Appendix D: Stormwater Assessment

HAIGH WORKMAN LTD
Civil & Structural Engineers

Stormwater Report
For Proposed Solar Farm
At The Point, Ohau C, Mackenzie Country
for Far North Solar Farm Ltd

Haigh Workman reference 23 119

2 August 2023 – FINAL

Revision History

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Executive Summary

Haigh Workman Ltd was commissioned by Far North Solar Farm Ltd to undertake a stormwater assessment and subsequent management plan for a proposed solar farm to be located at The Point, Ohau C, Mackenzie Country. The proposed development would see the erection of photovoltaic modules and ancillary infrastructure across 577 ha. The periphery of the development is to be planted with 89 hectares of low-lying native shrubbery (500,000 plants initially).

It was found that peak flowrates are expected to decrease in heavy rain events because of the proposed development. A 2.3% reduction in runoff is expected in a 10% AEP event. The proposed native planting will encourage ground infiltration as the hydraulic retention time of surface water will increase.

The water quality of stormwater is expected to remain the same or improve in the parameters set out in Schedule 5 of the regional plan. Temperature increases are not foreseen as rainwater will only run on impervious PV modules for a short period. The hydraulic retention time will not increase and may decrease as the proposed native planting strip will intercept sheet runoff. E.Coli and other faecal contaminants may decrease as cattle grazing is to be replaced with sheep grazing.

There is a predisposition for alluvial fan erosion along the eastern boundary where most stormwater runoff from the Site flows. The reduction in heavy rain event runoff will reduce the likelihood and extent of erosion. It is recommended that no bunding earthworks or raised access tracks be permitted, as these will concentrate flowrates into channels at points along the eastern drop-off.

1 Introduction

Haigh Workman Ltd was commissioned by Far North Solar Farm Ltd (the Client) to undertake a stormwater assessment for consent application. The proposed development is a 577 ha photovoltaic solar farm. The site sits on the north bank of Lake Benmore on an alluvial plain between Twizel River and Pukaki Stream. The proposed development is within the LINZ land parcel identified as Section 3 SO 384036.

2 Objective and Scope

The objectives of this investigation are to:

- Make site observations of stormwater flow paths, catchments, hazards, and other features.
- Review the regulatory framework for rules, policies, and objectives as it relates to stormwater.
- Assess the stormwater effects from the proposed development.
- Prepare a compliant stormwater management plan for consent application as necessary.

2.1 Limitations

This report is intended to support consent application with Mackenzie District Council and/or Environment Canterbury. It is to be used by the Client, Far North Solar Farm Ltd, and the Council(s) when considering the application for the proposed development. The information and opinions expressed in this report shall not be used in any other context without prior approval from Haigh Workman Ltd.

All details and scheme plan for the proposed development have been given to Haigh Workman Ltd by the Client. If the design differs from the conceptual brief, the recommendations of this report will need to be revisited.

Haigh Workman Ltd does not take responsibility for the engineering aspects of the proposed development that are not covered in the agreed brief.

3 Site Description

3.1 Site Location

Site Address:	The Point, Ohau C, Mackenzie Country
LINZ identification	Section 3 SO 384036
Parcel Area:	973 ha

3.2 Site Features

3.2.1 Geologic Overview

GNS mappings shows that the Site sits on a sedimented plain that consists of Late Pleistocene river and glacial deposits. The material is described as generally unweathered with variable mixtures of poorly compacted gravel/sand/silt/and clay deposited in extensive terraces and plains.

