managed Aquifer Recharge
NCC	Nelson City Council
NWWTP	Nelson North Wastewater Treatment Plant
WWTP	Wastewater Treatment Plant

Table of Contents

Table of Figures

Table of Tables

Appendices

1.0 Introduction

Nelson City Council (NCC) are seeking a new discharge consent for the Nelson North Wastewater Treatment Plant (NWWTP). As part of this work, Stantec NZ (Stantec) have led a Project Team to assess a range of options for the methodology, and for the location of the NWWTP discharge, to determine the Best Practicable Option (BPO) for the NWWTP discharge.

To support the Project Team in assessing potential discharge schemes and locations, Stantec commissioned Pattle Delamore Partners Ltd (PDP) to assist with assessment of potential Land Application (LA) and Managed Aquifer Recharge (MAR) schemes.

This report brings together the work that PDP has undertaken to assist in determining the BPO for the discharge from the NWWTP which includes:

- Part 1 – 27 April 2021
  An initial desktop review to identify potential locations where discharge via LA and/or MAR may be potentially feasible. This is referred to as the 'Preliminary Site Selection Assessment'; and
- Part 2 – 11 November 2021
  Subsequent work was undertaken to assess a refined list of identified potential LA and MAR discharge schemes. This included concept level assessment of technical items, such as: proposed irrigation areas, proposed application rates, buffer allowance areas, storage facility volumes, cost estimates, etc. This is referred to as the 'Options Assessment'.
- Part 3 – December 2022
  This report (Part 3) brings together the earlier parts of work (1 & 2) so that a comprehensive compilation of work is available, which can be used to support the future consent applications and associated Assessment of Environmental Effects.

2.0 Preliminary Site Selection Assessment – Land Application and Managed Aquifer Recharge

As part of the initial phases of work to assess the BPO for the NWWTP discharge, PDP were engaged to assist with an alternatives assessment, focusing on potential options for LA and MAR. It is noted that MAR can also be referred to as high-rate infiltration in some instances.

PDP undertook an assessment to evaluate where discharge via LA and/or MAR could be potentially feasible, within a pre-defined Area of Interest (AOI) (provided/agreed by the Project Team).

The purpose of the assessment was to provide the Project Team with an initial indication of the likely location, availability/capacity, and general suitability of land/aquifers which could be potentially feasible for LA or MAR schemes. It is noted that at the time of this assessment, concept discharge schemes had not yet been developed.

In summary, the initial site selection/scoping assessment was:

- A preliminary, desktop based assessment to identify locations for potentially feasible LA and MAR areas/targets within the AOI; and
- Undertaken based solely on existing mapping and investigations, readily available geospatial data (e.g., land zoning, land use, soil mapping etc.), climate data, and PDP's knowledge of the area.

2.1 Basis of Assessment

2.1.1 Assumptions

The following guidance and assumptions formed the basis of the preliminary site selection assessment and were relevant when this work was commissioned:

- The existing NWWTP discharge is to the marine environment (Tasman Bay) via a ~350 m outfall which is located adjacent to the NWWTP. Prior to marine discharge, treated effluent also traverses through an engineered wetland.
- There is the possibility that in the medium-long term future the NWWTP may be disestablished or moved to a different location due to existing/impending risks such as flooding, sea level rise, regional wastewater management rationalisation and others, associated with the existing NWWTP location.
  - Land application or managed aquifer recharge discharge schemes considered within this alternatives assessment should be located and designed (as far as practical) to avoid potential capital investment regret i.e., avoid discharge schemes that may not be feasible in the future if the NWWTP is moved.
- The Project Team understands that there has not been a particular drive from iwi or other stakeholders for a year-round land discharge scheme. Although iwi have expressed strong opposition to the existing marine outfall having ever been established.
  - PDP understands that the engagement process is still ongoing. e.
- Any LA and/or MAR schemes would ideally be located within ~15 km of the NWWTP. However, locations up to 30 km from the site will be considered if feasible.

- Where possible and appropriate, this assessment should build on existing information, assessments, and outcomes from the Bell Island WWTP AEE Alternatives Assessment (2017), and the Nelson North WWTP – Issues and Options Report (2001).
- The 2059 design horizon Average Dry Weather Flow (ADWF) for the NWWTP is estimated as 9,743 m3/d (provided by Stantec).
- Existing Total Nitrogen (TN) and Total Phosphorous (TP) concentrations within the treated effluent are ~15 g/m3 and ~6 g/m3 respectively.
- NCC has a long-term commitment to carbon neutrality, so options with potentially large carbon footprints are unlikely to be favoured.
  - However, some land application discharges may present an opportunity for carbon offset such as the establishment of a new forestry area.

2.2 Land Application Preliminary Assessment

Land Application (LA) is the irrigation/discharge of treated wastewater to land. The treated wastewater is typically moved by gravity or pump via a pipe network to a land-application area. Discharge via land application occurs, typically onto a selected commercial cropping system (can also include forestry), where the water and nutrients aid in crop growth via Evapotranspiration (ET) processes. Within the soil, bacterial and geochemical processes can also add another element of 'treatment'. There are a variety of methods that LA schemes can adopt including; spray irrigation, surface drip irrigation, gravity soakage beds, or subsurface systems such as dripline of low-pressure effluent distribution (LPED) beds.

2.2.1 Land Area Requirements

At the time of this preliminary assessment, detailed calculations to estimate the irrigation area required for a LA scheme had not been performed. Therefore, to assess the feasibility of a land application scheme, a high-level estimate of the area required was made.

Based on the estimated 2059 Average Daily Flow (ADF) of 14,420 m^3/d, and an estimated annual irrigation rate of 300 mm/yr, a year-round land application scheme would require an active irrigation area of the order of 1,750 ha. The total area would be larger to account for buffer areas and practical coverage inefficiencies. Incorporating a typical 30% buffer allowance, this would equate to ~2,500 ha of land in total. A requirement for land size of this magnitude is significant when compared to other wastewater treatment schemes within New Zealand. For example, the Taupo WWTP has more than 400 ha of land application area and the Pines (Rolleston) WWTP has 350 ha, with the ability to expand this to 500 ha in the future.

It is noted that a seasonal or summer only scheme would require a considerably smaller area. However, the reduction in area would largely depend on the location and configuration of the scheme.

2.2.2 Methodology

The following methodology was used to identify locations which could be potentially feasible (from a technical perspective only) for an LA scheme:

- Within 30 km of the NWTP;
- Avoidance of urbanised and/or residential areas;
- Preference for areas where there is >2,500 ha of contiguous appropriately zoned land e.g., Rural Zone;
- Identity potential existing land use activities which may benefit from this type of water re-use;
- Avoid land on steep slopes e.g., 30% slope was considered the maximum potentially feasible slope.
- Areas proximal to general supporting infrastructure preferred e.g., roading, electricity, etc.

2.3 Land Application Locations

The preliminary assessment identified five generalised areas which were considered potentially feasible for LA discharge schemes.

Overall, these locations were similar to those identified in previous assessments, including the options assessment for both the Nelson North WWTP (2001) and Bells Island WWTP (2017).

The five main land application (LA) areas identified were:

- LA Area 1 - Wakapuaka Flats;
- LA Area 2 and 2b - Hira Forest and Rai Forest (respectively);
- LA Area 3 - Eastern Valleys;
- LA Area 4 - Rai Valley; and
- LA Area 5 - Waimea Plains.

These areas are shown in Figure 1. Each area is further described in the following sections, including the perceived advantages and disadvantages (qualitative comparison).

An additional area(s) – golf courses and/or open recreational areas - were also identified as potential existing freshwater irrigators and/or land uses that could benefit from re-use of a treated wastewater stream.

