

TREES FOR CANTERBURY

Optimising Native Plant Regeneration on Marley Hill

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1. Executive Summary

- What is an optimal native-plant regeneration strategy which fits the drainage flow for Marley Hill and 'Flying Nun' mountain bike track?
- Trees for Canterbury are a well-established community organisation who expressed a need to optimise native plant regeneration efforts within the Port Hills, specifically on Marley Hill and the 'Flying Nun' mountain bike track. The research objective focusses on drainage as an important variable when addressing optimal regeneration.
- Physical soil samples were collected and analysed in the field and in the laboratory, as well as using a Geographic Information System (GIS) to model the hydrological processes of Marley Hill. Combined, these analysis techniques gave an understanding of the soil composition and drainage to deliver an optimal planting guide.
- Soil moisture and drainage play the most important roles in site suitability for the native plants, as well as being the most varied elements. Soil testing showed consistent results for most soil characteristics except for drainage capability. Soils are composed of silt loam. The result of GIS hydrology modelling produced two specific maps. One displays a stream order or drainage network. The second identifies the location waypoints that validate the models integrity. The final figure displays the site specific planting guide.
- There is a limitation in the validity of infiltration results. There was also significant manipulation of the Digital Elevation Model for features such as depressions. Another limitation identified is the representation of all possible soil characteristics which influence native plant survival.
- The addition of a non-regeneration zone, and a larger more accurate scientific sample as well as analysis of soils is recommended for a further defined classification of appropriate plants for regeneration.

2. Introduction

The community partner, Trees for Canterbury, a well-established community organisation, introduced a need to best optimise regeneration efforts, by analysing the physical characteristics within a recreational environment. Trees for Canterbury has an aim to employ, educate and regenerate. The goal of this research project is to offer an educational set of tools so that Trees for Canterbury can optimise their regeneration effort within the Port Hills, specifically on Marley Hill. This research site is located on the Port Hills in Christchurch, and is currently utilised as a recreational mountain bike area. This report addresses the issue of successful native plant regeneration, focused on the question, what is an optimal native-plant regeneration strategy which fits the drainage flow for Marley Hill and 'Flying Nun' mountain bike track? The research objective focusses on drainage as an important variable when addressing optimal native plant regeneration. Background on the sites history and regeneration concepts are introduced, followed by processes utilised in answering the research question focusing on optimisation of regeneration.

The Port Hills was originally covered in native vegetation that was cleared for pasture during early European settlement (Ogilvie, 2000). The Port Hills have been covered in gorse for many years (Williams, 1983) initiating the need for native regeneration. Native deforestation has produced problems with increased erosion and storm water drainage issues (Ogilvie, 2000). Land intensification by grazing sheep, cattle, rabbits and possums as well as competing introduced weeds, has contributed to the reduction of native tussocks, threatened bush, and increased the problems associated with land management (Ogilvie, 2000). Managing active land use, as well as protecting and preserving the natural environment results in a complicated issue. Certain areas of the Port Hills, including Marley Hill, are protected by the Christchurch City Council (CCC), while other areas are in private ownership. As economic conditions have changed some farmers have resorted to planting exotic forests in areas that were previously grazed (Ogilvie, 2000). The scenic views the Port Hills offer are the main attraction for recreation and tourism (Brumley, 1980). Activities such as walking, running, rock climbing and mountain biking have become popular over the last decade (Ogilvie, 2000). With many well-kept tracks suited to multiple fitness levels. These tracks can be linked to form extensive circuits (Summit Road Society, n.d.). One track being the 'Flying Nun' situated on Marley Hill.

3. Concepts and Literature Review

3.1 Regeneration

Linehan and Gross (1998) insist that landscape planning must incorporate and account for a challenge to social, political, and economic influences on ecology; that social attitudes

determine the direction that ecological restoration processes take. This can be witnessed by regeneration efforts on Marley Hill as Trees for Canterbury and CCC operate to restore land use activities from economic driven agriculture back to a regenerated natural ecosystem. Thurston and Reader (2001) concluded that in relatively short-term time scales (years) effects on soil and forest habitat would be impacted greatest by mountain biking and other recreational activity. Because of this recreational impact it is of great importance that any regeneration efforts made are planned effectively for optimal survival of plants. This not only benefits the natural ecosystem, but maximises Trees for Canterbury's investment and involvement in native regeneration. Trees for Canterbury and the CCC have been investing time in the Marley Hill recreational area prior to approaching the University with an opportunity. It had been noticed that the same species of native plants were experiencing different growth rates and survival potential within close proximity to each other, as seen in Figure A.1, Appendix A.

The current vegetation of Marley Hill is predominately introduced species, with a large amount of gorse and broom. Meurk & Swaffield (2000) identified Gorse and Broom as species able to act as nurseries for native plant regeneration, meaning Marley Hill is a good candidate for regeneration efforts. Areas of regeneration in close proximity to the track are often trampled by riders as they avoid areas of slower saturated track. It is important that resilient species of plant are planted in these areas. This concept is strengthened in Hartley's study (1979; cited in Price, 1985), as he expresses that carbohydrate reserves in roots and underground storage organs of plants were significantly lower in plants nearer to the trail. This reduces the reproductive potential of the plant, while also being smaller in size. This is an important consideration to take into account when the planting plan is being applied to Marley Hill.

3.2 Soil and Drainage

Soil type is the most important factor influencing erodibility. Fine silts and sands are most easily eroded, while clays reduce erosion (Goefft & Alder, 2001). Loess and basalt are the main erodible material for soil production in the Port Hills, the rate of which is affected by local microclimates (Pattle Delamore Partners LTD, 2007). Soil of this type is typically susceptible to further erosion as it has a minimal cohesion between soil particles. Nonetheless, the presence of vegetation increases the stability of the soil (Environment Canterbury, 2011). It has also been identified that increased saturation of soils alongside downhill recreation tracks are the most susceptible to erosion (Chiu & Kriwoken, 2003; Goefft & Adler, 2001). Sediment loss is further increased in these areas of saturation when poor braking techniques, resulting in skidding occur, loosening the soil (Goefft & Adler, 2001). This braking technique can lead to channel creation, draining water off the track unnaturally, impacting the growth of plants as they have specific requirements (Goefft & Adler, 2001). It is important regeneration within a recreation area focus on effective drainage to limit saturation of track soil.

