Ecologically Significant Wetlands and Rocky Outcrops in Mt Vernon Park: Characterisation, Impacts, Restoration and Future Management.

Carmen Payne, Donje Jamieson, Ella Hoodless, Stefan Millard and Elliot Caddick

School of Earth and Environment, University of Canterbury

GEOG309: Research for Resilient Environments and Communities

Supervisor: Sam Hampton

Community Partner: Alan McDonald

18th October 2024

Cite as *'Payne C, Jamieson D, Hoodless E, Millard S and Caddick E, 2024, Ecologically Significant Wetlands and Rocky Outcrops in Mt Vernon Park: Characterisation, Impacts, Restoration and Future Management. A report produced as part of the GEOG309 Research for Resilient Communities course, University of Canterbury, 2024.'*

Table of Contents

Acknowledgements

As a group, we are very grateful to have had the opportunity to conduct this research project proposed by our community partner Alan McDonald on behalf of the Port Hills Park Trust and hope that our findings help them greatly. We would like to say a huge thank you to Sam Hampton for all his guidance and support towards the completion of this project. We also want to thank the School of Earth and Environment for organising and supplying us with the necessary factors that have allowed this project to run smoothly. As a group, we are thankful for each other and the work and time each member has put into the project to get it to completion.

Executive Summary

This project focused on the ecologically significant areas within Mt Vernon Park and established information about this understudied locality. How to identify, map and manage the ecologically significant areas formed the research question for the project. Two areas of ecological significance, wetlands and rocky outcrops, became the centre of the research. Wetlands were identified through an initial digital assessment, followed by onsite investigation for distinctive characteristics including headcuts and springs. A qualitative approach assessed rocky outcrops which were classified based on health condition. Both areas were found to be ecologically significant and were digitally mapped using ArcGIS and Field Maps. The key findings included the discovery of slope wetlands in degraded to highly degraded conditions and a variety of rocky outcrops from optimal to degraded. Due to the size of Mount Vernon Park, not all potential wetlands were digitised. Additionally, not all key points such as water sources and land conditions could be recorded. Time constraints meant quadrats could not be used for the rocky outcrops for specific analysis. The management plans provided, act as a starting point for the restoration of these ecologically significant areas. It is recommended that future research undertake extensive recordings of all wetlands present within the park, as well as a flora and fauna census for both outcrops and wetlands, with documentation of the proposed restoration in these areas to monitor their success.

Introduction

Mount Vernon Park

Mount Vernon Park (MVP) is a 235.2 hectare park located in the Port Hills. The land was purchased by the Christchurch Civic Trust in 1985, with the objective to preserve it for recreational use for Canterbury residents, preventing housing developments on the land. It is currently owned by the Port Hills Park Trust (PHPT) and maintained to 'conserve and enhance the natural environment and provide opportunity for public recreation' (Port Hills Park Trust, 2006).

Current Management

The MVP Management Committee is responsible for the everyday management of the park. The MVP Management Plan outlines methods for the management of MVP, covering issues such as landscape management, soil erosion, vegetation control and fire risk. Management plans relating to vegetation and habitat are of relevance due to the project's focus on ecological significance. The management aims within this category to prioritise the protection of the tussock grassland and other ecological associations.

Vegetation and Restoration

Currently, most of the vegetation within MVP is tussock and grassland. Native shrubs and trees are found in the moist gulleys of the park. Weeds and garden plants are under control with the current grazing regimes, however, if minimised, spreading will increase. The management plan also states if shrub or forest habitats are established further, certain weeds or invasive plants will become a problem (Port Hills Park Trust, 2006). This stresses a need for controlled management of potential planting or forest habitat reestablishment.

Several plans for restoration have recently been implemented in March 2024. These include restoring Albert Gorge and Upper Albert Valley through vegetation plantings. Native planting has occurred, and new fencing has been created to align with these planting projects, protecting areas from sheep. Planting is used as a method for soil stabilisation, habitat creation and restoring the valley's natural systems (Port Hills Park Trust, n.d.).

Grazing

Grazing currently has multiple reasons for occurring at MVP. Grazing currently produces the income required to fund further developments of the park. Overgrowth of dry vegetation is flammable and is a fire risk to the Port Hills. Grazing prevents this overgrowth and is therefore used as a mitigation method for fire risk. Grazing also controls exotic grass species and weeds within the park, which would otherwise compete with the native vegetation.

The MVP management plan recognised changes are needed around grazing management. The plan states there is a need for a more sophisticated grazing regime to optimise tussock health (Port Hills Park Trust, 2006). Grazing is also recognised as a declining source of income, highlighting a need for new income sources. The park fund needs to be supplemented by other sources of income, such as grants or covenants.

A few paddock blocks have been retired, including Albert Gorge, with plans for more in the future. Sheep retirement is currently occurring in erosion-prone areas, to reduce sediment input into the Ōpāwaho Heathcote River (Port Hills Park Trust, n.d.). Retirement also allows for the new vegetation plantings in these blocks to be established.

Research Objectives and Scope

The research question, “How can we identify, map and manage areas of ecological significance in MVP” was proposed after receiving a brief for the project. This question allowed for research to be done to determine what areas of ecological significance could be present in the park. After consulting literature, wetlands and rocky outcrops were identified to be a potential focus area of significance. Mapping ecologically significant areas has enabled frameworks for databases to be created for use in the future. Management plans have been developed to best protect and preserve wetlands and rocky outcrops.

Section 1: Wetlands

Introduction

Within MVP, wetland existence was previously unknown until conducting this research. Wetlands are semi-aquatic ecosystems within the land that have fully saturated soils that support a unique range of flora and fauna species (Tomscha, 2019). Historically, wetlands were perceived as obstructions within the land, which resulted in 90% of Aotearoa's wetlands being drained (Tomscha, 2019). Today, wetlands are considered one of the world's most productive ecosystems (Department of Conservation, n.d.). This is especially so in Aotearoa, as wetlands are home to many native species (Environment Canterbury, 2024).

The ecological significance of wetlands stems from their capacity to benefit their surrounding environments and human communities through performing various ecosystem functions (LePage, 2011) (Table 1). Wetlands significantly benefit the environment and enhance biodiversity by supplying habitats for fauna and flora, water purification and mitigating flooding risks (Blackwell & Pilgrim, 2011).

Table 1

Ecosystem Functions Provided by Wetlands

Major Service Types	Specific Ecosystem Services
Structure	Biodiversity
	Wildlife habitat
Functions	Carbon sequestration
	Water purification
	Nutrient retention
	Flood prevention
	Fisheries support
	Food provisioning
	Soil development
	Storm mitigation
	Rare species support
	Waste assimilation
	Climate change mitigation
Processes	Nutrient cycling
	Primary productivity
	Nitrogen removal
Goods	Grains, tuber, fibres
	Fish, shellfish, crustaceans
Uses	Recreation
	Spiritual practices
	Human well-being
	Bird watching
	Inspiration
	Ecotourism
	Relaxation

Note. From LePage, B. (2011). Wetlands: Integrating Multidisciplinary Concepts. *Springer.* (https://link.springer.com/book/10.1007 /978-94-007-0551-7)

The types of ecosystem functions produced by the wetlands are linked to the type of wetland present (LePage, 2011). Johnson and Gerbeaux (2004) use surrounding landscapes, hydrosystems, and vegetation to classify New Zealand wetlands into their wetland types. Based on the topography of MVP (Port Hills Trust, n.d.), if wetlands were present, they are likely to persist down a slope. Wetlands on slopes are associated with only certain types of wetlands (Johnson & Gerbeaux, 2004) (Figure A.1, A.2). Slope wetlands are highly valuable sites (Stein et. al, 2004) and the loss of these would be devastating for local ecosystems.

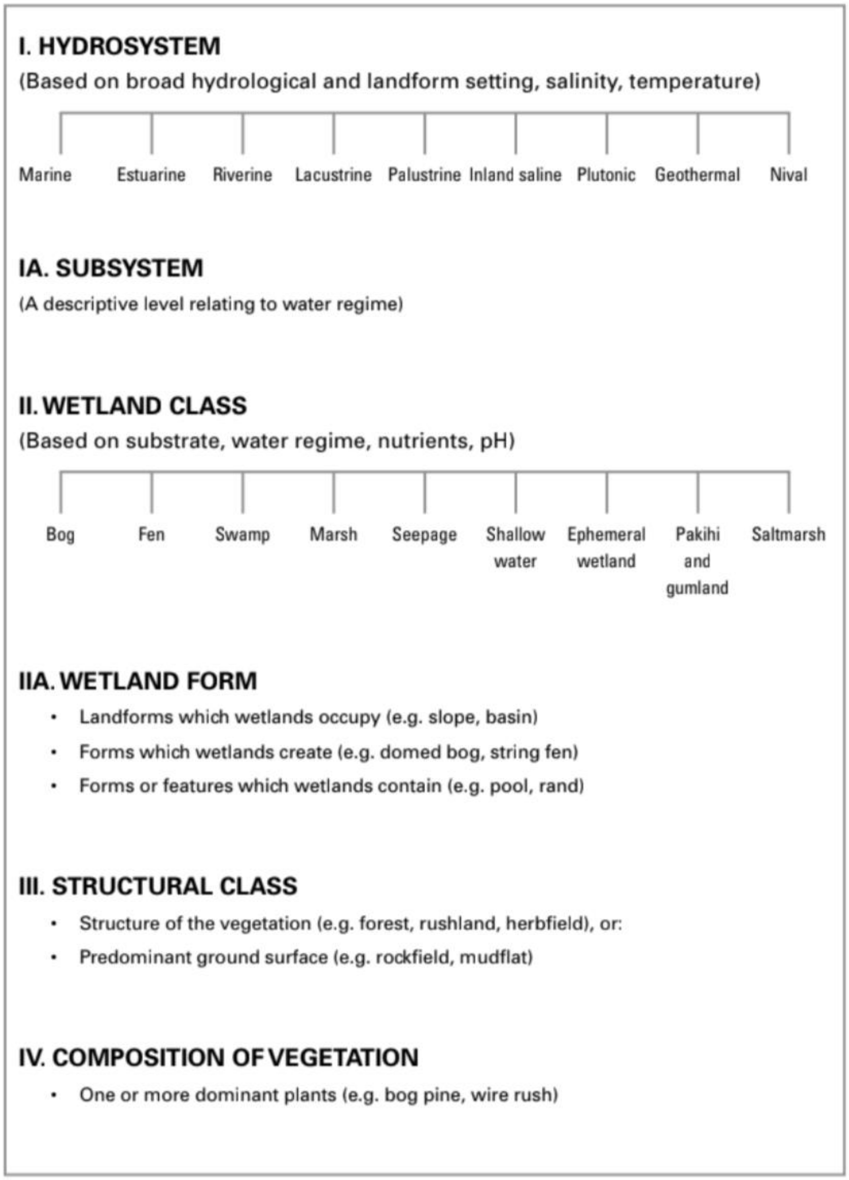
Wetlands within MVP have the potential to positively affect the surrounding environment, which would align with the aims of the PHPT, to enhance and conserve the natural environment (Port Hills Trust, n.d.). Therefore, this project's section aimed to identify slope wetlands, map their locations, and provide management options to guide restoration and management efforts to improve current wetland conditions.

Wetland Identification

Wetland classification can be conducted in one of two ways. The Ministry of the Environment (2022) outlines a delineation protocol to identify wetlands. Johnson and Gerbeaux (2004), classify wetlands based on a hierarchical system (Figure 1). From this classification method, the wetlands present on MVP take the form of slope wetlands. Identification of wetlands being present on slopes is important as Walton et al. (2019) include detailed practices and principles for the restoration of these systems, which are included later in this report. Ultimately, the main identification characteristics of wetlands were based on physical features (Walton et al., 2019), vegetation presence (Stein et al., 2004) and hydrological regimes (Greater Wellington Regional Council, 2005) (Figure A.1, A.2).

Figure 1

Classification System for NZ Wetlands



Note. From Johnson. P. & Gerbeaux. P. (2004). Wetland Types in New Zealand. *Department of Conservation; Te Papa Atawhai.*

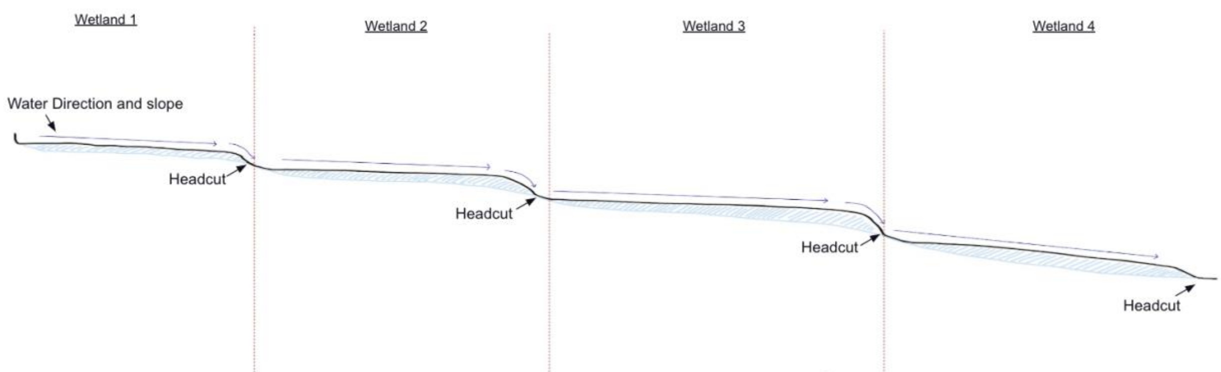
(https://www.doc.govt.nz/globalassets/documents/science-and-technical/wetlandtypes.pdf).

Physical Features

Slope wetlands are highly interconnected systems (Figure 2). Landscape attributes of slope wetlands are linked with hydrogeological processes, which influence how water moves and interacts within the wetland (Stein et al., 2004). Where water pools within a slope is related to the topography of the landscape present (Stein et al., 2004).

Figure 2

Diagram of the physical features present within a slope wetland.



