Hedgehope Makarewa Catchment Group Project

Summary report of landscape data | Roslyn Downs

Executive Summary

Many farmers are actively seeking opportunities to reduce their environmental impact to meet their goals, regulations, consumer and community expectations.

Land and Water Science Ltd (LWS) have undertaken a new, high-resolution physiographic approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales. Landscape variability has a significant role in governing the type and severity of water quality outcomes, even when land use is the same. Landscape variability also significantly affects soil greenhouse gas (GHG) production.

Linking the landscape susceptibility and farm system allows farmers to target mitigations and contaminant load reductions to reduce their environmental impact. This report summarises the datasets but does not deliver an integrated plan for mitigating environmental challenges. Instead, this data summary report seeks to *present* the key data and insights that can be used by the landowners and their farm systems specialists/advisors to apply mitigation opportunities to the identified areas.

Method

LWS, i. prepared the preliminary landscape data report which was supplied to the landowners of Roslyn Downs; ii. met with the landowners on farm; iii. walked the property; iv. sought the landowner's perspective on the environmental challenges they face, and; v. discussed their preferred pathway for mitigating environmental risk.

The Farm

The property is located at 187 McDonald Road, Glencoe, Southland. The farm is ~570 hectares in size, operates as a sheep and cattle property, and is known as 'Roslyn Downs'. The Hedgehope Stream travels through the north-western most part of the property. The property is a mix of low relief and rolling country, with a mean slope of 7.3° and a range of 1 to 87° (reflecting steep sides of drainage ditches), and lies between 30m and 95m Relative to Sea Level (RSL).

Environment Southland designates the property as occurring within the Makarewa Groundwater Management Zone.

The Catchment

The property is situated within the Hedgehope sub-catchment, which is located on the eastern side of the Hedgehop-Makarewa Catchment. The Hedgehope-Makarewa catchment is located within the greater Oreti catchment in Southland, New Zealand. It extends from the divide draining the southern side of the Hokonui Hills to the north of Invercargill. The total area of the catchment is approximately 111,940 hectares (ha).

The Hedgehope sub-catchment accounts for 19,277 ha of land, or 17% of the wider catchment, and is drained by the Hedgehope Stream. This Hedgehope Stream is fed by a diverse network of smaller streams that run in a south-west direction through the sub-catchment. Towards the bottom of the sub-catchment, the Hedgehope Stream converges with the Titipua Stream before entering the Makarewa River. The Makarewa River flows in a south-west direction before joining the Ōreti River and discharging to the sea via the New River Estuary at Invercargill.

Landscape Susceptibility

The landscape datasets generated for Roslyn Downs have been presented. The landscape package includes a farm-specific model of surface drainage, terrain ruggedness, and high-resolution (3 cm) drone captured photographic images. It is important to emphasise that the susceptibility models do not consider land use nor any existing management practices of physical mitigations (e.g., sediment traps, wetlands) already in place. As such, landscape susceptibility models only identify the inherent or natural susceptibility of the land, they do not indicate that the areas of elevated susceptibility are losing high rates of contaminants.

Within the context of the above paragraph, the main landscape susceptibilities associated with the property are thought to include:

i. Small areas of mass wasting (slips, slumps, earthflows) and erosion (stream channel incision) susceptibility;

ii. A moderate soil-zone nitrous oxide susceptibility due to fine textured and poorly drained soils;

iii. Moderate nitrate, nitrite and nitrogen (NNN) susceptibility to loss via the surface water or subsurface drainage network across lower relief parts of the property, with some high susceptibility areas in the northern part of the property associated with the Makarewa soils;

ii. Some elevated areas of landscape susceptibility to particulate phosphorus (PP) loss that tend to coincide with the steeper terrain in the southern part of the property; and

iii. Elevated Total Kjeldahl Nitrogen (TKN) landscape susceptibility which coincides with imperfectly to poorly drained soils and areas of elevated runoff risk.

Managing runoff to reduce PP, TKN, and a component of likely microbial losses appears to be important for Roslyn Downs. Nitrate-nitrite-nitrogen is best managed by reducing excess NNN in the soil before and during late autumn and early spring. With regards to soil nitrous oxide, several inhibitors are being trialled within the agricultural industry at present.

1. The Project

In the following landscape data report, existing soil and geological datasets and the physiographic classification provided by LandscapeDNA are used to provide a generalised overview of the farm setting before the presentation of a high-resolution and data-driven assessment of landscape susceptibility. Here the objective is to move beyond the low resolution of historic soil and geological maps towards property, paddock, and sub-paddock scale assessment of landscape susceptibility. The aim is to provide landscape knowledge capable of supporting a spatially targeted and highly efficient approach to mitigating soil GHG and water quality-related losses.

2. The Farm Landscape

2.1 Site description

The property is located at 187 McDonald Road, Glencoe, Southland. The farm is ~570 hectares in size, operates as a sheep and cattle property, with the Hedgehope Stream travelling through the north-western most part of the property.

From the LandscapeDNA site, the physiographic environments for the property are varied. At the northern end of the property is the Reducing Soil - Oxidising Aquifer family, through the centre of the property is the Reducing Soil and Aquifer family, along with a large area of Oxidising Soil - Reducing Aquifer family, concluding in the southern part of the property with the Strong Bedrock family (Fig. 1). The physiographic classes identify that any aquifers underlying the property are unlikely to be highly susceptible to nitrate leaching losses. Rather, the loss of nitrate via the drainage network, including via sub-surface artificial drainage, is more relevant for Roslyn Downs. The remainder of contaminants, particulate phosphorus, organic and ammoniacal nitrogen, sediment, and microbes are more likely to be lost in response to surface runoff and in some instances via the subsurface artificial drainage network.

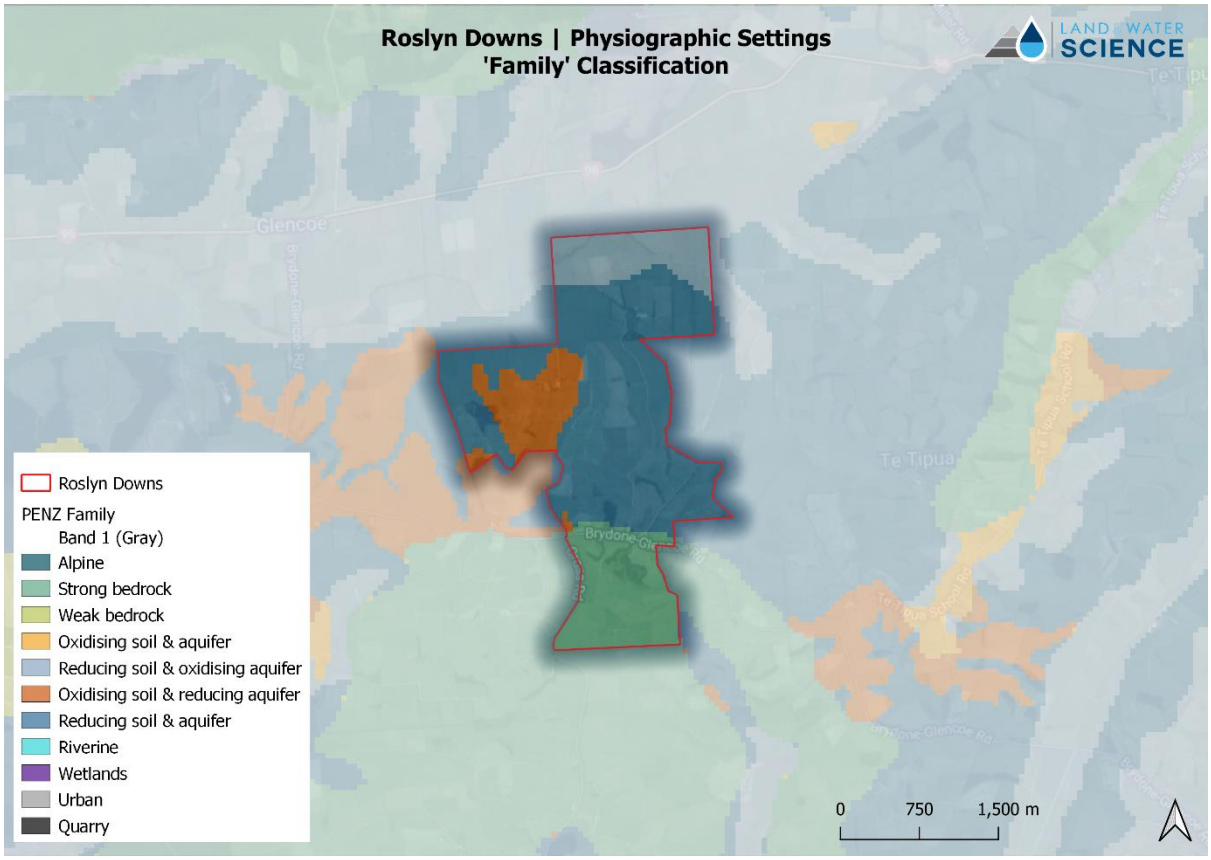

Figure 1. Case Study property – Roslyn Downs. Physiographic Families classification.

LandscapeDNA integrates geology, soil, and topographic variation to identify at a generalised broad level the susceptibility of the landscape to contaminant loss. The geological component identifies that the property resides within several different geological units (blue lines in Fig. 2). The main rock type is sandstone which is described as "sandstone with lignite and carbonaceous mudstone" by the regional geological survey (Q-Map V3). The maximum age estimate of this landform is 27 million years old. A small area of the property, located in the southern and western areas, identifies gravel as the main rock type, described as "quartz gravel with minor quartz sand carbonaceous mudstone and

lignite." The maximum age estimate of this landform is 4 million years old. The northern area of the property is comprised of river deposits that are comprised of "unconsolidated gravel, sand, silt, clay, and minor peat" with a maximum age estimate of 14 thousand years.