4. Method

In order to answer the research question, physical soil samples and measurements of Marley Hill were collected and analysed in the field, and in geography laboratory. A Geographic Information System (GIS) was used to analyse digital data, and model the hydrological processes of the research site. Combined, these analysis techniques gave an understanding of the soil composition and drainage to deliver an optimal planting guide.

4.1 Vegetation Identification

Following meeting with the CCC Rangers for the Port Hills, a list of native plants to the Port Hills was provided. The list was then modified to suit the specific conditions of Marley Hill. This was so that effective regeneration could occur in such a way that met the standards set by Trees for Canterbury. For each of the plants selected the key properties affecting growth were investigated. The properties that repeatedly appeared as important were soil moisture content, drainage potential of the soil, sun exposure and pH. The conditions best suited for each plant were recorded on a planting table. This planting table ranked the plants by each property and helped in the creation of planting guide.

4.2 Field Soil Analysis

Analysing the characteristics of soils on Marley Hill determined what conditions would be affecting growing conditions. From prior visits to the site, potential points of interest were noted. The sites noted gave a fair representation of the local conditions as well as sites that showed significant variation from surrounding areas, such as areas of ground saturation. At Marley Hill two soil tests were completed, a penetration test and an infiltration test. These two tests have been designed to provide an indication of the drainage conditions. The first test was a basic penetration test. This involved using a standard penetrometer supplied by the Geography Department. A penetrometer is a device used to measure the force required to penetrate a certain depth into the soil. The penetrometer was inserted just below the top layer of the soil until its marker line was in line with the surface. A reading was taken from the scale on the penetrometer which measure the force required to reach this line. The second test completed was an infiltration test. This testing method was completed by digging a hole of 30 cm diameter and to a depth where there was a noticeable change in soil characteristics. The hole was then filled with 10cm of water. The time it took for the water to drain away was recorded.

4.3 Laboratory Soil Analysis

At each site where field testing occurred a sample was taken to be analysed in the laboratory. Three tests were used as a part of the research process. The first test completed was pH testing. Using a spatula a small soil sample was mixed with barium sulphate. Barium Sulphate does not affect the acidity of the soil sample because it is insoluble, so no

exchange of hydrogen ions occurs (Baver & Rehling, 1930). Two drops of water were mixed with the soil and barium sulphate. Then two drops of universal indicator were added, the colour change was observed and measured against a pH chart. The second test was the Emerson Crumb Dispersion Test to measure erodibility. Erodibility is related to the cohesion of the soil and the impact moisture has on this. The testing involved submerging a small sample of the soil in a container of water for 10 minutes. Once this time was completed, the samples were observed to determine the dispersion of particles (Maharaj, 2011). Figure B.1 in Appendix B contains the visual rating guide for the Emerson Crumb Dispersion Test. Finally, basic grain size analysis was completed for each sample. Grain size analysis involves measuring the size distribution of the particles that make up soil, and classifying it by the size limits that define different soil types (Gee & Or, 2002). A small representative sample of soil was examined using magnifying glasses to observe grain size. This was followed by a fingernail test of the fines to determine whether they were a coarser silt or finer clay. The soil was named, first focusing on the soil size that made up the largest proportion of the soil and following a standard classification table.

4.4 Geographic Information Systems Analysis

A GIS, specifically Esri-ArcMap 10.2 was used as a tool to create a hydrological flow model across the surface of Marley Hill and the Flying-Nun mountain bike track. The hydrology model was used to map the drainage flow and channels of the area, assisting in identifying areas of plant suitability. A hydrological model requires a Digital Elevation Model (DEM) for manipulation. The models created in this research project used DEM(s) supplied through the University of Canterbury and accessed under the Creative Common License. The raw Data and metadata can be retrieved from

file://canterbury.ac.nz/universal/bulk/geodata/NZ/Lidar/Christchurch/2011_03_08/

The DEM data was retrieved from a series of New Zealand Aerial Mapping data sets which were created using LiDAR point cloud data. This LiDAR data was collected on the 8th of March 2011, in a response to the February 22nd 2011 Canterbury earthquake sequence. The LiDAR point cloud data and the resulting DEM(s) are spatially referenced with New Zealand Transverse Mercator (NZTM) and NZGC 2000 ellipsoidal heights. The DEM show elevation difference between a 0.5m contours in a grid spacing, and were interpolated from a TIN using the LiDAR point cloud data set values. The DEM files are in Esri ASCII Grd format.

Initially, the research site was represented by four individual DEM(s), as seen in Figure C.1, Appendix C. The hydrological model requires on continuous layer and so a Data Management tool, *Mosaic to New Raster* was used to create a single DEM, seen in Figure C.2, Appendix C. This DEM was then used as an input for a *Flow Direction tool* which created an output layer that measured the direction of surface flow across the research area. A depressionless DEM was then created using a *Fill tool* to remove any imperfections or 'sinks' in the data. A *Flow Accumulation* was measured from the depressionless DEM, which assigned a weighted value to each cell in the DEM depending on variables such as flow

direction. Finally, a stream order tool was used to infer a drainage network (these steps are visually shown in Figure D.1, Appendix D and described in a flow chart Figure D.2, Appendix D). Stream ordering is a method of assigning numeric order to a network by identifying and classifying types of streams based on a numeric threshold. For example, first order streams are dominated by overland or surface water flow and do not have any contributory flow from above streams.

Once the drainage network of the site had been identified a validation exercise was performed in the field, where by an observation of any drainage or surface flow would be marked as a waypoint in a GPS and a photograph taken in evidence. This waypoint was then spatially referenced with the same NZTM co-ordinate system and portrayed in ArcMap. The proximity of the waypoint to modelled drainage would then indicate the validity of the mapped drainage network.