Note. Headcuts are present in-between wetlands one through four. In a pristine slope wetland, one continuous wetland would persist down a slope with the absence of headcuts (Walton et al., 2019). The formation of a headcut is a result of water concentrating in a section of the slope causing the surrounding soil to erode, generating an abrupt drop in elevation. Therefore, at the base of a headcut water is almost expected to be present. The headcuts can be used to indicate the start and the end of a wetland segment. Channels of water within the centre of each wetland segment are also key indicators of a degraded wetland and can be easily identified. Figure adapted from Walton, M., J. W. Jansens, J. Adams, M. Tatro, and T. E. Gadzia. (2019). Applying Keyline Design Principles to Slope Wetland Restoration in a Headwater

Ecosystem. *New Mexico Environment Department Surface Water Quality Bureau Wetlands Program.* (https://quiviracoalition.org/wp-content/uploads/2019/12/keylineguide_FINAL.pdf).

Wetland Vegetation

Slope wetlands can be identified by using the vegetation present, as slope wetlands often contain a diverse range of wetland plants (Stein et al., 2004). The type of wetland vegetation present can be insightful towards soil conditions and wetland classification (Sieben et al., 2017). Where wetland vegetation accumulates has been used as an indicator of where the water concentrates within the land (Walton et al., 2019), creating a link between wetland vegetation and topography. Wetland vegetation is adapted to thrive in fully saturated soils in the absence of oxygen (LePage, 2011). Compared to other wetland types, slope wetlands have greater biodiversity due to having increased plant diversity providing more fauna habitats (Stein et al., 2004).

Hydrological Regime

The hydrological regime of a wetland involves the movement of water in and out of a wetland, which can be determined by a wetland's water source and topography (Greater Wellington Regional Council, 2005). Slope wetlands are dominantly fed by groundwater inputs (seeps and springs) and direct inputs from surface runoff (Stein et al., 2004). For example, the slope wetland present within Victoria Valley (MVP) consists of a spring-fed system, hosted within the underlying volcanic layers. Similarly, groundwater seep zones present in MVP are related to underlying geological conditions and surface runoff during rainfall events (Hampton et al., 2018).

Method

Field Techniques

Wetland location approximations were identified before fieldwork using ArcGIS to define on-site investigation locations for efficient use of field work time. Maps were created in ArcGIS, to be able to collate the data taken during site investigations. Within this map, layers were created (Table 2) to organise and categorise the data points. On-site investigations were required to identify and classify wetlands within MVP. Using a mobile offline version of Arc Field Maps, data that was collected in the field was inserted within their designated layers in the map with accurate locations.

Field Observations

Two field days in total were completed, the first located potential wetlands whereas the second identified wetland characteristics (Figure A.3). Wetland locations were determined by identifying; water sources, headcuts, vegetation, topography and channelisation. These characteristics were recorded using Field Maps and each data point was categorised within its associated layer in the map. This data provided information to assess the boundary of each wetland and draw it within the map. Characteristics associated with stressors and threats were also investigated and were recorded within the appropriate map layers.

Table 2

Layers Created within ArcGIS

GIS Layer	*Purpose*
Hole Sites	An area where a hole was dug within the wetland. This was to locate the water source within the wetland.
Wetland Headcuts	Identified where an abrupt drop in elevation was present, which indicated the start and the end of the wetland.
Fauna	Animals that were found within the wetland.
Wetland Channelisation	Channels of water which ran through the wetland.
Animal Impact Trails	Areas in which animals have disturbed areas of the wetland.
Springs and Seep Zones	Areas where springs and seeps were located within the wetland.
Threats	Any identifiable factors located within the wetland areas that are potential threats to the wetland.
Wetland Vegetation	Location and identification of wetland vegetation.
Current Wetland Extent	Boundaries of the current wetlands present.
Case Studies 1, 2 and 3	Identifies the specific areas within the slope wetland that the results will focus on.

Note. The layers that were created within ArcGIS to categorise the data points that were collected during the field observations.

Results

Wetlands in Mount Vernon

The presence of wetlands was recorded within MVP in the valley track area (Figure 3). The wetlands of MVP can be classified as slope wetlands.

Figure 3

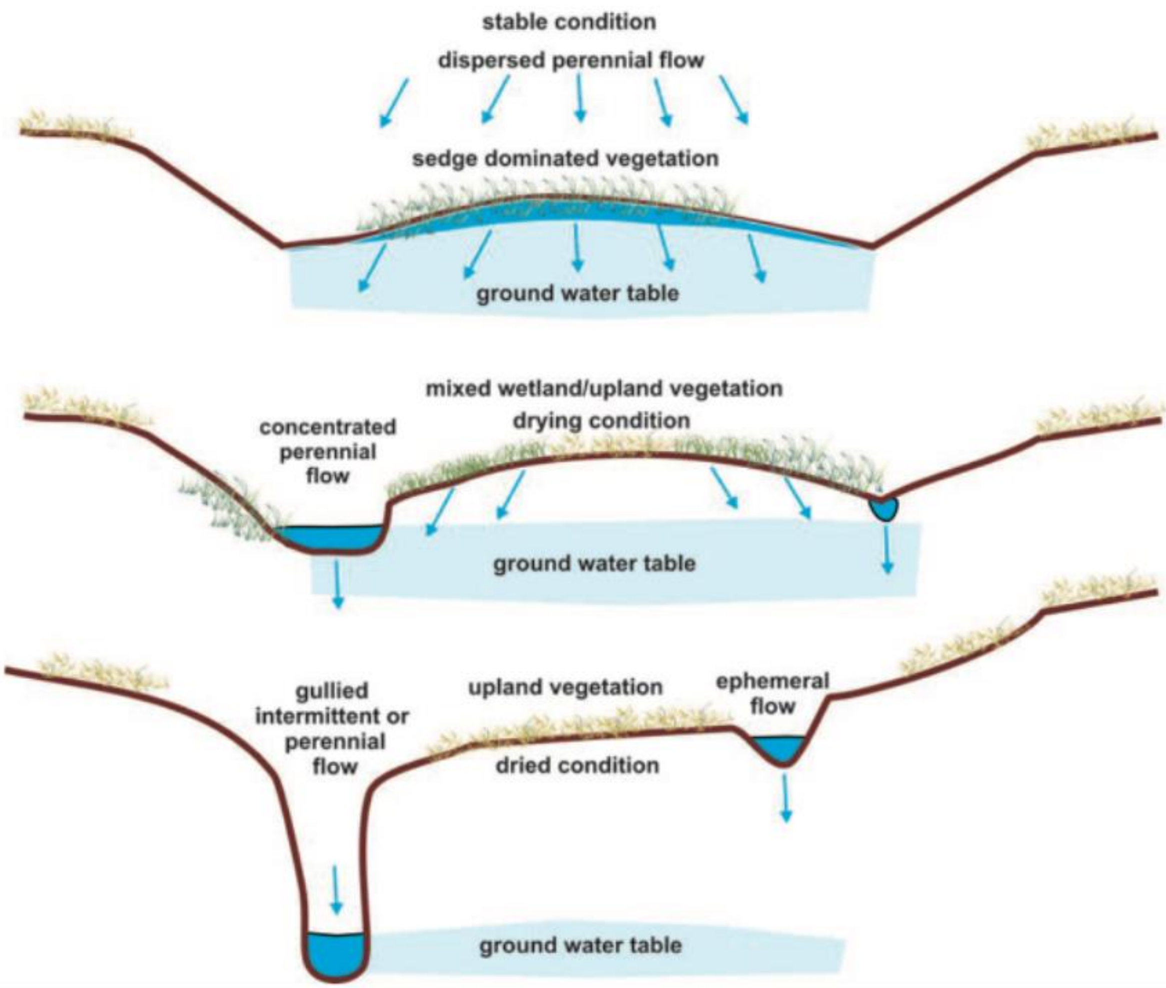
Wetlands Within Mt Vernon Park

Note. Wetlands are located alongside the Valley Track in MVP, within Victoria Valley.

Within these wetlands are multiple incisions and channels, the surrounding vegetation condition was dry and there was a reduced water table. Following the Keyline Study Guide (Walton et al., 2019), the general condition of the slope wetlands of upper Victoria Valley are degraded to highly degraded (Figure. 4)

Figure 4

Slope Wetland Conditions



Note. Key features of pristine, degraded and highly degraded slope wetlands. The pristine wetland has a full groundwater table, sedge-dominated vegetation and no incisions (Walton et al., 2019). A degraded wetland has a reduced groundwater table and a drying condition to the vegetation and incisions. A highly degraded wetland has a low groundwater table, a change to upland vegetation due to the reduced water table, and deep incisions. The MVP wetlands are degraded to highly degraded due to the multiple channels and incisions present, leading to a reduced groundwater table and a drying condition of the vegetation.

Wetland Case Studies

Three case study sites along the slope wetland systems with different characteristics were selected to account for variability in the system (Table 2).

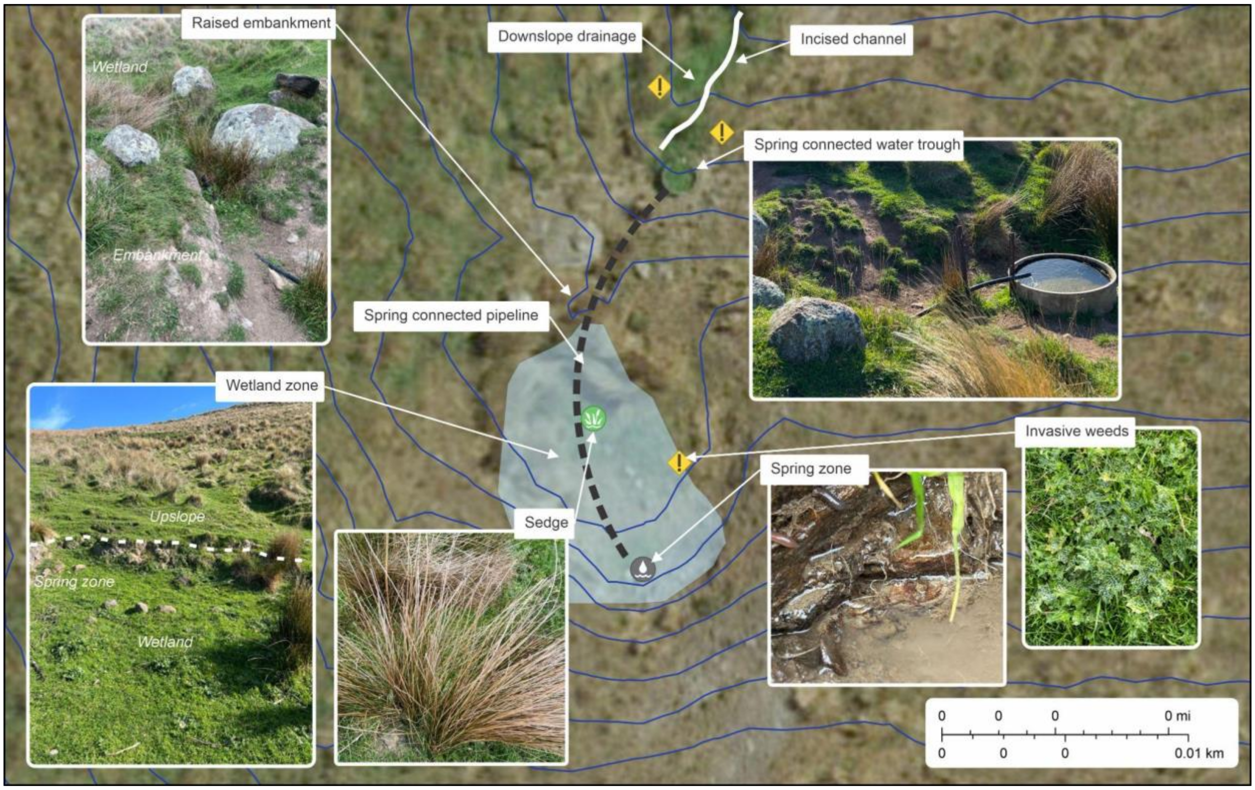
Table 2

Three Case Study Wetlands Within MVP

	Water Source	Description	Vegetation	Impacts
Case Study 1: Trough Wetland **Figure. 5**	Spring	The wetland is characterised by the presence of a spring. The spring lies at the top of an excavated area, potentially an early, now-infilled, pond. This modification to the ground surface has made an enclosed area where groundwater is directed. A breach to the earthen embankment occurs on the downslope, lowering the drainage level of the wetland area. Further, a polythene pipe (20mm) has been installed subsurface directly to the spring to feed a downslope stock water trough. The trough has a natural overflow, redirecting water further downstream, however this results in the section of the wetland being starved of this additional water. Measurements of the flow rate and input into the water trough occurred on two visits, 0.03L/s and 0.018L/s.	Vegetation at the wetland is minimal. It is predominantly grass with few sedges present. Both visits found only part of the ground to be saturated close to the spring zone.	There is extensive damage from sheep defecation and trampling in the waterway, spring zone and wetland area. Invasive weeds are also present. Whilst there are no deep incisions, the wetland is highly degraded.
Case Study 2: Weta Wetland **Figure. 6**	Spring	The wetland boundary is distinguishable in this area due to the density of the sedges. A headcut marks the end of the wetland and a spring was located as a key water source. Overall, the wetland is broad and sited within an area of lower topography.	Dominated by sedge vegetation. Deep channel cuts provided shaded conditions and moisture from water provided a humid environment. Mosses and filmy ferns are within these areas. There was a new plant type within this wetland (Streamside) and a Weta was found.	Channels were present in this wetland site, leading to the drying condition of the sedge present.
Case Study 3: Seep-zone Wetland **Figure. 7**	Seep zone and spring	The water source includes a seep zone and spring currently located on the high edge of the wetland coming through rocks. The seeps are located by the footpath for the valley track. The wetland is narrow and long, defined by a deeply incised channel between significant head cuts.	Sedge was present in the wetland.	There is a boggy mud area that humans and sheep are walking through. The track follows the edge of the wetland and crosses the seep zone.