The soil component in LandscapeDNA is derived from S-Map. S-Map (portal) identifies a variety of soil types across the property (Fig. 1). Makarewa soils are described as deep, poorly drained clay; Woodlands soils as deep, imperfectly drained silt; Pukemutu soils as moderately deep, poorly drained silt over clay; Paroa (Dacre) soils, as deep, poorly drained silt; Pebbly soils, as shallow, well-drained silt; Aparima soils, as deep, imperfectly drained silt over clay, and; lastly Glenlea soils, are described as shallow, moderately well-drained silt. The S-Map portal specifies 'low' confidence in the spatial accuracy of soil siblings across the property. The high-resolution landscape susceptibility layers generated by Land & Water Science (LWS) have a resolution of 40 x 40 m (0.16 ha) and provide greater resolution over changes in soil properties than is currently provided by S-Map or LandscapeDNA.

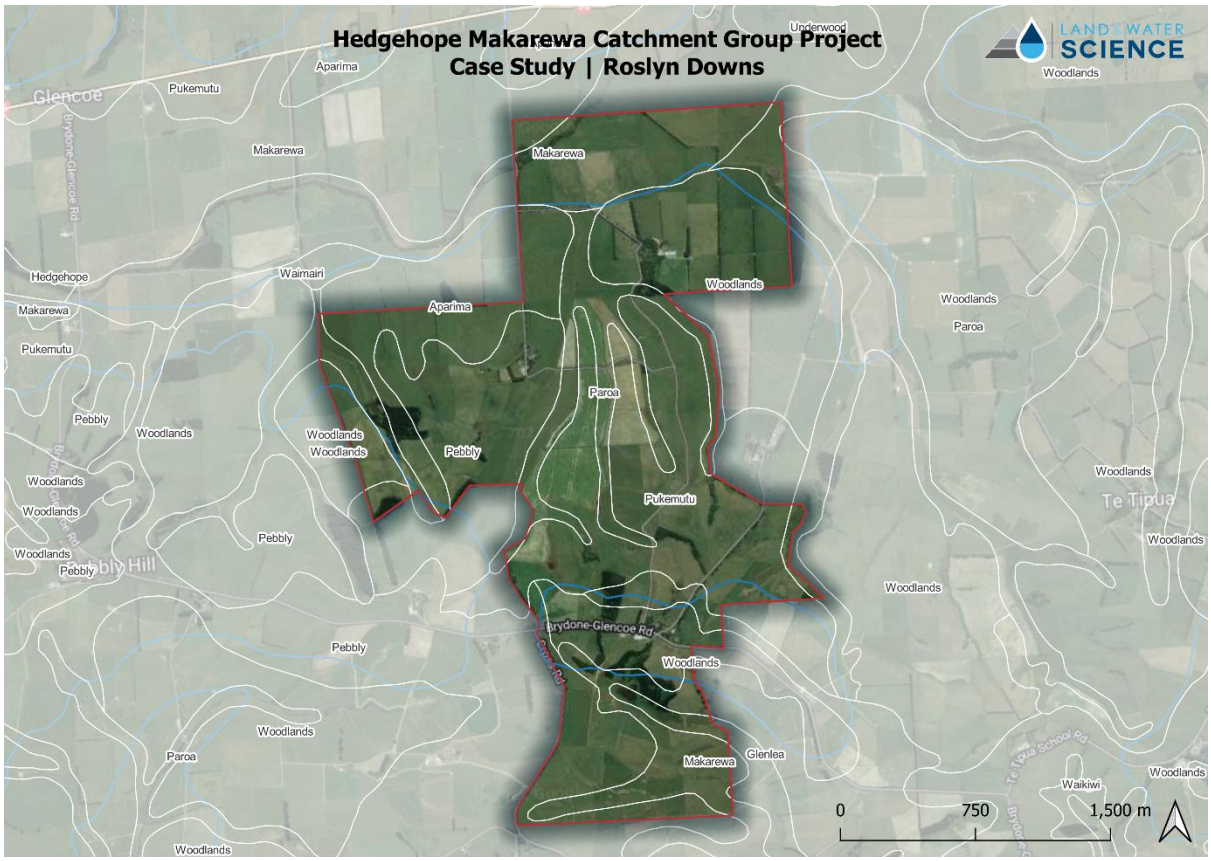

Figure 2. Case Study property - Roslyn Downs. The blue lines are from Q-Map denoting the geological units, the white lines and labels are from S-Map denoting the soil siblings. Please note that the soil polygons identified here are a general simplification of a more complex pattern which is subsequently described in the body of this report.

3. New soil map

Although not presented here, a new soil map was developed for the Hedgehope Makarewa Catchment Group as part of the Thriving Southland funded project. The map is available for viewing online in the catchment group's StoryMap application. The soil map was developed as a key step towards a more refined soil resource for the catchment.

4. Digital Terrain Model (DTM)

Roslyn Downs was surveyed with a drone to develop a high-resolution Digital Terrain Model (DTM) with a vertical accuracy of 0.02cm. A DTM provides the basis for resolving in high-resolution the topographic variation across the property (Figs. 3 and 4). Topography is a dominant control over the movement of water across a property and as such the transport of contaminants from one area to another. The drone-derived DTM of the property has a mean slope of 7.3° and a range of 1 to 87° (reflecting steep sides of a drainage ditch) and lies between the 30m and 95 m Relative to Sea Level (RSL) contour (Fig. 4). The mean slope of 7.3° is consistent with a mix of low relief and rolling country.

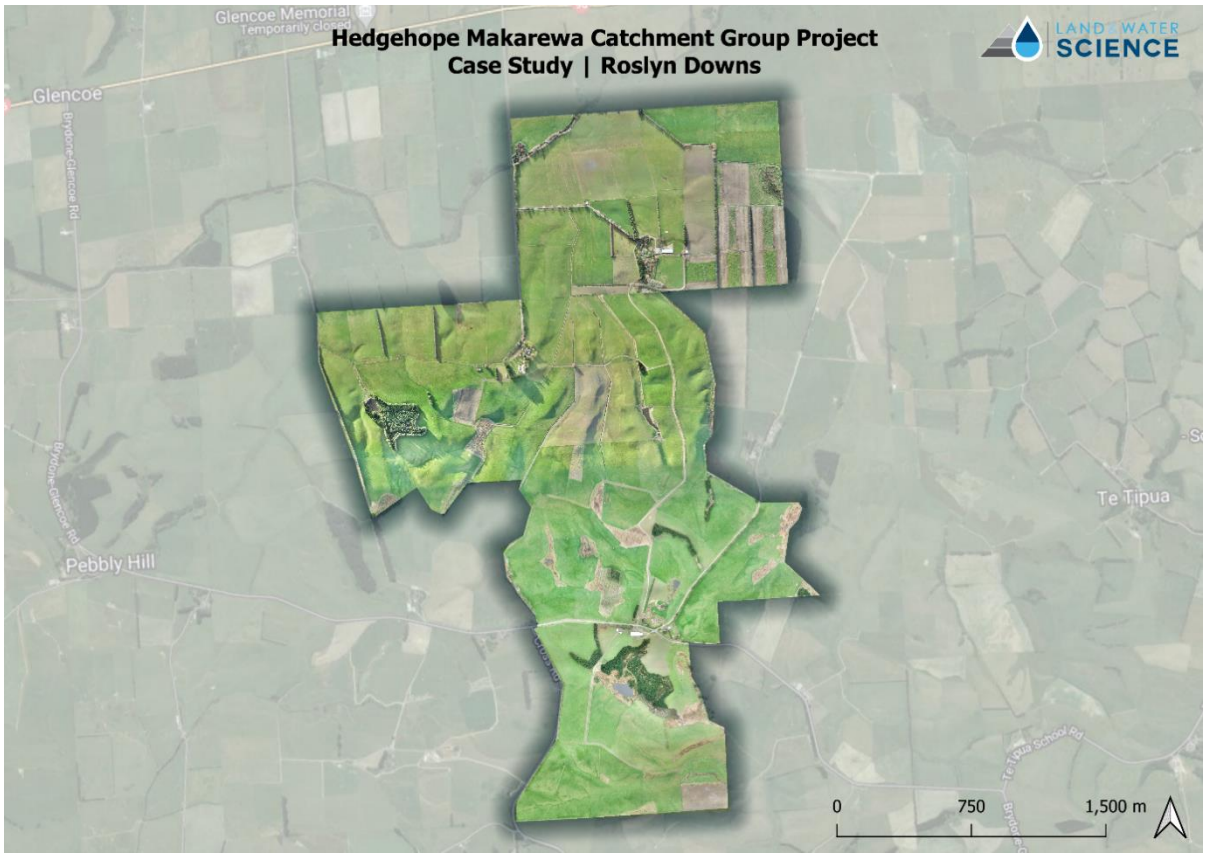

Figure 3. Roslyn Downs. The photogrammetry survey generates an orthomosaic output at 3cm resolution, producing a Digital Elevation Model of 12cm/pixel, with a vertical geolocation accuracy of 0.02cm. The high-resolution orthophotos are useful for identifying erosion-prone areas.