5. Results

5.1 Native Plant Habitat Preferences

Plant habitat condition preferences were categorised by soil moisture, drainage, sun exposure and pH, with a scale of 1 to 5 (Table 1).

- 1 = dry , 5 = saturated
- 1 = poor drainage, 5 = good drainage
- 1 = fully shaded, 5 = full sun exposure
- 1 = acidic pH, 5 = basic pH
- 3 = neutral condition, or 3* = no preference

Most plants prefer well-draining moist soil or well-draining dry soil. Soil moisture and drainage play the most important roles in site suitability for the native plants as they have the greatest variability in different locations on the site and plant preferences, compared to sun exposure and pH.

Table 1: Native plant habitat condition preferences

Factors /Plant	Soil moisture	Drainage	Sun exposure	pH
<i>Coprosma propinqua</i> ¹⁰	5	5	3	-
<i>Plagianthus regius</i> ²¹	5	5	5	3*
<i>Podocarpus cunninghamii</i> ²³	5	5	3*	-
<i>Cordyline Australis</i> ²	5	3	4	3
<i>Austroderia richardii</i> ⁸	5	3	5	-
<i>Prumnopitys taxifolia</i> ²⁴	4	3*	3	3*
<i>Hebe Salicifolia</i> ⁵	4	5	3	4
<i>Coprosma lucida</i> ¹¹	4	5	3	-
<i>Coprosma robusta</i> ¹²	4	5	3	-
<i>Podocarpus totara</i> ²²	4	4	3	2
<i>Coprosma Virescens</i> ¹	4	4	5	3
<i>Hoheria Angustifolia</i> ⁷	3	5	3	-
<i>Griselinia Littoralis</i> ⁴	3	5	5	3
<i>Carmichaelia australis</i> ⁹	3	5	3	-
<i>Myoporum laetum</i> ¹⁵	3	5	5	3*
<i>Pseudopanax arboreus</i> ²⁵	3	5	1	3
<i>Pittosporum tenuifolium</i> ²⁰	3	3	3	3*
<i>Pittosporum eugeniodes</i> ¹⁹	2	-	4	-
<i>Sophora microphylla</i> ²⁶	2	5	4	3
<i>Coprosma rubra</i> ¹³	1	5	3	-
<i>Kunzea ericoides</i> ¹⁴	1	5	5	-
<i>Myrsine australis</i> ¹⁶	1	5	4	-
<i>Olearia paniculata</i> ¹⁷	1	5	4	-

¹ New Zealand Plant Conservation Network (2014). Retrieved from http://www.nzpcn.org.nz/flora_details.aspx?ID=1741

² The Native Plant Centre (2007). Retrieved from <http://www.nznativeplants.co.nz/shop/Native+Trees/Cordyline+australis.html>

³ Vibrant Earth (2012). Retrieved from

<http://vibrantearth.co.nz/catalogue/plantsdetail.php?pid=486&name=Dodonaea%20viscosa%20%27Purpurea%27>

⁴ Rainbow Trees (2014). Retrieved from <http://www.rainbowtrees.co.nz/trees/product.cfm?cid=176&pid=21>

⁵ Royal Horticultural Society (2014). Retrieved from <https://www.rhs.org.uk/plants/details?plantid=6324>

⁶ Oratia Native Plant Nursery (2007). Retrieved from http://www.oratianatives.co.nz/catalogue_item.php?products_code=HEBESTRT

⁷ Vibrant Earth (2012). Retrieved from <http://vibrantearth.co.nz/catalogue/plantsdetail.php?pid=735&name=Hoheria%20angustifolia>

⁸ Pukerau Nursery (2012). Retrieved from <http://www.pukeraunursery.co.nz/product/austroderia-richardii-cortaderia/>

⁹ The Native Plant Centre (2007). Retrieved from <http://www.nznativeplants.co.nz/shop/Native+Shrubs/Carmichaelia+australis.html>

¹⁰ Pukerau Nursery (2012). Retrieved from <http://www.pukeraunursery.co.nz/product/austroderia-richardii-cortaderia/>

¹¹ Pukerau Nursery (2012). Retrieved from <http://www.pukeraunursery.co.nz/product/coprosma-lucida/>

¹² Pukerau Nursery (2012). Retrieved from <http://www.pukeraunursery.co.nz/product/coprosma-propinqua-x-robusta-green/>

¹³ Pukerau Nursery (2012). Retrieved from <http://www.pukeraunursery.co.nz/product/coprosma-rubra/>

¹⁴ Plantman (2013). Retrieved from

<http://www.plantman.co.nz/afawcs0158272/CATID=0/SUBID=30/ID=2125/SID=750666993/productdetails.html>

¹⁵ Plantman (2013). Retrieved from

<http://www.plantman.co.nz/afawcs0158272/CATID=0/SUBID=30/ID=1583/SID=750666993/productdetails.html>

¹⁶ Plantman (2013). Retrieved from

<http://www.plantman.co.nz/afawcs0158272/CATID=0/SUBID=30/ID=1584/SID=750666993/productdetails.html>

¹⁷ Plantman (2013). Retrieved from

<http://www.plantman.co.nz/afawcs0158272/CATID=0/SUBID=167/ID=1304/SID=750666993/productdetails.html>

¹⁸ Davis Landscape Architecture (n.d.). Retrieved from <http://davisla.wordpress.com/2011/08/15/plant-of-the-week-phormium-tenax/>

¹⁹ Trees and more (2014). Retrieved from <http://www.treesandmore.co.nz/cs/prodview.asp?idproduct=412>

²⁰ New Zealand Plant Conservation Network (2014). Retrieved from http://www.nzpcn.org.nz/flora_details.aspx?ID=1139

²¹ T.E.R.R.A.I.N (2013). Retrieved from <http://www.terrain.net.nz/friends-of-te-henui-group/table-1/ribbonwood-plagianthus-regius.html>

²² The Gymnosperm Database (2013). Retrieved from http://www.conifers.org/po/Podocarpus_totara.php

²³ The Gymnosperm Database (2013). Retrieved from http://www.conifers.org/po/Podocarpus_cunninghamii.php

