SOUTHLAND
PHYSIOGRAPHIC ZONES

WATER AND LAND 2020 & BEYOND

OXIDISING
Technical information

Physiographic zones are part of the *Water and Land 2020 & Beyond* project that aims to maintain and improve water quality in the Southland region, and to help us as a community achieve our goals for water.

Understanding our water

The Physiographics of Southland project was developed to better understand the evolution of water across Southland. By understanding where water comes from and the processes it undergoes as it moves through drainage networks, we can better understand the reasons for different water quality outcomes across the region.

The findings of the Physiographics of Southland project have been published in two reports, which identify the key drivers of hydrochemistry and water quality variability in Southland (Rissmann *et al*., 2016), and describe a classification system for managing land use effects on water quality (Hughes *et al*., 2016).

Physiographic zones and water quality

Physiographic zones represent areas of the landscape that have a common influence over water quality. The proposed Southland Water and Land Plan identifies nine physiographic zones in Southland that can be used to manage land use effects on water quality.

Physiographic zone technical information

The purpose of this booklet is to describe generalised water quality risks associated with individual physiographic zones. A companion booklet titled *Guide for using the Southland physiographic zones technical information* explains the terms and source data used in this booklet.

What's inside

environment SOUTHLAND REGIONAL COUNCIL
Te Taiao Tonga

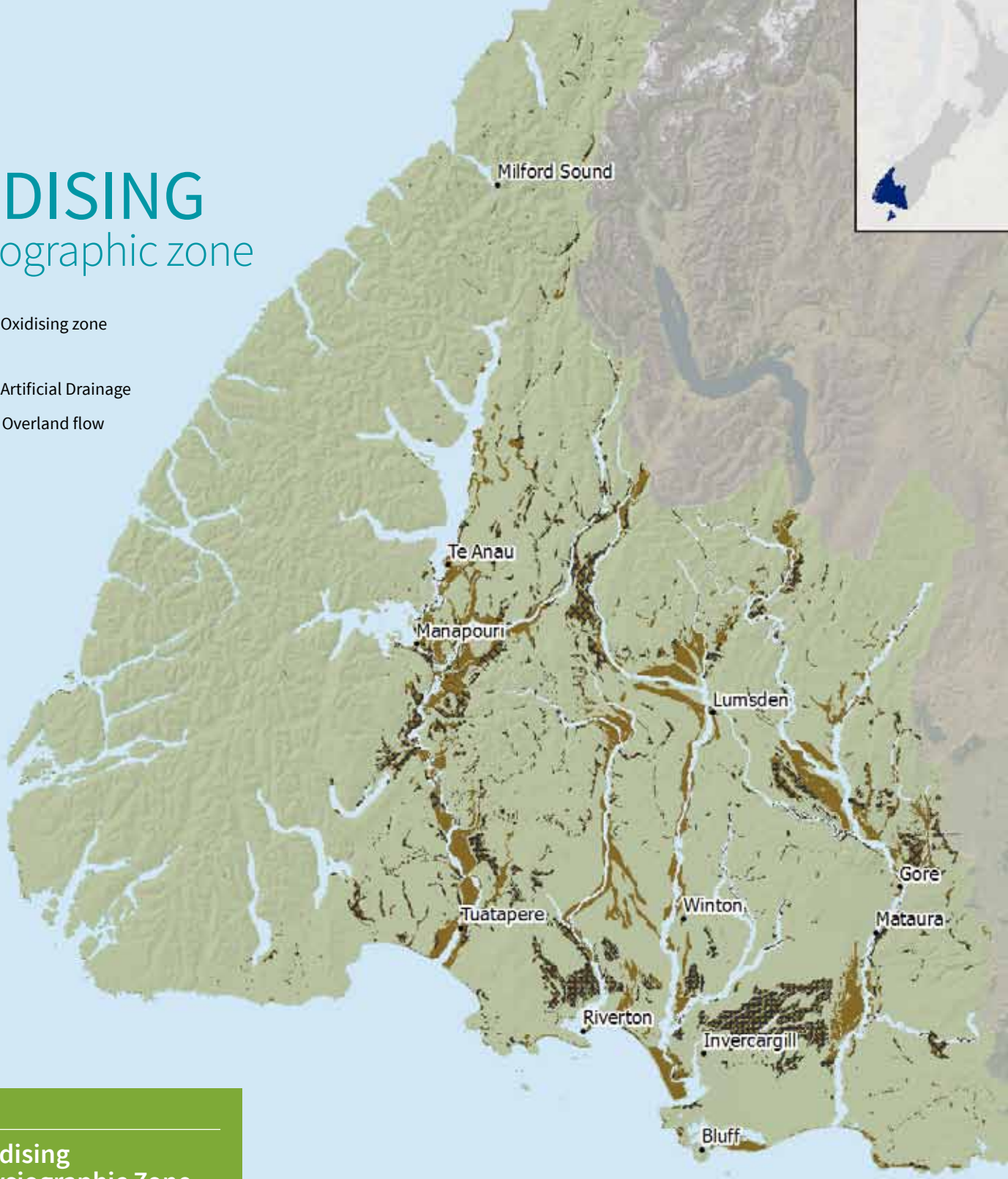
OXIDISING
physiographic zone

Oxidising zone

VARIANTS

Artificial Drainage

Overland flow



Oxidising Physiographic Zone

APPROXIMATE AREA

277,190 hectares

GEOGRAPHIC DISTRIBUTION

Intermediate alluvial terraces along the margins of the major river systems and inland basins.

MAIN SURFACE WATERWAYS

So Big Creek, McKellar Stream, Meadow Burn, Otama Creek, Okapua Creek.