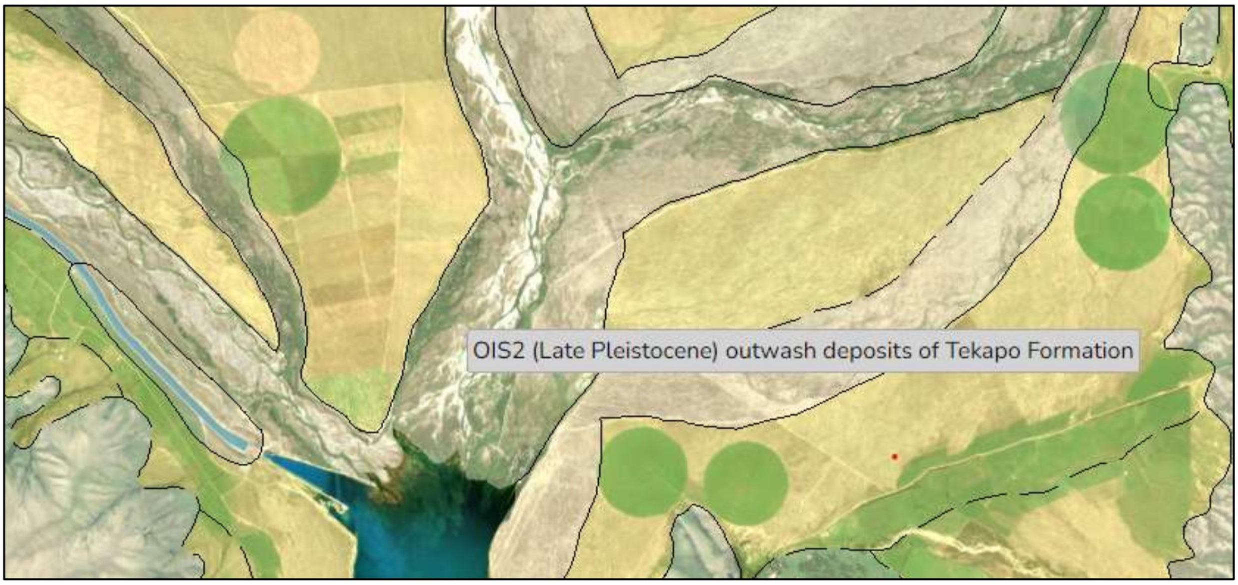

Figure 1: GNS Geologic Mapping for Site

Onsite observations conducted during a walkover confirmed the Site comprises poorly to moderately graded alluvial deposits to a depth greater than 15m. The maximum sized aggregates found onsite were 30cm avg. diameter (Figure 2). Gravels were smooth river stone. The gravels were interspersed with sand. Negligible silts and clays were observed (<10%). The steep drop-off on the eastern bank showed the material was consistent for more than 15m with no strata. There was some evidence of alluvial fanning with an angle of repose of approximately 30 degrees (Figure 3). The material is regarded to be high soakage. Supporting this notion is that the few overland flow paths (OLFP) that were observed were shallow with small cross sections for the size of catchments (Figure 4). All site observations are agreeable with the geologic mapping of the area.

Figure 2: Several clearance piles of river gravels showed that the largest aggregates were 30cm diameter stones.

Figure 3: The eastern drop-off showed consistent material for a depth >15m.

Figure 4: Low capacity OLFP from large catchment area indicates good soil soakage rates.

3.2.2 Site Observations

The Site forms the point between Twizel River and Pukaki River on the northern bank of Lake Benmore in Mackenzie Country. The site sits on a plain elevated approximately 390m to 410m NZVD 2016. The site is ringed by alluvial cliffs with inclines ranging from 35% to 10%. The height of the alluvial cliffs bordering Pukaki river at the eastern boundary range in height from 25m to 15m (Figure 3). The incline of the plain is towards the south to south east direction with an incline of 0.75%. There are some shallow OLFP paths observable in the north-east section of the Site (Figure 4). The majority of non-infiltrated runoff is sheet flow.

The Site is non irrigated grazed pasture (grazed by cattle). The site has a few wilding pines up to 6m in height around the periphery. Of note was the grass growth under the pines. On the day of the site visit, 12th July 2023, the grass across the Site was long but brown. However, grass under a small amount of shade in the day was greener because of less evapotranspiration (See Figures 6 and 7). If this is the case in the middle of winter it can be assumed to be more so in the summer. The makeup of the grass in shady areas had more shade tolerant varieties such as moss and broadleaf weeds than the Site generally. No patches of surfaces without grass cover were found on the plain.