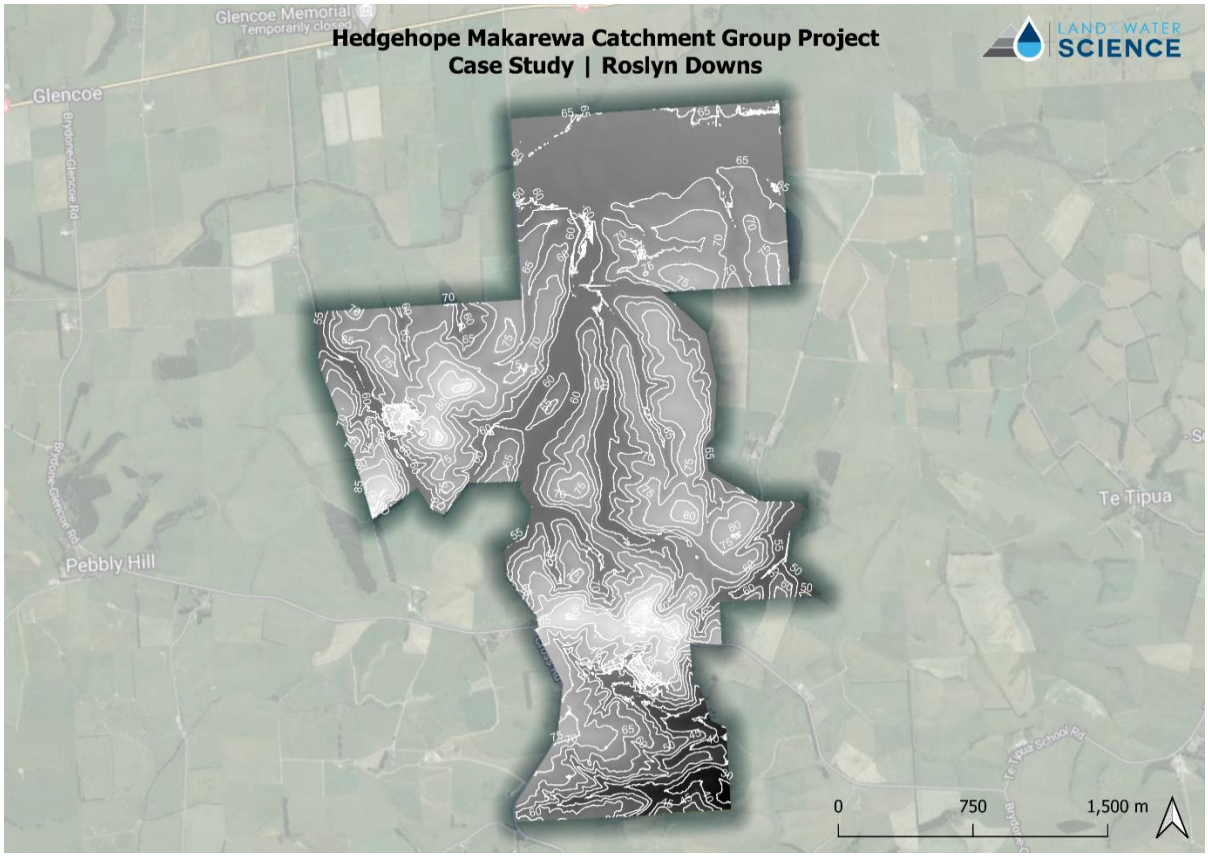

Figure 4. Shade model of elevation overlaid with elevation contours (5m) of property in meters relative to sea level. Note that the closer the spacing of contours, the steeper the land.

Following the survey, the DTM was utilised to build a digital model of the hydrology of the property, which includes the generation of watersheds, a digital drainage network, and nodes or junctions where drainage channels intersect or leave the property. The need to better define the hydrology of the property reflects the role of water in transporting contaminants from one area to another and at times, off-site.

Ultimately, water is the vehicle that transports contaminants from land to water. A better understanding of the area water collects from and drains to is a critical component of effective land management. Furthermore, soil moisture also tends to follow the drainage network, with higher soil moisture and greater incidences of saturation associated with low-lying areas that receive drainage from higher elevation parts of the property. The saturation of the soil with water also controls soil GHG generation (section 5.2).

4.1 Hydrological network for Roslyn Downs

Watersheds (Fig. 5), the drainage lines and associated network (Fig. 6), discharge nodes (Fig. 7), and priority nodes (Fig. 8 & 9) were generated for the property. Watersheds encompass the area that collects and drains water to a node. Water drains towards a common collection point, following the lowest lying pathway to a drainage line. Hence the water that flows through a drainage channel during a runoff event is sourced from the entire area within the watershed. Discharge notes identify the location at which water leaves the survey area, and priority nodes identify where small drainage channels connect to and feed into larger drainage channels. Each drainage line or 'channel' is ranked (ordered) according to its level of branching. A low-order drainage line, e.g., order 1, defines the smallest drainage features, whereas a high-order drainage network, e.g., order 6, represents the

largest drainage features, such as broad or incised swales, drainage ditches, and in some instances, flowing stream channels. Typically, higher-order drainage lines are more likely to contain water for extended periods, whereas low-order drainage lines may only channel water in response to wet conditions and associated surface runoff events.

Critically, the DTM does not detect nor consider any artificial drainage that has been undertaken. Where present, artificial drainage will significantly modify the hydrological properties and behaviour of water movement across or through the landscape. Accordingly, knowledge of artificial drainage is important given its role in water and contaminant export. Most typically, artificial drainage follows the topographic drainage, with many low-order drainage channels tiled or piped to expedite soil drainage and/or, in some settings, to prevent a shallow water table from rising and flooding the property. It will be helpful to discuss with the property owners the general extent and layout of any artificial drainage.

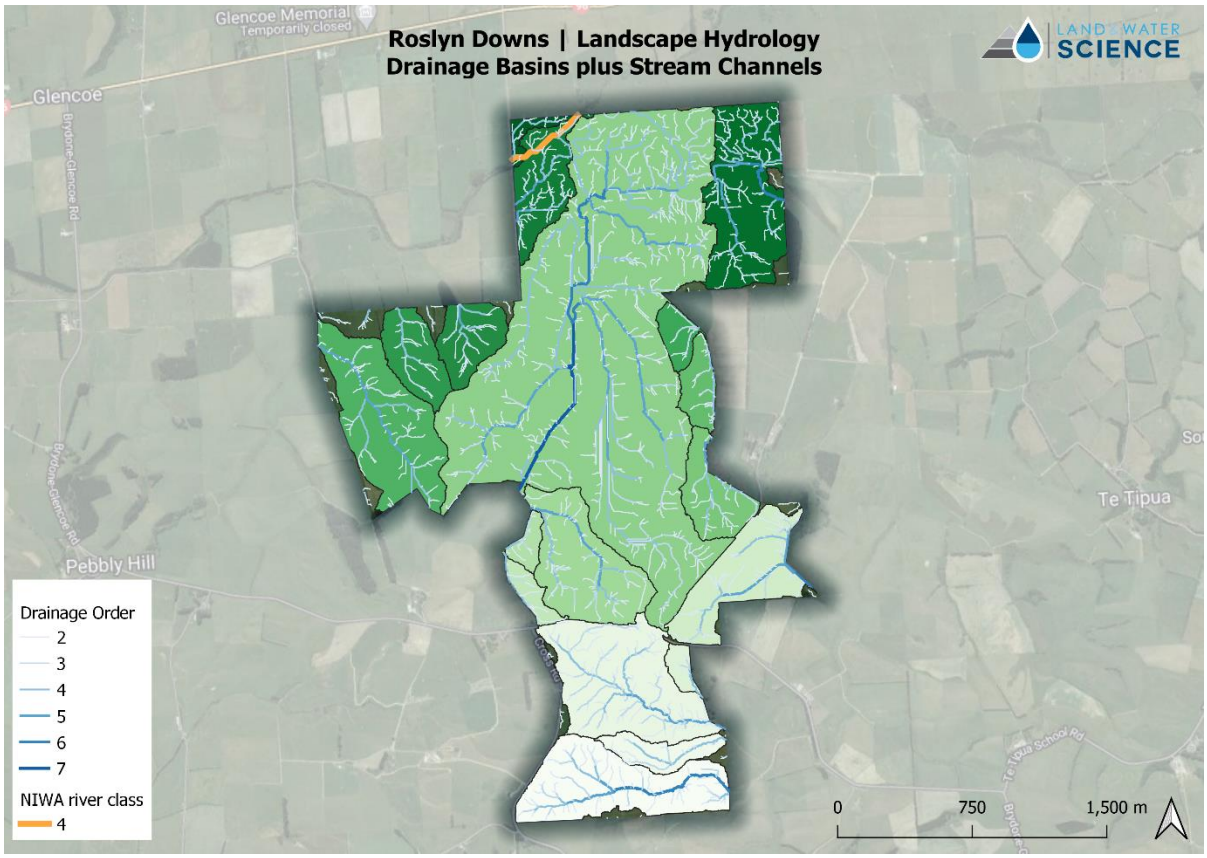

Figure 5. Roslyn Downs - landscape hydrology – watershed basins plus drainage network. These watersheds can be further subdivided for each tributary.