Go to our online BEACON mapping service to view the physiographic zones of Southland in more detail.

Overview

The Oxidising physiographic zone is characterised by well drained soils, which overlie alluvial deposits that contain an extensive groundwater resource.

Key features

- Located on intermediate alluvial terraces along the margins of the major river systems.
- Predominately well drained, fine to coarse textured soils.
- Recharge occurs almost exclusively from local precipitation infiltrating through the soil matrix.
- Deep drainage to groundwater is the main contaminant pathway.
- Soils and aquifers have low denitrification potential.

Water quality implications

- Groundwater is susceptible to elevated nitrate concentrations.
- There is limited potential for contaminant losses to surface water where deep drainage predominates.
- Following heavy or sustained precipitation, episodic contaminant losses to surface waterways may occur in areas where there is an elevated potential for overland flow or artificial drainage.

WATER QUALITY RISK	OXIDISING	OXIDISING(a)	OXIDISING(o)
Contaminant pathways	Deep drainage	Deep drainage and artificial drainage	Deep drainage and overland flow
Dilution and attenuation processes	Filtration and adsorption	Filtration and adsorption	Filtration and adsorption
Primary receiving environments	Aquifers	Aquifers and surface waterways	Aquifers and surface waterways
Water quality risk	Nitrogen	Nitrogen, phosphorus, sediment, microbes	Nitrogen, phosphorus, sediment, microbes

Variants and associations

Variants

Variants identify areas within physiographic zones where there is increased water quality risk when soils are wet. Contaminant losses from variants occur along alternate drainage pathways that have lower attenuation potential.

The Oxidising physiographic zone has two identified variants.

Oxidising(a) – Artificial Drainage variant

Areas of undulating land that have slow subsoil permeability and may be seasonally wet. This results in an increased potential for artificial drainage to maintain agricultural production.

Approximate area: 48,240 ha

Oxidising(o) – Overland Flow variant

Areas of undulating to rolling land that have elevated potential for overland flow, due a combination of steeper slopes and/or less well drained soils.

Approximate area: 93,620 ha

Associations

The Oxidising physiographic zone is commonly associated with three physiographic zones in Southland (Figure 1).

Bedrock/Hill Country

The Oxidising zone occurs along the base of the Bedrock/Hill Country zone, where well drained soils occur on late Quaternary alluvium.

Overland flow from headwaters in the Bedrock/Hill Country zone may comprise a significant proportion of flow in streams traversing the Oxidising zone, and provide recharge to underlying aquifers.

Riverine

The Oxidising zone occupies older and/or elevated alluvial terraces that occur along the margins of the Riverine zone.

Groundwater and surface water discharge from the Oxidising zone provides significant baseflow to main stem rivers in the Riverine zone.

In some areas the Oxidising zone may also receive a minor component of recharge from the Riverine zone.

Gleyed

At a regional scale, the Oxidising zone occupies intermediate alluvial terraces between the Riverine and Gleyed zones.

However, within many lowland catchments, this relationship is often reversed with the Gleyed zone occurring in poorly drained soils along the margins of smaller streams draining the Oxidising zone reflecting localised accumulation of overbank silt deposits.