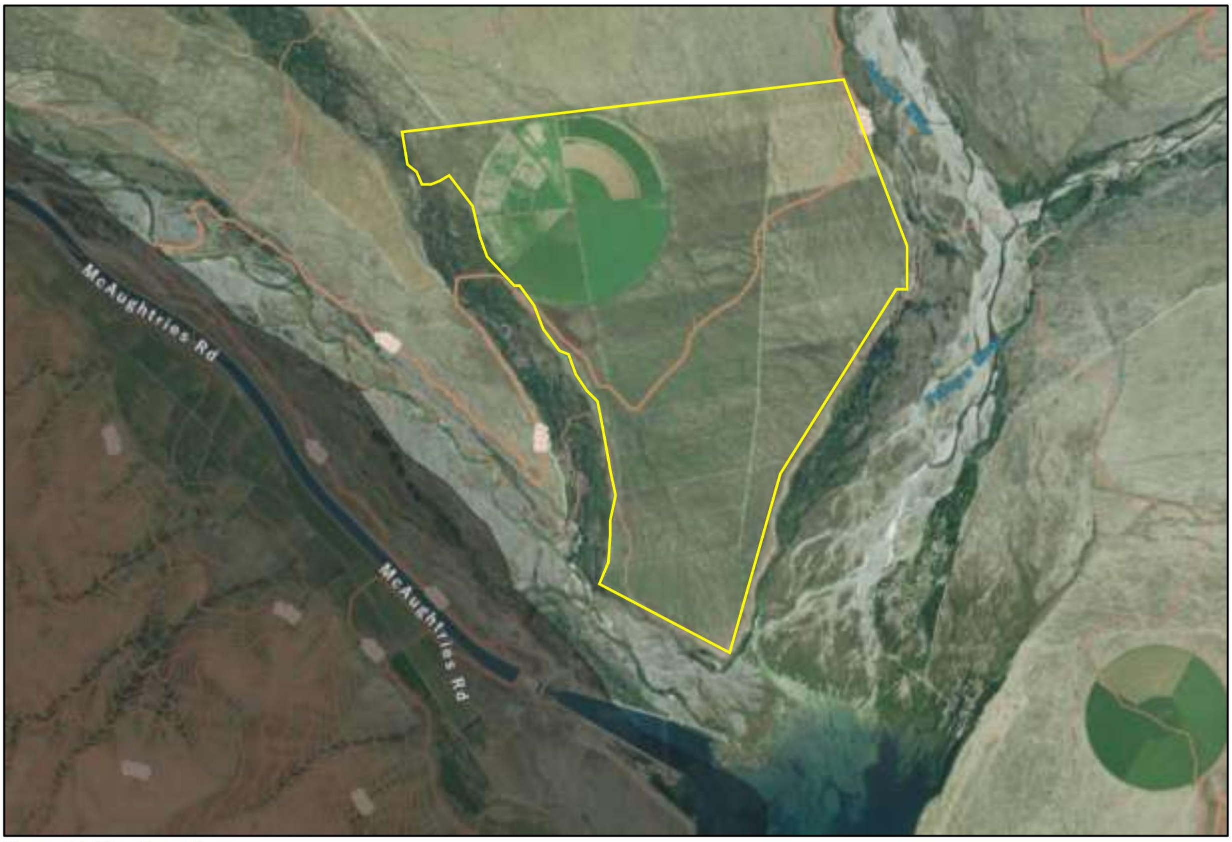

Figure 5: Site Overview

Figure 6: Wilding Pines around the periphery of the Site.

Figure 7: Grass growth is better under pines and places with partial shade.