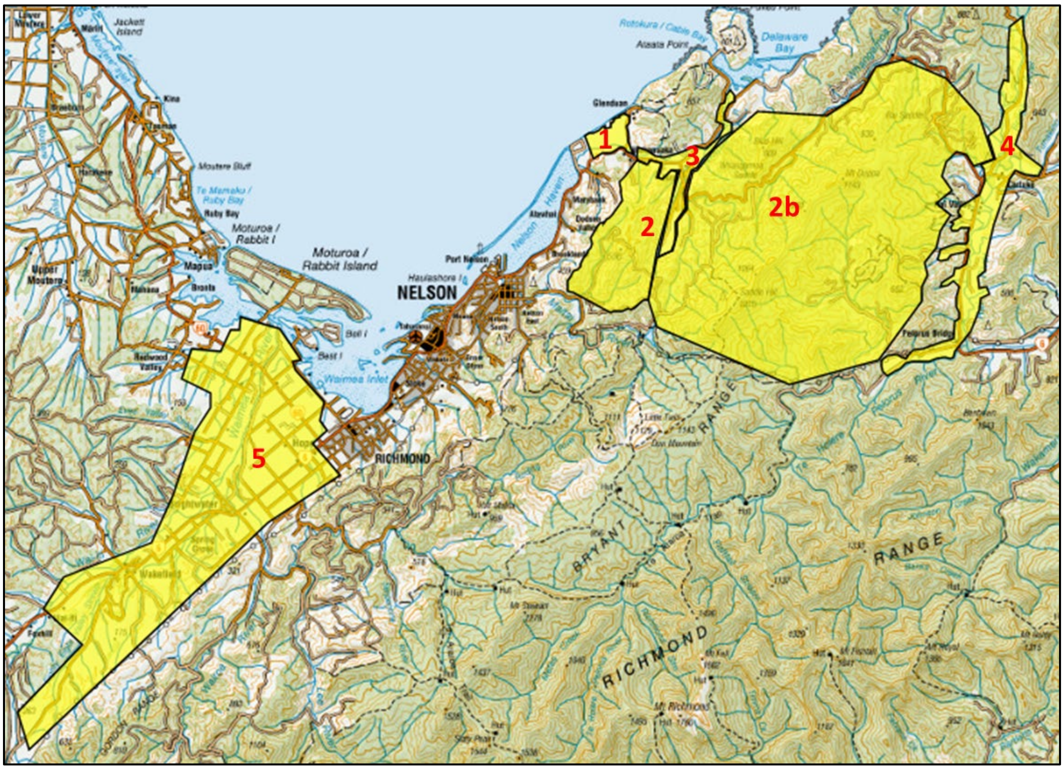

Figure 1: Preliminary Assessment – Locations of Potentially Feasible LA Areas 1 – 5.

This was a technical feasibility study only and no specific iwi / archaeological input regarding the suitability of the five areas, from a cultural or heritage perspective, was sought at this stage.

2.3.1 LA Area 1: Wakapuaka Flats

- The Wakapuaka Flats are located immediately to the east of the existing NWWTP. This close proximity is a key advantage of this area with respect to transmission distances.
- The total potentially useable area is however only approximately 330 ha, and hence would not be feasible for a year-round LA scheme.
- The land is predominantly reclaimed and extends from the upper reaches of Nelson Haven.
- The land is currently used for agricultural purposes and is zoned as Rural. However, there is some conservation land to the south which is not considered suitable for land application and is excluded from this nominated area.
- If the existing NWWTP is required to be relocated in the future, there is a higher chance of lost capital associated with this area.
- This area is known to be at risk from flooding.

- Published soil maps indicate this land has poor drainage properties, as it is low-lying, and is predominantly underlain by marine and swamp deposits. Review of borehole data proximal to the NWWTP indicates that groundwater levels are likely to be within 1 m of the ground surface.
- A low irrigation rate would be required to ensure that surface ponding and prolonged saturation of the soil due to a heightened groundwater table did not occur.
- This area would only be suitable for 'summertime' application under deficit or near deficit schemes. There is unlikely to be sufficient area available to irrigate all of the ADWF flow each day.
- There is a risk of nutrient leaching to Nelson Haven. This is considered most likely to occur via groundwater migration into the existing drainage channels, which then discharge as surface water to the Haven. However, the net impact is dependent on the existing quality of the shallow groundwater beneath the area (from existing land use practices). A reduction in the leached contaminant load could potentially be achieved through a well-managed, seasonal-only land application and cropping system. This would require further investigation and assessment to determine.
- This area was assessed in the 2001 alternatives assessment. The area was discounted as a result of:
  - Perceived operational difficulties and uncertainty related to the sizing of an irrigation scheme.
  - It was noted that operational difficulties could be overcome if this discharge option was thought to be beneficial to the environment.
  - Due to the poor drainage in this area, deficit irrigation (summer-autumn only) is likely to be the only possible option.

2.3.2 LA Area 2: Hira Forest and Rai Forest

- The Hira Forest (2) comprises large swaths (>2,500 ha) of both native forest and exotic forestry, between 5 to 15+ km of the NWWTP. Further afield, land may be suitable within the Rai Forest (2b), but this is at a greater distance from the NWWTP.
- Area 2 is located across hill country to the south and east of the site, extending from east of Nelson Haven towards the Bryant Range and Rai Valley. Elevations typically range from ~100 m RL to 300 m RL, with a number of peaks/ridgelines above 300 mRL.
- The area is zoned as Rural.

- Published soil maps indicate that the soils are generally well-drained throughout the area. Although it is noted that mapping accuracy may be lower for these areas.
- As most of the area is located across steep, forested hill-country, there are likely to be constraints relating to access and design of a land application scheme, as well as slope stability considerations.
- The steep slopes would make any irrigation scheme highly susceptible to runoff, so irrigation rates would likely be required to be lower than typical for a well-drained soil type. Other potential management measures may also be required.
- Irrigation would likely to be seasonally restricted as irrigation in winter is generally not considered suitable for this terrain. Irrigation may also be limited during rainfall events.
- It is understood there are some streams within or downgradient of the area that are used for recreational swimming. These would require careful management of potential nutrient runoff and leaching.
- This area was assessed in the 2001 alternatives assessment and discounted as a result of:
  - Perceived operational difficulties and uncertainty related to the sizing of an irrigation scheme.
  - It was noted that operational difficulties could be overcome if this discharge option is thought to be beneficial to the environment.

2.3.3 LA Area 3: Eastern Valleys

- The area is predominantly flat and located to the east of the NWWTP. This area generally forms a strip of land along SH6, with some additional area to the north along Cable Bay Road.
- The area is zoned as Rural.
- When accounting for buffer zone requirements, there may not be sufficient land area to irrigate the full NWWTP flow.
- Published soil maps indicate that the soils are generally moderately-well to well-drained throughout the area.
- There are some streams within or downgradient of the area that are understood to be used for recreational swimming and would therefore require careful management of potential nutrient runoff and leaching.

- This area was assessed in the 2001 alternatives assessment. The area was discounted as a result of:
  - Perceived operational difficulties and uncertainty related to the sizing of an irrigation scheme.
  - It was noted that operational difficulties could be overcome if this discharge option is thought to be beneficial to the environment.

2.3.4 LA Area 4: Rai Valley

- The Rai valley area is located approximately 25 km from the NWWTP and has a reasonable amount of flat land (>2,000 ha), which could be considered for a land application scheme.
- This area is located in a different surface water catchment and also a different district and unitary authority (Marlborough District Council).
- The area is zoned as Rural.
- Pumping wastewater to this location would likely be costly (CAPEX and OPEX) and is likely to be disruptive to SH6 during construction.
- The well-drained nature of the soils and the flat topography suggests the area could host a year-round scheme.
- There may not be sufficient land area available to cover 100% of the ADWF. Consequently, a dual-discharge scheme such as a combined land discharge and marine outfall, is likely to be required.
- The Rai River discharges to Pelorus Sound. Pelorus Sound is likely to require strict nutrient management for any potential land application scheme within this catchment due to other existing industries/values within these waters.
- This area was not considered in the 2001 alternatives assessments as it was outside the study investigation radius from the NWWTP site.
- Due to the challenges associated with establishing a land application scheme a considerable distance from the NWWTP, it was recommended this area only be considered further if a larger scale or longer duration scheme was intended to be pursued.

2.3.5 LA Area 5: Waimea Plains

- The Waimea Plains is a relatively large (>7000 ha) and flat area, located to the southwest of Nelson city.
- The area is zoned as Rural.
- Given the large area and that the soils are generally well-drained, this area is potentially capable of a year-round scheme.