Figure 5

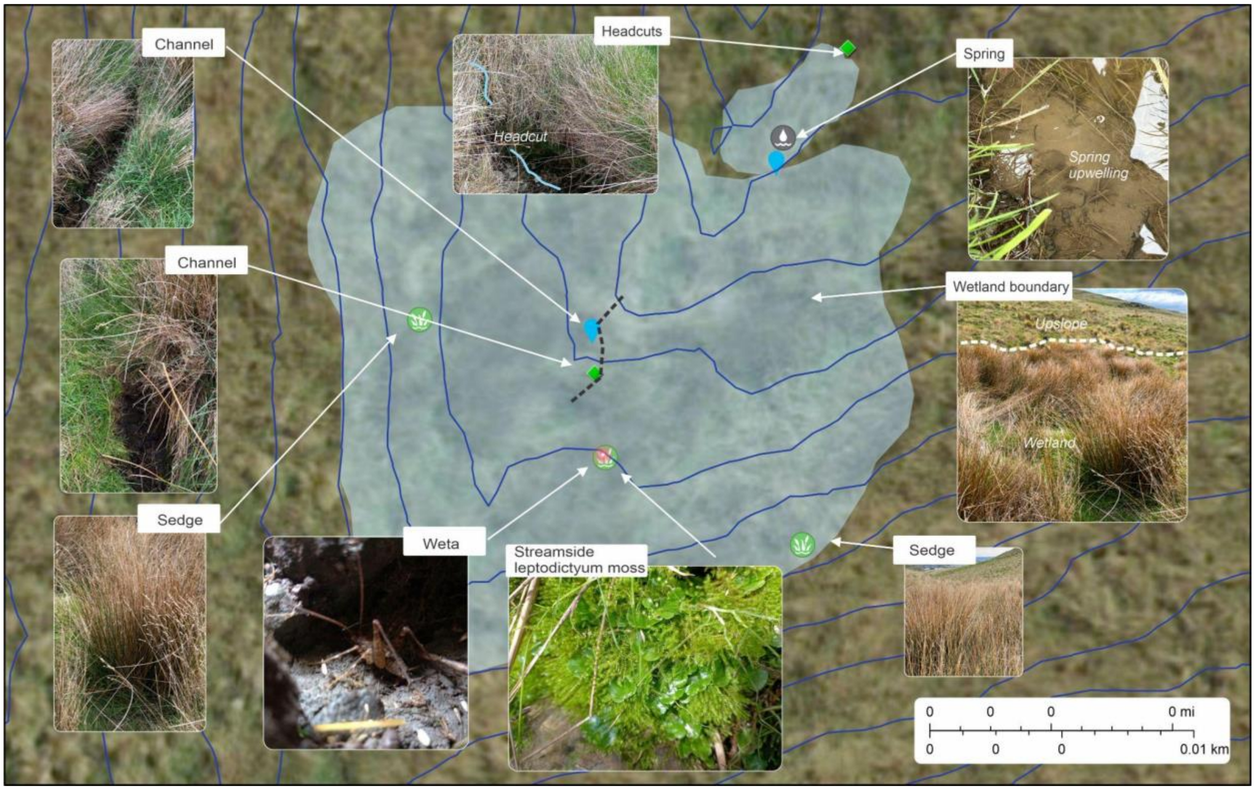
Case Study 1: Trough Wetland



Note. A spring is located on-site. This wetland site may have formerly been a stock pond, however, the spring is now being diverted through a pipe into a water trough for sheep.

Figure 6

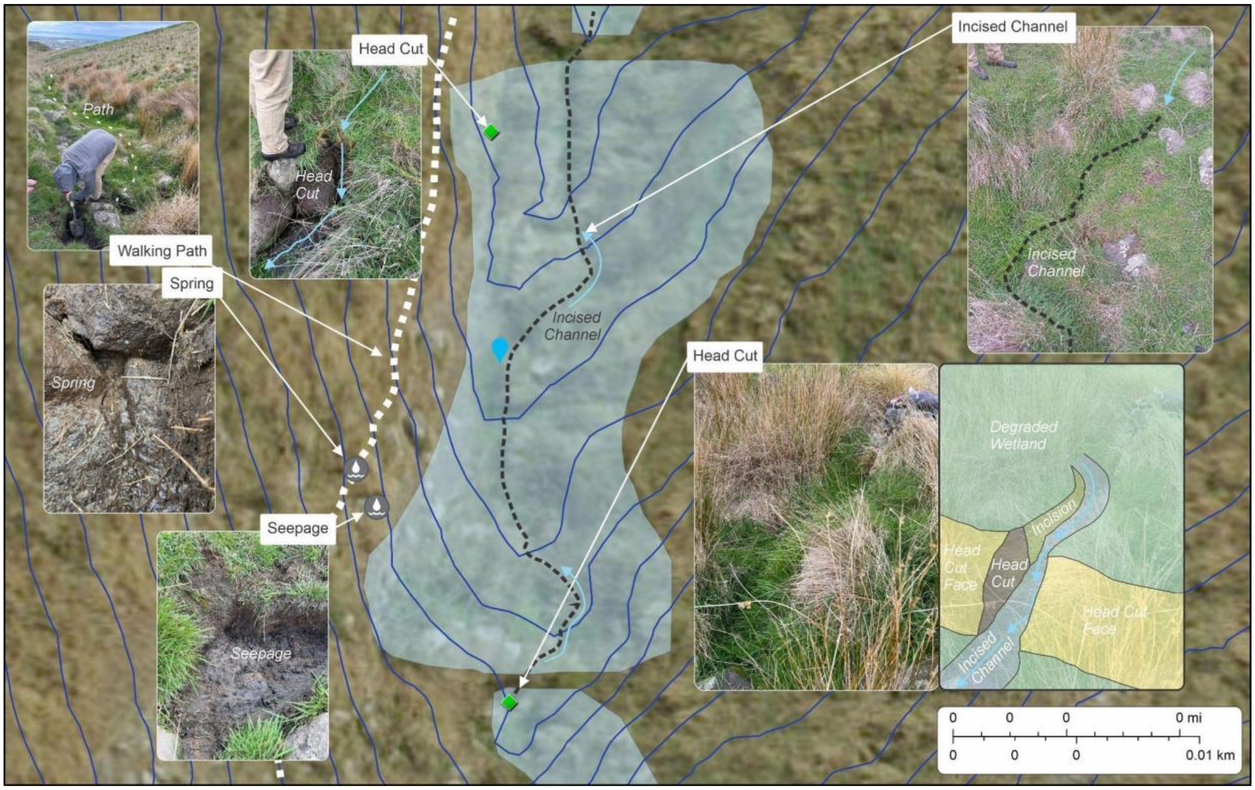
Case Study 2: Weta Wetland



Note. Weta Wetland is dominated by sedge vegetation which is a positive sign of health. There is a distinguishable boundary to this area due to the density of the sedges. There was a new plant type discovered here, and a Weta was found. A headcut marks the end of the wetland and a spring was located as a key water source. Channels were present in this wetland site, leading to the drying condition of the sedge present.

Figure 7

Case Study 3: Seep-zone Wetland



Note. The water source included a seep zone currently located on the high edge of the wetland coming through rocks. The seeps are located by the footpath for the Victoria Valley track. There is a boggy mud area that humans and sheep are walking through. Sedge was present in the wetland.

Discussion

Slope Wetland Conditions

MVP hosts fens and seeps which can be grouped within a system termed slope wetland. The importance of the latter classification is that slope wetlands are flow-through wetlands and have characteristics different from their flat land relatives (Walton et al., 2019). The wetland systems with MVP are valuable (Department of Conservation, n.d.). How valuable, in what condition, and what can be done to support these systems is the focus of the following sections.

The slope wetlands on MVP are ecologically significant sites and their further degradation and eventual loss would be devastating for local ecosystems and the Port Hills. Wetlands are relatively rare in the Banks Peninsula, with the only recorded sites in literature in Wainui, Akaroa Harbour (Shanks & Turney, 2013). Wetlands of all sizes have ecological significance and benefit an ecosystem through their functions. Whilst most management plans focus on larger wetlands (Junk et al., 2006), small wetlands are still able to provide ecosystem functions (Blackwell & Pilgrim, 2011). Individually there are varying sizes of wetlands present within MVP, but size should not be a dominating factor when considering which to restore, as restoration of smaller wetlands could increase their size and functions. The degraded condition of the slope wetlands requires action to protect and restore these ecologically significant areas.

Wetland Health Check – How to Fix Degraded Wetlands

Detention

It is advised to create a pond high in the valley to hold the water, from which water can be distributed. Causing further land change through excavation is not advised within the current landscape. However, in some locations existing anthropogenic features may be reutilised to achieve the same results. For example, Case Study 1 (Figure 5) would be an advisable keypoint to use as an area for water storage, due to the spring presence and the likelihood of this being a former stock pond.

Headcut Stabilisation

The following methodology is largely informed by the guide constructed by Walton et al. (2019). Headcuts should be stabilised upstream before the restoration work is undertaken on specific wetlands. Ongoing stressors such as grazing can increase the degradation of headcuts, which results in erosion accelerating if the headcuts get larger. As headcuts move upslope, the below channels can cut more into the landscape which can lead to the reduction of water and increased vegetation drying. Headcut stabilisation can be achieved using rocks and other materials to reduce the amount of water flowing downstream to the below wetland, keeping water in the wetland (Figure 8).

Channelisation – Silt Socks and Silt Fences

Channels in slope wetlands tend to form at either side of a valley, concentrating the water flow to one area, resulting in dry areas. Channels are created in the land through the water force of surface run-off on both sides of the valley. Surface water then moves through the system at the valley floor, which over time incises into the now exposed soft wetland soils. Two issues arise from this, the slope runoff and the now incised channel.

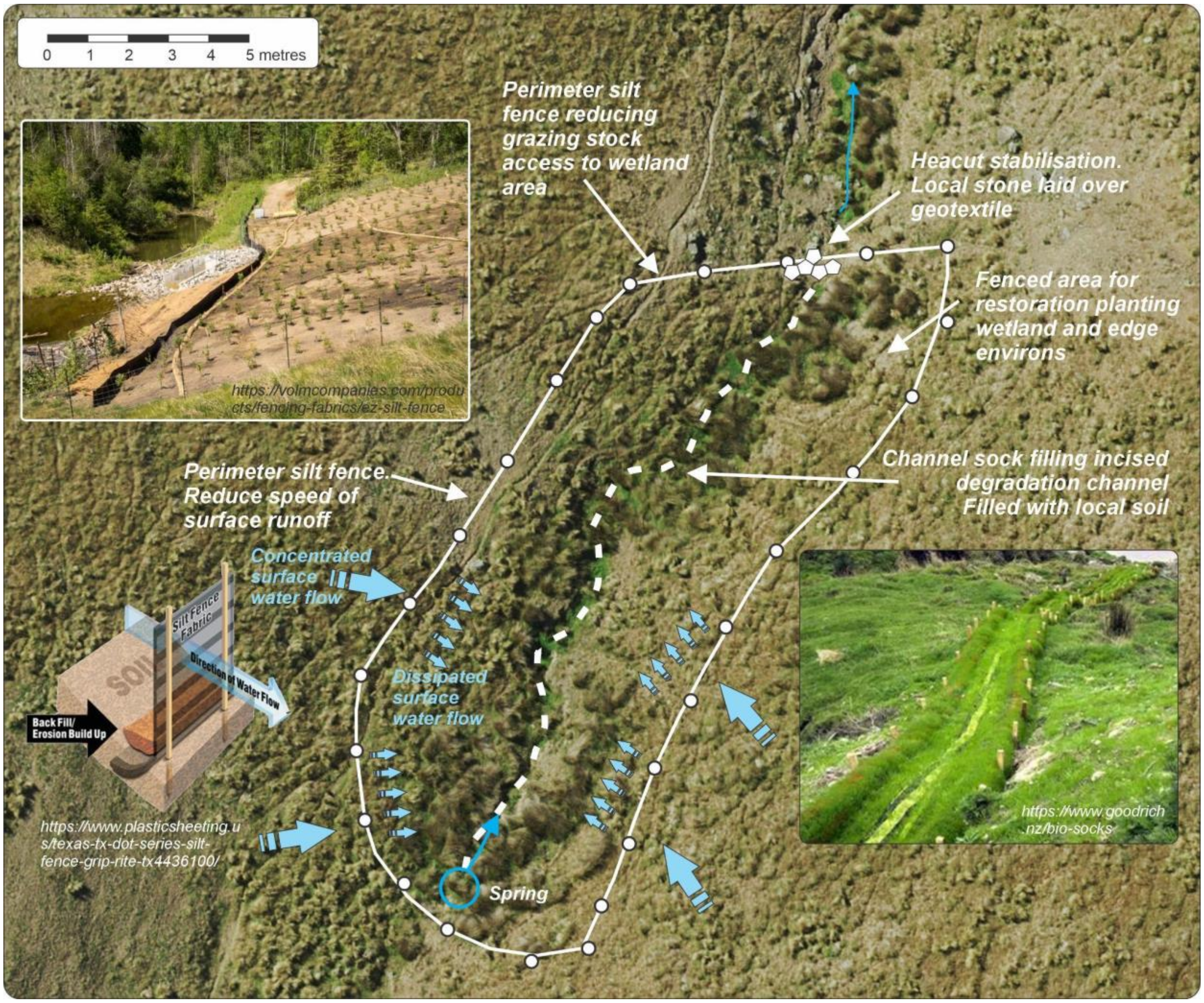
Walton et al. (2019) advises the use of surficial embankments and engineered structures to direct surface flows during rainfall events. Earthworks of this kind are not appropriate in the environs of MVP. However, to reduce the force at which the run-off enters the valley, it is proposed to implement silt fences in the diversion, direction, and dissipation of surface water flows (Figure 8). Silt fences when positioned upslope from the wetland and drainage systems will slow the surface runoff, as they act as a permeable barrier.

Surface runoff in this area is high due to its deforested nature, and the low coefficient that grass and tussock cover provides (Bright Hub Engineering, n.d.).

To restore the deeply incised channels throughout the valley, it is recommended to fill them with local soils to return the height of the incisions to precut level (Walton et al., 2019). However, the direct placement of soil in the incised channels in MVP would lead to a direct loss downstream via erosion. It is therefore recommended that a silt sock is used to achieve a similar effect. The silt sock would contain the material within the channel, reducing its ability to be entrained in water flows and help restore the water table. It would also help support a decrease in erodibility by stabilising the channel. Restoring the water table will help to rewet the dried vegetation (Figure 8). There are biodegradable silt socks available that break down over a 2–6-month period and therefore do not need to be removed (Cirtex Industries Ltd, 2022). These could be trialled in certain areas to ascertain if this period is long enough to allow the regeneration of the wetland areas. Non-biodegradable alternatives are available as well as channel socks that can stabilise and prevent erosion of channel beds (Good Rich Environmental Solutions, n.d.). Case studies 2 and 3 are examples where silt socks and fences would be ideal candidates, however, these mechanisms should be repeated through the valley to restore all identified slope wetlands.