²⁴ New Zealand Plant Conservation Network (2014). Retrieved from http://www.nzpcn.org.nz/flora_details.aspx?ID=1193

²⁵ New Zealand Plant Conservation Network (2014). Retrieved from http://www.nzpcn.org.nz/flora_details.aspx?ID=1194

²⁶ New Zealand Plant Conservation Network (2014). Retrieved from http://www.nzpcn.org.nz/flora_details.aspx?ID=1302

5.2 Soil Characteristics

The soil tests were carried out in six different locations, with 1 at the top of the track and 5 at the bottom, 2a is located in the middle of the track (Table 2). Results from soil testing show consistent results over the samples for most of the soil characteristics except for drainage capability. Most of the soil on and around the track is composed out of silt loam, with soil penetration strengths that varied from 1 to 3.5. Infiltration time fluctuated from minutes to hours, between locations. Soil type and pH remained consistent throughout the different locations.

Table 2: Soil Characteristics of the Flying Nun mountain bike track

Soil Sample Analysis								
Soil Sample	Northing	Easting	Strength (kg/cm ²)	Infiltration time (min)	Infiltration time (s)	pH	Emerson Soil Test	Soil Type
1	43 36.723S	172 38.141E	1	8.57	537	4	1	silt loam
2	43 36.691 S	172 38.182 E	2.25	1.02	62	5	2.5	silt loam
2a	43 36.691 S	172 38.182E				5.5	1	gravel silt loam
3	43 36.689 S	172 38.190 E	1	4.27	267	5	1	silt loam
4	43 36.654 S	172 38.211 E	1.5	60+		5.5	1	silt loam
5	43 36.619 S	173 38.220 E	3.5	30+		5	1	silt loam

5.3 GIS Figures

The result from the GIS hydrology modelling produced two specific maps. *Figure 1* displays a stream order or drainage network. This ordered network defines different channels by a threshold value from >1000 to >50000 (Refer to Legend). These different thresholds represent increasing levels of flow across the area. *Figure 2* identifies the location of waypoints taken in the field that identify physical drainage channels or areas saturated by draining water. Waypoints Fn2, Fn3 and Fn4, (*Figure 2*) all have corresponding photographic evidence displaying what has been identified as drainage.