- It is noted however, that most of the land in this area is high-value horticultural and viticultural land and hence may not be considered well-suited for this type of land use from a social and/or economic perspective. Land values are also likely to be high.
- There are also hundreds of existing water supply boreholes located across the Waimea Plains area. Detailed and site-specific groundwater quality assessments would be needed for any land application scheme in this area, and strict nutrient management limits are likely to be applied.
- A land application scheme in this location would involve pumping wastewater from Nelson North to the Bell Island WWTP catchment, which would likely be considered counter-productive and inefficient regarding conveyance infrastructure.
- This location was assessed and deemed unsuitable during the Bell Island WWTP discharge options assessment, the detailed reasons for this have not been provided at this stage, however the higher land costs and the other difficulties associated with acquiring the land are understood to be some of the key factors.
- This area was incorporated into the Bell Island WWTP discharge alternatives assessment, but was discounted based on a number of factors, some of which are mentioned above.

2.3.6 LA Area 6: Nelson Golf Club / Golf Courses / Recreational Areas

There is the possibility to reuse treated effluent by irrigating open recreational areas such as golf courses, which require freshwater irrigation and fertiliser application for normal operations. As an example, the Nelson Golf Club and Green Acres Golf Courses were assessed as potential options as part of the Bell Island WWTP options assessment. However, other golf courses within the region could also be considered.

- The Nelson Golf Club (and other courses within the wider area) do not have sufficient area for irrigation of the full wastewater flow and would likely only wish to accept irrigation in 'summer time' conditions.
- 18-hole golf courses typically have a land holding between 50-100 ha, and have freshwater takes of approximately 100,000 - 200,000 m3 per irrigation season (if irrigating greens, tees, and fairways).
- Irrigation of golf course(s) would likely require the construction of infrastructure from the NWWTP through Nelson city to the golf courses that is likely to be costly and disruptive.
- Irrigation would reduce the volume of freshwater required by the golf course and/or could provide an irrigation supply to golf courses which do not currently have one. This would be considered beneficial reuse.

- The Nelson Golf Club is located on sandy soils with good drainage properties. However, underlying these soils are lower permeability marine sediments which may limit discharge rates due to potential for groundwater mounding. However, this is not likely to be an issue for a summer only irrigation scheme.
- The irrigation method will likely need to be sub-surface drip. Whilst it is not known what irrigation infrastructure the club has, it is likely to be spray based, and hence a change to the existing irrigation infrastructure may also be needed, which would have cost implications.
- The use of golf courses was assessed in the Bell Island WWTP discharge options assessment. This option was not taken forward due to the limited area available and requirement for another primary discharge method.

2.4 Managed Aquifer Recharge Preliminary Assessment

Managed Aquifer Recharge (MAR) is the purposeful application of water to the ground surface or subsurface with the intention that the applied water ultimately enters the groundwater system. A MAR scheme could include high-rate infiltration basins, trenches, galleries, borehole injection, or other style of water-to-ground application.

The practice is typically designed to harness an aquifer's storage, transmission and filtration properties, and can also provide opportunity for beneficial reuse. This could include groundwater replenishment (to offset abstraction stress), water quality improvement, or other associated benefits. It is noted that not all MAR options have reuse benefits.

2.4.1 Preferred Characteristics for Managed Aquifer Recharge Schemes

They key aquifer properties which are generally preferable for managed aquifer recharge schemes are:

- High transmissivity;
- High storage characteristics (e.g. greater porosity);
- Deeper/lower water tables;
- A greater distance from third-party groundwater users (although it is noted that in some instances a closer distance may be more preferable); and
- Generally, a longer residence time (longer flow path) to potential users and other receptors is preferred.

While aquifer water quality is also a key consideration, local aquifer water quality properties can vary from potable through to saline. Ultimately, the desired aquifer water quality is dependent on the type of managed aquifer recharge scheme being considered. It is noted that for a managed aquifer recharge scheme, the municipal wastewater is likely to require a very high level of treatment before discharge i.e., potable or near potable standard.

Due to the potentially small land footprint area of MAR schemes, land zoning is less of a factor compared to LA schemes. There are examples around New Zealand, and the world, where MAR style water discharge occurs within urban/residential/industrial areas – and hence land zoning has not been considered a limiting factor for this stage of assessment.

2.5 Managed Aquifer Recharge Locations

The potential locations for managed aquifer recharge scheme(s) within the region are considered limited to the fluvial gravel deposits within valleys and floodplain areas. From a hydraulic capacity perspective, the best areas are larger and thicker gravel deposits. The surrounding hill country is hard rock, generally low transmissivity and storage, and is not considered appropriate for this type of managed aquifer scheme.

This preliminary assessment identified four general areas (Areas 1 - 4) that could be further considered for a managed aquifer recharge scheme. It is noted that the Bell Island WWTP AEE Alternatives Assessment (2017) and the Nelson North WWTP – Issues and Options Report (2001) did not reference or consider a managed aquifer recharge scheme to be practicable as an alternative discharge option for any of the potentially feasible areas identified by this assessment.

The four managed aquifer recharge areas (MAR) identified were:

- MAR Area 1 - Appleby Gravel Unconfined Aquifer and Adjacent Coastal Areas.
- MAR Area 2 - Maitai River and Tributaries;
- MAR Area 3 - Wakapuaka Vicinity; and
- MAR Area 4 - Wakapuaka River / Eastern Valleys.

These areas are shown in Figure 2. Each area is further described in the following sections, including the perceived advantages and disadvantages. For these areas, further research and investigation is required to confirm the aquifer characteristics, water resource usage and allocation to inform the overall feasibility for a managed aquifer recharge scheme.

Figure 2: Preliminary Assessment –
Locations of Potentially Feasible MAR Areas 1 – 4.

Similar to the assessment of potential land application areas (as outlined in Section 3.3.1), it is noted that the low-lying land located adjacent to the south and east of the NWWTP (Wakapuaka flats) is generally not considered feasible for a managed aquifer recharge scheme. This is primarily due to the shallow groundwater environment where poorly draining soils overly low-permeability marine and swamp deposits:

- Shallow boreholes in the wider area of the site identify silty and clayey strata at least 7 m deep; and
- Shallow groundwater conditions have been identified at approximately 0.5 m below the ground surface.

This suggests that the permeability characteristics and storage availability within the soil profile above the water table to accommodate shallow groundwater mounding effects may not be suitable.

2.5.1 MAR Area 1: Appleby Gravel Unconfined Aquifer and Adjacent Coastal Areas.

- This encompasses the north-eastern extent of the Appleby Gravel Unconfined Aquifer (AGUA), which underlies the Nelson suburbs of Stoke and Richmond. This area also includes the coastal margins where Nelson Airport and the Nelson Golf Club are located, which are underlain by sand dune deposits.
- This area is approximately ~10-15 km southwest of the NWWTP site.
- This area has potential to serve a year-round ADWF scheme.
- Large portions of the area underlain by the aquifer are zoned as residential or commercial. Consequently, wastewater is likely to require treatment to a potable standard and the reinjection infrastructure will require a small footprint (such as boreholes). However, there are also reasonable portions of rural and open space recreation areas (e.g., Saxton Field) which provide more physical space and could potentially be considered more compatible.
- Groundwater mounding impacts would require careful management.
- It is likely the Appleby Aquifer has the highest overall transmissivity, throughflow, and capacity for groundwater mounding effects, for both injection and spreading application methods, compared to the other potential areas.
- The surface water receiving environment is expected to largely be the marine environment (Waimea Estuary and Tasman Bay).
- Along the coastal margin, there is a reasonable portion of land seaward of the Nelson Airport runways which could be feasible. However, the low-topography and associated mounding potential would be a limitation for application rates.
- It is assumed that Nelson Golf Club (which is a ‘Links’ style course) uses freshwater resources for irrigation. It is recommended that the Nelson Golf Club is approached as part of future assessment to gauge potential interest in both land application and managed aquifer recharge options, as there may be a beneficial reuse and freshwater resource benefits.
- This area was not covered in the NWWTP 2001 alternatives assessments as it was outside the proposed investigation radius from the site.