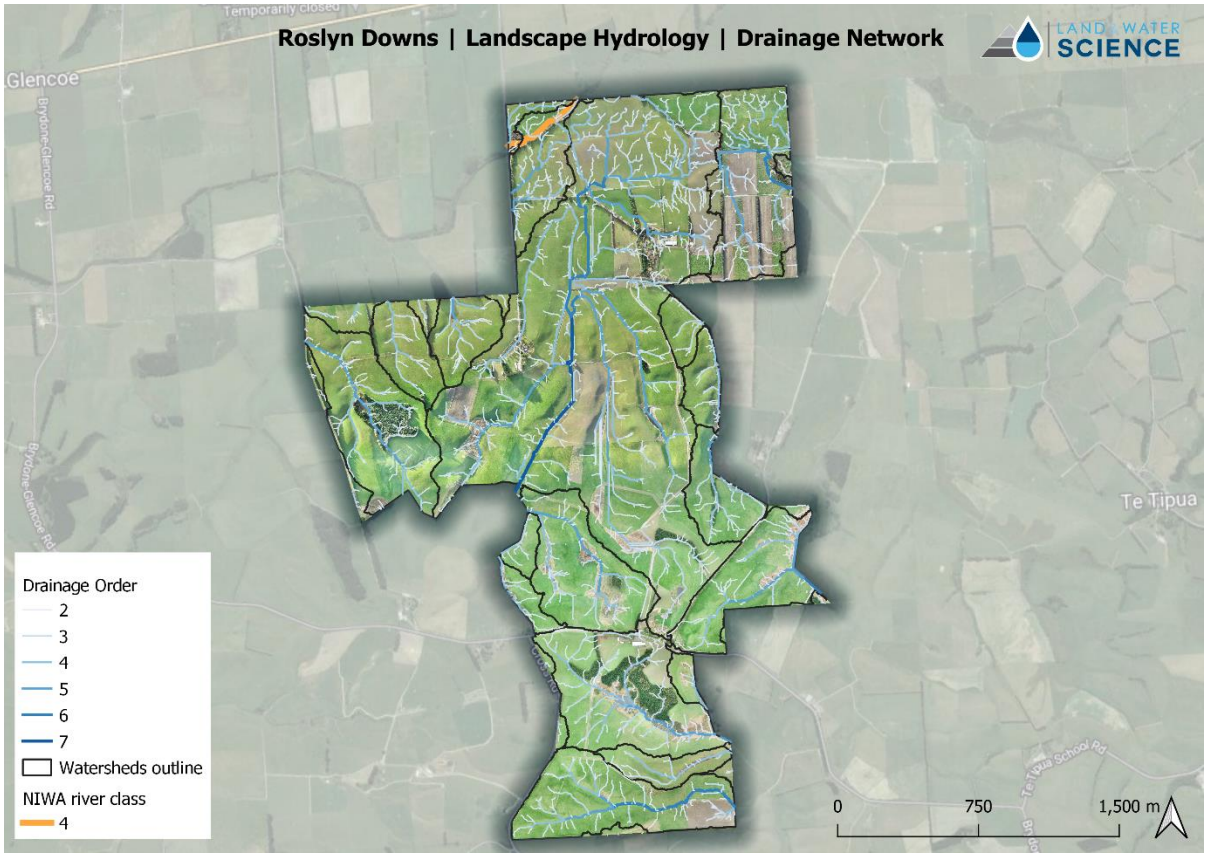

Figure 6. Roslyn Downs - landscape hydrology – drainage network. The legend denotes the 'order' of drainage lines, with low order drainage connecting to generate higher order drainage lines.

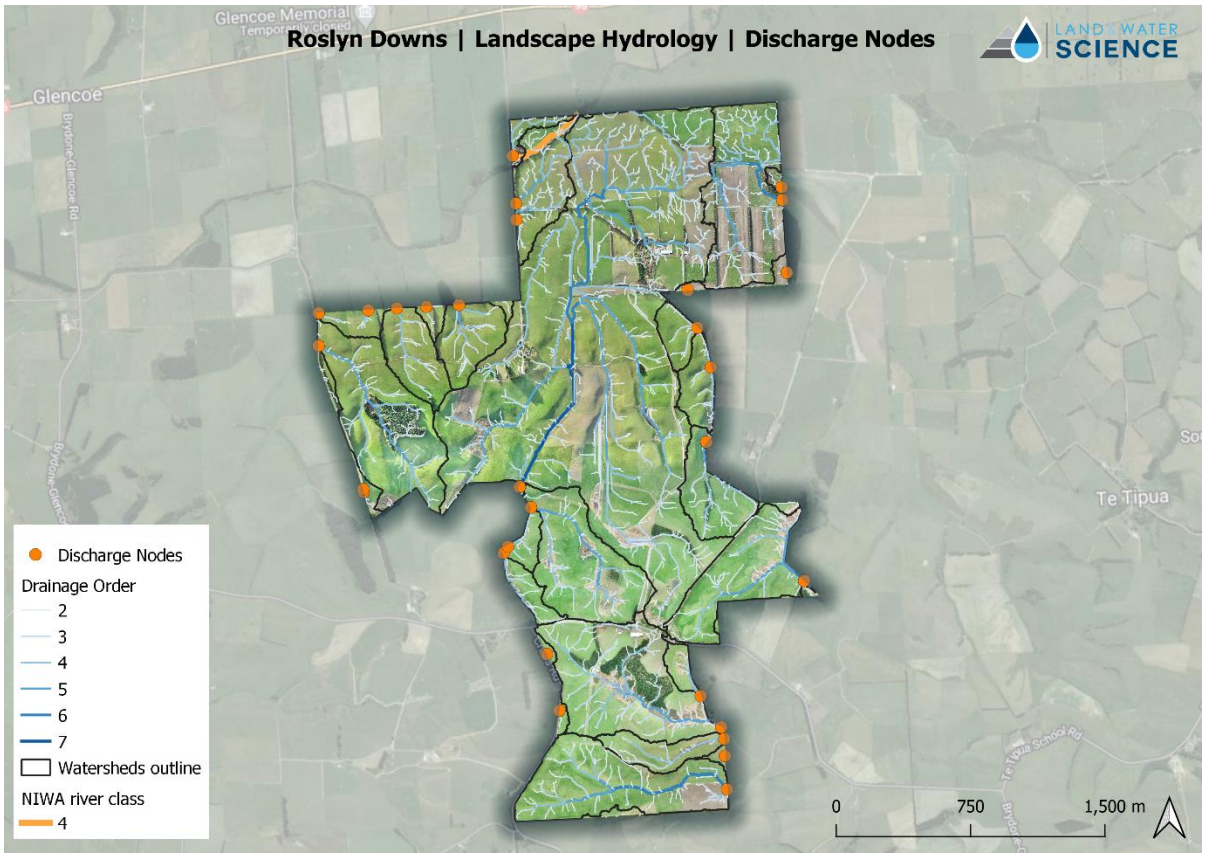

Figure 7. Roslyn Downs - landscape hydrology – 'discharge' nodes plus drainage network. Discharge nodes identifies the points surface water or shallow subsurface flows leave the property.

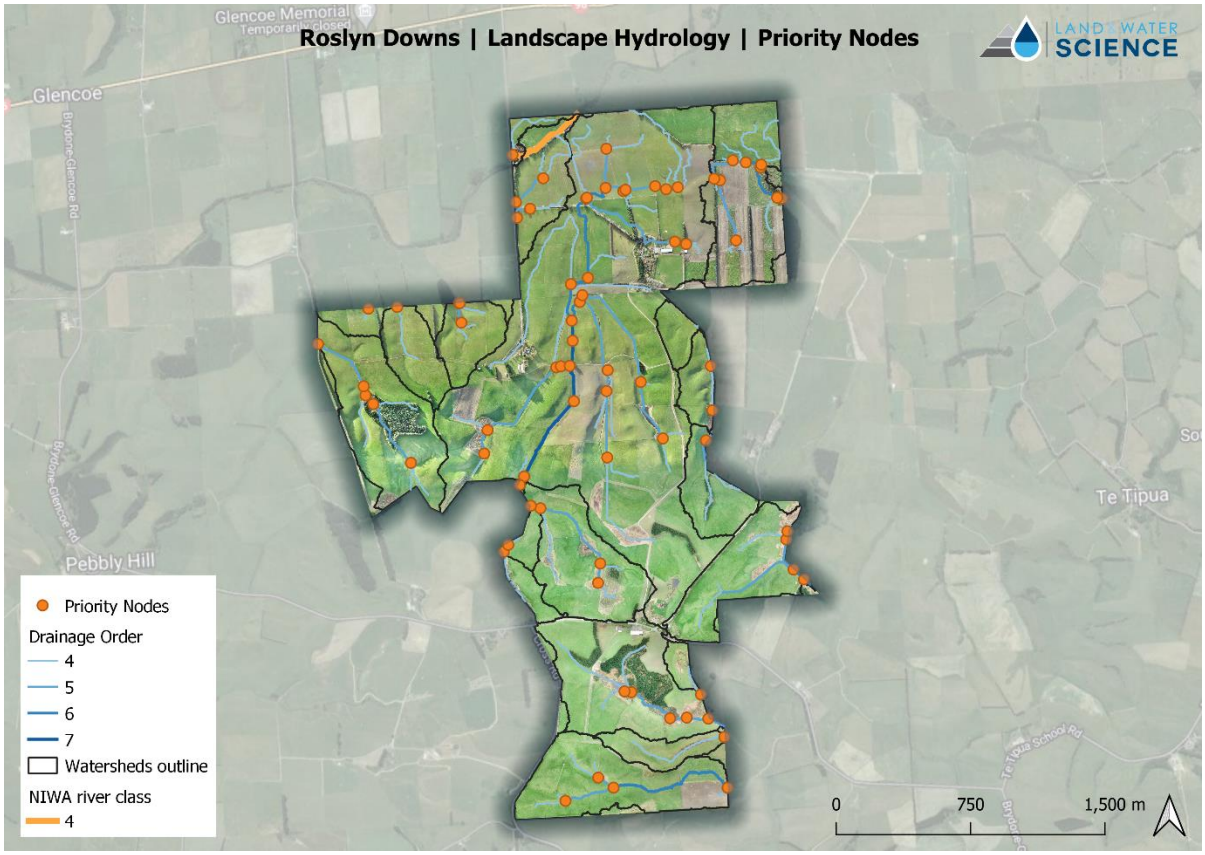

Figure 8. Roslyn Downs - landscape hydrology – drainage orders 4 - 7 only (i.e., the major drainage channels), plus the related junctions and discharge nodes. Junctions are where drainage channels join.

Figure 9. Roslyn Downs – zoomed in view of several priority nodes identified. Junction nodes (orange circles) identify where drainage channels converge or join.

The spatial context provided with the hydrological mapping creates insights as to the source and movement of water across the property. Again, water is the dominant control over contaminant loss. As such, the hydrological network generated here is seen as a critical starting point for understanding and prioritising possible mitigations to support a more resilient farm system, e.g., sediment traps ('Duck Ponds'), wetland areas etc. We recommend that the hydrological model of the property be used as a spatial framework through which the susceptibility of the farm landscape is viewed and ultimately managed.

5. Landscape Susceptibility for Roslyn Downs

The landscape is a significant driver of variability in the type and severity of water quality and soil GHG loss, even when land use is the same. Land & Water Science Ltd (LWS) have generated a new, high-resolution approach to mapping the inherent and varied susceptibility of the landscape to land use activities at property scales (Figs. 10 - 19).

The mapping provides integrated knowledge of the property-scale landscape factors that control water quality and soil nitrous oxide emissions across Southland. The maps of landscape susceptibility highlight the various contaminants and their forms using a scale of very low, low, medium, and high. As with any model, ground truthing in partnership with rural communities is the best way to ensure that the outputs are relevant.