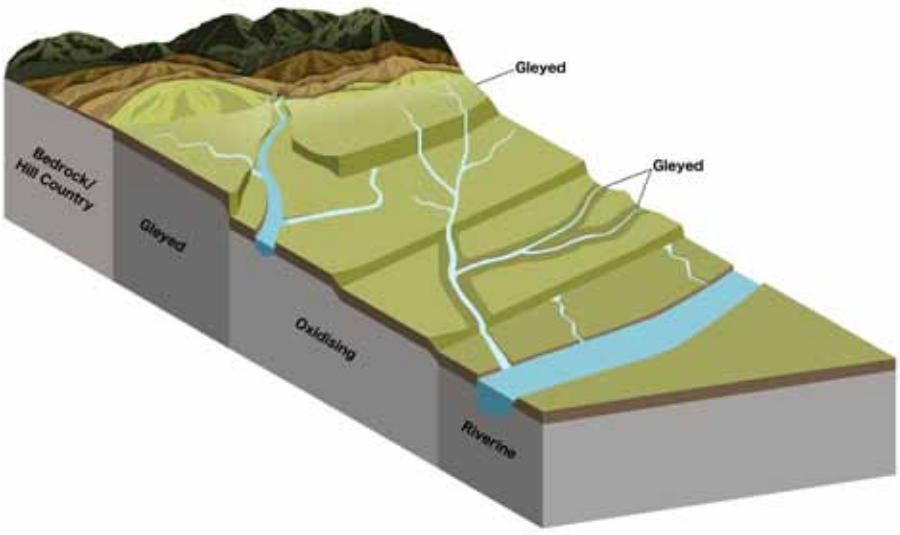
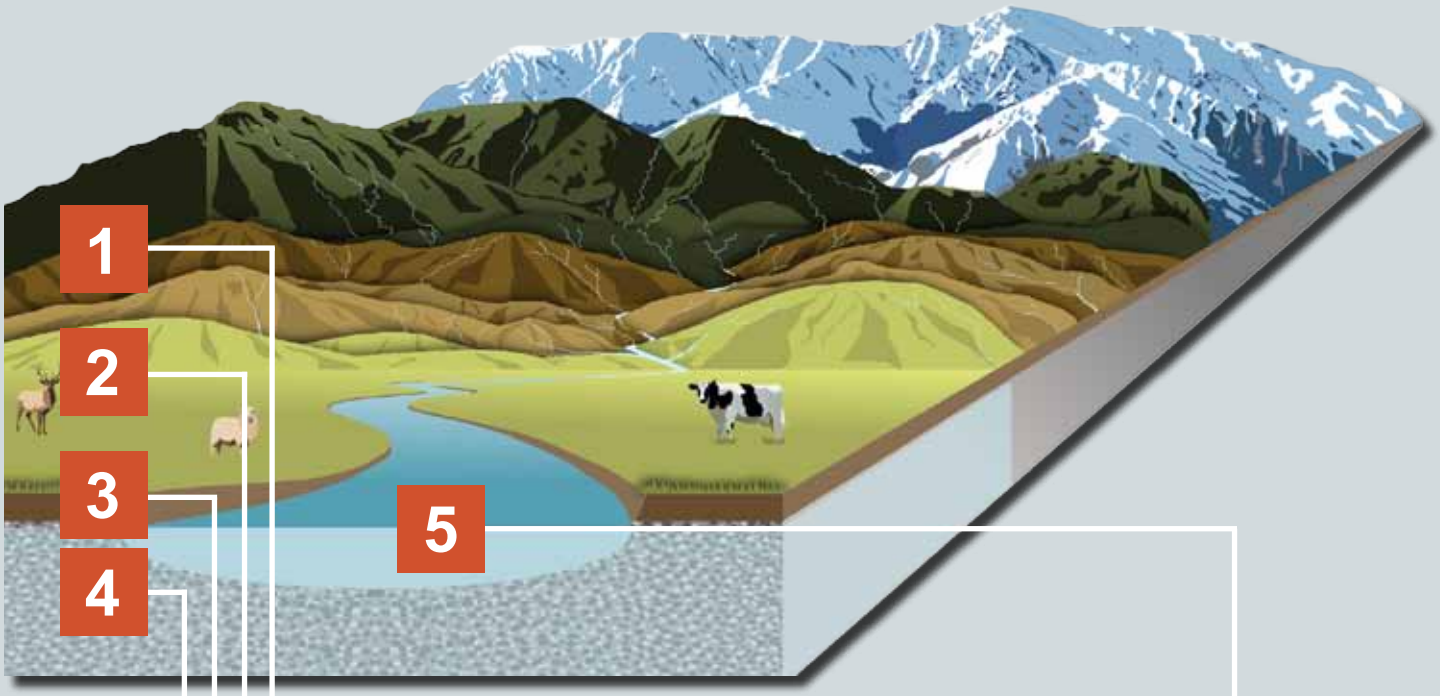


Figure 1: Landscape context image showing neighbouring zones. The Oxidising zone occupies alluvial terraces that are elevated above major river channels. Most of this zone has low slopes and well-drained soils. Streams that transect this zone are often perched above (disconnected from) the underlying water table. Only streams that are sufficiently incised to intersect the water table receive groundwater discharge from this zone.

Dominant characteristics that affect water quality



Landscape characteristics

Surface zone characteristics

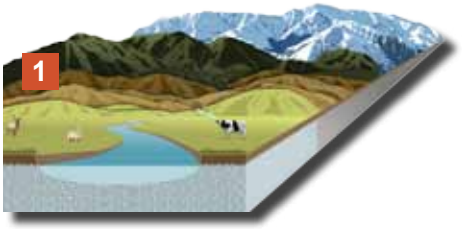
Soil zone characteristics

Saturated zone characteristics

Water quality implications

1 Landscape characteristics

The Oxidising physiographic zone is distributed across elevated alluvial terraces along the outer margins of the major river systems and inland basins.



Topography

Elevation

Most of this zone occurs at elevations of less than 300 metres relative to sea level (m RSL).

The Artificial Drainage variant is typically located at lower elevations of less than 100 m RSL.

The Overland Flow variant is typically located at higher elevations with 72% occurring between 100 and 500 m RSL.

Slope

Most of this zone occupies flat to undulating land (≤3° slope).

The Artificial Drainage variant almost exclusively occurs in flatter areas where soils are less well drained.

The Overland Flow variant is typically located on steeper land (generally ≤15°).

Geology

This zone is mainly distributed across alluvium, terrace gravels and outwash deposits of Q2 to Q4 age.

The alluvial deposits are generally comprised of poorly sorted sand and gravel, with accessory lenses of finer-grained silt and clay.

The texture of alluvial deposits reflects their deposition on aggrading floodplains. Reworking of alluvial materials occurs along active river channels. Reworked alluvium is interspersed with deposition of finer-grained overbank deposits along channel margins.

The Artificial Drainage variant typically occurs on older alluvial terraces, such as Q8 to Q10 Kamahi Formation, which occupies most the variant area.

The majority of alluvial deposits are fresh and only slightly weathered. However, the older alluvium of the Kamahi Formation is moderately weathered.

Climate

Areas in Fiordland experience very high annual rainfall totals of around 9,000 millimetres (mm). Elsewhere rainfall generally ranges between 780mm near Riversdale to 1,600mm in higher elevation areas of the coastal Longwoods.

Average annual rainfall in the Overland Flow variant is generally greater reflecting its occurrence at higher elevations.

