7.7 Surface erosion/runoff control

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State of knowledge of the "Surface erosion / runoff control" attribute: Good / established but incomplete

Good state of knowledge because we understand the surface erosion process, there are quite a few studies that have been carried out across the country and there is agreement on what surface erosion is, and what the benefits are of reducing it. Similarly, runoff control. There is, however, little to no spatial coverage of either current active surface erosion or of land where past areas of surface erosion have been treated. Surface erosion may be persistent over time, or it may change rapidly. Bare ground has been used as a proxy for surface erosion but not all bare ground is eroding. This limits this attribute as a potential national attribute.

Part A—Attribute and method

A1. How does the attribute relate to ecological integrity or human health?

The control of runoff and surface erosion can benefit the ecological integrity of adjacent waterbodies in several ways. Principally this is aimed at reducing soil loss and sediment deposition in receiving environments and avoiding sediment affecting drinking water and water quality, in general, which may be an issue if contaminants such as E. coli 'attach' to sediment particles (Davies-Colley et al., 2018). Reductions in water clarity also affect swimming quality and may mask submerged hazards posing risks to swimmers (West et al. 2015)

Surface erosion is a natural geomorphic process (along with other erosion processes) which occurs on all land surfaces to varying degrees (Basher 2013). Land disturbance (earthworks) and land use practices (ploughing, tillage, grazing, etc) can increase surface erosion (Basher 2013).

Unlike mass movement processes (landslide/soil slip, slump, earthflow), surface erosion involves the movement of a thin layer of particles across the ground by water, wind or gravity. There are several sub-process types – splash, sheet, and rill erosion (Morgan 1986).

The impacts of surface erosion (and all erosion) are loss of soil and productive capacity on land (Rosser & Ross 2011) and impacts on waterbodies via changes in water clarity and deposition of sediment in the beds of rivers, lakes and estuaries (Ryan 1991; Gluckman 2017).

The extent of benefit afforded by runoff control and reduction in surface erosion on ecological integrity and human health is spatially and temporarily variable and depends on many factors (landscape, climatic, biological, and land use). Factors that affect control performance include land use and practice(s), degree of physical disturbance, vegetative cover, topography, rainfall intensity and duration, land use legacy, exposure time, etc., (Basher 2013).

Where erosion and sediment control (ESC) practices have been implemented, the ecological integrity and health of adjacent waterbodies is expected to improve, especially locally. However, complete control is rarely achieved as many ESC practices are not completely effective, i.e., their treatment performance is always less than 100% (Basher & Moores 2016; Phillips et al. 2020).

Various studies have measured surface runoff (and its contaminants e.g., nutrients, sediment) to help quantify the effects on water quality, from plot-scale field experiments (e.g., Smith & Monaghan 2003; McDowell et al. 2005), performance of straw mulch at earthworks sites (e.g., ARC 2000), in-situ rainfall simulation from within paddocks (Russell et al. 2001), and paddock-scale small catchments (e.g., Monaghan et al. 2017). Surface runoff measurements from plot-scale field experiments can be highly variable and dependent on many factors. These types of measurements in plot studies usually require material (e.g., wood, metal, plastic) to be inserted in the soil, to divert flows so they can be measured and collected at the downhill point and contain a known area of ground. Other studies have measured surface runoff (and its contaminants) from small catchments to evaluate control measures, such as sediment traps in agriculture, detainment bunds, etc (Levine et al. 2021; Smith & Muirhead 2023) and sediment retention via silt fences, vegetated buffers, decanting earth bunds and sediment ponds (e.g., Winter 1998; Babington and Associates 2004) in urban earthworks.

A2. What is the evidence of impact on (a) ecological integrity or (b) human health? What is the spatial extent and magnitude of degradation?

It is well known that land clearance and land use practices can disturb soils and thus expose the soil surface to wind, rain and gravity. Loss of soil by erosion (including surface erosion) will have contributed to the degradation of freshwater and downstream receiving environments by enabling sediment to enter water bodies where it affects water clarity and is deposited on the beds of streams, potentially smothering habitat. It will continue to do this wherever bare soil or disturbance coincides with rainfall, i.e., it is almost a ubiquitous process, though the amount of soil eroded and transported will vary widely.