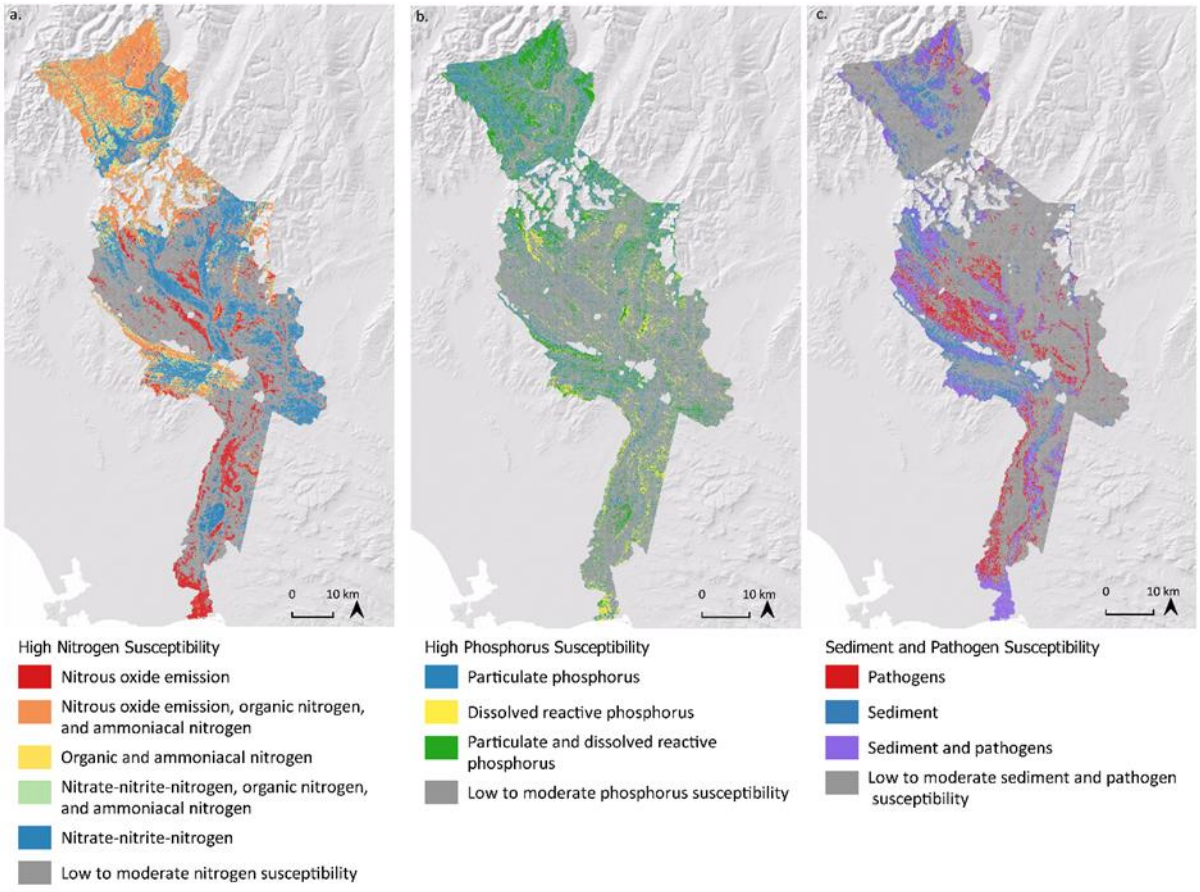

Figure 10. Example maps of landscape susceptibility (high) for the Mataura Catchment, Southland

Before reading any further, it is important to emphasise:

A. that the susceptibility models presented below do not take into account land use nor any existing management practices or physical mitigations (e.g., sediment traps, wetlands) that are already in place, and;

B. when reviewing the maps, please note they are ***not*** identifying actual losses, instead they seek to identify the natural susceptibility of the landscape to inform land users of the risks and opportunities associated with their landscape.

5.1 Landscape Susceptibility to Erosion

To assess the susceptibility of the property to erosion, the drainage network derived from the drone survey was overlaid with an earlier classification of the susceptibility of the landscape to erosion and sediment loss (Fig. 11). The erosion susceptibility layer is based on the integration of several datasets, not limited to airborne radiometric and a regional scale digital terrain model. Within the erosion susceptibility classification, red areas are identified as having a naturally elevated susceptibility to erosion and are mainly associated with hill and high-country areas that have erodible geologies. For the subject property, this classification identifies some elevated areas of 'Moderately high ESC' (orange colour) and 'Moderate ESC' (yellow colour).

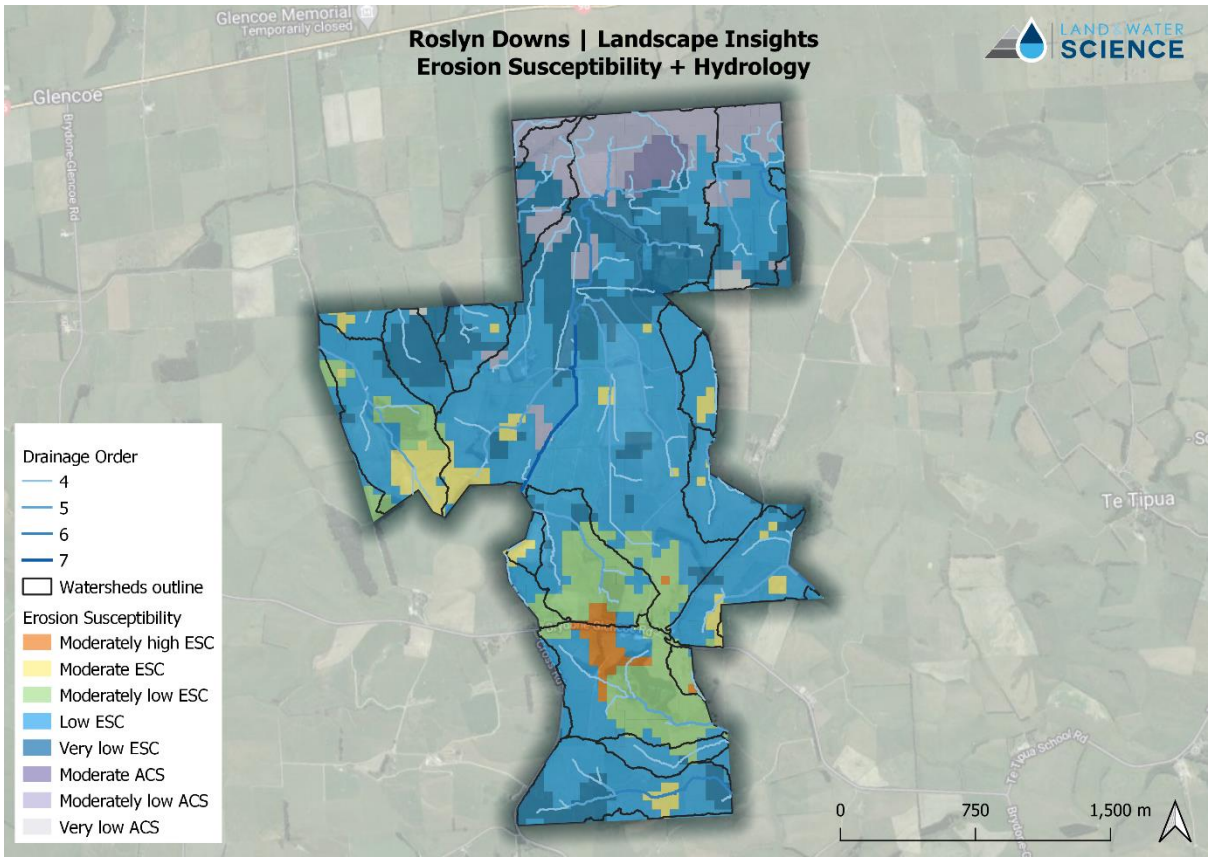

Figure 11. Roslyn Downs - landscape hydrology overlaid with Erosion Susceptibility (ESC), developed by Land and Water Science (2020).

Two different types of erosion susceptibility are identified. The lowest lying and flattest areas are associated with a mauve colour and a 'Moderate ACS' to 'Moderately low ACS.' Where ACS defines the 'activity status' of the low-lying area in terms of its susceptibility to sediment mobilisation in response to runoff.