Figure 8

Proposed Management Plan for Slope Wetlands



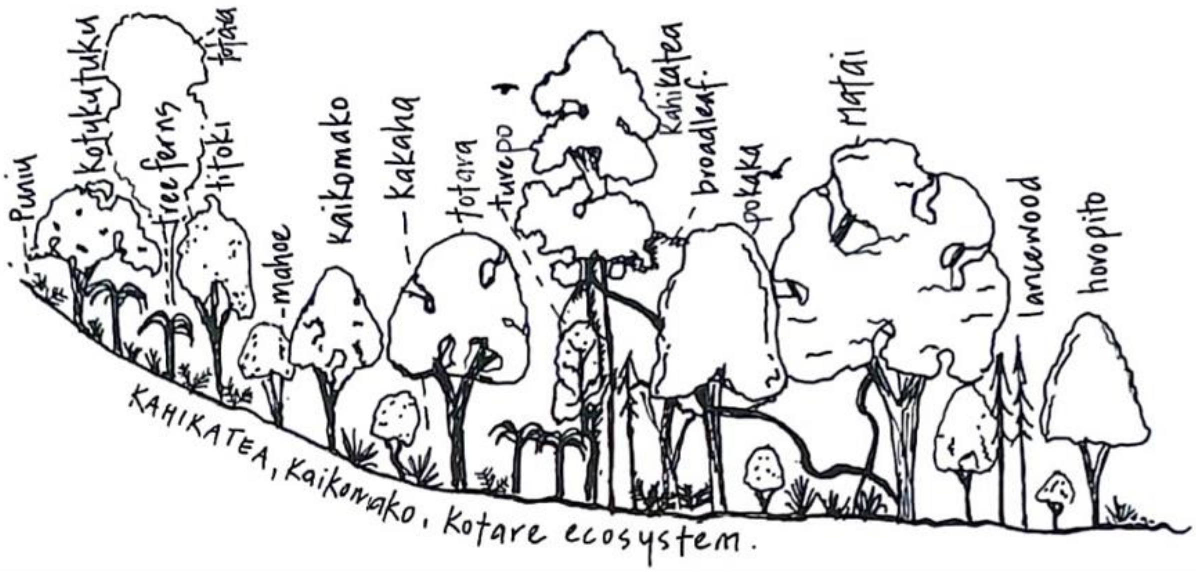
Note. An example of how to restore a slope wetland. Key restoration tools include headcut stabilisation, silt fencing, silt socks and revegetation. A combined approach ensures the likelihood of a successful restoration accompanied by ongoing monitoring and maintenance of weeds.

Vegetation

Re-vegetation of the wetlands is advised, with a focus on high-canopy vegetation to protect the wetlands (Figure 8). Planting can be passive or active, but a reduced effort could cost the project's success (Spieles, 2022). Passive restoration can leave the site vulnerable to invasive species, but an active approach will likely be more successful and is worth the additional time and resources (Spieles, 2022). It is recommended that planting is active, and a planting map be created to identify moist, wet and standing water zones (Greater Wellington Regional Council, 2009; Peters & Clarkson, 2010). The vegetation should complement the ecological values present and match the soil type and hydrological conditions (Greater Wellington Regional Council, 2009; Peters & Clarkson, 2010). Knowledge of appropriate flora for MVP is available (Lucas, 2011). Different planting zones should be restored at different times of the year (Greater Wellington Regional Council, 2009). It is essential to fence out stock to protect the establishing vegetation, and riparian buffers are recommended for water cleanliness (Myers et al., 2013). Waterway planting should follow guidelines identified within the report Indigenous Ecosystems of Lyttelton Harbour Basin (2005) (Figure 9).

Figure 9

Streamside Restoration Plantings



Note. Streamside restoration plantings for slope wetland systems, from Lucas (2005). Streamside is "the wet, swampy, or riparian (streamside habitats). Seepages are present on slopes from near the tops of the hills all the way down to the base which support harakeke, sedges and rushes. Before farmers drained the flats, valley swamps existed with wet, gleyed soils (Horolane) on alluvium and the slopes of the surrounding hills, Harakeke, toetoe, tussock sedges and rushes, and the woody mikimiki, cabbage trees, manuka and lowland ribbonwood (manatu), with raupo in the wettest places, and would have eventually reverted to the original mature swamp forest of kahikatea, pokaka, and a diverse array of other hardwood trees and shrubs, ferns, lilies, grasses and mosses."

Management and Monitoring

Frequent observations of animal impacts through trampling and defecation were noted throughout the wetlands. If left unaddressed, they will compromise the success of the restoration plan. Certain areas are also vulnerable to human impacts as they go through or via the slope wetland areas. Maintenance also involves controlling weeds which is laborious, this is where volunteers and support from government agencies for maintenance are beneficial. This could be in the form of covenants or reaching out to form relationships with government agencies (Myers et al., 2013; Peters, 2010; Greater Wellington Regional Council, 2009).

Monitoring enables data collection to track progress and maintenance (Greater Wellington Regional Council, 2009). Photographs of the initial planting should be taken, and regularly updated with images from a set photo point (Peters & Clarkson, 2010; Greater Wellington Regional Council, 2009; Taddeo & Dronova, 2018). Different indicators can be used to monitor success. Structural indicators, including plant coverage, can be estimated from observer data or aerial imagery, however, drone footage is advised to provide higher quality imagery (Taddeo & Dronova, 2018; Peters & Clarkson, 2010). Whilst these methods cannot determine plant type, this can be addressed through the species composition indicator (Taddeo & Dronova, 2018). This focuses on the diversity of species through stem measurement or thorough visual estimation (Taddeo & Dronova, 2018). These indicators provide quick responses to measure restoration success and can help identify ecosystem stressors; however, it is recommended that the project monitoring styles change with time based on the initial project goals and use a combination of techniques (Taddeo & Dronova, 2018). Detailed monitoring can support funding applications and should therefore be an important component of the Trusts management plan (Peters & Clarkson, 2010).

Covenant

Covenants are legally binding agreements signed by parties to protect and manage a wetland (Peters, 2010). Placing a covenant over the wetland is a recurring suggestion for best management practice on private land and allows for possible funding and rate exemption (Myers et al., 2013; Peters, 2010; Greater Wellington Regional Council, 2009). However, sites must meet certain criteria to be eligible. Therefore, an application may need to be submitted following an initial restoration plan to meet the criteria (Peters, 2010). As highlighted in the Mt Vernon Park Management Plan (2006), objective 9 of the Trust is to receive financial support for the development of projects, recognising grazing as a declining source of income. By restoring the wetlands, the Trust could seek to place a covenant on the site to ensure support for future regeneration.

Summary

This research focused on the identification, mapping and proposal of management for wetlands in MVP. The identification of these ecologically significant wetlands was a huge success. Wetland identification and classification, mapping through ArcGIS and assessment using relevant literature have informed proposed management strategies to restore the slope wetlands. Generalised recommendations for restoring slope wetlands are illustrated in Figure 8. By incorporating a mixed-method approach, there is a higher chance of successfully restoring these ecologically significant areas. The inclusion of silt socks and fences is an adaptation of the recommendations from Walton et al. (2019) as appropriate for New Zealand wetlands and the specific requirements of MVP. By following the restoration advice provided, the wetlands can continue to provide habitats for native species and carry out their ecosystem services whilst being key places of ecological significance within MVP.

Section 2: Rocky Outcrops

Introduction

Rocky outcrops are areas of exposed bedrock that thousands of years of erosion on the Port Hills have exposed, occurring through the removal of softer rock and soil, creating unique structural features. These features support a wide range of biodiversity both fauna and flora. In agricultural landscapes many outcrops are often degraded, lacking formal protection, requiring management to restore the conservation value. The goal of this project was to identify and map all rocky outcrops at MVP and then make recommendations on how to best improve these ecologically significant areas. The greatest limitation was time, which influenced the assessment methodology. Despite this, multiple metrics were recorded for each outcrop.

Methodology for Identifying and Mapping Rocky Outcrops

Multiple pre-existing GIS layers provided relevant information such as existing fence lines and current land use (Figure B.1). Field data collected summarises the key factors that are influential determinants of an outcrop's ecological significance. All data was collated on ArcGIS using separate layers, ArcGIS Field Maps allowed for accurate, in-person, field data collection.

Initial assessment of MVP using previous LIDAR data informed potential locations of outcrops, indicated by the reflectivity indices of the topography. Analysis indicated outcrops were likely to be present throughout the entirety of the MVP, with the majority sitting within the steeper portions of either valley.

The methodology for classifying outcrops was adapted from the literature to give the best overview of all the outcrops present and their current health (Michael & Lindenmayer, 2018) (Figure 10). This qualitative approach assessed the vegetation structure and habitat complexity, each being graded by their condition, ranging from 'degraded' to 'optimal'.

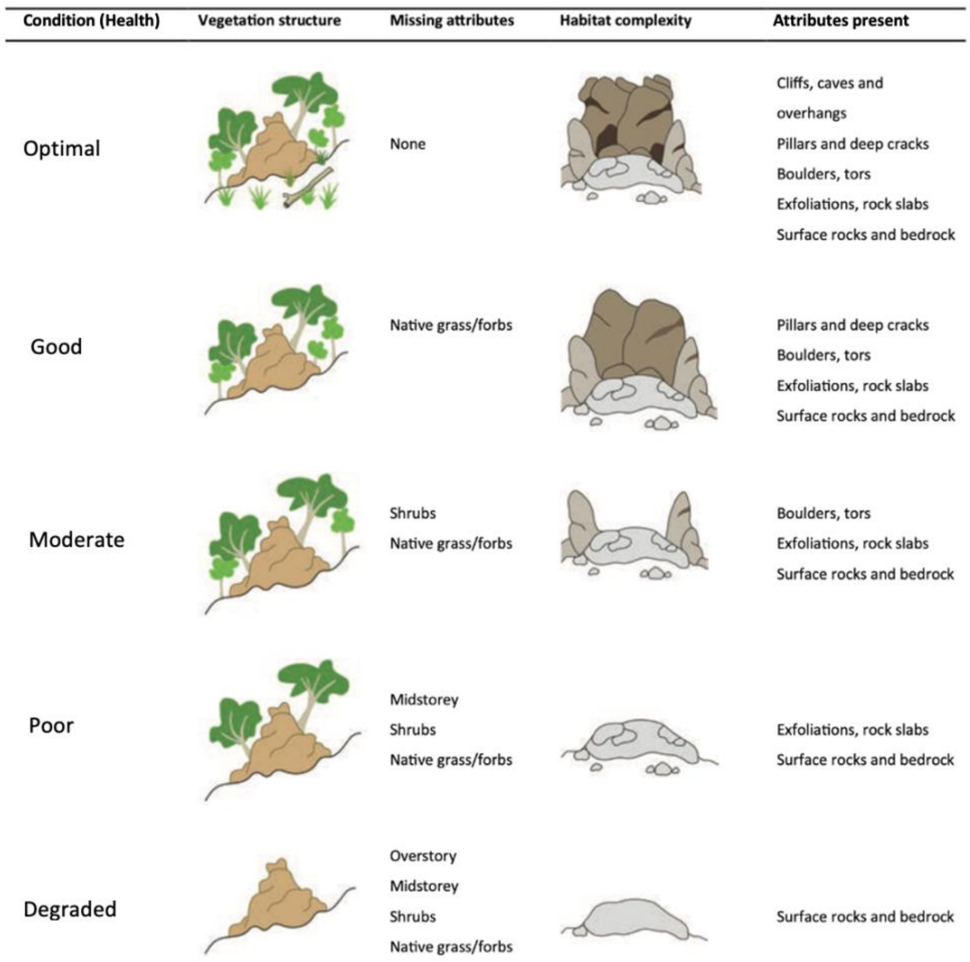
The two condition scores recorded for each outcrop were averaged to give an overall measure of outcrop health, allowing for comparison between outcrops. This assessment summarised the relationship between habitat complexity and vegetation structure, which is indicative of biodiversity. This cost and time-effective classification method allowed us to assess all the outcrops present at MVP over multiple field days and informed our management recommendations.

Surrounding structure, aspect and their extent were also influential determinants of an outcrop's ecological significance and therefore were also recorded. Surrounding structures were classified either as open or closed, an outcrop was considered closed when more than 50% of the rock structure was covered by either the landscape or vegetation, providing protection. Extent is important as larger patches are less sensitive to disturbance and biological invasion, and therefore require less management. The extent was determined in GIS after data collection using a combination of satellite imagery, LIDAR and field photography.

Due to the time constraints of this project, an assessment of the biophysical attributes of the outcrops was not able to be completed. However, understanding the biophysical attributes present, particularly flora, would greatly inform management strategies. Quadrats should be used to quantify the species percentage cover on selected outcrops that are representative of others of the same condition. Other key determinants of outcrop composition must also be considered such as slope, aspect (which also includes broad inclined for flat/rounded outcrops), soil, condition, and altitude (Wiser et al., 1996; Do Carmo et al., 2015). Repeating quadrats every three years would allow the compositional vegetation changes to be measured, providing a benchmark for assessing the effectiveness of the strategies selected (Fitzsimons & Michael, 2017). Regular and accurate monitoring can also be used to support funding applications.

Figure 10

Rubric for Classifying Rock Outcrops Based on Condition



Vegetation structure is considered ‘optimal’ when there are multiple levels of vegetation structure present, these are grasses, shrubs, midstory and overstorey. Habitat complexity also requires multiple attributes to be present to be considered ‘optimal’, these are caves, overhangs, deep cracks, and cliffs.

An ‘optimal’ outcrop has attributes that can support a wider range of both fauna and flora. As attributes are lost, their condition reduces until it is considered degraded. For ‘optimal/good’ outcrops, little to no management may be necessary to maintain them, in contrast, ‘poor/degraded’ outcrops may require substantial management and resources to improve their conservation value (e.g. fencing, weed control).