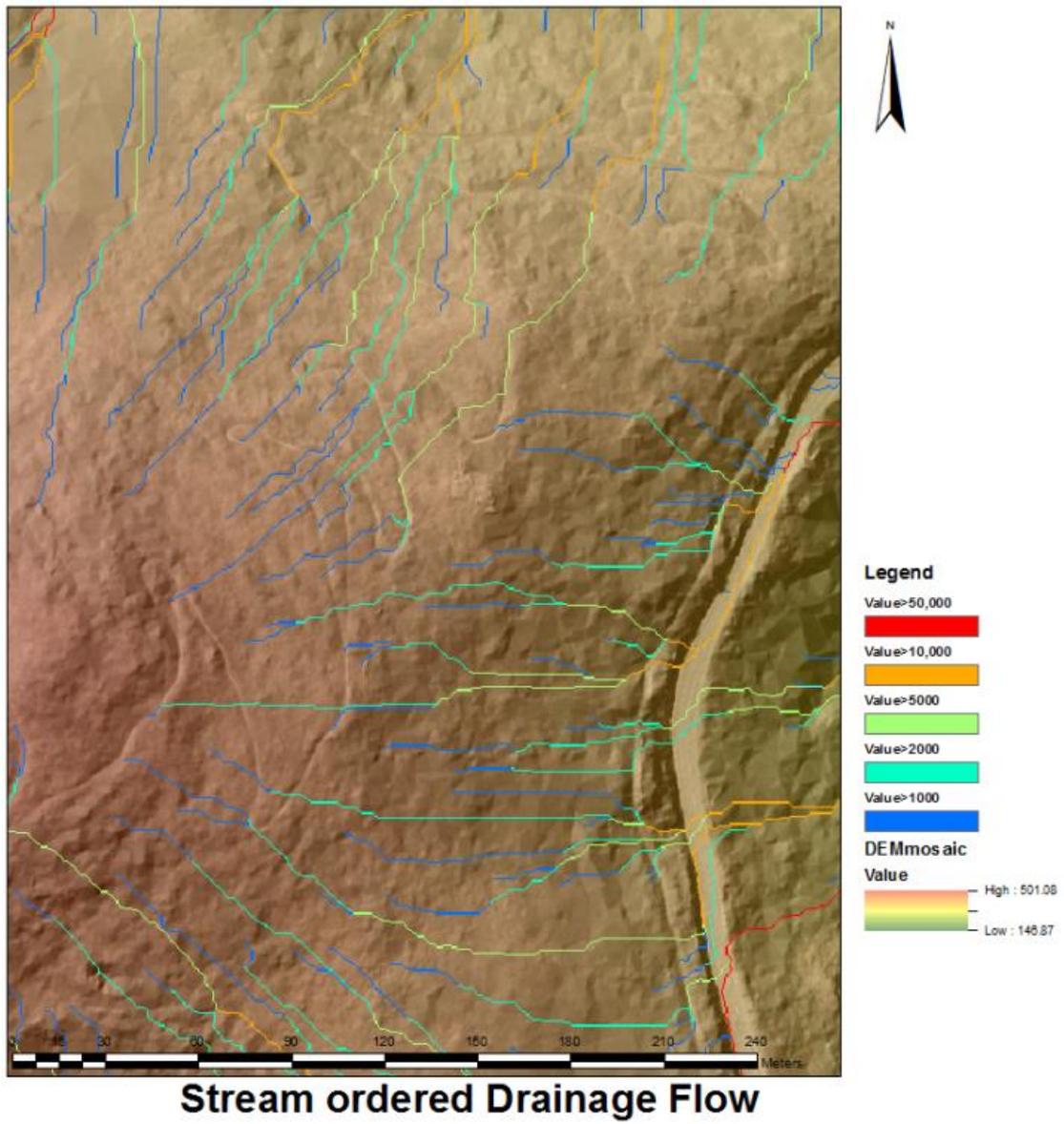
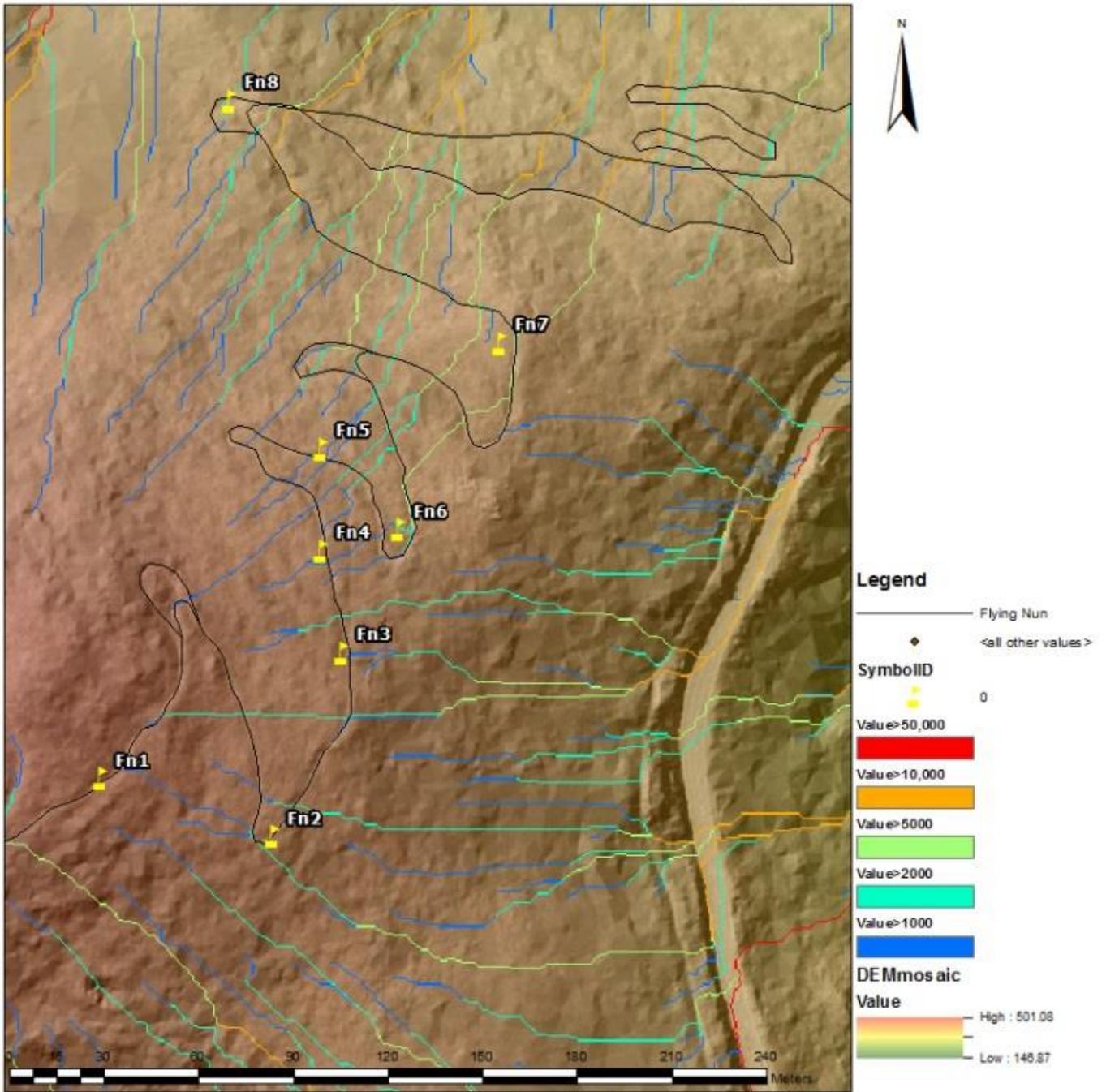


Figure 1: Stream Order Drainage



GPS Validity Exercise

Figure 2: Validity

5.4 Validating Photograph Evidence of Way Points, Fn2, Fn3, and Fn4

The photographs, as seen in Figure 3, are illustrated with arrows and boxes indicating areas of track saturation. The photos were taken on a fine day so no surface runoff is visible.



Fn2:

The GPS Waypoint for this location has an error of +/- 3m to the SE of the photos location. This photo is illustrating the distinct fork shape (Figure 2 above point Fn2) of two primary >1000 value drainage channels which combine at the track edge to form a secondary >2000 value drainage network channel.

The red boxes highlight areas of track which are visibly more saturated than the remaining area of track.



Fn3:

This GPS Waypoint illustrates a point of track surface runoff accumulation, which acts as a source of a primary >1000 network channel. There is evidence of human manipulation of the accumulation area, presumably in an effort to increase the rate of drainage in order to dry out this section of track.



Fn4:

At this Waypoint a demonstration of the drainage channel flowing across the track is identified.

Figure 3: Photograph evidence validating the GIS hydrological model

5.5 Native Regeneration Plan

The proposed distribution of native plants regeneration on the research site was generated based on the drainage map (Figure 4). It is advised that the plants are planted according to the drainage and soil moisture, which is a consequence of drainage, determines suitability of plants on different areas on the site.