Awareness of soil erosion and the need for soil conservation became a matter of national concern by the 1940s resulting in the passing of the 1941 Soil Conservation and Rivers Control Act and the establishment of catchment boards to manage erosion and sediment problems. It was also the time when a wide variety of techniques were developed for controlling erosion.

In the urban environment Auckland Regional Council published a set of ESC guidelines for earthworks in 1995 that was significantly revised and published as TP90 in 1999 (Auckland Regional Council 1999). TP90 has formed the basis of subsequent ESC guidelines across New Zealand. Specific ESC guidance has also been produced for the horticulture industry (Franklin Sustainability Project 2000; Barber & Wharfe 2010; Barber 2014) and the forestry sector (e.g., Bryant 2007; New Zealand Forest Owners Association 2007; Gilmore et al. 2011).

In the rural environment, emphasis has been on biological erosion control using trees and plants because of its relatively low cost and its effectiveness, particularly in reducing the incidence of rainfall-triggered shallow landslides (Phillips et al., 2020). There is generally less focus in New Zealand's rural environment on surface erosion than other erosion processes, in part because the volume of soil lost by other processes is orders of magnitude greater. However, focus has intensified in recent years on surface erosion and runoff control as intensive grazing and winter forage cropping on both hilly and flat land have bought these issues to the public's attention (Donovan & Monaghan 2021; Monaghan et al. 2021). With such practices the ecological impacts tend to be more 'continuous' or chronic rather than episodic or acute as the rainfall required to result in 'muddy' water from surface erosion will be significantly less than that to trigger a mass movement.

A3. What has been the pace and trajectory of change in this attribute, and what do we expect in the future 10 - 30 years under the status quo? Are impacts reversible or irreversible (within a generation)?

Land use and land practices, together with rainfall, are the primary drivers of surface erosion (Morgan 1986). Land slope is also a significant driver. Surface soil erosion will also vary with soil type (Basher 2013; Lynn et al., 2021).

Climate change projections suggest increasing storminess in many regions indicating a concomitant increase in erosion is likely (Neverman et al., 2023). How this will preference surface erosion over other erosion processes is unknown, though if rainfall becomes more intense, it is likely that surface erosion will increase.

Surface erosion has been included in several erosion models and in models aimed at understanding climate change impacts, e.g., Basher et al. 2020; Neverman et al. 2023; Donovan 2021.

Historically, erosion modelling focused on surface erosion processes and many models had/have at their heart the Universal Soil Loss Equation (USLE – Wischmeier & Smith 1978) or variants thereof. The USLE consists of an empirical equation which calculates the mean annual soil-erosion rates on agricultural slopes as a function of six variables (R, precipitation factor; L, slope length factor; S, slope factor; C, vegetation cover and tillage factor; K, soil-erodibility factor; P, erosion-protection factor).

The SedNetNZ sediment budget model (Dymond et al. 2016) was developed to represent the range of erosion processes that occur in New Zealand (e.g., shallow landslides, earth flows, gully erosion, surficial erosion, and stream bank erosion). This makes the model more suited to New Zealand's diverse landscape and environmental management and planning needs compared to models like RUSLE (the Revised Universal Soil Loss Equation) or SWAT (Soil and Water Assessment Tool) which largely focus on surface erosion processes. For example, RUSLE represents a limited range of erosion processes (sheet and rill erosion), and SWAT (Soil and Water Assessment Tool) uses MUSLE (the Modified Universal Soil Loss Equation) to model hillslope erosion but does not include mass movement processes such as landslides, which is a significant erosion process in New Zealand.

SedNetNZ is not available nationally. National erosion models include the Highly Erodible Land model (HEL – Dymond et al. 2005) and New Zealand Empirical Erosion Model (NZEEM, Dymond et al. 2010) but these include all erosion processes. Donovan (2021) provided the first national-scale surface soil erosion model based on RUSLE and found surface erosion rates for winter-forage paddocks (11 t ha^{-1} y^{-1}) were substantially higher than pastoral grasslands (0.83 t ha^{-1} y^{-1}), woody grasslands (0.098 t ha^{-1} y^{-1}), forests (0.103 t ha^{-1} y^{-1}) and natural soil production rates (≤1–2 t ha^{-1} y^{-1}). Model results were validated with empirical measurements from sediment traps, sediment cores, and chemical fingerprinting. Further, the study suggested that surface erosion could account for up to 24–32% of sediment yield over timescales sufficiently long to allow 100% sediment delivery.