MVP Rocky Outcrops

Overview of Observations

- 172 Rocky outcrops were identified, approximately 8.44% of the area at MVP (Figure 11)
- 47.67% of rocky outcrops had no vegetation (Figure 12)
- 4.65% have overstorey and 5.81% have midstorey (Figure 12)
- 14.53% rocky outcrops in good-optimal range (Figure 11)
- 27.9% rocky outcrops in the moderate range (Figure 11)
- 57.56% rocky outcrops in the poor-degraded range (Figure 11)
- 47.67% of rocky outcrops were in a closed area (Figure 13)
- 52.33% of rocky outcrops were in an open area (Figure 13)
- 81.4% of rocky outcrops are unfenced (Figure 14)
- 18.6% of rocky outcrops are fenced (Figure 14)
- Rocky outcrops face all aspects including ‘broad inclined’ (Figure 15)

Figure 11

Map of Rocky Outcrop Health Classification

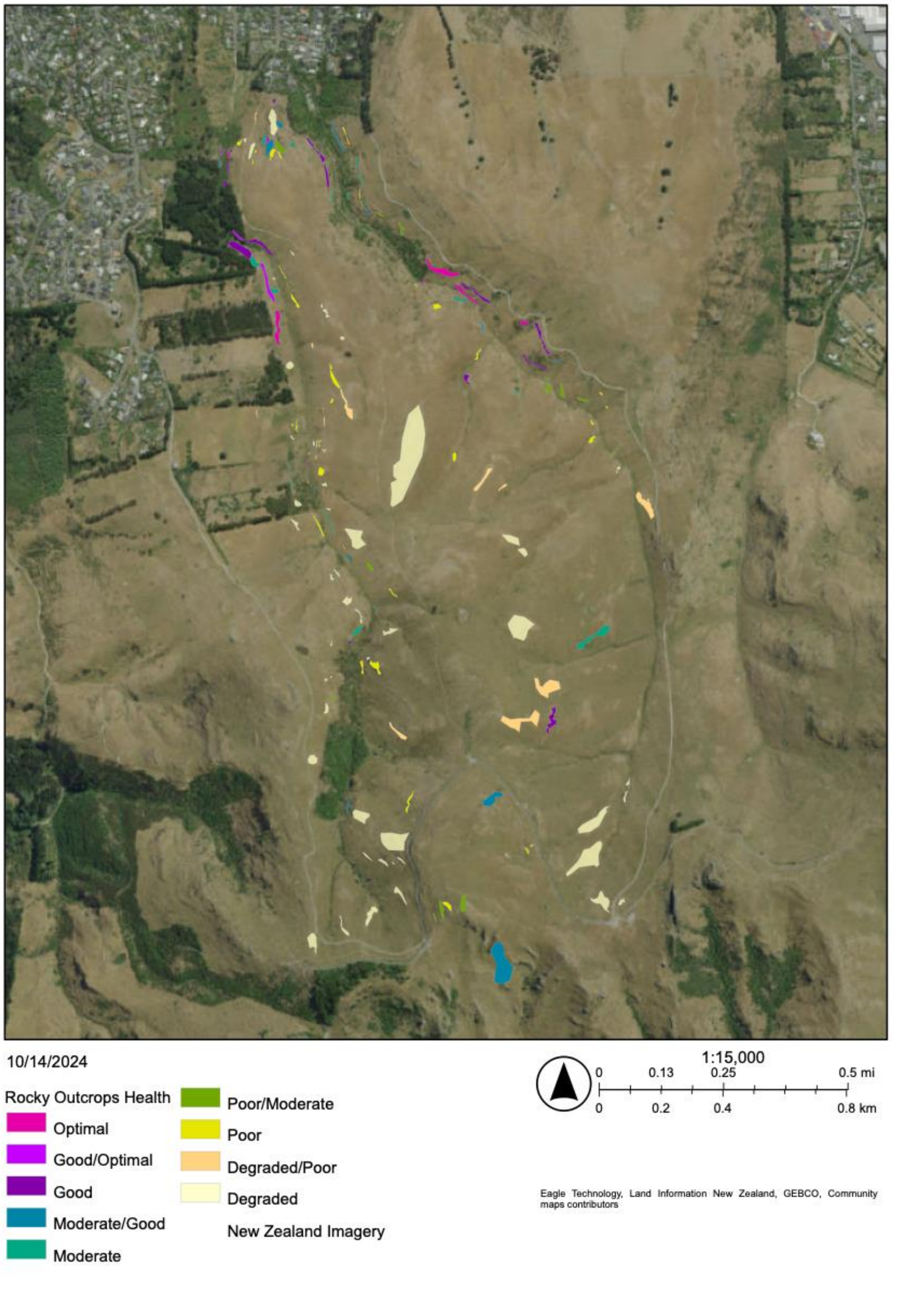


Figure 12

Map of Rocky Outcrop Vegetation Structure Classification

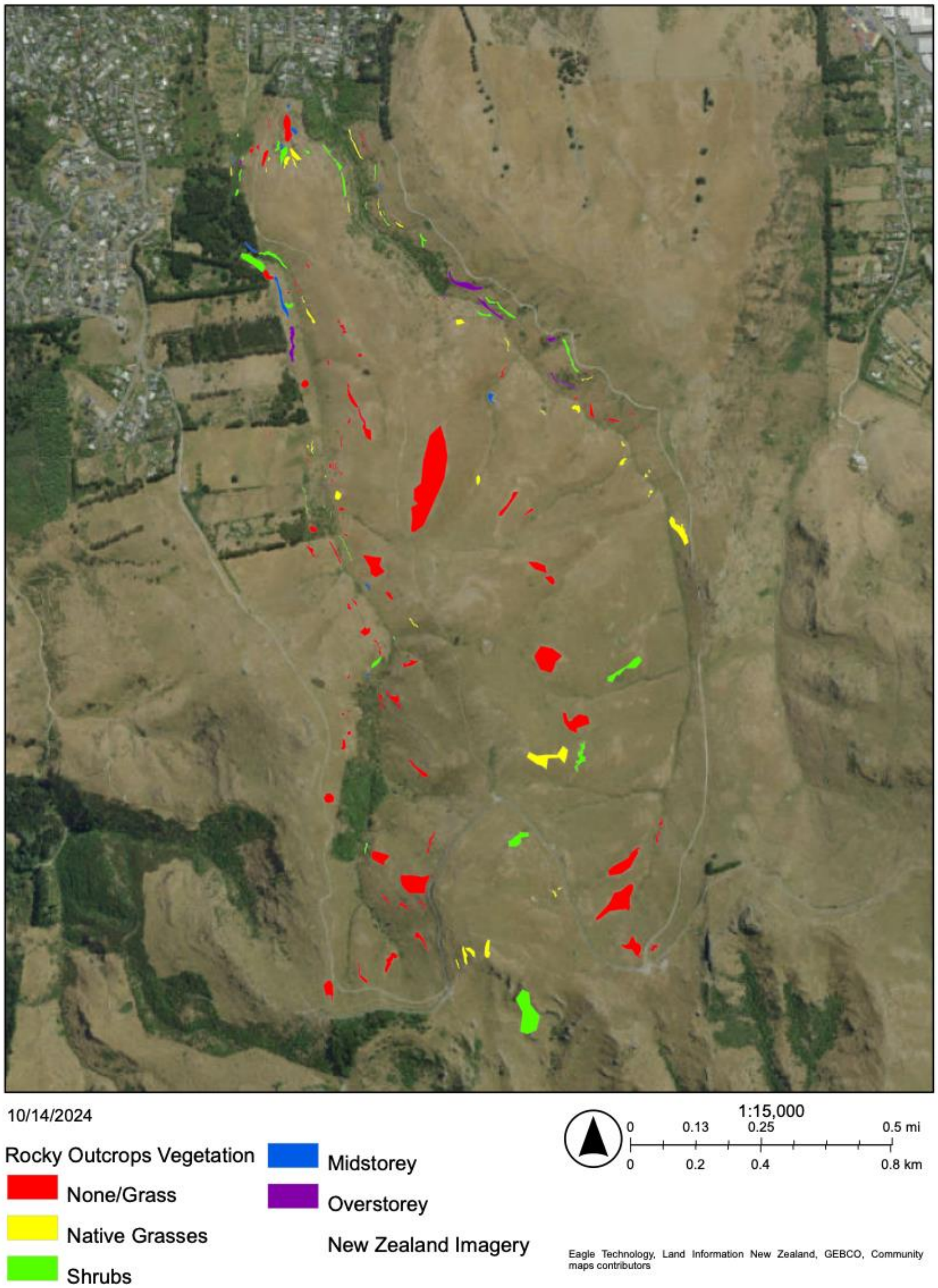


Figure 13

Map of Surrounding Structure of Rocky Outcrops

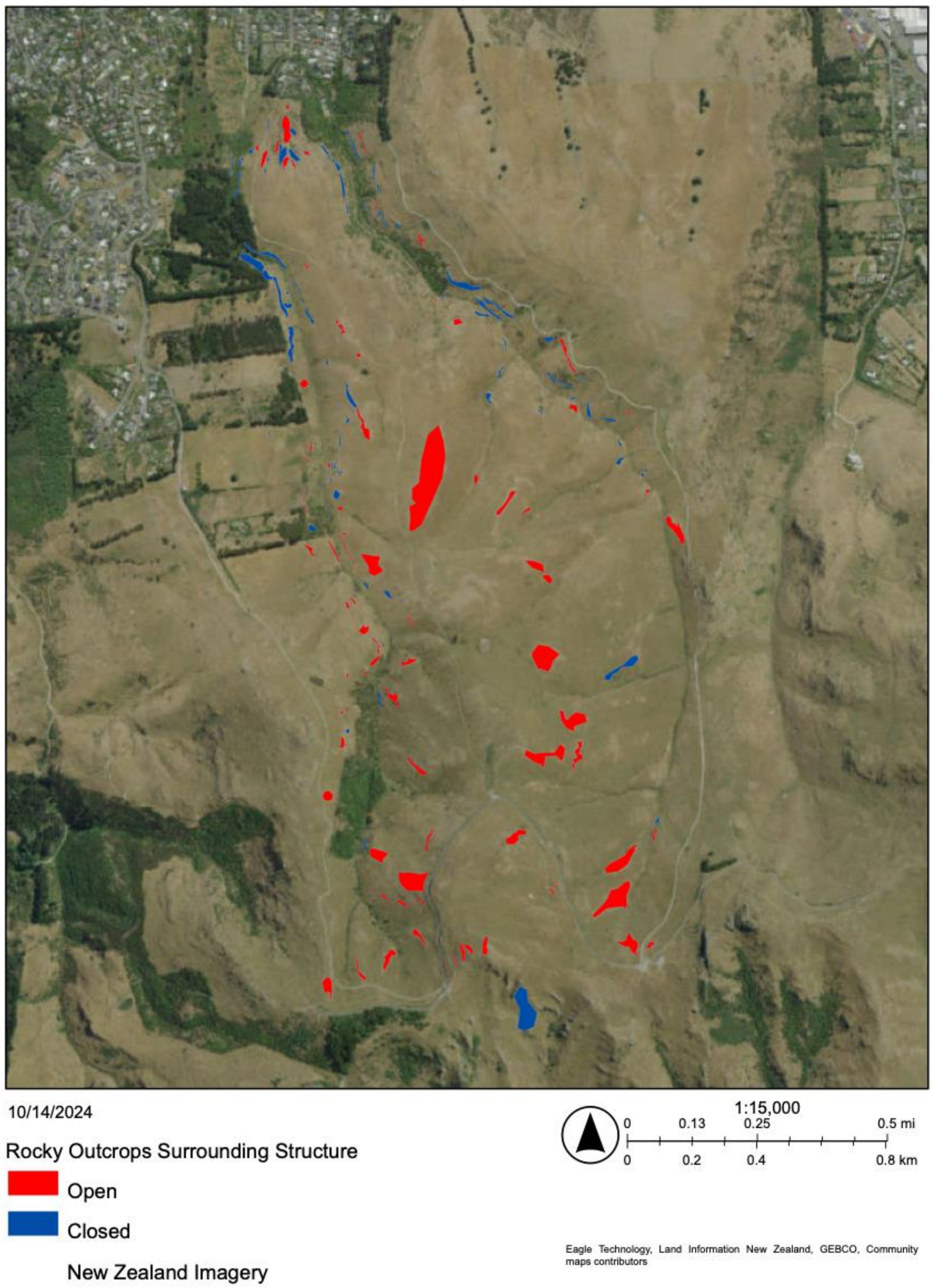
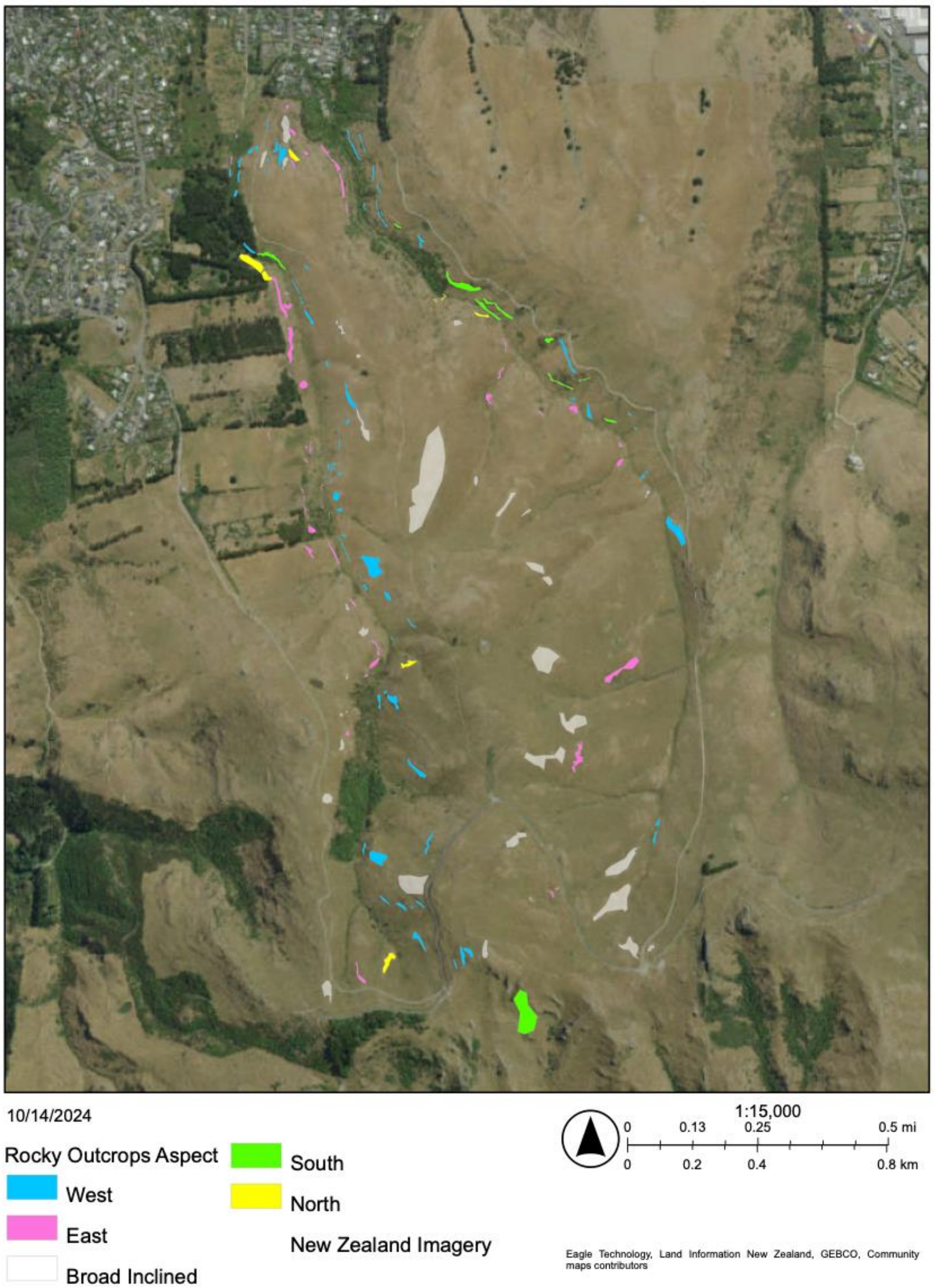