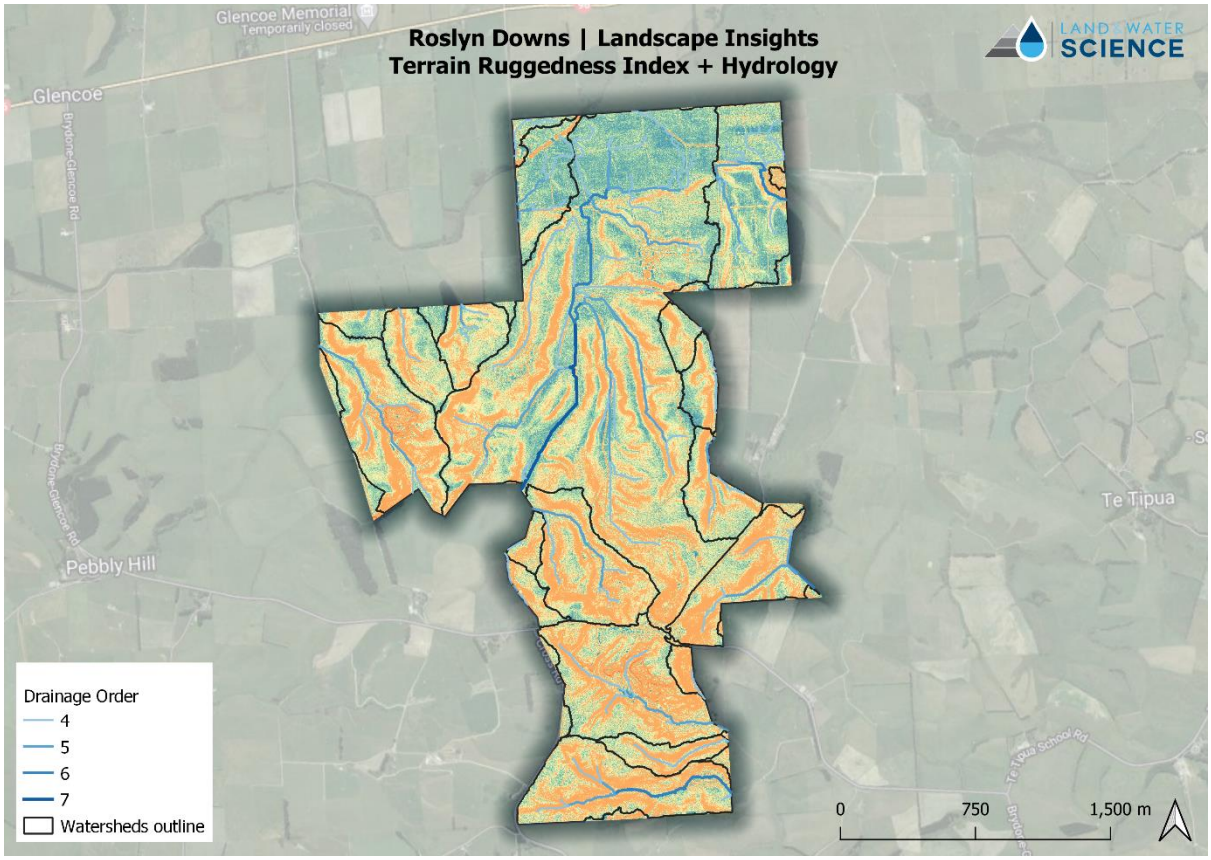

Figure 12. Roslyn Downs. Terrain Ruggedness Index shows the areas of the property which has the roughest terrain.

The drone survey also enabled a new, higher resolution (0.7 x 0.7 m with a vertical resolution of 0.02 cm) model of terrain ruggedness to be defined for the property (Fig. 12). The Terrain Ruggedness Index (TRI) presented here is a new output that provides much finer scale resolution over the ruggedness of the landscape. The TRI has been widely used nationally and internationally to support identifying areas of active erosion. The new TRI layer can be utilised to identify sub-paddock scale erosional features such as slips, slumps, soil creep (terracettes), and erosional features that are generated in response to ephemeral runoff. The TRI map, when used in combination with the digital drainage network and landscape susceptibility models, could be used to narrow down ('hone in') the areas of highest susceptibility for prioritisation. The utility of the TRI as a tool for sub-paddock scale identification of erosion will be provided as part of the farm visit.

The TRI output identifies the steeper slopes throughout the property as having the greatest susceptibility to erosion and sediment loss. Where high TRI coincides with poorly drained and slowly permeable soils, the risk of erosion and runoff is elevated. During a high-intensity rainfall event, e.g., a thunderstorm, runoff may result in these soils being incised, and the eroded soil carried to the drainage network. Included in the figure above is an overlay of the watersheds (black outlines) and drainage lines that receive and export sediment from the most rugged parts of the farm to lower-lying areas. This very high-resolution layer needs to be viewed at sub-paddock scales to extract the maximum value (i.e., Fig 13 & 14).

Figure 13. Roslyn Downs. High resolution zoomed in view from drone output looking at erosion susceptibility along the southern boundary paddock.

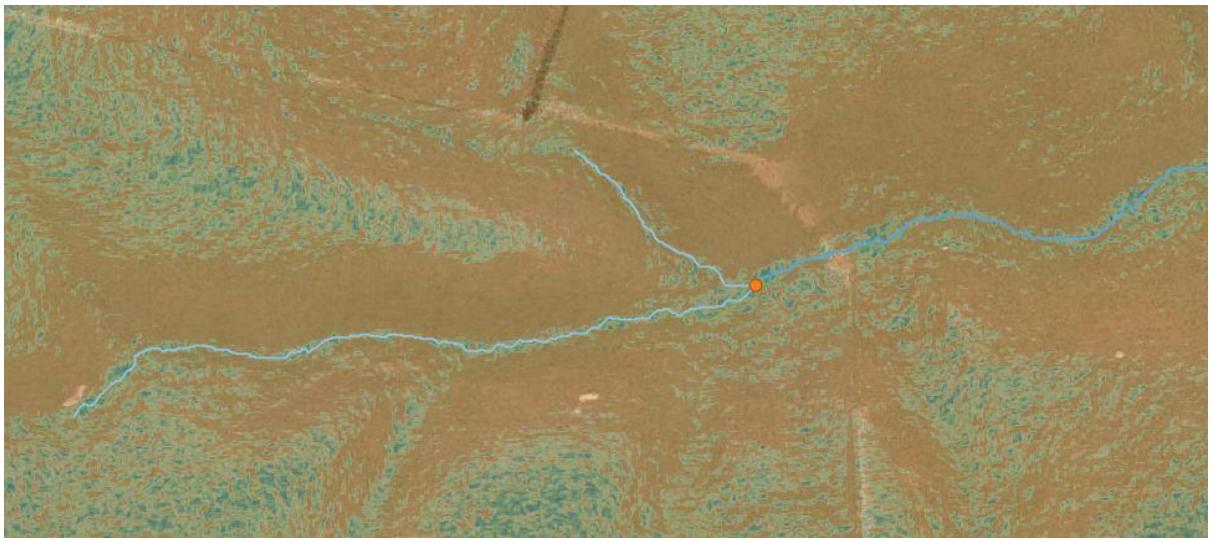

Figure 14. Roslyn Downs. Corresponding location to Fig 13 above showing high TRI.

Susceptibility to runoff and sediment loss is an important consideration for the property and is a natural phenomenon of contoured landscapes. However, land use does exacerbate the loss of sediment, with high-intensity land use on top of naturally susceptible areas associated with the highest rates of contaminant loss. Fortunately, through identifying the inherent susceptibility of the landscape to erosion, it is possible to design strategies to limit contaminant loss that are data-driven and targeted. In summary, inherently susceptible areas (highest TRI) are more likely to generate sediment when developed than less susceptible areas. Overall, the susceptibility of the property to sediment loss is considered low, but the potential for runoff is elevated. Managing runoff is an important approach to support the reduction of multiple different contaminants including sediment, phosphorus, nitrogen, and microbes to waterways.

5.2 Landscape susceptibility to soil zone nitrous oxide loss

When soil becomes saturated with water, even for a short period of time, it may generate nitrous oxide. Nitrous oxide is a potent soil GHG with a warming potential of c. 273 times that of carbon dioxide[1]. It is produced from soils that saturate easily, either due to slowly permeable topsoil or imperfect to poor drainage. However, if the soil lacks nitrate, then very little nitrous oxide will be

produced. Urine patches from livestock are a key source of urea that is rapidly converted to nitrate and potentially nitrous oxide under the right conditions.

In brief, the mass of nitrous oxide produced is a factor of the surplus of nitrate in the soil, soil temperature, and the duration of saturation of the soil. Low volumes of nitrous oxide are generated when soil temperatures are low, soil nitrate concentrations are low, and the topsoil is not saturated. High volumes of nitrous oxide are generated when soil temperatures are elevated, soil nitrate concentrations are high, and topsoil becomes saturated. The preliminary susceptibility map indicates that soil nitrous oxide is moderately important for Roslyn Downs. This is consistent with a significant area of imperfectly to poorly drained soils that, under specific conditions, can result in soil nitrous oxide generation. Current research has identified an environmentally friendly product for reducing soil nitrous oxide emissions from agricultural soils. Work trialling this nitrous oxide inhibitor is ongoing but should be available on the market within the next 24 months.

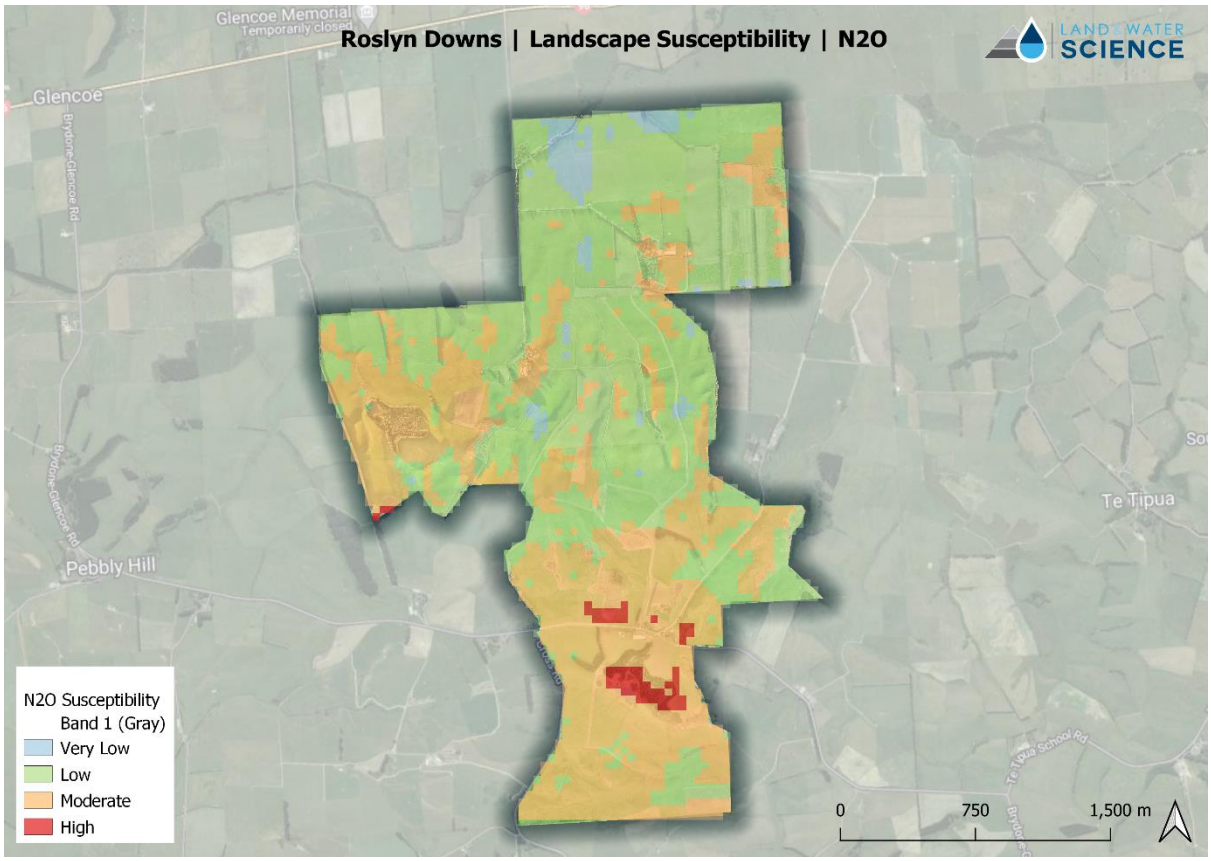

Figure 15. Roslyn Downs - landscape susceptibility to soil N_2O (Nitrous Oxide) emission.