2.5.2 MAR Area 2: Maitai River and Tributaries

- This area is located approximately 8 km southwest of the NWWTP site and comprises zones of modern floodplain and gravel fan deposits. These are near-surface, unconsolidated, well sorted gravels which are mapped around the Maitai River and three of its tributaries (including York Stream and the Brook).
- Within the Maitai River valley, the uppermost area of gravelly strata is mapped over a portion of the Waahi Taakaro Golf Course and appear to pinch out before re-widening, possibly due to the shape/constraints of the underlying bedrock. No further hydrogeologic information (e.g., bore logs) has been reviewed for this area.
- Groundwater and surface water takes from the Maitai River and its tributaries, including community water supplies and source protection zones, would need to be assessed.
- Most of the gravel areas are zoned as primarily residential, although some open space recreation and rural areas exist within the Maitai River valley. There are numerous recreation areas within the valleys.
- Relative to the AGUA and coastal margin (Section 2.5.1), there is likely to be less aquifer capacity in this area.
- It is interpreted that a managed aquifer recharge type discharge would emerge within the Maitai River and its tributaries. The groundwater residence times will be dependent on the distance from surface water but is generally likely to be quite short (months to years, rather than tens of years).
- The Maitai River and its tributaries flow into the Nelson Haven, which is considered the ultimate receiving environment.
- There may be beneficial reuse applications, such as supporting low-flows or improving river water quality. This would likely require a potable or near potable treatment level.
- This area was not covered in the NWWTP 2001 alternatives assessments as it was outside the proposed investigation radius from the site.

2.5.3 MAR Area 3: Wakapuaka Area

- A ~75 ha area of young unconsolidated gravelly deposits has been mapped approximately 2.5 km and 3.5 km to the east-southeast of the NWWTP site (GNS, 1998). These deposits correspond with tributaries of Hillwood Stream and Hillwood Stream North, which flow through the foothills and across the Wakapuaka flats. The surficial extent of these deposits appears to terminate near the inland boundary of the marine and river flats. However, they may continuously extend beneath the flats towards the Tasman Bay.

- The key zone of consideration is of higher elevation, near the main stem of Hillwood Stream along SH6. This is zoned as rural low-density.
- Hillwood Stream and Hillwood Stream North are likely to be groundwater fed. They both discharge into Nelson Haven.
- This area is considered small compared to the other potential areas and is likely limited in terms of throughflow capacity and mounding limitations.
- Shorter groundwater residence times (e.g., <2-years) could be expected in some of these areas.
- This area was not covered in the NWWTP 2001 alternatives assessment as it was outside the proposed investigation radius from the site.

2.5.4 MAR Area 4: Wakapuaka River / Eastern Valleys

- Approximately 6 to 9 km southeast of the NWWTP site, recent gravelly river deposits bound the lower Wakapuaka River valley (near Hira). These deposits are not mapped to be continuous along the course of the river, as they are dissected by older gravelly and probably less transmissive strata. As a result, the younger gravelly river deposits may pinch out and have limited thicknesses and lateral extents.
- This area is zoned as rural low-density and rural.
- The Lud and Wakapuaka Rivers flow into Delaware Bay, which are considered the ultimate receiving environment of the discharge.
- Depending on existing groundwater and surface water abstraction, a highly treated discharge could provide freshwater allocation benefits, such as reduced water stress.
- It is understood that water quality within the Wakapuaka River is generally good. If this is not the case, there may also be potential for water quality improvements e.g., if there are nutrient issues within the existing catchments then a high treatment quality of the discharge could provide a dilution benefit.
- Reasonable residence times prior to the discharge emerging from the groundwater system at Delaware Bay could be expected in the upper areas near Hira. However, there is also potential for discharge to rapidly feed into the river if injection locations are nearby.
- This area was not covered in the NWWTP 2001 alternatives assessment as it was outside the proposed investigation radius from the site.

2.6 Conclusions of the Preliminary Assessment

The preliminary assessment identified a range of areas around the NWWTP that may be suitable for land application or managed aquifer recharge wastewater discharge schemes. However, based on the assessment outcomes and the land/aquifer targets available, it is unlikely that a year-round scheme would be feasible without being located more than 5 km from the NWWTP site, within another catchment, and with associated high capital cost.

PDP recommended that the preliminary assessment be used as a basis to develop a suite of concept level land application and managed aquifer recharge schemes. Subsequently, more specific locations could be proposed and further technical detail on physical land and aquifer characteristics could be gathered to improve the confidence in the feasibility of these areas.

3.0 Options Assessment - Land Application and Managed Aquifer Recharge

Incorporating the outcomes of the preliminary site selection assessment, the NWWTP Project Team developed a list of concept level options to formally consider within the BPO for the discharge from the NWWTP. The list comprised Options 1 – 9 which incorporated multiple discharge methodologies (i.e., to land, surface water and groundwater), seasonal restrictions, land cover and infrastructure.

PDP was commissioned by the Project Team to undertake a secondary assessment of the proposed land application and managed aquifer recharge options (Options 4 - 8) to provide details such as (where appropriate):

- Description of the scheme and key considerations;
- Land area requirements including proposed irrigation and buffer allowance areas;
- Storage facility volumes; and
- CAPEX and OPEX estimates.

The following sections provide a summary of the key considerations incorporated into the assessment of each concept option, while a summary of the outcomes of this options assessment, including indicative comparative capital and operating cost estimates, are provided in Appendix A.

3.1 Summary of Schemes

The five scheme options included in this assessment are summarised as:

- Option 4: Year-Round Forestry Scheme – Hira and Rai Forests
  - Located within LA Area 2 identified in the preliminary assessment.

    - Irrigation of average daily flow to a forestry scheme, year-round.
    - Located on steeply inclined slopes.
    - Days with peak flows (> 97th percentile wastewater flow) will discharge to the existing marine outfall.
- Option 5: Year-Round Pastoral Scheme – Eastern Valleys
    - Located within LA Area 3 identified in the preliminary assessment.
    - Irrigation of average daily flow to a pastoral scheme, year-round. It is likely that 'cut and carry' system would be utilised.
    - Located on largely flat land within valleys.
    - Days with peak flows (> 97th percentile wastewater flow) will discharge to the existing marine outfall.
- Option 6a and 6b: Summer Dry Period Scheme – Hira Forest and Eastern Valleys
    - Located within LA Area 2 (Option 6a) and LA Area 3 (Option 6b) identified in the preliminary assessment.
    - Irrigation of average daily flow during summer period, assumed to be November – April (inclusive).
    - Located on sloped forestry land or flat pastoral land.
    - Days with peak flows (> 97th percentile wastewater flow) will discharge to the existing marine outfall.
- Option 7: Deficit Only Scheme – Wakapuaka Flats
    - Located within LA Area 1 identified in the preliminary assessment.
    - Deficit irrigation of allowable volume during summer period, assumed to be November – April (inclusive).
    - Located on largely flat land adjacent to NWWTP.
- Option 8: Year-Round Managed Aquifer Recharge Scheme
    - Located within the Waimea Plains – Appleby Gravel Unconfined Aquifer (AGUA) – proximal to the Waimea River, south-west of Richmond.
    - Whilst this specific area of the AGUA was not covered within the preliminary assessment outlined in Section 2 (as it was physically closer to Bell Island WWTP and had been assessed/ruled-out during the Bell Island WWTP Discharge consent due to the presence of a large number of water bores across the area), it was agreed to be re-introduced. This is due to the desire to incorporate an MAR scheme

with a realistic beneficial re-use element. For the Waimea Plains AGUA, this was considered to be in the form of: replenishing aquifer head levels, salt-water intrusion mitigation, nitrogen groundwater quality improvement, and/or other aquifer or receiving surface water related benefit.

- Injection of ADWF to suitable aquifer, year-round.
- All other flows to be discharged via the existing marine outfall.
- The wastewater will likely require a potable treatment standard.

3.2 Basis of Assessment

The following assumptions were used in the development of the options (LA, and MAR where applicable):

- A soil moisture model was used to calculate the required land sizes:
  - Rainfall and PET data were obtained from the NIWA virtual climate network.
  - A 30-year climate data set was obtained to ensure the model could be run for a sufficient duration.
  - The ADWF[1] used for the assessment was 9,750 m3/d.
  - The ADF[2] used was 10,330 m3, projected for 2059.
  - Due to the large surface area of the existing NWWTP pond system (~43 ha) and assuming an average daily rainfall of 2.7 mm/d, an additional discharge volume of 1,150 m3/d was incorporated to account for rainfall on the ponds (it has been assumed that the level in the ponds can vary to account for the possible increase in peak flows).
  - Soil moisture model based on high level estimates of soil properties based on Fundamental Soil GIS data.
- Climate data from Nelson Airport was used for the modelling of all options.
- A maximum winter irrigation depth of 30 mm/month was used for options on the steeper slopes within the design parameters (Option 4), and a maximum summer irrigation depth of 50 mm/month was used (Option 6a).
- A maximum winter irrigation depth of 50 mm/month used for options in the flatter valleys (Option 5, 6b).