As with other erosion forms, impacts are partially reversible and rely on ESC and soil conservation measures to reduce erosion in the first place.

A4-(i) What monitoring is currently done and how is it reported? (e.g., is there a standard, and how consistently is it used, who is monitoring for what purpose)? Is there a consensus on the most appropriate measurement method?

This attribute is not routinely monitored either nationally or regionally.

Some councils may carry out periodic surveys and bare ground assessments (as a proxy for erosion). At finer and local scales, councils and catchment groups may undertake stream monitoring (water clarity, stream bed cover assessment, etc) or catchment surveys to determine areas where erosion (including surface erosion is likely to occur).

There is no consistent methodology in use and no nationally agreed monitoring methodology for assessing surface erosion in New Zealand. Internationally, plot studies have been used to determine the influence of factors on surface erosion (e.g., Anache et al., 2017; Carollo et al., 2024). Similarly, there is unlikely to be any standard methodology to determine treatment monitoring, other than perhaps by modelling (Morgan et al., 1998) or by remote sensing (e.g., Sepuru & Dube 2018; North et al., 2022).

There is also no consistent methodology to measure surface runoff from small catchments to evaluate control measures from its retention in sediment traps and detainment bunds etc (Levine et al. 2021; Smith & Muirhead 2023).

A4-(ii) Are there any implementation issues such as accessing privately owned land to collect repeat samples for regulatory informing purposes?

If this attribute were to be monitored, it would require access to private land to firstly undertake an erosion assessment and secondly, determine what treatment has been carried out and if it was successful.

Remote sensing may be effective in monitoring bare ground as a proxy for surface erosion (and vice versa previous bare ground now vegetated as evidence of control) (North et al., 2022). Repeat aerial photographs or other remote sensing methods including LiDAR may also be suitable.

Differentiating sediment sources by erosion process at the catchment scale is currently only possible using sediment fingerprinting techniques (Vale et al, 2022). While these have been used in New Zealand, there is some disagreement on the results each method provides (Vale et al., 2022) and in relation to contributions of sediment from different land uses.

A4-(iii) What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (e.g., purchase of equipment) and on-going operational costs (e.g., analysis of samples).

Monitoring of this attribute is not being done routinely and, therefore, costs are hard to assess.

Repeat remote sensing and/or repeat on-ground bare ground assessment might be a useful methodology but currently this is likely to be expensive. It would also require validation because all bare ground may not be losing soil from surface erosion, i.e., it just looks bare.

A5. Are there examples of this being monitored by Iwi/Māori? If so, by who and how?

We are not aware of any monitoring being carried out by representatives of iwi/hapū/rūnanga. However, erosion is of high interest to Māori and some hapū/iwi are focused on monitoring erosion and mitigating risk. Successful erosion control within the Waiapu River catchment, for example, is required to achieve the cultural aspirations of Ngāti Porou. Measures of erosion (including visual observations and other remotely-sensed measurements) are parts of an holistic approach to assessing a catchment's state.

A6. Are there known correlations or relationships between this attribute and other attribute(s), and what are the nature of these relationships?

Surface erosion is correlated and could be grouped with other erosion processes, e.g., shallow landslide erosion, surface erosion, and gully erosion in assessments of erosion (e.g., NZEEM, HEL, SedNetNZ).

In the LUC/Land Resource Inventory the key/dominant erosion process for that polygon is described along with its severity. Surface erosion includes sheet (Sh), wind(W), and scree (Sc) (Lynn et al. 2021), along with secondary erosion processes. Severity of erosion is rated in 6 classes based on % of the area affected by that process (Lynn et al. 2021).

Part B—Current state and allocation options

B1. What is the current state of the attribute?