Oxidising LANDSCAPE zone characteristics

ELEVATION
0 – 800 m RSL

SLOPE
Flat to gently undulating

GEOLOGY
Quaternary sediments

LANDFORM AGE
Q2–Q4

AVERAGE ANNUAL RAINFALL
1,267 mm per year

Oxidising(a) LANDSCAPE zone characteristics

ELEVATION
0 – 800 m RSL

SLOPE
Flat to gently undulating

GEOLOGY
Quaternary sediments

LANDFORM AGE
Q8–Q10

AVERAGE ANNUAL RAINFALL
1,092 mm per year

Oxidising(o) LANDSCAPE zone characteristics

ELEVATION
0 – 800 m RSL

SLOPE
Flat to rolling

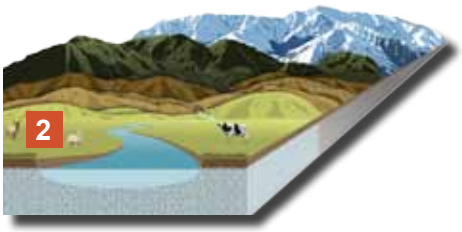
GEOLOGY
Quaternary sediments

LANDFORM AGE
Q2–Q10

AVERAGE ANNUAL RAINFALL
1,378 mm per year

2 Surface zone characteristics

Recharge to the Oxidising physiographic zone occurs via local rainfall infiltrating through the soil matrix, with some overland flow from adjacent higher areas.



Dilution

This zone is predominately recharged via land surface recharge (matrix flow). There is limited potential for dilution of contaminant concentrations associated with this recharge mechanism.

Some dilution may occur in parts of the Overland Flow variant where there is runoff from higher elevation alpine and hill country areas.

Surface waterways

Many of the streams located on elevated alluvial terraces have their origins in headwaters that drain adjacent higher elevation areas in the Bedrock/Hill Country or Gleyed zones.

Streams traversing this zone are often perched so have limited interaction with the Oxidising zone in terms of a receiving environment for overland flow or baseflow. Surface waterways receive discharge via the artificial drainage network in the Artificial Drainage variant.

However, exceptions occur in areas of older alluvium where streams are sufficiently incised to intercept the underlying water table.

A moderately dense network of streams is found in the Overland Flow variant. This is due to the combination of steeper topography and generally poorer soil drainage.

Overland flow

Localised ponding may occur during precipitation events when soils are wet. Where there is sufficient slope, this results in saturation excess overland flow, particularly in the Overland Flow variant (Oxidising(o)).

Oxidising SURFACE zone characteristics

DILUTION POTENTIAL
Low recharge flux

DRAINAGE DENSITY
Moderate

STREAM ORDER
Mixed

OVERLAND FLOW POTENTIAL
Very low

Oxidising(a) SURFACE zone characteristics

DILUTION POTENTIAL
Low recharge flux

DRAINAGE DENSITY
Low

STREAM ORDER
Predominately small

OVERLAND FLOW POTENTIAL
Very low

Oxidising(o) SURFACE zone characteristics

DILUTION POTENTIAL
Low recharge flux

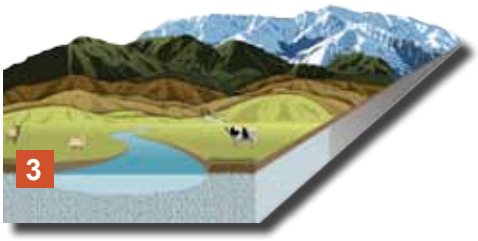
DRAINAGE DENSITY
Moderate

STREAM ORDER
Mixed

OVERLAND FLOW POTENTIAL
Moderately high to high

3 Soil zone characteristics

Soils in this physiographic zone are generally well drained, fine textured and characteristically lack redoximorphic features such as mottling or gleying.



Soils

The two main soil groups are Brown Firm and Brown Orthic soils.

Brown Firm soils have a silt loam topsoil texture. Stones are present throughout the soil profile, which can limit rooting depth and water-holding capacity. In some areas the subsoil has become cemented, restricting vertical infiltration.

Brown Orthic soils also have a silt loam topsoil texture. However, these soils are typically stone-free and have no impediments to vertical infiltration.

Soils in the Artificial Drainage variant typically exhibit finer-grained textures (more clay and less sand) so often have lower subsoil permeability.

Reduction potential

Due to their good internal drainage and relatively low organic carbon content, soils in this zone have low reduction potential (i.e. denitrification is limited so there is an elevated risk of nutrient leaching).

The oxidising nature of these soils is primarily a feature of good drainage but also partly reflects the high proportion of loess parent materials, derived from base (and electron donor) poor siliceous/felsic rocks.

Artificial drainage

Soils in this zone are typically classified as well drained.

However, dense subsoil in the Artificial Drainage variant can reduce vertical permeability, making soils prone to seasonal waterlogging. Artificial (mole-pipe) drainage is extensively used to remove excess soil water to maintain agricultural production in these areas.

Lateral drainage

In soil types that have restricted drainage, lateral flow may occur above slowly permeable layers within the soil profile. However, in these areas the extent of lateral flow is limited due to the artificial drainage network.

Oxidising SOIL zone characteristics

SOIL ORDER
Brown

PROFILE DRAINAGE
Well drained

PERMEABILITY
Moderate over moderate, slow and rapid over rapid

ANION STORAGE CAPACITY
Moderate

REDUCTION POTENTIAL
Low

ARTIFICIAL DRAINAGE DENSITY
None to moderate

LATERAL DRAINAGE POTENTIAL
Localised

Oxidising(a) SOIL zone characteristics

SOIL ORDER
Brown

PROFILE DRAINAGE
Well to moderately well drained

PERMEABILITY
Moderate over moderate, slow

ANION STORAGE CAPACITY
Moderate

REDUCTION POTENTIAL
Low

ARTIFICIAL DRAINAGE DENSITY
Moderate

LATERAL DRAINAGE POTENTIAL
Localised

Oxidising(o) SOIL zone characteristics

SOIL ORDER
Brown

PROFILE DRAINAGE
Well to moderately well drained

PERMEABILITY
Moderate over slow*

ANION STORAGE CAPACITY
Moderate*

REDUCTION POTENTIAL
Low

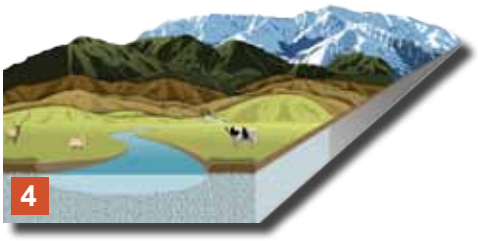
ARTIFICIAL DRAINAGE DENSITY
Low to none

LATERAL DRAINAGE POTENTIAL
Localised

*A significant proportion (>50%) of the zone does not have available data.