The OLFPs in the northeast have some braided formation before draining into the Pukaki River at two entry points. The entry points are channels that emerged from flows becoming concentrated at historical alluvial fans. The first channel, Channel A shown in Figure 7 and 8, is 200m long with a 6% incline and 12m drop. The cross section is trapezoidal with a bottom with of 20m, a depth of 10m, and 1v:2h batters, tapering to the head of the channel. Channel A is the concentration point for a 3,250,000m^2 catchment. Channel B is 500m to the south of Channel A and is 230m long with a 6% incline with a 14m drop. The cross section is trapezoidal with a 10m bottom width, 8m depth, and 1v:2h batters tapering to the head of the channel. Channel B is the concentration point for a 3,700,000m^2 catchment.

Figure 8: The start of Channel A

Figure 9: Channel A outlet into Pukaki River. Photo from Site boundary.

Figure 10: The Start of Channel B

Figure 11: Channel B

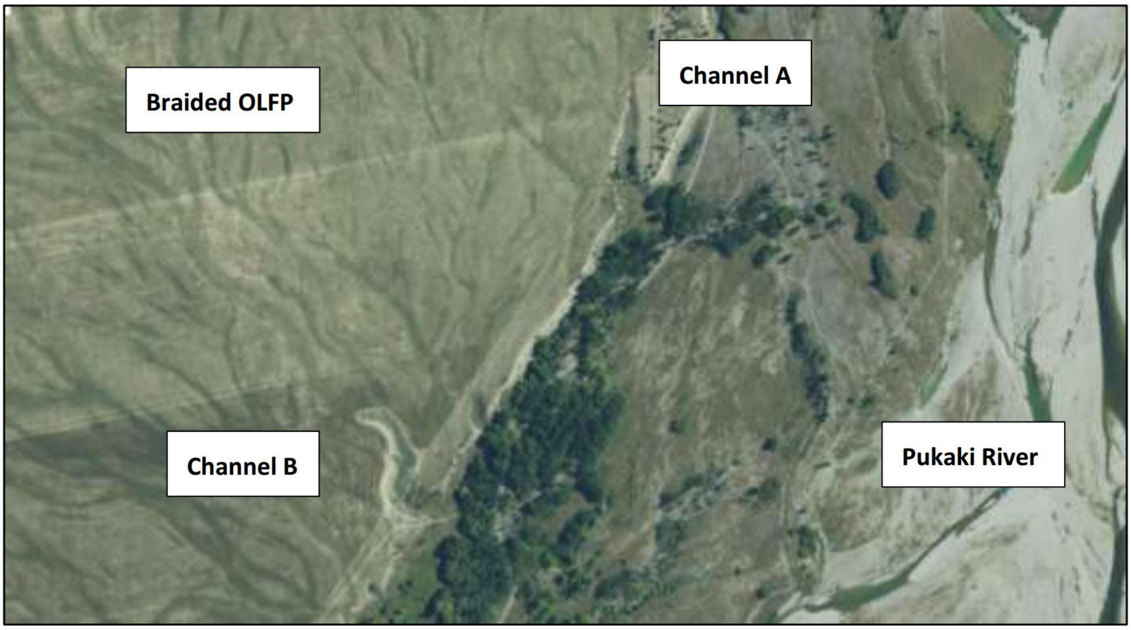

Figure 12: Stormwater drainage in the northeast corner of the Site.

3.3 Proposed Development

The proposed development will see 577 hectares of photovoltaic (PV) panels erected across the Site. The panels will be set on 2.285m wide tables that will rotate on a north-south axis 60 degrees. The height of the axis support posts is to be 1.5 which will mean that the minimum distance from the ground for the PV modules is 1.015m. The free space between each module table is to be 3.997m. The ground is to remain grassed and tended by sheep (as opposed to cattle which is the current livestock). The proposed arrangement will not have PV modules within a 40m corridor for the transmission line that passes through the Site. The access tracks will remain unpaved.