Surface erosion is well understood in a broad qualitative sense but not quantitatively, spatially or temporally, at least at the regional and national levels. The process is very well understood as are the main ways to reduce or control it (Basher 2013; Phillips et al., 2020). 'Understanding' in the context of quantitatively monitoring surface erosion spatially and temporally at regional and national levels is not advanced enough for this to be used as a national indicator, though locally it may be possible to monitor it once a baseline state is determined.

Like other erosion processes, to be used as an indicator would require significant investment and assessment to establish a baseline state for each region of active surface erosion, and then its treatment. Once a national layer was available, it could be monitored (5-yearly) relative to the starting baseline.

B2. Are there known natural reference states described for New Zealand that could inform management or allocation options?

We are unaware of any known natural reference states for this attribute.

As surface erosion is a natural geomorphic process understanding what the situation was like pre-European is impossible, i.e., we know that erosion was less under a natural forest cover and prior to human settlement, but we do not know what erosion process was dominant or the relative balance between different processes.

A pre-European reference state, while potentially attractive, would be difficult to quantify and would not be attainable in contemporary NZ. Surface erosion would have existed in NZ pre-Europeans, but it was the clearance of indigenous forest in both islands for farming that exacerbated erosion of all types, including surface erosion. Land use and land use practices on erosion-prone land are still contributing to further erosion, e.g., Donovan (2021).

B3. Are there any existing numeric or narrative bands described for this attribute? Are there any levels used in other jurisdictions that could inform bands? (e.g., US EPA, Biodiversity Convention, ANZECC, Regional Council set limit)

We are unaware of any existing numeric or narrative bands for this attribute.

B4. Are there any known thresholds or tipping points that relate to specific effects on ecological integrity or human health?

We are unaware of specific thresholds or tipping points for this attribute.

Severe surface erosion (and erosion in general) is likely to have significant local effects on ecological integrity, i.e., within metres of source areas but effects would dissipate rapidly from the active source.

B5. Are there lag times and legacy effects? What are the nature of these and how do they impact state and trend assessment? Furthermore, are there any naturally occurring processes, including long-term cycles, that may influence the state and trend assessments?

Many ESC approaches such as mulching are effective immediately they are implemented on bare ground. Others, such as hydroseeding and planting may take longer to become effective.

B6. What tikanga Māori and mātauranga Māori could inform bands or allocation options? How? For example, by contributing to defining minimally disturbed conditions, or unacceptable degradation.

In addition to discussing this attribute directly with iwi/hapū/rūnanga, there is likely to be tikanga and mātauranga Māori relevant to informing bands, allocation options, minimally disturbed conditions and/or unacceptable degradation in treaty settlements, cultural impact assessments, environment court submissions, iwi environmental management and climate change plans etc.

Erosion or disturbed land may be one metric in cultural health assessments (Tipa & Tierney 2003).

Part C—Management levers and context

C1. What is the relationship between the state of the environment and stresses on that state? Can this relationship be quantified?

The state of surface erosion protection is driven by the need for land to continue to be used for agriculture and urban purposes. Where surface erosion is severe, ‘productive’ land may be impacted by rain events, requiring landowners to employ soil conservation or ESC methods to reduce soil loss. Most councils require earthworks to be controlled and, in some regions, regional rules may require that farmers follow prescribed practices either as part of consent conditions or central Government policies. Where land has protective measures in place and active areas of surface erosion have been treated and stabilised, such measures are expected to benefit the ecological health of adjacent waterbodies in ways described in Section A.

C2. Are there interventions/mechanisms being used to affect this attribute? What evidence is there to show that they are/are not being implemented and being effective?

C2-(i). Local government driven

There are several mechanisms employed to affect control of surface erosion and runoff in New Zealand. Principally these are delivered to landowners and developers through regional and district councils via regulatory processes (consents), land development levies, voluntary actions or in some cases via incentives. Council staff usually provide advice to landowners/developers via urban planning, farm planning or catchment planning processes. Most councils have clear ESC guidelines that land developers are required to adhere to (MfE 2023). This may or may not apply to other land users such as farmers and foresters. The NES-CF has an erosion susceptibility map, the classes of which trigger a range of requirements in terms of consenting regime. Measures used to control surface erosion and reduce runoff are many and most can be found related to earthworks and urban and transport development (e.g., Auckland Regional Council 1999).