4 Saturated zone characteristics

The Oxidising physiographic zone is characterised by coarse, poorly sorted alluvial deposits that host spatially extensive unconfined aquifers.



Groundwater

Aquifers in this zone typically exhibit little or no direct connectivity with main stem river systems, except in areas along the margins of recent floodplains.

Throughflow from aquifers underlying higher elevation alluvial terraces may also contribute to the overall water balance in some areas.

Aquifers in this zone exhibit a wide range of hydraulic properties that reflect the overall heterogeneity of the alluvial materials. However, aquifer permeability is generally high when compared to other areas of Southland.

The highest permeabilities occur in recent (Q1-Q2) alluvium proximal to the major rivers. Lower permeabilities are typically observed in aquifers underlying older, elevated terraces.

Groundwater levels in this zone typically range between 5 to 10 metres below ground level, often sufficient to limit hydraulic connection to overlying surface waterways.

Groundwater levels exhibit a regular seasonal variation with limited response to individual precipitation events. This reflects the moderating effect of drainage through the thick, fine-grained soil profile and underlying unsaturated zone.

Groundwater discharge occurs as baseflow to streams and rivers on terraces that are sufficiently incised. It also occurs as:

- springs around the base of terrace risers
- throughflow to aquifers underlying lower elevation terraces.

Reduction potential

Aquifers within this zone have low reduction potential due to their low organic carbon content. As a result, there is low potential for denitrification to occur within the groundwater system.

Deep drainage

Deep drainage to groundwater is the main drainage mechanism in this zone due to the predominantly flat-lying topography and well-drained soils.

Deep drainage is typically seasonal. Most recharge occurs when soil moisture is at or near field capacity, generally between late autumn and spring.

However, drainage to the water table can occur at any time of the year in response to heavy or sustained precipitation.