Figure 14

Map of Protection showing Fenced and Unfenced Rocky Outcrops

Figure 15

Map of Rocky Outcrop Aspect



A greater proportion of optimal rocky outcrops lie within the retired areas. This can be attributed to these areas being in the lower portions of either valley, being the steepest and most densely vegetated areas, it contributes to both the structural and vegetation complexity of the outcrops. Broad-inclined areas within the grazed land hold most of the outcrops in poor/degraded health, with little vegetation and complexity. Currently, these outcrops have little conservation value and have been heavily affected by sheep and human activities.

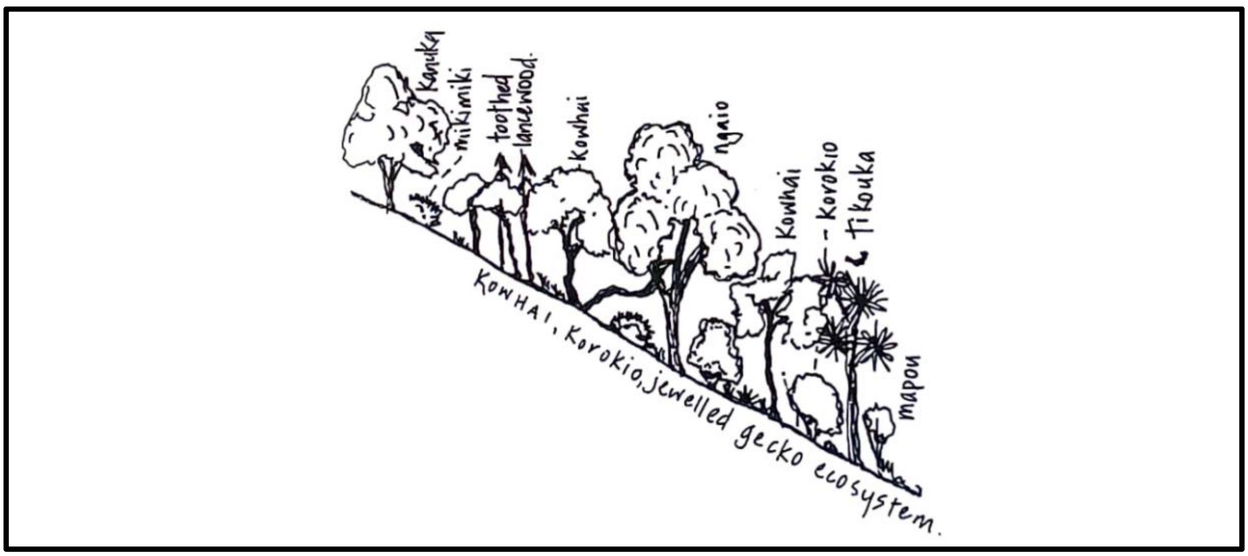
There are exceptions to these findings across the park due to the variability of outcrops and terrain. A notable example is an outcrop within the grazed area of good health. It was determined that due to its surrounding structure being closed, the outcrop had ample protection from climatic conditions allowing vegetation to establish. The presence of multiple lizards within this outcrop exhibits that this is an optimal habitat for these vulnerable species.

Restoration Plantings and Outcrop Health

Historically, the Port Hills were under podocarp/hardwood forest (Christchurch City Council, n.d.). The Dry Bush Reserve remnant and other existing vegetation at MVP are good indicators of which species can thrive and how ecological succession will occur. A wide range of flora inhabits the rocky outcrops which typically lie on steep slopes. Soils at MVP are imperfectly drained, silt loam of shallow to moderate depth, which are often eroded. The natural vegetation of these sites are drought-tolerant trees, shrubs, herbs, as well as lichen and mosses. Where conditions are shadier and more humid, a greater range of forest species can survive. Current plantings at MVP have been selected to restore the natural system of the valley, future plantings should be selected to meet the same criteria. A diverse variety of species that encapsulate differing structural levels would best improve an outcrop's health, by increasing available habitat for flora and fauna. Allowing for other species to establish and biodiversity to increase, improves the ecological significance and health of the site. Figure 16 shows the idealised structure of flora species on steep, shallow soils. Appropriate species for planting in this habitat would be Coprosma Crassifolia, Sophora Prostrata, Pseudopanax Crassifolius, Myoporum Laetum, Kunzea Ericoides and Corokia Cotoneaster (Lucas, 2005). Looking at previous plantings in the park, fencing greatly improves the success of plantings by reducing disturbance, allowing species to establish and thrive and restoring natural ecosystem function.

Figure 16

Restoration Plantings for Rocky, Steep Slopes with Shallow, very Well-drained Soils



Note: Plantings for restoration. From Lucas (2005). Indigenous ecosystems of the Lyttelton Harbour Basin*: a guide to native plants, their ecology and planting*. Lucas Associates.

Rocky Outcrop Threats

Understanding the threats and their severity to rocky outcrops determines the priority of management actions. Degradation can be caused by a wide variety of stressors (Michael et al., 2010), such as disturbance, competition, erosion and fire, which can all deteriorate fragile micro-habitats, reducing the native plant cover and increasing the potential for weed colonisation (Fitzsimons & Michael, 2017). Species diversity decreases as the amount of disturbance increases (Sharma et al., 2023), therefore, to improve biodiversity, disturbance must be reduced.

Table 3

Threats to Rocky Outcrops at MVP

Threats	Description	Impacts	Suggested Management
Stock	Livestock are associated with several negative effects on rocky outcrop structure. Rocky outcrops are dry areas with a diverse range of vegetation coverage. Their characteristics make them vulnerable to livestock. Rocky outcrops are recognised as areas that livestock inhabit (Evans, 1988), meaning they are susceptible to damage. Intensive grazing results in a loss of vegetation coverage, associated with degraded vegetation structure (Figure 17).	Following field research, observations were made of the sheep's impacts on the land. There was clear evidence of grazing, trampling and defecation. These effects were observed to have degraded specific areas of MVP, including rocky outcrops. Outcrops typically with low rated habitat complexity were most at risk, due to their broad inclined aspect and open surrounding structure. These outcrops had evidence of sheep related disturbance, including manure, trampling, and tracking. Compaction leads to poor water infiltration and strips areas of vegetation leaving barren soil, which leads to erosion. Tracking causes void spaces between rocky outcrops and surrounding vegetation.	**Stock cycling** is a potential management method to be used. Partially removing stock by reducing stocking rates could benefit rocky outcrops. A combination of stock cycling with low intensity grazing ensures that exotic species are controlled which reduces environmental risk to biodiversity. Resting the land by removing livestock allows recovery from the impacts of sheep. Increasing paddock rest times has been proven to produce greater biomass along with ground cover (McDonald et al., 2019). **Stock exclusion** is another potential management method to consider. Stock exclusion is a way to protect the land from negative livestock impacts such as trampling and degradation of soil, vegetation and land. Exclusion can increase plant abundance but doesn't solely increase vegetation diversity (Filzzaola et al., 2020; McDonald et al., 2019). Native plantings support an increase in species diversity, which characterises 'optimal' vegetation structure. Stock exclusion does remove weed control and fire mitigation, therefore methods of these may need to be developed alongside blocks that will be retired.

Weeds	If sheep are removed from an area, the growth of weeds and grass is no longer suppressed by grazing. This means native and desirable flora are quickly outcompeted and are unable to survive. Proposed plantings will eventually outcompete the unwanted species to establish a canopy which then allows desired species to establish underneath.	Overgrowth of grasses and weeds causes an increased fire risk. Without the presence of livestock or any form of grazing, both can grow freely. Weeds and invasive species have adapted to rapidly produce biomass. A faster growth rate outcompetes native species. Lack of grazing gives invasive/weed species more opportunity to occupy space and outcompete other species, therefore it is more difficult to establish native bush/forest for the future.	Annually going out to target areas and clearing weeds, using a mixture of hand weeding and herbicide. Using powders or solid herbicides rather than sprays to target weeds without collateral damage to native species. Providing information boards with photos of weeds that the public can help identify and remove. This motivates the public to mark locations where invasive or weed species are present (i.e. INaturalist), to help volunteers and park workers eradicate these.
Fire	Full removal of stock from paddocks creates a potential fire risk when there is overgrowth of weeds and dry grasses. Sheep are a form of mitigation for fire risk in these dry areas, therefore a new strategy needs to be in place to control this fire hazard when they are removed.	Fire will cause loss of vegetative habitat. Occupation of paddock space by weeds, grasses and invasive species is usually relatively flammable compared to native species, this leads to the area becoming more prone to fire risk.	The best way to mitigate fire risk is by reducing dead or dry organic matter available on the ground. This involves maintaining the grass biomass to a manageable level to reduce the amount of potential fuel available. This requires a brush-cutter with plastic blades until plantings develop enough to shade grass, which will suppress growth. Planting fire-resistant species along the borders of at-risk areas of the park can help stop the spread of fire; the same can be achieved by excluding flammable species in proximity.

Erosion	Rocky outcrops are already relatively bare areas of land, which means further trampling may worsen the effects of erosion and runoff experienced. Animal trampling creates barren areas of soil that are easily eroded by rainfall and runoff (Evans, 1988). Eroded material travels downslope to enter the local river catchment, the Ōpāwaho Heathcote River. Currently, native plantings are used as a mitigation strategy for material runoff.	Surface water runoff directly onto rocky surfaces results in soil loss, therefore reducing the capacity of the outcrop to host plant species. Eroded rock faces are smooth with no overhangs, few crevices and structures for vegetation or other species to occupy. Erosion of the rocky outcrops could lead to trails/pathways becoming blocked in the future. Vegetation around outcrops such as grasses provides minimal soil stabilisation. Heavy rainfall events can cause landslides and runoff of sediment and soil, exposing bedrock.	Structural complexity is a natural determinant and cannot be improved easily. Improving vegetation structure is a much more effective solution to mitigate erosion risk. Increasing structural complexity is linked with more diverse root depth, further stabilising soils, therefore varied vegetation will create the most support. Redirection of direct surface runoff from tracks away from rocky outcrop faces. Excluding outcrops from livestock will reduce direct trampling effects. Moving the livestock to more open areas away from ecologically significant areas will reduce the effects of erosion caused by stock.
Humans	Outcrops are typically located away from marked paths or have a ‘closed’ structure, being inaccessible. Mid Albert Valley and Coronation Ridge have paths over outcrops, meaning their structures have potentially become degraded over time due to human activities.	Traffic is evident where soil has been turned over, compacted, or lost, where pathways have been created leading to patches of no vegetation and bare rock surfaces. Continued traffic will cause rocky outcrop faces to become more unstable with erosion and could lead to some areas being degraded beyond repair. With a high amount of degradation, trails and areas around the rocky outcrops could become more unstable.	If outcrops have a ‘closed’ surrounding structure, little management is needed. If an ‘open’ structured outcrop is at risk, temporary fencing or redirection of tracks could reduce trampling. Signage to encourage the public to keep to the defined trails will minimise the effects of disturbance. Specifically, when entering fenced areas, signage on entrance points will ensure the message is received.

Figure 17

Examples of Threats to Rocky Outcrops at MVP

Multiple rocky outcrops within MVP are in a degraded condition. However, several of these outcrops have the potential to be restored and improved. Selected areas will greatly benefit from management schemes that seek to improve outcrop health.

A proposed management method is to establish new areas of fencing, to exclude livestock and to protect future planting efforts. This land would be retired from grazing to allow for the new plantings to be established. This method is supported by previous success of revegetation in lower valleys of MVP.

Revegetation through plantings regenerates the native vegetation of the area, this is valuable for rocky outcrops as neighbouring vegetation improves health by developing multiple layers of vegetation structure. Establishing midstorey and overstorey would create a late ecological succession, a climax community of flora species, which can support the most biomass and biodiversity, improving the conservation value of the outcrops (Michael & Lindenmayer, 2018). The most beneficial way to improve the health of rocky outcrops is to therefore focus on re-establishing the vegetation present around the outcrops.

Fencing

Fencing is a key tool available to the PHPT. Suggested future fencing for protection of ecologically significant rocky outcrops is presented in Table 4 and Figure 18. Proposed fencing is identified within stages and selected due to factors such as cost and time effectiveness, benefits to rocky outcrops, and simplicity. Stages allow for fencing to occur in different time frames, providing time to prepare restoration plantings.