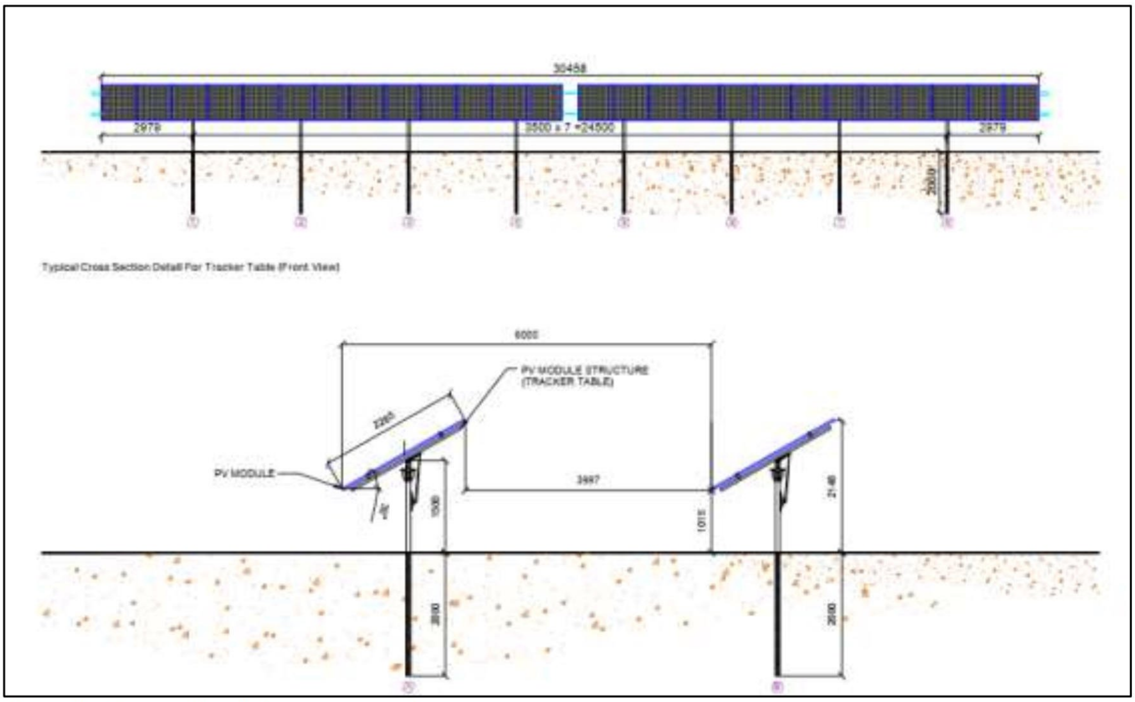

Figure 13: Proposed module arrangement

The the PV modules are to be surrounded with a 40m wide minimum landscape mitigation strip (89 hectares in total). The stip will be characterised by indigenous shrubs, tussocks, low lying native plants including kanuka, matagouri, manatu, tree daisy, korokio, and mingimingi. The intial planting will be 500,000 individual native plants with the scope to increase up to 890,000 plants over the project life. The planting will be on land that is currently grazed pasture, i.e. at the higher plain level.