Plants more suited to saturated conditions (Refer to Table 1), are planted on the drainage flows, which are shaded in blue. Plants suited for drier areas are to be planted on the drier areas shaded in yellow. Plants with no preference or prefer moderate conditions are planted between the dry and saturated areas which are shaded in green

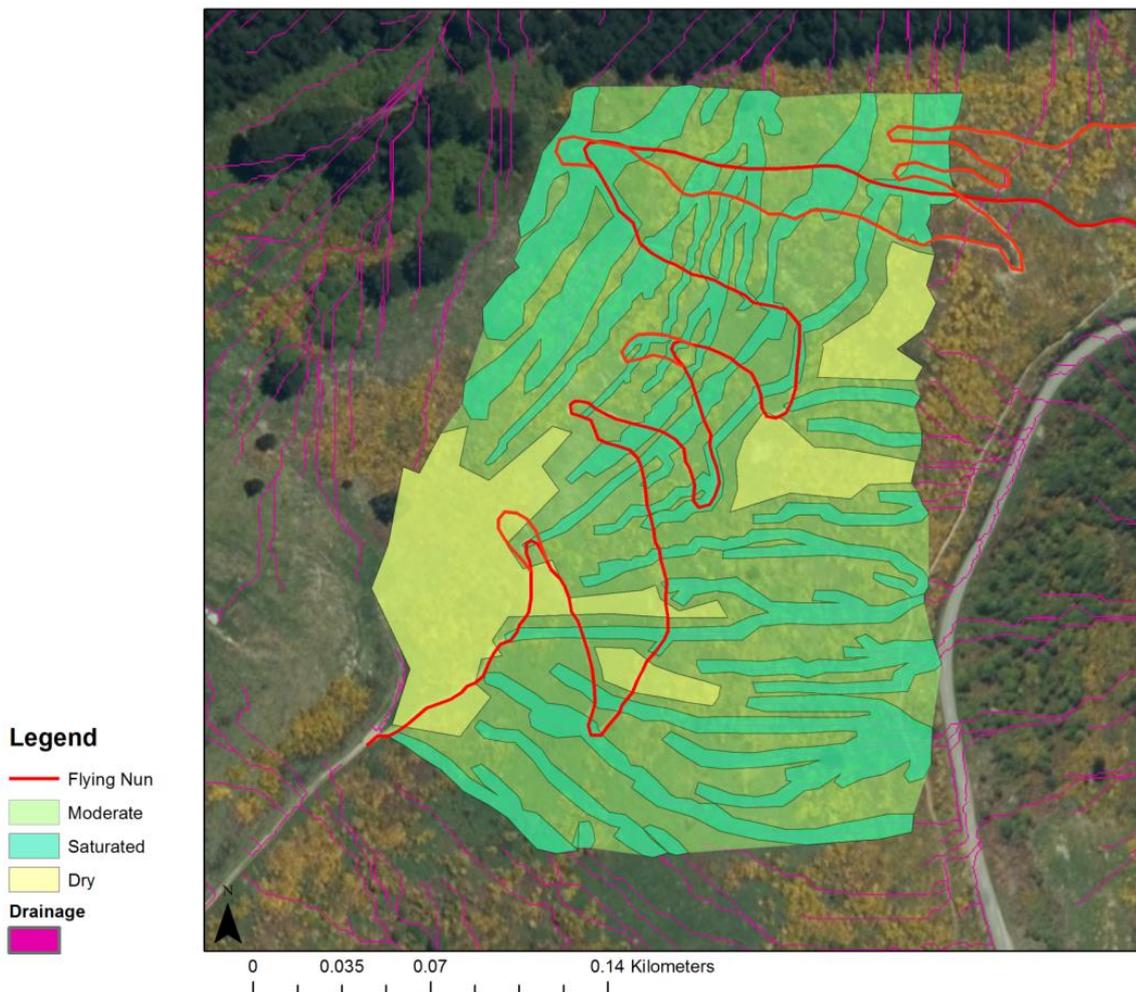


Figure 4: Native plant regeneration map

6. Discussion

A guideline for optimal native plant regeneration that has been offered in this report utilises drainage flow as the defining characteristic, influencing plant survival during regeneration. This is parallel to the research aim of optimising native plant regeneration on Marley Hill and the 'Flying Nun' mountain bike track. This guideline was formed by analysing soil and plant characteristics, and linking the produced results to a hydrological flow model of Marley Hill.

Results from the soil analysis showed infiltration as the most variable soil characteristic across the research site, while results from pH, Emerson Crumb Dispersion, and grain size analysis testing remained constant. Therefore, infiltration and soil moisture were the soil characteristics focused on in the production of a planting plan as they would have the greatest influence on plant survival. Marley Hill offered little variation in the exposure of sunlight that plants would receive because of its north facing aspect (Figure E.1, Appendix E). From Table 1, it can be observed that all plants required a moderate to high level of sunlight. For this reason, sunlight exposure was not considered important to the aim of modelling different plant characteristics to determine suitability. A discrepancy occurred when investigating the pH preference for native plants, as not all species were identified to have a pH preference. Therefore, even though a pH measurement was analysed as a soil characteristic, it was not applied specifically as a defining variable because of the inconsistency in information obtained.

Soil strength and infiltration time appear to have little correlation. At location 2, the soil strength is 0.75 kg/cm^2 higher than site 4, although the infiltration time at site 2 is on the scale of minutes, whereas site 4 had an infiltration time measured in excess of an hour. As soil strength is a measure of compaction and all the soil samples have been identified as the same silt loam texture, it would be expected that stronger soil strength would result in a longer infiltration time. This has not been observed and the results are likely to be affected by variables unable to be controlled during the field analysis, such as soil moisture at the time of testing. Moisture affects the compaction of the soil as dry soils are not compacted to their maximum density (Ghosh, 2013).

Due to soil moisture being identified as the soil characteristic most influential in optimising native plant regeneration, GIS drainage modelling was used as the basis for identifying areas of different soil moisture, and to generate the proposed distribution of native plants across the research site. The proposed regeneration plan addresses Trees for Canterbury's interest in optimising plant growth by determining the most suited areas for particular species wellbeing. This model could be improved further by introducing a zone of non-regeneration parallel to the track to protect plants which are vulnerable to trampling as has been discussed in the literature review of Hartley's study (1979; cited in Price, 1985).

The use of ArcGIS to model hydrology became the foundation of the final planting guide. The maps that were produced accurately identified the location of drainage channels. This is displayed by Figure 2, which plots the position of validation waypoints measured in the field close to modelled channels. The hydrology is accurately modelled because the DEM manipulated was of high resolution LiDAR data, which has the benefit of penetrating the thick vegetation of the research area, producing a clean digital surface layer. This could not be achieved as accurately if an Orthophoto of the area have been interpolated to form a DEM.