[1] Provided by Stantec (17/6/21)
[2] As above.

- A rainfall interception factor of 0.15 was used for forestry schemes and a factor of zero was used for the pastoral schemes.
- Irrigation cannot occur on a day when the rainfall exceeds 25 mm.
- For non-deficit irrigation schemes, the maximum allowable soil moisture content before irrigation must be stopped is 50% between field capacity and saturation.
- A 30% buffer area has been allowed for each option, with the exception of Option 4 that has a 50% allowance to account for the large portion of un-irrigable areas in the forestry location.
- To determine the peak wastewater flows an assumed average winter flow peaking factor of 33% has been applied to reflect the possible increase in flow due to wet weather. In reality, larger peaks in flow would be expected however it is understood that some flow balancing would be available at peak flow times in the existing oxidation pond and wetland by operating a variable top water level.
- The maximum slope suitable for irrigation is 30%.

3.3 Land Application Options (4, 5, 6, and 7) Assessment

3.3.1 Indicative Area Requirements

The land area requirements (for the land application options) were based on achieving an average monthly irrigation depth in-line with the adopted limits (as detailed above in Section 3.2). This was a major determining factor for the land areas, as using larger land areas does not necessarily make the options able to operate at all required times. Therefore, once the area was determined, the required storage volume was adjusted until the modelling indicated sufficient capacity.

Table 1 below provides a summary of the (current) minimum land areas for each option. The total area required has been calculated assuming 70% utilisation of the total area, leaving the remaining 30% for buffer zones, set-backs, access roads, etc.

Table 1: Summary of LA Option Estimated Irrigation Areas

Option	Location Description	Irrigation area (ha) [1]	Total area (ha) [1]	Comments
Option 4	Year-Round Forestry Scheme – Hira and Rye Forests	1,530	3,060	There is only a maximum of ~800 ha irrigable area (< 30% slope) in the Hira Forest, so the LA scheme must be expanded into the Rai Forest. 50% buffer area assumed instead of 30% due to the terrain.
Option 5	Year-Round Pastoral Scheme – Eastern Valleys	920	1,315	Only a maximum of ~700 ha irrigable area in the Eastern Valleys, so the LA scheme must be expanded into the Rai Valley or Hira Forest.
Option 6a (LA Area 2)	Summer Dry Period Scheme – Hira Forest	720	1,030	Insufficient area available in the Hira Forest, so scheme must be spread between Hira Forest and Eastern Valleys.
Option 6b (LA Area 3)	Summer Dry Period Scheme – Eastern Valleys	640	915	Insufficient area available in the Eastern Valleys so scheme must be spread between Hira Forest and Eastern Valleys.
Option 7	Deficit Only Scheme – Wakapuaka Flats	230	330	Available area only sufficient for irrigation of 25% ADWF (on average).

Notes:

1. *Area required inclusive of buffer zone allowance*

The required land area for Option 5 is greater than what is available in the Eastern Valleys. Therefore, the scheme would need to be split between the Eastern Valleys and the Rai Valley. The indicative comparative costing of this option is based on a split between the Eastern Valleys and Rai Valley, to be in keeping with the initial option description. However, it may be more cost effective to achieve the required land area by irrigating the Hira Forest rather than conveying the treated wastewater to the Rai Valley.

The assessment of Option 6 (a and b) has shown that neither the Hira Forest nor Eastern Valleys have sufficient irrigable area available on their own for the option to operate as required. Option 6a could be extended to the Rai forest. However, it would be impractical for Option 6b to extend to the Rai valley so it would need to extend into the Hira Forest. Therefore, for the purpose of costing and options comparison, Option 6 is proposed to be located such that 50% of the flows to the scheme are irrigated to the Eastern Valleys and 50% to the Rai Forest. This minimises the transmission distances for the scheme. The irrigated areas would therefore be 360 ha in the Hira Forest and 320 ha in the Eastern Valleys, with total areas of 515 ha and 460 ha respectively to allow for buffer areas. If required, the split between forestry slopes and valleys could be optimised by more detailed assessment.

As stated in Table 1, there is insufficient irrigable area in the preferred locations of some of the options. For Option 4 specifically, this is due to the amount of the Hira Forest that is on very steep slopes that are not suitable for irrigation, noting that 30% has been used as the maximum slope cut off for irrigation. Figure 3 shows that based on slope angle, the split between irrigable and non-irrigated land (within the potential irrigation area), most irrigation schemes within the forestry areas will be made up of many small irrigation areas. This could be challenging and be expensive to both construct and operate.

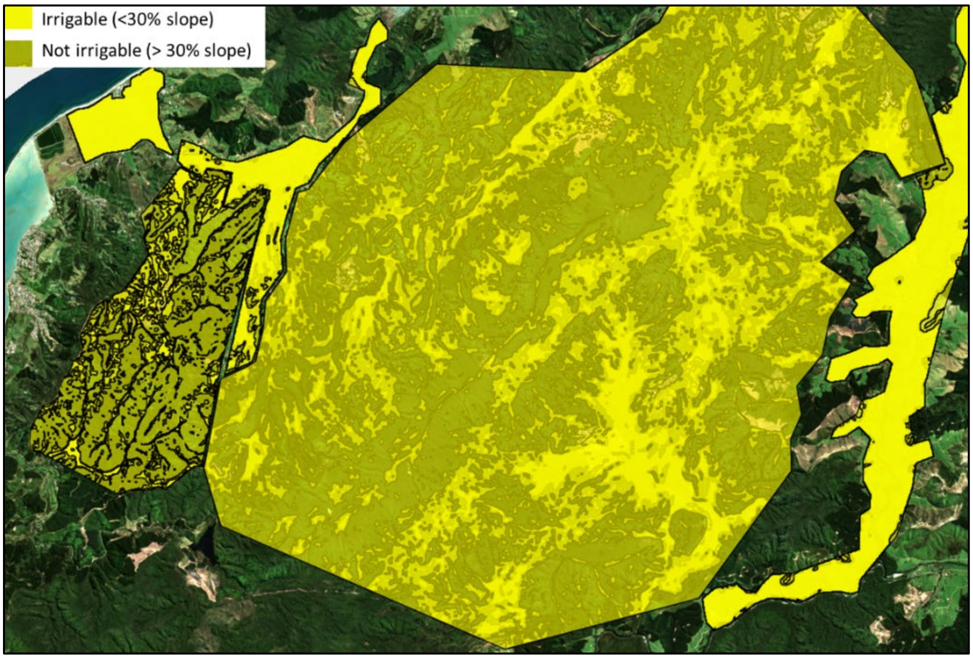

Figure 3: Potential LA irrigation areas based on slope angle.

3.3.2 Storage Requirements

For Option 7, no storage facility is proposed as the existing storage on site is considered sufficient given that treated wastewater would be discharged via the marine outfall during wet periods.

For Options 4, 5 and 6, supplementary storage facilities are proposed to provide buffering from above-average NWWTP inflows and to bridge wet periods where land application is not suitable or practicable. The optimum location for storage is at the irrigation site. Therefore, the storage provided by the wetlands and oxidation ponds is not considered suitable for the irrigation schemes, although this can be used for peak flows.

Following assessment of the estimated required land areas for each option, the estimated capacity requirements for the associated storage facility have been developed. The proposed storage capacities for each option are presented in Table 2. These sizes may change if land areas change following the confirmation of the proposed locations and land uses.

Table 2: Proposed Storage Volumes

Option	Operational Storage Volume (m^3)
Option 4	50,000
Option 5	50,000
Option 6	50,000
Option 7	-

It was initially expected that Option 6 would require a lesser storage volume. However, the climate data indicates significant wet periods during the summer period. Therefore, to ensure the required volume of treated wastewater is irrigated, the storage volume cannot be decreased.

3.3.3 Nutrient Leaching Considerations

Quantitative nitrogen leaching assessments have not been completed as part of this assessment due to the concept level of assessment and the limited information available at the time regarding the operation of the land application system. However, qualitatively, nitrogen leaching is not expected to be a limiting factor in the sizing of these systems. This is based on the average total nitrogen (TN) concentration of the treated wastewater[3] of 15 g/m^3 used as part of the assumptions and the relatively low proposed irrigation rates to avoid runoff to surface water, particularly with the schemes located on steeper hill country/forestry land. Preliminary nitrogen balances support the conclusion that nitrogen leaching is not likely to be a limiting factor, assuming the current level of treatment is maintained.