5.3 Landscape susceptibility to nitrate-nitrite-nitrogen (NNN) loss

Nitrate and nitrite nitrogen (NNN) is highly soluble and is easily transported through the soil if not used by plants and microorganisms. NNN that moves below the root zone is at risk of being lost via lateral subsurface flow (including via mole-pipe drainage) and via vertical leaching to the underlying water table. Unlike organic or ammoniacal forms of nitrogen, NNN is not typically mobilised in surface runoff. Instead, it is 'rinsed' or leached from the soil and travels to the drainage network via subsurface flowpaths.

NNN leaching losses are often most significant where soils are permeable, well-drained and deep. Typically, flatter land with well-drained soils generates a greater proportion of NNN, which may be

lost below the root zone during soil water drainage - drainage usually occurs during the cooler months of the year. However, artificially drained and well-drained hill country soils may also lose appreciable concentrations of NNN if intensively farmed.

The susceptibility of the subject property to NNN loss is elevated across lower relief parts of the property, with some high susceptibility areas in the northern part of the property (Fig. 16). This is unsurprising given the imperfectly drained nature of Makarewa soils. However, whether excess NNN loss occurs across the areas with high susceptibility will be strongly controlled by land use intensity. It is important to emphasise that the susceptibility models do not consider land use nor any existing management practices of physical mitigations (e.g., sediment traps, wetlands) already in place. As such, landscape susceptibility models only identify the inherent or natural susceptibility of the land, they do not indicate that the areas of elevated susceptibility are losing high rates of contaminants.

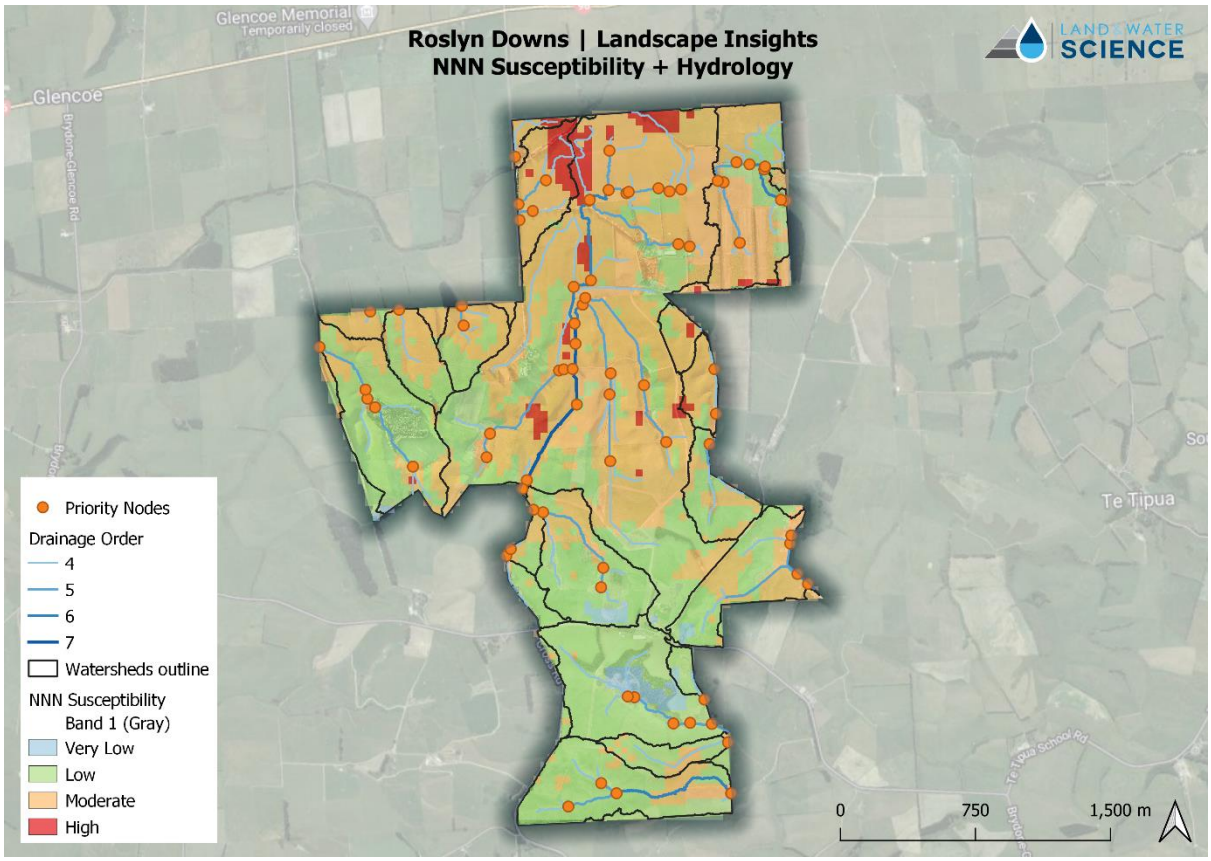

Figure 16. Roslyn Downs - landscape susceptibility to NNN (Nitrate-Nitrite Nitrogen) contaminants, overlaid with the hydrology content.

An important factor when considering the landscape's susceptibility to contaminant loss is the presence or otherwise of artificial drainage. Drainage of formerly imperfectly to poorly drained soils commonly favours NNN loss. In summary, the landscape settings suggest that NNN appears to be of moderate importance for Roslyn Downs.

5.4 Landscape susceptibility to Particulate Phosphorus (PP) loss

Particulate phosphorus (PP) refers to phosphorus that is attached to sediment that is mobilised in response to runoff. This includes organic and inorganic phosphorus from natural rock weathering, erosion of soil (stream or drainage channel erosion), animal manures, and fertiliser. Soils with high

Olsen-P values can produce large quantities of PP if eroded. As with sediment, PP is transported by water across the land to the drainage network. The abundance of P in soil is a factor of the P content of the geology the soil is formed in, the P that has been added by animals, the addition of inorganic fertiliser, and the breakdown of organic matter. As noted for NNN, it is important to emphasise that the susceptibility models do not consider land use or current environmental mitigations that are already in place. As such, they only highlight the inherent or natural susceptibility of the land.

Referring to the map image below, there are some elevated areas of landscape susceptibility to PP loss that tend to coincide with the steeper terrain in the southern part of the property. Managing runoff to reduce PP loss appears to be important for Roslyn Downs.

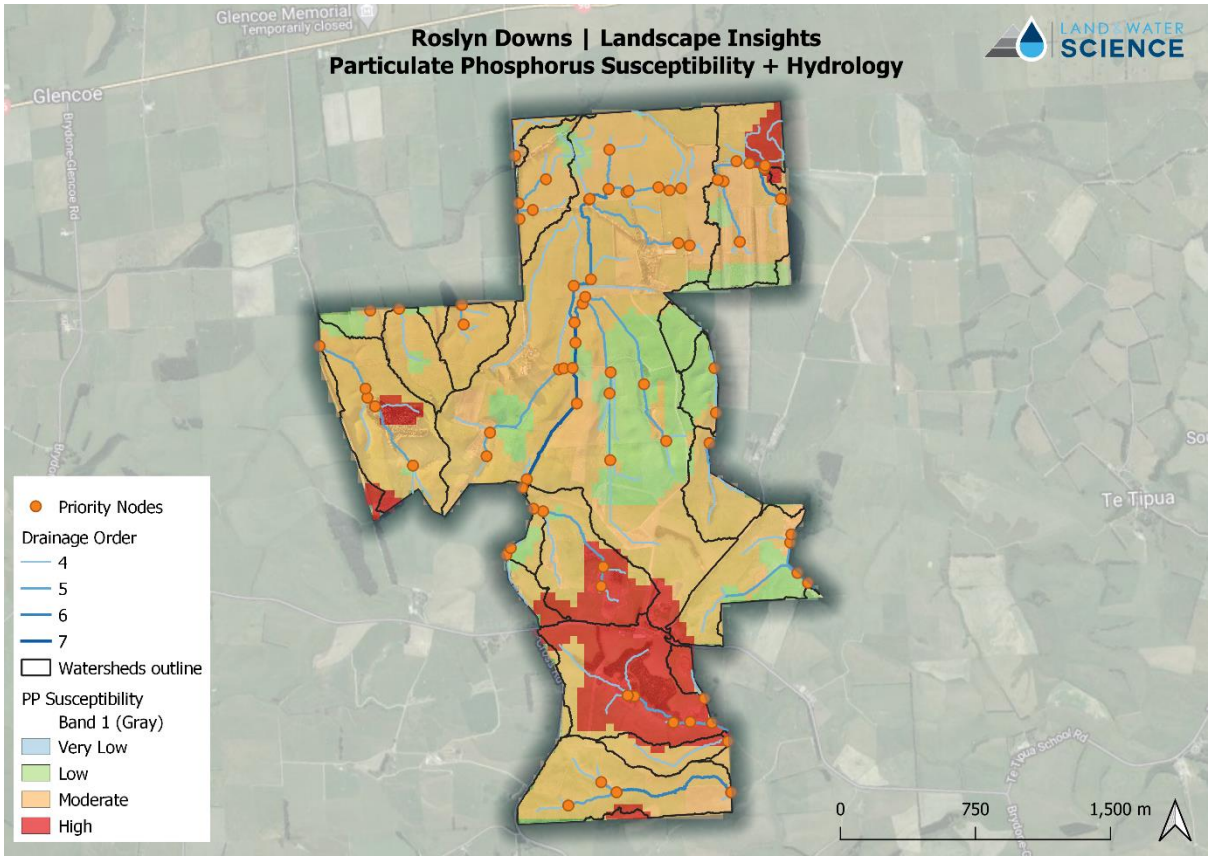

Figure 17. Roslyn Downs - landscape susceptibility to PP (Particulate Phosphorus) contaminants overlaid with the hydrology.