Figure 1 identifies the location of these channels or drainage networks and more crucially indicates which networks carry substantial flows of water due to the threshold values the model assigns based on a measurement of contributory cells. In these areas it could be inferred that saturation would be more intense in the adjacent soil and remain saturated for longer periods of time than channels identified as primary due to a threshold of surface runoff. These maps could be further improved by including modelled length of time moisture will remain and saturate soil after a rain full event.

6.1 Limitations

The infiltration tests at the last two locations took significantly longer than earlier tests. One of the possible reasons for this fluctuation is a division between wet and dry soil, which can remain for a long period of time (Russell & Russell, 1973). This happens when a fixed amount of water moves down a deep dry soil layer with a distinct wetting front. This front becomes almost static when free water on the soil surface has percolated in the soil. Another possible reason for this fluctuation is that below the layer of soil being measured was an impermeable boundary such as hard clay, or volcanic rock. Time limitations did not allow for the collection of multiple infiltration measurements at each site. This limited the possibility of averaging infiltration times eliminating any disruptive variables such as impermeable layers of clay below the surface soil.

Limitations to GIS modelling included an error in triangulation by the GPS during the validation exercise. This could be due to a lack of connected satellites or a time delay by the GPS in recalculation a steady position when moving between different waypoints. The largest limitation to GIS modelling is that the hydrology modelling requires a significant manipulation of the DEM when using the *Fill tool*, (Figure D.2, Appendix D) which removes sinks in the data. These sinks are effectively features in the landscape which stops the flow of water moving across the landscape, such as depression like 'puddles' which accumulate water instead of allowing it to flow. This is obviously a huge manipulation of realistic features found in a normal landscape.

7. Conclusion

Trees for Canterbury introduced a need to best optimise their regeneration efforts. The goal of this research project was to offer an educational tool set so that Trees for Canterbury could optimise their regeneration efforts on Marley Hill. What was produced was a number of maps and tables that can act as a guideline for optimal native plant regeneration. The drainage flow of the research area was found to be the defining characteristic which impacted plant survival. Modelling of drainage was verified to be an accurate representation of the areas hydrology, because the DEM manipulated was from high resolution LiDAR data that produced a clean digital surface layer. Future work to improve these models would be to measure the length of time these drainage channels and the adjacent soils retained water, so that native plants could further be classified into the amount of time saturated environment can be tolerated. The addition of a planting margin or zone of non-regeneration would be of a further benefit to native plant survival as this limits the disruption of trampling. Furthermore, a larger and more accurate scientific sampling and analysis of soil samples is required for a reliable classification of the Marley Hill research area. Currently, the soil results are a limited representation of all possible soil characteristics influencing the survival of native plant regeneration in Marley Hill and the 'Flying Nun' mountain bike track.

8. Acknowledgements

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10. Appendices

Appendix A



(a)



(b)

Figure A.1: An example of native regeneration which is struggling because of drainage flowing at its base. (a) is an example of a healthy native plant species, this photo was taken 100m above Waypoint Fn2 (Figure 2) along the Flying Nun track facing west up the hill slope. (b) is taken to the left is on the opposite side of the track looking east toward Lyttelton.

Appendix B

Table B.1: Grading of the Emerson Crumb Dispersion Test (Walker, 1997; cited in Maharaj, 2011)

Grade	Reaction	Description
1	No Reaction	Crumbs may slake, but no sign of cloudiness caused by colloids in suspension
2	Slight Reaction	Bare hint of cloudiness in water at surface of crumb
3	Moderate Reaction	Easily recognisable cloud of colloids in suspension, usually spreading out in thin streaks on bottom of beaker
4	Strong Reaction	Colloid cloud covers nearly the whole bottom of the beaker, usually a thick skin