3.3.4 Treated Wastewater Transmission Locations

To enable the Project Team to complete indicative comparative costing assessments of all BPO treated wastewater discharge options, PDP developed assumed locations for which transmission of treated wastewater would be required (Table 3).

Some options require wastewater transmission to two irrigation sites due to the lack of irrigable area at each individual site, so for some options two locations have been specified. The approximate locations are shown in Figure 4.

[3] As reported by Stantec.

Table 3: Assumed Wastewater Transmission Locations

Location	Option(s)	Description	Approximate Coordinates
Location 1	4 and 6	Hira and Rai Forests	-41.25, 173.38
Location 2	5 and 6	Eastern Valleys	-41.41, 173.40
Location 3	5	Rai Valley	-41.22, 173.59
Location 4	7	Wakapuaka Flats	-41.20, 173.35
Location 5	8	Waimea Plains	-41.318, 173.18

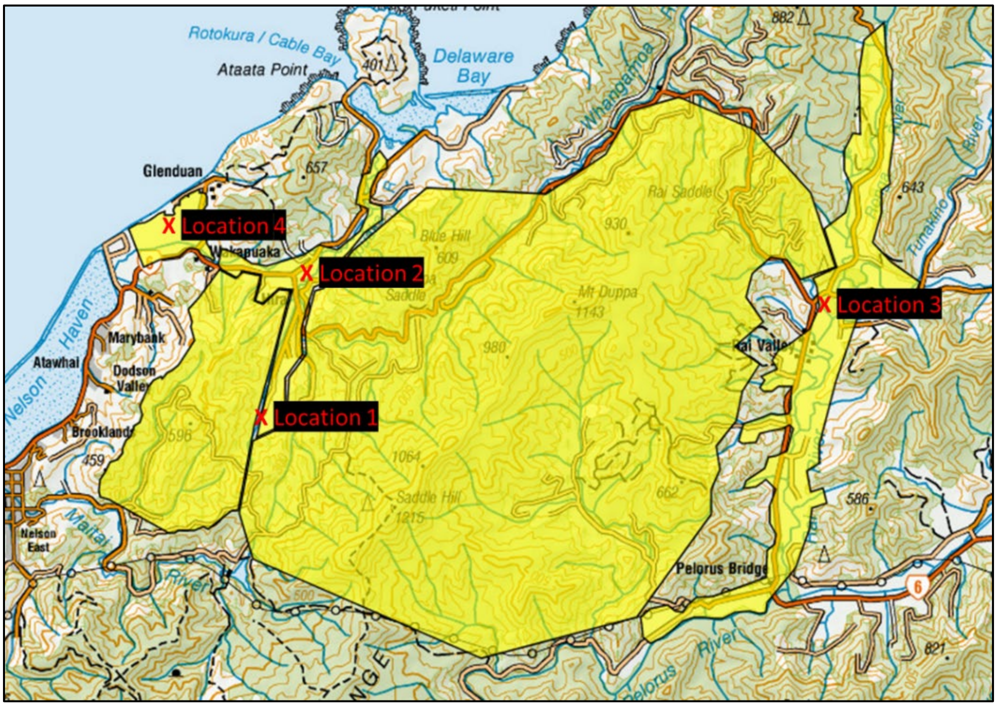

Figure 4: Approximate wastewater transmission locations (for costing).

3.3.5 Odour Management

The risk of generating odour predominantly arises from the anaerobic degradation of Biochemical Oxygen Demand (cBOD) in low oxygen atmospheres than can develop over long pipe runs. This is a possibility in some of the rising mains to the proposed land application scheme options. Generally, odour is managed with good cBOD treatment in the NWWTP, and by flushing the irrigation pipelines with fresh water if odour becomes an issue. However, this will only address odour that develops in the irrigation pipework and not the rising main to the irrigation site.

Sample data for the current discharge shows that there is a reasonable cBOD concentration in the treated effluent (41 g/m^3). Therefore, there is a moderate risk of odour generation in some of the options involving distant land application locations, particularly as it is unlikely that flushing the conveyance lines with fresh water will be a practical option, as it will not address odour formation in the rising mains. It is likely that some form of odour management will be required at the treated effluent reception location at the land application sites.

The concept developed at this stage of investigation assumes that " the aeration of treated effluent prior to irrigation has been allowed for to manage odour. It has been assumed that the flushing of the irrigation lines will not be required to manage odour. If an odour issue arises, this can be managed with trickle starts on the irrigators and if flushing was required, an additional fresh water supply to the irrigation site would be required. Improved BOD treatment at the NWWTP may also reduce the odour risk. However, there may still be a residual risk depending on the length of the rising main to the irrigation site.

3.3.6 Spray Drift Management

Spray drift would be managed in the first instance with the use of separation distance (buffer zones) between the irrigation infrastructure and the site boundary. For sensitive receptors such as dwellings, schools, and marae this distance may be over 100 m. For less sensitive or less accessible areas, this may be reduced. All options include a 30% allowance for buffer areas to allow for inclusion of separation distances required to mitigate against spray drift.

Operational measures can also be utilised to manage spray drift. During periods of high wind, irrigation can be stopped across the site or in specific high-risk areas to minimise the risk of spray drift. The irrigation system can also be designed to minimise spray drift in high-risk areas with the use of low-pressure sprinkler heads, which produce larger droplets that are less susceptible to drift, and to reduce casting distances and heights. Centre pivot irrigators do not typically cause large casting distances, as the irrigator moves. Centre-pivot irrigation is best suited to larger, flatter areas such as that available in Option 7 (Wakapuaka Flats). The forestry schemes are likely to pose less risk to receptors via spray drift as a result of their remote location in addition to forestry cover (when trees are of reasonable maturity).

To reduce the health risks associated with exposure to spray drift, UV disinfection could be installed at the NWWTP to inactivate any pathogens in the treated wastewater.

3.4 Managed Aquifer Recharge Option (8) Assessment

Option 8 involves the injection of a portion of treated wastewater flow into an aquifer. It is anticipated that this method could provide beneficial reuse of the wastewater such as replenishing aquifer head/pressure levels, salt-water intrusion mitigation, and/or nitrogen groundwater quality improvement.

Assessment of managed aquifer recharge potential near the NWWTP, and within the Nelson and Stoke areas, indicates that there is limited potential for beneficial reuse. While there will be areas where managed aquifer recharge could occur, realistic recharge targets that would enable reuse benefits, have not been identified. This is due to the limited extent of highly productive aquifers and a general lack of water abstraction stress (by which a recharge scheme could provide an alleviation benefit to).

However, a concept scheme has been developed (Option 8) which is situated within the Appleby Gravel Unconfined Aquifer (AGUA) of the Waimea Plains. Significant groundwater abstraction presently occurs within this area for horticulture, agriculture, industry, and municipal supply. Pumping tests conducted within the AGUA have returned transmissivity values between 3,000 m^2/day and 22,000 m^2/day (Song & Zemansky, 2013), which indicates highly transmissive conditions.

The other major aquifers in the Waimea Plains area are the 'Upper Confined Aquifer – UCA', and the 'Lower Confined Aquifer – LCA'. These aquifers are also of high transmissivity, although are an order of magnitude lower than for the AGUA (Song & Zemansky, 2013).

The various aquifers beneath the plains are under some level of abstraction and water quality stress.

3.4.1 Concept Scheme

The concept scheme for the MAR portion of flow for Option 8 is detailed below:

- The capacity of managed aquifer recharge is the ADWF of 9,750 m3/day and is a year-rounds scheme;
- The target aquifer is the Appleby Gravel Unconfined Aquifer (AGUA);
- The treatment quality is anticipated to be potable or near-potable quality (to match the AGUA water quality) – which would require a significant upgrade to the existing NWWTP;
- Reuse benefits are anticipated to be one or more of:
  - Aquifer head replenishment (and associated benefits of base flow support, salt-water intrusion risk reduction and promotion of additional freshwater abstraction ability); and
  - Downstream water quality improvement (nitrate).
- Scheme presently is assumed to comprise 20 injection boreholes, that are ~20-30 m depth (not all may be active at any one time).

A generalised location for the injection is provided in Figure 5 below.