5.5 Landscape susceptibility to Dissolved Reactive Phosphorus (DRP) loss

Excess P, both as DRP and PP, is a key nutrient for plants and algae, with high concentrations leading to weed growth and algae blooms in waterways. Dissolved reactive phosphorus (DRP) refers to the phosphorus compounds that are dissolved in water as opposed to those that are attached to sediment, i.e., PP. Typically, DRP is characterised by very small molecules that are strongly held by most soil and geological materials. As DRP binds strongly to soil and geological materials, it will become PP if the soil is eroded or fine sediment is lost via the subsurface artificial drainage network.

The DRP susceptibility map for Roslyn Downs indicates low landscape susceptibility (Fig. 18). The landscape settings suggest that DRP susceptibility is unlikely to be important for this property. However, areas of artificial drainage may act as a conduit for subsurface DRP loss.

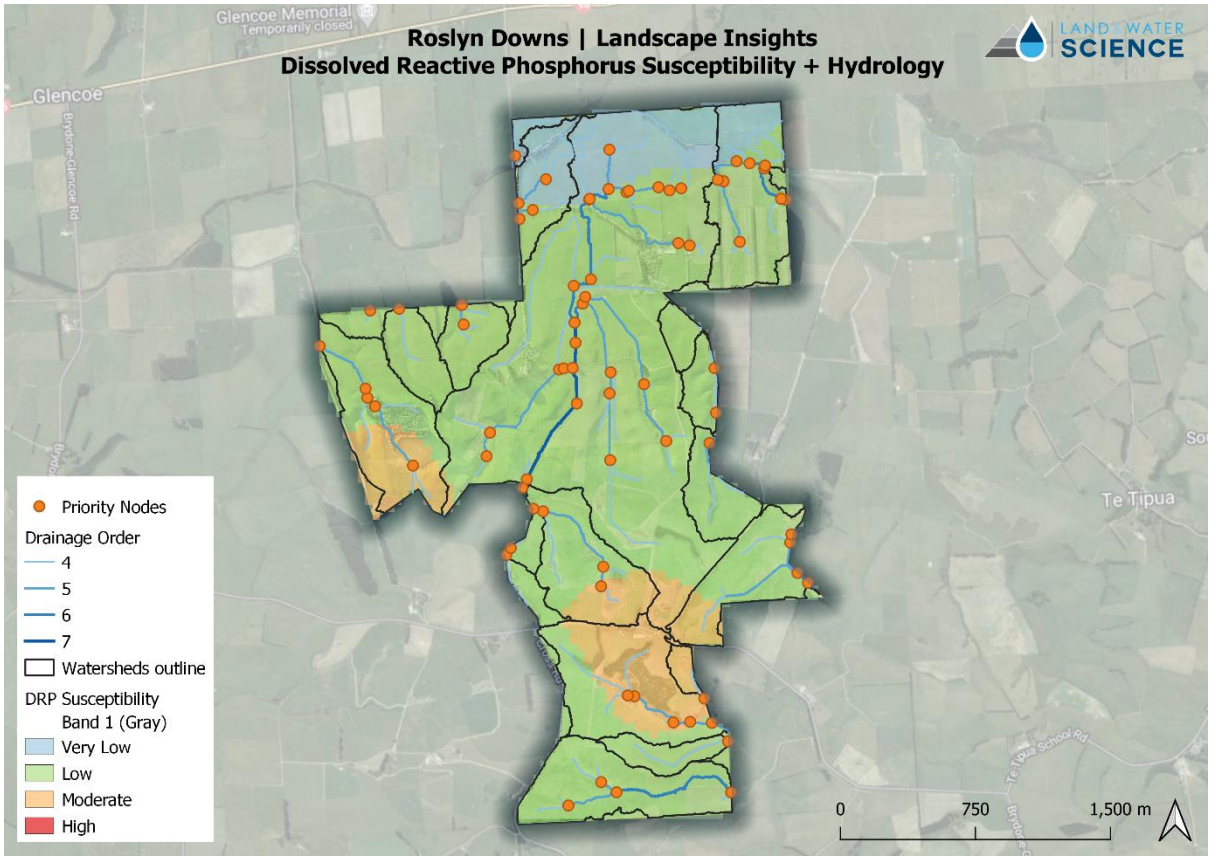

Figure 18. Roslyn Downs - landscape susceptibility to DRP (Dissolved Reactive Phosphorus) contaminants, overlaid with the hydrology.

5.6 Landscape Organic and Ammoniacal Nitrogen (TKN) Susceptibility

Total Kjeldahl Nitrogen (TKN) is a measure of organic and ammoniacal N. Organic and ammoniacal nitrogen are derived from the breakdown of organic matter, soil organic matter, manure, and animal urine. Organic nitrogen is mineralised to ammoniacal N, ammoniacal N is oxidised to nitrite and, ultimately nitrate. The loss of excessive TKN from land, e.g., from a recently cultivated paddock, is, therefore, an important factor controlling stream health. However, it is essential to note that all natural systems generate TKN, with TKN loss occurring from natural state landscapes and farmed land. The main difference between a natural state and any developed landscape is the magnitude of losses.

Commonly, natural TKN losses are elevated for soils that are imperfect to poorly drained or prone to saturation for extended periods of the year. The TKN susceptibility map for Roslyn Downs indicates higher elevation levels, which coincides with imperfectly to poorly drained soils and areas of elevated runoff risk. Managing runoff to reduce TKN loss appears to be important for Roslyn Downs.

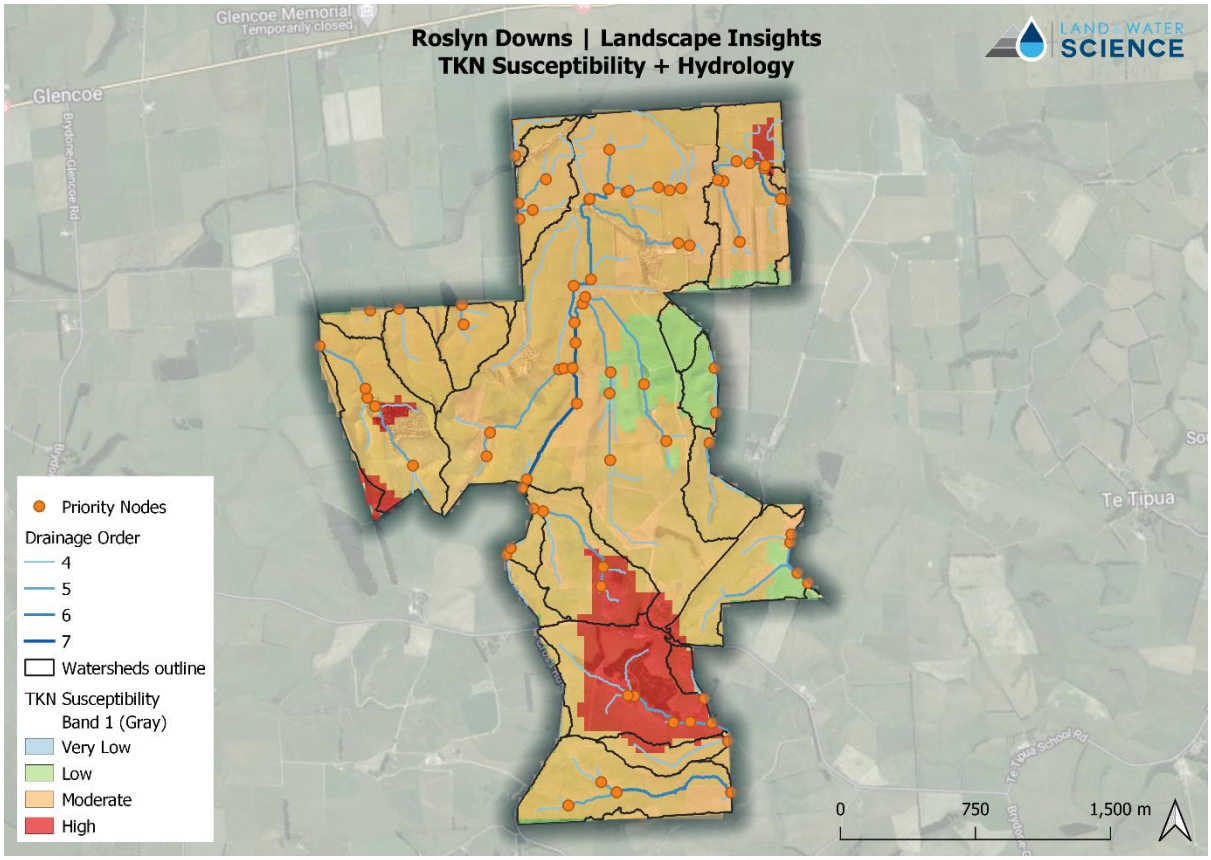

Figure 19. Roslyn Downs - landscape susceptibility to TKN (total Kjeldahl nitrogen – organic and ammoniacal nitrogen) contaminants, overlaid with the hydrology.

6. Next steps

This report introduces the landscape datasets and insights available for Roslyn Downs and provides an assessment of the susceptibility of the farm's landscape. We hope that the datasets presented here provide some helpful insights that can be used to support aligning the farm system with the landscape variability through input from specialist farm systems experts, and feedback from other farmers during the planned field day.