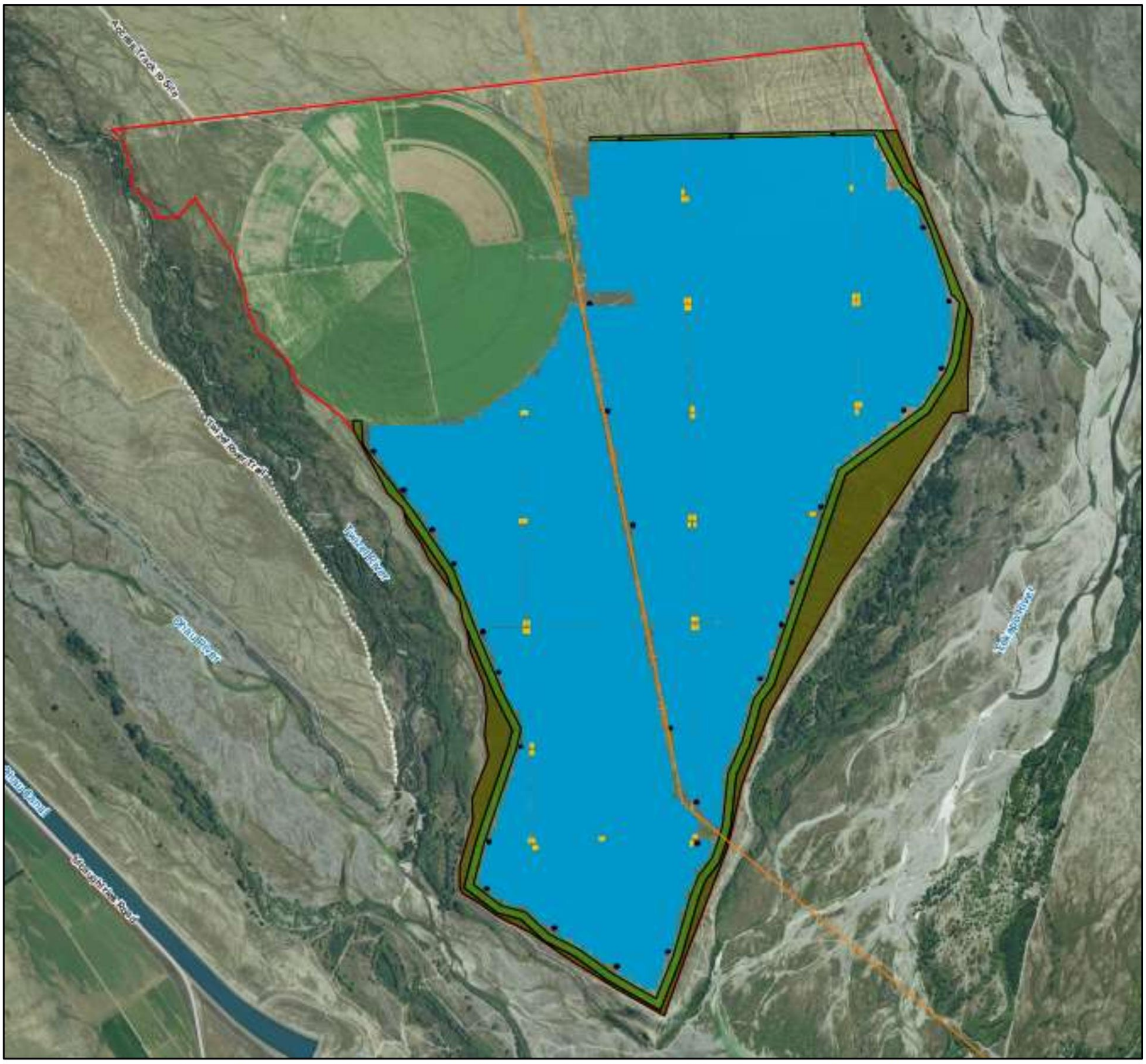

Figure 14: Proposed Development with PV modules (blue) and landscape mitigation zones (green).

4 Stormwater Management

4.1 Regulatory Framework

Mackenzie District Plan 2022

The Site sits within the Rural Zone and the Mackenzie District Subzone. Objective 2 states that the stability of the margins of waterbodies, including rivers, needs to be maintained in a way that no plant or animal habitat is lost. Policy 2A seeks to meet Objective 2 by way of controlling adverse effects including maintaining bank stability, water quality, and water quantity.

Operative Environment Canterbury Land and Water Regional Plan 2018

The Regional Plan gives policies, rules, and targets for various Canterbury catchments for the ecological conservation of river systems. Policy 4.3 states that the natural variability of flowrates, including floods, is to be maintained. The natural colour of water in a river is not to be altered. Developments are to consider how sedimentation of rivers is to be avoided or minimized (4.22). The discharge of stormwater into a river is a permitted activity so long as the river is not a wetland and not in a natural state (5.95) The discharge is not to increase the 20% AEP flowrate by more than 1% from pre-development. In addition, the discharge is to meet the water quality standards found in Schedule 5.

Schedule 5 gives the parameters for water quality. The Total Suspended Solids (TSS) of the stormwater discharge is not to exceed 50g/m3. Pertinent to large high country lakes, a 2.0°C temperature change is not to be exceeded. The water quality testing flowrate for design purposes is to be the seven-day mean annual low flow rate (7DMALF).