C2-(ii). Central government driven

Examples of current and past funds that have supported erosion control (in general) using a range of methods include One Billion Trees Fund, the Provincial Growth Fund, Hill Country Erosion Fund, Jobs for Nature, etc. Such funds are usually implemented via MPI or MfE. Most of these programmes report metrics on funding inputs rather than on what has been achieved. MfE (2023), as part of the NPS for Freshwater provide information relating to the management and monitoring of surface erosion and sediment control.

C2-(iii). Iwi/hapū driven

Iwi planning documents such as Environmental Management Plans and Climate Change Strategies/Plans may contain policies/objectives/methods seeking to influence landscape outcomes for the benefit of current and future generations.

C2-(iv). NGO, community driven

Increasingly, community catchment groups undertake aspects of erosion control by planting and action on the ground, either in partnership with councils and landowners or increasingly directly with collectives of landowners within catchments. Such actions would include treatment of areas of surface erosion, but they are generally targeted at a broader range of processes and outcomes such as biodiversity improvement. Some of these initiatives fall under the umbrella of organisation such as the NZ Landcare Trust, Tane’s Tree Trust, NZ Farm Forestry Association, Forest & Bird, The Nature Conservancy of Aotearoa New Zealand, Pure Advantage (O Tatou Ngahere) while others are developed independently.

Some primary sector bodies via industry levies (e.g., Dairy NZ, Beef&Lamb NZ, Fonterra, etc) also provide advice to landowners on what and how to implement erosion control and may require landowners to keep records as part of farm plan implementation.

There are many pathways for landowners to get advice and to implement action on the ground to protect land, water, habitats, and biodiversity which erosion of all forms can impact. While there are many initiatives, coordination is often lacking and recording of what is being done where is less than optimal.

C2-(v). Internationally driven

There may be some international agencies, including WWF, The Nature Conservancy, IUCN, etc., that also contribute advice and/or funding to projects in which surface erosion is controlled either directly or as a co-benefit of other actions.

Part D—Impact analysis

D1. What would be the environmental/human health impacts of not managing this attribute?

If this attribute (or erosion in general) was not managed, further losses to ecological integrity (sedimentation in rivers, wetlands, hydro dams, estuaries and oceans), reduced clarity in freshwaters, etc., particularly in the areas where surface erosion is active would likely result. Continuing degradation of both hill country and lowland soils would lead to reduced productivity (Rosser & Ross 2011), and in some cases loss of high value land on flood plains.

Not managing this attribute may lead to further cultural impacts for Māori particularly in some sensitive locations. It may also impact the mental wellbeing of some landowners who try unsuccessfully to manage erosion if there is no support from councils to assist in mitigation, especially after large events, i.e., they see their soil and land wash away.

D2. Where and on who would the economic impacts likely be felt? (e.g., Horticulture in Hawke's Bay, Electricity generation, Housing availability and supply in Auckland)

Economic impacts from not managing this attribute (and erosion in general) will affect both urban and rural sectors in New Zealand. Ultimately it affects all New Zealanders as taxes and rates are the major sources of funding for managing this.

Farmers and landowners, iwi and urban dwellers are all affected. Impacts are likely to include further decline in freshwater health, increased costs of managing sediment in water bodies, drinking water etc, and increased costs associated with repairing flood damage resulting from large storm events (MfE 2020).

D3. How will this attribute be affected by climate change? What will that require in terms of management response to mitigate this?

Climate change is projected to result in more storminess, but some regions may experience either a decline in total rainfall or an increase. As rainfall is a key driver of most erosion, climate change impacts are likely to be variable, though erosion overall is expected to be greater (Neverman et al., 2023).

Managing this attribute will improve overall resilience to future climate changes. It may not be as significant as retiring land prone to mass movement erosion and planting or reverting to more intact forest cover. However, the pace of implementation of measures to manage erosion (in general) is unlikely to keep up with the perceived, modelled, or real changes arising from climate change (e.g., Vale et al. 2022; Vale & Smith 2023).

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