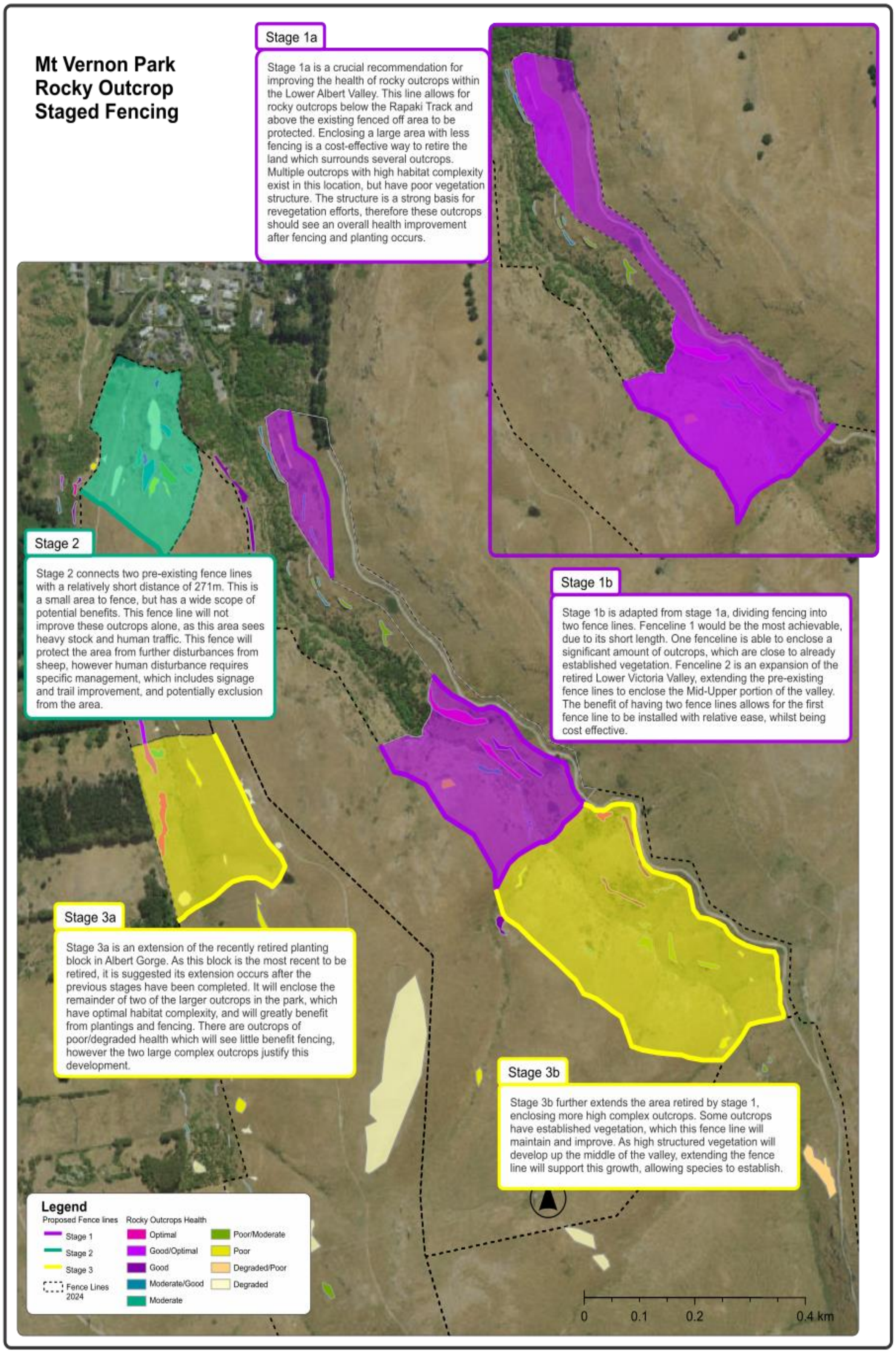
Table 4

Proposed Fencing Stages

Stage Number (Figure X)	Stage Location	Fencing Style	Fencing Description	Length of Fencing
1a	Lower/Mid-Upper Victoria Valley	Fencing enclosing all outcrops in lower valley	One fence line extends the existing fence along the west side of the valley, before turning 90°, transecting the valley before joining the existing fence line above the Rapaki track.	814m
1b	Lower/Mid-Upper Victoria Valley	Fencing enclosing all outcrops in lower valley	Two fence lines, the first connects the northernmost fence line, enclosing outcrops before rejoining with the existing fence line on the Eastern side of the valley. The second fence extends the existing fence along the West side of the valley, before turning 90°, transecting the valley, then turning 90° again it rejoins the existing fence on the Eastern side of the valley below Rapaki Track.	416m 1,279m
2	Mid Albert Valley	Fence enclosing all outcrops from the ridge to lower valley	Fence connecting existing fence at Dry Ridge Track down to the lower fence line at the Lower Albert Valley.	271m
3a (West)	Albert Gorge to the Mid Albert Valley	Fences extending the current retired area	Extends from Albert Gorge to the Mid Albert Valley, then back Westward connecting to the existing fence line boundary. An extension of the current planting block that has been retired for revegetation (Figure B.1).	681m
3b (East)	Mid-Upper and Upper Victoria Valley	Fences extending the proposed retired area	Fence lines further extend the retired area Southward to meet the proposed stage 2 fence line that transects the valley, creating a partition between the Mid-Upper and Upper Victoria Valley Areas.	1765m

Figure 18

Staged Fencing Proposal of Rocky Outcrops of MVP



Conclusion

Areas of ecological significance in MVP were researched and defined to be wetlands and rocky outcrops. These zones were identified to be highly ecologically significant. Wetlands are considered ecologically significant based on the various ecosystem functions they provide for their surrounding environment, ultimately promoting healthy ecosystems. The main ecosystem functions wetlands promote are biodiversity increments, biochemical functions, filtering and cleaning affiliated water and mitigating potential flooding risks (LePage, 2011). Other ecosystem functions are outlined in Table 1. Rocky outcrops are considered small natural features and are ecologically significant because they provide ecosystem services to many different flora and fauna (Fitzsimons & Michael, 2016). They are microhabitats of inorganic structure that provide long-term habitat to sensitive species requiring refuge (Fitzsimons & Michael, 2016). They provide microcosms to a range of species separating from the surrounding environment leaving them less exposed to disturbances such as weather extremes and high-intensity fires (Fitzsimons & Michael, 2016).

Wetlands and rocky outcrops were identified within MVP using methodologies developed from the literature. Wetlands within the park were found to be slope wetlands, which were in a degraded to highly degraded condition. Rocky outcrops were rated from degraded to optimal based on their health which was defined by their habitat complexity and vegetation structure. These features were mapped using ArcGIS to create a database. Effective management recommendations have been made to protect and sustain these sensitive areas. These include headcut stabilisation, silt socks, silt fences and revegetation for wetlands, and fencing and revegetation for rocky outcrops.

Limitations were found to exist within the scope of research. Other wetlands sites, not identified in this project, are likely to exist within MVP. Following the methodology discussed, these should be sought out and mapped using Field Maps and ArcGIS to collect more data to inform future restoration projects. Rocky outcrops were rated on vegetation structure; however, this category did not quantify biodiversity, which plays a role in outcrop health as part of an ecologically significant habitat. Future research should identify the key role vegetation diversity plays, by specifically quantifying presence.

References

Blackwell, M. S. A., & Pilgrim, E. S. (2011, December, 16). Ecosystem services delivered by small-scale wetlands. Hydrological Sciences Journal, *56*(8), 1467–1484. https://doi.org/10.1080/02626667.2011.630317

Bright Hub Engineering. (n.d.). *Rational Method Runoff Coefficient Tables for Storm Water Runoff Calculation*. Retrieved October 11, 2024, from https://www.brighthubengineering.com/hydraulics-civil-engineering/93173-runoff-coefficients-for-use-in-rational-method-calculations/

Christchurch City Council (n.d). Port Hills. Retrieved August 1, 2024, from https://www.ccc.govt.nz/assets/Documents/Parks-Gardens/Find-a-park/FactsheetPORTHILLS-naturalenvironment.pdf

Cirtex Industries Ltd. (2022, April, 7). *EnviroPlus Silt Socks & Grow Socks—Cirtex*. https://cirtexcivil.co.nz/products/silt-control/enviroplus-silt-socks-grow-socks/

Clarkson, B., & Peters, M. (2010). Revegetation. In M. Peters & B. Clarkson (Eds.), *Wetland Restoration: A handbook for New Zealand freshwater systems* (2nd ed., pp. 154-183). Manaaki Whenua Press.

Department of Conservation. (n.d.). Wetlands. https://www.doc.govt.nz/nature/habitats/wetlands/

Do Carmo, F.F., De Campos, I.C. & Jacobi, C.M. (2015). 'Effects of fine-scale surface heterogeneity on Rock Outcrop Plant Community structure', *Journal of Vegetation Science*, 27(1), pp. 50–59. doi:10.1111/jvs.12342.

Environment Canterbury. (2024, June, 10). Importance of wetlands. https://www.ecan.govt.nz/your-region/your-environment/biodiversity-and-biosecurity/biodiversity/wetlands/importance-of-wetlands/

Evans, R. (1998). *The erosional impacts of grazing animals.* Progress in Physical Geography: Earth and Environment, *22*(2), 251–268. https://doi.org/10.1177/030913339802200206

Filazzola, A., Brown, C., Dettlaff, M. A., Batbaatar, A., Grenke, J., Bao, T., Peetoom Heida, I., & Cahill, J. F. (2020). The effects of livestock grazing on biodiversity are multi-trophic: A meta-analysis. *Ecology Letters*, *23*(8), 1298–1309. https://doi.org/10.1111/ele.13527

Fitzsimons, J.A. & Michael, D.R. (2017). 'Rocky outcrops: A Hard Road in the conservation of critical habitats', *Biological Conservation*, 211, pp. 36–44. doi:10.1016/j.biocon.2016.11.019.

Good Rich Environmental Solutions. (n.d.). *New Zealand's leaders in erosion control and bio-engineering.* GoodRich. Retrieved October 11, 2024, from https://www.goodrich.nz/bio-socks

Greater Wellington Regional Council. (2005). Understanding the 'wet' in wetlands: A guide to the management of freshwater wetland hydrology. https://www.gw.govt.nz/assets/Documents/2009/07/1893wetlandhydrologs3589.pdf

Greater Wellington Regional Council. (2009, June). *A beginner's guide to wetland restoration*. https://riversgroup.org.nz/wp-content/uploads/2018/06/4.0_GW-Guide-to-wetland-restoration.pdf

Hampton, S., McGuire, C., Carrol, B., Armanetti, C., Pontifex, T., Holzer, I., & Bell, D. (2018). Hydrogeology, mapping, and management strategies for volcanic derived perched springs of Banks Peninsula. pp. 1-22. https://www.greaterchristchurch.org.nz/indicators/environment/water-use

Hampton, S.J. & Cole, J.W. (2009). 'Lyttelton volcano, Banks Peninsula, New Zealand: Primary Volcanic landforms and eruptive centre identification', *Geomorphology*, *104*(3–4), pp. 284–298. doi:10.1016/j.geomorph.2008.09.005.

Hunter, M.L. (2017). 'Conserving small natural features with large ecological roles: An introduction and definition', *Biological Conservation*, 211, pp. 1–2. doi:10.1016/j.biocon.2016.12.019.

Johnson. P., & Gerbeaux. P. (2004). Wetland Types in New Zealand. Department of Conservation; Te Papa Atawhai. https://www.doc.govt.nz/globalassets/documents/science-and-technical/wetlandtypes.pdf

LePage, B. (2011). Wetlands: Integrating Multidisciplinary Concepts. *Springer.* https://link.springer.com/book/10.1007/978-94-007-0551-7

Lucas, D. (2005). Indigenous ecosystems of the Lyttelton Harbour Basin*: a guide to native plants, their ecology and planting*. Lucas Associates.

Lucas, D. (2011). *Christchurch Eco Systems.* https://www.lucas-associates.co.nz/ecosystems/porthills.html

McDonald, S. E., Lawrence, R., Kendall, L., & Rader, R. (2019). Ecological, biophysical and production effects of incorporating rest into grazing regimes: A global meta-analysis. *Journal of Applied Ecology*, *56*(12), 2723–2731. https://doi.org/10.1111/1365-2664.13496

Michael, D., & Lindenmayer, D.B. (2018). Rocky outcrops in Australia: *ecology, conservation and management*. 199-152 Clayton, South VIC: CSIRO Publishing.

Michael, D.R., Lindenmayer, D.B., & Cunningham, R.B. (2010). ‘Managing rock outcrops to improve biodiversity conservation in Australian agricultural landscapes’, *Ecological Management & Restoration*, *11*(1), pp. 43–50. doi:10.1111/j.1442-8903.2010.00512.x.

Myers, S. C., Clarkson, B. R., Reeves, P. N., & Clarkson, B. D. (2013). Wetland management in New Zealand: Are current approaches and policies sustaining wetland ecosystems in agricultural landscapes? *Ecological Engineering*, *56*, 107–120. https://doi.org/10.1016/j.ecoleng.2012.12.097

Peters, M. (2010). Restoration Planning. In M. Peters & B. Clarkson (Eds.), *Wetland Restoration: A handbook for New Zealand freshwater systems* (2nd ed., pp. 10-25). Manaaki Whenua Press.

Peters, M. (2010). Wetland Protection. In M. Peters & B. Clarkson (Eds.), *Wetland Restoration: A handbook for New Zealand freshwater systems* (2nd ed., pp. 262-273). Manaaki Whenua Press.

Port Hills Park Trust. (n.d.). Mt Vernon Park. https://www.mtvernonpark.org.nz/

Port Hills Park Trust (2006). Mt Vernon Park Management Plan.

Shanks, A., & Turney, G. (2013). Carews Peak, Edzell Farm, Wainui, Banks Peninsula: An Application to the Nature Heritage Fund. Unpublished Report prepared for the Nature Heritage Fund, July 2013. 46 p. (Trim: 15/284144).