Stormwater Management Devices in the Auckland Region: GD01

Neither the district nor regional council provides location-specific engineering standards for stormwater management. In that absence, the Auckland Council's engineering standard can be used. GD01 provides design parameters and guidelines for a range of water quality devices including vegetated swales and check dams.

New Zealand Building Code

Section 2.1 of E1/VM1 recommends the rational method for estimating the effects on runoff from changes in land use. Appropriate runoff coefficients for a variety of surfaces are given.

4.2 Water Quantity

4.2.1 Effects on Runoff

Because the Site has sheet runoff, high infiltration, and few points of concentration other than Channel A and Channel B, the rational method is the most logical approach to estimating the effects of runoff from the proposed development.

Because of the alluvial soil with high soakage, pasture has been given a runoff coefficient of 0.20 as proposed by Table 1 in ASVM/E1 of the NZ Building Code. Similarly, the Code recommends that bush and scrub cover is to have a runoff coefficient of 0.15.

It can be safely concluded that the photovoltaic modules will have no adverse effect on stormwater runoff. While the modules themselves are impervious, they sit on tables that are only 2.285m wide and oscillate. The tables have 20mm gaps every 1.3m between the PV panels to allow runoff to reach and infiltrate the ground. Precipitation will therefore be concentrated along lines that are perpendicular to the rotating axis with 1.3m spacing. The maximum size area that will receive no direct precipitation is the area of a fully inclined panel which is 1.15m by 1.3m. Runoff is concentrated around these perimeters. With such a small area, runoff will quickly disperse over the available area so that all available surfaces will be irrigated. The definition of impervious area in the Auckland Council Code of Practice is any surface that stops or significantly slows water soaking into the ground. This definition does not include slatted decks and pavers. We recommend that PV modules be treated in the same way.

It is also concluded that the module array will allow for ongoing grass coverage of the surface. This has been the experience of other solar farms in the region (see Figure 15). It is also observed in partially shaded areas at the Site that vegetation growth actually increases (Figure 6 and 7) because of reduced evapotranspiration. Grass can grow with indirect sunlight. It is expected that grasses that are more sensitive to shade (e.g. rye grass and tussock) will slowly be replaced by more shade tolerant grasses and plants such as dichondra, broadleaf weeds, and clover. What is not foreseen is a loss of vegetation cover and bare land that would exacerbate runoff flowrates and erosion.

The justification for the PV modules' not increasing runoff is as follows:

1. Site observations showed *more* grass growth in partially shaded flat areas (Figures 6 and 7).

2. Globally, solar farms in semi-arid conditions similar to Mackenzie Country have seen grass coverage maintained (Figure 16).

2. The experience of local solar farms, such as the Keswick Farm Solar Farm in Rangiora, has seen that grass coverage is retained, or even improves, after PV modules are erected (See Figure 15).

3. Grass growth: Grass does not necessarily require direct sunlight to grow. The large spacing between the modules and oscillating axis will allow light to reach the ground, minimising shading effects and the potential for bare surfaces. This means that grass can still grow in those areas, maintaining ground cover.

3. Rainwater Distribution: rain will fall through the spacing of the PV modules along 1.3m lines. Surface sheet runoff will distribute from these lines, so that no patch of the ground will become unirrigated.

4. Growth of other plants: In areas where grass may struggle to grow due to reduced sunlight, other plant species such as dichondra, broadleaf, and clover can thrive. These plants can provide additional ground cover and contribute to reducing runoff.

5. Reduced evapotranspiration: The partial shading provided by the PV modules can reduce evapotranspiration of the grass during dry summer months. This means that the grass cover may increase in dry seasons when there is a risk of greater runoff with hardened surfaces. Evidence from solar panel installations in Australia are available to support this.