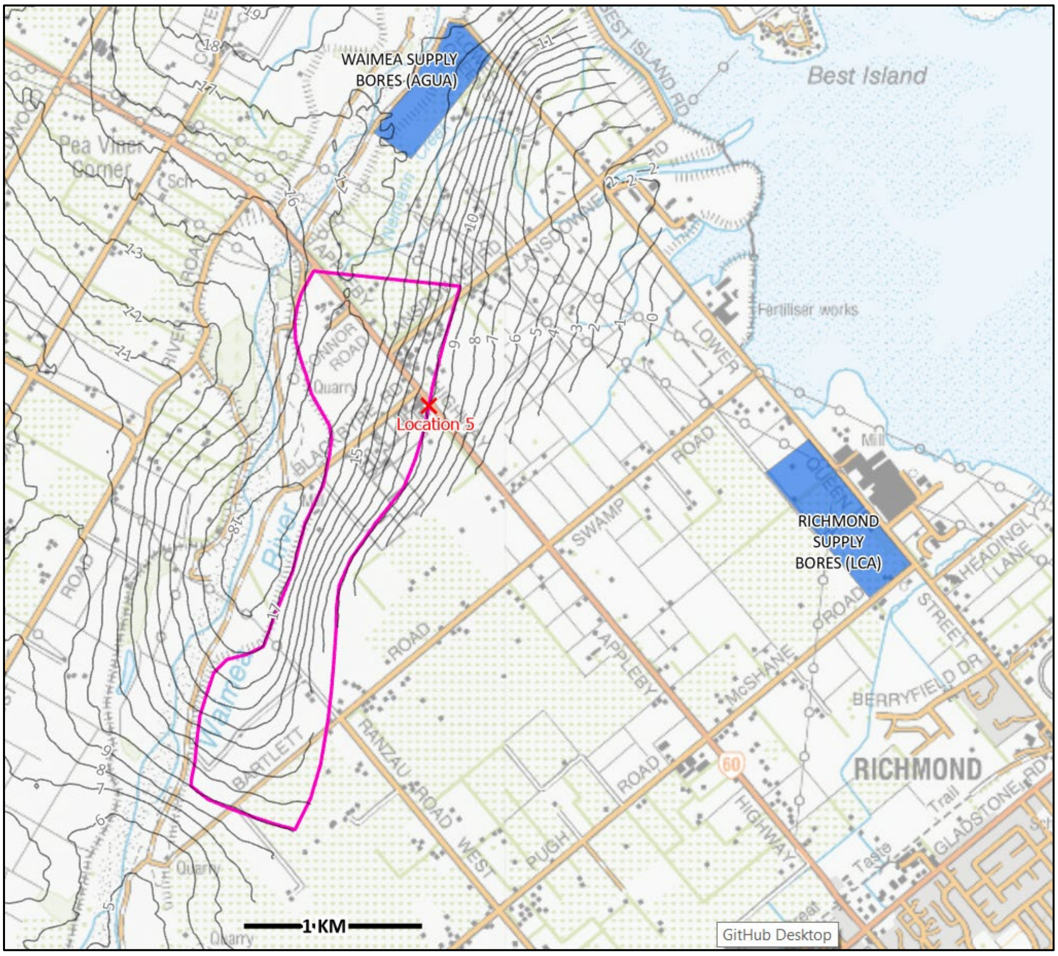

Figure 5: Generalised Injection Zone for Option 8 MAR Concept Scheme

Notes: *Magenta polygon (~175 ha) indicates generalised zone for where the injection borehole could be located.*

Approximate location of the municipal 'Waimea Supply Bores' and 'Richmond Supply Bores' indicated within the blue polygons.

Contours are AGUA thickness (from Song & Zemansky, 2013).

Location 5 indicates assumed termination of conveyance point from NWWTP (for transmission costing purposes only).

Key considerations for the Option 8 concept scheme are:

- There are hundreds of existing boreholes within the Waimea Plains, including municipal and domestic supply takes. Placement of injection boreholes would need to make account of these, to ensure appropriate separation distances are maintained (likely on the order of 300 m+). This is to avoid potential effects on these bores e.g., maintain reasonable travel time distances and residence times.
- Appropriate separation distances will be required from gravel pit quarries depending on the depth of quarry vs the depth on injection.

- Injection boreholes and associated pipe and pump infrastructure should be kept out of the flood prone areas of the Waimea River or have appropriate flood protection measures.
- It is assumed that 20 small portions of land would need to be delineated into new parcels and purchased to site the injection wells, associated headworks and access infrastructure. This is assumed to equate to 3 ha in total.
- Although aquifer characterises appear feasible for the scheme, a detailed field programme to investigate the injection potential, as well as pilot injection testing would be required to prove the concept can operate in a predictable manner.
- Further studies to assess the benefits, constraints and holistic return on investment (e.g., the value of water) is required to better understand this option.
- Public perception regarding the acceptance of the re-injection and re-use of highly treated wastewater is likely to be a highly contestable and may negatively impact the ability to consent the scheme.

4.0 Option Costing

Preliminary CAPEX and OPEX estimates for the land application components set out in concept Options 4, 5, 6, 7, and 8 have been prepared by PDP for incorporation into the overall BPO study. These cost estimates were produced in August 2021, and hence are reflective of cost rates and relevant assumptions at that time. Appendix A provides a breakdown of the costs for each option, and the associated costing assumptions and exclusions.

Note – these cost estimates reflect on-site LA/MAR infrastructure cost only, and hence do not reflect full option cost, e.g., do not include any treatment plant related costs, transmission costs, contingency allowances, etc – The overall scheme costing has been prepared by Stantec as part of the Assessment of Alternatives using this information.

5.0 Summary

PDP have completed a preliminary assessment of land application (LA) and managed aquifer recharge (MAR) potential, within a ~30 km radius of the Nelson North Wastewater Treatment Plant (NWWTP). The purpose of this assessment was to identify potentially feasible areas that could support the discharge (full i.e., all year round or partial i.e., summer periods only) of treated wastewater flow from the NWWTP, as part of the NWWTP assessment of alternatives study.

The study identified generalised areas which were considered potentially feasible in terms of capacity and site characteristics to manage full or partial projected treated wastewater discharges via LA and MAR methods. However, it was deemed unlikely that a year-round LA or MAR scheme would be feasible close to the NWWTP site and therefore significant additional conveyance, storage and infrastructure would be required.

In collaboration with the Project Team and utilising the findings from the preliminary potential feasibility assessment, concept level LA and MAR discharge options were then developed further. These comprised four LA options (of various flow sizes and seasonal flow durations), and one MAR option (which targeted a beneficial reuse).

Preliminary cost estimates (CAPEX and OPEX) were prepared for the on-site LA/MAR infrastructure, which were incorporated into overall option costings (by Stantec) and assessment of alternatives.

6.0 References

DWT, October 1999: Nelson City Council Wakapuaka Wastewater Treatment Plant Issues & Options Report. Ref: R0007AJT:MdG. Wellington: Duffill Watts & Tse Ltd.

DWT, November 2001: Nelson City Council Wakapukaka Wastewater Treatment Plant Updated Issues & Options Report. Ref: R0100APMO. Wellington: Duffill Watts & Tse Ltd.

Fenemor, A., 2020: Waimea Plains Nitrate Issues - Science Summary 2020. Nelson: Tasman District Council, Natural Resources Policy Team.

Song, S., & Zemansky, G., 2013: Groundwater level fluctuation in the Waimea Plains, New Zealand: changes in a coastal aquifer within the past 30 years. Environ Earth Sci, 70:2167-2178.

Stantec, March 2021: Project Technical Memorandum for the Nelson City Council, Project 2877 North Nelson WWTP Consent Renewal Flow and Load Projections. Ref: 30160. Stantec NZ Ltd.

Stantec, November 2017: Bell Island WWTP Application and AEE. Ref: 80509528. In 7. Alternatives Considered (pp. 34-52). Stantec NZ Ltd

Stewart, M. K., Stevens, G., Thomas, J. T., van der Raaij, R., & Trompetter, V., 2011: Nitrate sources and residence time of groundwater in the Waimea Plains, Nelson. Journal of Hydrology: New Zealand, 50(2): 313-338.