Oxidising SATURATED zone characteristics

WATER TABLE DEPTH
Shallow to moderate

AQUIFER PERMEABILITY
High

ACTIVE GROUNDWATER STORAGE
Extensive

REDUCTION POTENTIAL
Low

DEEP DRAINAGE POTENTIAL
High

Oxidising(a) SATURATED zone characteristics

WATER TABLE DEPTH
Moderate to shallow

AQUIFER PERMEABILITY
Moderate

ACTIVE GROUNDWATER STORAGE
Moderate

REDUCTION POTENTIAL
Low

DEEP DRAINAGE POTENTIAL
Moderate

Oxidising(o) SATURATED zone characteristics

WATER TABLE DEPTH
Shallow*

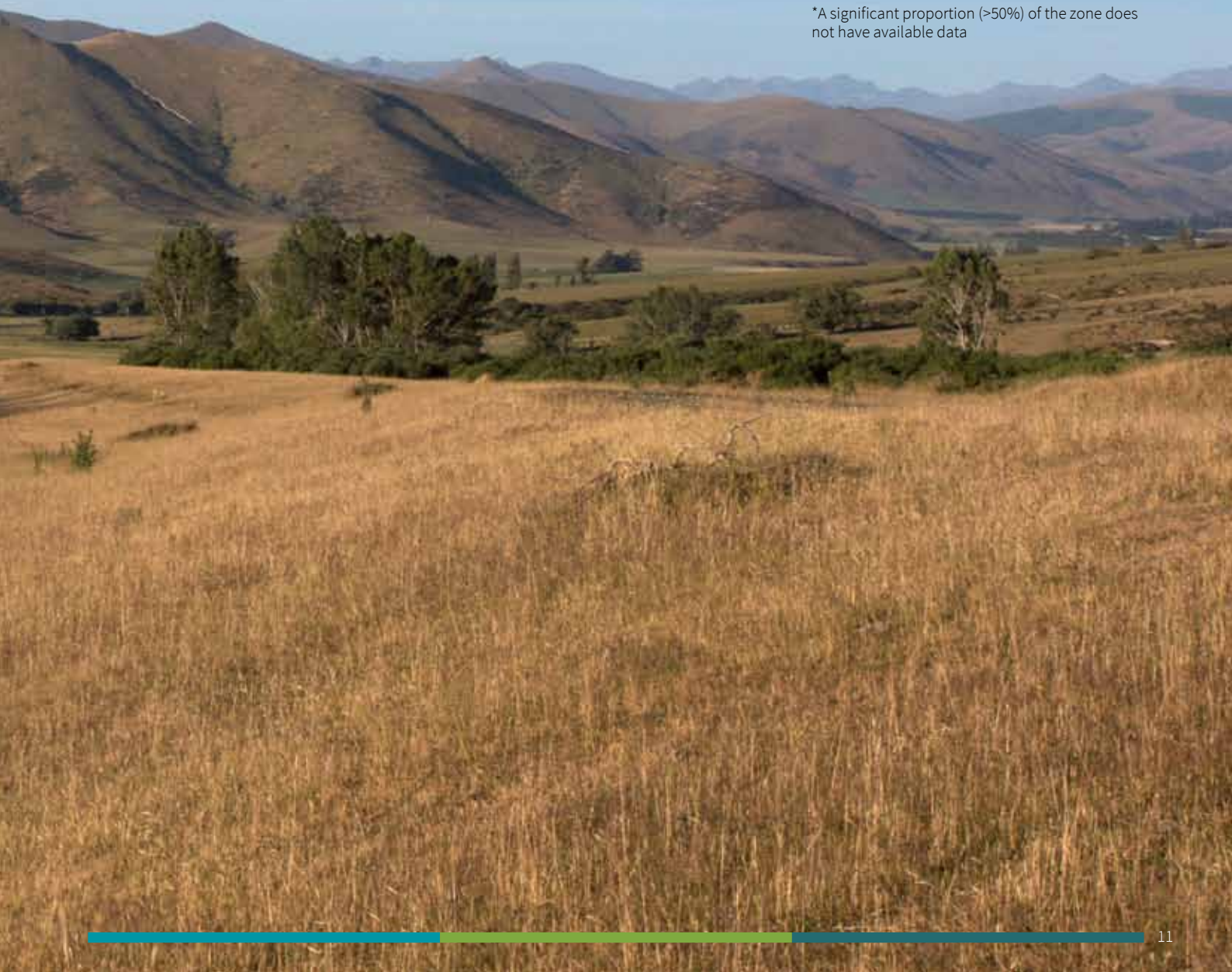
AQUIFER PERMEABILITY
Moderate

ACTIVE GROUNDWATER STORAGE
Moderate

REDUCTION POTENTIAL
Low

DEEP DRAINAGE POTENTIAL
High

*A significant proportion (>50%) of the zone does not have available data



5 Water quality implications

The main water quality issues for this physiographic zone are leaching of soil nitrate and subsequent accumulation in groundwater. Episodic losses of nutrients, sediment and microbes to surface water may occur when soils are wet in the Artificial Drainage and Overland Flow variants.

Influencing factors

Water quality in this zone is influenced by the low reduction potential in soils and underlying aquifers.

Water quality issues

Groundwater

Deep drainage is the main contaminant pathway for this zone (Figure 2). Nitrate concentrations can become elevated due to:

- low denitrification rates in the soil zone and underlying aquifers.
- the large contribution of land surface recharge (deep drainage) to the water balance.
- little to no riverine flushing.

Groundwater containing elevated nitrate concentrations contributes to:

- baseflow and nutrient loads in springs and spring-fed streams.
- the water balance and nutrient concentrations in adjacent aquifers.

Surface waters

Although soils are oxidising (have low reduction potential), surface waters in this zone have a predominantly mixed redox state reflecting their headwater origins in the Bedrock/Hill Country or Gleyed zones.

The difference in redox state between groundwater and surface water in part reflects the limited hydraulic connection between streams and aquifers in this zone.

Contaminant losses via artificial drainage (Figure 3) or overland flow (Figure 4) have the potential to adversely affect water quality in streams and rivers traversing the artificial drainage and overland flow variants.

Key HYDROCHEMICAL features

- Waters in this zone have low alkalinity compared to other zones. Reasons for this likely include the predominantly felsic parent material with lesser acidic buffering capacity and little to no carbonate minerals and limited denitrification occurring
- Elevated potassium (K), nitrate (NO_3) and sulphate (SO_4) concentrations reflect the dominance of soil zone recharge through relatively young geomorphic surfaces (as opposed to older more highly weathered alluvium)
- This zone is disseminated and heterogeneous. There are three main settings reflected in the hydrochemistry: well-drained, flat (Oxidising), undulating, slower subsoil permeability (Oxidising(a)) and rolling, slower subsoil permeability (Oxidising(o))

What affects water quality in the Oxidising zone?

WHERE	KEY CHARACTERISTICS	CONTAMINANT PATHWAYS	ATTENUATION PROCESSES	WATER QUALITY RISK
All areas	Localised precipitation Land surface recharge Well-drained soils	Lateral flow through the soil matrix when soils are wet	Filtration and adsorption removes virtually all particulate and microbial contaminants	Low water quality risk
		Deep drainage through soil and saturated zone when soils are wet	Filtration and adsorption of particulate and microbial contaminants Low denitrification potential in soils and aquifers	Nitrogen Elevated potential for nitrate losses to groundwater
Artificial Drainage variant	Low subsoil permeability Flat topography	Artificial drainage in response to sustained or heavy precipitation events	Low denitrification potential in soils	Nitrogen Phosphorus Microbes Sediment Contaminants discharged rapidly to surface water
Overland Flow variant	Sloping topography Higher volumes of precipitation	Overland flow in response to sustained or heavy precipitation events	Dilution of contaminant concentrations may occur where there are higher precipitation volumes	Nitrogen Phosphorus Microbes Sediment Contaminants discharged rapidly to surface water

CONTAMINANT PATHWAY	MITIGATION OBJECTIVES
Deep drainage	Reduce the accumulation of surplus nitrogen in the soil, particularly during autumn and winter
Overland flow	Protect soil structure, particularly in gullies and near stream areas Manage critical source areas Reduce phosphorus use or loss
Artificial drainage	Protect soil structure, particularly in gullies and near stream areas Reduce phosphorus use or loss Reduce the accumulation of surplus nitrogen in the soil, particularly over autumn and winter Avoid preferential flow of effluent through drains Capture contaminants at drainage outflows