Figure 15: Another solar farm from the region – Keswick Farm Dairies Ltd, Rangiora. This photo shows that grass coverage over the ground does not diminish because of the PV modules. Please note that this module arrangement causes more shade than the proposed development at The Point, Mackenzie Country.

Figure 16: Solar Farm at the Pluto LNG Facility, Western Australia, demonstrates that grass coverage does not diminish in semi-arid conditions. This PV arrangement is similar to the proposed development at The Point, Mackenzie Country.

Using the coefficients recommended by the NZ Building Code, the effects of runoff in a 10% AEP event (1 hour duration) is as follows:

Pre-Development Runoff

	Area m^2	C	I_{10} mm/hr	Q L/s
Pasture - good draining soil	9730000	0.2	43.74	23643.9
Total	9730000		43.74	23643.9

Post-Development Runoff

	Area m^2	C	I_{10} mm/hr	Q L/s
Pasture on good draining soil	3070000	0.2	43.74	7460.1
PV Modules	5770000	0.2	43.74	14021.1
Low-lying native bush	890000	0.15	43.74	1622.0
Total	9730000		43.74	23103.2
Excess run-off				-540.7

The landscape mitigation zone will reduce runoff into the receiving rivers by 540 L/s in a 10% AEP storm event. This accounts for a -2.3% change in runoff. The stormwater effects from extreme rain events will decrease because of the proposed development.

4.3 Water Quality

4.3.1 *Temperature Control*

PV modules operate best with cool surfaces but can reach temperatures of 35 degrees Celcius. Because the length of the PV modules is only 2.285m, water will not rest on the impervious surface for very long and there is minimal opportunity for it to be heated. Runoff will follow its normal course into the ground where it will cool as it does currently. The cooling effect on ground runoff may increase because of partial shading from the PV tables. Finally, the proposed native bush belt will slow down the hydraulic retention time of surface runoff as it moves towards the rivers, cooling it further. The temperature of runoff is expected to remain the same or improve (reduce) because of the proposed development. Water quality devices such as check dams or vegetated swales are not necessary.

4.3.2 *E.Coli and other contaminants*

The Site is currently grazed by cattle. Once the PV tables are erected, cattle will not be able to traverse the land and will be replaced with grazing sheep. Sheep produce less ammonia and other faecal contaminants than cows. Assuming the livestock to pasture ratio remains the same, faecal contaminants from the Site into the receiving waterbodies will decrease because of the proposed development.

4.4 Slope Stability

There is some evidence of natural erosion on the eastern boundary where the alluvial plain drops off to the Pukaki River flood plain (Figure 3). Site observations conclude the geology has a tendency for alluvial fans to form.

The risk of erosion could be exacerbated if sheet runoff were to be concentrated into overland flow paths. The developer is to take care to minimise earthworks and to not impede runoff with bunded areas or contour drains. Raised metalled tracks are not to be used as these can act as dams that concentrate runoff at points along the cliff.

Erosion risk is proportional to runoff flowrates. As shown in section 4.2, runoff is expected to decrease because of the proposed development. It is probable that the stability of the eastern drop-off will improve.

A review of historical aerials confirms that river migration has been stable within the braided flood plain for the past 20 years.

4.5 Flood Management

Runoff during extreme events is not expected to increase as a result of the proposed development. Adverse downstream effects are not foreseen. Runoff shall flow towards the Pukaki River and Twizel River where it will enter Lake Benmore. Lake Benmore is a hydro-lake operated by Meridian Energy. The hydro lake has a robust flood management plan.

5 Conclusions

The proposed development is not expected to increase runoff or change the stormwater patterns of the site. Runoff from heavy rain events is expected to decrease. Accordingly, slope stability is expected to improve so long as no bunds, raised tracks, or other earthworks occur that could concentrate runoff flows. Water quality is not expected to be affected negatively.

We found the proposed development to comply with Section 18: *Natural Hazards* of the Mackenzie District Plan and with the Objectives and Policies of Environment Canterbury's Land and Water Regional Plan. The proposed development will not lead to an infringement on the water quality standards found in Schedule 5 of the regional plan.