Appendix C

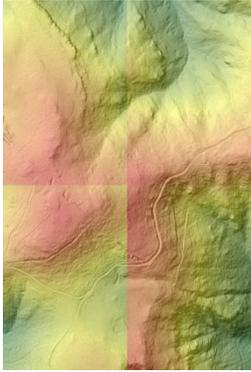


Figure C.1: Initial site representation by four individual DEMs

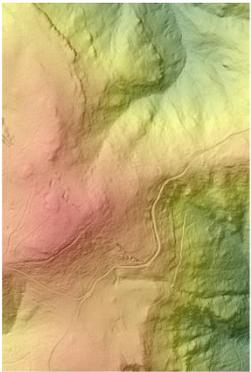


Figure C.2: Single DEM used as an input for Flow Direction

Appendix D

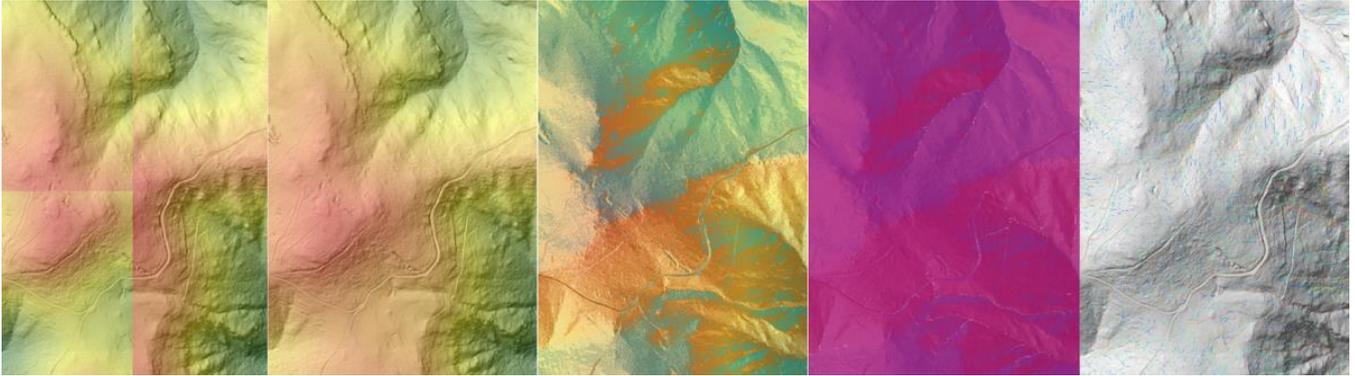


Figure D.1: Visual representation of creation of GIS drainage modelling

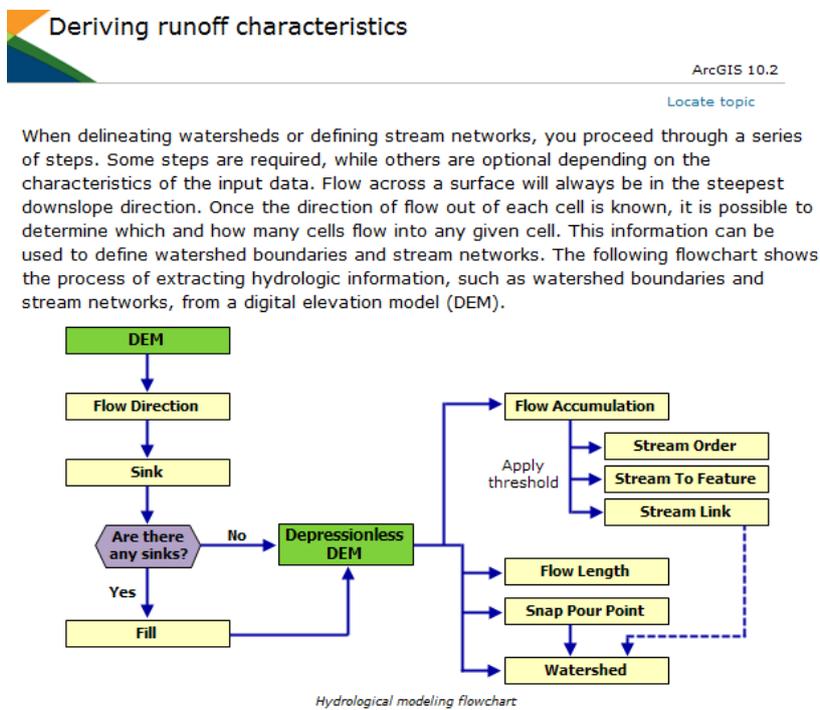


Figure D.2: Flowchart of steps taken in GIS drainage modelling

Appendix E

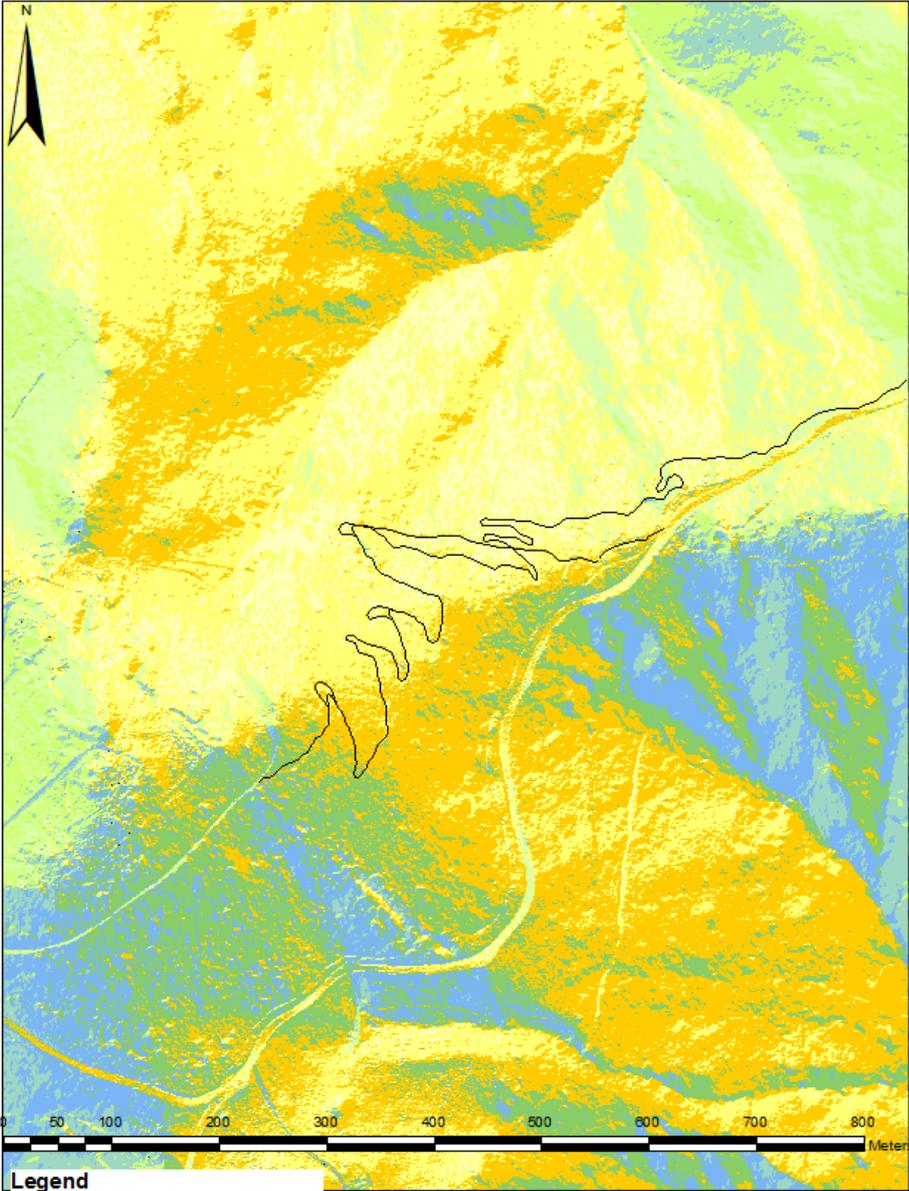


Figure E.1: Map showing the aspect of Marley Hill