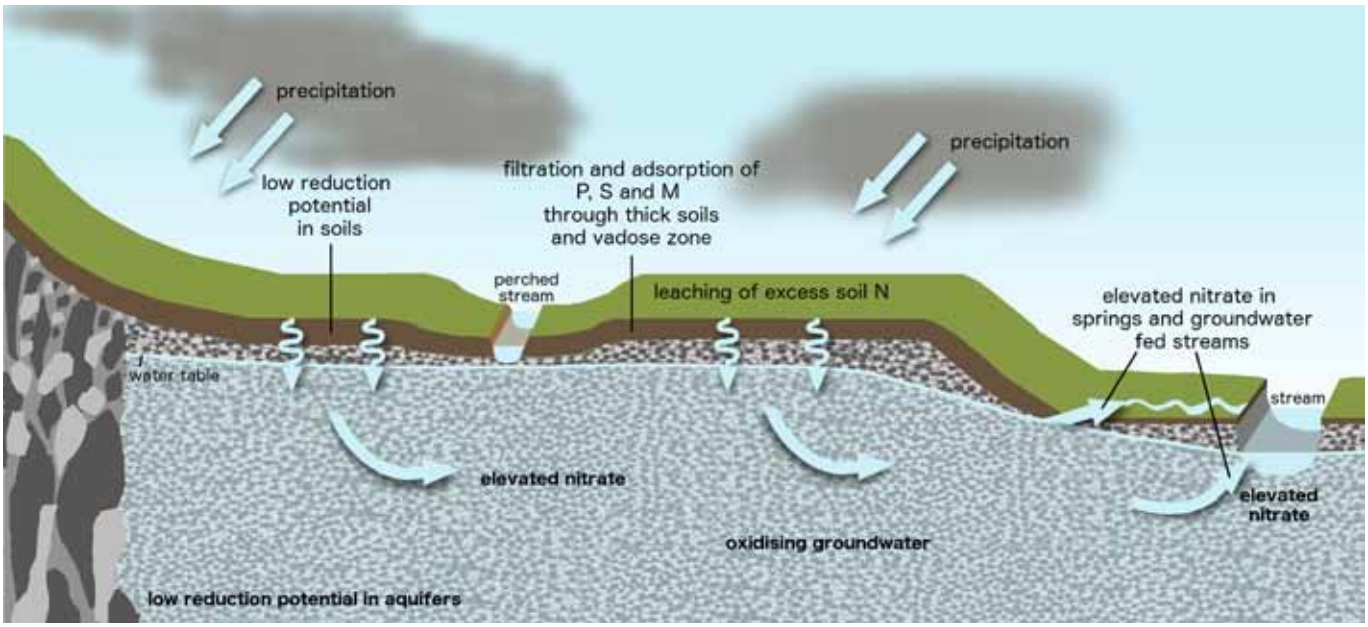


Figure 2: Main zone. Groundwater quality in the Oxidising physiographic zone is susceptible to nitrate accumulation and leaching in groundwater due to the predominantly flat topography, well drained soils and low denitrification potential of soils and aquifers. Nitrate which accumulates between summer and early autumn is leached to underlying groundwater during the drainage season (normally between autumn and spring). Groundwater containing elevated nitrate concentrations contributes to baseflow in streams and springs.