White, P. A., & Reeves, R. R., 1999: Waimea Plains aquifer structure as determined by three-dimensional computer modelling. Journal of Hydrology, New Zealand, 38(38): 49-75

Appendix A: Costs Estimate

Option	Assumed Location Description	Discharge Scheme & Key Infrastructure (PDP elements)	Land Area	Key Assumptions / Option Comments / Notes	PDP - Land Application / MAR Infrastructure CAPEX (excl. Land Costs)	PDP - Land Purchase Cost	PDP - Land Application / MAR OPEX (without Return on Agricultural Operation) per annum	PDP - Land Application OPEX (with Return on Agricultural Operation) per annum
Option 4	Hira and Rai Forests	• Irrigation to land of ADF on days when the wastewater flow is below the 97th percentile, all other flows to ocean outfall. • Solid set spray irrigation. • 50,000 m^3 active volume onsite storage facility (lined), lagoon area 1.5 ha, 4m operational depth + 1m freeboard.	Active Irrigation Area = 1,530 ha Total Area (Inclusive of 50% Buffer) = 3,060 ha	• Commercial forestry scheme, with average annual return of $1,700/ha/yr, includes $1,200/ha/yr from product and $500/ha/yr from emissions trading scheme (for first 18 years only). • Due to forestry harvesting and the loss of ETS benefits, after 18 years of operation the operating cost of this option will change to - $1.5 M per year.	$79 M	$77 M	$2.2 M	- $3.0 M
Option 5	Eastern Valleys	• Irrigation to land of ADF on days when the wastewater flow is below the 97th percentile, all other flows to ocean outfall. • 100% solid set irrigation as the majority of the land is unsuitable for pivots. • 50,000 m^3 active volume onsite storage facility (lined), lagoon area 1.5 ha, 4m operational depth + 1m freeboard.	Active Irrigation Area = 920 ha Total Area (Inclusive of 30% Buffer) = 1,315 ha	• Commercial cut and carry pastoral scheme, with average annual return on product of $1,250/ha/yr.	$40 M	$66 M	$1.2 M	- $0.2 M
Option 6	Hira Forest and Eastern Valleys	• Irrigation of full WW flow to land during summer, assumed November - April, WW flows to the marine outfall during winter. • Split wastewater flows 50% between Hira Forest and Eastern Valleys sites. • Solid set spray irrigation in Hira forest. • 100% solid set irrigation in Eastern Valleys as the majority of the land is unsuitable for pivots. • 50,000 m3 active volume onsite storage facility (lined), lagoon area 1.5 ha, 4m operational depth + 1m freeboard.	Hira Forest Active Irrigation Area = 360 ha Total Area (Inclusive of 30% Buffer) = 515 ha Eastern Valleys Active Irrigation Area = 320 ha Total Area (Inclusive of 30% Buffer) = 460 ha	• Commercial forestry scheme, with average annual return of $1,700/ha/yr, includes $1,200/ha/yr from product and $500/ha/yr from emissions trading scheme (for first 18 years only). • Commercial cut and carry pastoral scheme, with average annual return on product of $1,250/ha/yr. • Due to forestry harvesting and the loss of ETS benefits, after 18 years of operation the operating cost of this option will change to $0.1 M per year.	$34 M	$36 M	$ 1.0 M	- $0.3 M
Option 7	Wakapuaka Flats	• Irrigation to land during summer period, assumed November - April, daily volume dependant on soil moisture on average 25% ADWF. • 80% centre pivot irrigators and 20% solid set irrigation in areas unsuitable for pivots. • Use existing storage onsite (oxidation pond and wetland) for flow balancing.	Active Irrigation Area = 230 ha Total Area (Inclusive of 30% Buffer) = 330 ha	• Commercial cut and carry pastoral scheme, with average annual return on product of $1,250/ha/yr.	$7 M	$16 M	$0.4 M	$0.1 M
Option 8	Waimea Plains - MAR	•Borehole Injection at ADWF (year-round), assumed via an injection field consisting of 20 No injection bores •All other flows to be discharged via the existing marine outfall •Appleby Gravel Aquifer target for MAR injection (Waimea Plains, SW of Richmond), for which this portion of flow will likely require Advanced Treatment (e.g. potable or near potable standard)	Area allowance for injection boreholes = 3 ha (consisting of 20 No individual portions of land, spread across the indicated MAR area)	• Managed Aquifer Recharge scheme for ADWF portion. • Beneficial re-use in the form of aquifer head replenishment (and associated baseflow support, salt-water intrusion reduction, freshwater abstraction benefit), and/or nitrate groundwater quality improvement. • The 'value of water' not presently known, with respect to estimating a holistic return on investment figure	$9 M	$0.6 M	$ 0.8 M	-

General LA Assumptions and Comments
• Maximum slope for irrigation set at 30%.
• Due to the cBOD concentrations in the treated effluent there is a moderate risk of odour generation at the irrigation site, currently it has been assumed that this can be managed through the aeration of the trated wastewater prior to irrigation. This could be further mitigated with odour capture and treatment systems at the rising main outlet if required.
• Aerosol migration beyond the boundary can be managed with buffers. Management practices such as increased buffers downwind of the dominant wind direction or postponing irrigation of boundary paddocks during high winds could be used.
• Land irrigation of wastewaters elevated in sodium can result in dispersal of clay particles, which can reduce soil infiltration rates. This is typically managed with applications of gypsum or lime.
• Heavy metals and other pollutants can accumulate in topsoil, triggering guideline values for contaminated land. This is unlikely for biologically treated wastewater.
• Land cost assumes purchase of full land area required (including buffer allowance). Leasing could be considered to reduce purchase costs.
• Flat agricultural land in valleys (Options 5, 6b and 7) estimated to have a value of $50,000/ha + GST. Based on high level search of real estate in the area.
• Sloped forestry land (Options 4 and 6a) estimated to have a value of $25,000 /ha + GST (which includes a nominal allowance for forestry value). Underlying land value likely $2000-$5000 /ha. Actual valuations of forestry are required to provide more accurate Forestry costs. Potential ETS liabilities are forest dependant and have not been included.
• Estimated per ha per annum (on average) revenue is incorporated into OPEX estimate in Column J
• Nitrogen concentrations are assumed to be suitable for irrigation, 15 g/m^3 Total N as reported by Stantec, a quantitative assessment of nitrogen leaching has not been completed however due to the low TN concentrations and low winter irrigation depths nitrogen leaching is not considered to be a limiting factor in this assessment.
• Return on cut and carry operations based on grass baleage with a yield of 10 tonne DM/ha, at a moderate rate of return ($42 bales/ha/yr at $30/bale profit) = $1,250/ha/yr. A 50% decrease in returns has been assumed for the buffer areas.
• Land purchase costs are <u>not</u> based on the purchase of full parcels. There is potential slightly larger area may need to be purchased to fit the required land area onto existing parcels.

General MAR Assumptions and Comments
• Allowance for 20 injection boreholes
• Injection layout yet to be determined, but costing presently assumes relatively even spacing across a length of ~3 km
• Allowance for investigation of injection field, and a pilot trial
• Costing for drilling assumes a rig mobilised from Christchurch
• Allowance for purchase of 3 ha total land area, assumed to be spread across 20 small land purchases (~0.1 ha each, and 1 ha for main control/office, all of which will likely require subdivision from parent parcels). Rate of $200,000 /ha assumed for these purchases, due to the small scale and assumed need to subdivide.
• Allowance for annual injection borehole workovers/downhole maintenance

Costing Disclaimers
• Costing excludes contingencies (minimum 40 % contingency should be applied).
• Costing excludes preliminary and general (15 % is recommended)
• Costing excludes professional services (15 % is recommended)
• Costing excludes GST.
• Costing is in NZD.
• Costings do not include installation of power to the site.
• Costings have no allowance for foreign currency exchange.
• Operational costs include maintenance costs for equipment replacement and refurbishment.
• Costings do not include consenting costs.
• Costings do not include treatment requirement

Irrigation Scheme Sizing Assumptions
• Summer irrigation schemes to operate November to April (inclusive).
• Monthly irrigation rates on steep sloped areas to not exceed 30 mm/month during winter (June to August inclusive).
• Monthly irrigation rates on flat valley land to not exceed 50 mm during winter (June to August inclusive)
• Maximum irrigable soil moisture content is halfway between field capacity and saturation (applies to all options except 7). Option 7 to operate as a deficit irrigation scheme.
• Irrigation cannot occur if rainfall exceeds 25 mm per day.
• Assumes storage is uncovered and affected by evaporation and rainfall.