Sharma, A., Patel, S.K. & Singh, G.S. (2023). ‘Variation in species composition, structural diversity, and regeneration along disturbances in tropical dry forest of Northern India’, *Journal of Asia-Pacific Biodiversity*, *16*(1), pp. 83–95. doi:10.1016/j.japb.2022.11.004.

Sieben, E.J.J., Khubeka, S.P., Sithole, S. et al., (2017). The classification of wetlands: integration of top-down and bottom-up approaches and their significance for ecosystem service determination. Wetlands Ecology Management, *26,* 441–458. https://doi.org/10.1007/s11273-017-9585-4

Spieles, D. J. (2022). Wetland Construction, Restoration, and Integration: A Comparative Review. *Land*, *11*(4). https://doi.org/10.3390/land11040554

Stein, E.D., Mattson, M., Fetscher, A.E. et al. (2004, June). Influence of geologic setting on slope wetland hydrodynamics. Wetlands *24*, 244–260. https://doi.org/10.1672/0277-5212(2004)024[0244:IOGSOS]2.0.CO;2

Taddeo, S., & Dronova, I. (2018). Indicators of vegetation development in restored wetlands. *Ecological Indicators*, *94*, 454–467. https://doi.org/10.1016/j.ecolind.2018.07.010

Tomscha, S., J. Deslippe, M. deRóiste, S. Hartley, & B. Jackson. (2019). Uncovering the ecosystem service legacies of wetland loss using high-resolution models. *Ecosphere.* https://doi.org/10.1002/ecs2.2888

Walton, M., Jansens, J. W., Adams, J., Tatro, M., & Gadzia, T. E. (2019, December 11). Applying Keyline Design Principles to Slope Wetland Restoration in a Headwater Ecosystem. https://quiviracoalition.org/keyline-design-headwater-ecosystem/

Wiser, S. K., & Buxton, R. P. (2009). Montane outcrop vegetation of Banks Peninsula, South Island, New Zealand. *New Zealand Journal of Ecology*, *33*(2), 164–176. http://www.jstor.org/stable/24060619

Appendix A

Figure A.1

Distinguishing features of New Zealand wetlands

Wetland Class	Water origin (predominant)	Water flow	Drainage	Water table position cf. ground	Water fluctuation	Periodicity	Substrate	Nutrient status	pH
Bog	rain only	almost nil	poor	near surface	slight	wetness permanent	peat	low or very low	3–4.8
Fen	rain + groundwater	slow to moderate	poor	near surface	slight to moderate	wetness near-permanent	mainly peat	low to moderate	4–6
Swamp	mainly surface water + groundwater	moderate	poor	usually above surface in places	moderate to high	wetness permanent	peat and/or mineral	moderate to high	4.8–6.3
Marsh	groundwater + surface water	slow to moderate	moderate to good	usually below surface	moderate to high	may have temporary wetness or dryness	usually mineral	moderate to high	6–7
Seepage	surface water and/or groundwater	moderate to fast	moderate to good	slightly above to below surface	nil to moderate	permanent wetness to temporary dryness	peat, mineral, or rock	low to high	4–7
Shallow water	lake, river, etc., or adjacent groundwater	nil to fast	nil to good	well above surface: inundated	nil to high	wetness almost permanent	usually mineral	moderate	4–7
Ephemeral wetland	groundwater + rain	nil to slow	moderate to good	well above to well below surface	marked wet/dry alternation	seasonal, sometimes temporary wetness/dryness	mineral	moderate	5.5–7
Pakihi and gumland	mainly rain	almost nil	poor	below surface	slight to moderate	wetness near-permanent but prone to temporary drought	mineral or peat	very low to low	4.1–5
Saltmarsh	seawater, brackish water, salt spray, groundwater from land	moderate to slow	good	closely below surface between tides	tidal, or slight in supratidal zone	mainly tidal	mainly mineral	moderate	4.9–8

Note. From Johnson. P., & Gerbeaux. P. (2004). Wetland Types in New Zealand. Department of Conservation; Te Papa Atawhai. (https://www.doc.govt.nz/globalassets/documents/science-and-technical/wetlandtypes.pdf)

Figure A.2

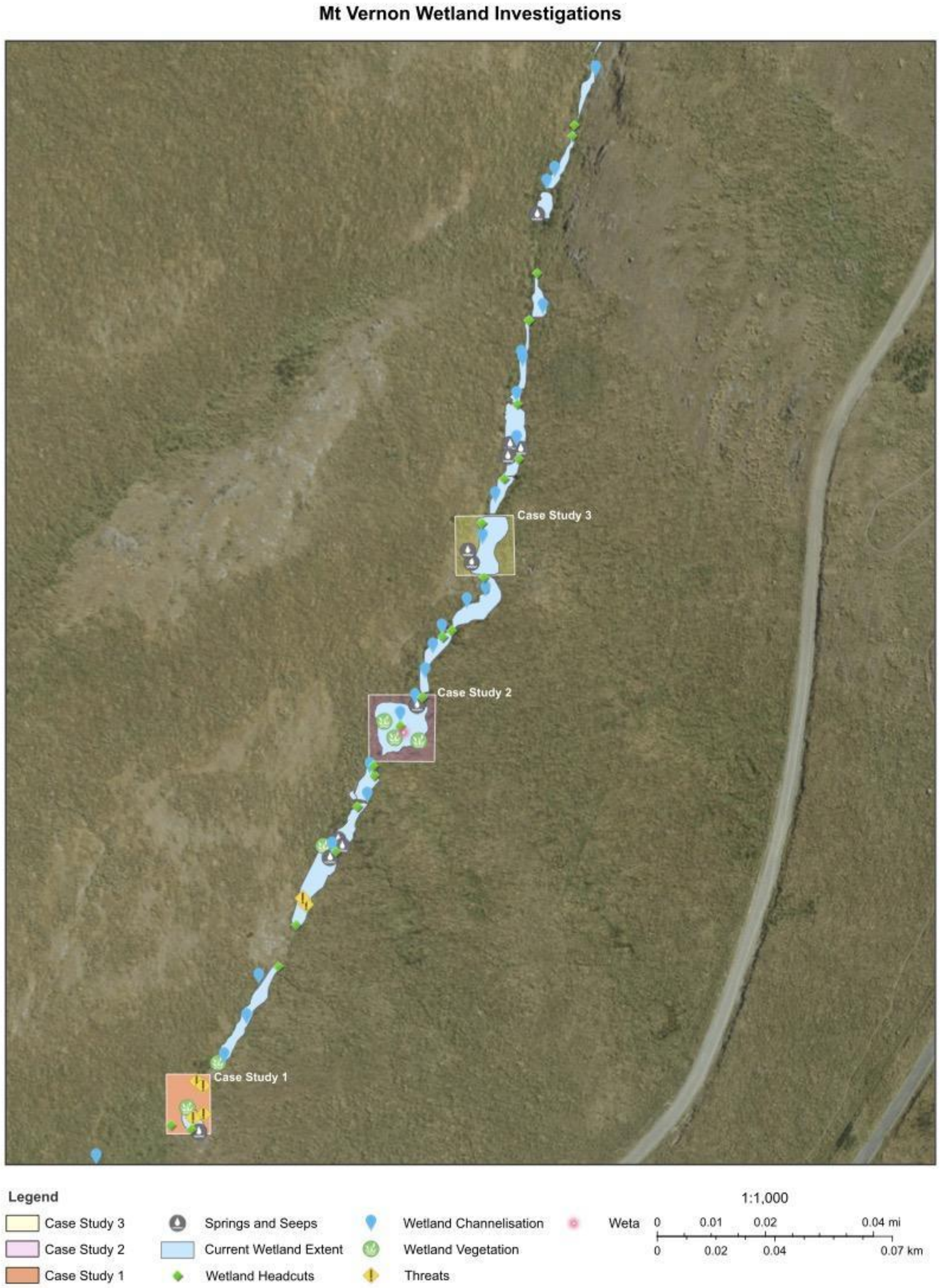
Landforms, vegetation and key indicators plants associated with wetland class in New Zealand

Wetland Class	Predominant landforms	Common vegetation structural classes	Some key indicator plants
Bog	usually almost level ground, including hill crests, basins, terraces	wide range including moss, lichen, cushion, sedge, grass, restiad, fern, shrub, and forest types	*Sphagnum*, *Oreobolus*, *Baumea tenax*, *Sporadanthus*, *Empodisma*, *Dracophyllum*, *Epacris*, *Leptospermum*, *Halocarpus*
Fen	slight slopes of bog margins, swamp perimeters, hillside toe slopes, alluvial fans	usually sedge, restiad, rush, fern, tall herb, or scrub types	*Schoenus pauciflorus*, *S. brevifolius*, *Empodisma*, *Chionochloa rubra*, *Hebe odora*, *Baumea teretifolia*, *Leptospermum*
Swamp	mainly on valley floors, plains, deltas	usually sedge, rush, reed, tall herb, and scrub types, often intermingled, and including forest	*Phormium*, *Carex*, *Coprosma*, *Gahnia*, *Typha*, *Cordyline*, *Dacrycarpus*, *Laurelia*, *Syzygium*
Marsh	slight to moderate slopes, valley margins, edges of water bodies	typically rush, grass, sedge, or shrub types	*Juncus*, *Carex*, *Agrostis*, *Cortaderia*
Seepage	moderate to steep hill slopes, scarps; heads and sides of water courses	usually low-stature moss, cushion, or sedge types; sometimes scrub or forest	*Carpha alpina*, *Montia*, mosses
Shallow water	ponds, pools, streams; margins of lakes, lagoons, rivers	submerged, floating, or emergent aquatics	*Myriophyllum*, *Potamogeton*, *Azolla*, *Bolboschoenus*, *Baumea*, *Ruppia*, *Schoenoplectus*, *Isolepis*
Ephemeral wetland	closed depressions especially on moraines, bedrock, dunes, tephra	marginal zones of turf and sedge sward, sometimes rushland and scrub	*Glossostigma*, *Lilaeopsis*, *Myriophyllum*, *Pratia*, *Isolepis*, *Carex gaudichaudiana*, *Eleocharis*
Pakihi and gumland	level to rolling or sloping land having impervious soils, including pakihi, gumland, and formerly forested land	mixtures of heaths and other small-leaved woody plants with restiads, ferns, sedges, lichens, mosses	*Empodisma*, *Baumea tenax*, *Gleichenia*, *Schoenus*, *Leptospermum*, *Dracophyllum*, *Nothofagus*, *Dacrydium*
Saltmarsh	margins of estuaries; wet coastal platforms	seagrass meadow, turf, herbfield, rushland, scrub, mangroves	*Zostera*, *Sarcocornia*, *Samolus*, *Apodasmia*, *Plagianthus divaricatus*, *Avicennia*

Note. From Johnson. P., & Gerbeaux. P. (2004). Wetland Types in New Zealand. Department of Conservation; Te Papa Atawhai. (https://www.doc.govt.nz/globalassets/documents/science-and-technical/wetlandtypes.pdf)

Figure A.3

Map of Wetlands with Legend

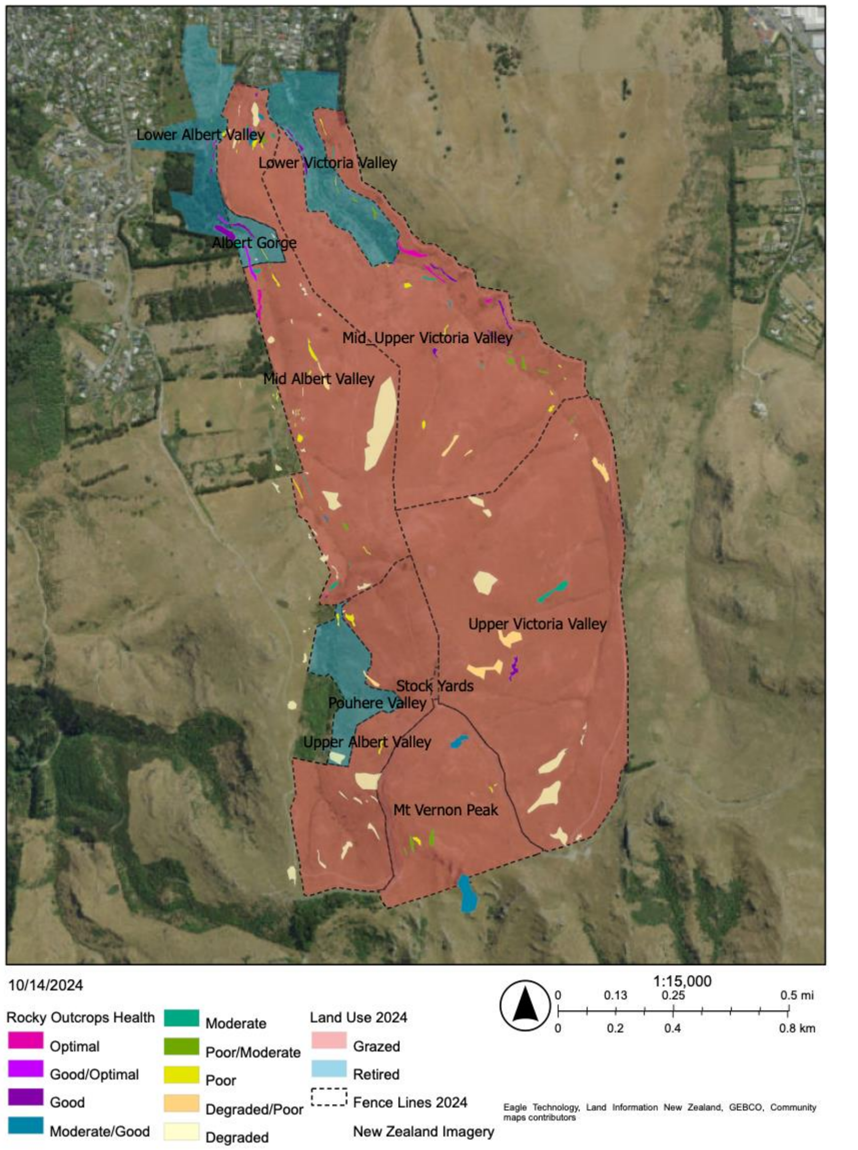


Note. Map showing the wetlands and their associated characteristics present within Mt Vernon Park

Appendix B

Figure B.1

Map of current land use at MVP



Note. MVP land use in terms of retired and grazed blocks. Proposed fence lines extend from these existing lines.