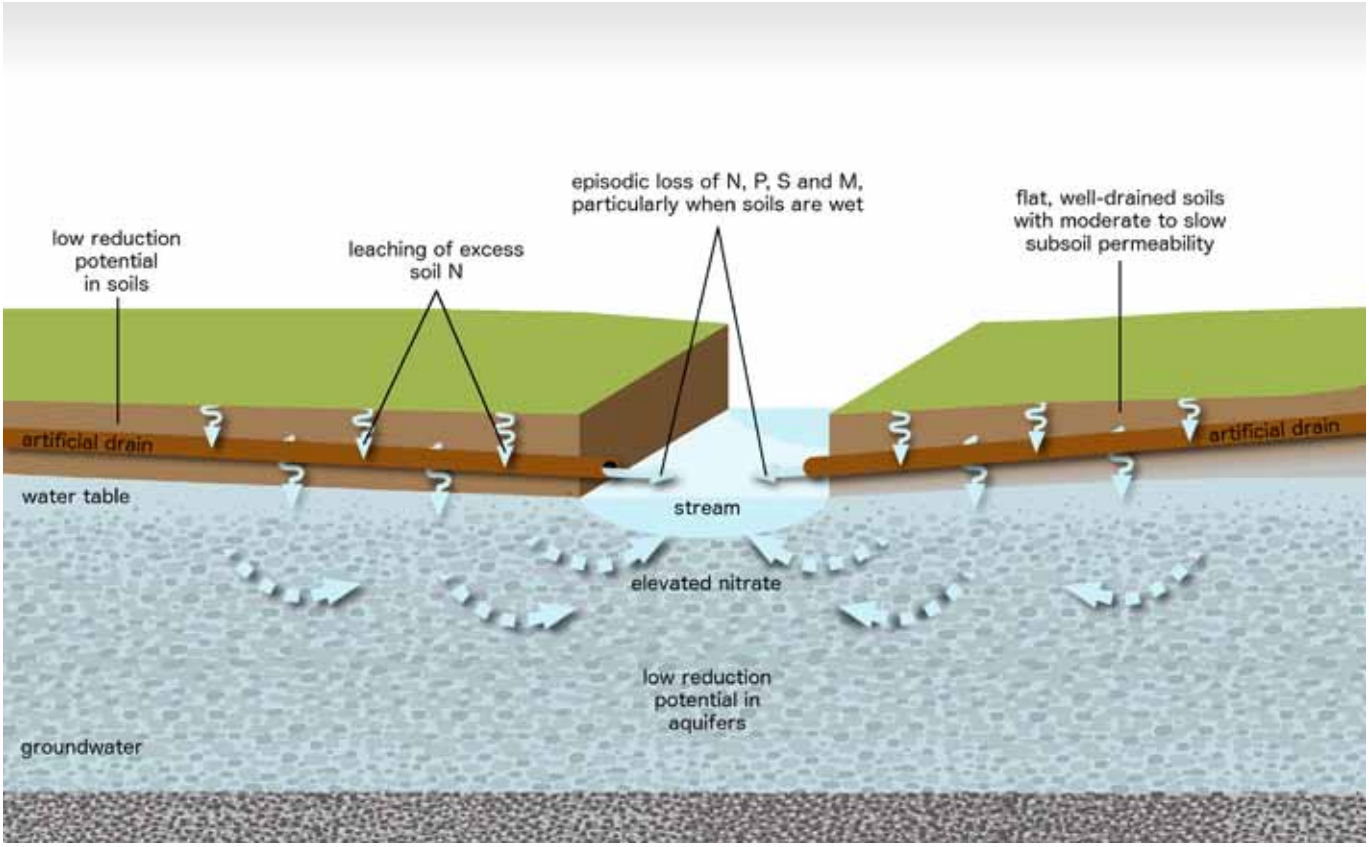


Figure 3: Artificial Drainage variant. In areas where soils have low subsoil permeability, artificial drainage via mole-pipe drains provides a pathway for episodic losses of nitrogen (N), phosphorus (P), sediment (S) and microbes (M) to surface waterways.

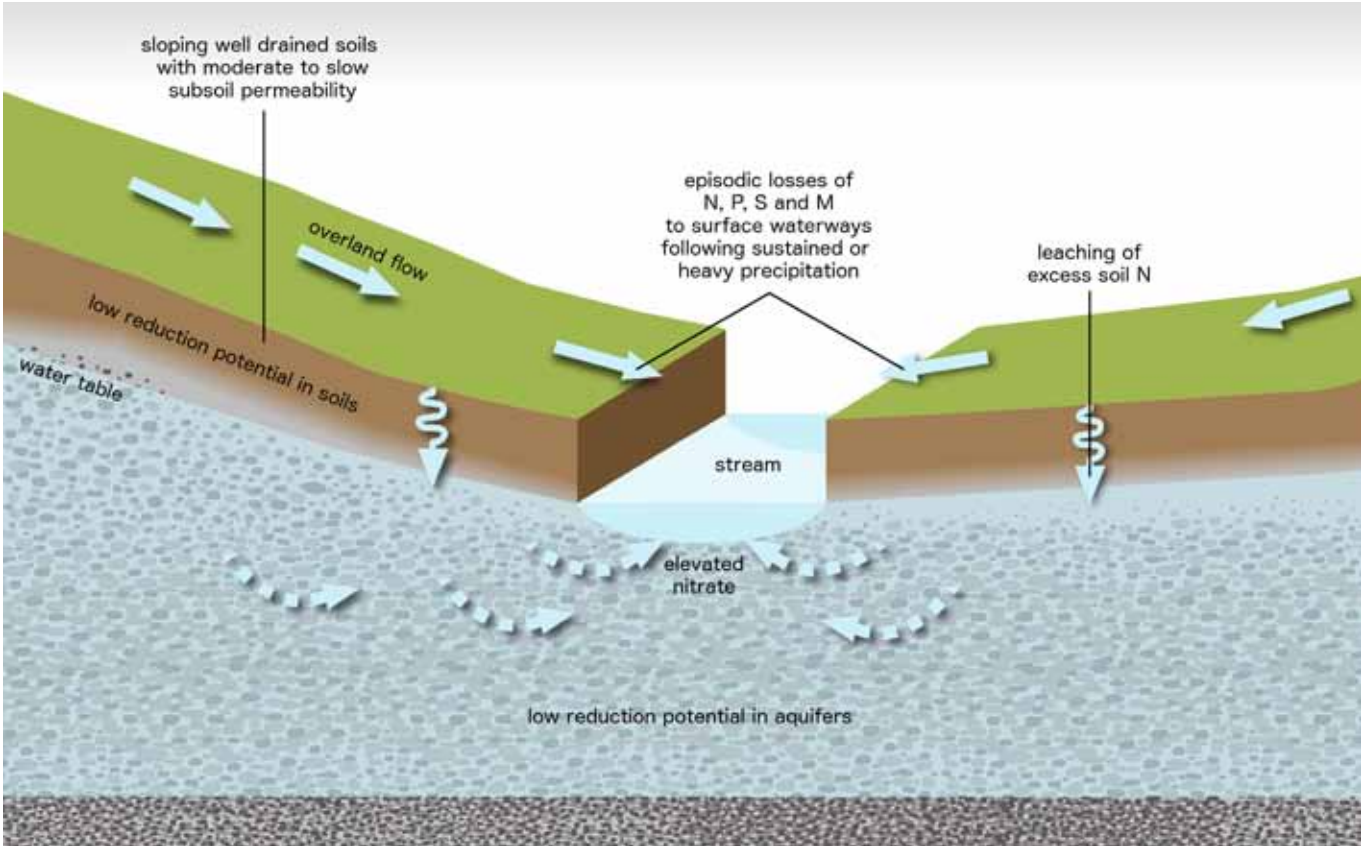


Figure 4: Overland Flow variant. In more sloping areas overland flow provides a pathway for episodic losses of nitrogen (N), phosphorus (P), sediment (S) and microbes (M) to surface waterways.